On-scene Investigation / Vehicle to Vehicle
Dynamic Science, Inc. / Case Number: DS99017
1999 BMW
Arizona
February 1999

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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 crash occurred in February, 1999 during the early morning hours in Arizona. This crash occurred on an interstate roadway. The crash began when a non-contact vehicle, a 1999 Cadillac, sustained a flat tire. The vehicle felt unstable to the driver and she was finally able to stop the vehicle in the gore area between the first westbound travel land and the on-ramp. The driver then began an attempt to cross the on-ramp to get to the shoulder on the north side of the roadway. Vehicle 3, a 1991 Geo Prism driven by a properly restrained 30-year-old female, was initially traveling westbound on the interstate on-ramp. This vehicle contained two child occupants who were using some type of child restraints at the time of the crash. This driver saw the non-contact vehicle moving from the gore to the shoulder and stopped her vehicle. She flashed her high beam headlights, signaling the Cadillac to change lanes. Vehicle 1, a 1999 BMW 323i four-door sedan driven by a properly restrained 26-year-old female, was initially traveling westbound on the interstate on-ramp. Vehicle 1 was traveling behind Vehicle 3. As Vehicle 3 came to a stop, this vehicle also slowed to a stop. Vehicle 2, a 1999 Ford F-150 XLT extended cab pickup truck driven by a properly restrained 55-year-old male, was traveling westbound on the interstate on-ramp at a police estimated speed of 80 km/h (50 mph). The driver was putting his mobile phone down and looking over his left shoulder at westbound traffic on the interstate, attempting to merge on the interstate. Vehicle 4, a 1988 Ford F-150 4x4 pickup truck driven by an unrestrained 42-year-old male, was traveling westbound in the second travel lane at a police estimated speed of 97 km/h (60 mph). Vehicle 5, a 1999 Ford pickup truck driven by a restrained 47-year-old male, was traveling westbound in the third travel lane at a police estimated speed of 97 km/h (60 mph). The driver of Vehicle 2 saw that Vehicle 1 had stopped and began braking and steering to the right. The front of his vehicle struck the right rear of Vehicle 1. Vehicle 1 was pushed into a counterclockwise rotation. The right side of Vehicle 1 impacted the left rear of Vehicle 3. Vehicle 1 continued its counterclockwise rotation as it first crossed the gore area and then the first westbound travel lane. As Vehicle 1 entered the second westbound travel lane it was struck in the left side by Vehicle 4. At impact, the driver's side air bag and the Inflatable Tubular Structure (ITS) deployed. Vehicle 1 continued on and entered the third westbound travel lane. The driver of Vehicle 5 saw Vehicle 1 and steered the left. The front of Vehicle 1 contacted the right side of Vehicle 5. The driver of Vehicle 1 sustained serious injuries.

17. Key Words	18. Distribution Statement
Air bag, deployment, accident, serious injury, side air bag	

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Dynamic Science, Inc.
Accident Investigation
Case Number: DS99017

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BACKGROUND:

Description:	This case was initiated in response to a report of a side air bag deployment in a 1999 BMW 3 series four-door sedan.
Investigation Type:	On-scene
Crash Location:	Arizona
Crash Date:	February 1999
Notification Date:	March 24, 1999
Field Work Completed:	April 6, 1999

SUMMARY:

This crash occurred in February, 1999 during the early morning hours in Arizona. This crash occurred on an interstate roadway. The roadway at this location is comprised of three straight and level concrete westbound travel lanes, a shoulder on the south side of the roadway, a marked gore area on the north side of the roadway which is bounded on the right by an on-ramp. Westbound traffic is separated from eastbound traffic by a raised concrete median barrier. The speed limit in the area is 89 km/h (55 mph). The weather was clear and dry. It was dark and the streetlights were on. Traffic was heavy at this time of day.

Figure 1. Overview of approach to areas of impact (westbound)

The crash began when a non-contact vehicle, a 1999 Cadillac, sustained a flat tire. The vehicle felt unstable to the driver and she was finally able to stop the vehicle in the gore area between the first westbound travel lane and the on-ramp. The driver then began an attempt to cross the on-ramp to get to the shoulder on the north side of the roadway.

