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ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN-04-013

LOCATION - Nebraska

VEHICLE - 2002 VOLKSWAGEN PASSAT GLX

CRASH DATE - April 2004

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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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15. <i>Supplementary Notes</i> On-site side air bag investigation involving a 2002 Volkswagen Passat with manual safety belts, dual front air bags, side impact air bags and side curtain air bags.					
16. <i>Abstract</i> This report covers an on-site investigation of an air bag deployment crash that involved a 2002 Volkswagen Passat (case vehicle), which ran-off-road and rolled over ejecting the driver. This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System (AOPS) features, including redesigned front air bags, front seat back-mounted side impact air bags and side curtain air bags, and the case vehicles' driver (37 year-old, female) was ejected from the vehicle and sustained fatal injuries. The case vehicle was traveling north on a two-lane, gravel county roadway. For an unknown reason, the driver lost control of the case vehicle and it began to rotate clockwise. The case vehicle departed the east side of the roadway in a clockwise yaw and the lower front bumper, left front wheel and front undercarriage impacted a ditch causing the case vehicle's driver and front right passenger air bags to deploy. In addition, this impact produced sufficient lateral deceleration to cause the driver's seat back-mounted side impact air bag and left side curtain air bag to also deploy. The case vehicle then ramped up the back slope of the ditch (which became an embankment), tripped, became airborne and rolled over, driver side leading. During the rollover, the driver was ejected through the open sunroof. The case vehicle rolled over at least three full rolls (12 quarter rolls). The case vehicle came to rest on its wheels facing southeast with the back of the vehicle on the roadway. Just prior to the crash the case vehicle's driver was seated in an unknown posture. She likely had both hands on the steering wheel. Her seat track was located between its middle and forward-most position, and the tilt steering wheel was located between its full up and center positions. The position of the driver's seat back is not known. The driver was not restrained by her manual, lap-and-shoulder, safety belt system. It is not known what actions the driver may have taken to avoid the crash. During the initial ditch impact, the driver sustained multiple contusions and abrasions to her face from contact with her deployed side curtain air. She also sustained a nonanatomic brain injury, thoracic cavity injury and liver laceration as well as numerous other injuries during the rollover as she was ejected through the open sunroof and impacted the ground, and was possibly rolled upon by the case vehicle. The driver's non-use of her safety belt system resulted in her ejection from the case vehicle and the fatal injuries she sustained during the rollover. The driver was transported by helicopter to a hospital where she was pronounced dead. The result of the driver's blood alcohol test was 0.237.					
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This investigation was brought to NHTSA's attention on May 13, 2004 by a NASS researcher. This crash involved a 2002 Volkswagen Passat GLX (case vehicle), which ran-off-road and rolled over. The crash occurred in April 2004 in Nebraska and was investigated by the county sheriff department. The time of the crash is not known, but the police were notified of the crash at 8:20 p.m. This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System (AOPS) features, including redesigned front air bags, front seat back-mounted side impact air bags and side curtain air bags, and the case vehicle's driver [37-year-old, White (non-Hispanic) female] was ejected from the vehicle and sustained fatal injuries. This contractor inspected the scene and vehicle on May 19, 2004. This report is based on the police crash report, police incident report, e-mail correspondence with two of the on-scene police investigators, scene and vehicle inspections, occupant kinematic principles, emergency room records, autopsy report and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling north on a two-lane, gravel county roadway. For an unknown reason, the driver lost control of the case vehicle and it began to rotated clockwise. The case vehicle departed the east side of the roadway in a clockwise yaw and the lower front bumper, left front wheel and front undercarriage impacted a ditch causing the case vehicle's driver and front right passenger air bags to deploy. In addition, this impact produced sufficient lateral deceleration to cause the driver's seat back-mounted side impact air bag and left side curtain air bag to also deploy. The case vehicle then ramped up the back slope of the ditch, which became an embankment, tripped, became airborne and rolled over, driver side leading. During the rollover, the driver was ejected through the open sunroof. The case vehicle rolled over at least three full rolls (12 quarter rolls). The total airborne and rollover distance was approximately 51 meters (167 feet). The case vehicle came to rest on its wheels facing southeast with the back of the vehicle on the roadway.

The CDCs for the case vehicle were determined to be **10-FDLW 1 (310 degrees)** for the front bumper damage and **10-FLWN-3 (310 degrees)** for the left front wheel damage. The CDC for the rollover was determined to be **00-TDDO-3**.

The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's impacts because rollover events are out-of- scope for the program and the swiping type nature of the impact to the lower front bumper and undercarriage violates the WinSMASH program's common velocity assumption. Based on the crush to the case vehicle's roof, the rollover crash severity was determined to be moderate. A separate speed reconstruction analysis was performed and indicated the minimum speed of the case vehicle as it became airborne and initiated its driver side leading rollover was approximately 56 km.p.h. (35 m.p.h). In addition, the case vehicle's minimum speed was approximately 77 km.p.h. (48 m.p.h) at the beginning of the first visible tire marks in the gravel (i.e., identified by police).

