TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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CALSPAN REMOTE SIDE IMPACT AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA97-011

VEHICLE - 1997 BMW 528I

LOCATION - NEBRASKA

CRASH DATE - DECEMBER, 1996

Contract No. DTNH22-93-Q-07222

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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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.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. CA97-011	*2. Government Accession No.*	*3. Recipient's Catalog No.*
4. Title and Subtitle Calspan Remote Side Impact Air Bag Deployment Investigation Vehicle - 1997 BMW 528i Location - Nebraska		*5. Report Date*: September, 1998 *6. Performing Organization Code*
7. Author(s) Crash Research Section		*8. Performing Organization Report No.*
9. Performing Organization Name and Address Transportation Sciences Crash Research Section Calspan Operations P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* 1115 (7300-7309) *11. Contract or Grant No.* DTNH22-94-D-07058
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date 12/96 *14. Sponsoring Agency Code*
15. Supplementary Notes Remote investigation		

16. Abstract

This remote investigation focused on a 1997 BMW 528i, 4-door sedan that was involved in an intersection crash with a 1974 GMC pickup truck. The BMW was equipped with frontal driver and passenger air bags, and a side impact air bag system for the two front seated positions. Both air bag systems deployed as a result of the right side impact sequence. A 3 year old male child passenger was seated in the right front position of the BMW and was unrestrained. He sustained multiple soft tissue injuries of the head and face from contact with the side impact air bag module cover flap.

The 1997 BMW sustained moderate right side damage that resulted in a 02 o'clock impact force (CDC of 02-RZAW-3) and a SMASH generated total delta V of 26 km/h (16 mph). The specific longitudinal and lateral components were -13 km/h (-8 mph) and -22km/h (-14 mph) respectively. These components were of sufficient magnitude to deploy the frontal and right side impact air bags. The driver of the BMW was a 39 year old male with a height of 180 cm (71") and weight of 86 kg (190 lb). He was not restrained by the manual 3-point lap and shoulder belt system. The driver responded to the 2 o'clock impact force by moving laterally right and forward. His sustained a left leg contusion from contact with the knee bolster. The 3 year old child occupant was unrestrained and was seated in the right front position with the seat track adjusted to a rear track position. At impact, the side impact air bag module cover flap opened at the designated tear points and struck the right aspect of the child's head. As a result, he sustained multiple soft tissue injuries (AIS-1) which included a laceration of the right eyelid, avulsion of the right face, contusion, abrasion, and laceration of the right face, and a laceration of the right outer ear. He was transported to a local hospital where he was admitted overnight for treatment and observation.

17. Key Words Frontal air bag system, Side impact air bag system, 2 o'clock impact force, AIS-1 injuries		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 7	*22. Price*

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Background

This remote air bag deployment investigation focused on a 1997 BMW 528i, 4-door sedan, that was involved in an intersection-type crash with a 1974 GMC pickup truck. The BMW was equipped with a frontal air bag system and a side impact air bag system. The right side impact deployed the frontal air bags and the right side impact air bag that was incorporated into the right front door panel. A 3 year old male was seated in the right front position of the BMW. He was not restrained in a child safety seat or by the vehicle's manual 3-point lap and shoulder belt system. The child sustained multiple lacerations of the right face from the deployment of the side impact air bag.

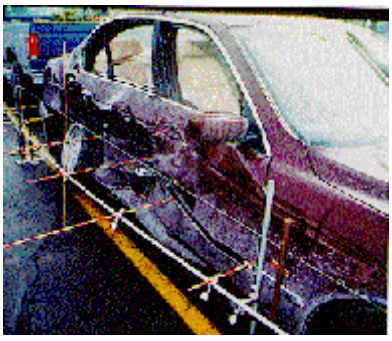

Figure 1. Right side damage to the BMW 528i.

The crash was assigned to the Calspan Special Crash Investigation team on March 13, 1997 for the preparation of a detailed summary report. This remote investigation was assigned to SCI due to the right front position of an unrestrained child occupant and his involvement with a frontal and side impact air bag.

Crash Sequence

The crash occurred at a four-leg intersection in a residential subdivision that was under construction, therefore there were no traffic controls regulating traffic flow through the intersection (refer to **Figure 1**). Both roadways were two lanes paved with concrete with a posted speed limit of 40 km/h (25 mph). The conditions were police reported as daylight, dry, with no visual obstructions.

