

CRASH DATA RESEARCH CENTER

Calspan Corporation
Buffalo, NY 14225

**CALSPAN ON-SITE ADVANCED OCCUPANT PROTECTION SYSTEM
CRASH INVESTIGATION**

CASE NO: CA02-014

VEHICLE: 2001 BMW 325i

LOCATION: VIRGINIA

CRASH DATE: APRIL 2002

Contract No. DTNH22-01-C-17002

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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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SCI CASE NO.: CA02-014
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BACKGROUND

This on-site investigation focused on the severity of the crash, the source of injury, and the Advanced Occupant Protection System (AOPS) in a BMW 325i (**Figure 1**). The BMW was occupied by a 17-year old male driver and a 17-year old male front right passenger that departed the roadway and struck a large diameter tree resulting in severe frontal damage and deployment of the AOPS frontal air bag system. The AOPS consisted of dual stage air bags for the driver and front right positions and safety belt buckle pretensioners. In



Figure 1. Front right view of the 2001 BMW 325i.

In addition, the BMW was equipped with door mounted side impact air bags for the front outboard positions and a Head Protection System (HPS) that consisted on tubular inflatable air bags for the four outboard positions. The side impact and HPS systems did not deploy in this crash. Both occupants sustained multiple fractures and were removed from the vehicle by rescue personnel and transported to a regional trauma center where they were admitted for treatment of their injuries.

Notification of the crash was provided to NHTSA by the investigating police officer. Due to the severity of the crash and the deployment of the AOPS, the crash was assigned to the Calspan Special Crash Investigations (SCI) team on April 23, 2002 for on-site investigation.

SUMMARY

Crash Site

The crash occurred on a two lane road in a rural area during dark, night time hours. The roadway was painted with solid white edge lines and double yellow centerlines. The posted speed limit was 64 km/h (40 mph). On approach to the crash site, the roadway curved slightly to the left for the BMW and transitioned to a straight segment with a hillcrest. Both edges of the asphalt roadway were bordered by



Figure 2. Overall view of the approach to the crash site.

shallow drainage ditches that were located immediately outboard of the travel lanes and earthen embankments with a mix of large and small diameter trees (**Figure 2**). The struck tree was a 42 cm (16.5”) diameter pine that was located 2.4 m (8’) off-road. The Crash Schematic is included as **Figure 11** of this narrative report.

Vehicle Data

The involved vehicle in this single vehicle run-off-road crash was a 2001 BMW 235i, 4-door sedan. The BMW was manufactured in March 2001 and was identified by Vehicle Identification Number (VIN): WBAAV33471E (production number deleted). The odometer reading was unknown. The placarded Gross Vehicle Weight Rating was 1,985 kg (4,376 lb). The rear-wheel drive platform was powered by a 2.8 liter, inline 6-cylinder engine linked to a 5-speed automatic overdrive transmission with a console mounted shifter. The service brakes were four-wheel disc with anti-lock. The vehicle was equipped with traction control and electronic stability control as standard equipment. The 325i was equipped with multi-spoke alloy wheels and Michelin MXV4 Plus performance all-season radial tires, size P205/55R16. The specific tire data at the time of the SCI inspection was as follows:

Position	Measured Pressure	Measured Tread Depth	Damage
LF	224 kPa (32.5 PSI)	7 mm (9/32”)	None, suspension and steering damage
LR	Tire Flat	6 mm (7/32”)	~300 degrees of circumferential abrasions to the bead lip
RF	259 kPa (37.5 PSI)	7 mm (9/32”)	None
RR	248 kPa (36 PSI)	6 mm (7/32”)	Debris embedded into bead

The interior of the BMW was configured with leather surfaced front bucket seats with adjustable head restraints and a two-passenger rear bench seat. All seated positions were equipped with adjustable head restraints that were in the full-down positions.

Crash Sequence

Pre-Crash

The 17-year old male driver of the BMW was traveling in a northeasterly direction on the two lane road at a high-rate of speed. The police estimated the initial speed of the vehicle at approximately 113 km/h (70+ mph) while the driver admitted to a speed of 97 km/h (60 mph). The posted speed was 64 km/h (40 mph). It was presumed that the driver approached the hillcrest at a high-rate of speed in an attempt to vault the vehicle over the down slope of the hill. As the BMW crested the hill, it initiated a slight clockwise yaw as it departed the right road edge. The BMW overrode a shallow drainage ditch and an earthen embankment.

