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ON-SITE SMALL OVERLAP/OBLIQUE INVESTIGATION

CASE NUMBER - IN10034

LOCATION - MISSOURI

VEHICLE - 2010 TOYOTA CAMRY LE

CRASH DATE - September 2010

Submitted:

March 14, 2011



Contract Number: DTNH22-07-C-00044

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
National Center for Statistics and Analysis
Washington, D.C. 20590-0003

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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.

Technical Report Documentation Page

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|--|--|---|--|-----------------------------------|---|
| 1. <i>Report No.</i> IN10034 | | 2. <i>Government Accession No.</i> | | 3. <i>Recipient's Catalog No.</i> | |
| 4. <i>Title and Subtitle</i> On-Site Small Overlap/Oblique Investigation Vehicle - 2010 Toyota Camry LE Location - Missouri | | | 5. <i>Report Date:</i> March 14, 2011 | | |
| | | | 6. <i>Performing Organization Code</i> | | |
| 7. <i>Author(s)</i> Special Crash Investigations Team #2 | | | 8. <i>Performing Organization Report No.</i> | | |
| 9. <i>Performing Organization Name and Address</i> Transportation Research Center Indiana University 501 South Madison, Suite 105 Bloomington, Indiana 47403-2452 | | | 10. <i>Work Unit No. (TRAIS)</i> | | |
| | | | 11. <i>Contract or Grant No.</i> DTNH22-07-C-00044 | | |
| 12. <i>Sponsoring Agency Name and Address</i> U.S. Department of Transportation (NVS-411) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003 | | | 13. <i>Type of Report and Period Covered</i> Technical Report Crash Date: September 2010 | | |
| | | | 14. <i>Sponsoring Agency Code</i> | | |
| 15. <i>Supplementary Notes</i> On-site investigation of a small overlap/oblique impact to a 2010 Toyota Camry LE. | | | | | |
| 16. <i>Abstract</i> This on-site investigation focused on the small overlap/oblique impact to a 2010 Toyota Camry LE and the sources of the driver's injuries. The Toyota was occupied by a restrained 64-year-old female driver, a restrained 8-year-old male second row left passenger, and a restrained 10-year-old male second row right passenger. The Toyota was traveling west on a 2-lane state highway. A 1994 Chevrolet Cavalier was traveling east and entered the Toyota's travel lane. The front left corner of the Chevrolet impacted the front left corner of the Toyota. The direction of force on the Toyota was within the 12 clock sector and the impact force was sufficient to trigger a stage 2 deployment of the driver's frontal air bag. The driver's knee air bag also deployed. Following the impact debris from the Toyota and Chevrolet impacted a 1994 Jeep Grand Cherokee. The driver of the Toyota was transported by ambulance to a hospital where she was treated in the emergency room and released. She sustained minor injuries from loading the safety belt. The second row passenger's of the Toyota were not transported to a medical facility. The second row right passenger sustained a minor injury. The second row left passenger sustained no injuries. | | | | | |
| 17. <i>Key Words</i> Small Overlap/Oblique | | | Motor Vehicle Traffic Crash Injury Severity | | 18. <i>Distribution Statement</i> General Public |
| 19. <i>Security Classif. (of this report)</i> Unclassified | | 20. <i>Security Classif. (of this page)</i> Unclassified | | 21. <i>No. of Pages</i> 10 | 22. <i>Price</i> |

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This on-site investigation focused on the small overlap/oblique impact to a 2010 Toyota Camry LE (**Figure 1**) and the sources of the driver's injuries. This crash was brought to the attention of the National Highway Traffic Safety Administration (NHTSA) on October 4, 2010 by Special Crash Investigation Team 2. The investigation was assigned on October 6, 2010. The crash involved the Toyota, a 1994 Chevrolet Cavalier, and a 1994 Jeep Grand Cherokee. The crash occurred in September, 2010, at 1430 hours, in Missouri and was investigated by the Missouri State Highway Patrol. The Toyota and the crash scene were inspected on October 11, 2010. The driver's husband was interviewed on October 13, 2010. The Jeep and the Chevrolet were not inspected. This report is based on the police crash report, crash scene inspection, vehicle inspection, exemplar vehicle inspection, interview information, occupant kinematic principles, and evaluation of the evidence.