Figure 2. Overall view of the crash scene.

The 39 year old male driver of the 1997 BMW was traveling in a northerly direction at a driver estimated speed of 32 km/h (20 mph). The driver was not aware of an approaching 1974 GMC pickup truck that was traveling in a westerly direction, therefore he did not initiate avoidance actions (i.e., braking) as he entered the four-leg intersection.

The driver of the GMC pickup truck was searching for a job sight and had directed his attention to his right, away from the travel path of the BMW, as he approached the intersection. He estimated his travel speed at 48 km/h (30 mph).

The full frontal area of the pickup truck impacted the right passenger side area of the BMW in a T-configuration (refer to **Figure 2**). Resultant directions of force were within the 2 o'clock sector for the struck BMW and 11

o'clock for the pickup truck. The damage algorithm of the SMASH program computed total velocity changes of 26 km/h (16 mph) and 15 km/h (9 mph) for the BMW and GMC pickup truck respectively. Specific longitudinal and lateral components for the BMW were -13 km/h (-8 mph) and -22 km/h (-14 mph) which were sufficient to deploy both the frontal driver and passenger air bag system and the right front door mounted side impact air bag. **Figures 3 and 4** identify the frontal damage to the GMC pickup truck.

The crash occurred rearward of the BMW's center of gravity which induced a clockwise (CW) rotation as the vehicle was redirected laterally to its left. The lateral component of the pickup truck's impact force induced a CW rotation. The damage pattern was documented to the leading aspect of the right front fender and bumper corner that was associated with a subsequent sideslap with the pickup truck. There was no related damage to the pickup truck. Based on the dynamics of the crash and the rotation of the vehicles, the BMW would had to rotated rapidly CW and engaged with the right front fender area of the truck. The damage pattern to the BMW could have resulted from impact with a fixed object at the crash scene. This scenario was not documented by the investigating officer.

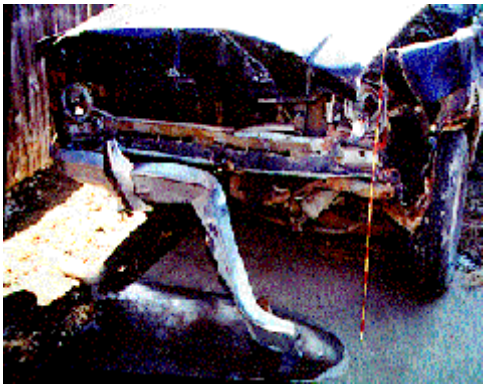

Figure 3. Frontal damage to the GMC pickup truck.

Figure 4. Right front three-quarter view of the GMC pickup truck.

There was no physical evidence at the crash scene to support impact and final rest positions of the involved vehicles. The investigating officer noted on his report schematic that the BMW came to rest off-road at the northwest quadrant of the intersection, facing in a westerly direction. This impact displaced final rest position would have required approximately 270 degrees of post-impact CW rotation. The GMC pickup truck rotated approximately 90 degrees CW, coming to rest west of the intersection with the frontal area of the vehicle straddling the north edge line.

The driver of the BMW exited his vehicle unassisted, however, due to the injury of his child right front passenger, the child remained in the vehicle for the arrival of the paramedics. The 25 year old male driver of the GMC pickup truck exited his vehicle at the scene and was not injured.

Air Bag Vehicle Damage

Exterior: The BMW was initially struck on the right passenger compartment area by the full frontal area of the GMC pickup truck. The direct contact damage on the mid aspect of the right front door and extended 203 cm

(80") rearward to the mid aspect of the right rear quarter panel. Contact damage from the hood of the pickup truck extended above the beltline of the BMW onto the right upper B-pillar. Maximum crush was documented at 33 cm (13") located at the mid aspect of the right rear door. The combined induced and direct contact damage length was 318 cm (125") which extended from the leading edge of the right front door to the rear bumper corner. The crush profile at mid door level was as follows: C1 = 0 cm, C2 = 11 cm (4.3"), C3 = 27 cm (10.6"), C4 = 33 cm (13"), C5 = 6 cm (2.4"), C6 = 0 cm. The Collision Deformation Classification (CDC) for this impact sequence was 02-RZAW-3.

