



# INDIANA UNIVERSITY

## TRANSPORTATION RESEARCH CENTER

School of Public and Environmental Affairs  
222 West Second Street  
Bloomington, Indiana 47403-1501  
(812) 855-3908 Fax: (812) 855-3537

## ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN97-027  
LOCATION - WISCONSIN  
VEHICLE - 1996 PLYMOUTH GRAND VOYAGER  
CRASH DATE - November, 1996

Submitted:

June 3, 1999

Revised Submission:

July 31, 2001



Contract Number: DTNH22-94-D-17058

Prepared for:

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

## DISCLAIMERS

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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.

1. <i>Report No.</i> IN97-027	2. <i>Government Accession No.</i>	3. <i>Recipient's Catalog No.</i>	
4. <i>Title and Subtitle</i> On-Site Air Bag Fatality Investigation Vehicle - 1996 Plymouth Grand Voyager Location - Wisconsin		5. <i>Report Date:</i> June 3, 1999; July 31, 2001	
		6. <i>Performing Organization Code</i>	
7. <i>Author(s)</i> Special Crash Investigations Team #2		8. <i>Performing Organization Report No.</i> Task # 0107; Task 0265	
9. <i>Performing Organization Name and Address</i> Transportation Research Center Indiana University 222 West Second Street Bloomington, Indiana 47403-1501		10. <i>Work Unit No. (TRAIS)</i>	
		11. <i>Contract or Grant No.</i> DTNH22-94-D-17058	
12. <i>Sponsoring Agency Name and Address</i> U.S. Department of Transportation (NRD-32) 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: November, 1996	
		14. <i>Sponsoring Agency Code</i>	
15. <i>Supplementary Notes</i> On-site air bag deployment investigation involving a 1996 Plymouth Grand Voyager, four-door minivan, with manual safety belts and dual front air bags, and a 1991 Chevrolet Cavalier, two-door station wagon.			
16. <i>Abstract</i> This report covers an on-site investigation of an air bag deployment crash that involved a 1996 Plymouth Grand Voyager, minivan (case vehicle), and a 1991 Chevrolet Cavalier, four-door station wagon (other vehicle). This crash is of special interest because the case vehicle's unrestrained, front right passenger (8-year-old female) sustained critical cervical spinal cord injuries as a result of impacting the deploying front right passenger air bag. The case vehicle was traveling north in the northbound lane of a two-lane, undivided, State roadway. The Chevrolet was traveling south in the northbound lane of the same two-lane, undivided, State roadway. It was nighttime and the Chevrolet had no headlights on. The crash occurred in the northbound lane of the roadway. The front of the Chevrolet impacted the front of the case vehicle, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle's front right passenger (8-year-old female) was seated upright with her seat track located in it's middle position and was not using her available, active, three-point, lap-and-shoulder, safety belt system. She sustained, according to her medical records, critical brain and cervical injuries which included: a spinal cord injury involving a complete cord syndrome (i.e., quadriplegia) with cervical dislocations (i.e., atlanto-occipital and C <sub>2</sub> -C <sub>3</sub> ), a nonanatomic brain injury, diffuse cerebral edema, subarachnoid hemorrhage, and an intraventricular hemorrhage. In addition, she sustained unspecified abrasions to her "head" (i.e., it is unknown if these abrasions involved her face and/or neck). The case vehicle's driver (33-year-old male) was seated with his seat track located in its rearmost position, and the tilt steering wheel was located in its upmost position. He was not wearing his available, active, three-point, lap-and-shoulder, safety belt system and sustained, according to his interview and medical records moderate injuries which included: a fracture/dislocation of his right hip, a fractured left rib, a laceration to his forehead, and other soft tissue injuries.			
17. <i>Key Words</i> Air Bag Deployment 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> 13	22. <i>Price</i> \$9,800

