On-Site Rollover Investigation
Dynamic Science, Inc. (DSI), Case Number DS10009
2009 BMW 328i
California
February 2010

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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-site investigation focused on a 2009 BMW 328i that was involved in a rollover. This single vehicle crash occurred in February 2010 at 0700 hours in a rural area of California. The crash site was a two-lane, undivided, east/west state highway. The subject vehicle was being driven eastbound by a restrained 23-year-old male. The front right seat was occupied by a restrained 36-year-old male and the second row right seat was occupied by a 24-year-old male. As the vehicle entered and then exited a sag in the roadway the driver lost control of the vehicle. The vehicle veered to the right onto a gravel shoulder and as the driver steered to the left to return to the roadway the vehicle began a counterclockwise rotation. The vehicle tripped as it reentered the roadway and began a right side leading rollover. The BMW rolled eight quarter-turns as it crossed both travel lanes and departed the roadway on the north side where it came to rest on its wheels facing west. All the occupants exited the vehicle under their own power through the side windows. The driver sustained minor contusions and abrasions, the front right passenger sustained an eye injury, and the second row right passenger sustained a chest contusion. All three occupants visited a walk-in clinic later in the day where they were treated and released. The BMW was towed from the scene due to damage and was declared a total loss by the insurance company.

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Crash Investigation
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BACKGROUND

Figure 1. Subject vehicle, 2009 BMW 328i

This on-site investigation focused on a 2009 BMW 328i that was was involved in a rollover (**Figure 1**). This single vehicle crash occurred in February 2010 at 0700 hours in a rural area of California. The crash site was a two-lane, undivided, east/west state highway. The subject vehicle was being driven eastbound by a restrained 23-year-old male. The front right seat was occupied by a restrained 36-year-old male and the second row right seat was occupied by a 24-year-old male. As the vehicle entered and then exited a sag in the roadway the driver lost control of the vehicle. The vehicle veered to the right onto a gravel shoulder and as the driver steered to the left to return to the roadway the vehicle began a counterclockwise rotation. The vehicle tripped as it reentered the roadway and began a right side leading rollover. The BMW rolled eight quarter-turns as it crossed both travel lanes and departed the roadway on the north side where it came to rest on its wheels facing west. All the occupants exited the vehicle under their own power through the side windows. The driver sustained minor contusions and abrasions, the front right passenger sustained an eye injury, and the second row right passenger sustained a chest contusion. All three occupants visited a walk-in clinic later in the day where they were treated and released. The BMW was towed from the scene due to damage and was declared a total loss by the insurance company.

This investigation was identified by a DSI investigator during a review of an auto auction internet site. Photographs of the subject vehicle were submitted to the National Highway Traffic Safety Administration (NHTSA) and on April 12, 2010 DSI was directed to commence the investigation. The subject vehicle was inspected on April 12, 2010. For a variety of reasons the insurance company was unable to locate a police report associated with this crash. DSI contacted several police agencies and was eventually able to obtain a police report on October 11, 2010 and field work was completed on October 13, 2010.

SUMMARY

Crash Site

Figure 2. Eastbound approach showing sag in roadway

This crash occurred on a straight two-lane, undivided, east/west state highway. The travel lanes measured 3.6 m (12.0 ft) in width and were separated by solid/broken yellow center lines. The asphalt roadway was bordered on both sides by solid white lines and 3.0 m (10.0 ft) gravel/dirt shoulders. The shoulders were separated from the open desert by small dirt embankments. At a point 89.3 m (293.0 ft) prior to where the driver lost control of the vehicle the roadway began to sag

(**Figure 2**). There was a descending 4.0 percent negative grade and the roadway bottomed out 40.5 m (133.0 ft) later. The roadway then began ascending at a positive 6.6 % grade. Just prior to the area where the vehicle went out of control, the roadway was near level with a positive grade of 0.8%. The weather was cloudy, visibility in all directions was good, and the roadway was dry. The posted speed limit for this roadway was 105 km/h (65 mph).

