Side Air Curtain Investigation / Vehicle to Vehicle
Dynamic Science, Inc. / Case Number: 2003-79-057E
2003 Volvo XC90 sport utility vehicle
California
March, 2003

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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

This side air curtain crash involved three vehicles and occurred in March, 2003 at 1130 hours. The crash took place on a divided six-lane interstate highway. The roadway was level and straight. It was constructed of concrete and was dry at the time of the crash. The speed limit is 105 km/h (65 mph).

The case vehicle is a 2003 Volvo XC90 sport utility vehicle driven by a restrained 45-year-old female. The front right seat was occupied by a restrained 9-year-old male. The first other vehicle is a 1998 Ford Mustang driven by a 56-year-old male. The second other vehicle is a 1995 Chevrolet Camaro 3-door hatchback driven by a 45-year-old male. The Volvo was traveling northbound in the fifth lane from the right. The Camaro was behind the Volvo. The Mustang was in the fourth lane from the right.

For unknown reasons, the driver of the Mustang steered to the left and entered the adjacent lane. The front of the Mustang struck the left rear of the Volvo–causing it to begin a clockwise rotation. The Volvo continued rotating until tripping onto its left side. The Volvo rolled a total of six quarter turns before coming to rest on its roof. The Mustang also began a clockwise rotation before being struck by the Camaro. The Volvo came to rest on its roof facing south and blocking the third and fourth travel lanes.

The two restrained occupants of the Volvo remained in their seats during the rollover. They sustained minor lacerations. The Volvo was later declared a total loss by the insurance company.

17. Key Words	18. Distribution Statement
Air bag, deployment, injury, side air curtain, rollover, SUV, passenger.	

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Dynamic Science, Inc.
Crash Investigation
Case Number: 2003-79-057E

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BACKGROUND:

Description:	This Side Air Curtain Case was identified by the local National Automotive Sampling System (NASS) Primary Sampling Unit (PSU) team, NASS PSU 79. The case was sampled as a NASS Crashworthiness Data System (CDS) case. DSI was assigned the case on April 25, 2003. This is an SCI/CDS combination case.
Investigation Type:	Side Air Curtain
Crash Location:	California
Crash Date:	March, 2003
Notification Date:	April 25, 2003
Field Work Completed:	NA

SUMMARY

Crash Site

This three vehicle crash occurred in March, 2003 at 1130 hours. The crash took place on a divided six-lane interstate highway. The roadway was level and straight. It was constructed of concrete and was dry at the time of the crash. The speed limit is 105 km/h (65 mph).

Figure 1. Overview of crash scene (north)

Pre-Crash

The case vehicle is a 2003 Volvo XC90 sport utility vehicle driven by a restrained 45-year-old female (157 cm/62 in, 54 kg/119 lbs). According to several sources, this was a relatively new vehicle and the driver may not have been completely familiar with its handling characteristics. The front right seat was occupied by a restrained 9-year-old male (unknown height and weight).

Figure 2. Front right, case vehicle

The first other vehicle is a 1998 Ford Mustang driven by a restrained 56-year-old male. The second other vehicle is a 1995 Chevrolet Camaro 3-door hatchback driven by a restrained 45-year-old male who was wearing a manual 3-point lap and shoulder safety belt system.

The Volvo was traveling northbound in the fifth lane from the right. The Camaro was behind the Volvo. The Mustang was in the fourth lane from the right.

Crash

Figure 3. Right rear, case vehicle

For unknown reasons, the driver of the Mustang steered to the left and entered the adjacent lane. The front of the Mustang struck the left rear of the Volvo (05BCMN1)–causing it to begin a clockwise rotation. The Volvo continued rotating until tripping onto its left side. The manufacturer indicates that the vehicle will sense an impending rollover and activate the side curtains and seat belt pretensioners. Both side curtains did deploy. It should be noted that the curtain air bags are designed to remain inflated for a longer time in order to protect the occupants in the event of a multiple rollover sequence. The left side curtain came into contact with the ground after the side glass shattered. The seat belt pretensioners at all five seating positions actuated. The Volvo rolled (00TDDO3) a total of six quarter turns before coming to rest on its roof. The Mustang also began a clockwise rotation before being struck by the Camaro.

