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## ON-SITE CERTIFIED ADVANCED 208-COMPLIANT VEHICLE INVESTIGATION

CASE NUMBER - IN-06-028

LOCATION - MICHIGAN

VEHICLE - 2006 JEEP GRAND CHEROKEE LAREDO

CRASH DATE - June 2006

Submitted:

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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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16. <i>Abstract</i> This report covers an on-site investigation of a an air bag deployment crash that involved a 2006 Jeep Grand Cherokee Laredo (case vehicle), which ran-off-road and impacted several objects on the roadside and an overpass bridge. This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System (AOPS) features and the case vehicle's driver (21-year-old, male) and front right passenger (28-year-old, male) sustained police reported "A" (incapacitating) injuries as a result of the crash. The case vehicle was traveling east in the outside eastbound lane of a multi-lane Interstate highway. The driver became drowsy and fell asleep. The case vehicle drifted to the right, crossed the shoulder and departed the road. The case vehicle impacted a clump of two small trees, an embankment and a bridge overpass structure. The front air bags most likely deployed when the case vehicle sustained the embankment impact. As a result, the driver and front right passenger were protected only by their three-point, lap-and-shoulder safety belt systems at the time of the severe impact with the overpass bridge structure. The driver and front right passenger were both transported by ambulance to a hospital and admitted. The front right passenger's injury potential was increased due to the loading of his seat back by the unrestrained back right passenger.					
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This investigation was brought to NHTSA's attention on or before August 16, 2006 by NASS GES sampling activities. This crash involved a 2006 Jeep Grand Cherokee Laredo (case vehicle), which ran-off-road and impacted two small trees, an embankment and an overpass bridge. The crash occurred June, 2006, at 12:10 p.m., in Michigan and was investigated by the Michigan State Police. This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System (AOPS) features and the case vehicle's driver [21-year-old, White (non-Hispanic) male] and front right passenger [28-year-old, White (non-Hispanic) male] sustained police reported "A" (incapacitating) injuries as a result of the crash. In addition, the manufacturer of the case vehicle has certified that it meets the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. This contractor inspected the case vehicle and scene and interviewed the case vehicle's front right passenger on 28-29, August 2006. The back right passenger was interviewed on October 30, 2006. This report is based on the police crash report, scene and vehicle inspections, front right passenger and back right passenger interviews, occupant medical records, occupant kinematic principles, and this contractor's evaluation of the evidence.

## SUMMARY

The case vehicle was traveling east in the outside eastbound lane of a multi-lane Interstate highway. The driver became drowsy and fell asleep. The case vehicle drifted to the right, crossed the shoulder and departed the road. The case vehicle's front center impacted a clump of two small trees (event 1). The case vehicle was then airborne across a marshy area and the lower front bumper and front undercarriage plowed into a small embankment on the far side of the marshy area (event 2) as the case vehicle touched down. This impact most likely deployed the driver's and front right passenger's air bags. The case vehicle continued through a field and up an embankment toward an Interstate overpass bridge. As the case vehicle reached the top of the embankment it vaulted and became airborne. The right front wheel impacted and sideswiped the corner of the overpass bridge abutment (event 3). The front of the case vehicle then immediately impacted the steel bridge deck support beam (event 4). Following the impact with the bridge deck support beam, the case vehicle dropped down to the ground and came to rest heading southeast. At the time of the crash the light condition was daylight, the atmospheric condition was cloudy, and the roadway pavement was dry.

The CDCs for the case vehicle were determined to be: **12-FC??-1 (0 degrees)** for the impact with the clump of two small trees (event 1), **12 FDLW-? (0 degrees)** for the embankment impact (event 2), **00-RFWS-1** for the right front wheel sideswipe impact to the bridge abutment (event 3), and **00-FDEW-3** for the front impact with the steel bridge deck support beam (event 4). The case vehicle sustained 72 centimeters (28.3 inches) of maximum residual crush to the front end. The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's highest Delta V for the impact with the steel bridge deck support beam because non-horizontal impacts are out-of-scope for the program. The crash severity for this impact was estimated to be high [greater than 40 km.p.h. (25 m.p.h.)]. The second highest severity impact was most likely the embankment impact (event 2). Its crash severity was estimated to be low [14-23 km.p.h (9-14 m.p.h.)]. The case vehicle was towed due to damage.

The case vehicle's driver was restrained by his manual, three-point, lap-and-shoulder safety belt system. The deployment of his air bag most likely occurred due to the embankment impact (event 2), which was of low severity, and he was protected only by his safety belt system at the time of the bridge deck support beam impact (event 4). As a result, he heavily loaded his restraint system during the bridge deck support beam impact and fractured his 2<sup>nd</sup> lumbar vertebrae due to loading his lap belt. As the safety belt energy management feature paid-out the safety belt, he impacted the steering wheel with his chest deforming the steering wheel. He spilled off the left side of the steering wheel and impacted his forehead on the left "A"-pillar and sustained a non-anatomic brain injury with loss of consciousness. The driver was transported by ambulance to a hospital and admitted for treatment of his injuries.

