On-Site Side Air Bag Investigation
Dynamic Science, Inc. (DSI), Case Number DS10021
2009 Toyota Camry
California
August 2010

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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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16. Abstract

The focus of this side air bag investigation was the deployed side impact inflatable curtain (IC) air bag in a 2009 Toyota Camry that was being driven by a restrained 74-year-old male. There were two additional occupants in the Toyota, a restrained 52-year-old female seated in the front right seat and an unrestrained 73-year-old female seated in the second row left seat. The other vehicle was a 1999 Kia Sportage that was being driven by a 23-year-old female. The crash occurred in a three-leg intersection controlled by three-phase traffic signals. The Toyota was initially stopped facing south at a red light. When the light turned green he entered the intersection to initiate a left eastbound turn. The Kia was traveling westbound approaching the intersection. The driver stated that she saw the Toyota enter the intersection and braked but could not stop in time. The front end of the Kia impacted the left side of the Toyota in the passenger compartment section. At impact, the Toyota's left side inflatable curtain (IC) air bag and seat-mounted side impact air bag deployed. Both vehicles came to rest in the intersection. The driver of the Toyota sustained pelvic fractures and multiple lacerations. He was transported and then hospitalized for five days. The front right occupant sustained minor injuries and was transported to a local hospital where she was treated and released. The second row left occupant sustained multiple fractures and contusions. She was transported and then hospitalized for two days. The driver of the Kia complained of pain to her left leg but refused treatment. Both vehicles were towed due to damage.

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TABLE OF CONTENTS

Background 1

Summary 1
- Crash Site 1
- Pre-Crash 2
- Crash 2
- Post-Crash 3

Vehicle Data - 2009 Toyota Camry 3

Vehicle Damage - 2009 Toyota Camry 4
- Exterior Damage 4
- Interior Damage 4

Manual Restraints 4

Supplemental Restraint Systems 5

Event Data Recorder 6

Vehicle Data - 1999 Kia Sportage 8

Occupant Demographics 8

Occupant Injuries 10

Occupant Kinematics 11

Attachment 1. Scene Diagram 13

BACKGROUND

Figure 1. Subject vehicle, 2009 Toyota Camry

The focus of this side air bag investigation was the deployed side impact inflatable curtain (IC) air bag in a 2009 Toyota Camry (**Figure 1**) that was being driven by a restrained 74-year-old male. There were two additional occupants in the Toyota, a restrained 52-year-old female seated in the front right seat and an unrestrained 73-year-old female seated in the second row left seat. The other vehicle was a 1999 Kia Sportage that was being driven by a 23-year-old female. The crash occurred in a three-leg intersection controlled by three-phase traffic signals. The roadways were straight and the posted speed limit at this location is 72 km/h (45 mph). The Toyota was initially stopped facing south at a red light. When the light turned green he entered the intersection to initiate a left eastbound turn. The Kia was traveling westbound approaching the intersection. The driver stated that she saw the Toyota enter the intersection and braked but could not stop in time. The front end of the Kia impacted the left side of the Toyota in the passenger compartment section. At impact, the Toyota's left side inflatable curtain (IC) air bag and seat-mounted side impact air bag deployed. Both vehicles came to rest in the intersection. The driver of the Toyota sustained pelvic fractures and multiple lacerations. He was transported and then hospitalized for five days. The front right occupant sustained minor injuries and was transported to a local hospital where she was treated and released. The second row left occupant sustained multiple fractures and contusions. She was transported and then hospitalized for two days. The driver of the Kia complained of pain to her left leg but refused treatment. Both vehicles were towed due to damage. The Toyota was later declared a total loss by the insurance company. The status of the Kia is not known.

This on-site side air bag investigation was identified by a Dynamic Science, Inc. (DSI) investigator from a review of an auto auction internet sale list. DSI obtained images of the vehicle from the auction facility website and obtained the police report. On September 27, 2010, DSI submitted images of the subject vehicle and a copy of the police report to the National Highway Traffic Safety Administration (NHTSA) for review and on September 28, 2010 DSI was instructed to commence the investigation. Field work was completed on October 5, 2010. The Toyota's Event Data Recorder (EDR) was imaged during the inspection and the data is summarized later in this report.

