

Advanced Occupant Protection Systems Investigation / Single Vehicle Rollover
Dynamic Science, Inc. / Case Number: DS03003
2003 BMW M3
Washington
December 2002

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract This on-scene in-depth investigation focused on a crash in which the case vehicle was equipped with a Rollover Safety System. This single vehicle rollover crash occurred in December, 2002 at 1358 hours. It was overcast at the time and the bituminous/asphalt roadway surface was wet. The crash took place on the roadside of a narrow, two-lane undivided roadway located in a suburban neighborhood of Washington state. At the crash location, the roadway consists of a series of curves with a positive/ uphill grade. There is a -45% grade embankment located at the east roadside while a steep hill is at the west side of the roadway. There are no traffic controls and the speed limit is 48 km/h (30 mph). The case vehicle is a 2003 BMW Z3 two-door convertible that was being driven by a restrained 47-year-old male. The front right seat was occupied by a 43-year-old male who was also wearing the lap and shoulder safety belt. The front right seated occupant is a car sales person and the vehicle was being test driven for the purpose of a potential sale. The driver of the case vehicle was initially traveling east at a reported speed of 32-40 km/h (20-25 mph) and was negotiating a series of curves. The case vehicle entered a hairpin, right curve and the driver applied the brakes which initiated a driver loss of control. In an effort to correct the loss of control, the driver probably applied several counter-steering applications. The case vehicle traversed the opposing travel lane while rotating in counterclockwise fashion before departing the east roadside. The case vehicle was leading with its right side as it traveled a short distance down the -45% embankment grade before initiating a rollover sequence. The case vehicle rolled onto its right side plane and then onto its soft, convertible roof top (00TDDO2). The rollover protection system activated, and the dual rear roll bars which were integrated into the head restraints, deployed. The case vehicle slid down the -45% embankment for approximately 24 m (80 ft.) while on its roof. The case vehicle slid into a tree with its frontal plane (00FDEW1) as it came to rest on its top and facing easterly. The driver of the case vehicle reported a possible injury consisting of back pain. The front right occupant indicated that the driver actually had a pre-existing medical condition involving his back/spine. The front right seated occupant was un-injured. Both the driver and the front right passenger exited their vehicle unassisted and did not require medical treatment or transport to a medical facility. The police report indicates that the fire department was on scene. It is unknown if the driver sought medical treatment at a later time.					
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Dynamic Science, Inc.
Crash Investigation
Case Number: DS03003

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BACKGROUND:

Description:	This Advanced Occupant Protection Systems (AOPS) case was identified by the local National Automobile Sampling System Primary Sampling Unit. The case was assigned to DSI by the National Highway Traffic Safety Administration (NHTSA) on January 29, 2003. All field work was completed on February 1, 2003.
Investigation Type:	Advanced Occupant Protection System/Rollover Protection System
Crash Location:	Washington
Crash Date:	December, 2002
Notification Date:	January 29, 2003
Field Work Completed:	February 1, 2003

SUMMARY

Crash Site

This on-scene in-depth investigation focused on a crash in which the case vehicle was equipped with a Rollover Safety System. This single vehicle rollover crash occurred in December, 2002 at 1358 hours. It was overcast at the time and the bituminous/asphalt roadway surface was wet. The crash took place on the roadside of narrow, two-lane undivided roadway located in a suburban neighborhood of Washington state. At the crash location, the roadway consists of a series of curves with a positive/ uphill grade. There is a -45% grade embankment located at the east roadside while a steep hill is at the west side of the roadway. There are no traffic controls and the speed limit is 48 km/h (30 mph).

Pre-Crash

The case vehicle is a 2003 BMW Z3 two-door convertible that was being driven by a restrained 47-year-old male (175 cm, 69 in/100 kg, 220 lb). The front right seat was occupied by a 43-year-old male (173 cm, 68 in/77 kg, 170 lb) who was also wearing the lap and shoulder safety belt.



Figure 1. Initial travel path and approach to curve (east)



Figure 2. View showing area of case vehicle east roadside departure

The front right seated occupant is a car sales person and the vehicle was being test driven for the purpose of a potential sale. The driver of the case vehicle was initially traveling east at a reported speed of 32-40 km/h (20-25 mph) and was negotiating a series of curves. The case vehicle entered a hairpin, right curve with a radius of 24 m (72 ft) and a critical speed of 35.35 km/h (21.97 mph). The driver applied the brakes which initiated a driver loss of control. In an effort to correct the loss of control, the driver probably applied several counter-steering applications. The case vehicle traversed the opposing travel lane while rotating in counterclockwise fashion before departing the east roadside.



