

**TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER**

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**GENERAL DYNAMICS REMOTE ADVANCED OCCUPANT PROTECTION SYSTEM
INVESTIGATION**

SCI TECHNICAL SUMMARY REPORT

NASS/SCI COMBO CASE NO. - 02-011-011C

VEHICLE – 2001 BMX X5

LOCATION - STATE OF MICHIGAN

CRASH DATE – JANUARY 2002

Contract No. DTNH22-01-C-17002

Prepared for:

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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>6. Abstract This remote investigation focused on the performance of the Advanced Occupant Protection System (AOPS) features in a 2001 BMW X5 sport utility vehicle. The AOPS included dual stage frontal air bags, an occupant sensing system for the front right seating position, and safety belt buckle pretensioners. In addition to the AOPS, the BMW was equipped with door panel mounted side impact air bags and a Head Protection System (HPS) that consisted of roof side rail mounted air bags for the front occupant positions. The BMW was occupied by an unrestrained 46-year-old male driver. The X5 was involved in a run-off-road crash resulting in frontal impacts with a stop sign, two trees and a mile marker post. The tree impact resulted in the deployment of the driver's frontal air bag. Although there was no direct side impact associated with this crash sequence, the door panel mounted side impact air bag deployed. The HPS did not deploy. The BMW came to rest and a small fire ensued in the center instrument panel. The BMW was equipped with an Event Data Recorder (EDR) that was retrieved from the vehicle and provided to BMW for download. The recorded data identified that the frontal air bag deployed both stages and that the safety belt pretensioners did not fire. The driver did not utilize the safety belt; therefore the AOPS did not fire the pretensioners. The driver sustained a left eyelid contusion, a superior facial abrasion, nasal rupture of the mucosal/vessels, posterior cervical spine facet fracture, and a posterior cervical spine fracture of the transverse process. He was transported by ambulance to a local hospital where he was diagnosed for his injuries. The driver was despondent over the crash and departed the hospital against the advice of the medical staff.</p>			
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TABLE OF CONTENTS

BACKGROUND	1
SUMMARY	2
<i>CRASH SITE</i>	2
<i>VEHICLE DATA – 2001 BMW X5</i>	2
<i>CRASH SEQUENCE</i>	2
<i>PRE-CRASH</i>	2
<i>CRASH</i>	2
<i>POST-CRASH</i>	3
<i>VEHICLE DAMAGE</i>	4
<i>EXTERIOR DAMAGE – 2001 BMW X5</i>	4
<i>INTERIOR DAMAGE – 2001 BMW X5</i>	4
<i>MANUAL RESTRAINT SYSTEMS– 2001 BMW X5</i>	5
<i>ADVANCED OCCUPANT PROTECTION SYSTEM – 2001 BMW X5</i>	5
<i>SIDE IMPACT AIR BAG SYSTEM - 2001 BMW X5</i>	6
<i>EVENT DATA RECORDER – 2001 BMW X5</i>	7
<i>OCCUPANT DEMOGRAPHICS – 2001 BMW X5</i>	7
<i>DRIVER</i>	7
<i>DRIVER INJURIES</i>	7
<i>DRIVER KINEMATICS</i>	7
<i>MEDICAL TREATMENT</i>	8
<i>FIGURE 14: SCENE SCHEMATIC</i>	9

**GENERAL DYNAMICS REMOTE ADVANCED OCCUPANT PROTECTION
SYSTEM INVESTIGATION
SCI SUMMARY TECHNICAL REPORT
NASS/SCI COMBO CASE NO. 02-011-011C
SUBJECT VEHICLE – 2001 BMW X5
LOCATION - STATE OF MICHIGAN
CRASH DATE - JANUARY 2002**

BACKGROUND

This remote investigation focused on the performance of the Advanced Occupant Protection System (AOPS) features in a 2001 BMW X5 sport utility vehicle. The AOPS included dual stage frontal air bags, an occupant sensing system for the front right seating position, and safety belt buckle pretensioners. In addition to the AOPS, the BMW was equipped with door panel mounted side impact air bags and a Head Protection System (HPS) that consisted of roof side rail mounted air bags for the front occupant positions. The BMW was occupied by an unrestrained 46-year-old male driver. The X5 (**Figure 1**) was involved in a run-off-road crash resulting in frontal