Vehicle 3, a 1991 Geo Prism driven by a properly restrained 30-year-old female, was initially traveling westbound on the interstate on-ramp. This vehicle contained two child occupants who were using some type of child restraints at the time of the crash. This driver saw the non-contact vehicle moving from the gore to the shoulder and stopped her vehicle. She flashed her high beam headlights, signaling the Cadillac to change lanes.

Vehicle 1, a 1999 BMW 323i four-door sedan driven by a properly restrained 26-year-old female, was initially traveling westbound on the interstate on-ramp.

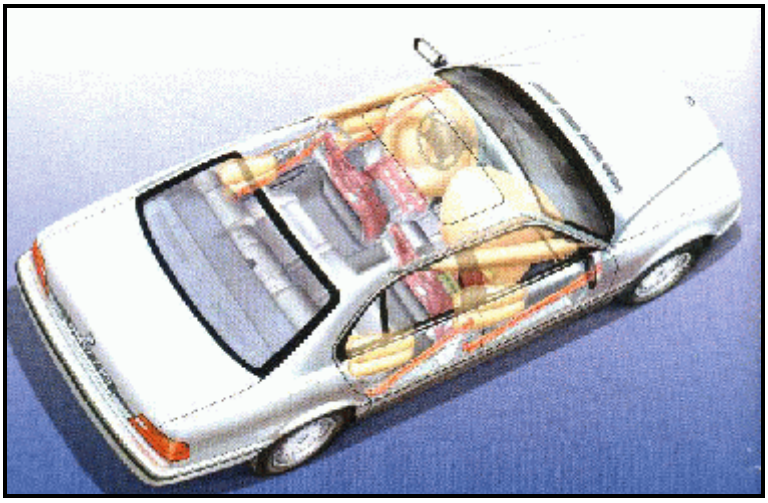

Figure 2. Overview of air bag locations. Note: rear torso air bags are an option.

Vehicle 1 was equipped with front seat automatic safety belt pretensioners and six air bags: a driver's side steering wheel mounted air bag, a passenger side dash-mounted air bag, left and right door-mounted torso air bags, and left and right Inflatable Tubular Structure (ITS) type air bags. The front air bags include a "smart" dual-threshold deployment system (i.e., when the belts are in use, the air bag will not deploy at a lower crash severity). The ITS is entirely concealed above the front doors and within the A-pillar and roof cladding or upholstery. The ITS is a hollow, flexible, essentially airtight tube. At one end, this tube is anchored inside the vehicle's A-pillar, near the bottom of the pillar. At the other end, it is anchored in the roof just above the rear door. Upon side impact, the inflator, mounted on one end of the tube, inflates the tube with an inert gas. A relatively airtight inner tube of silicon material manages the inflation; a woven Polyamid outertube manages the tube's shape. The diameter increase forced by inflation causes the length to decrease. In turn, the tube no longer fits inside the area where it is stored; it pulls out of the headliner and forms a soft, straight tube and stretched in a straight line from the lower windshield pillar to the roof. According to BMW literature on the ITS, the tube is designed to stay inflated for approximately 6 seconds after deploying. The ITS is described in BMW's literature as the Head Protection System (HPS). Vehicle 1 was also equipped with a door anchoring system which prevents the doors from opening during a crash.

Vehicle 1 was traveling behind Vehicle 3. As Vehicle 3 came to a stop, this vehicle also slowed to a stop.

Vehicle 2, a 1999 Ford F-150 XLT extended cab pickup truck driven by a properly restrained 55-year-old male, was traveling westbound on the interstate on-ramp at a police estimated speed of 80 km/h (50 mph). The driver was putting his mobile phone down and looking over his left shoulder at westbound traffic on the interstate, attempting to merge on the interstate.

Figure 3. Exterior, front left, Vehicle 1

Vehicle 4, a 1988 Ford F-150 4x4 pickup truck driven by an unrestrained 42-year-old male, was traveling westbound in the second travel lane at a police estimated speed of 97 km/h (60 mph).

Vehicle 5, a 1999 Ford pickup truck driven by a restrained 47-year-old male, was traveling westbound in the third travel lane at a police estimated speed of 97 km/h (60 mph).