The case vehicle's front right passenger was seated in a slumped position and was restrained by his manual, three-point, lap-and-shoulder safety belt system. As with the driver, the deployment of his air bag most likely occurred due to the embankment impact, and he was protected only by his safety belt system at the time of the bridge deck support beam impact. He heavily loaded his restraint system during the bridge deck support beam impact and additionally was shoved forward due to the impact to his seat back by the unrestrained back right passenger. His left knee heavily loaded the knee bolster and his left foot impacted the toe pan fracturing and dislocating his left ankle. He also fractured his 11<sup>th</sup> and 12<sup>th</sup> thoracic vertebrae with resulting paraplegia as a result of the forward displacement of his seat back due to loading by the unrestrained back right passenger. The front right passenger was transported by ambulance to a hospital and admitted for treatment of his injuries.

The back right passenger was not restrained by his three-point, lap-and-shoulder safety belt system. The impact with the bridge deck support beam caused him to continue forward as the case vehicle decelerated and he loaded the front right passenger's seat back deforming the seat back forward and fracturing the back right passenger's right forearm and his left femur. The back right passenger most likely continued forward over the front right passenger's seat back and impacted his head on the windshield fracturing the windshield. The back right passenger's non-use of his safety belt system increased his injury potential and increased the injury potential of the front right passenger.

## **CRASH CIRCUMSTANCES**

***Crash Environment:*** The trafficway on which the case vehicle was traveling was an eight-lane, divided, Interstate highway traversing in an east-west direction. Each roadway had four travel lanes. Each travel lane was approximately 3.7 (12 feet) meters in width and was bordered by wide concrete shoulders. The trafficway was divided by a grass median. Roadway pavement markings consisted of solid white edge lines, broken white lane lines and a solid yellow median line. The speed limit was 113 km.p.h. (70 m.p.h.). At the time of the crash the light condition was daylight, the atmospheric condition was cloudy, and the roadway pavement was dry, level concrete with an estimated coefficient of friction of 0.70. The traffic density was unknown and the site of the crash was commercial. See the Crash Diagram at the end of this report.

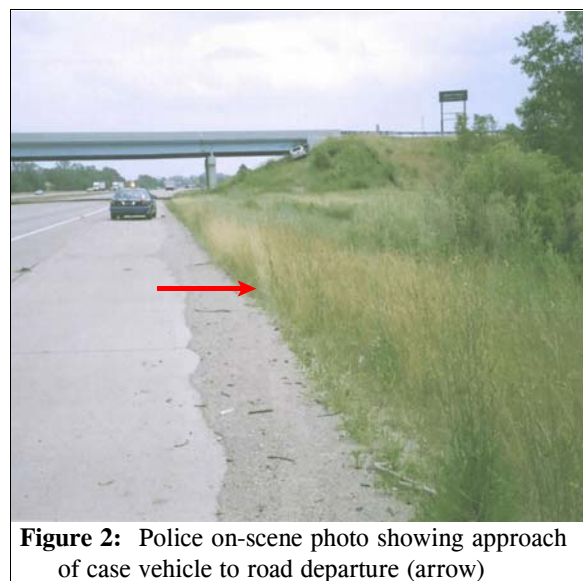
**Pre-Crash:** The case vehicle was traveling east in the outside eastbound lane (**Figure 1**). The driver was intending to continue eastbound. The driver became drowsy and fell asleep. The case vehicle drifted to the right, crossed the shoulder and departed the road (**Figure 2**). The scene evidence indicated the driver made no steering or braking avoidance actions prior to the crash. The police crash report indicated that the results of a blood alcohol test were negative. The driver's medical records indicated he tested positive for marijuana, cocaine and amphetamines. The crash occurred off the road on the south side of the Interstate.

**Crash:** The case vehicle departed the shoulder, traveled through the grass and the front center impacted a clump of two small trees [(event 1), **Figure 3** below] located approximately 5.5 meters (18 feet) off the road. The case vehicle was then airborne across a marshy area and the lower front bumper and front undercarriage plowed into a small embankment on the far side of the marshy area [(event 2), **Figure 4**, below] as the vehicle touched down. This impact most likely deployed the first stage of the driver's and front right passenger's multi-stage air bags. The case vehicle continued through a field and up an embankment toward an Interstate overpass bridge (**Figure 5** below). As the case vehicle reached the top of the embankment is vaulted and became airborne. The right front wheel (**Figure 6** below) impacted and sideswiped the corner of the overpass bridge abutment [(event 3), **Figure 7** below]. The front of the case vehicle (**Figure 8** below) then immediately impacted the steel bridge deck support beam [(event 4), **Figure 9** below]. The evidence indicates the case vehicle was rolled left approximately 15 degrees when it impacted the bridge deck support beam.