Pre-Crash

The BMW was traveling eastbound at a driver reported speed of 113 km/h (70 mph). As the vehicle entered the sag the driver allowed the vehicle to move to the left. As the vehicle departed the sag the driver overcorrected to the right and began braking. The vehicle traveled 64.6 m (212.0 ft) before it departed the roadway on the right side and entered the shoulder. The vehicle traveled 85.9 m (282.0 ft) on the shoulder. The driver steered to the left and the vehicle began a counterclockwise rotation.

Crash

As the vehicle re-entered the roadway it tripped at the junction between the gravel shoulder and asphalt roadway and began a right side leading rollover (**Figure 3**). The vehicle rolled eight quarter-turns on a diagonal across both lanes of travel for 28.3 m (93.0 ft) before departing the roadway and coming rest on its wheels in the open desert.

Figure 3. Area vehicle returned to roadway (looking east)

Post-Crash

All the occupants exited the vehicle under their own power through the side windows. The interviewee stated that all three occupants sustained minor lacerations to their arms and hands during the exit. Additionally, the driver sustained minor contusions and abrasions, the front right passenger sustained an eye injury, and the second row right passenger sustained a chest contusion. All three occupants visited a walk-in clinic later in the day where they were treated and released. The BMW was towed from the scene due to damage and was declared a total loss by the insurance company.

Vehicle Data -2009 BMW 328i

The 2009 BMW 328i 4-door 5-passenger sedan was identified by the Vehicle Identification Number (VIN): WBAPH53549Axxxxxx. The vehicle date of manufacture was September 2008. The vehicle mileage was not known due to a lack of power to the instrument panel. The BMW was equipped with a 3.0-liter, 6-cylinder engine, automatic transmission, rear wheel drive, stability control, braking assist, 4-wheel ABS, front/rear disk brakes, and a steering wheel with tilt and telescopic functionality. The BMW was equipped with Continental ContiProContact 205/55R16 tires. The tire manufacturer's stated maximum pressure was 352 kPa (51 psi); the vehicle manufacturer's

recommended cold pressure was 221 kPa (32 psi). The tires were manufactured during the 33rd week of 2008. The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	207 kPa (30 psi)	6 mm (7/32 in)	No	None
LR	221 kPa (32 psi)	6 mm (7/32 in)	No	None
RR	165 kPa (24 psi)	5 mm (6/32 in)	Yes	None
RF	Tire Flat	6 mm (7/32 in)	No	De-beaded

The seating in the BMW was configured with front leather-covered bucket seats with adjustable head restraints and a rear bench seat with adjustable head restraints.

Vehicle Damage

Exterior Damage

The BMW sustained damage to the left side, right side, back and top during the rollover event (**Figure 4**). The direct damage to the top of the vehicle extended laterally from roof side rail to roof side rail and measured 118.0 cm (46.4 in). The damage extended laterally across the entire hood and measured 131.0 cm (51.5 in). The hood was shifted to the right. The direct damage began 59.0 cm (23.2 in) forward of the front axle and extended rearward to include the entire hood and roof.

Figure 4. Rollover damage, 2009 BMW 328i

The maximum vertical crush measured 18.0 cm (7.0 in) and was located at the windshield header 20.0 cm (7.8 in) left of the right roof side rail (**Figure 5**). The maximum lateral crush measured 2.0 cm (0.8 in) and was located at the right A-pillar and roof junction. A second vertical crush measurement was taken at the backlight header. The crush measured 9.0 cm (3.5 in) and was located 15.0 cm (5.9 in) right of the left roof side rail. The direct damage to the left side was located 50.0 cm (23.2 in) forward of the front axle and extended 420.0 cm (165.3 in) rearward. There was a 23.0 cm (9.0 in) gap in the direct damage that was located at the second row door. The direct damage to the right side began 85.0 cm (33.4 in)

Figure 5. Maximum vertical crush

rearward of the rear axle and extended forward 380.0 cm (149.6 in). The damage to the doors was primarily light scratching. The rear bumper fascia was displaced on the right side. There was contact evidence to the rear edge of the trunk lid. The trunk had come open during the rollover and was wired shut at the time of the vehicle inspection. The Collision Deformation Classification (CDC) for the rollover was 00TDDO2.