Figure 4. Exterior, left rear, Vehicle 1

The driver of Vehicle 2 saw that Vehicle 1 had stopped and began braking and steering to the right. The front of his vehicle struck the right rear of Vehicle 1 (CDC=06BZEW3). Vehicle 1 sustained a longitudinal delta v of 33.4 km/h (20.7 mph). Vehicle 1 was pushed into a counterclockwise rotation. The right side of Vehicle 1 (CDC=12RZEW2) impacted the left rear of Vehicle 3. Vehicle 1 continued its counterclockwise rotation as it first crossed the gore area and then the first westbound travel lane. As Vehicle 1 entered the second westbound travel lane it was struck in the left side by Vehicle 4 (09LZAW3). At impact, the driver's side air bag and the Inflatable Tubular Structure (ITS) deployed. Vehicle 1 sustained a lateral delta v of 44.3 km/h (27.5 mph) and a longitudinal delta v of 7.8 km/h (4.9 mph). Vehicle 1 continued on and entered the third westbound travel lane. The driver of Vehicle 5 saw Vehicle 1 and steered the left. The front of Vehicle 1 contacted the right side of Vehicle 5.

Figure 5. Exterior, Vehicle 2 (1999 Ford F150 pickup)

Vehicle 1 continued on and came to rest facing south on the shoulder and the southernmost travel lane. Vehicle 2 came to rest facing west on the on-ramp. Vehicle 3 came to rest on the on-ramp and was moved to the northbound shoulder. Vehicle 4 was pushed into a counterclockwise rotation and came to rest near the center concrete barrier—there may also have been an impact with the barrier. Vehicle 5 came to a controlled stop on the shoulder facing west.

Figure 6. Exterior, Vehicle 3 (1991 Geo Prism)

The driver of Vehicle 1 sustained the following injuries: collapsed left lung, fractured ribs, lacerated spleen, torn diaphragm, torn bladder, laceration above the left eye, fractured left clavicle, possibly a fractured pelvis, and multiple contusions and lacerations. The left side injuries are primarily related to the intruding door panel. She was entrapped in the vehicle. After being freed, she was flown by air ambulance to a local trauma center where she underwent surgery and was hospitalized. The driver has had several surgeries since the time of the crash. She is currently out of the hospital and recovering at home.

Figure 7. Exterior, Vehicle 4 (1988 Ford pickup)

The driver of Vehicle 2 sustained injuries to his face and chest from contact with the deploying steering wheel air bag. He was transported to a local hospital where he was treated and released.

Figure 8. Exterior, Vehicle 5 (1997 Ford pickup)

The driver of Vehicle 3 sustained minor injuries to her neck and back. She was transported by ground ambulance to a local hospital where she was treated and released. The two child occupants of this vehicle were also transported but no injuries were reported.

The driver of Vehicle 4 sustained minor injuries to his chest and forehead. He was transported to a local hospital where he was treated and released.

The driver of Vehicle 5 sustained possible injuries to his neck and was treated at the scene by the area fire department.

Vehicle 1 sustained extensive damage to the rear, the left side, and the right side. There was 36 cm (14 in.) of intrusion through the driver's side door. The intrusion was mostly lateral, but there was a longitudinal component also. The driver's seat was forced to the right and rearward into the rear seat area. There was also intrusion of the B-pillar, A-pillar, door sill, and instrument panel. As stated earlier, the driver was entrapped and needed to be extricated by emergency personnel. The roof was cut off by emergency personnel. The ITS deployed, but was cut away also by emergency personnel.