The Volvo came to rest on its roof facing south and blocking the third and fourth travel lanes.

Post-Crash

The other vehicles were moved to the roadside to expedite traffic. The Volvo and Mustang were towed from the scene due to damage. The Camaro was driven from the scene to a gas station adjacent to the interstate. At that point the Chevrolet was towed, and subsequently declared a total loss.

According to information provided on the police accident report, the driver of the Volvo complained of pain to her neck and upper back. She sustained minor lacerations to her hands. She was transported from the scene by a fire department ambulance to a local hospital for emergency room treatment. The front right occupant also complained of pain to his neck and back. He sustained minor lacerations to his arms. He was transported from the scene by a fire department ambulance to a local hospital for emergency room treatment also.

There were no reported injuries to the driver of the Mustang.

The daughter of the driver of the Chevrolet Camaro indicated that her father had been uninjured and was able to exit his car and leave the crash site on his own.

SCENE DIAGRAM

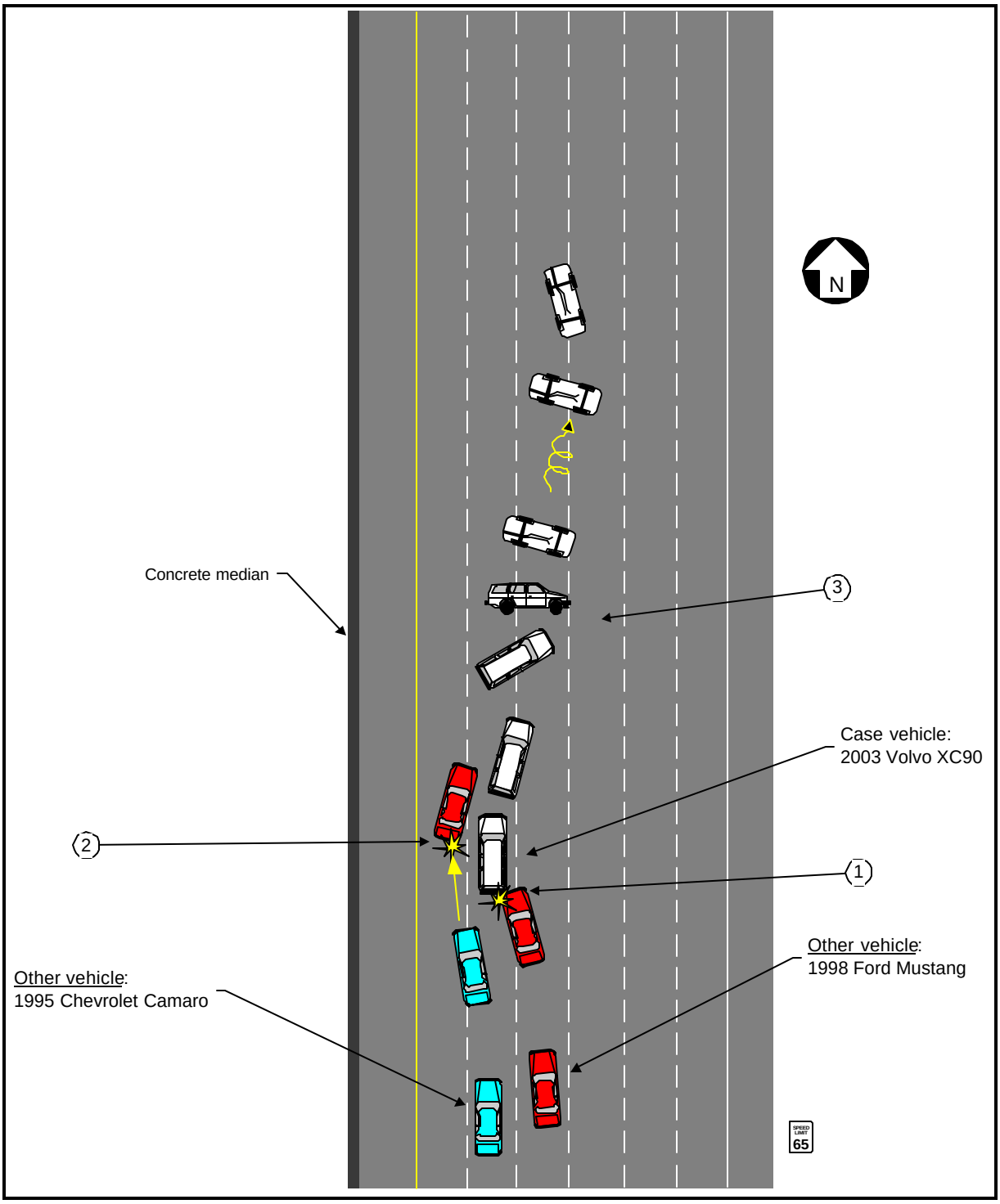

Figure 4. Scene diagram

VEHICLE DATA - 2003 Volvo XC90 sport utility vehicle

The 2003 Volvo XC90 was a five-passenger sport utility vehicle. The vehicle was equipped with a semi-automatic transmission that Volvo refers to as their "Geartronic" transmission. It essentially combines an automatic transmission with the gear-shifting feature of a manual transmission without the use of a foot-operated clutch. In the normal automatic transmission drive mode, the transmission behaves like any other automatic. The manual-shifting feature allows more control over the full range of rpms the engine offers. Standard features for the vehicle include: anti-lock disc brakes, rollover stability control, and boron steel B pillars and roof structure. The XC90 has a center of gravity of 66.3 cm (26.14 in.) and a static stability factor of 1.22[1].