Crash

The front center and right area of the BMW impacted a 42 cm (16.5”) diameter pine tree

(**Figure 3**) that resulted in an impact force of 12 o'clock. The impact deformed the entire frontal area of the vehicle and crushed the front bumper to a depth of 124 cm (48.75"). The damage algorithm of the WinSMASH program computed a total velocity change of 88 km/h (55 mph) with longitudinal and lateral components of -88 km/h (-55 mph) and -16 km/h (-10 mph).

The BMW deflected off the tree and rebounded in a rearward direction while rotating in a counterclockwise direction. The vehicle rotated approximately 150 degrees counterclockwise coming to rest with its center of gravity 2.6 m (8') rearward of its at crash position and 3.4 m (11') laterally to the right (**Figure 4**). At rest, the vehicle was facing in a westerly direction, diagonal to its initial trajectory.

A fire originated in the forward mid instrument panel area of the vehicle as it came to rest. The fire appeared to have spread slowly and was contained to the instrument panel area prior to being extinguished by the first arriving officer. A dry compound extinguisher was used to suppress the fire.



Figure 3. Roadside departure of the BMW.



Figure 4. Struck tree and rotation to final rest.

Post-Crash

Rescue personnel arrived on-scene and opened the left side doors to gain access to the passenger compartment of the vehicle. They also used hydraulic equipment to cut the right B-pillar and the front door hinges and removed the right doors and pillar as a single unit. Both teenage male occupants were removed from the vehicle and placed on backboards prior to ground ambulance transport to a regional trauma center. Both occupants were admitted for treatment of their injuries. The BMW sustained severe damage and was towed to police impound where he was held for this SCI investigation.

Vehicle Damage ***Exterior***

The BMW sustained severe frontal damage as a result of the impact with the tree. Maximum crush was 124 cm (48.75") located on the bumper beam 51.4 cm (20.25") right of center. The direct contact damage began at the centerline of the vehicle and extended 43 cm (17") to the right. The damage deformed the full frontal width of the vehicle and deformed the bumper beam to a U-shape. The Field L measurement of the combined direct and induced damage length was 42 cm (16.5") that spanned the corners of the

deformed bumper beam (**Figure 5**). A crush profile was measured along this damage with using six equidistant points and was as follows: C1 = 0 cm, C2 = 31 cm (12.25”), C3 = 122 cm (48”), C4 = 124 cm (48.75”), C5 = 122 cm (47.9”), C6 = 120 cm (47.4”). The Collision Deformation Classification (CDC) this tree impact was 32-FZEW-6. The 12 o’clock direction of force was incremented with a value of 20 to reflect the vertical displacement of the frontal structure (**Figure 6**).



Figure 5. Frontal view of the direct contact damage.



Figure 6. Lateral view documenting the extent of frontal crush. And vertical displacement.

As the frontal area of the vehicle crushed against the tree, the rear of the BMW pitched upward resulting in severe bending of the vehicle’s structure at the A- to B-pillar area. This upward deflection is reflected in the CDC noted above.

Both left side doors remained closed during the crash. Rescue personnel open both doors to gain access to the interior and occupants of the BMW. Due to the severe body damage to the vehicle, these doors would not re-latch post-crash. The right side doors were jammed closed by the severe deformation of the uni-body construction. Rescue personnel cut the right front door hinges and the left B-pillar and removed the right side doors from the vehicle to aid in the extrication of the front right occupant.

The laminated windshield was 100 percent cracked by displacement of the A-pillars and contact from the vehicle’s hood. The plastic laminate was torn along the right upper A-pillar. The left front door glazing was fractured while the left rear door and backlight glazing remained intact. The glazing in both right side doors was shattered. The sunroof was open at the time of the crash and remained intact.

Interior

The interior of the BMW sustained severe damage that was associated with intrusion of frontal components, occupant contact, and a crash-induced fire that involved the mid instrument panel area of the vehicle. Maximum intrusion involved 61 cm (24”) of rearward displacement of the right toe pan into the front right passenger’s position. The following table identifies the various intrusions by location, component, direction, and magnitude.