Figure 3. Area of final rest (east)

Crash

The case vehicle was leading with its right side as it traveled a short distance down the -45% embankment grade before initiating a rollover sequence. The case vehicle rolled six quarter turns coming to rest on its soft, convertible roof top (00TDDO3). Upon the initial leading right side rollover sequence, the rollover protection system activated, and the dual rear roll bars which were integrated into the head restraints, deployed. The case vehicle slid down the -45% embankment for approximately 24 m (80 ft) while on its roof. The case vehicle slid into a tree with its frontal plane (00FDEW1) as it came to rest on its top and facing east. The case vehicle sustained significant rollover related deformation with damage documented to all of its planes. The integrity of the case vehicle was greatly compromised as the front windshield was holed, and the side glazing and backlight disintegrated due to the impact forces. There were numerous intrusions with the leading intruding component involving 11 cm (4 in) of vertical intrusion to the roof top immediately behind the front seats. The front A-pillars were not vertically displaced, but there was damage noted to the windshield header area. The vehicle was towed from the crash location, however, the engine would start and technically was driveable. The case vehicle was subsequently declared a total loss by the insurance company.



Figure 4. Exterior left side damage to case vehicle



Figure 5. Exterior damage to case vehicle

Post-Crash

The driver of the case vehicle had a pre-existing medical condition involving his back/spine. He did not sustain any injuries as a result of this crash. The front right seated occupant was uninjured. Both the driver and the front right passenger were upside down and held in their respective seats by the lap and shoulder safety seat belts. They both exited the vehicle unassisted and did not require medical treatment or transport to a medical facility. The police report indicates that fire department was on scene.

VEHICLE DATA -2003 BMW M3

VIN: WBSBR93463PXXXXXX
 Odometer: 23 kilometers / 14 miles
 Engine: 3.2 L / 6 cyl.
 Reported Defects: None Reported
 Cargo: None

The 2003 BMW M3 Two-Door Convertible was equipped with Continental Contisoor + Contact M3 low profile performance tires (front P225/40ZR19, rear P255/35ZR19). The vehicle manufacturer recommended cold tire pressure was 248 kPa (36 psi) for the front and 317 kPa (46 psi) for the rear. The specific tire data is as follows:

Tire	Tread	Pressure	Tire Manufacturer Maximum Pressure
LF	7 mm (9/32 in)	214 kPa (31 psi)	352 kPa (51 psi)
LR	6 mm (8/32 in)	Flat/Cut	352 kPa (51 psi)
RF	7 mm (9/32 in)	248 kPa (36 psi)	352 kPa (51 psi)
RR	7 mm (9/32 in)	214 kPa (31 psi)	352 kPa (51 psi)

The front seating positions in the 2003 BMW M3 two-Door Convertible consist of leather covered forward facing bucket seats. The front seats are power adjustable seat with a 3-setting memory system and a 4-way power lumbar support adjustment. The front seats also have a 3-stage heating system and integral head restraints. The front left (driver's) seat was adjusted at the middle seat track position while the front right seat was adjusted between the middle and rearmost seat track position.

VEHICLE DAMAGE**Exterior Damage - 2003 BMW M3**

Damage Description: Moderate/ Primary Rollover Collision (Highest delta V):
 Pocket sheet metal deformation noted to the right quarter panel area, hood top surface and entire left side plane. Rollover damage associated to the windshield resulting in a hole to the laminated glazing. Vertical displacement to the windshield header, and convertible top cover. Tempered side glazing and backlight glazing disintegrated due to the impact forces. Rear fascia completely separated exposing underlying rear bumper bar.

Minor/ Secondary Frontal (Non-Horizontal) Tree Impact (Second Highest Delta V): Minor front end damage consisting of surface abrasions to the front bumper fascia.

CDC: Crash Event 1: 00TDDO3
 Crash Event 2: 00FDEW1

Delta V ¹ :	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

C measurements: None / Crash events 1 and 2 were none horizontal and not applicable to documenting a crush profile.

¹Non-horizontal rollover collision sequence beyond scope of WinSmash 2.41 energy calculation program.

