

**TRANSPORTATION SCIENCES
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**REMOTE ADVANCED OCCUPANT PROTECTION SYSTEMS INVESTIGATION
SCI TECHNICAL SUMMARY REPORT**

NASS/SCI COMBO CASE NO. 01-43-019E

VEHICLE - 2000 BMW 328Ci

LOCATION - STATE OF NORTH CAROLINA

CRASH DATE - FEBRUARY 2001

Contract No. DTNH22-94-D-07058

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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 are 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.

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<p>16. <i>Abstract</i> This remote investigation involved a 2000 BMW 328Ci that was equipped with an Advanced Occupant Protection System (AOPS) which included redesigned frontal air bags, side air bags, Head Protection System (HPS), and frontal seat belt pretensioners. The BMW was occupied by a 15-year-old male driver, two 16-year-old male passengers, and a 12-year-old male passenger. All occupants were properly restrained by the manual 3-point lap and shoulder belt systems. The BMW was involved in a run-off-road crash with a culvert that tripped a rollover with multiple impacts. The frontal impact with the culvert resulted in the firing of the front pretensioners and deployment of the redesigned frontal air bag system. The subsequent rollover and multiple impacts deployed both side air bag systems and HPS's. The occupants of the BMW loaded the manual restraints, and since they were properly restrained, they remained in position during the rollover and subsequent impacts. The driver sustained a cervical spine strain from head motion and abrasions to the left shoulder from loading the shoulder belt. Contact with the driver's redesigned frontal air bag resulted in facial abrasions. The front right passenger sustained a right acromioclavicular joint dislocation from loading the shoulder belt webbing. He sustained multiple minor abrasions, lacerations and contusions of the upper and lower extremities from interior contacts and flying glass during the rollover. He also had complaints of a chest contusion from loading the manual restraint, a facial contusion, and a scalp laceration from interior contacts. The rear left occupant sustained seat belt related contusions, minor facial lacerations, and minor left arm abrasions and lacerations from interior contacts. The rear right occupant sustained minor facial lacerations, minor scalp contusions, abrasions, and lacerations, and a right arm abrasion and laceration from contact with the right C-pillar, interior surfaces, and flying glass. He also sustained a facial contusion from probable contact with the front right seat back. The occupants were transported by private vehicle to a local hospital and treated and released.</p>			
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**REMOTE REDESIGNED AIR BAG DEPLOYMENT INVESTIGATION
SCI TECHNICAL SUMMARY REPORT
NASS/SCI COMBO CASE NO. 01-43-019E
VEHICLE - 2000 BMW 328Ci
LOCATION - STATE OF NORTH CAROLINA
CRASH DATE - FEBRUARY 2001**

BACKGROUND

This remote investigation involved a 2000 BMW 328Ci that was equipped with an Advanced Occupant Protection System (AOPS) which included redesigned frontal air bags, side air bags, Head Protection System (HPS), and frontal seat belt pretensioners. The BMW was occupied by a 15-year-old male driver, two 16-year-old male passengers, and a 12-year-old male passenger. All occupants were properly restrained by the manual 3-point lap and shoulder belt systems. The BMW was involved in a run-off-road crash with a culvert that tripped a rollover with multiple impacts (**Figure 1**). The frontal impact with the culvert resulted in the firing of the front pretensioners and deployment of the redesigned frontal air bag system. The subsequent rollover and multiple impacts deployed both side air bag systems and HPS's.



Figure 1. Damage to the 2000 BMW 328Ci

The occupants of the BMW loaded the manual restraints, and since they were properly restrained, they remained in position during the rollover and subsequent impacts. The driver sustained a cervical spine strain from head motion and abrasions to the left shoulder from loading the shoulder belt. Contact with the driver's redesigned frontal air bag resulted in facial abrasions. The front right passenger sustained a right acromioclavicular joint dislocation from loading the shoulder belt webbing. He sustained multiple minor abrasions, lacerations and contusions of the upper and lower extremities from interior contacts and flying glass during the rollover. He also had complaints of a chest contusion from loading the manual restraint, a facial contusion, and a scalp laceration from interior contacts. The rear left occupant sustained seat belt related contusions, minor facial lacerations, and minor left arm abrasions and lacerations from interior contacts. The rear right occupant sustained minor facial lacerations, minor scalp contusions, abrasions, and lacerations, and a right arm abrasion and laceration from contact with the right C-pillar, interior surfaces, and flying glass. He also sustained a facial contusion from probable contact with the front right seat back. The occupants were transported by private vehicle to a local hospital and treated and released.