Figure 1: The damaged 2010 Toyota Camry LE

CRASH CIRCUMSTANCES

Crash Environment: This crash occurred on an 2-lane undivided state highway during daylight hours and cloudy weather conditions. The roadway traversed in an east-west direction and was curved to the west. There was one bituminous travel lane in each direction and the roadway was bordered by bituminous shoulders. Each travel lane was 3.6 m (11.8 ft) in width and each shoulder was 2 m (6.7 ft) in width. The roadway pavement markings consisted of solid white edge lines, a broken yellow center line for westbound traffic, and a solid yellow centerline for eastbound traffic. The grade for the Toyota was positive 5% at 75m (246 ft) east of the impact area and became level in the area of the impact. The grade for the Chevrolet was positive 3.3% 40 m (131.2 ft) prior to the impact. At the time of the crash the roadway was dry and the traffic density was moderate. The speed limit was 89 km/h (55 mph). The Crash Diagram is on page 10 of this report.

Pre-Crash: The Toyota was occupied by a restrained 64-year-old female driver, a restrained 8-year-old male second row left passenger, and a restrained 10-year-old male second row right passenger. The Toyota was traveling west behind a school bus, which turned left approximately 125 m (410 ft) prior to the crash location. The Toyota continued westbound and the driver was accelerating and negotiating a left curve (**Figure 2**) as the vehicle crested a hill. The Jeep was

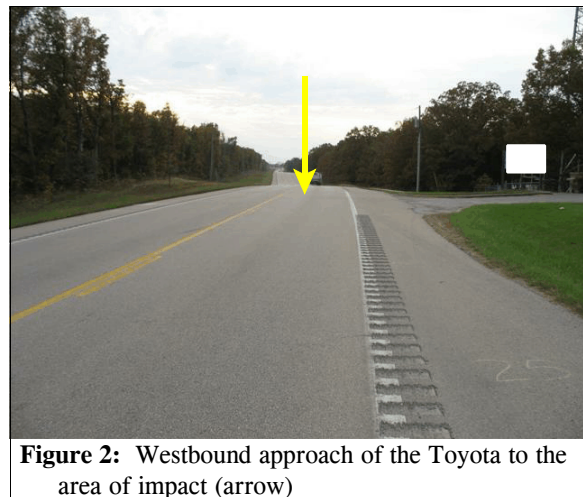


Figure 2: Westbound approach of the Toyota to the area of impact (arrow)

behind the Toyota. The unrestrained 18-year-old female driver of the Chevrolet was traveling east and entered the Toyota’s travel lane. The Toyota’s driver initiated a right steering maneuver and applied the brakes in an attempt to avoid the crash. The Toyota’s Event Data Recorder (EDR) reported the following pre-crash data. A row was added to convert mph to km/h.

| Seconds | -5 | -4 | -3 | -2 | -1 | -0.6 |
|---------------------|---------------|---------------|---------------|---------------|------------|------------|
| Speed (mph) | 26.1 | 28.6 | 31.1 | 34.8 | 33.6 | 22.4 |
| Speed (km/h) | 42.0 | 46.0 | 50.0 | 56.0 | 54.1 | 36.0 |
| Brake | Off | Off | Off | Off | On | On |
| Accelerator (Volts) | Middle (1.72) | Middle (1.72) | Middle (1.64) | Middle (1.52) | Off (0.78) | Off (0.78) |
| Engine (rpm) | 2400 | 2400 | 2400 | 2800 | 2000 | 1200 |

Crash: The Chevrolet entered the Toyota’s travel lane (**Figure 3**) and the front plane of the Chevrolet impacted the front plane of the Toyota (event 1). The impact on the Toyota occurred outside of the left frame rail on the corner of the front bumper. The Toyota’s fender, hood, and left front wheel were engaged and the left front wheel was displaced rearward 31 cm (12.2 in, **Figure 4**). The direction of force on the Toyota was within the 12 clock sector and the impact force triggered a stage 2 deployment of the driver’s frontal air bag. The driver’s knee air bag also deployed. Debris from the Toyota and Chevrolet impacted the Jeep (event 2).