SCENE DIAGRAM

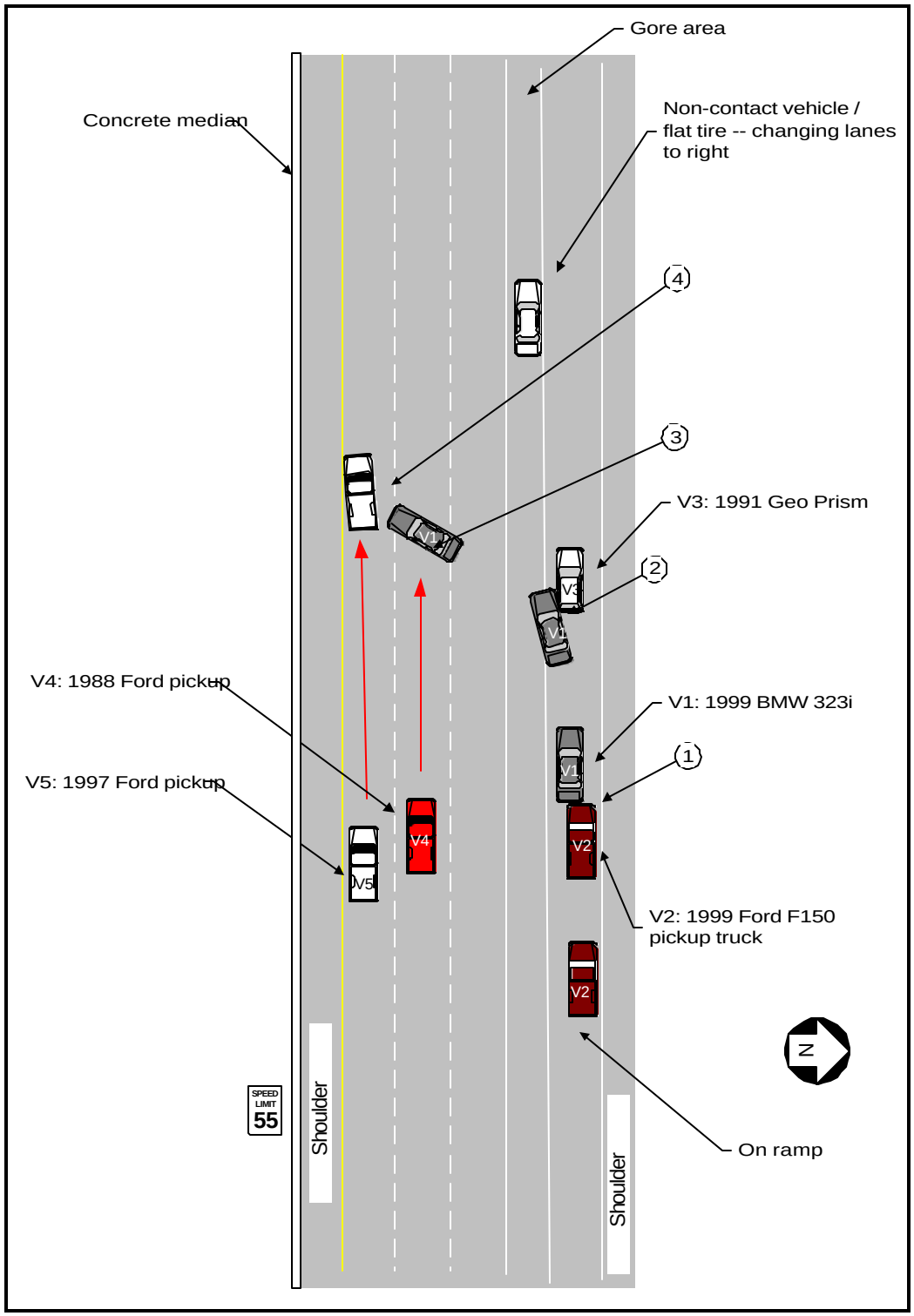

Figure 9. Scene Sketch

DETAILED INFORMATION

Vehicles

Vehicle 1

Description:	1999 BMW 323i four-door sedan	
VIN:	WBAAM334XFPXXXXX	
Odometer:	Unknown	
Engine:	2.3 L	
Reported Defects:	None	
Cargo:	None	
Damage Description:	Extensive lateral crush through the left side. Both left side doors were jammed and the side glass disintegrated. Moderate right side damage extending from the front door to the rear of the vehicle. Major damage to rear of vehicle. All pillars were cut and the roof removed to extricate the single occupant.	
CDC:	Impact #1: 06BZEW3 Impact #2: 12RZEW2 Impact #3: 09LZAW3 Impact #4: Unknown	
Delta V (Impact #1):	Total	33.4 km/h (20.7 mph)
	Longitudinal	33.4 km/h (20.7 mph)
	Lateral	0 km/h (0 km/h)
	Energy	40,160 joules (29,638 ft-lbs)
Delta V (Impact #3):	Total	45.0 km/h (28.0 mph)
	Longitudinal	7.8 km/h (4.9 mph)
	Latitudinal	44.3 km/h (27.58 mph)
	Energy	92,528 joules (68,245 ft-lbs)