**Post-Crash:** Following the impact with the bridge deck support beam, the case vehicle dropped down to the ground and came to rest heading southeast (**Figure 10** below).



**Figure 1:** Police on-scene photo showing opposite approach of case vehicle from overpass bridge, arrows show case vehicle's tire marks



**Figure 2:** Police on-scene photo showing approach of case vehicle to road departure (arrow)



**Figure 3:** Police on-scene photo showing case vehicle approach to marshy area and impact with two small trees (red arrow), blue arrows show left and right side tire tracks in grass



**Figure 4:** Case vehicle's lower front bumper and undercarriage impacted embankment on east side or marshy area



**Figure 5:** Police on-scene photo showing approach of case vehicle up embankment to impact with overpass bridge



**Figure 6:** Arrows show damage to case vehicle's right front wheel from impact with overpass bridge abutment



**Figure 7:** Arrow shows right front wheel impact to overpass bridge abutment, measurement rod graduated in tenths of meter





**Figure 8:** Damage to front of case vehicle primarily from impact with steel bridge deck support beam



**Figure 9:** Police on-scene photo showing impact impression to steel bridge support beam



**Figure 10:** Police on-scene photo showing case vehicle's final rest position

### CASE VEHICLE

The 2006 Jeep Grand Cherokee Laredo was a four wheel drive, four-door, sport utility vehicle (VIN: 1J4GR48K66C-----). The manufacturer of this vehicle has certified that it meets the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The case vehicle was equipped with a 3.7L, V6 engine; five-speed automatic transmission; four wheel, anti-lock disc brakes; traction control and electronic stability control. The front seating row was equipped with bucket seats with adjustable

head restraints, multi-stage driver and front right passenger air bags; manual, three-point, lap-and-shoulder safety belts with adjustable upper anchors, usage sensors, pretensioners and energy management features. Furthermore, there was an occupant weight sensor for the front right passenger seating position. The back seating row was equipped with a split bench seat with adjustable head restraints; three-point, lap-and-shoulder safety belts and LATCH system features in the outboard seating positions. Side curtain and front seat back-mounted side impact air bags were an option, but the case vehicle was not so equipped. The case vehicle's specification wheelbase was 278 centimeters (109.4 inches). The case vehicle's odometer reading at the time of the inspection is not known because the case vehicle was equipped with an electronic odometer.

The various sensors in the case vehicle's advanced occupant restraint system analyze a combination of factors including the predicted crash severity and driver and front right passenger safety belt usage to determine the front air bag inflation level appropriate for the severity of the crash. For the front right seat position, an occupant weight sensor in the seat cushion determines if an occupant is on the seat and enables or suppresses deployment of the air bag based on the amount of weight on the seat.

**Exterior Damage:** The case vehicle’s impact with the two small trees most likely involved a small area in the center of the front left bumper. Due to the absence of the front bumper fascia and overlapping damage from the embankment and steel bridge deck support beam impacts, a direct damage length could not be determined. The case vehicle’s impact with the embankment most likely involved the lower portion of the front bumper and the front undercarriage. The direct damage most likely extended across the full width of the lower portion of the front bumper. Dirt and grass were jammed into the front cross member and front undercarriage components. The case vehicle’s right front wheel sideswipe to the bridge abutment scuffed the tire and heavily abraded and fractured the lip of the wheel rim. The front impact with the steel bridge deck support beam involved the entire front end. The front bumper, both headlamp/turn signal assemblies, the grille, hood and both fenders were directly damaged and crushed rearward. The direct damage began at the front left bumper corner and extended 137 centimeters (53.9 inches) across the front end. A crush profile was taken to document the totality of the front crush due to the embankment and steel bridge deck support beam impacts. The majority of the crush was related to the bridge deck support beam impact. The residual maximum crush was measured as 72 centimeters (28.4 inches) occurring at C<sub>1</sub> (**Figure 11**). The table below shows the case vehicle’s front crush profile.



**Figure 11:** Top view of crush to front of case vehicle, each increment on rods is 5 cm (2 in)

Units	Event	Direct Damage		Field L	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	2 & 4	137	72	137	72	63	60	50	46	40	0	0
in		53.9	28.3	53.9	28.3	24.8	23.6	19.7	18.1	15.7	0.0	0.0

The case vehicle’s right side wheelbase was reduced 12 centimeters (4.7 inches). Measurements determined the rather curious condition of the left side wheelbase being extended 9 centimeters (3.5 inches) due to the condition of the left front wheel. It is likely that the left front axle was broken. In addition, potential forward displacement of the left front wheel may have occurred when the case vehicle fell to the ground following the impact. The left front wheel was observed to be in the approximate same location in the police on-scene photographs as it was at the time of the inspection indicating it was jammed in that position during the crash. Induced damage involved the hood, both fenders, right side doors and the windshield was cracked. Lastly, there was some unrelated damage to the right corner of the back bumper. This damage was not present in the police on-scene photos.