VIN:	YV1CM59H531xxxxxx
Odometer:	Unknown, digital.
Engine:	5 cylinder, 2.5L
Reported Defects:	None noted
Cargo:	None

The 2003 Volvo XC90 was equipped with Michelin Synchome P235/65R17 tires. The specific tire data is as follows:

Tire	Tread	Pressure	Maximum recommended pressure
LF	6 mm (0.23 in)	262 kPa (38 psi)	352 kPa (51 psi)
LR	8 mm (0.31 in)	Tire flat	352 kPa (51 psi)
RF	8 mm (0.31 in)	255 kPa (37 psi)	352 kPa (51 psi)
RR	8 mm (0.31 in)	255 kPa (37 psi)	352 kPa (51 psi)

The front seating positions in the 2003 Volvo XC90 were configured with leather covered bucket seats with integral head restraints. The driver seat track was found to be somewhere between the forward most and middle setting, and no seat performance failures were noted. The seat back was adjusted to 70.7 degrees from horizontal and appears to have remained in the position during the collision events.. The front-right bucket seat was occupied by a 9-year-old male. At the time of the inspection the seat track was found to be in the middle track position and the seat back was adjusted to 74.5 degrees from horizontal. It too appeared to have retained its pre-impact position, and no failures were noted. The rear seating positions were configured with a leather covered bench seat with three folding backs. The

[1]Static Stability Factor (SSF)=average track width / (2 * CG height)

outboard rear seats had fixed head restraints that could be folded down for storage. The middle seat had an adjustable head restraint. The front and rear seats were equipped with Volvo's whiplash protection system. The rear seats were equipped with ISOFIX Baby/Child Seat attachments. No seat performance failures were noted. Behind the second row was the cargo area. No intrusions were noted in this area.