TABLE OF CONTENTS

	<u>Page No.</u>
BACKGROUND . . . . .	1
CRASH SUMMARY . . . . .	1
CRASH CIRCUMSTANCES . . . . .	3
CASE VEHICLE: 1996 PLYMOUTH GRAND VOYAGER . . . . .	4
CASE VEHICLE DAMAGE . . . . .	4
AUTOMATIC RESTRAINT SYSTEM . . . . .	5
 CASE VEHICLE OCCUPANTS	
CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS . . . . .	6
CASE VEHICLE FRONT RIGHT PASSENGER INJURIES . . . . .	8
CASE VEHICLE DRIVER KINEMATICS . . . . .	10
CASE VEHICLE DRIVER INJURIES . . . . .	10
 OTHER VEHICLE: 1991 CHEVROLET CAVALIER . . . . .	11
 CRASH DIAGRAM . . . . .	13
 SELECTED PHOTOGRAPHS	
Figure 1: Case vehicle's northbound path of travel view just prior to impact . . . . .	3
Figure 2: Case vehicle's frontal deformation view from left . . . . .	4
Figure 3: Case vehicle's driver air bag . . . . .	5
Figure 4: Bottom portion of case vehicle's front right passenger air bag showing green and gold cloth transfers . . . . .	6
Figure 5: Vertical view of case vehicle's front right passenger seating area showing deployed air bag and contacted windshield . . . . .	6
Figure 6: Close-up of case vehicle's windshield contact from outside vehicle . . . . .	7
Figure 7: Interior view of contacted to case vehicle's windshield from inside . . . . .	8
Figure 8: Deformation to case vehicle's steering wheel rim and knee bolster . . . . .	10
Figure 9: On-scene view of the Chevrolet at final rest . . . . .	12
Figure 10: Chevrolet's frontal damage and induced damage viewed from left . . . . .	12

This on-site investigation was brought to NHTSA's attention on August 27, 1997 by an attorney who has been involved in previous SCI cases. This crash involved a 1996 Plymouth Grand Voyager (case vehicle) and a 1991 Chevrolet Cavalier (other vehicle). The crash occurred in November, 1996, at 8:06 p.m., in Wisconsin and was investigated by the applicable city police department. This crash is of special interest because the case vehicle's unrestrained, front right passenger [8-year-old, White (non-Hispanic) female] sustained a critical spinal cord injury, resulting in quadriplegia, from contacting her deploying passenger air bag. This contractor inspected the scene and case vehicle on September 10-11, 1997. This contractor interviewed the driver for the case vehicle in the Spring of 1998. This summary is based on the Police Crash Report, interviews with the case vehicle's driver and the investigating police officer, scene and case vehicle inspections, police photographs of the Chevrolet, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

**SUMMARY**

The case vehicle was traveling north in the northbound lane of a two-lane, undivided, state roadway and intended to continue in its northward direction of travel. The Chevrolet was traveling south, with no headlights on, in the northbound lane of the same two-lane, undivided, state roadway and intended to continue traveling south. The case vehicle's driver made no avoidance maneuvers prior to the crash. The driver of the Chevrolet braked, depositing 6.7 meters (21.9 feet) of skid marks from the left rear tire, attempting to avoid the crash. The crash occurred in the northbound lane.

The front of the case vehicle was impacted by the front of the Chevrolet, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle rebounded off of the Chevrolet, rotated slightly counterclockwise, and came to rest heading north in the northbound lane. The Chevrolet rebounded off the case vehicle, rotated approximately 10 degrees clockwise, and came to rest heading south-southwestward, primarily in the northbound lane.

The front right passenger [124 centimeters and 29.5 kilograms (49 inches, 65 pounds)] was not using her available, active, three-point, lap-and-shoulder, safety belt system. An inspection of the passenger's air bag, which was located in middle of the instrument panel, revealed a 6 x 14 centimeter (2.4 x 5.5 inch) area of skin transfer to the front left portion and a large area of a green and yellow cloth transfer (i.e., from her Green Bay Packers coat) to the front right and bottom portion. An inspection of the front right air bag module's cover flap revealed no evidence of contact. In addition, there was no reported evidence of belt pattern bruising and/or abrasions to the passenger's body. The inspection of the front right passenger's seat belt webbing, "D"-ring, and latch plate showed no evidence of loading or blood evidence.

The case vehicle's impact with the Chevrolet, not only deployed the passenger's air bag, but thrust the passenger forward and slightly rightward towards the 10 degree Direction of Principal Force. The passenger was thrust into the deploying front right air bag, and her torso was subsequently lifted upwards toward the windshield. The passenger's head would have contacted

the windshield, but the fabric of the air bag mitigated the impact by serving as a buffer between her head and the windshield. The passenger did not sustain any lacerations to her head, but the top portion of the air bag had numerous small cuts from the cracked windshield. The passenger subsequently rebounded upwards, contacting the windshield header/sun visor area before she rebounded backwards. The passenger came to rest on the floor between the two front bucket seats with her feet in the floorboard area of the front right passenger seating area.