Figure 3: Eastbound approach of the Chevrolet to the area of impact

Post-Crash: The police were notified of the crash at 1434 hours and arrived on scene at 1450 hours. The driver of the Toyota exited the vehicle through the left front door. She was transported by ambulance to a hospital where she was treated in the emergency room and released. The second row left and right passengers of the Toyota sustained no police reported injury. The driver of the Chevrolet sustained a fatal injury. The driver of the Jeep sustained no injuries. The Toyota and the Chevrolet were towed from the scene due to damage. The Jeep was driven from the scene.



Figure 4: The displacement of the Toyota’s left front wheel

The 2010 Toyota Camry LE was a front wheel drive, 5-passenger, 4-door sedan (VIN: 4T4BF3EK7AR-----) equipped with a 2.5-liter, 4-cylinder engine, a 6-speed automatic transmission, 4-wheel anti-lock brakes with electronic brake force distribution, traction control, and electronic stability control. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder safety belts, driver and front right passenger frontal air bags, driver knee air bag, seat-mounted side impact air bags, and side impact inflatable curtain (IC) air bags that provided protection for the front and second row outboard seating positions. The second row was equipped with a bench seat, lap-and-shoulder safety belts, adjustable head restraints, and Lower Anchor and Tethers for Children (LATCH) in the outboard seating positions. The drivers husband estimated the vehicle’s mileage at approximately 10,000 miles (16,093 kilometers). The specified wheelbase was 278 cm (109.4 in).

CASE VEHICLE DAMAGE

Exterior Damage: The Toyota sustained front plane damage during its impact with the Chevrolet. The front bumper, left headlamp/turn signal assembly, grille, hood, left fender, left front wheel, and left front door were directly damaged. The direct damage began at the front left bumper corner and extended 37 cm (15 in) across the bumper. The crush measurements were taken on the bumper bar. A second set of measurements was taken at the upper radiator support level. The maximum residual crush at the bumper level was 6 cm (2.4 in) occurring at C₁. The maximum crush at the radiator support level was 15 cm (5.9 in) at C₁. The vehicle’s left side wheelbase was reduced 31 cm (12.2 in), while the right side wheelbase was reduced 2 cm (0.8 in). The crush values at the bumper level and upper radiator support level did not meet the crush measurement averaging protocol and the table below presents the vehicle’s front crush profile at the bumper level.

| Units | Event | Direct Damage | | Field L | C ₁ | C ₂ | C ₃ | C ₄ | C ₅ | C ₆ | Direct | Field L |
|-------|-------|---------------|-----------|---------|----------------|----------------|----------------|----------------|----------------|----------------|--------|---------|
| | | Width CDC | Max Crush | | | | | | | | ±D | ±D |
| cm | 1 | 37 | 15 | 117 | 6 | 0 | 0 | 0 | 0 | 0 | -25 | 0 |
| in | | 14.6 | 5.9 | 46.1 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -9.8 | 0.0 |

Damage Classification: The Collision Deformation Classification was 12FLEE7 (350 degrees). The Missing Vehicle algorithm of the WinSMASH program calculated the Toyota’s total Delta V as 14 km/h (8.7 mph). The longitudinal and lateral velocity changes were -14 km/h (-8.7 mph) and 0.0 km/h, respectively. The results should be considered borderline since this was a narrow end engagement impact. The vehicle’s EDR reported the maximum velocity change as 44.6 km/h (27.7 mph).

The manufacturer's recommended tire size was P215/60R16. The Toyota was equipped with the recommended size tires. The vehicle's tire data are shown in the table below.

| Tire | Measured Pressure | | Vehicle Manufacturer's Recommended Cold Tire Pressure | | Tread Depth | | Damage | Restricted | Deflated |
|------|-------------------|------|---|-----|--------------|-----------------------------|---------------|------------|----------|
| | kPa | psi | kPa | psi | milli-meters | 32 nd of an inch | | | |
| LF | Flat | Flat | 234 | 34 | 6 | 7 | Side wall cut | Yes | Yes |
| LR | 234 | 34 | 234 | 34 | 5 | 6 | None | No | No |
| RR | 248 | 36 | 234 | 34 | 7 | 9 | None | No | No |
| RF | 214 | 31 | 234 | 34 | 6 | 8 | None | No | No |

Vehicle Interior: The inspection of the interior of the Toyota revealed a lip stick imprint of the driver's upper and lower lips on the lower center portion of the driver's frontal air bag. There was no other discernable evidence of occupant contact. There was no deformation of the steering wheel or compression of the energy absorbing steering column.