VEHICLE DAMAGE

Exterior Damage - 2003 Volvo XC90

Damage Description:	Moderate to major rollover damage to all sides of vehicle. Minor damage to rear bumper. Vehicle declared a total loss by insurance company.	
CDC:	Impact 1: 05BCMN1 Impact 2: 00TDDO3	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

Figure 5. Top damage to Volvo XC90

An external examination of the Volvo XC90 revealed a 5-door sport utility vehicle with moderate damage to the top and side planes from rolling over (Event 3), and minor damage to the rear plane from being initially struck by the Ford Mustang (Event 1). None of the wheels were visibly restricted, but the right rear axle was bent and canted underneath the Volvo at a noticeable angle. The left rear tire was flat. The top plane sustained the maximum crush, which was measured at15.0 cm (5.9 in). This resulted in a CDC of 00TDDO3. The rear impact, Event 1, resulted in a CDC of 05BCMN1 and was very minor. The rollover impact resulted in integrity loss due to the fracturing and consequent disintegration of both the left and right side window glazing. The roof glazing also disintegrated, and the windshield sustained a hole that was large enough to allow a human head to exit the vehicle. The sunroof glazing had also disintegrated as the vehicle rolled over. None of the side doors opened, nor were they jammed shut. The rear hatch did come open; a failure of the door support structure was noted during the inspection.

Interior Damage - 2003 Volvo XC90

Interior damage to the Volvo XC90 was moderate and attributed to occupant contact and passenger compartment intrusion. The entire windshield was fractured from impact forces. The side glass for the front right and front left doors disintegrated. The rear hatch came open. A number of interior components intruded as a result of the rollover[2]. The greatest intrusion, 9.0 cm (3.5 in), occurred as the right roof rail was displaced vertically inward. The right A pillar moved vertically a distance of 7.0 cm (2.8 in). The right front windshield header moved vertically 1.0 cm (0.4 in). The left front A pillar, the left front roof rail and the left front roof area were visibly observed to have intruded vertically a small amount-somewhere in the 3.0-8.0 cm (1.1-3.1 in) range. There were bilateral knee contacts to the left lower knee bolster. There was scuffing to the left interior door and the glove compartment door. The upper half of the steering wheel rim was bent approximately 3.0 cm (1.1 in).

[2]SCI change

MANUAL RESTRAINT SYSTEMS - 2003 Volvo XC90

The Volvo XC90 was configured with manual 3-point lap and shoulder belts with sliding latch plates for both front positions and the rear outboard positions. The middle rear seat was configured with an integral lap and shoulder belt with a sliding latch plate and a belt positioning device. The driver's seat belt had an emergency locking retractor while all the other seat belts were equipped with switchable retractors. All the seat belts were also equipped with pretensioners and force limiters. The pretensioners at all seat positions actuated during the rollover. The driver's seat belt caused the cover of the automatic adjustable shoulder belt positioner to be dislodged. The cover of the shoulder belt positioner on the passenger side remained in place. The belt positioning guide for the rear middle seat was broken due to pretensioner movement. The rear left seat belt anchorage was not attached to the anchorage point at the time of the inspection. The reasons for this are unclear. There were no indications that the two components were forced apart.

Figure 7. Driver's seat belt

Figure 8. Shoulder belt positioner on driver's side

Figure 9. Shoulder belt positioner for front right passenger

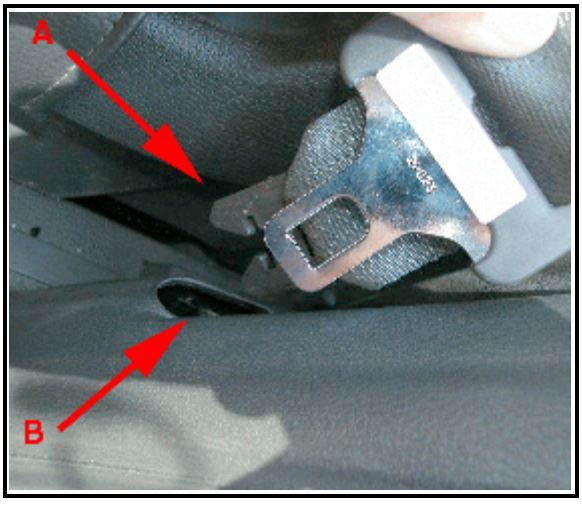

Figure 10. Rear left seat belt. A=belt anchorage, B=vehicle anchorage point

AIR BAG SYSTEM - 2003 Volvo XC90

The Volvo was equipped with driver and front passenger dual-threshold air bags, inflatable side curtains, and seat mounted side impact air bags for driver and front passenger.