The case vehicle’s recommended tire size was: P245/65R17, and the case vehicle was equipped with tires of this size. The case vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 <sup>nd</sup> of an inch			
LF	234	34	228	33	8	10	None	No	No
RF	228	33	228	33	9	11	Side wall abraded, rim abraded and broken	No	No
LR	234	34	228	33	9	11	None	No	No
RR	228	33	228	33	9	11	None	Yes	No

**Vehicle Interior:** Inspection of the case vehicle’s interior (Figures 12 and 13) revealed heavy deformation of the steering wheel and forward displacement of the energy absorbing steering column (Figure 14 below) due to driver loading. The driver’s “D” ring was heavily abraded due to loading from the driver’s shoulder belt, and the driver’s buckle-mounted pretensioner had actuated. The front right passenger’s knee bolster was heavily deformed due to loading by the front right passenger’s left knee. The front right passenger’s “D”-ring was also heavily abraded and his pretensioner had actuated. The front right passenger’s seat back was displaced forward (Figure 14 below), and there were skin transfers on the back of the seat back and scuffs on the right “B”-pillar due to contact by the back right passenger. In addition, the head restraint was knocked off the front right seat. The back of the center console was also cracked, possibly due to contact by the back right passenger’s left leg. Blood stains and a possible occupant contact scuff were found on the driver’s air bag. Blood stains and a probable cloth transfer were found on the front right passenger’s air bag. A “star burst” type fracture was noted to the right front windshield. No other occupant contacts were noted. Lastly, The windshield intruded into the driver’s occupant space approximately 5 centimeters (2 inches) due to hood contact, and the



Figure 12: Overview of case vehicle’s steering wheel, instrument panel and windshield



Figure 13: Overview of center and right instrument panel and the windshield

instrument panel intruded approximately 7 centimeters (2.8 inches). In addition, the brake pedal intruded 14 centimeters (5.5 inches) longitudinally and the front right seat back intruded forward approximately 15 centimeters (5.9 inches).

**Damage Classification:** Based on the vehicle and scene inspections, the CDCs for the case vehicle were determined to be: **12-FC??-1 (0 degrees)** for the impact with the clump of two small trees (event 1), **12 FDLW-? (0 degrees)** for the embankment impact (event 2), **00-RFWS-1** for the right front wheel sideswipe impact to the bridge abutment (event 3), and **00-FDEW-3** for the front impact with the steel bridge deck support beam (event 4). The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's highest Delta V for the impact with the steel bridge deck support beam because non-horizontal impacts are out-of-scope for the program. In addition, a crush profile could not be determined due to the front overlapping damage from the embankment impact. The crash severity for the front impact to the bridge deck support beam (event 4) was estimated to be high [greater than 40 km.p.h. (25 m.p.h.)]. The second highest severity impact was most likely the embankment impact (event 2). Its crash severity was estimated to be low [14-23 km.p.h (9-14 m.p.h.)]. The case vehicle was towed due to damage.



**Figure 14:** Left side view of damage to steering wheel and overview of forward displacement of front right seat back

#### AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with manufacturer certified advanced-208 compliant front air bags. Both the driver and front right passenger air bags deployed, most likely as a result of the case vehicle's front impact with the embankment (event 2).

The case vehicle's driver air bag was located in the steering wheel hub. The air bag module cover consisted of essentially "H"-configuration cover flaps (**Figure 15**). The upper cover flap was 15 centimeters (5.9 inches) in width and 8 centimeters (3.1 inches) in height. The lower cover flap was 14.5 centimeters (5.7 inches) in width and 4.5 centimeters (1.8 inches) in height. An inspection of the air bag module cover flaps and the air bag fabric revealed that the cover flaps opened at the designated tear points. 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 two tethers each 15



**Figure 15:** Case vehicle's driver air bag module cover flaps

centimeters (5.9 inches) in width and had two vent ports (Figure 16 below), each approximately 2.5 centimeters (1 inch) in diameter, located at the 11 and 1 o'clock positions. The deployed driver's air bag (Figure 17) was round with a diameter of approximately 59 centimeters (23.2 inches). The distance between the mid-center of the driver's seat back, as positioned as the time of the vehicle inspection (i.e., seat between middle and rear-most track position, seat back slightly reclined), and the front surface of the air bag's fabric at approximate full excursion was 38 centimeters (14.9 inches). Inspection of the driver's air bag revealed a few blood stains on the bottom central portion of the air bag and a possible occupant contact scuff on the bottom right portion of the air bag.