Position	Component	Direction	Magnitude
Front Left	Left aspect of mid instrument panel	Rearward	1 cm (0.5")
Front Left	Center hub of steering assembly	Forward	6 cm (2.5")
Front Left	Brake pedal	Rearward	8 cm (3")
Front Left	Left toe pan	Rearward	19 cm (7.5")
Front Right	Right instrument panel	Rearward	32 cm (12.5")
Front Center	Center mid instrument panel	Rearward	32 cm (12.4")
Front Right	Right toe pan	Rearward	61 cm (24")
Front Right	Right A-pillar at beltline	Rearward	31 cm (12.1")
Front Right	Right windshield header	Rearward	3 cm (1")
Front Right	Right floor	Vertically	8 cm (3")

The driver contacted the left mid and lower instrument panel and knee bolster with his knees and lower legs. The left mid panel was deformed by the knee contact and was evidenced by blue fabric transfer. His right knee contact was distorted by the fire.

The unrestrained driver loaded through the deployed air bag and deformed the lower steering wheel rim 2 cm (0.75") forward. In addition, the energy absorbing steering column compressed as evidenced by 1 cm (0.5") of right shear capsule separation. The driver's loading of the column and subsequent intrusion of the toe pan and front cowl resulted in vertical rotation of the steering column. The post-crash steering column angle was 75 degrees, 50 degrees vertical of its pre-crash angle. Although the column intruded into the driver's space, the center hub of the column was approximately 6 cm (2.5") forward of its pre-crash position.

The front right passenger's lower extremities contacted the intruding mid and lower instrument panel and the glove box door. He loaded the deployed front right air bag which was evidenced by body fluid that resulted from facial abrasions associated with flying glass.

A post-crash fire occurred within the center mid instrument panel of the vehicle. The fire was apparently slow in progression as it was suppressed by the first arriving officer with using a dry compound extinguisher. The compound was present over the frontal interior surfaces of the vehicle. The occupants were not affected by the fire in terms of thermal burns or inhalation issues.

Frontal Air bag System

The 2001 BMW 325i was equipped with dual stage frontal air bags for the driver and front right passenger positions. Both air bags deployed as a result of the severe frontal

crash with the tree. In addition to the frontal air bags, the BMW was equipped with safety belt buckle pretensioners. The driver was not restrained by the manual safety belt system; therefore the driver's side pretensioner did not fire. The front right passenger was restrained and this buckle pretensioner fired. Although this vehicle was equipped with an Event Data Recorder (EDR) that could be downloaded by the manufacturer only, the EDR was not removed by the SCI investigator at the request of NHTSA personnel; therefore the deployment stages are unknown.

The driver's air bag deployed from symmetrical cover flaps from the steering wheel mounted module assembly. The air bag was not tethered and was vented by a single 4 cm (1.75") diameter vent port located at the 12-o'clock sector of the air bag. The driver's air bag was approximately 58 cm (23") in diameter in its deflated state. The bag was partially fused due to the post crash fire. There was no distinct driver contact evidence to the air bag membrane. The following nomenclature was stamped on the air bag at the 12 o'clock sector:

BMW N113 10.0 – B3
>PA66+S1<
08 01 01
B1076 BS227 1S
DU-11.0014
TRS-TAKATA DE MEXICO

The front right passenger air bag deployed from a mid mount module that was concealed by a single cover flap. The top hinged flap measured 20 cm (8") vertically at the inboard side, 17 cm (6.6") at the outboard vertical edge, and 36 cm (14.25") horizontally along the top hinge point. The front right air bag was not tethered and was vented by two 6 cm (2.5") diameter ports located at the top panel of the bag at the 11 and 1 o'clock sectors. The face of the deployed air bag was 51 cm (20") in width and 56 cm (22") vertically. The top seam protruded 33 cm (13") from the mid panel while the maximum excursion of the non-tethered air bag was 6 cm (2.5"). Blood deposits were noted to the face of the air bag. There was no damage to the deployed front right air bag.

Side Impact Air Bag System

The BMW was equipped with front door mounted side impact air bags and a roof side rail mounted Head Protection System that consisted of tubular head air bags. These side impact air bags did not deploy in this severe frontal crash.

Manual Safety Belt Systems

The BMW was equipped with manual 3-point lap and shoulder belts for the four outboard seated positions. All safety belt systems utilized continuous loop webbing and sliding latch plates and webbing sensitive retractors. The driver's retractor was an emergency locking (ELR) while the remaining three utilized switchable ELR/Automatic Locking Retractors (ALR). Both front buckles were equipped with pyrotechnic retractors. The driver's belt system was not utilized in this crash; therefore there was no related loading to the safety belt system or firing of the buckle pretensioner (**Figure 7**).