The driver's air bag was steering wheel mounted and did not deploy. The front right passenger air bag was top instrument panel mounted and it also did not deploy. The seat back mounted side air bags for both front seat positions did not deploy.

During the rollover sequence, both side curtains did deploy. The deployed left side curtain air bag was measured and found to be 150 cm (59.0 in) in length, and approximately 37.0 cm (14.6 in) in width. It had two tethers. The tether which was attached to the A pillar was found to be approximately 34.0 cm (13.4 in) in total length. The other tether, which was affixed to the area near the C pillar, was found to be approximately 33.0 cm (12.9 in) in length. Both the left and right side curtain air bags were identical. The curtain air bags descend vertically almost to the base of the side windows and extend longitudinally to provided coverage for both front and rear seat occupants.

The left side curtain came into contact with the roadway/ground after the side glass shattered. There was no damage noted to the air bag fabric from this ground contact.

Figure 11. Exterior view, left side air curtain

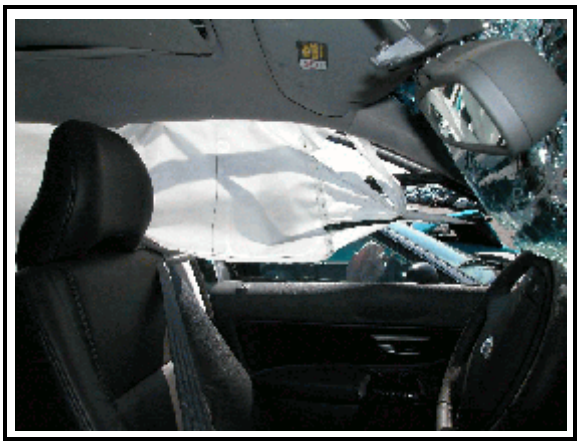

Figure 12. Interior view, left side curtain

Figure 13. Interior view, right side air curtain

ROLLOVER PROTECTION - 2003 Volvo XC90

The Volvo XC90 was equipped with a Roll Stability Control system (RSC). It is in operation from 9.6 km/h (6.0 mph) up to top speed while cornering, taking evasive maneuvers, braking, and accelerating. According to Volvo literature, the RSC's gyroscopic sensor continuously monitors roll angle and rate, assessing the risk of rollover. If necessary, the system activates Dynamic Stability and Traction Control (DSTC) to automatically stabilize the XC90. DSTC itself collects data from a steering wheel angle sensor, lateral force sensor, yaw rate sensor and speed sensors, and then by comparing the information calculates if the car is moving in the intended direction or not. DSTC interacts by braking one or more wheels and/or reducing engine torque to keep the car on track by transforming the impending oversteer into under steer. If rollover is not preventable, RSC deploys curtain air bags on both sides covering both rows of seats before impact ever occurs. The bags remain inflated long enough for the XC90 to roll four times.

It does not appear that the driver was able to make any substantive efforts at recovering the vehicle after the initial contact with the rear from the Mustang. The vehicle appears to have immediately gone into a clockwise yaw and rolled onto its left side without the driver ever successfully countering the rotation with steering input.