There were scrapes to the left rear, right rear, and right front rims. The right rear wheel was rotated clockwise 10 degrees and canted inboard 9 degrees. The strut was fractured and displaced at the right rear axle (**Figure 6**).

Figure 6. Right rear strut displaced

Interior Damage

The BMW sustained moderate interior damage as a result of intrusions, occupant loading, and occupant contacts. Vertical intrusion was located in the front row at the windshield header, roof, and roof side rail. Lateral intrusion was located at the right B-pillar. Vertical intrusion was located in the second row at the roof and back light header.

Figure 7. Contact to roof and visor

Evidence of occupant loading and contacts were documented to the driver's safety belt, the safety belt latch plate, left roof, and visor (**Figure 7**). The blood evidence to the roof was located 25.0 cm (9.8 in) right of the roof side rail, 25.0 (9.8 in) rearward of the windshield header, and measured 24.0 x 7.0 cm (9.4 x 2.8 in). There was also blood evidence located at the center console and along the right IC air bag module cover.

Figure 8. Driver's safety belt

Manual Restraints

The front row seating positions were equipped with 3-point manual lap and shoulder belts with sliding latch plates and retractor pretensioners. The driver's safety belt had an Emergency Locking Retractor (ELR) and the front right passenger's safety belt had a switchable ELR/Automatic Locking Retractor (ALR). The driver's safety belt latch plate was scratched indicating historical usage. There was an 11.0 cm (4.3 in) area of possible loading to the safety belt webbing located 57.0 cm (22.4 in) from the anchorage (**Figure 8**). Based on the vehicle inspection, the belt was used to restrain the driver during the crash. The front right

safety belt displaced the B-pillar fascia. Based on the vehicle inspection, the belt was used to restrain the front right during the crash. The rear seat safety belts exhibited signs of historical usage but there were no indications of loading.

Supplemental Restraint Systems

This vehicle's Supplemental Restraint System (SRS) included driver and passenger frontal air bags, seat-mounted side air bags for the front row, side impact IC air bags, and safety belt pretensioners for the front row. The BMW was a Certified Advanced 208-Compliant (CAC) vehicle. It was equipped with advanced frontal air bag and front right seat occupant detection based on analysis of seat cushion impression . The multi-stage air bags were certified by the manufacturer to be compliant with the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The driver's air bag was located within the steering wheel hub and the front right passenger air bag was located within the top of the right instrument panel. During the crash, the left and right IC air bags and the left and right seat-mounted side air bags deployed. The frontal air bags did not deploy and the pretensioners did not actuate. Based on the interview the air bags were original to the vehicle and had not been recalled or serviced.

Figure 9. Right IC air bag

The side IC air bags deployed through the roof rail cladding from a module located at the roof side rail (**Figure 9**). The air bags were generally rectangular and measured 165.0 cm (64.9 in) in length and 32.0 cm (12.6 in) in height. The forward aspects of the bags were attached to the A-pillar by tethers that measured 10.0 cm (3.9 in); the rear aspects were attached to the C-pillar. The longitudinal area of coverage began near the A-pillar and extended to the C-pillar. The bag's vertical coverage began at the roof rail and extended downward below the window frame. There were no indications of loading to the IC air bags.

