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ON-SITE REDESIGNED AIR BAG INVESTIGATION

CASE NUMBER - IN00-001
LOCATION - WISCONSIN
VEHICLE - 2000 CHEVROLET SILVERADO K-1500
CRASH DATE - October, 1999

Submitted:

March 11, 2003

Contract Number: DTNH22-94-D-17058

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
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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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On-site air bag deployment investigation involving a 2000 Chevrolet Silverado K-1500, three-door pick-up truck, with manual safety belts and dual redesigned front air bags, and a 1988 Chevrolet G-20 conversion van

16. *Abstract*

This report covers an on-site investigation of an air bag deployment crash that involved a 2000 Chevrolet Silverado K-1500 pick-up truck (case vehicle) and a 1988 Chevrolet G-20 based conversion van (vehicle #2). This crash is of special interest because the case vehicle was equipped with redesigned air bags that deployed as a result of the crash event, and the case vehicle's restrained driver [18-year-old, White (non-Hispanic) male] sustained a fatal cervical injury in this high speed crash as a result of bottoming out the driver's redesigned air bag and impacting the steering wheel rim. The case vehicle was traveling southwestward, in a slight right-hand curve, in the southwestbound lane of a two-lane, undivided, U.S. Highway and for unknown reasons crossed into the northeastbound lane. Vehicle #2 was traveling northeastward, in a slight left hand curve, in the northeastbound lane of the same U.S. Highway. The case vehicle's driver made no avoidance maneuvers prior to the crash. The driver of vehicle #2 braked and steered to the right. The crash occurred in the northeastbound lane of the roadway towards the edge line. The front of the case vehicle impacted the front of vehicle #2, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. Both vehicles rotated clockwise with vehicle #2 coming to rest heading south-southeastward in the middle of the roadway and the case vehicle coming to rest on the northeast shoulder of the road heading in a west-southwestward direction. The case vehicle's driver was seated with his seat track located just forward of the rearmost position, and the tilt steering wheel was located in its down-most position. He was restrained by his available, active, three-point, lap-and-shoulder, safety belt system and sustained, according to his medical records, fatal injuries which included: a spinal cord laceration at cervicomedullary junction with atlanto-occipital dislocation, a diffuse axonal injury, a nonanatomic brain injury, subdural and/or epidural hemorrhage in the posterior cranial fossa, a comminuted right basilar skull fracture, bilateral contusions to the inferior frontal gyri, subarachnoid hemorrhages over both frontal lobes, diffuse cerebral edema, diffuse cerebellar edema, a subarachnoid hemorrhage over the right superior cerebellum, a lacerated spleen, and a laceration and abrasion to his right knee.

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BACKGROUND

IN00-001

This on-site investigation was brought to NHTSA's attention on January 20, 2000 by the parent of the case vehicle's deceased driver. This crash involved a 2000 Chevrolet Silverado K-1500 pick-up truck (case vehicle) and a 1988 Chevrolet conversion van (vehicle #2). The crash occurred in October, 1999, at 8:35 a.m, in Wisconsin and was investigated by the applicable county sheriff department. This crash is of special interest because the case vehicle was equipped with redesigned air bags, and the case vehicle's driver [18-year-old, White (non-Hispanic) male] sustained a fatal cervical injury in this high speed crash as a result of bottoming out the driver's redesigned air bag and impacting the steering wheel rim. This contractor inspected the vehicles on 31 January and 1 February, 2000. This report is based on the Police Crash Report, an interview with investigating police officer, vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling southwestward, in a slight right-hand curve, in the southwestbound lane of a two-lane, undivided, U.S. Highway and for unknown reasons crossed into the northeastbound lane. Vehicle #2 was traveling northeastward, in a slight left hand curve, in the northeastbound lane of the same two-lane, undivided, U.S. Highway and intended to continue travel northeastward. The case vehicle's driver made no avoidance maneuvers prior to the crash. The driver of vehicle #2 braked and steered to the right, attempting to avoid the crash. Based on the county sheriff's scene reconstruction, the crash occurred in the northeastbound lane of the roadway towards the edge line; see **CRASH DIAGRAM** below. The roadway's posted speed limit was 89 km.p.h. (55 m.p.h.).

The front of the case vehicle impacted the front of vehicle #2, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The frontal crash was slightly offset toward the right side of each vehicle. The case vehicle's front bumper slightly overrode vehicle #2's front bumper because the front of vehicle #2 dipped downward during its braking maneuver, while attempting to avoid the crash. At maximum engagement, both vehicle's rotated clockwise, with vehicle #2 rotating approximately 100 degrees while being pushed backwards. Vehicle #2 came to rest heading south-southeastward in the middle of the roadway, straddling the southwestbound and northeastbound lanes. The case vehicle rotated approximately 60 degrees and came to rest on the northeast shoulder of the road near the northeastbound lane, heading in a west-southwestward direction, straddling the partition between gravel and paved portions of the shoulder. Although the crash was off-set, the severity of the impact resulted in "wrap-around" direct damage to the entire fronts of both vehicles.

The case vehicle's driver [195 centimeters and 115 kilograms (77 inches, 254 pounds)] was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. The inspection of the driver's seat belt system showed that the belt had been cut to the shoulder portion with the latch still engaged. The webbing and latch plate showed evidence of loading (i.e., waffling and heat abrasion) as well as a skin transfer on the shoulder portion. It should be noted that the retractors for the front seat shoulder belts were mounted in the driver's seat back and were designed without a "D"-ring.

The case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of his available safety belts, his pre-impact body position remained unchanged just prior to the impact. The case vehicle's impact with vehicle #2 enabled the case vehicle's driver to continue forward and slightly upward, while loading and locking-up his three-point, lap-and-shoulder, safety belt system as the case vehicle decelerated. Because of the differential deceleration, the driver's head flexed forward, with his right side leading. The deploying air bag contacted the driver's torso and probably his neck and chin, most likely lifting his head momentarily upwards. Because of the severity of the crash and resulting intrusions, the driver's head, upper torso, and lower limbs continued forward, through the air bag, simultaneously collapsing the steering column, fracturing the rim, and deforming the knee bolsters. Presumably the driver's shoulder belt being integrated (i.e., anchored in the seat back), combined with the high impact speeds which resulted in the stretching of the seat belt webbing, allowed for further forward excursion by the case vehicle's driver. However, the case vehicle's seat back showed no apparent signs of bending. As the two vehicle's reached maximum engagement, the case vehicle rotated clockwise causing the driver to rebound backwards from the steering column and slide off his stretched safety belt to the left where he contacted the side of the driver's door with his left lower torso and the left roof side rail with his head. At final rest the driver was found restrained and slumped over the intruding steering column.

The driver was transported by ambulance to the hospital where he was stabilized before being air lifted to a trauma center. He sustained fatal injuries but was kept alive on life support until his bones, organs, and some skin could be harvested. He was pronounced dead between 30 and 31 hours post-crash. Based on his medical records and his the autopsy, the injuries sustained by the case vehicle's driver included: a spinal cord laceration at cervicomedullary junction with atlanto-occipital dislocation, a diffuse axonal injury, a nonanatomic brain injury, subdural and/or epidural hemorrhage in the posterior cranial fossa, a comminuted right basilar skull fracture, bilateral contusions to the inferior frontal gyri, subarachnoid hemorrhages over both frontal lobes, diffuse cerebral edema, diffuse cerebellar edema, a subarachnoid hemorrhage over the right superior cerebellum, a lacerated spleen, and a laceration and abrasion to his right knee.