All the doors remained closed and operational. The pre-crash status of the window glazing was either closed or fixed. There was no damage to the window glazing. The passenger compartment sustained no intrusions.

EVENT DATA RECORDER

Toyota's EDR was imaged via direct connection to the air bag control module using the manufacturer's EDR readout tool with software version 1.4.1.0. The imaged data was subsequently read and printed using version 1.4.1.1. The EDR reported the driver's safety belt switch status as "Belted" and the driver's seat position as "RW." The transmission shifter position was reported as "Others," which is understood to indicate that the transmission was not in the park, neutral, or reverse positions and was not invalid data. The EDR reported data for a frontal event and a side event. The "Frontal Crash Page 0" data block reported the time from the pre-crash trigger as 0 ms. The frontal air bag and pretensioner deployment times were reported as 9 ms and 8 ms, respectively. The frontal air bag deployment stage was reported as "High," which is understood to indicate a second stage deployment. The EDR reported 200 ms of velocity change data, which are presented in the table below. A column was added to convert mph to km/h.

Frontal Crash Page 0 Velocity Change Data

| ms | mph | km/h | ms | mph | km/h | ms | mph | km/h | ms | mph | km/h |
|----|------|------|-----|------|------|-----|------|------|-----|------|------|
| 10 | 1.6 | 2.6 | 60 | 18.3 | 29.5 | 110 | 26.1 | 42.0 | 160 | 27.4 | 44.1 |
| 20 | 3.7 | 6.0 | 70 | 21.6 | 34.8 | 120 | 26.5 | 42.6 | 170 | 27.6 | 44.4 |
| 30 | 7.8 | 12.6 | 80 | 23.2 | 37.3 | 130 | 26.6 | 42.8 | 180 | 27.7 | 44.6 |
| 40 | 10.8 | 17.4 | 90 | 24.3 | 39.1 | 140 | 26.8 | 43.1 | 190 | 27.7 | 44.6 |
| 50 | 14.4 | 23.2 | 100 | 25.4 | 40.9 | 150 | 27.1 | 43.6 | 200 | 27.7 | 44.6 |

The “Side Crash Page O” data block for the driver’s side reported the time from the pre-crash trigger as 7 ms. The time from the trigger to the initial g was reported as 3 ms. Velocity change data was reported in 4 ms intervals beginning at -21 ms and extending to 75 ms, which was the limit of the recording. At -21 ms the velocity change at the B-pillar, C-pillar, and floor were reported as 0.2 km/h (-0.1 mph), 0.0 km/h, and -0.0 km/h, respectively increasing to 9.7 km/h (6.0 mph), 15.0 km/h (9.3 mph), and 7.6 km/h (-4.7 mph), respectively at 75 ms. The deployment times at the B-and C-pillars for the side impact air bags were reported as “Not Fired.” The EDR pre-crash data was discussed in the Pre-Crash section on page 2 of this report.

AUTOMATIC RESTRAINT SYSTEM

The Toyota was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system and a driver’s knee air bag. Based on the Holmatro Rescuer’s Guide to Vehicle Safety Systems, the frontal air bag sensors were located on the inner fenders. The driver’s frontal air bag and knee air bag deployed in this crash. No front right passenger was present so the deployment of the front right passenger air bag was suppressed by the CAC system. The manufacturer has certified that the vehicle is compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

The Toyota was also equipped with a side air bag system that consisted of roof rail-mounted side impact IC air bags and front seat-mounted side impact air bags. No side impact air bags deployed during this crash.