SUMMARY

Crash Site

This two-vehicle crash occurred within a three-leg intersection controlled by a three-phase traffic signal. The intersection was configured with an east/west roadway intersecting a north/south roadway. The east leg of the intersection was comprised of three eastbound travel lanes, three westbound travel lanes, and a right turn lane. The westbound travel lanes were separated from the eastbound travel lanes by a raised concrete median and were separated from the right turn lane by

a marked bicycle lane (**Figure 2**). The north leg of the intersection was comprised of one northbound and one southbound travel lane that were separated by a grass-covered median (**Figure 3**). The asphalt roadways were straight and the posted speed limit at this location is 72 km/h (45 mph) for both roadways. Conditions at the time of the crash were daylight, clear, and dry. The weather at the nearest reporting station was 26.7° C (80.1° F), 29 percent humidity, and 16.0 km (10.0 mph) winds out of the north.

Figure 2. Westbound approach

Figure 3. Southbound approach

Pre-Crash

The Toyota was initially stopped at a red light at the intersection in the southbound travel lane. The driver stated that he waited at the light for approximately 30 seconds before it cycled to green and he entered the intersection intending to turn left. According to the EDR, the vehicle accelerated from 0 to 19.9 km/h (12.4 mph). DSI calculated that the vehicle had traveled approximately 13.7 m (45.0 ft) before impact[1]. The Kia was traveling westbound in the outboard travel lane adjacent to the bicycle lane at a driver reported speed of 75.6 km/h (47.0 mph). The driver reported that she saw the Toyota pull into the intersection and began braking.

Crash

The driver of the Kia was unable to stop in time and the front end of the Kia impacted the left side of the Toyota (Event 1). The missing vehicle algorithm of the WinSMASH program computed a Total Delta-V of 21.0 km/h (13.0 mph). The longitudinal and lateral components were -10.0 km/h (-6.8 mph) and 18.0 km/h (11.2 mph), respectively. The Barrier Equivalent Speed (BES) was 26.0 km/h (16.1 mph). The results appear reasonable based on the crush profile and vehicle speeds. The EDR reported a maximum longitudinal Delta-V of 16.4 km/h (10.2 mph) at 100 milliseconds (ms) after Algorithm Enable (AE), a maximum lateral Delta-V of 30.5 km/h (19.0 mph) at the B-pillar at 34 ms, and a maximum lateral Delta-V of 36.3 km/h (22.6 mph) at the C-pillar at 74 ms. The impact resulted in sufficient lateral deceleration of the Toyota to command the deployment of the left side IC air bag and the driver's seat-mounted side impact air bag. For the Kia, the WinSMASH program computed a Total Delta-V of 24.0 km/h (14.9 mph). The longitudinal and lateral components were -24.0 km/h (-14.9 mph) and -4.0 km/h (-2.5 mph), respectively.

[1]Calculated using initial velocity, ending velocity, and acceleration rate (calculated).

Post-Crash

The Toyota was redirected in a counterclockwise direction and came to rest in the intersection facing southeast. The Kia was redirected in a counterclockwise direction and came to rest in the intersection facing generally west. The driver of the Toyota remained in his seat after the crash and was extricated from the vehicle by rescue personnel. He sustained a sacral fracture, an acetabular fracture, and multiple lacerations. He was transported to a local hospital by ground ambulance and arrived with a Glasgow Coma Score (GCS) of 15. He was admitted and remained in the hospital for five days, primarily due to his age and a history of atrial fibrillation[2]. The front right occupant remained in her seat after the crash and was able to exit the vehicle under her own power. She sustained minor injuries and was transported by ground ambulance to a local hospital for treatment. She arrived with a GCS of 15 and was treated and released. The second row left occupant was displaced from her seat during the crash and came to rest on the floor behind the driver's seat. She was extricated from the vehicle by rescue personnel. She sustained fractures to the ribs and clavicle and multiple contusions and was transported by ground ambulance to a local hospital for treatment. She arrived with a GCS of 15 and was hospitalized for two days.