Interior Damage - 2003 BMW M3

The integrity of the case vehicle was greatly compromised as all side glazing disintegrated, the laminated windshield glazing was holed and the tempered backlight glazing disintegrated due to the rollover impact forces. The left and right doors remained closed and operational and the restrained driver and front right passenger remained inside of the vehicle as the case vehicle came to rest. The convertible soft top roof crushed vertically downward and intruded into the greenhouse area approximately 11.0 cm (4.3 in). The interior was void of occupant contacts which is consistent with no reported injuries. Both advanced, dual stage/dual threshold frontal air bag units were non-deployed as a result of the non-horizontal rollover force and the minor (non-horizontal) frontal tree impact. The front bucket seats were undamaged in the crash sequence.

The second row consists of a split bench seat with separate seatback cushions. The rear seat accommodates two passengers at the outboard positions. There was obvious contact evidence noted to both roll bars of the Rollover Protection System.

MANUAL RESTRAINT SYSTEMS - 2003 BMW M3

The front left and front right seats are equipped with integrated manual three-point lap and shoulder safety belts. The front integrated safety belts are also equipped with automatic height adjustment, and safety belt pretensioners and force limiters. The barrels of both pretensioners were measured and comparison values were obtained from an exemplar vehicle. The documented comparison values indicated that the safety belt pretensioners did not activate during the crash. The outboard rear seated positions have manual three-point lap and shoulder safety belts with factory equipped belt position devices.

Supplemental Restraint System - 2003 BMW M3

The case vehicle was equipped with:

- Driver's and front right passenger's front air bag with "smart" dual-stage and dual threshold deployment, and a sensor to help prevent unnecessary front right passenger's air bag deployment. The driver's air bag was mounted in the steering wheel hub. The front right passenger's air bag was a mid-instrument panel type mount. The front air bags did not deploy.
- Door mounted side impact air bags. The side impact air bags did not deploy.

Advanced Occupant Protection Systems Discussion

The case vehicle was equipped with the following advanced occupant protection systems:

- Automatic front safety belt pretensioners and force limiters. The barrels of both pretensioners were measured and compared to measurements taken from an exemplar vehicle. The comparison indicated that the safety belt pretensioners did not activate during the crash.
- Front integrated safety seat belts with automatic height adjustment.
- Interlocking door anchoring system to help protect against door intrusion in side impacts.



Figure 6. Case vehicle-driver's area

Rollover Protections System Discussion

- The BMW Rollover Protection System deployed both roll bars in the rear head restraints. The system is comprised of *“two recessed aluminum bars fitted behind the rear-seat headrests and pre-tensioned by powerful springs. When the angle of the vehicle changes and exceeds a certain point, the bars instantaneously move up by a maximum of 27 cm (11 in) and then are held back by a dampened mechanism just in front of the soft roof or hardtop. The pop-up roll-bars fully deploy in 110 milliseconds. They remain securely in position for optimal safety. The windscreen columns are strong enough to support the entire weight of the car”*².
- According to Extrication.com³, *“The rollbars are activated by an inclinometer that senses the vehicle inclination and lateral acceleration. There is also a G-sensor that detects vehicle weightlessness. According to BMW, their system will deploy when the control module senses any of the following:*
 - *When the vehicle approaches a lateral angle limit of 62 degrees.*
 - *When the vehicle experiences a lateral acceleration of approximately 3 Gs.*
 - *When the vehicle approaches it's longitudinal angle limit at approximately 72 degrees.*
 - *When a combination of longitudinal acceleration and longitudinal angle would cause the vehicle to roll over in the forward direction.*
 - *When the vehicle becomes airborne and achieves weightlessness for at least 80ms.*
 - *If the vehicle is tilted or accelerated enough, the sensor then sends a signal to the processing chip in the controller. The control unit will then send a signal to the actuator solenoids in each of the roll bar cassettes. This then releases the restraining catches and the twin roll bars will spring upward in less than two to three tenths of one second. BMW has stated that the force delivered by their rollbar "is not great," but that it deploys in less than three tenths of a second. It also uses a mechanical (ratchet gear) lock, when it comes in contact with an object it will stop and lock”*.