The front right passenger air bag was located in the top of the instrument panel. The air bag module cover (Figure 18) consisted of "H"-configuration cover flaps, although the lower flap was slightly trapezoidal-shaped. The upper cover flap was 21 centimeters (8.3 inches) in width and 5 centimeters (2 inches) in height. The lower flap was 21 centimeters (8.3 inches) in width, 5 centimeters (2 inches) in height on the left and 4 centimeters (1.6 inches) in height on the right. An inspection of the air bag module cover flaps revealed that the cover flaps opened at the designated tear points. There was no evidence of damage to the cover flaps or the air bag fabric. The deployed front right passenger's air bag (Figure 19 below) was approximately oval in shape. The deployed air bag was approximately 56 centimeters (22 inches) in height and approximately 60 centimeters in width (23.6 inches) at the center. The air bag was designed with 2 tethers, each 17 centimeters (6.7 inches) in width. There were two vent ports, one on each side of the air bag, at the approximate 3 and 9 o'clock positions. Each vent port was 5 centimeters (2 inches) in diameter. Inspection of the air bag fabric revealed some blood stains and probable cloth transfers on the lower left portion of the air bag.



Figure 16: Case vehicle driver's air bag vent ports (arrows)



Figure 17: Case vehicle driver's air bag



Figure 18: Case vehicle's front right passenger's air bag cover flaps

Immediately prior to the crash the case vehicle's driver [21-year-old, White (non-Hispanic) male; [183 centimeters and 77 kilograms (72 inches, 170 pounds)] was most likely seated in an approximate upright position. He had reportedly fallen asleep just prior to the crash. The position of his hands and arms is not known, although he most likely had at least one hand on the steering wheel. His right foot was most likely on the accelerator pedal and his left foot on the floor. The driver's seat track was positioned between the middle and rear-most track position and his seat back was slightly reclined. The tilt steering column was most likely adjusted to its middle position. It is not known if the driver was wearing glasses or contact lenses at the time of the crash.

Based on this contractor's vehicle inspection, the case vehicle's driver was restrained by his manual, three-point, lap-and-shoulder safety belt system. Heavy load abrasions were found on the "D"-ring (**Figure 20**) and there were abrasions on the shoulder belt. In addition, the safety belt system was equipped with a buckle-mounted pretensioner (**Figure 21** below) and energy management feature, which actuated during the crash. Measurements from an exemplar vehicle indicated that the driver's pretensioner piston moved approximately 5 centimeters (2 inches) during the crash.

After the case vehicle departed the road, the driver most likely woke up and braced against the steering wheel just prior to the case vehicle impacting the clump of two small trees and traveling across the marshy area. The case vehicle's front impact with the embankment as it exited the marshy area most likely caused the driver to move down into his seat and continue forward along a path opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated. The driver's pretensioner most likely actuated, he loaded his safety belt and his face and upper chest contacted his deployed air bag causing lacerations to his left eye lid, lip and chin. The driver rebounded back into his seat and the case vehicle continued through the field and up an embankment approaching the overpass bridge. The driver was most likely positioned upright in his seat as the case vehicle vaulted at the top of the embankment. The driver continued forward loading his safety belt system as the right



Figure 19: Front right passenger air bag



Figure 20: Load marks on case vehicle driver's "D" ring and shoulder belt

front tire sideswiped the bridge abutment and the case vehicle decelerated. The immediate impact with the steel bridge deck support beam then caused the driver to continue forward as the case vehicle decelerated violently and he heavily loaded his safety belt and the lap portion of the safety belt caused fractures to his 2<sup>nd</sup> lumbar vertebra. The driver continued to move forward and ride down the crash as his safety belt’s energy management feature paid-out the safety belt. He moved forward to the extent that his chest impacted the now deflated air bag and the steering wheel deforming the steering wheel. The driver spilled off the left side of the steering wheel and his forehead impacted the left “A”-pillar causing a contusion to his right eyebrow and a non-anatomic brain injury with loss of consciousness. He rebounded back into his seat as the case vehicle fell to the ground and impacted his left ear on the left “B”-pillar lacerating his ear. His back also loaded the seat back causing a contusion to his lower back. He remained restrained in his seat and exited the vehicle under his own power following the crash.