This crash was selected for investigation by the National Automotive Sampling System (NASS) as CDS case number 01-43-019E. The crash occurred in February 2001. Initial notification of this crash was made to the Veridian Special Crash Investigations team following a NASS CDS case review. The NASS PSU performed the vehicle inspection and scene inspection. Due to the presence of the Advanced Occupant Protection Systems, NHTSA assigned the tasks of case review and report preparation to the Veridian Special Crash Investigation (SCI) team on February 27, 2001.

SUMMARY

Crash Site

This crash occurred in February 2001 during daylight hours on the roadside of a north/south two-lane undivided state highway. At the time of the crash, there were no adverse weather conditions and the asphalt roadway surface was dry. The two-lane roadway curved left and had a positive northbound grade. The travel lanes were separated by a double-yellow centerline and the roadway was bordered by dirt shoulders and grassy drainage ditches. The roadside environment consisted of grassy areas, trees, and residential properties. The posted speed limit for the roadway was 72 km/h (45 mph). According to the NASS interview, a curve warning sign was present south of the crash site that advised a 56 km/h (35 mph) speed.

Pre-Crash

The 15-year-old licensed male driver was operating the BMW northbound on a two-lane state roadway during daylight hours. The driver was reportedly operating the vehicle northbound at a high rate of speed on approach to a left curve (**Figure 2**). The estimated travel speed was police-reported at 137 km/h (85 mph). The driver failed to negotiate the curve and lost control of the vehicle. The BMW traveled onto the dirt shoulder and into the grassy drainage ditch (**Figure 3**). The BMW was equipped with anti-lock brakes (ABS) and the driver attempted to regain control by braking (without lockup) and steering left, which caused the BMW to initiate a counterclockwise (CCW) yaw in the drainage ditch. Tire marks in the ditch were documented by the NASS researcher from the right front and right rear tires of the BMW. The right front tire mark measured 10.6 m (34.8') and the right rear tire mark measured 6.4 m (21.0').



Figure 2. Pre-crash trajectory of the BMW



Figure 3. Point of roadway departure

Crash

The 2000 BMW 328Ci impacted a driveway culvert with the front right undercarriage area (**Figure 4**). The direction of force could not be determined due to overlapping damage. However, the frontal impact to the undercarriage area was sufficient to fire the frontal seat belt buckle pretensioners and deploy the redesigned frontal air bag system in the BMW. The forward momentum of the BMW combined with the undercarriage impact caused the BMW to vault over a private driveway and initiate a rollover. The exact rollover sequence was not confirmed due to the nature of the crash and overlapping damage. However, based on the scene evidence and vehicle damage it appears that the BMW rolled laterally a total of ten quarter turns with the right side leading. The approximate total distance traveled during the rollover was of 65 m (215') along the roadside. The right front passenger's side air bag and right side HPS probably deployed as the right plane of the BMW struck the ground on the first quarter turn. A large gouge mark was present in the vehicle's trajectory as a result of ground contact with the roof and left side plane as it rolled (**Figure 5**). As the BMW entered the fifth quarter-turn, the rear aspect of the car was vaulted upward as the right front corner gouged the roadside surface. The BMW impacted a wood fence with the right rear area during this portion of the rollover. While the vehicle was upside down in the sixth quarter turn, it impacted a utility pole with the left front area (**Figure 6**). This impact with the pole probably deployed the driver's side air bag and left side HPS. The BMW rotated counterclockwise (CCW) through the pole, across a private driveway and impacted the ground, evidenced by a gouge. It rolled an additional four quarter-turns and impacted a second wood fence. The fence was fractured and collapsed from sustained contact as the vehicle rolled on top of it. The BMW came to rest on its roof against the fence facing southwest (**Figure 7**).



Figure 4. Point of impact with the culvert



Figure 5. Gouge mark



Figure 6. Wood fence impact and utility pole (replaced)



Figure 7. View showing gouge, second wood fence impact, and final rest position

Post-Crash

The occupants reportedly exited the vehicle under their own power through the right side window openings, as the right door was jammed shut. The driver did not receive medical treatment at the scene, but was transported by private vehicle to a hospital later the same day where he was treated and released. The remaining occupants were transported by private vehicle to a local hospital where they were treated and released.