²www.bmwworld.com/technology/glossary.htm

³www.extrication.com/rops.htm, 10/14/99



Figure 7. Deployed roll bars



Figure 8. Exemplar non-deployed roll bars

OCCUPANT DEMOGRAPHICS - 2003 BMW M3

	Occupant 1	Occupant 2
Age/Sex:	47/Male	43/Male
Seated Position:	Front left	Front right
Seat Type:	Power adjustable forward facing, leather covered bucket seats. Seat adjusted to middle track position, seatback slightly reclined	Power adjustable forward facing, leather covered bucket seats. Seat adjusted to between middle and rear most track position, seatback slightly reclined.
Height:	175 cm (69 in)	173 cm (68 in)
Weight:	100 kg (220 lbs)	77 kg (170 lbs)
Occupation:	Unknown	Car dealer sales person
Pre-existing Medical Condition:	Probable pre-existing lower back spinal injury with history of back surgery	None
Alcohol/Drug Involvement:	None	None
Driving Experience:	Presumed to be >10 years	Not applicable
Body Posture:	Upright facing forward, specifics are unknown	Upright, facing forward
Hand Position:	At least one hand on steering wheel at an unknown o'clock location	Unknown
Foot Position:	Right foot depressing brake, pedal, left foot on floor	Both feet on floor
Restraint Usage:	Three-point manual lap and shoulder belt used in a normal and correct fashion with the shoulder belt extending across his chest and the lap belt placed across his hip region	Three-point manual lap and shoulder belt used in a normal and correct fashion with the shoulder belt extending across his chest and the lap belt placed across his hip region

Air bag:	Steering wheel hub mounted drivers advanced “smart” dual stage/dual threshold front air bag (non-deployed). Door mounted side impact air bag (non-deployed)	Front right passenger’s air bag was a mid-instrument panel mount (Non-deployed). Door mounted side impact air bag (non-deployed)
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OCCUPANT INJURIES -2003 BMW M3

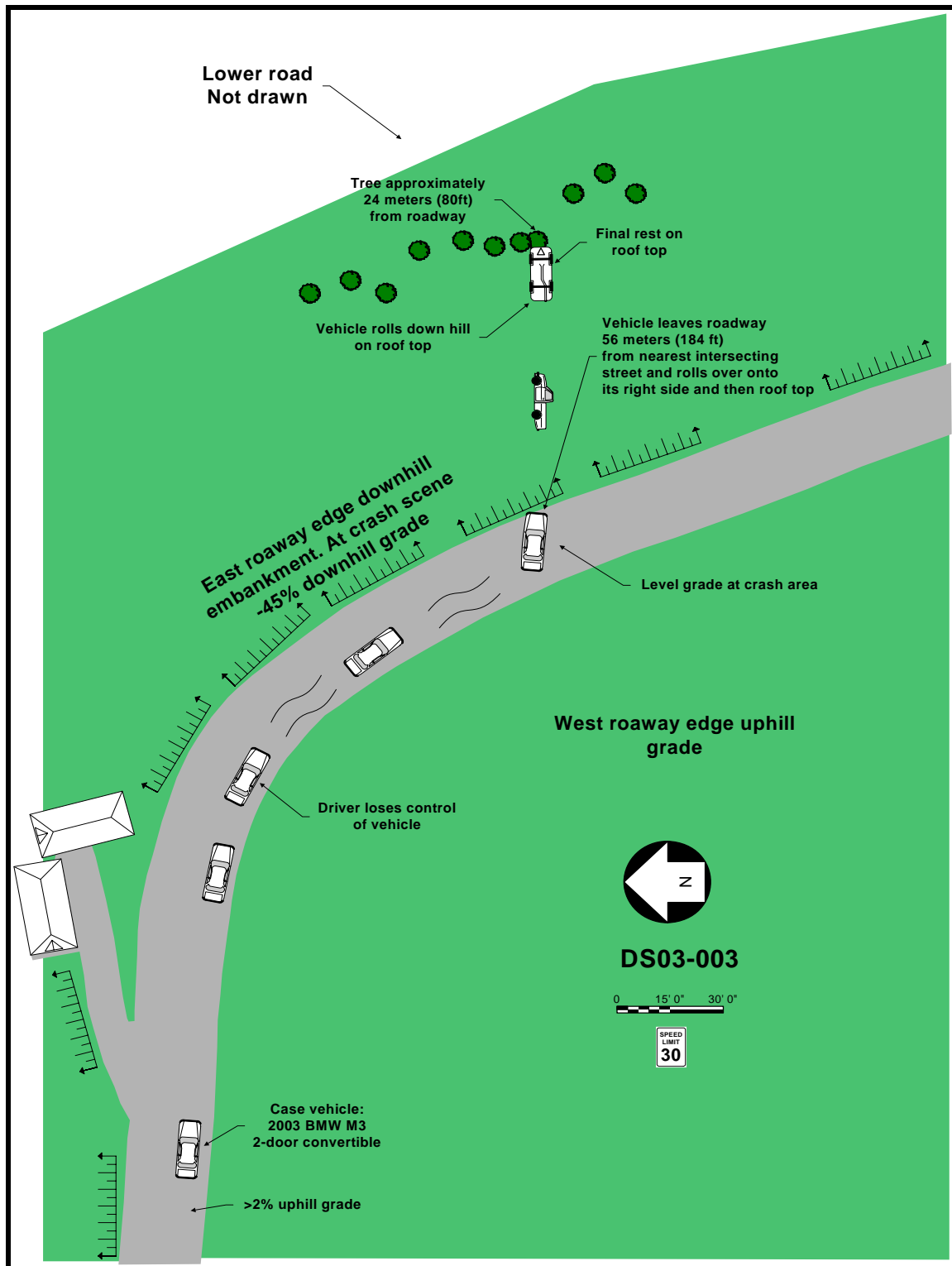
	Injury	OIC Code	Injury Mechanism	Confidence Level
Driver:	No injuries as a result of this crash. Police report indicates “possible injury” consisting of “back pain.” Pre-existing condition involving his back/spine.	N/A	N/A	N/A
RF Occupant:	Not injured	N/A	N/A	N/A