The case vehicle's front right passenger was transported by ambulance to the hospital. She sustained critical brain and spinal cord injuries and was hospitalized for 55 days post-crash. According to her medical records, her cervical spinal cord injury involved a complete cord syndrome (i.e., quadriplegia) and cervical dislocations (i.e., atlanto-occipital and C<sub>2</sub>-C<sub>3</sub>). Her brain injuries included: a nonanatomic brain injury, diffuse cerebral edema, subarachnoid hemorrhage, and an intraventricular hemorrhage. In addition, she sustained unspecified abrasions to her "head" (i.e., it is unknown if these abrasions involved her face and/or neck). This contractor believes that this unrestrained, passenger's severe injuries are a result of her being struck by the deploying passenger air bag.

The 1996 Plymouth Grand Voyager SE was a front wheel drive, four-door minivan (VIN: 1P4GP44R3TB-----). The case vehicle was equipped with anti-lock brakes. The 1991 Chevrolet Cavalier is a front wheel drive, four-door station wagon (VIN: 1G1JC84G8M7-----). Both vehicles were towed from the scene due to damage. Based on the vehicle inspection and available photographs, the CDCs were determined to be: **12-FDEW-3 (+10)** for the case vehicle [maximum crush was 43 centimeters (16.9 inches)] and **12-FDEW-2 (-10)** for the Chevrolet [maximum crush was estimated as 48 centimeters (18.9 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm, was used on the highest severity impact to the case vehicle. The Total, Longitudinal, and Lateral Delta V's are, respectively: 39.8 km.p.h. (24.7 m.p.h.), -39.2 km.p.h. (-24.4 m.p.h.), and -6.9 km.p.h. (-4.3 m.p.h.).

The case vehicle's initial contact with the Chevrolet involved the entire front end. Direct damage extended from bumper corner to bumper corner, a measured distance of 148 centimeters (58.3 inches). The front bumper fascia, bumper reinforcement beam, grille, and radiator were crushed rearward. Both front tires were physically restricted with the front right tire being aired out.

Immediately prior to the crash the front right passenger was seated upright with her back against the seat back, her feet hanging down over the front of her seat cushion, and both hands in an unknown position. Her seat track was found in its rearmost position; however, the seat track may have been moved back during her extrication process because the driver stated it was in the middle position pre-crash.

The case vehicle's driver [33-year-old, White (non-Hispanic) male] was seated upright with his back against the seat back, his left foot on the floor, his right foot on the brake, and both hands on the steering wheel. His seat track was located in its rearmost position, the seat back was upright, and his tilt steering wheel was found in its upmost position; however, the steering wheel

may have been moved during the extrication because the driver stated it was in the center position pre-crash.

The case vehicle's driver [185 centimeters and 102 kilograms (73 inches, 225 pounds)] was also not using his available, active, three-point, lap-and-shoulder, safety belt system. An inspection of the driver's air bag, which was located in the steering wheel hub, revealed no visible evidence of contact. An inspection of the driver air bag module's cover flap revealed no evidence of contact. The case vehicle's driver was transported by ambulance to the hospital. He sustained moderate injuries and was hospitalized 18 days post-crash. The injuries sustained by the case vehicle's driver included: a fracture/dislocation of his right hip, a fractured left rib, a laceration to his forehead, and other soft tissue injuries.

### CRASH CIRCUMSTANCES

The case vehicle was traveling north in the northbound lane of a two-lane, undivided, state roadway (**Figure 1**) and intended to continue in its northward direction of travel. The Chevrolet was traveling south in the northbound lane of the same two-lane, undivided, state roadway and intended to continue traveling south (see **CRASH DIAGRAM**). In the area of the crash there is a "W"-beam guardrail along the east shoulder parallel to the trafficway. The roadway was constructed of bituminous material and was straight and level near the area of impact. At the time of the crash it was precipitating, and the roadway was wet. The north and southbound lanes are divide by yellow dashed lines with a solid white fog line along each outside edge. The northbound roadway was 4.2 meters (13.9 feet) wide with a 2 meter (6.6 feet) gravel shoulder on each side of the roadway. The estimated coefficient of friction for the roadway is 0.70% when dry. The legal speed limit is 56 km.p.h. (35 m.p.h.). The area is primarily commercial with some undeveloped rural areas along the roadway.