The case vehicle was a four wheel drive 2000 Chevrolet Silverado K-1500, three-door, pick-up truck (VIN: 2GCEK19T5Y1------) with a cap over the truck's bed. The case vehicle was equipped with four-wheel anti-lock brakes, front seat-mounted retractors for the shoulder belts, and a key operated On/Off switch for the front right supplemental restraint (air bag). Vehicle #2 is a rear wheel drive 1988 Chevrolet G20 (three-quarter-ton), 4x2, incomplete vehicle equipped with a full sized conversion van (VIN: 1GBEG25H8J7------). The case vehicle and vehicle #2 were both towed due to damage. Based on the vehicle inspection, the CDCs were determined to be: **12-FDEW-5 (10)** for the case vehicle [maximum crush was 127 centimeters (50.0 inches) at C_6] and **12-FDEW-6 (350)** for vehicle #2 [maximum crush was 147 centimeters (57.9 inches) above the bumper at C_5]. The WinSMASH reconstruction program, damage only algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 87.1 km.p.h. (54.1 m.p.h.), -85.8 km.p.h. (-53.3 m.p.h.), and -15.1 km.p.h. (-9.4 m.p.h.). These results do not appear to be that unreasonable considering the travel speeds and damage.

The case vehicle's initial contact with vehicle #2 involved the entire front. Direct damage extended from bumper corner to bumper corner, a measured distance of 144 centimeters (56.7 inches). As previously mentioned the maximum crush to the front right bumper corner was 127 centimeters (50.0 inches). The case vehicle's wheelbase was shortened 96 centimeters (37.8 inches) on the right side but only 15 centimeters (5.9 inches) on the left side. The frontal impact caused the case vehicle's hood to fold backwards, directly contacting the windshield and holing it on the right side [44 x 12 cm (17.3 x 4.7 inches)]. The case vehicle's right front door and third door (jump door) were displaced rearward, but the hinges and latches remained intact. The top of the right front door frame was bowed outward approximately 45 centimeters (17.7 inches) because the right "A"-pillar was pushed so far rearward. The intrusion to the case vehicle's interior, primarily to the front right passenger seating area, was near catastrophic. The intrusions measured: 73 centimeters (28.7 inches) at the toe pan, 52 centimeters (20.5 inches) at the right "A"-pillar, and 64 centimeters (25.2 inches) at the right instrument panel. The right instrument panel was pushed nearly on top of the leading edge of the front right passenger's seat. There was contact evidence readily apparent on the driver's air bag, steering wheel rim, knee bolster, center instrument panel, left roof side rail, and driver's door.

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and air bag fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with four tethers, each 10 centimeters (3.9 inches) wide. The driver's air bag had two vent ports, approximately 3 centimeters (1.2 inches) in diameter, located at the eleven and one o'clock positions. The deployed driver's air bag was round with a diameter of 66 centimeters (26.0 inches). There were three areas of skin transfer evidence readily apparent on the driver's air bag. The skin transfers were located on the top, center, and right side of the air bag's fabric.

The front right passenger's air bag was located in the middle of the instrument panel. As previously mentioned, the case vehicle was equipped with a key-operated On/Off switch for the front right passenger air bag which was turned to the "**On**"position. An inspection of the front right air bag module's cover flap and air bag revealed that the cover flap opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The front right passenger's air bag was designed without any tethers. The front right air bag had two vent ports, approximately 5 centimeters (2.0 inches) in diameter, located at the ten and two o'clock positions. The deployed front right air bag was rectangular with a height of approximately 32 centimeters (12.6 inches) and a width of approximately 56 centimeters (22.0 inches). There was no contact evidence readily apparent on the front right air bag; although, there was a drop of blood on the far left side of the front portion.

During this contractor's on-scene investigation, this contractor removed the case vehicle's **S**ensor and **D**iagnostic **M**odule (SDM) with help from the local fire department and sent the unit to this contractor's NCSA COTR for downloading; see **SENSOR AND DIAGNOSTIC MODULE** below.

According to General Motors, the SDM is able to record near deployment events. These near deployment events would include impacts up to and below the vehicle's threshold for a deployment event. Impacts at or higher than the threshold would, of course, cause deployment of the vehicle's air bags. Essentially the recording is taken at any deceleration event the case vehicle incurs higher than **"2gs"**. The SDM is also capable of recording the driver's safety belt status, pre-crash brake switch status, and the vehicle's travel speed just prior to the last recorded event. In addition, the SDM records any air bag warnings that were detected (pre- or post-crash). Another important bit of information that SDM is capable of retaining is the maximum Delta V the case vehicle sustained during its deployment event (crash).

The SDM recorded and stored a **crash event** that occurred on ignition cycle number 430. The SDM system reported no faults or warning codes because the SIR Warning Light was OFF at the time of the deployment. The case vehicle's air bags were commanded to deploy 30 milliseconds into the event (i.e., after the collision was first detected by the SDM). The SDM recorded a maximum change in velocity (Delta V) of 84 km.p.h. (52 m.p.h.). The Delta V reached this maximum value at 110 milliseconds after the crash was first detected. The SDM did not record any **near-deployment** events prior to ignition cycle 430 (i.e., the crash in question). The SDM indicated that the driver's safety belt was latched at the time the deployment occurred.

Immediately prior to the crash the case vehicle's restrained driver was seated, presumably asleep or dozing off, in an upright posture, with his back against the seat back, his left foot on the floor, his right foot on the accelerator, and both hands on the steering wheel. His seat track was located just forward of the rearmost position, the seat back was upright, and the tilt steering wheel was located in its down-most position.

Vehicle #2's driver [19-year-old, White (unknown if Hispanic) male] was seated, presumably in an upright posture, 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. The location of his seat track and seat back are unknown. It is also unknown if vehicle #2 was equipped with a tilt steering wheel. Vehicle #2's driver (of unknown height and weight) was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. The driver was transported by ambulance to the hospital. He sustained unknown injuries and was hospitalized post-crash. The injuries sustained by vehicle #2's driver are unknown at this time, but in this contractor's opinion, given the severity of this crash, his survival is a ***"success story"*** for safety belt restraint usage.

CRASH CIRCUMSTANCES

The case vehicle was traveling southwestward, in a slight right-hand curve, in the southwestbound lane of a two-lane, undivided, U.S. Highway and intended on continuing travel southwestward. For unknown reasons (e.g., preoccupied or had fallen asleep and did not realize he had crossed into the centerline) the case vehicle crossed into the northeastbound lane (**Figure 1** below). Vehicle #2 was traveling northeastward, in a slight left hand curve, in the northeastbound lane of the same two-lane, undivided, U.S. Highway and intended to continue travel northeastward (**Figure 2** below). The case vehicle's driver made no avoidance maneuvers prior to the crash. The driver of vehicle #2 braked and steered to the right, attempting to avoid

the crash (**Figure 3**). Based on the county sheriff's scene reconstruction, the crash occurred 2.9 meters (9.4 feet) into the northeastbound lane of the roadway towards the edge line; see **CRASH DIAGRAM** below.

Figure 2: On-scene southwestward view of case vehicle's final rest position on southeast shoulder; Note: vehicle #2 was traveling northeastward in left-hand curve (case photo #02)

The U.S. highway was curved slightly to the right for southwestbound traffic [i.e., case vehicle (**Figure 1**); left for northeastbound traffic (i.e., vehicle #2; **Figure 2**)] and level at the area of impact. The pavement was bituminous, and according to police measurements, the width of the travel lanes for both vehicles was 3.7 meters (12 feet). The shoulders were improved (i.e., bituminous), with a 0.9 meter (3.0 foot) wide paved shoulder and a 2.7 meter (8.9 feet) wide gravel shoulder immediately adjacent. There was a guardrail along the southeast side of the road which was adjacent to a small cement bridge, approximately 3 meters (10 feet) west of the impact area. Pavement markings consisted of a single broken yellow centerline for both northeast and southwestbound traffic. In addition, solid white edge lines were present. The estimated coefficient of friction was approximately 0.85 when dry. There were no visible traffic controls in the immediate area. The posted speed limit was 89 km.p.h. (55 m.p.h.). At the time of the crash the light condition was daylight, the atmospheric condition was cloudy, and the road pavement was

Figure 1: On scene view of case vehicle's southwestward travel path in right hand curve as it crossed into northeastbound lane where crash occurred; Note: case vehicle's final rest position on southeast shoulder (case photo #01)

Figure 3: On scene northeastward view of case vehicle's final rest position on southeast shoulder and vehicle #2's straight line skid marks into impact near right (southeast) edge line; Note: case vehicle had been traversing a right-hand curve (case photo #04)

Figure 4: Overhead view of crush to case vehicle's front with contour gauge present showing offset (toward right) nature of crash (case photo #11)

dry. Traffic density was unknown, and the site of the crash was primarily rural undeveloped. In addition, there was a connecting county roadway an unknown distance northeast of the crash site.