Just prior to the crash the case vehicle's driver was seated in an unknown posture. It is likely that both of her hands were on the steering wheel. The position of her feet is not known. Her seat track was located between its middle and forward-most position, and the tilt steering wheel was located between its full up and center positions. The position of the driver's seat back is not known.

It was found deformed rearward about 40 degrees. The driver was not restrained by her manual, lap-and-shoulder, safety belt system.

It is not known specifically what pre-crash avoidance actions the case vehicle's driver may have taken. The tire mark evidence on the roadway documented by the police indicates that the case vehicle was in a clockwise yaw prior to leaving the roadway. As a result of the clockwise yaw, the case vehicle's driver was most likely leaned to the left as the case vehicle departed the roadway. The impact of the lower front bumper and left front wheel with the ditch caused the unrestrained driver to move forward and to the left along a path opposite the case vehicle's 310 degree direction of principal force as the case vehicle decelerated. The left side of the driver's face contacted the deployed left side curtain air bag causing a contusion and laceration to the driver's left eyelids, contusions to the left side of her face, jaw, chin and neck and a contusion to her right eyelids. The driver's left arm, chest and abdomen contacted her deployed seat back-mounted side impact air bag scuffing the air bag and causing abrasions to her left upper arm, left chest and abdomen. The driver's left upper forearm, left hand, and left thigh also impacted the driver's door causing a contusion on her forearm, hand and thigh. The driver likely continued to move to the left and toward the roof as the case vehicle became airborne and rolled over, driver side leading. During the course of the rollover she moved rearward during a hard ground impact to the back of the case vehicle when it landed on its back end completing one roll, and she deformed her seat back rearward. She was then ejected from the case vehicle through the open sunroof as the case vehicle landed on the top of the right fender, hood, and roof as it completed one-and-one-half rolls. She impacted her head on the ground causing a nonanatomic brain injury, multiple lacerations and abrasions to her head and face, contusions to her right lower forearm, hand and wrist, and a dislocated right wrist. In addition, she sustained a laceration to her abdomen and contusions to her right and left thigh on the edge of the sunroof during the ejection. The driver's abdomen may also have been pressed between the roof of the case vehicle and the ground as she was being ejected causing a laceration to her liver. The driver's non-use of her safety belt system resulted in her ejection from the case vehicle and the fatal injuries she sustained during the rollover. The result of the driver's blood alcohol test was 0.273.

The police incident report indicated the driver was transported from the scene by ambulance to a local fire department where she was transferred to a helicopter and transported to a hospital. The emergency room record indicated the driver was pronounced dead 83 minutes after the crash.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the case vehicle was traveling was a two-lane, undivided, county roadway, traversing in a north-south direction. The roadway was 6.1 meters (20 feet) wide. The roadway surface was composed of hard-packed gravel with narrow gravel and grass shoulders. The roadway had no pavement markings. Each side of the roadway was bordered by a ditch. The back slope of the east ditch was part of a positive sloped embankment that bordered a farm field. There was no posted speed limit on the trafficway, but the police incident report indicated that the speed limit was 80 km.p.h. (50 m.p.h.). At the time of the crash the light condition was dusk, the atmospheric condition was clear and the roadway surface was dry with an estimated coefficient of friction of 0.70. In addition, the roadway had a negative 7.6% grade in the area where the case vehicle departed the roadway. Traffic density was light and the site of the crash was rural

agricultural. See the two Crash Diagrams at the end of this report.

Pre-Crash: The case vehicle was traveling north; however, it is not known if the case vehicle was traveling in the northbound lane. The driver lost control of the case vehicle for an unknown reason, and it was in a clockwise yaw prior to departing the roadway. The location of the control loss is not known; however, the police documented about 18 meters (59 feet) of the case vehicle's yaw path prior to the roadway departure. The police documentation of the tire marks indicated the case vehicle was yawed clockwise about 47 degrees at the beginning of the documented tire marks. The case vehicle continued to rotate and was yawed about 57 degrees clockwise as it departed the east side of the roadway and traveled an additional 5 meters (16.4 feet) to the first impact (**Figure 1**).

Crash: The case vehicle departed the east side of the roadway in a clockwise yaw and entered a ditch. The lower portion of the case vehicle's front bumper, the left front wheel and the front undercarriage impacted the ditch and the back slope of the ditch in a swiping type motion. The impact was severe enough to tear off the lower front bumper fascia and components of the front undercarriage (**Figure 2**), displace the left front wheel (**Figure 3**) rearward approximately 4 centimeters (1.6 inches), and crush the left corner of the front bumper bar approximately 3 centimeters (1.2 inches). There were no other impacts through the front plane of the case vehicle; therefore, it appears the impact with the ditch was severe enough to cause the case vehicle's driver and front right passenger air bags to deploy. It also appears that the lateral component of the deceleration was sufficient enough to deploy the driver's seat back-mounted side impact air bag and the left side curtain air bag. The bases for this conclusion are twofold: (1) there was an occupant contact on the upper front portion of the left side curtain air bag that contained a scuff of makeup and a few eye lashes, and (2) the reconstruction of



Figure 1: Police on-scene photo showing case vehicle's approach to roadway departure and final rest position; arrows show final rest and area of ditch impact and location where case vehicle became airborne (bare strip in grass to right of arrow in foreground is not crash related)



Figure 2: Police on-scene photo showing close view of ditch impact area; Note: components are case vehicle's lower front bumper fascia (arrow) and an unidentified undercarriage component



Figure 3: Damage and rearward displacement of case vehicle's left front wheel

the rollover event indicated the driver had been ejected from the vehicle before any other impacts occurred to the left side of the vehicle.