VEHICLE DATA - 1998 Ford Mustang

Description:	1998 Ford Mustang	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None reported on the PAR	
Cargo:	Unknown	
Damage Description:	Scratches and dents to front left bumper, hood buckled, cracked and dented front quarter panel and fender. The vehicle was towed from the scene with what has been described as *moderate* damage.	
CDC:	Unknown. The police report drawing indicated damage to the front-left area and to the right rear quarter panel.	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

VEHICLE DATA - 1995 Chevrolet Camaro

Description:	1995 Chevrolet Camaro 3-door hatchback	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None reported	
Cargo:	A computer in the hatch area and a monitor in the rear seating area. Estimate weight of 16 kg (35 lbs.)	
Damage Description:	The police report indicated that the vehicle had sustained *moderate* damage, but was driven from the scene by the driver. The interviewee stated that the vehicle was driven to a gas station near the scene, and towed from that location. It was subsequently declared a total loss.	
CDC:	Unknown. The daughter of the driver indicated that the vehicle sustained damage to its right quarter panel from the Mustang, which then raked down the right side of the car as they remained in contact prior to disengagement.	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

OCCUPANT DEMOGRAPHICS - 2003 Volvo XC90

	Occupant 1	Occupant 2
Age/Sex:	45/Female	9/Male
Seated Position:	Front left	Front right
Seat Type:	Leather covered bucket seat. Seat adjusted to between forward most and middle track position. Seat back adjusted to 70.7 degrees from horizontal.	Leather covered bucket seat. Seat adjusted to middle track position. Seat back adjusted to 74.5 degrees from horizontal.
Height:	157 cm (62 in)	Unknown
Weight:	54 kg (119 lbs)	Unknown
Occupation:	Unknown	NA
Pre-existing Medical Condition:	Unknown	Unknown
Alcohol/Drug Involvement:	None	NA
Driving Experience:	Unknown-the driver of Camaro told his daughter that this driver had just picked up the Volvo from the dealership and did not appear to be familiar with how the vehicle handled.	NA
Body Posture:	Unknown	Unknown
Hand Position:	Unknown	Unknown
Foot Position:	Unknown	Unknown
Restraint Usage:	Lap and shoulder belt available, used. The driver's seatbelt pretensioners actuated. The force limiters were not loaded.	Lap and shoulder belt available, used. The passenger's seatbelt pretensioners actuated. The force limiters were not loaded.
Air bag:	Driver's air bag available, did not deploy. Seat back mounted side air bag available, did not deploy. Side air curtain available, did deploy.	Front right passenger air bag available, did not deploy. Seat back mounted side air bag available, did not deploy. Side air curtain available, did not deploy.

OCCUPANT DEMOGRAPHICS - 1998 Ford Mustang

Age/Sex:	56/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	183 cm (72 in)
Weight:	82 kg (180 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None per PAR
Driving Experience:	Presumed to be > 10 years
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Unknown. The police report coding indicated the driver had been wearing a lap and shoulder belt

OCCUPANT DEMOGRAPHICS - 1995 Chevrolet Camaro

Age/Sex:	45/male
Seated Position:	Front left
Seat Type:	Unknown
Height:	178 cm (70 in)[3]
Weight:	77 kg (170 lb)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None per PAR coding
Driving Experience:	Unknown
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt (manual) and air bags (non-deployment) The vehicle has been in one other crash that the interviewee knew about. She is unsure if the air bags had deployed in the past.

[3]Change due to follow up interview

OCCUPANT INJURIES -2003 Volvo XC90

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Minor laceration to left and right hands	790600.1,3	884.0	Flying glass
RF Occupant:	Minor laceration to left and right hands	790600.1,3	884.0	Flying glass

OCCUPANT INJURIES - Mustang

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Not injured			

OCCUPANT INJURIES - Camaro

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Not injured			

OCCUPANT KINEMATICS - 2003 Volvo XC90

The 45-year-old female driver of the case vehicle was seated in a normal, upright fashion. The leather covered bucket seat was adjusted to between the forward most and middle track position. The seat back was adjusted to 70.7 degrees from horizontal. The driver was wearing the 3-point lap and shoulder belt. The 9-year-old front right occupant was seated in a normal, upright fashion. The leather covered bucket seat was adjusted to the middle track position. The seat back was adjusted to 74.5 degrees from horizontal.