Figure 5: Extensive crush to case vehicle's front right portion viewed from left of front; Note: both "A"-pillars are deformed (case photo #14)

Figure 6: Case vehicle's extensive, offset, frontal crush viewed from right of front; Note: rearward movement of right "A"-pillar and holed windshield on right side (case photo #31)

Figure 7: Vehicle #2's extensive, offset, frontal crush viewed from left of front with contour gauge present (case photo #65)

The front of the case vehicle (**Figure 4** above and **Figures 5** and **6**) impacted the front of vehicle #2 (**Figure 7** and **Figure 8**), causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The frontal crash was slightly offset toward the right side of each vehicle; see **SELECTED PHOTOGRAPHS** below (**Figures 20** and **21**). The case vehicle's front bumper slightly overrode vehicle #2's front bumper because the front of vehicle #2 dipped downward during its braking maneuver, while attempting to avoid the crash. The case vehicle's impact to vehicle #2 was severe enough that vehicle #2 was pushed backwards approximately 6 meters (20 feet). At maximum engagement, both vehicle's rotated clockwise (**Figures 9** and **10** below), with vehicle #2 rotating approximately 100 degrees while being pushed backwards. Vehicle #2 came to rest heading south-southeastward in the middle of the roadway, straddling the southwestbound and northeastbound lanes (**Figure 10** below). The case vehicle continued forward while rotating approximately 60 degrees and came to rest on the northeast shoulder of the road near the northeastbound lane (**Figure 9**). At final rest the case vehicle was heading in a west-southwestward direction, straddling the partition between gravel and paved portions of the

Figure 8: Vehicle #2's extensive, offset, frontal crush, with contour gauge present, viewed from right of front (case photo #70)

shoulder. Although the crash was off-set, the severity of the impact resulted in "wrap-around" direct damage to the entire fronts of both vehicles.

Figure 9: On scene southwestward view along the edge line bordering the northeastbound lane showing case vehicle (to left) and vehicle #2 (to right) at final rest; Note: technicians are attempting to stabilize vehicle #2's driver (case photo #05)

Figure 10: On scene northward view from southeast roadside showing vehicle #2 (to left) and case vehicle (to right) at final rest (case photo #07)

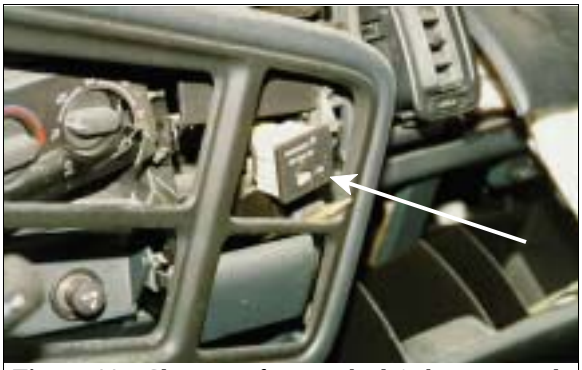

Figure 11: Close-up of case vehicle's key operated On/Off switch for front right passenger air bag; Note: switch was in On position (case photo #60)

CASE VEHICLE

The case vehicle was a four wheel drive 2000 Chevrolet Silverado K-1500, five-passenger, three-door, pick-up truck with a cap over the truck's bed (VIN: 2GCEK19T5Y1------). The case vehicle was equipped with power-assisted rack-and-pinion steering, a 5.3L, Vortec SCPFI V-8 engine, a four-speed automatic transmission with overdrive, front seat-mounted retractors for the shoulder belts, and a key operated On/Off switch (**Figure 11**) for the front right supplemental restraint (air bag). Braking was achieved by a power-assisted, front and rear disc, four-wheel anti-lock system. The case vehicle's wheelbase was 364 centimeters (143.5 inches), and the odometer reading at inspection is unknown because the case vehicle was equipped with an electronic odometer.

Inspection of the vehicle's interior revealed electronic window and door locks; adjustable front bucket seats with adjustable head restraints; an adjustable back split bench seat with folding backs and adjustable head restraints for the back outboard seating positions; and continuous loop, three-point, lap-and-shoulder, safety belt systems at the front (i.e., integrated) and back outboard positions; and a two-point, lap belt system at the back center position. The front seat belt systems were not equipped with manually operated height adjusters for the "D"-rings because the retractor system was stored in the front seat backs (**Figure 12** below). The vehicle was equipped with knee bolsters for both the driver and front right passenger. The case vehicle's driver knee bolster was scuffed and deformed. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver and front right passenger seating positions. Both front seat air bags deployed as a result of the case vehicle's impact with vehicle #2.

The case vehicle's initial contact with vehicle #2 involved the entire front. Direct damage extended from bumper corner to bumper corner, a measured distance of 144 centimeters (56.7 inches). The maximum crush was 127 centimeters (50.0 inches; **Figure 4** above) at the front right bumper corner (i.e., C_6). The case vehicle's wheelbase was shortened 96 centimeters (37.8 inches) on the right side but only 15 centimeters (5.9 inches) on the left side. The vehicle's right "A"-pillar was pushed significantly rearwards. The frontal impact caused the case vehicle's hood to fold backwards, directly contacting the windshield during maximum engagement and holing it (**Figure 6** above) primarily on the right side [44 x 12 cm (17.3 x 4.7 inches)]. The case vehicle's right front door and third door (jump door) were displaced rearward, but the hinges and latches remained intact. The top of the right front door frame was bowed outward (**Figure 6** above) approximately 45 centimeters (17.7 inches) because the right "A"-pillar was pushed so far rearward. The crash resulted in the case vehicle's driver door being jammed closed; it was opened by emergency personnel in order to remove the driver.

Figure 12: Case vehicle's driver seating area viewed from outside driver's door showing opening on seat back for driver's shoulder belt retractor; Note: intrusion to passenger area (case photo #42)

Figure 13: Case vehicle's driver seating area showing deployed driver air bag; Note: deformed and fractured steering wheel rim (case photo #46)

Figure 14: Close-up of case vehicle's steering wheel rim, fractured from loading by case vehicle's driver (case photo #50)

An examination of the case vehicle's interior revealed, in addition to the cracked and partially holed windshield, that the rearview mirror was knocked off by the impact forces of the crash. The energy absorbing steering column showed significant evidence of compression. The steering wheel was deformed (**Figure 12**) and cracked (**Figures 13** and **14**). The center instrument panel was broken (**Figure 11** above and **Figure 13**) and bloodied from contact with the driver's right knee. The shear capsules had become completely separated. The roof near the left side roof rail showed what appeared to be hair transfers from the driver's head during the clockwise rotation. The intrusion to the case vehicle's interior, primarily to the front right passenger seating

area, was near catastrophic. The intrusions measured: 73 centimeters (28.7 inches) at the toe pan, 52 centimeters (20.5 inches) at the right "A"-pillar, and 64 centimeters (25.2 inches) at the right instrument panel. The right instrument panel was pushed nearly on top of the leading edge of the front right passenger's seat (**Figure 12** above). There was contact evidence readily apparent on the driver's air bag, steering wheel rim, knee bolster, center instrument panel, left roof side rail, and driver's door.