**Figure 21:** Driver’s buckle-mounted pretensioner actuated compressing the buckle stalk cover

**CASE VEHICLE DRIVER INJURIES**

The police crash report indicated that the driver sustained an “A” (incapacitating) injury and was transported by ambulance to a hospital. He was hospitalized for nine days for treatment of his injuries. The driver had not returned to work as of the date of the interview (i.e., August 28, 2006). The driver’s medical records indicated that he tested positive for marijuana, cocaine and amphetamines. The table below shows the case vehicle driver’s injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with loss of consciousness, amnesia for events, with agitation, confusion, disorientation, combativeness, GCS = 13; no signs of cognitive deficit	moderate 160606.2,0	Left “A”-pillar	Probable	Hospitalization records

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
2	Fracture-compression, wedge, Chance <sup>1</sup> , including superior and inferior (primarily) anterior end-plates of L <sub>2</sub> , with retro-pulsion of posterior bony portion into anterior epidural space (spinal canal); no spinal cord lesion; spinal fusion L <sub>1</sub> to L <sub>3</sub> performed	serious 650634.3,8	Lap portion of safety belt system	Certain	Hospitalization records
3	Fracture L <sub>2</sub> pedicles-right and left	serious 650626.3,8	Lap portion of safety belt system	Certain	Hospitalization records
4	Fracture L <sub>2</sub> lamina-right and left	serious 650624.3,8	Lap portion of safety belt system	Certain	Hospitalization records
5	Fracture L <sub>2</sub> left transverse process	moderate 650620.2,8	Lap portion of safety belt system	Probable	Hospitalization records
6	Laceration posterior left ear, through cartilage	minor 290602.1,2	Left "B"-pillar	Probable	Hospitalization records
7	Contusion {hematoma} right eyebrow, not further specified	minor 290402.1,7	Left "A"-pillar	Probable	Emergency room records
8	Laceration left eyelid, not further specified	minor 297602.1,2	Air bag, driver's	Probable	Hospitalization records
9	Laceration lip, not further specified	minor 290602.1,8	Air bag, driver's	Probable	Emergency room records
10	Laceration, narrow, small, superficial, chin	minor 290602.1,8	Air bag, driver's	Probable	Emergency room records
11	Contusion {hematoma} left anterior chest wall	minor 490402.1,2	Torso portion of safety belt system	Probable	Emergency room records
12	Contusion {hematoma} lower thoracic back	minor 690402.1,4	Seat back, driver's	Probable	Emergency room records
13	Abrasions pelvis, bilaterally (abdomen, inferior)	minor 590202.1,8	Lap portion of safety belt system	Certain	Emergency room records
14	Abrasion over right tibial tuberosity	minor 890202.1,1	Knee bolster, driver's, right of steering column	Certain	Emergency room records

<sup>1</sup> The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

**fracture (frak'cher):** 1. the breaking of a part, especially a bone. 2. a break or rupture in a bone.

**Chance f.:** horizontal splitting of the neural arch and body of a vertebra, usually in the lumbar region, caused by a flexion-distraction force; called also *seat belt f.*



Immediately prior to the crash, the case vehicle's front right passenger [28-year-old, White (non-Hispanic) male; [178 centimeters and 77 kilograms (70 inches, 170 pounds)] was slumped down in his seat with his knees on the knee bolster. He was asleep. The position of his hands and arms is not known. The front right passenger's seat was positioned between the middle and forward track position and his seat back was slightly reclined. The passenger was not wearing glasses or contact lenses at the time of the crash.

Based on this contractor's vehicle inspection, the case vehicle's front right passenger was restrained by his manual, three-point, lap-and-shoulder safety belt system. Heavy load abrasions were found on the "D"-ring, there were abrasions on the shoulder belt and the shoulder belt was bunched-up in the forward corner of the "D"-ring (**Figure 22**). In addition, the safety belt system was equipped with a buckle-mounted pretensioner and energy management feature, which actuated during the crash. Measurements from an exemplar vehicle indicated that the front right passenger's pretensioner piston moved approximately 2 centimeters (0.8 inch) during the crash.



**Figure 22:** Front right passenger's shoulder belt jammed in front corner of "D"-ring and load marks on "D" ring

After the case vehicle departed the road, the front right passenger most likely woke up and braced his knees against the instrument panel just prior to the case vehicle impacting the clump of two small trees and traveling airborne across the marshy area. The case vehicle's front impact with the embankment as it exited the marshy area most likely caused the front right passenger to move down into his seat and continue forward along a path opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated. The passenger's pretensioner most likely activated, he loaded his safety belt, his knees loaded the knee bolster and his face and upper chest contacted his deployed air bag causing an abrasion to his left cheek and neck. The passenger rebounded back into his seat and the case vehicle continued through the field and up an embankment approaching the overpass bridge. The passenger most likely remained slumped down in his seat as the case vehicle vaulted at the top of the embankment. The passenger continued forward loading his safety belt system as the right front wheel sideswiped the bridge abutment and the case vehicle decelerated. The immediate impact with the steel bridge deck support beam caused the passenger to continue forward as the case vehicle decelerated violently. At the same time, the passenger's seat back was loaded from behind by the unrestrained back right passenger, which also pushed the front right passenger forward. His left knee loaded the knee bolster (**Figure 23** below) and his left foot loaded the toe pan fracturing and dislocating his left ankle, and he heavily loaded his safety belt. He also sustained fractures to his 11<sup>th</sup> and 12<sup>th</sup> thoracic vertebrae with resulting paraplegia. This was likely due to his slumped seating position as his left knee loaded the knee bolster and his seat back was loaded by the unrestrained back right passenger and displaced forward. As the passenger moved forward, the safety belt energy management feature