The front right belt system displayed loading evidence that consisted on a probable D-ring transfer on the webbing 38-42 cm (15-16.5”) above the stop button. The full width of the latch plate was abraded on the back side from frictional interaction with the belt webbing. Rescue personnel cut the shoulder belt webbing 57-58 cm (22.5-23”) above the floor anchor (**Figure 8**). The front right buckle pretensioner fired as a result of the impact.



Figure 7. Non-fired driver's buckle pretensioner.



Figure 8. Cut front right passenger's belt webbing.

Occupant Demographics/Data

Driver

Age/Sex:	17 year old/Male
Height:	183 cm (72”)
Weight:	82 kg (180 lb), police estimate
BAC:	.04
Seat Track Position:	Rear third track position
Manual Safety Belt Usage:	None
Usage Source:	Vehicle inspection
Egress from Vehicle:	Removed by rescue personnel
Type of Medical Treatment:	Admitted to a regional trauma center for treatment of his injuries

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Open left femur fracture	Serious (851801.3,2)	Induced fractured from loading the lower instrument panel/knee bolster
Bilateral tibia and fibula fractures	Moderate (853404.2,1; 853404.2,2; 851605.2,1; 851605.2,2)	Intruding toe/floor pan
Fracture of the left clavicle	Moderate (752200.2,2)	Steering wheel rim
Severe chest wall contusion	Minor (490402.1,9)	Steering wheel rim
Unspecified scalp lacerations	Minor (190600.1,9)	Flying glass

Source – Trauma center records

Driver Kinematics

The driver of the 2001 BMW 325i was seated in a rear track position and was unrestrained. The lack of belt usage was determined from the observations of the first responders, the stowed and non-loaded condition of the safety belt system, and the non-actuated status of the buckle pretensioner. The driver was dressed in a T-shirt, denim jeans and athletic shoes.

At impact, the frontal air bag system deployed. The unrestrained driver initiated a forward trajectory in response to the frontal 12 o'clock impact force. His knees loaded the knee bolster and the lower instrument panel which intruded rearward into the driver's space. The left knee and lower leg deformed the lower panel left of the bolster. Blue fabric transfers from his denim jeans were present at the contact site. The energy transmitted through the knee resulted in an open fracture of the left femur. The right knee contact was altered by the post-crash fire. His feet and lower extremities loaded the toe and floor pan resulting in bilateral tibia and fibula fractures.

The driver's torso and face contacted the deployed driver's air bag. His loading force was transmitted through the air bag into the steering assembly. The lower steering wheel rim was deformed forward 1.9 cm (0.75"). The right steering column shear bracket was compressed 1 cm (0.5") while the left side remained fully engaged. Due to the severity of the crash and the upward motion of the rear of the vehicle at maximum engagement, the driver loaded through the deployed air bag and engaged the steering assembly, deflecting the column upward and forward to a measured



Figure 9. Driver trajectory and contact points.

column angle of 75 degrees, 50 degrees above the normal column angle. As result of the engaging the steering assembly, the driver sustained a chest wall contusion and a fracture of the left clavicle. Figure 9 is a view of the driver's trajectory and contact points.

The driver also sustained unspecified lacerations of the scalp which were attributed to flying glass or other loose debris within the passenger compartment.

Front Right Passenger

Age/Sex: 17 year old/Male
Height: 183 cm (74")
Weight: 84 kg (185 lb), police estimate
BAC: .12
Seat Track Position: Rear track position
Manual Safety Belt Usage: 3-point lap and shoulder belt
Usage Source: Vehicle inspection
Egress from Vehicle: Removed by rescue personnel
Type of Medical Treatment: Admitted to a regional trauma center for treatment of his injuries

Front Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Unspecified brain injury with swelling	Unknown (115099.7,0)	Acceleration/impact force
Dicing lacerations of the face	Minor (290602.1,9)	Flying glass
Bilateral lower leg injuries, NFS	Unknown (815099.7,0)	Right instrument panel/glove box door
Left ankle fracture, NFS	Minor (850299.1,2)	Intruding toe pan

Source – Verbal from trauma center

Front Right Passenger Kinematics

The front right passenger of the 2001 BMW was seated in a rear track position and restrained by the manual 3-point lap and shoulder belt system. Belt usage was confirmed by the observations of the first responders who cut the webbing 57-58 cm (22.5-23") above the floor anchor and from a probable D-ring transfer and the fired status of the buckle pretensioner.

At impact, the passenger air bag deployed as the front right passenger initiated a forward trajectory. He loaded the manual safety belt webbing and the deployed air bag with his chest and facial regions. The acceleration of the crash and the impact force resulted in an unspecified brain injury with swelling.