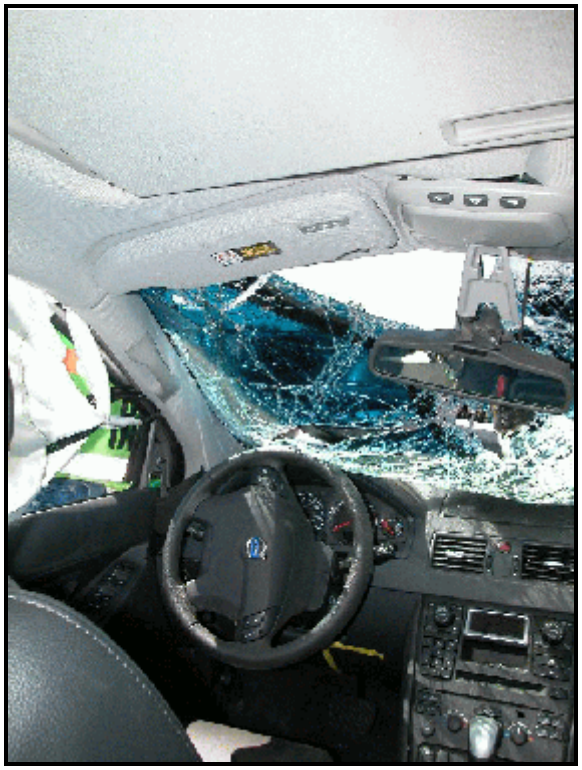

Figure 14. Driver's seated position

As the case vehicle was struck in the rear by the Ford Mustang (Event 1), both the restrained driver and restrained front-right occupant in the case vehicle moved toward the force direction. The impact resulted in only a small change in velocity. The driver and passenger subsequently loading their bucket seat backs as well as their integral head restraints with very little force; no contact points or seat failures were noted from this first impact.

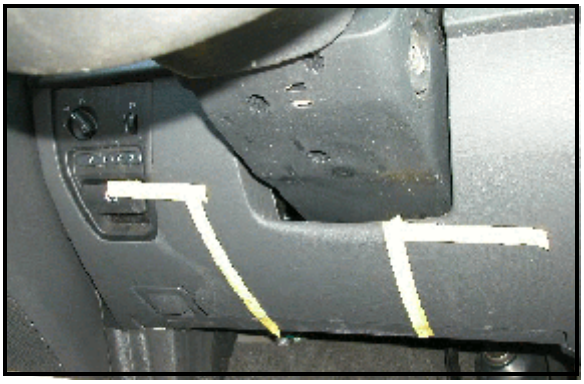

Figure 15. Driver knee contacts

As a result of the initial impact, the case vehicle made a rapid clockwise rotation. Upon so doing, the vehicle began a lateral movement which resulted in the vehicle rolling to the left. Although the manual 3-point lap and shoulder belt safety systems prevented the driver from leaving her seating position, occupant contacts visible within the vehicle illustrate that she did strike the rigid knee bolsters with her lower extremities. She may have also struck her left shoulder on the door area, as there was an area of deformation noted in that region . The driver complained of hand lacerations, as well as neck and upper back pain. The hand lacerations were most likely due to coming into contact with flying glass as the side window and roof glazing disintegrated during the rollover.

The 9 year-old male also moved toward the left as the vehicle began to rollover. The manual 3-point lap and shoulder belt prevented the boy from being thrown from this seat, or from being ejected from the case vehicle. The boy complained of arm lacerations, which were most likely the result of disintegrating window glazing coming into contact with him. He also reportedly sustained neck and back pain.

It is unclear how either of the occupants in the case vehicle were able to exit the sport utility vehicle, which had come to rest on its roof in the middle of the freeway.

Both occupants in Vehicle 1 were transported to a local hospital, where they were treated and released from the emergency room.

Neither driver of the other two involved vehicles were injured.

Figure 16. Front right passenger seated position