Based on the vehicle inspection, the CDC was determined to be: **12-FDEW-5 (10)** for the case vehicle. The WinSMASH reconstruction program, damage only algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 87.1 km.p.h. (54.1 m.p.h.), -85.8 km.p.h. (-53.3 m.p.h.), and -15.1 km.p.h. (-9.4 m.p.h.). These results do not appear to be that unreasonable considering the travel speeds and damage. The case vehicle was towed due to damage.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle's driver air bag was located in the steering wheel hub. The module cover consisted of symmetrical "I"-configuration cover flaps made of thick vinyl with overall dimensions of 8.5 centimeters (3.3 inches) at the left and right horizontal seams and 11 centimeters (4.3 inches) vertically (**Figure 15**). An inspection of the air bag module's cover flaps and air bag fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with four tethers, each 10 centimeters (3.9 inches) wide, sewn interiorly. The driver's air bag had two vent ports, approximately 3 centimeters (1.2 inches) in diameter, located at the eleven and one o'clock positions. The deployed driver's air bag was round with a diameter of 66 centimeters (26.0 inches). An inspection of the case vehicle's driver air bag revealed three areas of skin transfer and blood splotch evidence readily apparent on the driver's air bag. The largest area of skin was 12 x 6 centimeters (4.7 x 2.4 inch) located near the top. There was what appeared to be a small chunk of skin or possibly mucous in the center near the right side of the tether stitching, and there was skin and blood along the right side of the air bag's fabric (**Figure 16**). In addition, there was a small spot of blood on the backside of the air bag's shell near the top.

Figure 15: Case vehicle's loaded and deformed steering wheel showing deployed driver air bag, "I"-configuration cover flaps, and cracked rim (case photo #49)

Figure 16: Case vehicle's deployed driver air bag; Note: highlighted areas denote skin transfers (case photo #51)

The front right passenger's air bag was located in the middle of the instrument panel. As previously mentioned, the case vehicle was equipped with a key-operated On/Off switch for the front right passenger air bag which was turned to the "**On**"position (**Figure 11** above). There was a single, essentially rectangular, hinged modular cover flap (**Figure 17**). The cover flap was made of a thick vinyl over a thick cardboard type frame. The flap's dimensions were: 38 centimeters (15.0) along both horizontal seams and 14 centimeters (5.5 inches) along both vertical seams. The profile of the case vehicle's instrument panel was flush with the leading edge of the cover flap. An inspection of the front right air bag module's cover flap and air bag revealed that the cover flap opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The front right passenger's air bag was designed without any tethers. The front right air bag had two vent ports, approximately 5 centimeters (2.0 inches) in diameter, located at the ten and two o'clock positions. The deployed front right air bag was rectangular with a height of approximately 32 centimeters (12.6 inches) and a width of approximately 56 centimeters (22.0 inches). There was no contact evidence readily apparent on the front right air bag; although, there was a drop of blood on the far left side of the front portion.

Figure 17: Case vehicle's deformed center instrument panel and front right seating area showing front right passenger air bag module's On/Off switch and module's cover flap and deployed air bag (case photo #59)

During this contractor's on-scene investigation, this contractor removed the case vehicle's **S**ensor and **D**iagnostic **M**odule (SDM; **Figure 18**) with help from the local fire department and sent the unit to this contractor's NCSA COTR for downloading; see **SENSOR AND DIAGNOSTIC MODULE** section below (**Figures 22**, **23**, and **24** below).

Figure 18: Case vehicle's front seating area viewed from outside driver's door showing intrusion to front right passenger seating area; Note: area highlighted under driver's seat is location of the **S**ensing and **D**iagnostic **M**odule (case photo #37)

According to General Motors, the SDM is able to record near deployment events. These near deployment events would include impacts up to and below the vehicle's threshold for a deployment event. Impacts at or higher than the threshold would, of course, cause deployment of

the vehicle's air bags. Essentially the recording is taken at any deceleration event the case vehicle incurs higher than **"2gs"**. The SDM is also capable of recording the driver's safety belt status, pre-crash brake switch status, and the vehicle's travel speed just prior to the last recorded event. In addition, the SDM records any air bag warnings that were detected (pre- or post-crash). Another important bit of information that SDM is capable of retaining is the maximum Delta V the case vehicle sustained during its deployment event (crash).

The SDM recorded and stored a **crash event** that occurred on ignition cycle number 430. The SDM system reported no faults or warning codes because the SIR Warning Light was OFF at the time of the deployment. The case vehicle's air bags were commanded to deploy 30 milliseconds into the event (i.e., after the collision was first detected by the SDM). The SDM recorded a maximum change in velocity (Delta V) of 84 km.p.h. (52 m.p.h.). The Delta V reached this maximum value at 110 milliseconds after the crash was first detected. The SDM did not record any **near-deployment** events prior to ignition cycle 430 (i.e., the crash in question). The SDM indicated that the driver's safety belt was latched at the time the deployment occurred.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash the case vehicle's restrained driver [18-year-old, White (non-Hispanic) male] was seated, presumably asleep or dozing off, in an upright posture, with his back against the seat back, his left foot on the floor, his right foot on the accelerator, and both hands on the steering wheel. His seat track was located just forward of the rearmost position, the seat back was upright, and the tilt steering wheel was located in its down-most position.

The case vehicle's driver [195 centimeters and 115 kilograms (77 inches, 254 pounds)] was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. The inspection of the driver's seat belt system showed that the belt had been cut to the shoulder portion with the latch still engaged (**Figure 19**). The webbing and latch plate showed evidence of loading (i.e., waffling and heat abrasion) as well as a skin transfer on the shoulder portion. It should be noted that the retractors for the front seat shoulder belts were mounted in the driver's seat back and were designed without a "D"-ring (**Figure 12** above).

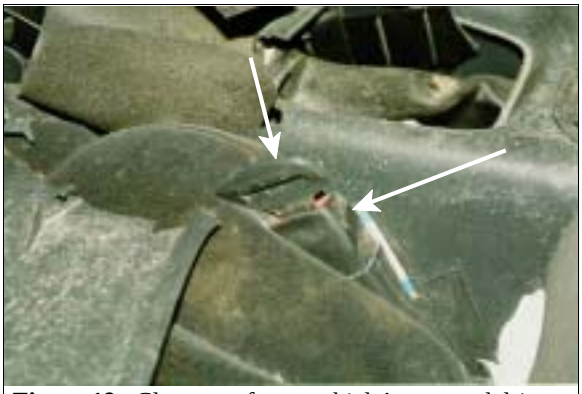

Figure 19: Close-up of case vehicle's engaged driver seat belt buckle and latch plate (case photo #39)

The case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of his available safety belts, his pre-impact body position remained unchanged just prior to the impact. The case vehicle's impact with vehicle #2 enabled the case vehicle's driver to continue forward and slightly upward, while loading and locking-up his three-point, lap-and-shoulder, safety belt system as the case vehicle decelerated. Because of the differential deceleration, the driver's head flexed forward, with his right side leading. The

deploying air bag contacted the driver's torso and probably his neck and chin, most likely lifting his head momentarily upwards. Because of the severity of the crash and resulting intrusions, the driver's head, upper torso, and lower limbs continued forward, through the air bag, simultaneously collapsing the steering column, fracturing the rim (**Figures 13** and **14** above), and deforming the knee bolsters. Presumably the driver's shoulder belt being integrated (i.e., anchored in the seat back), combined with the high impact speeds which resulted in the stretching of the seat belt webbing, allowed for further forward excursion by the case vehicle's driver. However, the case vehicle's seat back showed no apparent signs of bending. As the two vehicle's reached maximum engagement, the case vehicle rotated clockwise causing the driver to rebound backwards from the steering column and slide off his stretched safety belt to the left where he contacted the side of the driver's door with his left lower torso and the left roof side rail with his head. At final rest the driver was found restrained and slumped over the intruding steering column.