paid-out the safety belt. Abrasions on the safety belt indicated that it paid-out of the retractor approximately 61 centimeters (24 inches). A “star burst” fracture was observed on the windshield (Figure 24), which was likely caused by contact from the back right passenger, who likely traveled over the driver’s seat back and impacted the windshield during the impact with the bridge deck support beam. The front right passenger remained in his seat as the case vehicle came to final rest. The front right passenger’s medical records indicated he opened his door and rolled out of the vehicle following the crash.



Figure 23: Dent in passenger knee bolster from impact by front right passenger’s left knee

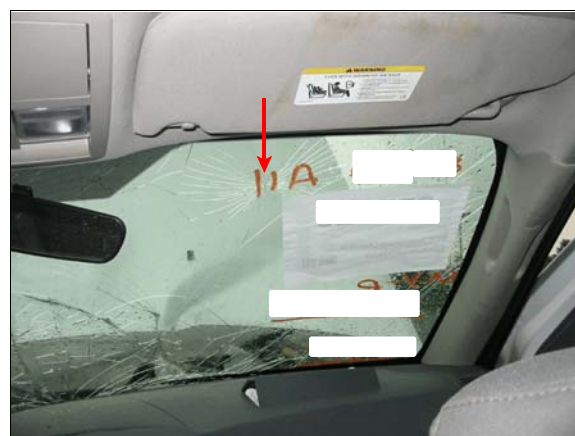


Figure 24: Arrow shows “star burst” fracture in right windshield

**CASE VEHICLE FRONT RIGHT PASSENGER INJURIES**

The police crash report indicated that the front right passenger sustained an “A” (incapacitating) injury and was transported by ambulance to a hospital. He was hospitalized for 23 days and was then transferred to a rehabilitation facility. He was still in a rehabilitation program at the time of his interview. The front right passenger’s medical records indicated that he tested positive for cocaine. The front right passenger lost his job as a result of the crash. The table below shows the front right passenger’s injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Fracture, compression {burst}, comminuted, body T <sub>12</sub> with dislocation {jumped} of T <sub>11</sub> -T <sub>12</sub> facets and spinal cord impingement, complete cord syndrome, and paraplegia; spinal fusion T <sub>9</sub> to L <sub>2</sub>	severe 640428.5,7	Seat back, front right passenger’s <sup>2</sup>	Probable	Hospitalization records

<sup>2</sup> Unrestrained back right passenger loaded the back of the front right seat back, jamming the seat back forward and, in this contractor’s opinion, into the back of the front right passenger.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
2	Fracture right T <sub>12</sub> facet	serious 650422.3,7	Seat back, front right passenger's	Probable	Hospitalization records
3	Fracture right T <sub>12</sub> lamina	serious 650424.3,7	Seat back, front right passenger's	Probable	Hospitalization records
4	Fracture right T <sub>12</sub> pedicle	serious 650426.3,7	Seat back, front right passenger's	Probable	Hospitalization records
5	Fracture inferior posterior endplate and body of T <sub>11</sub>	moderate 650430.2,7	Seat back, front right passenger's	Probable	Hospitalization records
6	Contusion right anterior lung, not further specified	serious 441406.3,1	Torso portion of safety belt system <sup>3</sup>	Certain	Hospitalization records
	Contusion {hematoma} mesentery, probable {likely} and a pelvic hematoma, without active bleeding, of unknown etiology	not coded			Hospitalization records
7	Fracture, closed, displaced, left talar neck {Hawkins type III <sup>4</sup> }	moderate 853200.2,2	Floor, including toe pan	Certain	Hospitalization records
8	Dislocation left ankle {pantalar}	moderate 850210.2,2	Floor, including toe pan	Certain	Hospitalization records
9	Abrasion left cheek, not further specified	minor 290202.1,2	Air bag, front right passenger's	Probable	Emergency room records
10	Abrasion anterior neck, not further specified	minor 390202.1,5	Air bag, front right passenger's	Probable	Emergency room records
11	Abrasion {seat belt sign} chest {across}, not further specified	minor 490202.1,1	Torso portion of safety belt system	Certain	Hospitalization records

<sup>3</sup> According to this occupant's medical records, he indicated that he had been sleeping prior to the crash, and he stated that he had loosen his shoulder harness "so I could breath."