His knees and lower legs engaged the right instrument panel and the glove box door which resulted in lower leg injuries. He sustained a left ankle fracture from the intruding toe and floor pans (**Figure 10**). The front right passenger also sustained dicing lacerations of the face from flying glass that was captured in the deployed air bag. He rebounded into the front right position where he came to rest.



Figure 10. Lateral view of the front right passenger's position and the deployed air bag.

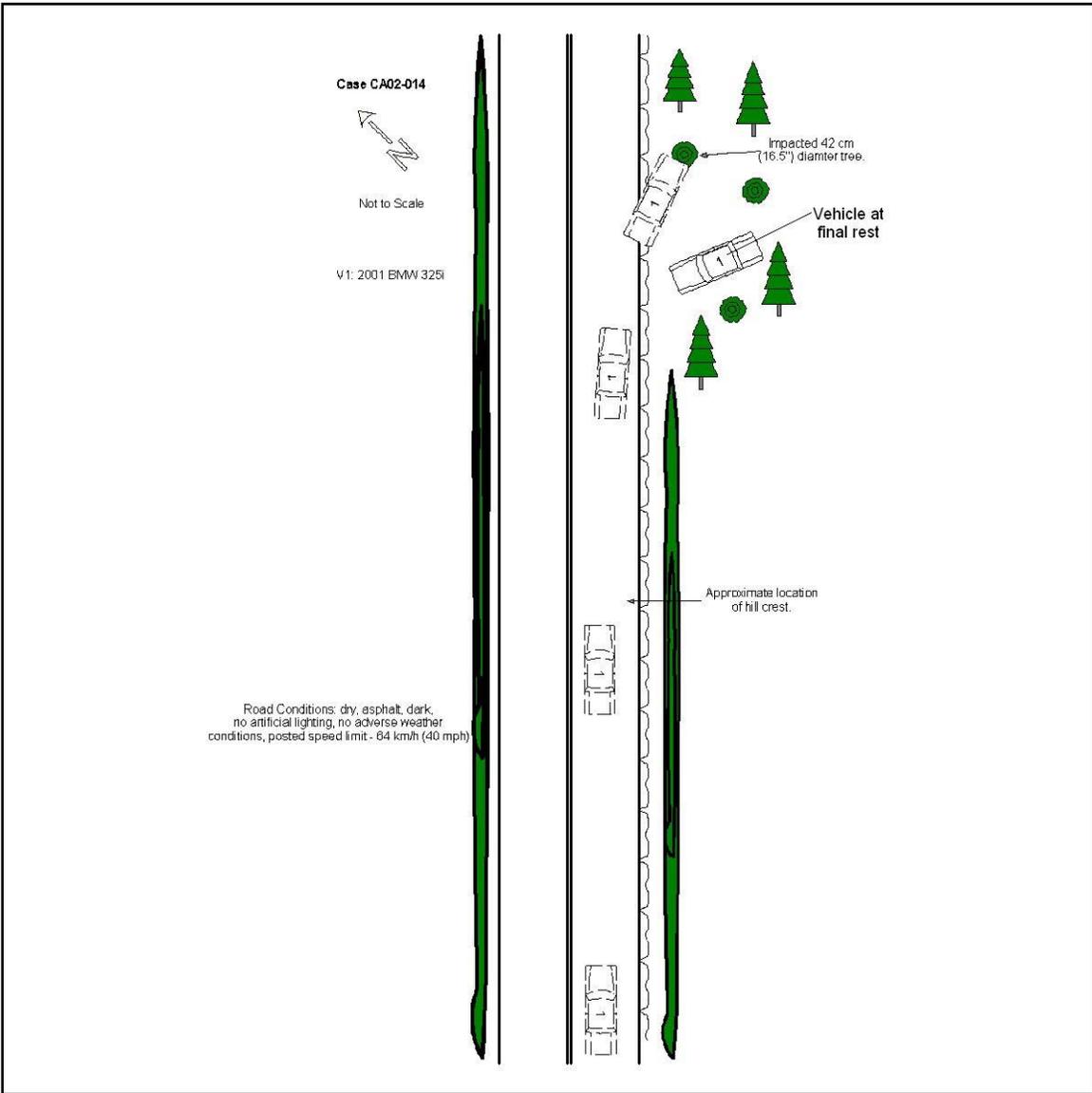


Figure 11 – Crash Schematic