**Figure 1:** Case vehicle's northbound path of travel just prior to impact (case photo #03)

The Chevrolet was traveling south in the northbound lane with its headlights off, making it nearly impossible for the case vehicle's driver to have seen it driving in the wrong lane until the last second. The case vehicle's driver made no avoidance maneuvers prior to the crash. The driver of the Chevrolet saw the case vehicle and braked, depositing 6.7 meters (21.9 feet) of skid marks from the left rear tire, attempting to avoid the crash. The head-on crash occurred in the northbound lane of the state highway.

The front of the case vehicle was impacted by the front of the Chevrolet, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. After the impact the case vehicle rebounded off of the Chevrolet, rotated approximately 10 degrees counterclockwise, and came to rest heading north-northwest in the northbound lane. The

Chevrolet rebounded off the case vehicle, rotated approximately 10 degrees clockwise, and came to rest heading south-southwestward, primarily in the northbound lane.

**CASE VEHICLE**

The case vehicle was a front wheel drive 1996 Plymouth Grand Voyager SE, seven-passenger four-door minivan (VIN: 1P4GP44R3TB-----) equipped with a 3.3L, MPI, V-6 engine and a transverse mounted, four-speed automatic transmission. The case vehicle had power-assisted, rack-and-pinion steering. Braking was achieved by a hydraulic, power-assisted, front disc and rear drum anti-lock system. The case vehicle had an extended wheelbase of 303 centimeters (119.3 inches), and the case vehicle was equipped with an electronic odometer so the recorded mileage is unknown. The case vehicle was bought new and had been driven approximately 16,100 kilometers (10,000 miles) during the past twelve months prior to the crash.

The interior of the case vehicle was equipped with adjustable front bucket seats with integral head restraints and three-point lap-and-shoulder, safety belt systems in the six outboard seating positions. In addition, there was a lap belt in the rear center seat position. The vehicle was equipped with rigid plastic knee bolsters for the driver and front right passenger. The second and rear seats had two-seat and three-seat bench seats, respectively, and neither the second seat nor the rear seat were equipped with head restraints. The front belt systems were equipped with manually operated height adjusters for the “D”-rings, and buckle webbing assembly energy management loops. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of frontal air bags for the driver and front right passenger positions. An examination of the interior revealed a brush abrasion to the right front door handle from the deploying passenger air bag as seen in previous SCI cases involving these type of minivans. The left instrument panel/knee bolster was deformed by the driver’s left knee.

**CASE VEHICLE DAMAGE**

The case vehicle’s initial contact with the Chevrolet involved the entire front end (**Figure 2**). The direct contact damage extended across the entire front end, from bumper corner to bumper corner, a distance of 148 centimeters (58.3 inches). The direct damage width and the field L were the same. The initial bumper fascia contact with the Chevrolet resulted in residual crush to the bumper reinforcement beam. The front bumper fascia, bumper reinforcement beam, grille, and radiator were crushed rearward. The hood was folded back towards the windshield. The windshield had stress fractures across the whole surface with a spider web from the passenger’s head impact on the passenger side. Both front tires were physically restricted from the front end damage with the right front tire being flat. The



**Figure 2:** Case vehicle’s frontal deformation viewed from front left with contour gauge present (case photo #10)

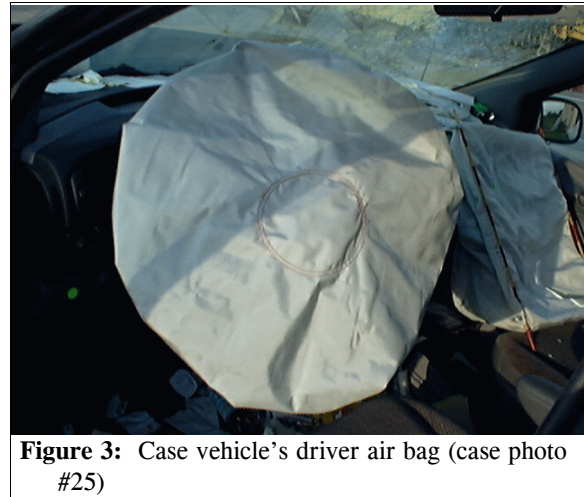


residual crush to the front bumper and bumper reinforcement bar was 20 centimeters (7.9 inches), 27 centimeters (10.6 inches), 37 centimeters (14.6 inches), 43 centimeters (16.9 inches), 25 centimeters (9.8 inches) and 14 centimeters (5.5 inches) respectively C<sub>1</sub> through C<sub>6</sub>. The wheelbase was altered by only 1 centimeter (0.4 inches) on the drivers side. Both fenders sustained induced damage from the frontal impact.