Figure 1. Front damage to the BMW X5 sport utility vehicle.

impacts with a stop sign, two trees and a mile marker post. The tree impact resulted in the deployment of the driver's frontal air bag. Although there was no direct side impact associated with this crash sequence, the door panel mounted side impact air bag deployed. The HPS did not deploy. The BMW came to rest and a small fire ensued in the center instrument panel. The BMW was equipped with an Event Data Recorder (EDR) that was retrieved from the vehicle and provided to BMW for download. The recorded data identified that the frontal air bag deployed both stages and that the safety belt pretensioners did not fire. The driver did not utilize the safety belt; therefore the AOPS did not fire the pretensioners. The driver sustained a left eyelid contusion, a superior facial abrasion, nasal rupture of the mucosal/vessels, posterior cervical spine facet fracture, and a posterior cervical spine fracture of the transverse process. He was transported by ambulance to a local hospital where he was diagnosed for his injuries. The driver was despondent over the crash and departed the hospital against the advice of the medical staff.

This crash was identified by the National Automotive Sampling System (NASS) PSU 11 during the weekly sampling of Police Accident Reports (PAR's) and was selected as CDS Case No. 02-011-011C. The NASS PSU performed the vehicle and scene inspections. Due to the presence of the AOPS and the cervical spine injuries sustained by the driver, NHTSA assigned the tasks of case review and report preparation to the Veridian SCI team.

SUMMARY

Crash Site

The crash occurred at a “T” intersection of an east/west roadway that intersected a north/south roadway. At the time of the crash, it was dark and the road was dry with adverse weather conditions. The east/west roadway was configured with two travel lanes in each direction that were separated by a double-yellow centerline. The roadway curved left for westbound travel with a downhill grade. The east/west roadway was bordered with a white fog line on the north and south road edge. Traffic flow through the intersection was not controlled for the east/west travel lanes. The posted speed limit for the east/west roadway was 80 km/h (50 mph). The NASS scene schematic is included as **Figure 12** of this report.

Vehicle Data – 2001 BMW X5

The 2001 BMW X5 was identified by the Vehicle Identification Number (VIN): WBAFA53571 (production sequence omitted). The odometer reading was unknown due to lack of power to the vehicle at the time of the inspection. The vehicle was a four-door sport utility vehicle that was equipped with a 3.0-liter, 6-cylinder engine, 4-wheel disc brakes with anti-lock, all-wheel drive, and a 4-speed automatic transmission. The tires on the BMW were Michelin Energy Radial XSE, size P235/65R17. The 2001 BMW was configured with front bucket seats and height adjustable head restraints. The driver’s seat was equipped with power adjustments for the seat track and recline adjustments. The rear seat was configured with a three-passenger bench seat with height adjustable head restraints.

Crash Sequence

Pre-Crash

The 46-year old male driver of the 2001 BMW X5 sport utility vehicle was traveling in a westerly direction on the two-lane road on an approach to the three-leg T-intersection (**Figure 2**). As the driver exited the curve, he allowed the vehicle to drift to the right onto the intersecting roadway. The BMW traversed the mouth of the intersection in a tracking mode and departed the northwest corner of the rural intersection. There was no physical evidence at the scene to support avoidance maneuvers (i.e., braking, steering). The driver’s loss of control was attributed to possibly falling asleep at the wheel while driving under the influence of alcohol.



Figure 2. Pre-crash approach to the intersection.

Crash

The frontal area of the BMW X5 impacted a closely spaced cluster of fixed objects that were located outboard of the northwest corner of the intersection. The front right area impacted a stop sign post that resulted in minor damage to the front bumper fascia and

hood. The front left area impacted a mile marker post as evidenced by a vertically oriented dent to the hood face. Both impacts resulted in force directions of 12 o'clock. The bumper damage resulting from these impacts was obscured by the subsequent tree impact.