OCCUPANT KINEMATICS - 2003 BMW M3

The 47-year-old male (175 cm, 69 in/100 kg, 220 lb) driver was wearing the available seat integrated three-point manual lap and shoulder belt in a normal fashion. The automatic shoulder belt upper anchorage height adjustment was in the mid position. The driver was in an upright attitude, forward facing with at least one hand on the steering wheel rim at an unknown location. It is possible that his right hand may have been gripping the center console transmission selector lever at the time. The driver's leather covered forward facing bucket seat was adjusted at the middle seat track position, and the seatback was reclined. As the case vehicle departed the east roadside and began to pitch to the right, the driver responded by moving to the right. The applied lap and shoulder restraint in conjunction with the pronounced lateral seatback supports helped cradle the driver, maintaining him in his respective seated position. The case vehicle completed six quarter turns coming to rest on its roof or top plane. During the rollover sequence, the left side plane sustained moderate damage and the driver probably responded to this impact force by moving to the left side. As the case vehicle came to rest, the driver was suspended upside down by the applied lap and shoulder safety belt. The driver was able to unbuckle the lap and shoulder safety belt and crawl out of the vehicle unassisted. The driver did not require medical attention and did not seek any medical treatment. The police report indicates that the fire department was on scene.

The front right seat was occupied by a 43-year-old male (173 cm, 68 in/77 kg, 170 lb). He was wearing the available seat integrated three-point manual lap and shoulder belt in a normal fashion. The automatic shoulder belt upper anchorage height adjustment was in the mid position. The leather bucket seat was adjusted to between the middle and rear most track position. As the case vehicle rolled to the right, the front right passenger responded by also moving to his right. He probably contacted the interior right door panel, however, there was no residual occupant contact evidence to the door panel or armrest. During the rollover sequence, the left side plane was fully contacted by the ground surface. He responded to this left side rollover impact by moving to his right. As the case vehicle completed six quarter turns, it coming to rest on its top surface and the front right seated occupant was suspended upside down. The passenger was held inside the vehicle by the applied lap and shoulder belt. He was able to release the buckle latch and crawl out of the vehicle unassisted. The front right passenger was uninjured and did not require any medical treatment or transport to a medical facility.

Attachment 1. Scene Diagram



Attachment 2. Critical Speed Calculation

CASE NUMBER: DS03003

Comments: Max speed vehicle can negotiate a curve without control loss

*** * CRITICAL SPEED W/ COEFF. OF FRICTION AND RADIUS * ***

$S = 3.86 \times \sqrt{R \times (\mu \pm e)}$

$S = 3.86 \times \sqrt{72.0000 \times (0.4500 - 0.0000)}$

$S = 3.86 \times \sqrt{72.0000 \times 0.4500}$

$S = 3.86 \times \sqrt{32.4000}$

$S = 3.86 \times 5.6920$

$S = 21.9711$

S = The Speed in MPH.
 3.86 = A Constant.
 R = The Radius in Feet.
 μ = The Coeff. of Friction, Level Surface.
 e = The Superelevation.

INPUTS:	
The Level Surface Coeff. of Friction is:	0.4500
The Radius in Feet is:	72.0000
The Percentage of Superelevation is:	0.0000

RESULTS:	
The Speed in MPH is:	21.9711
The Velocity in FPS is:	32.2096

AR Pro, Ver. 7.02: © Since 1994, Maine Computer Group.