The case vehicle was towed from the scene due to damage. Based on the vehicle inspection, the CDC was determined to be: **12-FDEW-3 (+10)** for the case vehicle [maximum crush was 43 centimeters (16.9 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm, was used on the highest severity impact to the case vehicle. The Total, Longitudinal, and Lateral Delta V's are, respectively: 39.8 km.p.h. (24.7 m.p.h.), -39.2 km.p.h. (-24.4 m.p.h.), and -6.9 km.p.h. (-4.3 m.p.h.). The case vehicle's barrier equivalent speed is: 37.0 km.p.h. (23.0 m.p.h.).

### AUTOMATIC RESTRAINT SYSTEM

As previously mentioned, the case vehicle was equipped with a SRS that consisted of frontal air bags at the driver and front right passenger positions. The SRS deployed as a result of the case vehicle's frontal impact with the front of the Chevrolet. The case vehicle's driver air bag was located in the steering wheel hub. The module cover consisted of circular asymmetrical cover flaps with overall dimensions of 17.5 centimeters (6.9 inches) at the horizontal seam and 5 centimeters (2.0 inches) vertically for the upper flap and 9 centimeters (3.5 inches) vertically for the lower flap. The air bag was 63 centimeters.



**Figure 3:** Case vehicle's driver air bag (case photo #25)

(24.8 inches) in diameter and was tethered by two 6 centimeter wide (2.4 inch) tethers sewn interiorly to the center of the face of the air bag. The driver's air bag had no vent ports. There was no visible evidence of direct contact to the driver's air bag from either occupants involvement (**Figure 3**). There were two vertical black transfers along the outside of the air bag, caused by the cover flaps during the deployment sequence.

The front right passenger air bag was mounted on the front of the right instrument panel. The air bag deployed from symmetrical double forward hinged cover flaps which opened at the designated tear points along the leading and outer edges of the flap. The top cover flap opened in an upward direction and the bottom flap opened in a downward direction. The cover flaps were made of a vinyl skin over a sheet metal frame/liner which acted as hinge points for the deploying flaps. The hinged flaps were not capable of contacting the windshield. The flaps showed no visible evidence of contact or abnormal deformation by the passenger. The impact resulted in the passenger moving forward into the deploying air bag. The top portion of the air bag membrane sustained several minor punctures from the windshield glass when it was caught between the passenger's head and the windshield. The dimensions for both flaps were 29 centimeters (11.4 inches) horizontally and 6 centimeters (2.4 inches) vertically. The profile of the case vehicle's

instrument panel was flush with the leading edge of the cover flap.

The front right passenger air bag was untethered and had no vent ports. The air bags front face was 46 centimeters (18.1 inches) wide and 56 centimeters (22 inches) tall. Examination of the passenger air bag revealed a heavy skin transfer to the front left portion of the air bag and a large amount of horizontal yellow and green cloth transfers to the front and bottom portions towards the center and right side of the air bag (**Figure 4**). The yellow and green transfers came from the passenger's Green Bay Packers jacket that she was wearing at the time of the crash. The skin evidence on the front of the air bag (**Figure 5**) was approximately 6 centimeters (2.4 inches) wide and 14 centimeters long (5.5 inches). The skin evidence started 17 centimeters (6.7 inches) down from the top horizontal edge of the air bag and 17 centimeters (6.7 inches) in from the left edge of the air bag. The yellow and green horizontal cloth transfers were 12 centimeters (4.7 inches) wide and started 25 centimeters (9.8 inches) down from the top horizontal edge of the air bag. They continued down onto the bottom portion of the air bag for an additional 21 centimeters (8.3 inches).



**Figure 4:** Bottom portion of case vehicle's front right passenger air bag showing green and gold cloth transfers from Green Bay Packers coat passenger was wearing at time of crash (case photo #38)

**CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS**

The case vehicle's front right passenger [8-year-old, White (non-Hispanic) female] was not using her available, active, three-point, lap-and-shoulder, safety belt system. In addition, there was no reported evidence of belt pattern bruising and/or abrasions to the passenger's body. The inspection of the passenger's seat belt webbing, "D"-ring, and latch plate showed no evidence of loading or blood evidence.