Vehicle Data - 2009 Toyota Camry

The Toyota Camry four-door sedan was identified by the Vehicle Identification Number (VIN): 4T4BE46K09Rxxxxxx. The vehicle mileage was 23,305 km (14,481 miles). The date of manufacture is not known since the left front door was jammed and the tag was not visible. The Toyota was equipped with a 2.4-liter 4-cylinder engine, automatic transmission, front and rear disc brakes, and 4-wheel ABS. The vehicle manufacturer's recommended tire size was P215/60R16 and the recommended cold tire pressure was 221 kPa (32 psi). The vehicle was equipped with Bridgestone Touranza P215/60R16 tires. The Bridgestone tires had a tire manufacturer's recommended tire pressure of 300 kPa (44 psi) and were all manufactured in 2008. The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	228 kPa (33 psi)	6 mm (8/32 in)	No	None
LR	241 kPa (35 psi)	7 mm (9/32 in)	No	None
RR	214 kPa (31 psi)	7 mm (9/32 in)	No	None
RF	241 kPa (35 psi)	6 mm (8/32 in)	No	None

The seating in the Toyota was configured with front bucket seats and a split folding rear seat. Adjustable head restraints were available for all seating positions.

[2]During atrial fibrillation, the heart's two small upper chambers (the atria) quiver instead of beating effectively. Source: http://americanheart.org.

Vehicle Damage - 2009 Toyota Camry

Exterior Damage

The Toyota sustained moderate left side damage from the impact with the front of the Kia (**Figure 4**). The direct damage began 60.0 cm (23.6 in) aft of the front axle and extended rearward 160.0 cm (62.9 in). The Field L began 44.0 cm (17.3 in) aft of the front axle and extended rearward 222.0 cm (87.4 in).

Figure 4. Left side damage, 2009 Toyota Camry

Six crush measurements were documented along the lower door as follows: C_1 = 0 cm, C_2 = 12.0 cm (4.7 in), C_3 = 22.0 cm (8.7 in), C_4 = 27.0 cm (10.6 in), C_5 = 24.0 cm (9.4 in), C_6 = 0 cm. Maximum crush was located at 129.0 cm (50.7 in) aft of the front axle and measured 37.0 cm (14.5 in). The height of the maximum door crush was 43.0 cm (16.9 in) and the Door Sill Differential (DSD) was 23.0 cm (9.0 in). The Collision Deformation Classification (CDC) for Event 1 was 10LPEW2.

Interior Damage

The Toyota sustained minor interior damage resulting from intrusion, occupant loading, and occupant contacts. There was minor lateral intrusion to the front left door panel, left armrest, driver's seat back, B-pillar, second row left door panel and frame. There was evidence of occupant contact to multiple locations on the left front door (**Figure 5**) and the center console was displaced. The left front door was jammed shut and the left front glazing was disintegrated.

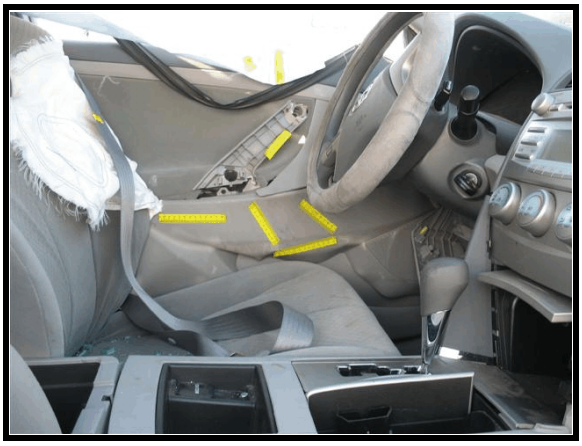

Figure 5. Left interior door contacts

Manual Restraints

The vehicle's front row seating was equipped with 3-point manual lap and shoulder safety belts with sliding latch plates, adjustable D-rings, and retractor pretensioners. The driver's safety belt was equipped with an Emergency Locking Retractor (ELR) and the front right passenger's safety belt had a switchable ELR/Automatic Locking Retractor (ALR). The three rear seat position were equipped with lap and shoulder belts with switchable ELR/ALR.