As the case vehicle was impacting the ditch it continued to yaw clockwise and ramped up the back slope of the ditch, which became an embankment. The case vehicle then tripped, became airborne, and rolled over with the driver side leading. It is likely the rollover was initiated at this point because the extent of the yaw would cause the case vehicle's left side suspension to load heavily and the left side wheels to dig-in, tilting the vehicle over to its left and trip it as it became airborne. Dirt and grass were jammed in the left front wheel (**Figure 3** above) and left rear wheel (**Figure 4**), indicating the wheels dug into the ground. In addition, no wheel ground divots were found along the case vehicle's rollover path by this contractor or indicated on the police crash schematic. The case vehicle was airborne for approximately 23.5 meters (77.1 feet) and had rolled between three and four quarter turns when it sustained a second ground impact on the back right corner of the vehicle as it completed its airborne trajectory. This impact created a large divot in the ground (**Figure 5**), crushed the back of the case vehicle (**Figure 6**), and broke the backlight creating a deposit of tempered glass fragments on the ground north of the divot. Further indications the vehicle was airborne between the ditch impact and the large ground divot were the lack of ground contacts and tempered glass deposits observed between these two points during this contractor's crash site inspection. In addition, the police officer who documented the crash site evidence reported to this contractor that he observed no major ground contacts between these two points.



Figure 4: Police on-scene photo of the case vehicle at final rest showing dirt and grass jammed in rim and bead of left rear wheel



Figure 5: Back of case vehicle impacted ground here

The impact to the back of case vehicle crushed primarily the right portion of the back bumper and trunk, shoved the right rear wheel forward, and vertically displaced the right portion of the trunk (**Figure 7** below). The damage indicates the force of the impact was non-horizontal coming from under the vehicle. This indicates the front of the case vehicle was off the ground and angled up to some degree when the impact occurred. Given the location and appearance of the direct damage to the back right



Figure 6: Damage to the back of the case vehicle

portion of the vehicle, it appears the vehicle had completed a little more than seven eighths of one roll at this point. The combination of this impact, the clockwise rotational motion of the case vehicle and the slope of the embankment resulted in a pirouetting motion of the case vehicle on its back end that redirected it to the northwest back toward the roadway. It appears the case vehicle then rolled over onto the top of its right fender and then onto the hood and windshield (**Figure 8**) as it completed a total of one-and-one-half rolls. It appears likely that the driver was ejected out of the open sun roof during this portion of the roll sequence and her injuries indicate the case vehicle may have rolled on her to some degree. Her final rest position (based on the police measurements) was about 6 meters (19.7 feet) northwest of the point where the back of the vehicle hit the ground at the end of the first complete roll, and she was oriented along the path the vehicle took to final rest.

The case vehicle continued to rollover with its driver side leading and traveled approximately 27 meters (88.6 feet) from the second ground impact point (i.e., location where the back end hit the ground) to its final rest location. During this final sequence of the rollover, the case vehicle sustained at least a third and likely a fourth ground impact occurring along the right roof side rail and right side windows (**Figure 9**). It is likely one of these impacts deployed the front right seat back-mounted side impact air bag and the right side curtain air bag. The impacts to the right roof side rail deposited grass, dirt, and a few pieces of gravel in the upper door seam, indicating the roof side rail contacted the ground on the embankment and again as the case vehicle reentered the roadway. A police on-scene photograph shows a longitudinal impression in the gravel roadway (**Figure 8**) just prior to the case vehicle's final rest position. The proximity of this divot to the case vehicle's final rest position and the gravel in the roof door seam are consistent with contact by the right roof side rail during the last quarter roll prior to the case vehicle coming to final rest on its wheels. The evidence indicates that the case vehicle completed at least three full rolls (12 quarter rolls) during the rollover sequence of this crash.



Figure 7: Damage to the back of case vehicle and right rear wheel



Figure 8: Police on-scene photo showing final rest position of case vehicle and damage to right fender and hood, arrow shows mark in gravel where right roof side rail impacted



Figure 9: Top view of the rollover damage to right roof side rail

Post-Crash: The case vehicle came to final rest on its wheels facing southeast with the back of the case vehicle on the roadway (**Figure 8** above). The case vehicle’s total airborne and rollover distance was approximately 51 meters (167 feet).