According to the case vehicle's driver (father), the front right passenger was restrained and the belts inertia locking system failed to lock during the frontal impact allowing her to be thrown forward into the deploying air bag and windshield (**Figure 5**). The driver also stated that the passenger's head starred the windshield. The case vehicle's driver claimed to have taken the van



**Figure 5:** Vertical view of case vehicle's front right passenger seating area; Note: contacts (dots) to dash air vent (broken/scuffed) and front of air bag (skin and cloth transfer) (case photo #35A)

back to the dealership on two separate occasions to have the passenger's seat belt system looked at. Both times the dealership told him that they could not find anything wrong with the seat belt system. This contractor conducted a field test on the front right belt system and found it to be working properly. Supplemental police reports also indicate a thorough investigation was done into the passenger's belt usage, with the final result being no belt restraint was used by the passenger at the time of the crash. The driver stated immediately following the crash he saw his daughter leaning forward so he unhooked her seat belt and she fell sideways towards him. The driver said that he attempted to catch her so he could check her vital signs. The driver said that after he felt her pulse he released her and laid her down between the seats. It should be noted that the first police officer at the scene happened to be only a few hundred feet away at a telephone booth when he heard the crash. The police officer immediately called for help and proceeded to the crash scene. The officer stated that he was the first person to approach the van following the crash. The officer recalls seeing the case vehicle's driver behind the steering wheel breathing and conscious and initially did not see the passenger. The driver told the officer his daughter was also in the vehicle. When asked where, the driver responded that he believed she was between the seats. The police officer added that it appeared that the driver's injuries were severe enough that his freedom of movement was limited. The police officer reported that he arrived at the scene within a minute post-crash.

Immediately prior to the crash the case vehicle's front right child passenger [124 centimeters and 29.5 kilograms (49 inches, 65 pounds)] was sitting upright, facing forward with her back against the seat back, her feet hanging down over the front of her seat cushion, and both hands in an unknown position (presumably on her lap). According to the case vehicle's driver, her adjustable seat track was located in the middle position and the seat back was upright. Based on the vehicle inspection her seat track was in its rearmost position; however, the seat track may have been moved back during her extrication process. With the seat track in the full rearmost position, the measured distance from the dash to the center of this occupant's seat back was 89 centimeters (35.0 inches), and if the seat track was in the middle position, the measured distance was 81 centimeters (31.9 inches). This contractor believes that the seat track was most likely in the middle position due to the fact that a firefighter mentioned in one of the supplemental reports that the seat was tilted back in order to extricate the passenger.

The case vehicle's impact with the Chevrolet, not only deployed the front right passenger's air bag, but thrust the passenger forward and slightly rightward towards the 10 degree Direction of Principal Force. The passenger was thrust into the deploying front right air bag (i.e., most likely the passenger's face, neck, and chest simultaneously contacted the front portion of the air bag as it deployed), and as the air bag reached maximum expansion, it lifted her torso upwards toward the windshield. The



**Figure 6:** Close-up of case vehicle's windshield contact; Note: the membrane of the deploying air bag was between the passenger's head and the windshield (case photo #19)



passenger's head would have contacted the windshield, but the fabric of the air bag mitigated the impact by serving as a buffer between her head and the windshield (**Figure 6** above and **Figure 7**). The passenger did not sustain any lacerations to her head, but the top portion of the air bag had numerous small cuts from the cracked windshield. The passenger subsequently rebounded upwards, contacting the windshield header/sun visor area before she rebounded backwards. As the case vehicle rotated approximately 10 degrees counterclockwise the passenger rebounded back and to the left falling between the two front bucket seats. At final rest the passenger was unconscious and her upper torso was laying on the floor between the two front bucket seats with her feet in the floorboard area of the front right passenger seating area (i.e., still in the passenger foot well).