The driver's safety belt D-ring anchorage was in the full-down position and the latch plate was scratched indicating historical usage. The safety belt was locked in the used position (spooled out)

at the time of the vehicle inspection. This was likely due to crush at the B-pillar. The EDR reported the belt switch status as "belted" and indicated that the pretensioner had "not fired". Based on the vehicle inspection it was determined that the safety belt was in use at the time of the crash.

The front right passenger's safety belt D-ring anchorage was in the full-down position and the latch plate was scratched indicating historical usage. The EDR reported the belt switch status as "belted" and indicated that the pretensioner had "not fired". Based on the vehicle inspection it was determined that the safety belt was in use at the time of the crash.

There was no indication of usage to the second row left and right safety belts. The second row middle safety belt latch plate was scratched indicating historical usage.

Supplemental Restraint Systems

This vehicle's Supplemental Restraint System (SRS) included an air bag control module (ACM), driver and passenger frontal air bags, a driver knee air bag, seat-mounted side impact air bags for the front row, side IC air bags, and retractor-mounted safety belt pretensioners for the front row. The Toyota was a Certified Advanced 208-Compliant (CAC) vehicle and was equipped with advanced frontal air bags. The multi-stage air bags were certified by the manufacturer to be compliant with the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The driver's air bag was located within the steering wheel hub and the front right passenger air bag was located within the right instrument panel. The left IC air bag and the driver's seat-mounted side impact air bag deployed during the impact with the Kia.

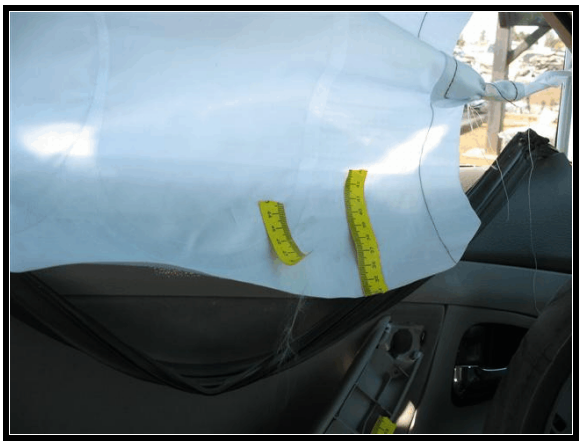

Figure 6. Loading scuff mark to side IC air bag

Figure 7. Seat-mounted side impact air bag

The left IC air bag deployed from the roof side rail above the front and rear rows. The IC air bag was rectangular in shape and measured 165.0 cm (64.9 in) in length and 36.0 cm (14.1 in) in height. An external 18.0 cm (7.0 in) tether attached the forward aspect of the air bag to the left A-pillar. A 9.0 x 5.0 cm (3.5 x 2.0 in) abraded area was documented on the exterior of the air bag. The abraded area was located 13.0 cm (5.1 in) aft of the leading edge of the air bag and 4.0 cm (1.6 in) above the bottom of the air bag. A 4.0 x 4.0 cm (1.6 x 1.6 in) occupant loading scuff mark was documented on the inboard panel of the air bag (**Figure 6**). The scuff mark was located at the bottom of the air bag 9.0 cm (3.5 in) aft of the leading edge of the air bag.

The left seat-mounted side impact air bag deployed at impact from the outboard aspect of the driver's seat back (**Figure 7)**. The air bag was semicircular in shape measuring 30.0 cm (16.5 in) in height and 28.0 cm (11.0 in) in length. In its deflated state, the air bag excursion covered the left B-pillar and rear upper quadrant of the door panel. The air bag was configured with three small vent ports in a non-inflatable sector located at its forward aspect. There were no indications of loading to the air bag. There was a small amount of blood located on the inboard panel of the air bag next to the seat back.