CASE VEHICLE

The 2002 Volkswagen Passat GLX was a front wheel drive, four-door sedan (VIN: WVWRH63B42P-----) equipped a 2.8L, V6 engine, a five-speed automatic transmission and electronic traction control. Braking was achieved by power-assisted, four wheel anti-lock brakes. The front seating row was equipped with bucket seats with adjustable head restraints; manual, three-point, lap-and-shoulder safety belt systems with height adjustable D-rings; seat back-mounted side impact air bags, redesigned driver and front right passenger air bags and side curtain air bags. The back bench seat was equipped with adjustable head restraints and manual, three-point, lap-and-shoulder safety belts systems in all three seating positions. In addition, the case vehicle was equipped with safety belt buckle switch sensors and safety belt pretensioners with load limiters in all outboard seat positions. The case vehicle’s wheelbase was 270 centimeters (106.3 inches) and the odometer reading at the time of the inspections was 60,049 kilometers (37,314 miles).

CASE VEHICLE DAMAGE

Exterior Damage: The direct damage to the case vehicle’s front bumper fascia began at the left corner of the bumper and extended across the full width of the lower front bumper fascia. Both the upper and lower bumper fascia were torn off the vehicle during the crash, so the crush measurements were taken at the front bumper bar. The residual maximum crush occurred at C₁ and was measured as 3 centimeters (1.2 inches). The crash caused direct damage to the case vehicle’s front bumper, hood, windshield, roof, left front door, both right side doors, the trunk lid, right quarter panel, back bumper and the left front and left rear wheels. The table below shows the bumper bar crush.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	129	3	129	3	0	0	0	0	0	0	0
in		50.8	1.2	50.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The case vehicle’s wheelbase was reduced 4 centimeters (1.6 inches) on the left side and 9 centimeters (3.5 inches) on the right side. Induced damage involved both fenders, the roof, left front door, both right side doors, both quarter panels, the trunk lid and the back bumper. In addition, the right front, right rear, and left front windows and the backlight were broken out during the crash.

The recommended tire size was: P205/55R16 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 nd of an inch			
LF	0	0	193	28	4	5	Bead separation	No	Yes
RF	234	34	193	28	5	6	None	No	No
LR	0	0	193	28	4	5	Bead separation	No	Yes
RR	172	25	193	28	4	5	None	Yes	No

Vehicle Interior: Inspection of the case vehicle’s interior revealed an occupant contact to the left, side curtain air bag on the forward, upper portion of the bag, a possible occupant contact on the driver’s seat back-mounted side impact air bag, and the driver’s door was bowed outward (**Figure 10**). The contact on the side curtain air bag consisted of a scuff of eye makeup and two eye lash hairs (**Figure 11**). In addition, the driver’s seat back was found deformed rearward about 40 degrees and was jammed in that position. It appeared the seat back was loaded by the driver when the vehicle sustained the ground impact to the back right corner of the case vehicle. No other areas of occupant contact were observed. The case vehicle also sustained numerous passenger compartment intrusions. Several of the most severe intrusions involved the roof, the right roof side rail, and right “B” and “C” pillars. It was determined the right roof side rail intruded laterally 12 centimeters (4.7 inches) and vertically 6 centimeters (2.4 inches) into the front right and back right seat positions. The roof intruded 12 centimeters (4.7 inches) into the front right seat position and 10 centimeters (4 inches) into the back right seat position. The right “B”-pillar intruded laterally 7 centimeters (2.8 inches) into the front right seat position and the right “C”-pillar intruded laterally 12 centimeters (4.7) into the back right seat position. Finally, there was no evidence of compression of the energy absorbing steering column, and no deformation of the steering wheel rim was observed (**Figure 12** below).



Figure 10: Case vehicle’s driver door is bowed outward from occupant loading

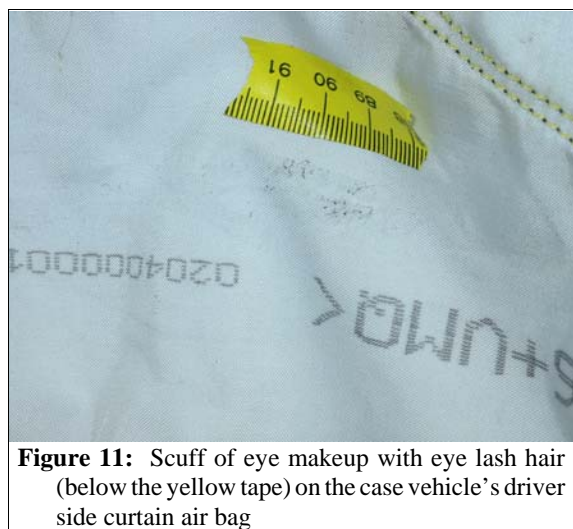


Figure 11: Scuff of eye makeup with eye lash hair (below the yellow tape) on the case vehicle’s driver side curtain air bag

The driver's door was found open upon this contractor's vehicle inspection, and was observed to be open in the police scene photographs. This and the outward bowing of the door raised the possibility that the door had come open during the crash. Inspection of the door gave conflicting indicators of it opening during the crash. Subsequent information provided by one of the police scene investigators indicated that the door had been forced open by the first two police officers on the scene in an attempt to find some identification of the victim and for an inventory of the items in the vehicle. This would explain the downward bending of the window frame and kink in the sheet metal below the exterior door handle, and the lack of dirt and other ground contact evidence on the door.