VEHICLE DATA - 2000 BMW 328Ci

The 2000 BMW 328Ci was identified by the Vehicle Identification Number (VIN): WBABM5343YJ (production sequence omitted). The vehicle was a two-door hardtop coupe and was equipped with a 2.8 liter, 6 cylinder engine, rear wheel drive, a 5-speed manual transmission, power 4-wheel disc brakes with anti-lock, a traction control system, power steering, a power sun/moon roof and a tilt steering wheel. Although the BMW was equipped with a digital odometer, the owner of the vehicle estimated the odometer reading to be approximately 22,531 km (14,000 miles). The seating was configured with front bucket seats with folding backs that were equipped with adjustable head restraints and a rear bench seat with a folding back. The outboard rear seat positions were equipped with adjustable head restraints that were in the full-down positions.

VEHICLE DAMAGE

Exterior Damage

The 2000 BMW 328Ci sustained moderate damage as a result of the multiple-event crash. Due to the overlapping nature of the damage from the multiple events, damage measurements were not recorded by the NASS researcher. The bumper fascia was separated from the vehicle, and deformation was noted on the frontal plane below the hood. The hood was buckled rearward slightly and displaced laterally to the right. The hood sustained direct contact damage on the left side from the utility pole impact, and the left front fender sustained lateral and rearward crush (**Figure 8**). The maximum lateral crush to the left front fender was approximately 40 cm (16"). The right edge of the hood was also deformed and abraded. Both front wheels were separated from the vehicle. Direct contact damage was noted on the entire left side of the BMW from the rollover. The left side mirror was separated from the vehicle. The roof side rail was laterally abraded, the left rear quarter panel was deformed and abraded, and the left rear wheel was partially separated from the vehicle. The trunk lid was open and deformed. Vertical abrasions and dirt patterns were identified on both rear bumper fascia corners. Both rear brake lights were fractured and displaced. The right fender, right door, and right rear quarter panel sustained direct contact damage (**Figure 9**). The right rear quarter panel was crushed laterally and sustained



Figure 8. Damage from utility pole impact



Figure 9. Right side damage

longitudinal abrasions across the area of the fuel filler cap. The fuel filler door was separated from the vehicle, and fragments of grass and dirt were embedded into the filler cap and the deformed edges of the quarter panel. Grass and dirt were also deposited along the rear edge of the right C-pillar window trim and right edge of the backlight frame. The right A-pillar was crushed vertically and the front right aspect of the roof and right aspect of the windshield header were also crushed. The right side mirror was partially separated from the vehicle and lateral abrasions were noted on the right roof side rail and right roof area. Collision Deformation Classifications (CDC's) were coded for the rollover event and the impact with the utility pole. The CDC for the rollover was 00-TDDO-9 and the CDC for the utility pole impact was 09-LYEW-9. The remaining impacts were not assigned CDC's due to overlapping damage.

Interior Damage

Interior damage to the 2000 BMW 328Ci was moderate and was attributed to passenger compartment intrusion and occupant contact. The NASS researcher documented integrity loss in the side window and backlight. The windshield laminate was in place and cracked from impact forces, and the tempered glazing in the side door windows, side windows, and backlight was disintegrated from impact forces. According to the left-rear occupant, his left arm was partially ejected out of the left rear side glass opening after the glazing had disintegrated. The power sun/moon roof was fully retracted prior to the crash and was not damaged. Multiple intrusions were identified in the BMW. The location of the most severe intrusion was the front right position, where intrusions of the right A-pillar, right toe pan, and windshield were identified (**Figure 10**). Occupant contact evidence was noted on both frontal redesigned air bag membranes. Occupant contact evidence was also noted on the front left and rear right manual 3-point lap and shoulder belts, evidenced by scuff marks. The bottom rear aspect of the front right seat back was also scuffed from occupant contact. The glove box door opened as a result of the crash.



Figure 10. Multiple passenger compartment intrusions

MANUAL RESTRAINT SYSTEM

The 2000 BMW 328Ci was configured with manual 3-point lap and shoulder belts with sliding latch plates for both front seat positions. The manual belt systems were used properly by the driver and front right passenger and the front latch plates also showed signs of historical use. Both frontal restraints were equipped with buckle pretensioners that were located longitudinally along the inboard aspects of the front seat tracks. Both frontal lap and shoulder belts were equipped with sliding anchorage adjustments that were in the full-up positions. The rear seat was configured with manual 3-point lap and shoulder belts for the outboard positions and a lap belt for the center position. The occupants seated in the rear outboard positions were properly restrained by the manual restraints and all rear restraints showed signs of historical use.