Event Data Recorder

The Toyota's EDR was imaged during the vehicle inspection by applying power to the vehicle's supplemental restraint system and connecting the Toyota EDR Read Out Tool (ROT) to the Diagnostic Link Connector (DLC) port under the instrument panel. The EDR captured pre-crash and post-crash data. The air bag module number was 89170-33490. The EDR did not capture rollover data. The recorded data was imaged and reported using software Version 1.4.1.1. The EDR data was summarized as follows:

Latest Pre-Crash Page0	
System Information	
Page No. of Latest Pre-Crash Data	Page.0
Time from Previous Pre-Crash TRG[3] Event	16381 ms
Freeze Signal	Freeze
AB Deployment Flag	SAB for Driver
Occupant Data	
Belt Switch Status Driver	Belted
Belt Switch Status Passenger	Belted
Occupant Detection	AF05[4]
Seat Position	RW
Shift Position	Others
PAB Manual Cut Off (N/A)	(N/A)
R/O CSA-Manual Cut Off (N/A)	(N/A)
Writing Flag for Pre-Crash/Occupant	Finished Writing

[3] Assumed to indicate Trigger

[4] Assumed to be Adult Female 5th percentile

Pre-Crash Data						
Time (sec)	-5	-4	-3	-2	-1	0
Speed (mph)	0.0	2.5	6.2	8.7	11.2	12.4
Brake	OFF	OFF	OFF	OFF	OFF	OFF
Accelerator (V)	0.86	1.17	1.13	1.09	1.17	1.17
Engine (rpm)	400	800	1600	1600	1600	1600

Next Most Recent Pre-Crash Page 1 - No data

Frontal Crash Page 0	
Max delta-Vx	10.2 (mph)[5]
TGR Counter	2 (times)
Previous Event	Lateral
Linked Pre-Crash Date Page No.	Page 0
Time from Pre-Crash to TGR	10 ms
Frontal AB Deployment Time	Not Fired
Pretensioner Deployment Time	Not Fired
Deployment Stage Driver	Not Fired
Deployment Stage Passenger	Not Fired
Writing Flag for Frontal Crash	Finished Writing

Frontal Crash Page 1 - No data

Side Crash Page 0	
Post-Crash Data (Vel Chg) B-Pillar	19.0 (mph) at 34 ms[6]
Post-Crash Data (Vel Chg) C-Pillar	22.6 (mph) at 74 ms
Post-Crash Data (Vel Chg) Floor	-11.2 (mph) at 58 ms
Time from TGR to Initial G	2 (ms)

[5] Maximum Post-crash Delta-V occurred at 90 ms

[6] Velocity Changes for B-pillar, C-pillar, and Floor represent the maximum recorded values

TGR Counter	1 (times)
Previous Event	No Event
Linked Pre-Crash Date Page No.	Page 1
Time from Pre-Crash to TGR	0 (ms)
Deployment Time (B-Pillar)	9 (ms)
Deployment Time (C-Pillar)	21 (ms)
Deployment Side	Driver's side
Writing Flag for Side Crash	Finished Writing

Side Crash Page 1 - No data

Vehicle Data - 1999 Kia Sportage

The 1999 Kia Sportage was identified from the police report. The Kia was a two-door sport utility vehicle that sustained moderate frontal damage. The vehicle came to rest in the intersection. The driver complained of pain to her left leg but refused any treatment. The Kia was towed from the scene and not inspected.

Occupant Demographics -2009 Toyota Camry

Driver

Age/Sex:	74/Male
Height:	188 cm (74 in)
Weight:	91 kg (201 lbs)
Seat type:	Bucket with adjustable head restraint
Seat track position:	Rear most
Manual restraint usage:	Lap and shoulder belt
Usage source:	Vehicle inspection
Air bags:	Frontal air bag and knee air bag not deployed, seat-mounted side impact air bag and IC air bag deployed
Alcohol, drug involvement:	None
Type of medical treatment:	Hospitalized for five days

Front Right Occupant

Age/Sex:	52/Female
Height:	168 cm (66 in)
Weight:	64 kg (141 lbs)
Seat type:	Bucket with adjustable head restraint
Seat track position:	Rear most
Manual restraint usage:	Lap and shoulder belt
Usage source:	Vehicle inspection
Air bags:	Frontal, IC, and seat-mounted side impact air bags not deployed.
Alcohol, drug involvement:	None
Type of medical treatment:	Transported, treated and released.

Second Row Left Occupant

Age/Sex:	73/Female
Height:	170 cm (67 in)
Weight:	59 kg (130 lbs)
Seat type:	Bench
Seat track position:	N/A
Manual restraint usage:	Lap and shoulder belt not used
Usage source:	Vehicle inspection, EMS report
Air bags:	IC side air bag deployed
Alcohol, drug involvement:	None
Type of medical treatment:	Hospitalized for two days

Occupant Injuries

Driver: Injuries obtained from discharge summary.