**Figure 7:** Interior view of contact to case vehicle's windshield from front right passenger (case photo #47)

#### **CASE VEHICLE FRONT RIGHT PASSENGER INJURIES**

The front right passenger was transported by ambulance to a hospital where she was resuscitated prior to being air lifted to a children's trauma facility. She sustained critical brain and spinal cord injuries and was hospitalized for 55 days post-crash prior to being moved to a rehabilitation facility. According to her medical records, her cervical spinal cord injury involved a complete cord syndrome (i.e., quadriplegia) and cervical dislocations (i.e., atlanto-occipital and C<sub>2</sub>-C<sub>3</sub>). Her brain injuries included: a nonanatomic brain injury, diffuse cerebral edema, subarachnoid hemorrhage, and an intraventricular hemorrhage. In addition, she sustained unspecified abrasions to her "head" (i.e., it is unknown if these abrasions involved her face and/or neck). This contractor believes that this unrestrained, passenger's severe injuries are a result of her being struck by the deploying passenger air bag.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury <sup>1</sup> , unconscious (GCS=3), pupils fixed & dilated, no response, flaccid	160824.5 critical	Air bag, front right passenger's	Certain	Hospitalization records
2	Diffuse cerebral edema (severity not specified) [Aspect = Unknown]	140668.3 severe	Air bag, front right passenger's	Certain	Hospitalization records
3	Hemorrhage, subarachnoid, location not further specified [Aspect = Unknown]	140684.3 severe	Air bag, front right passenger's	Certain	Hospitalization records
4	Hemorrhage, intraventricular [ventricle(s) not specified <sup>2</sup> ] [Aspect = Unknown]	140678.4 severe	Air bag, front right passenger's	Certain	Hospitalization records
5	Cervical spinal cord injury <sup>3</sup> with complete cord syndrome (i.e., quadriplegia) and cervical dislocations (i.e., atlanto-occipital and C <sub>2</sub> -C <sub>3</sub> --with complete ligament disruption both anteriorly and posteriorly with slight cord deformity secondary to flexion injury)	640266.5 critical	Air bag, front right passenger's	Certain	Hospitalization records
6	Abrasions head, not further specified	190202.1 minor	Air bag, front right passenger's	Certain	Emergency room records

<sup>1</sup> There is a strong possibility that this patient sustained an hypoxic ischemic encephalopathy as a result of the crash. According to the patient's discharge summary, she was comatose, pulseless, and nonbreathing (for up to ten minutes) at the scene.

These terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

**encephalopathy** (*en-sef''a-lop a-the*) - any degenerative disease of the brain. **hypoxic-ischemic e.** encephalopathy resulting from fetal or perinatal asphyxia. Common symptoms are lethargy, feeding difficulties, and convulsions; serious cases may involve necrosis of neurons in the brain with psychomotor retardation and spastic motor deficits such as cerebral palsy. If infants do not show signs of recovery by one week after birth, the prognosis is grave to poor.

**anoxia** (*a-nok se-a*) - a total lack of oxygen; often used interchangeably with **hypoxia** to mean a reduced supply of oxygen to the tissues.

**hypoxemia** (*hi''pok-se e-a*) - deficient oxygenation of the blood; hypoxia.

**hypoxia** (*hi-pok se-a*) - reduction of oxygen supply to tissue below physiological levels despite adequate perfusion of the tissue by blood. Compare with **anoxia**.

**hypoxia-ischemia** (*hi-pok se-a-is-ke me-a*) - the changes occurring in tissues when the blood supply is cut off, particularly in a fetus or infant with asphyxia.

**ischemia** (*is-ke me-a*) - deficiency of blood in a part, usually due to functional constriction or actual obstruction of a blood vessel.

<sup>2</sup> Although the ventricle was not specified, a ventriculostomy was performed, according to one source, to monitor intracranial pressure. Ventriculostomy is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows: **ventriculostomy** (*ven-trik''u-los te-me*): the operation of establishing a free communication or shunt between the floor of the third ventricle and the underlying cisterna interpeduncularis; for the treatment of hydrocephalus.

<sup>3</sup> This lesion was noted by both the physical therapist and occupational therapist to be of the shearing type.

The case vehicle's driver [33-year-old, White (non-Hispanic) male] was seated upright with his back against the seat back, his left foot on the floor, his right foot on the brake, and both hands on the steering wheel. His seat track was located in its rearmost position, the seat back was upright, and his tilt steering wheel was located in its middle position. The driver [185 centimeters and 102 kilograms (73 inches, 225 pounds)] was not using his available, active, three-point, lap-and-shoulder, safety belt system. The inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed no evidence of loading or separation of the buckle webbing assembly energy management loop.

The case vehicle's primary impact with the Chevrolet deployed both the driver the front right passenger's air bags. Since there were no avoidance maneuvers, the driver's upper torso would have remained against his seat back just prior to impact. At impact the case vehicle's driver moved into the deploying air bag, impacting it with his chest and head. The driver's left knee struck the left lower dash, braking off the parking brake handle, and his right knee impacting the right lower dash (cloth transfer) forcing his thigh back into his hip causing his right hip fracture/dislocation. The frontal impact and the deploying air bag lifted the driver upwards where he contacted the sun visor with his forehead cutting it prior to falling back down in his seat. An inspection of the driver's air bag, which was located in the steering wheel hub, showed no visible evidence of contact. An inspection of the driver air bag module's cover flap revealed no evidence of contact. The driver's interaction with the deploying air bag combined with the vehicle's moderate frontal impact most likely caused the steering column's energy absorbing shear capsules to separate to some degree, but the exact amount was not documented. The top half of the steering wheel rim (**Figure 8**) was deformed by 4 centimeters (1.6 inches).