The center frontal area of the X5 impacted a tree cluster that was located between the sign posts (**Figure 3**). The 12 o'clock direction of force impact crushed the frontal structure of the vehicle. The damage algorithm of the WinSMASH program was utilized by the SCI investigator to compute a revised total velocity



Figure 3. Struck objects by the frontal area of the BMW.

change of 25.0 km/h (15.5 mph) with longitudinal and lateral components of -25.0 km/h (-15.5 mph) and 0 km/h respectively. The impact was sufficient to deploy the driver frontal air bag and the Battery Safety Terminal (BST). The EDR data that was downloaded by BMW for this vehicle indicated a Stage 2 deployment for the driver's air bag, with Stage 2 deploying 35 ms after Stage 1 was deployed. The driver's seat belt buckle pretensioner did not deploy. The EDR data also indicated that the front right seat was not occupied, therefore the front right air bag did not deploy.

The tree impact was located slightly offset to the right of center of the BMW, which induced a clockwise (CW) rotation to the vehicle as it crushed to maximum engagement. The BMW X5 rotated approximately 100 degrees CW coming to rest perpendicular to the travel lanes, with its center of gravity resting near the centerline of the east/westbound roadway.

The left door mounted side impact air bag deployed during the crash; however, the left side HPS did not deploy. There was no side impact crash during this event to warrant the deployment of the side air bag system. The vehicle did rotate CW, which resulted in a lateral deceleration due to the side slipping of the left side tires. This deceleration should not have produced a lateral pulse sufficient to deploy the side air bag system.

As the BMW came to rest, an instrument panel fire originated in the center mid instrument panel. This fire did not result in significant damage to the vehicle.

Post-Crash

A motorist, who was following the BMW, witnessed and reported the crash. The driver of the BMW was removed from the vehicle by rescue personnel and transported to a local hospital where he was evaluated for injury and diagnosed with the cervical vertebrae fractures. The driver, against the advice of the physicians, refused additional treatment and left the hospital despondent over the crash.

Vehicle Damage

Exterior Damage – 2001 BMW X5

The 2001 BMW X5 sustained moderate frontal damage as a result of the impacts with the multiple fixed objects (**Figure 4**). The frontal damage from the stop sign consisted of a narrow vertically dent to the hood that was located approximately 25.0 cm (10.0”) right of the centerline. The Collision Deformation Classification for this impact was 12-FREN-1. The second impact with a mile marker post and was located 20.0cm (8.0”) left of center and was approximately 10.0cm (4.0”) in width. The Collision Deformation Classification for this impact was 12-FLEN-1. The subsequent tree impact deformed the frontal structure and separated the bumper system (fascia and beam) from the vehicle. The right outboard aspect of the bumper beam was attached to the right frame rail. The remainder of the beam had separated from the BMW, exposing both frame rails.



Figure 4. NASS image of crush profile.

The tree impact resulted in moderate frontal damage. The NASS researcher documented the direct contact damage from the tree impact on the separated bumper fascia. The damage began 44.0 cm (17.5”) inboard of the front left bumper corner and measured 48.0 cm (18.9”) in length. The combined direct and induced damage length (Field L) was 148.0cm (58.3”), which spanned the full frontal width of the vehicle. Due to the separation of the bumper beam, the researcher estimated a crush profile at bumper level. These estimated crush measurements were as follows: C1= 6.0 cm (2.4”) C2= 23.0 cm (9.1”) C3= 40.0 cm (15.7”) C4= 29.0 cm (11.4”) C5= 12.0 cm (4.7”) C6= 3.0 cm (1.2”). The Collision Deformation Classification for this impact was 12-FDEW-2. It should be noted that the SCI review of the NASS EDCS resulted in several enhancements to the electronic file. The right lateral shift was removed from the CDC (60 incremented to the 12 o’clock direction of force) and the documented crush was considered an estimate of the bumper beam profile. The calibrated measurement rods were not positioned against the structure of the vehicle (i.e., frame rails and lower radiator support).