The secondary impact damage to the right frontal area of the BMW was minor in severity. The longitudinal abrasions extended across the front right bumper fascia and onto the forward aspect of the right front fender. Maximum crush was estimated at 5 cm (2") located on the fender immediately rearward of the turn signal assembly (refer to **Figure 5**).

Figure 5. Secondary damage to the right front fender area.

Interior: The interior damage to the BMW resulted from air bag deployment and intrusion of the right side components. The frontal and side impact air bag systems deployed as designed from the respective module covers. The front passenger air bag module cover flap opened at the designated tear points and impacted and fractured the laminated windshield adjacent to the right windshield header area. The expanding front passenger air bag membrane contacted the interior rear view mirror. The contact separated the mirror from the swivel mounting stalk.

Maximum intrusion involved 17.0 cm (6.7") of lateral displacement of the lower right B-pillar into the right rear seated position. Additional intrusions included 10 cm (4") of lateral displacement of the right front door panel, 4.0 cm (1.6") of sill displacement into the right front position, 14.0 cm (5.5") of lateral displacement of the right rear door panel and sill.

Air Bag Vehicle/Automatic Restraint Systems

The involved 1997 BMW 528i, 4-door sedan was identified by vehicle identification number (VIN) WBADD63220VB (production number deleted). The vehicle was equipped with a Supplemental Restraint System (SRS) and an Advanced Side Airbag Protection (ASAP) system. Both systems deployed as a result of the initial intersection crash with the GMC pickup truck (refer to **Figure 6**). The SRS consisted of frontal air bags for the driver and right passenger positions. In addition to the frontal air bags, the SRS utilized automatic (pyrotechnic) seat belt tensioners in the front belt systems. The belt tensioners were located in the buckle assemblies of the manual belt systems and tighten both the lap and shoulder belts. It should be noted that the front belt systems were also equipped with manual

Figure 6. Overall interior view of the deployed frontal and side impact air bags.

height adjusters (D-rings). The vehicle was equipped with a dual threshold deployment system that monitored belt usage. In the event the front seat belt systems were not used, such as in this crash the frontal air bag system would a lower threshold to provide protection to the unbelted front seat occupant(s). Belt usage would trigger air bag deployment at a higher threshold, thus reducing unnecessary air bag deployment in minor crashes.

The driver air bag deployed from nearly symmetrical H-configuration cover flaps from a 4-spoke steering wheel rim. The horizontal width of the cover flaps was 15 cm (6") with vertical measurements of 9.0 cm (3.5") and 7.0 cm (2.8") respectively for the upper and lower flaps. The air bag was 60 cm (24") in diameter and was tethered. Two vent ports were located on the back side of the air bag at the 11 and 1 o'clock sectors. There was no damage or contact evidence reported to the driver air bag.

Figure 7. Front right mid mount air bag module cover.

The front passenger air bag deployed from a top mount module assembly (refer to **Figure 7**) that was concealed within the right upper instrument panel. The cover flap was 33 cm (13") in width (horizontally) and 20 cm (8") in height. Based on the NASS photographs, the front right module cover flap was tethered at the top edge which allowed the perimeter of the flap to totally disengage from the upper instrument panel. As the system deployed, the cover flap impacted and fractured the laminated windshield adjacent to the header area.

The front passenger air bag membrane was measured by the NASS researcher at 53 cm (21") horizontally and 62 cm (24") vertically. Although not documented, there were no vent ports visible in the provided photographs. The photographs did suggest that the front right passenger air bag was not tethered by internal straps or bands. Several blood spatters were noted to the center face area of the bag (refer to **Figure 8**). There was no direct occupant contact damage noted to the bag.

Figure 8. Deployed front right air bag with blood stain.

Figure 9. Deployed right side impact air bag.

The ASAP system consisted of side impact air bags that were mounted with the rear third aspect of the front door panels above the level of the armrests (refer to **Figure 9**). A single point electronic sensing system was utilized to detect the lateral crash pulse and deploy the respective side impact air bag. The right side impact air bag deployed as a result of the initial impact with the right side of the vehicle. The air bag was concealed within a dual cover flap configuration. The single outer flap was trapezoidal in shape (refer to **Figure 10**) and consisted of a perforated segment of the padded door panel that was

backed by a rigid foam panel. The cover flap appeared to have been hinged at the bottom segment thus opening on an inward and downward trajectory toward the front passenger seat.