Figure 12: Steering wheel and column showing lack of deformation

Damage Classification: The case vehicle's initial impact with the ditch involved the lower portion of the front bumper and the left front wheel with contact extending to the front undercarriage (**Figures 13 and 14**). The interaction of the left front wheel with the ground was severe enough to displace the wheel rearward approximately 4 centimeters (1.6 inches), break the tire bead and air-out the tire. Therefore, two CDCs were assigned to capture the damage to the front bumper and the left front wheel: **10-FDLW 1 (310 degrees)** for the front bumper damage and **10-FLWN-3 (310 degrees)** for the left front wheel damage. The CDC for the rollover was determined to be **00-TDDO-3**.

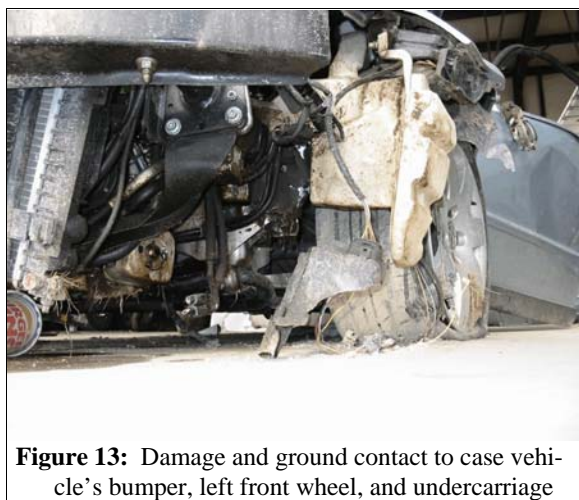


Figure 13: Damage and ground contact to case vehicle's bumper, left front wheel, and undercarriage



Figure 14: Left side view of damage to case vehicle's front bumper and left front wheel

The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's impacts because rollover events are out-of-scope for the program and the swiping type nature of the impact to the lower front bumper violates the WinSMASH program's common velocity assumption. Based on the crush to the case vehicle's roof, the rollover crash severity was determined to be moderate. A separate speed reconstruction analysis was performed and indicated the minimum speed of the case vehicle as it initiated its driver side leading rollover and became airborne was

approximately 56 km.p.h. (35 m.p.h). In addition, the case vehicle's minimum speed was approximately 77 km.p.h. (48 m.p.h) at the beginning of the first visible tire marks in the gravel (i.e., identified by police). The speed reconstruction is presented at the end of this report. The case vehicle was towed due to damage.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with redesigned air bags and seat back-mounted, side impact air bags at the driver and front right passenger positions. In addition, the case vehicle was equipped with side curtain air bags. All of the case vehicle's air bags deployed as a result of the crash.

The case vehicle's driver air bag was located in the steering wheel hub. It deployed as a result of the ditch impact as the case vehicle departed the roadway. 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 (**Figure 15**) and there was no evidence of damage to the air bag or the cover flaps. The two air bag module cover flaps were approximately rectangular in shape and were constructed of pliable vinyl. There was a small rounded contour on the center of each flap at the center tear seam, which accommodated the "VW" emblem. The top cover flap was 12.5 centimeters (4.9 inches) in width and 7 centimeters (2.8 inches) in height. The bottom cover flap was 12 centimeters (4.7 inches) in width and 6 centimeters (2.4 inches) in height. The deployed driver's air bag (**Figure 16**) was round with a diameter of approximately 60 centimeters (23.6 inches). The air bag was designed with four tethers, each approximately 8 centimeters (3.1 inches) in width and had one vent port, approximately 3 centimeters (1.2 inches) in diameter, located at the 12 o'clock position (**Figure 17**). The distance between the mid-center of the driver's seat back, as positioned at the time of the vehicle inspection, and the front surface of the driver air bag at maximum excursion was 35 centimeters (13.8 inches). Inspection of the air bag revealed no evidence of occupant contact; however, the entire surface of the air bag was covered intermittently with a rust colored stain.



Figure 15: Driver's air bag module cover flaps



Figure 16: Overview of the driver's air bag



Figure 17: Driver's air bag vent port

The front right passenger's air bag was located in the middle of the instrument panel (**Figure 18**). It deployed as a result of the ditch impact as the case vehicle departed the roadway. An inspection of the air bag module cover flap and the air bag fabric revealed that the cover flap opened at the designated tear points, and no deployment damage to the air bag or the cover flap was observed. The deployed front right air bag (**Figure 19**) was approximately 65 centimeters (25.6 inches) in width and 75 centimeters (29.5 inches) in height. The air bag was designed without tethers and had one vent port, approximately 5.5 centimeters (2.2 inches) in diameter, located at the 11 o'clock position. The air bag module cover flap was constructed of metal, covered by padded vinyl and was 33 centimeters (13 inches) in width and 15 centimeters (5.9 inches) in height. The distance between the mid-center of the front right passenger's seat back, as positioned at the time of the vehicle inspection, and the front surface of the front right passenger air bag at maximum excursion was 24 centimeters (9.5 inches).