<sup>4</sup> Hawkins class III fracture is a displaced fracture extending through the talar neck with dislocation at both the subtalar and tibiotalar joints. Undisplaced fractures are associated with a high proportion of good results. Type II fractures, where there has been subluxation of the subtalar joint, require accurate reduction to avoid subtalar joint incongruity, and have a 20% incidence of avascular necrosis. Type III fractures, with dislocation of the body of the talus, have a poor prognosis and have a 100% incidence of avascular necrosis. Hawkins' sign of subcortical radiolucency is helpful in ascertaining the presence or absence of avascular necrosis. Accurate open reduction and rigid internal fixation with early range of motion of the involved joints is recommended where a closed reduction has failed to provide anatomic reduction.

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

**sign (sn)** [L. **signum**]: an indication of the existence of something; any objective evidence of a disease [i.e., such evidence as is perceptible to the examining physician, as opposed to the subjective sensations (symptoms) of the patient].

**Hawkins sign**: in fractures of the talar neck, a radiolucent zone beneath the subchondral plate of the head of the talus, indicative of disuse osteoporosis; its absence reflects increased risk of talar avascular necrosis.

**avascular (a-vas'ku-lr)**: not supplied with blood vessels.

**necrosis (na-kro'sis)** pl. **necro'ses**: the sum of the morphological changes indicative of cell death and caused by the progressive degradative action of enzymes; it may affect groups of cells or part of a structure or an organ.

**avascular necrosis of bone**: *osteonecrosis*.

**osteonecrosis (oste-o-na-kro'sis)**: necrosis of bone due to obstruction of its blood supply. Called also *avascular n.* or *ischemic necrosis of bone*.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
12	Abrasion lower abdomen (i.e., seat belt sign across abdomen}	minor 590202.1,8	Lap portion of safety belt system	Certain	Hospitalization records
13	Contusion {hematoma} overlying T <sub>12</sub> and/or lumbosacral spine	minor 690402.1,8	Seat back, front right passenger's	Probable	Emergency room records
14	Abrasions right shin and ankle, not further specified	minor 890202.1,1	Knee bolster	Certain	Emergency room records

### CASE VEHICLE BACK RIGHT PASSENGER KINEMATICS

Immediately prior to the crash, the case vehicle's back right passenger [27-year-old, White (non-Hispanic) male; [188 centimeters and 91 kilograms (74 inches, 200 pounds)] was seated in an upright position. His seat track and seat back were not adjustable.

Based on the vehicle inspection, the back right passenger was not restrained by his three-point, lap-and-shoulder safety belt. Inspection of the safety belt assembly revealed no evidence of loading. In addition, the front right seat back was displaced forward due to loading by this passenger indicating he was not restrained in this crash.

After the case vehicle departed the road, the back right passenger may have braced against the back of the front right passenger's seat just prior to the case vehicle impacting the clump of two small trees and traveling airborne across the marshy area. The case vehicle's front impact with the embankment as it exited the marshy area caused the back right passenger to continue forward along a path opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated and he loaded into the front right passenger's seat back. The passenger most likely rebounded off the front right passenger's seat back, and the case vehicle continued through the field and up an embankment approaching the overpass bridge. The passenger continued forward and may have contacted the front right passenger's seat back as the right front tire sideswiped the bridge abutment and the case vehicle decelerated. The immediate impact with the steel bridge deck support beam caused the passenger to continue forward as the case vehicle



**Figure 25:** Contact marks on back of front right seat back from impact by back right passenger

decelerated violently. The passenger heavily loaded the front right passenger’s seat back deforming the seat back and displacing it forward (**Figure 25** above). The contact to the front right seat back fractured the back right passenger’s right forearm and fractured the neck of his left femur. The back right passenger likely continued over the top of the front right passenger’s seat and impacted and fractured the windshield (**Figure 24** above). The passenger most likely rebounded into the back seat following the bridge support beam impact. The back right passenger was removed from the case vehicle by emergency medical personnel.

**CASE VEHICLE BACK RIGHT PASSENGER INJURIES**

The police crash report indicated that the back right passenger sustained an “A” (incapacitating) injury and was transported by ambulance to a hospital. He was hospitalized for approximately ten days. The back right passenger had not returned to work as of August 28, 2006. The table below shows the back right passenger’s interviewee reported injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Fracture right radius, not further specified	moderate 752800.2,1	Seat back, front right passenger’s	Certain	Interviewee (same person)
2	Fracture right ulna, not further specified	moderate 753200.2,1	Seat back, front right passenger’s	Certain	Interviewee (same person)
3	Fracture neck left femur, not further specified	serious 851812.3,2	Seat back, front right passenger’s	Certain	Interviewee (same person)