Injury	Injury Severity (AIS 2005)	Injury Mechanism	Confidence Level
Left sacral fracture (non-displaced)	856100.2,4	Door panel, armrest/hardware, lower rear quadrant	Certain
Left acetabular fracture	856200.2,2	Door panel, armrest/hardware, lower rear quadrant	Certain
Laceration, left dorsal hand	710602.1,2	Flying glass	Possible
Laceration, left medial thigh, 20.0 cm (7.9 in)	810602.1,2	Door panel, lower forward quadrant	Certain
Laceration, left elbow	710602.1,2	Door panel, rear upper quadrant	Probable

Right Front Occupant: Injuries obtained from emergency room and ambulance records.

Injury	Injury Severity (AIS 2005)	Injury Mechanism	Confidence Level
Contusion, right lip	210402.1,8	Unknown	Unknown
Laceration, right lower leg, 1.3 cm (0.5 in)	810602.1,1	Lower instrument panel	Possible

The interviewee stated that the right front occupant had sustained a loss of hearing in the right ear since the day of the crash (approximately four months post-crash). He was unable to identify a specific injury related to the loss of hearing.

Second Row Left Occupant: Injuries obtained from discharge summary and ambulance record.

Injury	Injury Severity (AIS 2005)	Injury Mechanism	Confidence Level
Fracture, left clavicle	750500.2,2	Door panel, rear upper quadrant	Certain
Fractures, left ribs 2, 3, 4, 6	450203.3,2	Left armrest/hardware, forward upper quadrant	Certain
Contusion, anterior portion of lower left eye	210402.1,2	Unknown	Unknown
Contusion, left lower leg proximal to knee	810402.1,2	Seat back	Possible

Occupant Kinematics

Driver Kinematics

The 74-year-old male driver was seated in an upright posture and was restrained by the vehicle's lap and shoulder belt. The driver's seat was adjusted to the rear most track position and the seat back was slightly reclined. The driver was actively steering the vehicle and his right foot was presumably on the accelerator as the vehicle accelerated from a stop and entered the intersection while initiating a left turn. At less that one second prior to impact, the vehicle travel speed was reported by the EDR as 19.9 km/h (12.4 mph). At impact with the Kia the driver's seat-mounted side impact air bag and left IC air bag deployed. The driver was displaced left and slightly forward in response to the 10 o'clock direction of force. His left hip contacted the intruding left door panel, causing the left sacral and left acetabular fractures. His left thigh contacted the plastic trim surface of the door panel, causing a moderate laceration to the left medial thigh. The left arm rest cover was displaced, possibly by the driver's left arm. A scuff was located on the forward aspect of the IC curtain that may have been deposited by the driver's left hand. The driver remained in place until the vehicle came to rest. He was assisted from the vehicle by rescue personnel.

Front Right Occupant Kinematics

The 52-year-old female front right occupant was seated in an upright posture and was restrained by the vehicle's lap and shoulder belt. The right front seat was adjusted to the rear-most track position and the seat back was slightly reclined. At impact with the Kia the right front occupant was displaced left and forward in response to the 10 o'clock direction of force. Her left hip contacted and displaced the center console. Her right lower leg possibly contacted the lower instrument panel edge, causing a small laceration. She remained in place until the vehicle came to rest. She was able to exit the vehicle under her own power and was transported to a local hospital for treatment.

Second Row Left Occupant Kinematics

The 73-year-old female second left right occupant was seated in an upright posture and was not restrained by the vehicle's lap and shoulder belt. At impact with the Kia the left IC air bag deployed and this occupant was displaced left and forward. Her left leg contacted the back of the driver's seat and her left shoulder and chest impacted the rear upper quadrant of the door panel and the arm rest, causing the rib and clavicle fractures. Her head likely contacted the IC air bag but there were no indications of contact and no resultant injuries. She came to rest on the floor behind the driver's seat. She was extricated from the vehicle by rescue personnel.

Attachment 1. Scene Diagram