The case vehicle's front seat back-mounted, side impact air bags were located in the outboard side of the driver's seat back (**Figure 20** below) and the front right seat back. The left and right side curtain air bags were located along the left roof side rail (**Figure 21** and **22** below) and the right roof side rail. Both the driver and front right, seat back-mounted side impact air bags and the left and right side curtain air bags deployed in this crash. It is likely that the ground impact to the right roof side rail during the third or fourth roll caused the front right seat back-mounted side impact air bag and right side curtain air bag to deploy. The driver's seat back-mounted side impact air bag and the left side curtain air bag deployed during the initial impacts as the case vehicle departed the roadway and impacted the ditch. The bases for this conclusion are twofold: (1) the location of the occupant contact on the upper front portion of the left side curtain air bag is consistent with the driver's kinematics in response to the 310 degree direction of principal force acting on the vehicle during the impact with the ditch, and (2) the reconstruction of the rollover event indicated the driver was ejected from the vehicle before any other impacts occurred to the left side of the case vehicle.



Figure 18: Location of front right passenger's air bag in middle of right instrument panel



Figure 19: The front right air bag



Figure 20: Driver's seat back-mounted side impact air bag



Figure 21: Front portion of left side curtain air bag, arrow shows driver contact



Figure 22: Back portion of left side curtain air bag



Figure 23: Inboard surface of case vehicle's driver seat back-mounted side impact air bag, yellow tape shows possible occupant contact

Both driver and front right seat back-mounted, side impact air bags were approximately 59 centimeters (23.2 inches) in height and 21 centimeters (8.3 inches) in width at their widest point. The driver's seat back-mounted side impact air bag had a faint area of scuffing or discoloration on the lower inboard surface indicating a possible occupant contact (**Figure 23**). In addition, there was a small area of abrasion on the lower outboard surface of the air bag, which may have been related to the deployment of the air bag or contact with the driver's door during the impact to the air bag by the driver. No occupant contact marks or damage were observed to the front right seat back-mounted side impact air bag.

The driver's side curtain air bag was located in the left roof side rail. The air bag had several areas that were sewn with double stitching to form

inflatable chambers. The side curtain air bag was approximately 163 centimeters in length (64.2 inches) and 32 centimeters (12.6 inches) in height at its highest point (i.e., the middle of the air bag). There were two anchor straps at the front of the air bag. The upper anchor strap was approximately 15 centimeters in length (5.9 inches) and the lower anchor strap was approximately 13 centimeters in length (5.2 inches). In addition, there was a single anchor strap at the rear of the air bag, approximately 15 centimeters in length (5.9 inches). The air bag was not equipped with any vent ports. An occupant contact mark was observed on the forward upper portion of the driver's side curtain air bag consisting of a scuff of eye makeup and two eye lash hairs (**Figures 14 and 21** above). No other occupant contact marks or damage were observed on the air bag. The construction and dimensions of the right side curtain air bag were the same as the driver's side curtain air bag. No damage or occupant contact marks were observed on the right side curtain air bag.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash the case vehicle's driver [37-year-old, White (non-Hispanic) female; 168 centimeters (66 inches) and 136 kilograms (300 pounds)] was seated in an unknown posture. It is likely that both of her hands were on the steering wheel. The position of her feet is not known. Her seat track was located between its middle and forward-most position. The position of the driver's seat back is not known. It was found deformed rearward about 40 degrees and was jammed in that position due to occupant loading that occurred during the ground impact to the back right corner of the case vehicle.

The driver was not using her manual, three-point, lap-and-shoulder safety belt system. Inspection of the seat belt assembly revealed no load markings on the seat belt webbing, latch plate, or "D"-ring. In addition, the police report indicated the driver was not restrained.

It is not known what pre-crash avoidance actions the case vehicle's driver may have taken. The tire mark evidence on the roadway documented by the police indicates that the case vehicle was in a clockwise yaw prior to leaving the roadway indicating a right steer maneuver by the driver. The location of the tire marks in the roadway indicates the driver initiated the right steer while the case vehicle was on the roadway; however, the event that precipitated this steering maneuver could not be determined. As a result of the clockwise yaw, the case vehicle's driver was most likely leaned to the left as the case vehicle departed the roadway. The impact of the lower front bumper and left front wheel with the ditch caused the unrestrained driver to move forward and to the left along a path opposite the case vehicle's 310 degree direction of principal force as the case vehicle decelerated. The left side of the driver's face contacted the deployed left side curtain air bag depositing an eye makeup scuff and eye lashes on the air bag and causing a contusion and laceration to the driver's left eyelids, contusions to the left side of her face, jaw, chin and neck and a contusion to her right eyelids. The driver's left arm, left chest and left abdomen contacted the deployed seat back-mounted side impact air bag scuffing the air bag and causing abrasions to her left upper arm, left chest and left abdomen. The driver's left upper forearm, left hand and left thigh also impacted the driver's door causing a contusion on her left forearm, hand and thigh. The driver likely continued to move to the left and toward the roof as the case vehicle became airborne and rolled over driver side leading. The driver then most likely moved rearward contacting and deforming her seat back when the back right corner of the case vehicle impacted the ground as the vehicle landed and completed its first roll. The driver then most likely moved back toward the roof as the case vehicle pirouetted