**Figure 8:** Deformation to upper half of case vehicle's steering wheel rim and contact to knee bolster by driver's left knee (case photo #28)

### CASE VEHICLE DRIVER INJURIES

The case vehicle's driver was transported by ambulance to the hospital. He sustained moderate injuries and was hospitalized 18 days post-crash. Based on his medical records, the injuries sustained by the case vehicle's driver included: a fracture/dislocation of his right hip, a fractured left rib, a laceration to his forehead, and other soft tissue injuries.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1 2	Fracture and dislocation right hip, not further specified	852600.2 850610.2 moderate	Knee bolster, driver's, right side of steering column	Probable	Emergency room records
3	Fracture rib, left, not further specified	450212.1 minor	Steering wheel rim	Probable	Emergency room records
4	Lacerations forehead	290600.1 minor	Front left sun visor	Probable	Emergency room records
5	Wound <sup>4</sup> left chest	490099.1 minor	Steering wheel rim and/or hub	Possible	Emergency room records
6	Contusion {bruising/discoloration} lower chest (i.e., rib cage area), more on left side	490402.1 minor	Air bag, driver's	Probable	Emergency room records
7	Wound <sup>4</sup> left clavicle	790099.1 minor	Steering wheel rim	Possible	Emergency room records
8	Laceration left hand	790600.1 minor	Left instrument panel	Possible	Emergency room records
9	Wound <sup>5</sup> right knee	840404.2 moderate	Knee bolster, driver's, right side of steering column	Probable	Interviewee (same person)
10	Wound <sup>4</sup> right ankle with swelling	890099.1 minor	Left instrument panel and below	Possible	Emergency room records

## OTHER VEHICLE

The 1991 Chevrolet Cavalier is a front wheel drive, four-door station wagon (VIN: 1G1JC84G8M7-----) equipped with a 2.2L, TBI, L-4 engine, a three-speed automatic transmission, and front disc and rear drum brakes. The Chevrolet was not equipped with anti-lock brakes. The Chevrolet's wheel base was 262 centimeters (103.1 inches), and, according to the police, the odometer reading after the crash was 102,257 kilometers (63,539 miles). The vehicle was not physically inspected so based on police photographs and the VIN, the Chevrolet was equipped with front bucket seats with integral head restraints. The front outboard seats were equipped with automatic, three-point lap and shoulder restraints anchored in the door frames. The Chevrolet was not equipped with a supplemental restraint system. The back seat was a bench type with manual, three-point lap and shoulder restraints in the outboard seats and a lap belt only in the center position. The back bench seat was not equipped with head restraints.

<sup>4</sup> This occupant's medical records (i.e., nurses notes) imply that there was an wound at this location; however, the exact nature of the lesion was not clear. The lesion may have been a laceration.

<sup>5</sup> This occupant's medical records (i.e., nurses notes) imply that there was an wound at this location; however, the exact nature of the lesion was not clear. This occupant indicated that he sustained ligament damage.

The direct damage to the Chevrolet extended from bumper corner to bumper corner. The hood was folded back with both side fenders crushed rearwards as well (**Figures 9 and 10**). The windshield had two, holed, spider web contacts, one in the driver's area and the other in the passenger's area. Presumably, there was intrusion to the Chevrolet's toe pan, floor board, and dash. The steering wheel appeared collapsed from loading by the driver's chest.



**Figure 9:** On-scene view of Chevrolet at final rest with both front seat occupants removed; Note: moderate front end damage and head contacts to windshield (case photo #54)



**Figure 10:** Chevrolet's frontal damage and induced damage viewed from front left while in impound lot (case photo #58)

The Chevrolet was towed from the scene due to damage. Based on the available photographs, the CDC was determined to be: **12-FDEW-2 (-10)** for the Chevrolet [maximum crush was estimated as 48 centimeters (18.9 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm, was used on the highest severity impact to the Chevrolet. The Total, Longitudinal, and Lateral Delta V's are, respectively: 55.0 km.p.h. (34.2 m.p.h.), -54.2 km.p.h. (-33.7 m.p.h.), and +9.6 km.p.h. (+6.0 m.p.h.). The Chevrolet's barrier equivalent speed is: 57.5 km.p.h. (35.7 m.p.h.).