Figure 10. Exterior, Vehicle 1 (right rear)

Figure 11. Exterior, Vehicle 1 (left rear)

Vehicle 2

Description:	1999 Ford F-150 XLT extension cab 4 x 2 pickup truck	
VIN:	1FTRX17W1Xnxxxxxx	
Odometer:	Unknown	
Engine:	4.6 L	
Reported Defects:	None noted	
Cargo:	Boxes carrying light items like clothing.	
Damage Description:	Heavy front to rear crush beginning at the left front bumper corner and extending to the middle of the vehicle.	
CDC:	Impact 1: 12FYEW2	
Delta V:	Total	23.2 km/h (14.4 mph)
	Longitudinal	-23.2 km/h (-14.4 mph)
	Latitudinal	0 km/h (0 mph)
	Energy	64,005 joules (47,231 ft-lbs)

Figure 12. Exterior, Vehicle 2 (front)

Figure 13. Exterior, Vehicle 2 (front right)

Vehicle 3

Description:	1991 Geo Prism four door sedan	
VIN:	1Y1SK546XMZxxxxxx	
Odometer:	Unknown	
Engine:	1.6 L L4	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Minor bumper crush to left rear bumper corner.	
CDC:	Impact 2: 06BLEE3	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

Figure 14. Exterior, Vehicle 3 (rear)

Figure 15. Exterior, Vehicle 3 (left side)

Vehicle 4

Description:	1988 Ford F150 4x4 regular cab pickup	
VIN:	1FTEF14Y2JPBxxxxxx	
Odometer:	Unknown	
Engine:	4.9 L EFI (300 CID) I6	
Reported Defects:	None	
Cargo:	Rear bed completely filled with carpentry equipment. Unknown weight.	
Damage Description:	Moderate front bumper crush with some shifting to the left.	
CDC:	Impact 3: 01FDEW2	
Delta V:	Total	32 km/h (19.9 mph)
	Longitudinal	-30.9 km/h (-19.2 mph)
	Latitudinal	-8.3 km/h (-5.1 mph)
	Energy	111,809 joules (82,466 ft-lbs)

Figure 17. Exterior, Vehicle 4 (right side). Note the lack of contact to the barrier.

Figure 16. Exterior, Vehicle 4 (center front)

Figure 19. Exterior, Vehicle 4 (front right)

Figure 18. Vehicle 4 (carpentry cargo)

Vehicle 5

Description:	1997 Ford F250 4x2 regular cab pickup	
VIN:	1FTHF25G3VEBxxxxxx	
Odometer:	Unknown	
Engine:	7.5 l EFI V8	
Reported Defects:	None noted	
Cargo:	Carrying camper shell. Unknown additional weight.	
Damage Description:	Moderate front to rear crush at mid-door level and at frame rail level.	
CDC:	Impact 4: 01RDEW2	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

Figure 21. Exterior, Vehicle 5 (right side)

Figure 20. Exterior, Vehicle 5 (close up of right side damage)

Occupants

Vehicle 1	Occupant 1
Age/Sex:	26/Female
Seated Position:	Front left
Seat Type:	Bucket
Height:	Unknown
Weight:	Unknown
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Unknown
Body Posture:	Normal, upright prior to initial impact.
Hand Position:	Unknown
Foot Position:	Right foot on brake–vehicle stopped or slowing
Restraint Usage:	Lap and shoulder belt used
Air bag:	Front air bags available–did not deploy. Driver's side air bag and right front passenger's air bag available–driver's side air bag deployed. Left and right side tubular structures available–left side deployed.