CASE VEHICLE DRIVER INJURIES

The driver was transported by ambulance to the hospital where he was stabilized before being air lifted to a trauma center. He sustained fatal injuries but was kept alive on life support until his bones, organs, and some skin could be harvested. He was pronounced dead between 30 and 31 hours post-crash. Based on his medical records and his the autopsy, the injuries sustained by the case vehicle's driver included: a spinal cord laceration at cervicomedullary junction with atlanto-occipital dislocation, a diffuse axonal injury, a nonanatomic brain injury, subdural and/or epidural hemorrhage in the posterior cranial fossa, a comminuted right basilar skull fracture, bilateral contusions to the inferior frontal gyri, subarachnoid hemorrhages over both frontal lobes, diffuse cerebral edema, diffuse cerebellar edema, a subarachnoid hemorrhage over the right superior cerebellum, a lacerated spleen, and a laceration and abrasion to his right knee. This occupant's primary brain, skull, and cervical injuries were most likely caused by his contact with the case vehicle's steering wheel rim which resulted as a consequence of bottoming out the his deploying, redesigned air bag because of the impact forces generated by this high speed crash.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Laceration {severance} of cervical spinal cord at cervicomedullary junction with an atlanto-occipital dislocation, a posterior displacement of the odontoid process, and lacerations {tears, disruption} of the alar, cruciate, and posterior longitudinal ligaments–see discussion of **SPINAL INJURIES** below	640274.6[1] untreatable	Steering wheel rim {upper right}	Probable	Autopsy
2	Diffuse axonal injury (white matter shearing) right middle frontal gyri[2], medial parietal lobe, hippocampus, and corpus callosum	140628.5 critical	Steering wheel rim {upper right}	Probable	Autopsy

[1] The choice of injury code is difficult because the NASS CDS Injury Coding manual presumes, first, that one knows whether the spinal lesion is either a contusion or a laceration (i.e., no option for "unknown" is provided; although severance translates to laceration, the certainty is at best "probable"), and second, whether there was a complete or an incomplete cord syndrome. Because the only available medical record is an autopsy, the syndrome issue is not discernable (i.e., you cannot determine the difference in a deceased person). In the absence of protocol, this contractor chooses to assume the lesion was a laceration and that the syndrome was complete.

[2] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

corpus (kor′pes): 1. A discrete mass of material, as of specialized tissue. 2. In anatomical nomenclature, the entire body of the organism, or the main portion of an anatomical part, structure, or organ.

c. callo′sum: an arched mass of white matter, found in the depths of the longitudinal fissure, composed of three layers of fibers, the central layer consisting primarily of transverse fibers connecting the cerebral hemispheres; its subsections, from anterior to posterior, are called the rostrum, genu, trunk, and splenium.

fissure (fish′ar): any cleft or groove, normal or otherwise; especially a deep fold in the cerebral cortex which involves the entire thickness of the brain wall. Compare *sulcus*.

gyrus (ji′ras) pl. ***gyri (ji′ri)***: one of the convolutions of the surface of the brain caused by infolding of the cortex; see ***gyri cerebri***.

g. cerebel′li: folia cerebelli.

g. cerebra′les: cerebral gyri; the tortuous convolutions of the surface of the cerebral hemisphere, caused by infolding of the cortex and separated by the fissures or sulci. Many are constant enough that they have been given special names. Called also *gyri cerebri* and *gyri of cerebrum*.

g. ce′rebri, gyri of cerebrum: gyri cerebrales.

g. hippocam′pi, hippocampal gyrus: gyrus of hippocampus; a convolution on the inferior surface of each cerebral hemisphere, lying between the hippocampal and collateral sulci; called also *parahippocampal g.* and *g. parahippocampalis*.

g. parahippocampalis, parahippocampal g.: alternative for *g. hippocampi*.

sulcus (sul′kas) pl. ***sul′ci (sul′si)***: a groove, trench, or furrow; a general term for such a depression, especially one of those on the surface of the brain, separating the gyri. Compare *fissure*.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
3	Nonanatomic brain injury with loss of consciousness and no response to deep painful stimulation; GCS = 3; no corneal or gag reflex; diffuse ischemic changes, anoxic/hypoxic[3] injury/changes	160824.5 critical	Steering wheel rim {upper right}	Probable	Autopsy
4 5	Subdural hemorrhage[4] in posterior cranial fossa Epidural hemorrhage in posterior cranial fossa [Aspect = Unknown for both]	140650.4 severe 140630.4 severe	Roof left side rail	Possible	Autopsy
6	Contusions, bilateral, inferior frontal gyri[5]	140620.3 serious	Steering wheel rim {upper right}	Probable	Autopsy
7 8	Hemorrhage, subarachnoid, superior and medial surfaces of right frontal lobe Hemorrhage, subarachnoid, left frontal lobe–much less than right frontal lobe	140684.3 serious 140684.3 serious	Steering wheel rim {upper right}	Probable	Autopsy
9	Infarct[6], transcortical, acute, right frontal lobe	140676.3 serious	Steering wheel rim {upper right}	Probable	Autopsy
10 11	Edema, diffuse, generalized, cerebrum with mass effect bilaterally with widening of gyri	140668.3 140668.3 serious	Steering wheel rim {upper right}	Probable	Autopsy
12	Hemorrhage, subarachnoid, right superior cerebellum	140466.3 serious	Roof left side rail	Possible	Autopsy

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[3] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
anoxic (a-nok′sik): pertaining to or characterized by anoxia.
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.
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.

[4] It is most likely that there was really only one lesion, with two descriptions. In an early part of the autopsy the label subdural was used; later in the autopsy the label epidural was used.

[5] See footnote number two above for relevant definition.

[6] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
infarct (in′fahrkt): an area of coagulation necrosis in a tissue due to local ischemia resulting from obstruction of circulation to the area, most commonly by a thrombus or embolus.
infarction (in-fahrk′shen): 1. the formation of an infarct. 2. an infarct.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
13	Edema, diffuse, generalized, cerebellum	140454.3 serious	Roof left side rail	Possible	Autopsy
14	Fractures, comminuted, right basilar skull involving the medially anterior lambdoid suture and a diastasis[7] of the right mastoid suture[8]	150206.4 severe	Steering wheel rim {upper right}	Possible	Hospitalization records
15	Laceration spleen, not further specified, with intra peritoneal hemorrhage	544220.2 moderate	Steering wheel rim {lower left}	Probable	Hospitalization records
16	Abrasion, deep, near right knee	890202.1 minor	Center instrument panel and below	Probable	Autopsy
17	Laceration, large, open, to medial and lateral right knee	890600.1 minor	Center instrument panel and below	Probable	Hospitalization records

VEHICLE #2

Vehicle #2 is a rear wheel drive 1988 Chevrolet, 4x2, unknown-passenger, four-door incomplete vehicle, based on a G20 (three-quarter-ton) Sportvan, fitted with a full sized conversion van (VIN: 1GBEG25H8J7------). Vehicle #2 was equipped with power-assisted, worm and gear steering, a 5.0L, FI, V-8 engine, and a four-speed automatic transmission with overdrive. Braking was achieved by a power-assisted, front disc and rear drum system. Anti-lock brakes were not available for this vehicle. The case vehicle's wheelbase was 318 centimeters (125.0 inches), and the odometer reading at inspection is unknown.