clockwise on its back end, rolled right and landed on the top of the right fender, hood, and roof. It is likely the driver was ejected out of the open sun roof during this sequence as the case vehicle completed one-and-one-half rolls. She impacted her head on the ground causing a nonanatomic brain injury, multiple lacerations and abrasions to her head and face, contusions to her right lower forearm, hand and wrist, and a dislocated right wrist. In addition, she sustained a laceration to her abdomen and contusions to her right and left thigh on the edge of the sunroof during the ejection. The driver's abdomen may also have been pressed between the roof of the case vehicle and the ground as she was being ejected causing a laceration to her liver. The driver's final rest position was about 6 meters (19.7 feet) northwest of the point where the back of the case vehicle hit the ground at the end of its first roll, and she was oriented along the path the vehicle took to final rest. The driver's non-use of her safety belt system resulted in her ejection from the case vehicle and the fatal injuries she sustained during the rollover. The result of the driver's blood alcohol test was 0.273.

CASE VEHICLE DRIVER INJURIES

The police incident report indicated the driver was transported from the scene by ambulance to a local fire department where she was transferred to a helicopter and transported to a hospital. The emergency room record indicated the driver was pronounced dead 83 minutes after the crash. The driver's injuries and injury mechanisms are shown in the table below.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury ¹ with unconsciousness and no response to painful stimuli	critical 160824.5,0	Ground	Possible	Emergency room records
2	Injury thoracic cavity with pneumomediastinum ²	serious 442204.3,9 ³	Exterior roof in area of sunroof opening	Possible	Autopsy

¹ According to the autopsy, the cause of death was blunt trauma to head and face; however, no extradural, subdural, or subarachnoid collections of blood were found and the brain was not grossly unusual. Furthermore, no brain lesions or skull fractures were noted.

² The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
emphysema (em"fa-se'ma): a pathological accumulation of air in tissues or organs; applied especially to such a condition of the lungs (see *pulmonary e.*)
interstitial e.: the escape of air into the connective tissue of the lung, mediastinum (see *pneumomediastinum*), or subcutaneous tissue (see *subcutaneous e.*) resulting from a tear or rupture of the respiratory passages or alveoli, which may occur in association with bronchiolar obstruction or be caused by a penetrating wound of the chest wall or lung.
interstitial (in"tar-stish'al): pertaining to or situated between parts or in the interspaces of a tissue.
mediastinum (me"de-as"ti'nam): The mass of tissues and organs separating the two pleural sacs, between the sternum anteriorly and the vertebral column posteriorly {i.e., the bodies of the 12 thoracic vertebrae} and from the thoracic inlet superiorly to the diaphragm inferiorly. It contains the heart and its pericardium, the bases of the great vessels {e.g., aorta, aortic arch, vena cava, pulmonary arteries and veins}, the trachea and bronchi, esophagus, thymus, lymph nodes, thoracic duct, phrenic and vagus nerves, and other structures and tissues.
pneumomediastinum (noo"mo-me"de-as-ti'num): the presence of air or gas in the mediastinum, which may interfere with respiration and circulation, and may lead to such conditions as pneumothorax or pneumopericardium. It may occur as a result of trauma or a pathologic process, or it may be induced deliberately as a diagnostic procedure. Called also *Hamman's disease* or *syndrome* and *mediastinal emphysema*.