ADVANCED OCCUPANT PROTECTION SYSTEM (AOPS)

Front Seat Belt Buckle Pretensioners

The front seat manual restraints were equipped with buckle pretensioners that were located longitudinally along the inboard aspects of the front seat tracks (**Figure 11**). Both front seated occupants were restrained by the manual 3-point lap and shoulder belt system, therefore the pretensioners were armed at the time of the crash. Both pretensioners fired as a result of the frontal impact with the culvert.



Figure 11. Driver's buckle pretensioner

Redesigned Frontal Air Bag System

The 2000 BMW 328Ci was equipped with redesigned frontal air bags for the driver and front right positions that deployed as a result of the impact with the culvert (**Figures 12 and 14**). The delta-V probably exceeded 24 - 26 km/h (15 - 16 mph), which is an approximate threshold for air bag deployment with restrained occupants. The driver's redesigned air bag was housed in the center of the steering wheel with a single cover flap design hinged at the top aspect. The cover flap measured 15 cm (6") in width and 12 cm (5") in height. The redesigned air bag measured 57 cm (22") in diameter in its deflated state. It was vented by a single port located at 12 o'clock on the rear aspect of the air bag (**Figure 13**). The driver's air bag was not tethered. A blood smear was noted on the upper right quadrant on the face of the air bag.



Figure 12. Driver's redesigned air bag



Figure 13. Single vent port on driver's redesigned air bag

The front right passenger's air bag deployed from a mid-mount module with a single tethered cover flap design. The cover flap measured 60 cm (24") in width and 20 cm (8") in height. The redesigned front right passenger's air bag was rectangular in shape and measured 54 cm (21") in width and 60 cm (24") in height. A blood smear was noted on the upper left quadrant on the face of the air bag. The air bag was vented by two ports located on the side aspects at the 9 and 3 o'clock positions. The



Figure 14. Front right passenger's redesigned air bag

air bag was not tethered.

Side Impact Protection System

The 2000 BMW 328Ci was equipped with door-mounted side air bags and HPS for both front seated positions (**Figure 15**). The sensors for the HPS system and side air bag system were located on the lower aspect of the B-pillars. The door mounted side air bags deployed as a result of the rollover event. Both side air bags deployed in a lateral direction from the interior door panels above the arm rests. The cover flaps were in the shape of parallelograms and were hinged at the bottom aspects. The cover flaps measured 40 cm (16") in width and 12 cm (5") in height. The side air bags offered thorax protection and measured 47 cm (19") in width and 26 cm (10") in height. Each side air bag was tethered by one internal strap.



Figure 15. Deployed right front side air bag and right HPS

The 2000 BMW's HPS consisted of Inflatable Tubular Structures (ITS) for both front seated occupants that deployed as a result of the rollover event. The ITS deployed vertically from the A-pillars and roof side rails and were positioned diagonally across the side windows when fully inflated. Both ITS were tethered at the lower aspect of the A-pillars and at the roof side rails at the rear aspect of the B-pillars. The symmetrical ITS interior cover flaps extended from the base of the A-pillars to the rear aspect of the B-pillars and measured 6 cm (2") in width. The ITS were reinforced with Kevlar for structural integrity against intrusion. Each ITS measured 125 cm (49") in length in their deflated state. The ITS were not vented. There was no contact evidence identified on the HPS system.

OCCUPANT DEMOGRAPHICS

Driver

Age/Sex:	15-year-old male
Height:	173 cm (68")
Weight:	69 kg (152 lb)
Seat Track Position:	Mid-track
Manual Restraint Use:	Manual 3-point lap and shoulder belt
Usage Source:	Vehicle inspection, injury data
Eyewear:	Sunglasses
Type of Medical Treatment:	Not transported from the scene of the crash, but was treated and released from a local hospital later in the day

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Abrasion on bridge of nose	Minor (290202.1,4)	Driver’s redesigned air bag and eyewear
Lower forehead abrasion	Minor (290202.1,7)	Driver’s redesigned air bag and eyewear
Cervical spine strain	Minor (640278.1,6)	Indirect - shoulder belt webbing, forward head excursion
Left shoulder/clavicle abrasion	Minor (790202.1,2)	Shoulder belt webbing