Vehicle #2's contact with the case vehicle involved the entire front. Direct damage extended from bumper corner to bumper corner, a measured distance of 149 centimeters (58.7 inches). The maximum crush was 147 centimeters (57.9 inches) above the bumper at C_5. The wheelbase on vehicle #2's right side was shortened 54 centimeters (21.3 inches) while the left side was shortened only 8 centimeters (3.1 inches). Vehicle #2's front bumper, bumper fascia, grille, hood, radiator, right and left headlight assemblies and fenders, and right "A"-pillar was directly damaged and crushed rearward. Vehicle #2's left and right front tires were physically restricted, and the front left tire was crushed rewards from the crash.

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[7] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
diastasis (di-as´te-sis): a form of dislocation in which there is separation of two bones normally attached to each other without the existence of a true joint; as in separation of the pubic symphysis. Also, separation beyond the normal between associated bones, as between the ribs, or the ulna and radius.

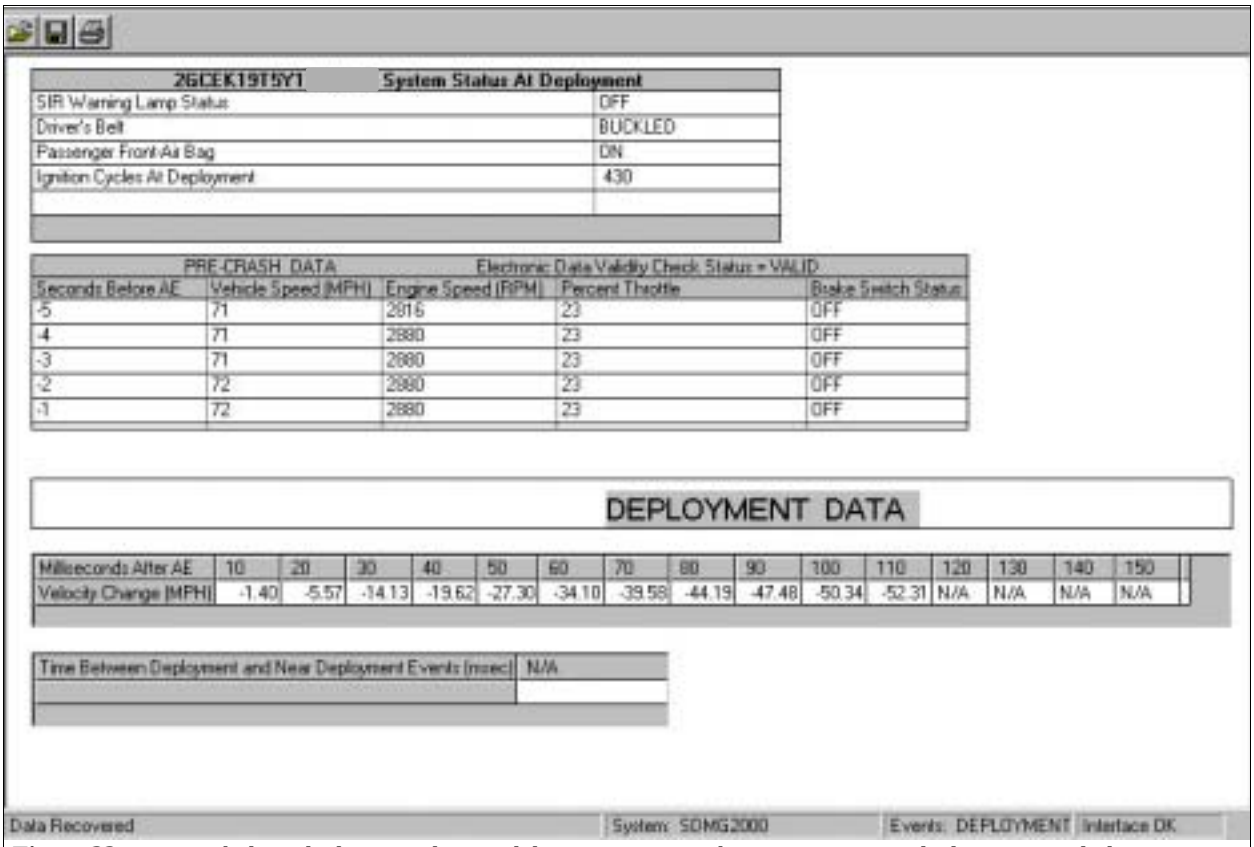
[8] It is unclear whether the diastasis occurred along the occipitomastoid suture or the parietomastoid suture.

Based on the vehicle inspection, the CDC was determined to be: **12-FDEW-6 (350)** for vehicle #2. The WinSMASH reconstruction program, damage only algorithm, was used on the vehicle #2's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 103.1 km.p.h. (64.1 m.p.h.), -101.5 km.p.h. (-63.1 m.p.h.), and +17.9 km.p.h. (+11.1 m.p.h.). These results do not appear to be that unreasonable considering the travel speeds and damage. Vehicle #2 was towed due to damage.

Vehicle #2's driver [19-year-old, White (unknown if Hispanic) male] was seated, presumably in an upright posture, 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. The location of his seat track and seat back are unknown. It is also unknown if vehicle #2 was equipped with a tilt steering wheel. Vehicle #2's driver (of unknown height and weight) was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. The driver was transported by ambulance to the hospital. He sustained unknown injuries and was hospitalized post-crash. The injuries sustained by vehicle #2's driver are unknown at this time, but in this contractor's opinion, given the severity of this crash, his survival is a ***"success story"*** for safety belt restraint usage.

Figure 20: Right side view of extensive deformation to case vehicle's front (case photo #27)

Figure 21: Vehicle #2's offset (toward right) frontal crush viewed along front reference line from right with contour gauge present (case photo #69)



2GCEK19T5Y1	System Status At Deployment
SIR Warning Lamp Status	OFF
Driver's Belt	BUCKLED
Passenger Front Air Bag	ON
Ignition Cycles At Deployment	430

PRE-CRASH DATA		Electronic Data Validity Check Status = VALID		
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Status
-5	71	2816	23	OFF
-4	71	2880	23	OFF
-3	71	2880	23	OFF
-2	72	2880	23	OFF
-1	72	2880	23	OFF

DEPLOYMENT DATA

Milliseconds After AE	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Velocity Change (MPH)	-1.40	-5.57	-14.13	-19.62	-27.30	-34.10	-39.58	-44.19	-47.48	-50.34	-52.31	N/A	N/A	N/A	N/A

Time Between Deployment and Near Deployment Events (msec)	N/A

Data Recovered | System: SDM62000 | Events: DEPLOYMENT | Interface OK

Figure 22: Pre-crash data, deployment data, and data pertaining to the system status at deployment, including ignition cycle, SIR Warning Lamp status, and restraint usage