³ Because the NASS CDS Injury Coding protocol does not allow the use of the most appropriate Aspect code (i.e., **Central**), the Aspect "**Unknown**" is used here. The mediastinum is centrally located within the thoracic cavity.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
3	Laceration, 7.0 cm (2.8 in) in length, 0.2 cm (0.1 in) in depth, anterior-superior right lobe of liver	moderate 541822.2,1	Exterior roof in area of sunroof opening	Possible	Autopsy
4	Dislocation right ulna in wrist (i.e., ulnocarpal joint)	moderate 751430.2,1	Ground	Possible	Autopsy
5	Laceration, 7.6 cm (3.0 in), transverse, mid-occipital scalp	minor 190602.1,6	Ground	Possible	Autopsy
6 7	Contusion {subgaleal hemorrhage} left temporal and bilateral occipital scalp	minor 190402.1,2 190402.1,6	Ground	Possible	Autopsy
8	Abrasions, 10.2 x 6.4 cm (4.0 x 2.5 in) aggregate area bilateral forehead	minor 290202.1,7	Ground	Possible	Autopsy
9	Lacerations {cuts}, scattered within abraded area cited above, bilateral forehead	minor 290602.1,7	Ground	Possible	Autopsy
10	Abrasions bridge of nose	minor 290202.1,4	Ground	Possible	Autopsy
11	Lacerations {cuts}, small, bridge of nose	minor 290602.1,4	Ground	Possible	Autopsy
12	Contusion {ecchymosis} right eyelids with swelling not further specified	minor 297402.1,1	Air bag, driver's side inflatable curtain	Probable	Emergency room records
13	Contusion {ecchymosis} left upper and lower eyelids with swelling	minor 297402.1,2	Air bag, driver's side inflatable curtain	Probable	Autopsy
14	Lacerations {cuts}, small, confluent with ecchymoses left upper and lower eyelids	minor 297602.1.2	Air bag, driver's side inflatable curtain	Probable	Autopsy
15	Contusion, diffuse, with swelling left face	minor 290402.1,2	Air bag, driver's side inflatable curtain	Probable	Autopsy
16	Contusion, diffuse, with swelling left jaw and chin	minor 290402.1,8	Air bag, driver's side inflatable curtain	Probable	Autopsy
17	Contusion, diffuse, with swelling left neck	minor 390402.1,2	Air bag, driver's side inflatable curtain	Probable	Autopsy
18	Abrasions, 11.4 x 4.4 cm (4.5 x 1.75 in) aggregate area left anterolateral chest	minor 490202.1,2	Air bag, driver's side impact	Probable	Autopsy

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
19	Abrasions, scattered, 8.9 x 2.5 cm (3.5 x 1.0 in) aggregate area, left lower abdomen and left lower lateral abdomen	minor 590202.1,2	Air bag, driver's side impact	Probable	Autopsy
20	Laceration, superficial, 2.5 x 1.3 cm (1.0 x 0.5 in) left lower abdomen	minor 590602.1,2	Sunroof components: edge of sunroof frame	Possible	Autopsy
21	Contusions left upper arm, not further specified	minor 790402.1,2	Air bag, driver's side impact	Probable	Autopsy
22	Contusions left upper forearm and dorsum left hand	minor 790402.1,2	Left side interior hardware and/or armrest	Probable	Autopsy
23	Contusions right lower forearm, right wrist, and dorsum right hand	minor 790402.1,1	Steering wheel hub and/or spokes and rim	Possible	Autopsy
24	Contusion left upper anterolateral thigh	minor 890402.1,2	Sunroof components: edge of sunroof frame	Possible	Autopsy
25	Contusion right lower medial thigh	minor 890402.1,1	Sunroof components: edge of sunroof frame	Possible	Autopsy

SPEED RECONSTRUCTION

The speed of the case vehicle at the point it tripped and became airborne is calculated using the "flip" equation (Reference: Traffic Accident Reconstruction by Lynn Ficke, Northwestern University Traffic Institute, pages 66-12 and 66-13).

The equation requires that the distance traveled horizontally and vertically by the vehicle's center of mass from the takeoff point to the landing point be known. In addition, a more refined speed estimate can be achieved if the angle of takeoff of the center of mass is known. This angle is seldom known in most investigations, and is not known in this case. Therefore, the form of the equation used in this reconstruction assumes a 45 degree take off angle, which gives a minimum speed estimate.

The Variables:

d= horizontal travel distance of center of mass

h= vertical travel distance of center of mass

g= acceleration of gravity, **32.2 feet/sec/sec**

Speed Reconstruction (Continued)

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The vertical travel distance of the center of mass is a range of reasonable values based on the case vehicle's approximate center of mass height and observations and measurements made at the crash scene.

The low range estimate is: **h**= 2 feet. The speed at trip is:

$$d := 77 \cdot \text{ft}$$

$$h := 2 \cdot \text{ft}$$

$$V_{\text{trip_low}} := d \cdot \sqrt{\frac{g}{d - h}}$$

$$V_{\text{trip_low}} = 34.386 \cdot \text{mph}$$

The upper range estimate is: **h**= 5 feet. The speed at trip is:

$$d := 77 \cdot \text{ft}$$

$$h := 5 \cdot \text{ft}$$

$$V_{\text{trip_high}} := d \cdot \sqrt{\frac{g}{d - h}}$$

$$V_{\text{trip_high}} = 35.095 \cdot \text{mph}$$

Working back from the trip point to determine the minimum speed of the case vehicle at the beginning of the tire marks identified by the police:

The Variables:

d= Case vehicle's travel distance in the clockwise yaw prior to trip point.

f= The drag factor, determined from separate analysis.

V_{trip}= Speed at the trip point.

The average of the speed range is used:

$$V_{\text{trip}} := 34.74 \cdot \text{mph}$$

$$d := 75 \cdot \text{ft}$$

The minimum speed at the beginning of the tire marks identified by the police is:

$$f := -0.5 \cdot g$$

$$V := \sqrt{V_{\text{trip}}^2 - 2 \cdot f \cdot d}$$

$$V = 48.256 \cdot \text{mph}$$