Interior Damage – 2001 BMW X5

The 2001 BMW X5 sustained moderate interior damage as a result of the crash. The damage consisted of occupant contacts to the interior components (**Figures 5 and 6**) and minor fire damage to the center instrument panel. There were no intrusions of interior components into the passenger compartment. The unrestrained driver was probably out of position forward at impact with the tree cluster. The expanding air bag contacted his face. His torso subsequently loaded through the air bag and deformed the



Figure 5. Occupant contact to sunvisor and headliner.

steering wheel rim. The lens for the center front dome light was cracked and the rear view mirror was displaced, consisted with a fling related contact from the driver's right hand. The left A-pillar was scuffed indicating a fling related contact from the driver's left hand. The driver's head impacted and deformed the sun visor and cracked the vanity mirror in the sun visor. Additionally, his head scuffed the headliner aft of the stowed visor location. Strands of hair were noted in the area of the headliner contact. The driver's left knee contacted and deformed the knee bolster. The researcher documented the front left seat back as deformed by occupant contact. This probably resulted from the driver rebounding into the seat back where he came to rest. The damage from the fire was contained to the interior of the center instrument panel air ducts, above the radio cluster (**Figure 7**). The fire melted the center air vents and the inner parts of the instrument panel. The minor severity fire did not require extinguishing.



Figure 6. Deformed steering wheel rim and occupant contact lower left knee bolster.



Figure 7. Fire damage to center instrument panel.

Manual Restraint Systems– 2001 BMW X5

The 2001 BMW was equipped with manual 3-point lap and shoulder belts for all five seated positions. The front safety belts were equipped with buckle pretensioners. The driver's safety belt was configured with a sliding latch plate and a belt-sensitive, Emergency Locking Retractor (ELR). The front right seat was not occupied; therefore the pretensioner did not fire. The remaining safety belts were configured with sliding latch plates and switchable ELR / Automatic Locking Retractors (ALR).

Advanced Occupant Protection System – 2001 BMW X5

The 2001 BMW X5 AOPS consisted of dual stage frontal air bags for the driver and front right passenger positions, occupant sensing for the front right seating position and safety belt buckle pretensioners. The driver's safety belt was not used in the crash and the pretensioner did not actuate (**Figure 8**). The driver's frontal air bag deployed (**Figure 9**) as a result of the impact with the tree. The EDR data indicated that both stages of the air bag deployed. The air bag module consisted of two cover flaps that had a common width of 16.0 cm (6.3"). The upper flap was 6.0cm (2.4") in height while the lower flap measured 7.0cm (2.8") in height. The diameter of the air bag was 57.0 cm (22.4"), measured in its deflated state. The bag was vented by two ports located at the 11 and 1 o'clock positions on the backside of the bag membrane. The air bag was tethered

internally by two tethers. No damage was documented to the deployed frontal air bag. The front right seat was not occupied; therefore the AOPS system did not deploy the air bag or the pretensioner.



Figure 8. Non-fired status of the front left buckle pretensioner.



Figure 9. Deployed front left air bag.

Side Impact Air Bag System - 2001 BMW X5

The 2001 BMW X5 was equipped with side impact air bags and a Head protection System (HPS) for the front-seated positions. The side impact air bags were located in the front door panels (**Figure 10**) and the HPS were located in the roof side rails (**Figure 11**), tethered between the A- and C-pillars. The side impact air bag system utilized impact sensors that were located under the front seats near the B-pillars. Although the BMW did not sustain a side impact event in this crash, the front left door mounted side impact air bag deployed. The HPS in the left roof side rail did not deploy. Based on previous SCI investigations, this side impact air bag system should have deployed both the left door and HPS air bags. The BMW did undergo a lateral deceleration that was associated with the post-crash spin-out. This event should not have produced the required lateral deceleration required to deploy the side impact air bag system.



Figure 10. Deployed door panel mounted side impact air bag.



Figure 11. Identification acronym for the non-deployed HPS at the left pillar.

Event Data Recorder – 2001 BMW X5

The 2001 BMW X5 was equipped with an Event Data Recorder (EDR). The EDR was removed from the vehicle by the NASS researcher and was forwarded by NHTSA to BMW for download. The EDR data was electronically forwarded to NHTSA, then to the SCI team where it was evaluated and compiled into this summary report. The EDR data indicated a Stage 2 deployment for the driver’s air bag, with Stage 2 deploying 35 ms after Stage 1 was deployed. The EDR also indicated that driver was not belted at the time of the air bag deployment, therefore the driver’s seat belt buckle pretensioner did not fire. Also the EDR indicated that the Battery Safety Terminal (BST) was triggered which eliminated power to the vehicle. Furthermore, the EDR indicated that and the front right seat was not occupied. The EDR also recorded four fault codes, however, the faults were unknown.