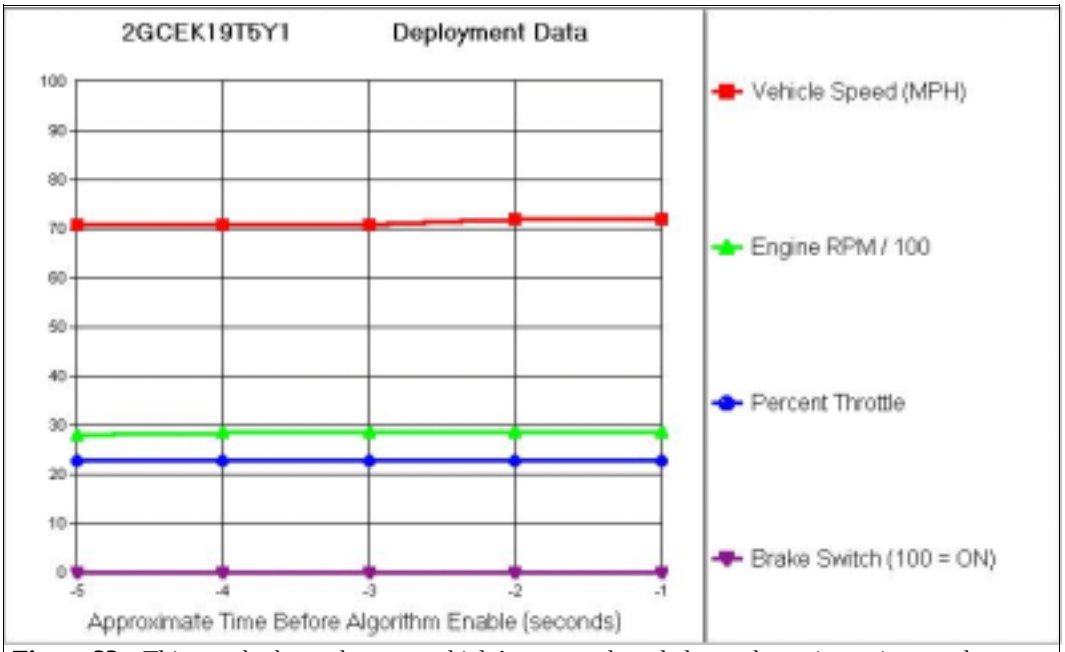


Figure 23: This graph charts the case vehicle's pre-crash and shows that prior to impact the case vehicle's speed was recorded at 115 km.p.h. (71-72 m.p.h.) and that the brake switch was OFF at the five recorded sample periods

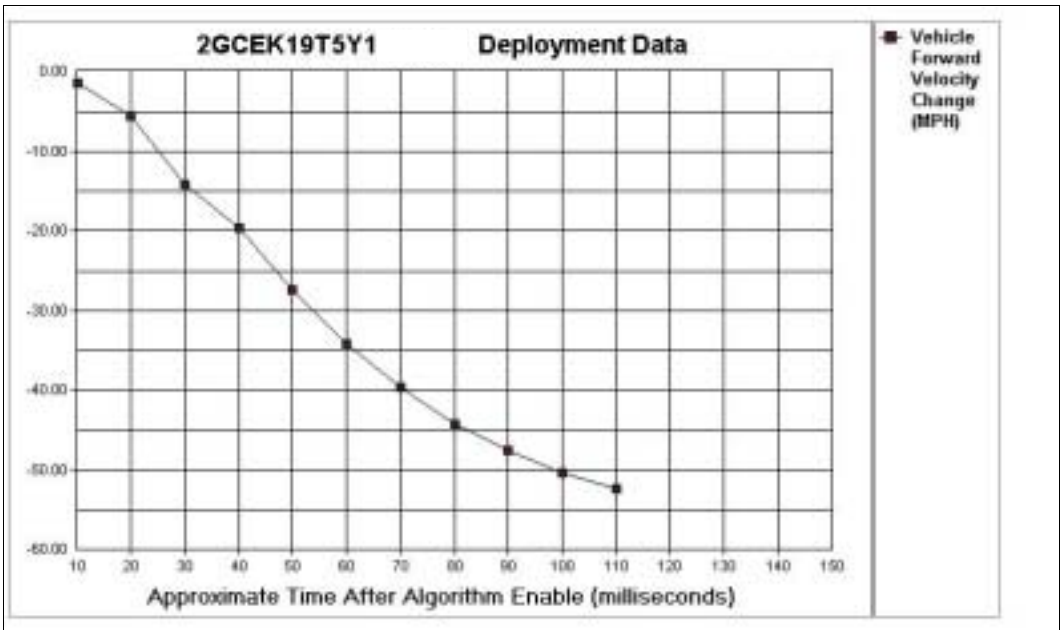


Figure 24: This graph charts the case vehicle's maximum velocity change of 84 km.p.h. (52 m.p.h.) which occurred 110 milliseconds after the crash was detected

The following material on ***spinal injuries*** was taken from the chapter entitled: "Spine," written by Anderson, Paul B., M.D., Harborview Medical Center, from the book Orthopaedic Trauma Protocols, edited by Hansen, Jr., Sigvard T., M.D.; and Swiontkowski, Marc F., M.D.; Raven Press, Ltd., New York, 1993.

ANATOMIC CONSIDERATIONS: The skull is affixed to the cervical spine at the occipitocervical articulation, which includes the atlanto-occipital and atlantoaxial joints. The strong ligament and bony structures allow a wide range of motion yet are rarely injured. The convex-shaped occipital condyles project downward from the occiput and articulate with corresponding concavities in the lateral masses of the atlas (C_1–**Figure 25**). The principal ligament structures that limit motion in the occipitocervical articulation are the alar ligaments and the tectorial membrane (**Figures 26** and **27** below). The alar ligaments attach on the tip of the dens and extend to the medial aspect of the occipital condyles. The tectorial membrane is the uppermost extension of the posterior longitudinal ligament and attaches to the anterior aspect of the foramen magnum. These ligaments span from the occiput to C_2 without attaching directly to C_1, which acts merely as a bushing. ***(p. 198)***

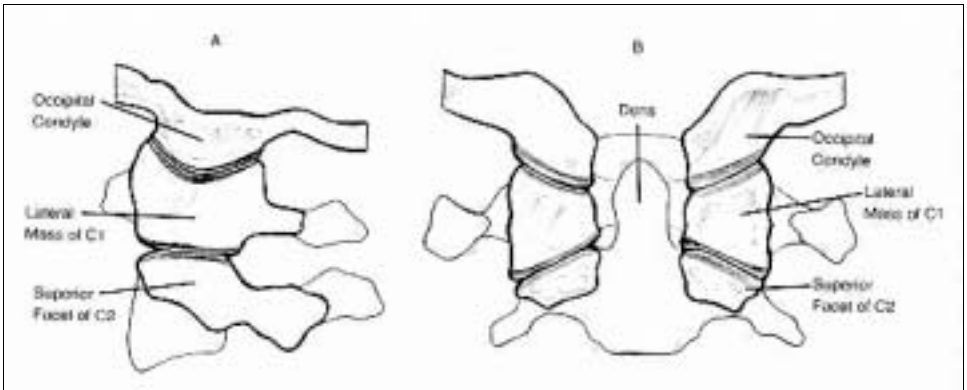


Figure 25: A - Lateral view of craniocervical articulation.
B - Anteroposterior view of bony anatomy of craniocervical articulation

CLASSIFICATION: ATLANTO-OCCIPITAL DISLOCATIONS: Patients rarely survive atlanto-occipital dislocations because of brainstem and the spinal cord damage. These injuries, which can range from mild instability to complete dislocation with marked vertical distraction, are often initially missed. Atlanto-occipital dislocations are classified by the direction of displacement: anterior, vertical, or posterior. Pathologically, all the major restraining and alar ligaments and the tectorial membrane are ruptured regardless of the direction of displacement. All injuries are unstable and require posterior occipitocervical fusion. ***(p. 200)***