*Injury source: Hospital discharge summary, NASS interview with parent

Driver Kinematics

The 15-year-old driver was seated in a mid-track position with the seat back slightly reclined. The adjustable head restraint was close to the full-down position. He was properly restrained by the manual 3-point lap and shoulder belt system. Belt usage was verified by the loading evidence on the webbing, belt-related injuries, and the firing of the buckle pretensioner. The anchorage adjustment was in the full up position. The driver’s parents reported that his hands were at the 10 and 2 o’clock positions on the steering wheel and that his feet were on the foot controls of the ABS-equipped vehicle prior to the crash. The driver was also wearing sunglasses at the time of the crash.

At impact with the culvert, the BMW’s redesigned frontal air bag system deployed and the driver’s buckle pretensioner fired. The driver initiated a forward trajectory and loaded the manual restraint. As a result of loading the manual belt system, he sustained a cervical spine strain from the forward head excursion and a left shoulder/clavicle abrasion from the shoulder belt webbing. The forward head excursion allowed his face to contact the deployed redesigned driver’s air bag. The driver’s sunglasses were compressed between his face and the air bag membrane. The compression of the sunglasses against the bridge of his nose and forehead resulted in an abrasion on the bridge of his nose and an abrasion on his lower forehead. The manual restraint prevented additional movement throughout the vehicle during the rollover event, even though he was redirected within the restraint due to the crash forces. Based on the nature of the rollover event and multiple impacts, the driver’s side air bag and left side HPS probably deployed as a result of the utility pole impact. Although there was no identifiable contact evidence on the HPS or side air bag, the nature of the crash events suggest that the driver most likely contacted both the HPS and the side air bag with his head and left side, respectively. The vehicle came to rest on its roof and the driver exited the vehicle through the right side window opening.

Front Right Passenger

Age/Sex: 16-year-old male
 Height: 170 cm (67")
 Weight: 72 kg (159 lb)
 Seat Track Position: Mid-track
 Manual Restraint Use: Manual 3-point lap and shoulder belt
 Usage Source: Vehicle inspection, injury data
 Eyewear: None
 Type of Medical Treatment: Transported by private vehicle to a local hospital and treated and released

Front Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Right acromioclavicular joint dislocation (separation)	Moderate (750230.2,1)	Shoulder belt webbing
Minor scalp lacerations	Minor (190602.1,9)	Flying glass
Contusion above right eye	Minor (290402.1,7)	Front right passenger's redesigned air bag
Right chest contusion	Minor (490402.1,1)	Shoulder belt webbing
13 cm (5") left forearm abrasion	Minor (790202.1,2)	Center console
Right upper shoulder contusion	Minor (790402.1,1)	Shoulder belt webbing
Multiple bilateral upper arm lacerations	Minor (790602.1,3)	Flying glass
Right big toe contusion	Minor (890402.1,1)	Right floor (including toe pan)
Multiple bilateral leg lacerations	Minor (890602.1,3)	Flying glass

*Injury source: Hospital discharge summary, NASS interview with parent

Front Right Passenger Kinematics

The 16-year-old male front right passenger of the BMW was seated in a mid-track position with the seat back slightly reclined. The adjustable head restraint appeared to be adjusted to the middle position. He was restrained by the manual 3-point lap and shoulder belt. Belt usage was verified by the loading evidence on the webbing, belt-related injuries, and the firing of the buckle pretensioner. The anchorage adjustment was in the full up position. The parents of the front right passenger reported that his hands were extended forward in an effort to brace prior to the impact.

At impact with the culvert, the BMW's redesigned frontal air bag system deployed and the front right passenger's buckle pretensioner fired. The front right passenger initiated a forward trajectory and loaded the manual restraint. As a result of loading the manual belt system, he sustained a right acromioclavicular joint dislocation, a right chest contusion, and a right upper shoulder contusion. His head probably struck the deployed redesigned air bag which resulted in a contusion above the right eye. The intrusion of the right floor pan and toe pan resulted in a contusion on his right big toe. The manual restraint prevented additional movement throughout the vehicle during the rollover event, even though he was redirected within the restraint due to the crash forces. His left forearm probably contacted the center console which resulted in a 13 cm (5") left forearm abrasion. Contact with flying glass caused minor scalp lacerations, multiple bilateral upper arm lacerations, and multiple bilateral leg lacerations. Based on the nature of the rollover event and multiple impacts, the right front passenger's side air bag and right side HPS probably deployed as a result of the right side impact with the ground during the first quarter-turn of the rollover. Although there was no identifiable contact evidence on the HPS or side air bag, the nature of the crash events suggest that the front right passenger most likely contacted both the HPS and the side air bag with his head and right side, respectively. The vehicle came to rest on its roof and the front right passenger exited the vehicle through the right side window opening. He was transported from the scene by private vehicle to a local hospital and treated and released.