The driver’s frontal air bag was located within the steering wheel hub. The module cover was a two flap configuration constructed of pliable vinyl. An inspection of the cover flaps revealed that they opened at the designated tear points and were undamaged. The top cover flap was 10 cm (3.9 in) in width at the top and 12 cm (4.7 in) in width at the bottom along the horizontal tear seam. The height of the top cover flap was 8 cm (3.1 in). The bottom cover flap was 12 cm (4.7 in) in width along the horizontal tear seam and 6 cm (2.4 in) in width at the bottom. The height of the bottom cover flap was 7 cm (2.8 in). The deployed air bag was 62 cm (24.4 in) in diameter and had two 4 cm (1.6 in) diameter vent ports on the back of the air bag at the 11 and 1 o’clock positions. There were two 12 cm (4.7 in) wide internal tethers, which were

sewn in a circular configuration to the center of the air bag. The air bag sustained no damage. A lip stick transfer was located on the lower center portion of the air bag.

The driver's knee air bag was located within the lower left instrument panel and deployed through a rectangular module cover, which was a two flap configuration constructed of pliable vinyl. Each cover flap was 25 cm (9.8 in) in width and 3 cm (1.2 in) in height. The cover flaps opened at the designated tear points and were undamaged. The deployed knee air bag was 58 cm (22.8 in) in width and 28 cm (11 in) in height. While the driver's knees probably loaded the air bag during the crash, there was no discernable evidence of contact on the air bag and the air bag was not damaged.

MANUAL RESTRAINT SYSTEM

The Toyota was equipped with lap-and-shoulder safety belts in all the seating positions. The driver's safety belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), sliding latch plate, and an adjustable upper anchor that was located in the full up position. The front passenger safety belt was similar but was equipped with a switchable ELR/Automatic Locking Retractor (ALR). Both safety belts were equipped with retractor mounted pretensioners. The driver's pretensioner actuated during the crash. The front right passenger pretensioner did not actuate since the seat was unoccupied. The second row safety belts were similar to the front right passenger's safety belt, but had fixed upper anchors and were not equipped with pretensioners.

The inspection of the driver's safety belt assembly revealed load abrasions on the latch plate belt guide. The retractor was jammed with a length of belt webbing extending out of the retractor consistent with usage. The length of the belt webbing from the stop button to the D-ring was 121 cm (47.6 in). This evidence indicated that the driver was restrained in this crash. The vehicle's EDR also reported the driver's safety belt switch status as "Belted."

The inspection of the second row left and right safety belt assemblies revealed no evidence of loading. The second row left and right passengers were reported as restrained by the lap-and-shoulder safety belts during the SCI interview with their father.

CASE VEHICLE DRIVER KINEMATICS

The restrained driver of the Toyota [64-year-old female, 168 cm (66 in) and 68 kg (150 lbs)] was seated in an upright posture with her back against the seat back. The seat track was located between the forward and middle positions and the seat back was slightly reclined. The steering column was adjusted to the full down position. The driver was wearing sunglasses at the time of the crash.

The impact to the front plane of the Toyota displaced the driver forward, opposite the 12 o'clock direction of force and she loaded the safety belt, which fractured her 1st left rib and contused her left shoulder, chest, and abdomen. She sustained contusions on both lower legs from

loading the deployed knee air bag and a 5 cm (2 in) abrasion on her left elbow from loading the frontal air bag. The driver remained restrained in her seat position throughout the crash and exited the vehicle without assistance through the left front door.

CASE VEHICLE DRIVER INJURIES

The driver was transported by ambulance to a hospital where she was treated in the emergency room and released. She had one follow-up visit to her family physician and no other injuries were diagnosed. The driver missed ten work days as a result of the crash.

| Injury Number | Injury Description (including Aspect) | NASS Injury Code & AIS 2005 | Injury Source | Source Confidence | Source of Injury Data |
|---------------|--|-----------------------------|-------------------------------------|-------------------|------------------------|
| 1 | Fracture, non-displaced, left 1 st rib, laterally | minor 450201.1,2 | Torso portion of safety belt system | Certain | Emergency room records |
| 2 | Contusion, oblique, across chest, not further specified | minor 410402.1,4 | Torso portion of safety belt system | Certain | Interviewee (relative) |
| 3 | Contusion, oblique, across abdomen to right hip, not further specified | minor 510402.1,1 | Torso portion of safety belt system | Certain | Interviewee (relative) |
| 4 | Contusion on left shoulder, not further specified | minor 710402.1,2 | Torso portion of safety belt system | Certain | Interviewee (relative) |
| 5 | Abrasion, 5.1 cm (2 in) over olecranon process of left elbow | minor 710202.1,2 | Air bag, driver's | Probable | Emergency room records |
| 6 | Contusions, 4 cm (1.6 in), anterior shins, bilaterally | minor 810402.1,3 | Air bag, driver's knee blocker | Probable | Emergency room records |