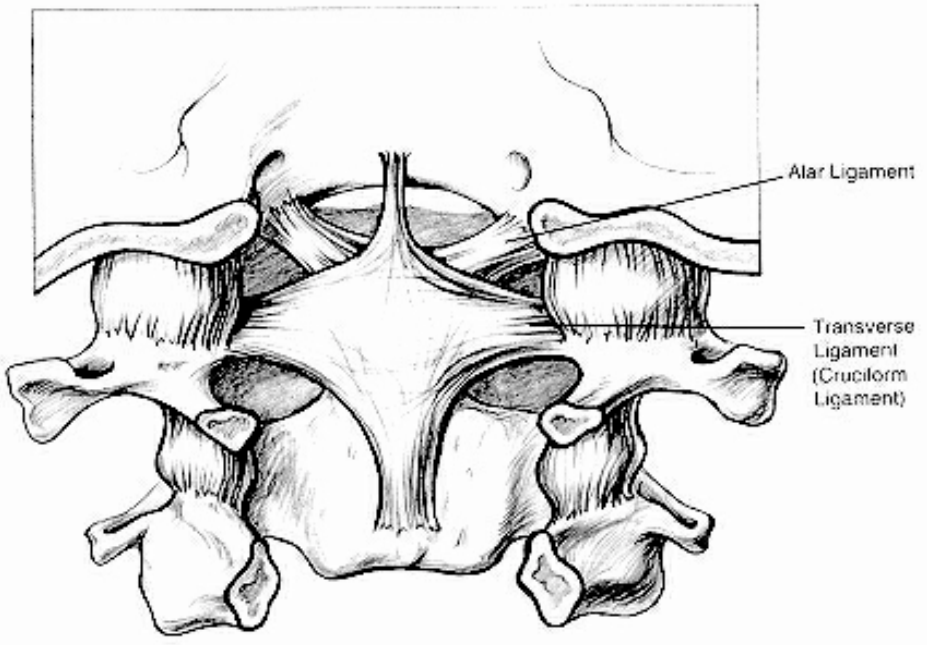


Figure 26: Posterior view of ligamentous anatomy of the craniocervical articulation

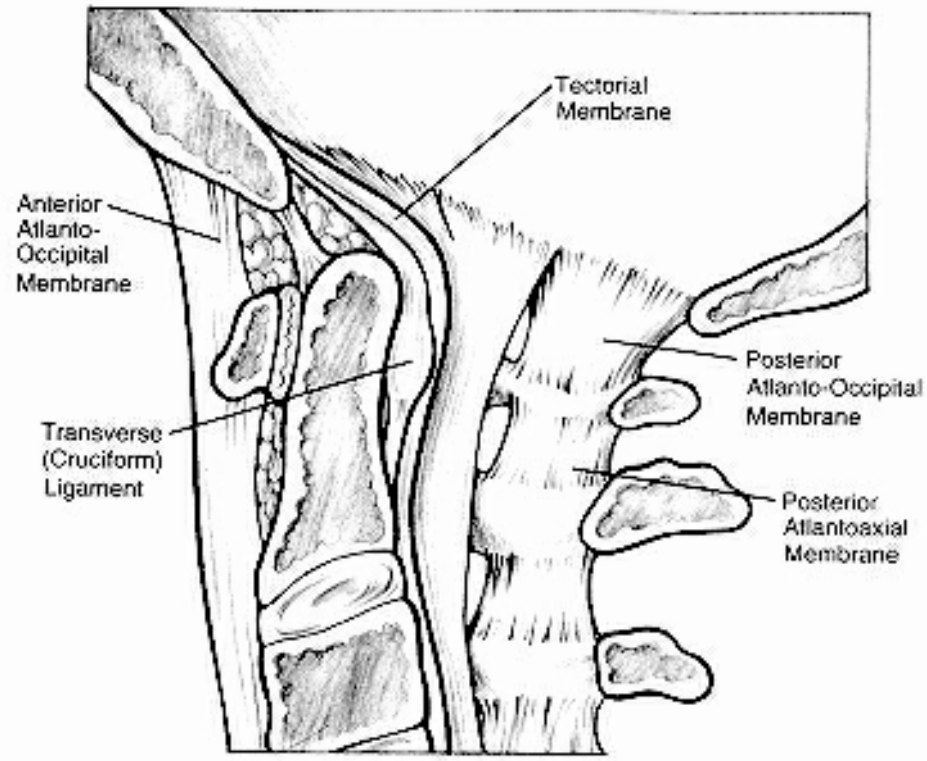
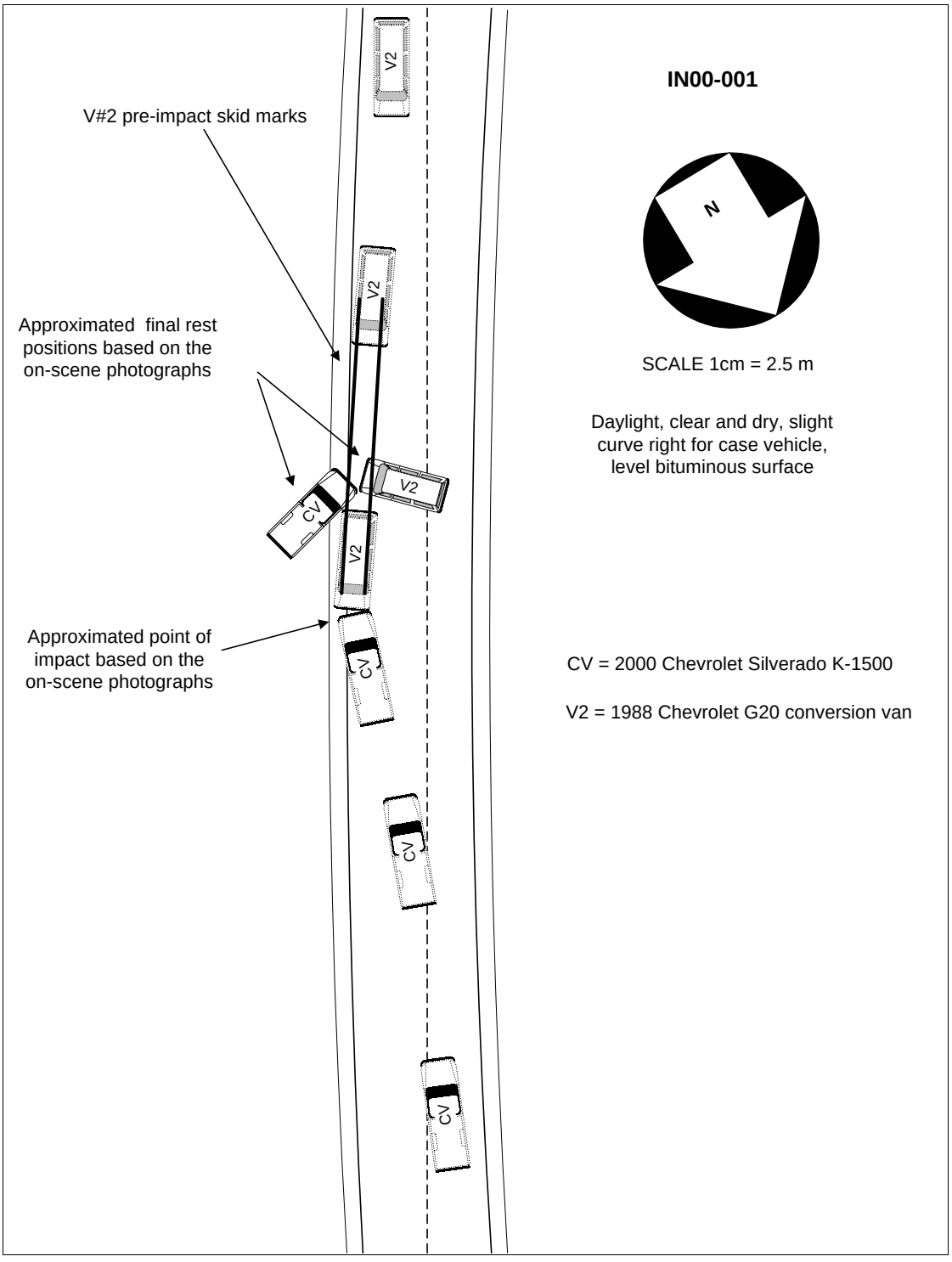


Figure 27: Lateral view of ligamentous anatomy of craniocervical articulation


IN00-001
V#2 pre-impact skid marks
Approximated final rest positions based on the on-scene photographs
Approximated point of impact based on the on-scene photographs
V2
CV
N
SCALE 1cm = 2.5 m
Daylight, clear and dry, slight curve right for case vehicle, level bituminous surface
CV = 2000 Chevrolet Silverado K-1500
V2 = 1988 Chevrolet G20 conversion van