The side impact air bag membrane deployed in both a forward and upward direction with afforded protection to the occupant above the level of the armrest to the beltline area (refer to Figure 11). The bag was tethered by an internal tether panel that was sewn to the face of the bag. There was no direct venting of the bag into the passenger compartment of the vehicle. There was no documented contact evidence on the cover flap of the deployed right side impact air bag.

Figure 10. Location of the right side impact air bag.

Figure 11. Side impact air bag cover flap.

Driver Demographics

Driver:	39 year old male
Height:	180 cm (71")
Weight:	86 kg (190 lb)
Manual Restraint	
Usage:	None, 3-point lap and shoulder belt was available
Usage Source:	Vehicle inspection, driver interview
Eyeware:	None
Medical Treatment:	None

Driver Injuries

Injury	Injury Severity (AIS 90)	Injury Mechanism
Contusion of the anterior left leg, distal to the knee	Minor (890402.1,2)	Knee bolster

Driver Kinematics

The driver of the BMW was in a presumed normal posture with his seat track adjusted to a rear track position. He stated that he was not restrained by the manual 3-point lap and shoulder belt system. There was no evidence within the vehicle to support routine usage prior to the crash. At impact, the frontal driver and right front passenger air bag system deployed as the driver probably moved on a lateral trajectory to his right in response to the 2 o'clock impact force. The anterior aspect of his left lower leg probably contacted the knee bolster which resulted in a soft tissue contusion of the leg, distal to the knee. His left thoracic area probably contacted the deployed driver air bag. There was no contact evidence within the vehicle to support his trajectory and no additional injury. He probably rebounded into the left seat back and came to rest in an upright attitude. The driver refused medical treatment for the leg contusion.

Passenger Demographics

Right Front Passenger:	3 year old male
Height:	91 cm (36")
Weight:	15 kg (32 lb)
Manual Restraint Usage:	None, 3-point lap and shoulder belt system was available, however, this child should have been positioned in a forward facing child safety seat in the center rear seat position of the vehicle.
Usage Source:	Driver interview, vehicle inspection
Medical Treatment:	Hospitalized overnight for treatment of his injuries and observation

Passenger Injuries

Injury	Injury Severity (AIS 90)	Injury Mechanism
Laceration of the right eyelid	Minor (297602.1,1)	Side impact air bag module cover flap
Avulsion of the right face	Minor (290802.1,1)	Side impact air bag module cover flap
Contusion of the right face	Minor (290402.1,1)	Side impact air bag module cover flap
Abrasion of the right face	Minor (290202.1,1)	Side impact air bag module cover flap

Injury	Injury Severity (AIS 90)	Injury Mechanism
Laceration of the right face (cheek)	Minor (290602.1,1)	Side impact air bag module cover flap
Laceration of the right outer ear	Minor (290602.1,1)	Side impact air bag module cover flap
Laceration of the right upper lip	Minor (290602.1,8)	Side impact air bag module cover flap

Passenger Kinematics

The 3 year old child passenger was seated in the BMW on the right front seat cushion with his back resting against the back cushion at impact. The seat was adjusted to a rear track position with the seat back slightly reclined. In this position, the child passenger was distant to the front passenger air bag module, however, his head was in close proximity to the door mounted side impact air bag module cover. He was not restrained by the manual belt system. This child should have been positioned in a forward facing child safety seat in the center rear of the vehicle.

At impact with the GMC pickup truck, the frontal and right side impact air bag systems deployed. There was no apparent interaction between the child passenger and the deploying non-tethered front right air bag. Based on the photographs, the front right module cover flap appeared to have been tethered at the top forward seam which allowed the cover flap to contact and fracture the laminated windshield below, but adjacent to the right sunvisor.

The right side impact air bag deployed from a single cover flap that was hinged at the bottom from the rear third area of the door panel. The cover flap contacted the right head and facial areas of the child occupant which resulted in multiple soft tissue injuries (AIS-1). These injuries included a laceration of the right eyelid, an avulsion/contusion/abrasion of the right face, a laceration of the right cheek, a laceration of the right outer ear, and a laceration of the right upper lip.

The child occupant probably came to rest within the right frontal area of the vehicle. Several areas of blood were noted within the vehicle, however, these areas probably resulted from movement within the vehicle post-crash.

The child was subsequently removed from the BMW by rescue personnel and transported by ambulance to a local hospital where he was treated for his soft tissue injuries and admitted overnight for observation.