Occupant Demographics – 2001 BMW X5

Driver

Age/Sex: 46-year old/Male
Height: 180 cm (71”)
Weight: 88 kg (194 lb)
Seat Track Position: Middle position
Manual Restraint Use: Manual 3-point lap and shoulder belt not use
Usage Source: Vehicle inspection
Eyewear: Unknown
Type of Medical Treatment: Transported by ambulance to a local hospital, treated for his injuries, and left the ER against hospital advice

Driver Injuries

Injury	Injury Severity	Injury Mechanism
Anterior facet fracture of C6	Serious (650222.3,6)	Driver’s frontal air bag
Posterior transverse process fracture of C5	Moderate (650220.2,6)	Driver’s frontal air bag
Left eyelid contusion	Minor (297402.1,2)	Driver’s frontal air bag
Forehead abrasion	Minor (290202.1,7)	Driver’s frontal air bag
Central nose-rupture of mucosal/vessels	Minor (251090.1,4)	Driver’s frontal air bag

Driver Kinematics

The driver of the BMW was initially presumed to have been seated in an upright driving posture with the seat track adjusted to a mid track position. This seat track position, in combination with his control loss that was possibly related to falling asleep and alcohol involvement, placed the driver out-of-position forward with respect to the steering assembly and the frontal air bag. He was not restrained by the manual safety belt system. The lack of belt usage was determined from the interior occupant contact points and the non-fire status of the safety belt buckle pretensioner.

The initial impacts with the signposts possibly displaced the driver forward as he responded to the 12 o’clock impact forces. At impact with the tree cluster, the frontal

driver air bag deployed. At deployment, the driver was positioned within the deployment path of the air bag. The expanding air bag contacted the face of the driver, which resulted in a left eyelid contusion, a forehead abrasion, and a rupture of the nasal mucosal vessels. The continued expansion of the air bag and the subsequent deployment of the second stage probably rotated the driver's head, which resulted in a torsional or extension motion of the neck. This air bag induced motion fractured the transverse process at C5 and the facet at C6. These injuries resulted in numbness of the right hand.

The air bag expansion elevated the driver in a vertical and rearward direction as he rebound from his initial forward trajectory. His superior scalp impacted and deformed the left sun visor. The contact also fractured the integral vanity mirror of the visor. His head scuffed the headliner. Strands of hair were noted at the location of the headliner contact.

The driver's chest loaded through the air bag and deformed the upper aspect of the steering wheel rim. No injury resulted from the chest loading. His left knee contacted and deformed the left aspect of the knee bolster. Although no injury occurred to the left knee, the driver complained of pain over the right knee.

The initial expansion of the air bag against his forearms possibly separated his hands from the steering wheel rim. A scuffmark to the left A-pillar was consistent with a fling-related hand contact. The fractured plastic lens on the roof mounted dome light and rear view mirror deflected forward could have resulted from a right hand fling-related contact.

The driver rebounded into the front left seat back where he came to rest. The NASS researcher noted that the seat back appeared to be deformed rearward, indicating a possible loading force by the driver during his rebound trajectory.

Medical Treatment

The driver was transported by ambulance to the emergency room of a local trauma center. The Emergency Medical Technicians (EMT's) noted the presence of alcohol on the driver. Upon arrival at the hospital, the driver was evaluated for injury. His head and cervical spine were evaluated using x-ray and CT scans. The CT scan of the neck revealed the facet fracture of C5. During his brief stay at the hospital emergency room, the driver became despondent and departed the facility against the orders of the medical staff. He did return to the medical facility after complaining of numbness and weakness to his right hand. His C-spine injury was confirmed and he was advised to consult with the Neurosurgery department as an outpatient.

Figure 12: Scene Schematic