Rear Left Passenger

Age/Sex:	16-year-old male
Height:	183 cm (72")
Weight:	77 kg (170 lb)
Seat Track Position:	Fixed
Manual Restraint Use:	Manual 3-point lap and shoulder belt
Usage Source:	Vehicle inspection, injury data
Eyewear:	None
Type of Medical Treatment:	Transported by private vehicle to a local hospital and treated and released

Rear Left Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Multiple minor facial lacerations on entire face and forehead	Minor (290602.1,0)	Flying glass
Left upper chest contusion	Minor (490402.1,2)	Shoulder belt webbing
Left forearm abrasion	Minor (790202.1,2)	Left side interior surface
Left upper shoulder contusion	Minor (790402.1,2)	Shoulder belt webbing
Multiple minor left lower arm lacerations	Minor (790602.1,2)	Flying glass
Two 1 cm (0.5") left dorsal hand lacerations	Minor (790602.1,2)	Flying glass
Bilateral hip contusion	Minor (890402.1,3)	Lap belt webbing

*Injury source: Hospital discharge summary, NASS interview with parent

Rear Left Passenger Kinematics

The 16-year-old male rear left passenger was seated in an upright position and restrained by the manual 3-point lap and shoulder belt. Belt usage was verified by the loading evidence on the webbing and belt-related injuries. His arms were reportedly extended forward in an effort to brace prior to the crash.

At impact with the culvert, the rear left passenger initiated a forward trajectory and loaded the manual restraint. As a result of loading the manual belt system, he sustained a left upper chest contusion, a left upper shoulder contusion, and bilateral hip contusions. The manual restraint prevented additional movement throughout the vehicle during the rollover event, even though he was redirected within the restraint due to the crash forces. It was possible that his left arm was ejected through the open left rear side window during the rollover event after the glazing had disintegrated, however, it could not be confirmed. Contact with flying glass and glass pieces from the window glazing caused multiple minor facial lacerations on his entire face and forehead, multiple minor left lower arm lacerations, and two 1 cm (0.5") left dorsal hand lacerations. He also sustained a left forearm abrasion from contact against the left side interior surface. The rear left passenger exited the vehicle through the right side window opening. He was transported from the scene by private vehicle to a local hospital and treated and released.

Rear Right Passenger

Age/Sex: 12-year-old male
Height: 155 cm (61")
Weight: 61 kg (134 lb)
Seat Track Position: Fixed
Manual Restraint Use: Manual 3-point lap and shoulder belt
Usage Source: Vehicle inspection, injury data
Eyewear: None
Type of Medical Treatment: Transported by private vehicle to a local hospital and treated and released

Rear Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Anterior scalp abrasion	Minor (190202.15)	Right C-pillar
Posterior scalp contusion	Minor (190402.1,6)	Right C-pillar
Minor posterior scalp laceration	Minor (190602.1,6)	Right C-pillar
Contusion above the left eye	Minor (290402.1,7)	Front right seat back
Multiple minor facial lacerations	Minor (290602.1,9)	Flying glass
Right forearm abrasion near the elbow	Minor (790202.1,1)	Rear right side interior surface
Right elbow laceration	Minor (790600.1,1)	Right C-pillar

*Injury source: Hospital discharge summary, NASS interview with parent

Rear Right Passenger Kinematics

The 12-year-old male right rear passenger was seated in an upright position and restrained by the manual 3-point lap and shoulder belt. Belt usage was verified by the loading evidence on the webbing. His arms were reportedly extended forward in an effort to brace prior to the crash.