CASE VEHICLE SECOND ROW LEFT PASSENGER KINEMATICS

The second row left passenger of the Toyota [8-year-old male, 122 cm (48 in) and 32 kg (70 lbs)] was seated in an upright posture with his back against the seat back. He was restrained by the lap-and-shoulder safety belt and was not using a booster or other child restraint system. The passenger was not wearing glasses at the time of the crash.

The impact to the front plane of the Toyota displaced the passenger forward within the safety belt, opposite the 12 o'clock direction of force. There was no discernable evidence of any occupant contact on the back of the driver's seat.

The second row left passenger was not transported and did not sustain any injuries.

CASE VEHICLE SECOND ROW RIGHT PASSENGER KINEMATICS

The second row right passenger of the Toyota [10-year-old male, 152 cm (60 in) and 54 kg (120 lbs)] was seated in an upright posture with his back against the seat back. He was restrained by the lap-and-shoulder safety belt and was not using a booster or other child restraint system. The passenger was not wearing glasses at the time of the crash.

The impact to the front plane of the Toyota displaced the passenger forward opposite the 12 o'clock direction of force and he loaded the safety belt. He sustained a contusion 2.5 cm (1 in) in diameter on his right shoulder from loading the safety belt.

CASE VEHICLE SECOND ROW RIGHT PASSENGER INJURIES

The second row right passenger was not transported to a medical facility. The table below presents the passenger's injury and injury source.

| Injury Number | Injury Description (including Aspect) | NASS Injury Code & AIS 2005 | Injury Source | Source Confidence | Source of Injury Data |
|---------------|--|-----------------------------|-------------------------------------|-------------------|------------------------|
| 1 | Abrasion, 2.5 cm (1 in) on right shoulder, not further specified | minor 710202.1,1 | Torso portion of safety belt system | Certain | Interviewee (relative) |

FIRST OTHER VEHICLE

The 1994 Chevrolet Cavalier was a front wheel drive, 5-passenger, 2-door coupe (VIN: 1G1JC1448R7-----) that was equipped with a 2.2-liter, 4-cylinder engine, a 5-speed manual transmission, and 4-wheel anti-lock brakes. The front row was equipped with bucket seats with folding backs, adjustable head restraints, lap-and-shoulder safety belts, and a driver's frontal air bag. The police crash report indicated that the driver's frontal air bag did not deploy in this crash.

Damage Classification: The Chevrolet was not inspected. The vehicle sustained frontal damage and was towed from the crash scene.

The Missing Vehicle algorithm of the WinSMASH program calculated the Chevrolet's total Delta V as 19 km/h (13 mph). The longitudinal and lateral velocity changes were -19 km/h (-11.8 mph) and 0.0 km/h, respectively. The results should be considered borderline since they are based only on the crush to the Toyota.

First Other Vehicle's Driver: The driver of the Chevrolet (18-year-old female) was not restrained by the lap-and-shoulder safety belt. She sustained a fatal injury and was transported from the crash scene to the county morgue.

SECOND OTHER VEHICLE

IN10034

The 1994 Jeep Grand Cherokee Laredo was a 4-wheel drive, 5-passenger, 4-door sport utility vehicle (VIN: 1J4GZ58Y0RC-----) that was equipped with a 5.2-liter, 8-cylinder engine and 4-wheel anti-lock brakes. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder safety belts, and a driver's frontal air bag. This vehicle was struck by flying debris from the crash and was driven from the crash scene.

The police crash report indicated that the driver of the Jeep (31-year-old female) was restrained by the lap-and-shoulder safety belt. She sustained no injury. The 33-year-old male front right passenger was restrained by the lap-and-shoulder safety belt. He sustained no injury.