Occupants

Vehicle 2

Age/Sex:	55/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	Unknown
Weight:	Unknown
Occupation:	Unknown
Pre-existing Medical Condition:	Arthritis. Using Glucosamine chondroitin and herbal vitamins for treatment.
Alcohol/Drug Involvement:	None
Driving Experience:	Presumed to be >20 years
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Unknown
Air bag:	Deployed, according to police

Occupants

Vehicle 3	Occupant 1	Occupant 2	Occupant 3
Age/Sex:	30/Female	2/Female	4/Female
Seated Position:	Front left	Rear left	Rear right
Seat Type:	Bucket	Bench with folding back	Bench with folding back
Height:	Unknown	Unknown	Unknown
Weight:	Unknown	Unknown	Unknown
Occupation:	Unknown	NA	NA
Pre-existing Medical Condition:	Unknown	Unknown	Unknown
Alcohol/Drug Involvement:	None	NA	NA
Driving Experience:	Presumed to be > 10 years	NA	NA
Body Posture:	Unknown	Unknown	Unknown
Hand Position:	Unknown	Unknown	Unknown
Foot Position:	Unknown	Unknown	Unknown
Restraint Usage:	Lap and shoulder belt used	Unknown make/model child restraint used	Unknown make/model child restraint used

Occupants

Vehicle 4

Age/Sex:	42/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	Unknown
Weight:	Unknown
Occupation:	Unknown
Pre-existing Medical Condition:	Unknown
Alcohol/Drug Involvement:	None
Driving Experience:	Presumed > 20 years
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	No restraints used

Occupants

Vehicle 5

Age/Sex:	47/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	Unknown
Weight:	Unknown
Occupation:	Unknown
Pre-existing Medical Condition:	Unknown
Alcohol/Drug Involvement:	None
Driving Experience:	Presumed >20 years
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt used

Injuries and Injury Mechanisms

Vehicle 1

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Torn diaphragm	440804.3,4	862.0	Door side panel
	Torn bladder	540620.2,8	867.0	Door side panel
	Lacerated spleen	544220.2,2	865.00	Door side panel
	Collapsed left lung	441499.3,2	861.20	Door side panel
	Fractured ribs, left	450210.2,2	807.00	Door side panel
	Laceration above left eye	290600.1,7	870.0	Unknown
	Fracture, left clavicle	752200.2,2	767.2	Door side panel
	Multiple lacerations	990600.1,0	--	Unknown
	Multiple contusions	990400.1,0	--	Unknown
	Possible pelvis fracture	Not codeable	--	Door side panel

Vehicle 2

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Unknown type injury to face	290099.1,9	--	Air bag
	Unknown type injury to chest	490099.1,9	--	Air bag

Vehicle 3

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Minor injury to back	490099.1,9	–	Unknown
	Minor injury to neck	390099.1,9	--	Unknown
Rear left occupant:	Possible injuries	Not codeable	–	--
Rear right occupant:	Possible injuries	Not codeable	–	--

Vehicle 4

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Minor injury to chest	490099.1,9	–	Unknown
	Minor injury to forehead	290099.1,9	--	Unknown

Vehicle 5

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Possible injury to neck	Not codeable	--	--

Occupant Kinematics

The driver of Vehicle 1 was seated in a normal, upright fashion. She was wearing the available lap and shoulder belt. Her right foot was on the brake and the vehicle was either stopped or slowing. Vehicle 2 struck Vehicle 1 directly from behind. The driver of Vehicle 1 reacted to the 180 degree direction of force by moving rearward into the rear seat back. Vehicle 1 was accelerated forward and to the left and engaged the left rear of Vehicle 3. The driver of Vehicle 1 reacted to this moderate longitudinal impact by moving forward and to the right, possibly loading the lap and shoulder belt to some extent. As Vehicle 1 continued its path across the freeway, it was struck in the left side by Vehicle 4. This was a significant impact and the door mounted left side air bag deployed, as did the left side ITS. The driver reacted to the 260 degree direction of force by moving sharply to the left and striking the intruding left side door surface. Any protection offered by the side air bag was likely offset by the extensive intrusion. All the major torso and abdominal injuries were as a result of the door contact. The ITS had been cut out during extrication. It appears likely, however, that the ITS provided some measure of head protection since there were no reported major head injuries. The driver was entrapped in the vehicle following the left side impact. Vehicle 1 continued on into the next lane and struck the right side of Vehicle 5. The driver did not react much to this collision–she was entrapped to some degree and was likely unconscious.

The driver was extricated from the vehicle after the roof was removed by cutting the pillars.

Figure 22. Left side of vehicle showing intruding components

Figure 23. Shows ITS and left side air bag

Figure 24. Driver's seated position