At impact with the culvert, the rear left passenger initiated a forward trajectory and loaded the manual restraint. There were no belt-related injuries reported. His head probably impacted the front right seat back resulting in a contusion above the left eye. The manual restraint prevented additional movement throughout the vehicle during the rollover event, even though he was redirected within the restraint due to the crash forces. As he rebounded rearward and to the right, his head struck the interior surface of the right C-pillar which resulted in an anterior scalp abrasion, a posterior scalp contusion, a minor posterior scalp laceration, and a right elbow laceration. Flying glass resulted in multiple minor facial lacerations. He exited the vehicle

through the right side window opening. He was transported from the scene by private vehicle to a local hospital and treated and released.

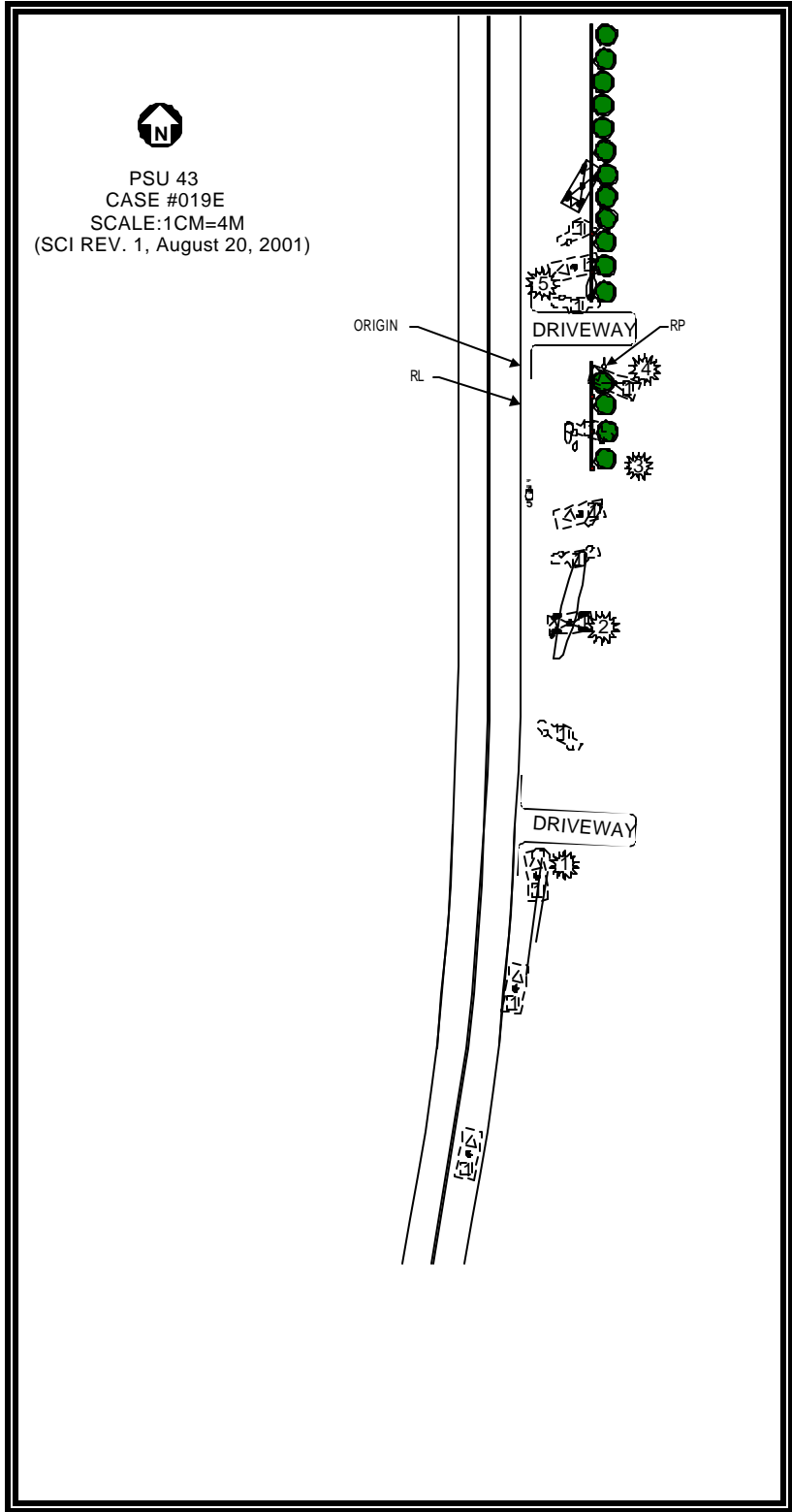


Figure 16. Scene schematic