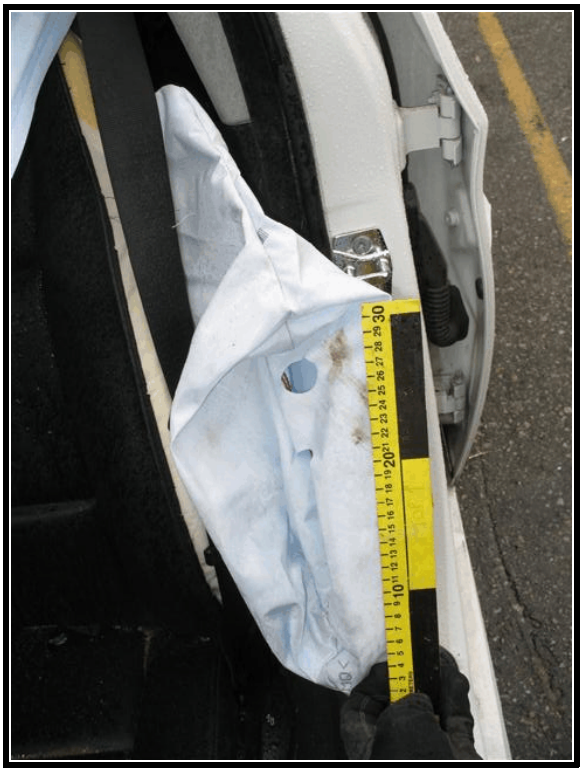


Figure 10. Driver's seat-mounted side air bag

The seat-mounted side air bags deployed longitudinally from the front seat backs (**Figure 10**). The air bags extended 21.0 cm (8.3 in) in length and 30.0 cm (11.8 in) in height. Two 3.0 cm (1.2 in) round vent ports were located at the

forward aspects of the air bags. A 16.0 x 5.0 (6.3 x 1.9 in) black scuff was located to the outboard side of the upper vent port on the driver's side air bag. There were no other contacts or damage.

Rollover Discussion

The BMW had a Static Stability Factor (SSF) of 1.44. The SSF of a vehicle is an at-rest calculation of its rollover resistance, which is based on its track width and center of gravity. The vehicle had a rollover resistance rating of 4 out of 5 stars, and had a 10% chance of rollover[1]. The vehicle was equipped with electronic stability control, 4-wheel ABS, and traction control.

Figure 11. Trip point at junction of roadway and shoulder

The BMW was traveling at a driver reported speed of 113 km/h (70 mph) when he lost control of the vehicle. The driver was braking and steering as the vehicle entered the right side shoulder. The vehicle traveled 85.9 m (282.0 ft) on the shoulder. At some point the driver steered to the left and the vehicle began a counterclockwise rotation. As the vehicle re-entered the roadway it tripped at the junction between the gravel shoulder and asphalt roadway and began a right side leading rollover (**Figure 11**). The vehicle rolled eight quarter-turns on a diagonal across both lanes of travel before departing the roadway and coming to rest on its roof in the open desert (**Figures 12-13**). The estimated roll distance from the trip point to final rest was 55.8 m (183.3 ft).

Figure 12. Rollover path across roadway

Figure 13. Look back view from final rest

[1] www.safercar.gov

OCCUPANT DEMOGRAPHICS

Driver

Age/Sex:	23/Male
Height:	170 cm (67 in)
Weight:	73 kg (160 lbs)
Seat type:	Bucket
Seat track position:	Rear-most
Manual restraint use:	Lap and shoulder belt
Usage source:	Vehicle inspection
Air bags:	Frontal air bag, not deployed. Side IC air bag and seat-mounted side air bag deployed.
Alcohol, drug involvement:	Had been drinking. No BAC test.
Type of medical treatment:	Sought treatment later

Front Row Right Occupant (02) Demographics

Age/Sex:	36/Male
Height:	180 cm (71 in)
Weight:	82 kg (180 lbs)
Seat type:	Bucket
Seat track position:	Rear-most
Manual restraint use:	Lap and shoulder belt
Usage source:	Vehicle inspection
Air bags:	Frontal air bag, not deployed. Side IC air bag and seat-mounted side air bag deployed.
Type of medical treatment:	Sought treatment later

Second Row Right Occupant (03) Demographics

Age/Sex:	24/Male
Height:	180 cm (71 in)
Weight:	82 kg (180 lbs)
Seat type:	Bench
Seat track position:	N/A
Manual restraint use:	Lap and shoulder belt
Usage source:	Interview
Air bags:	Side IC air bag deployed
Type of medical treatment:	Sought treatment later

Occupant Injuries

Driver: Injuries obtained from interviewee.

Injury	Injury Severity (AIS 2005)	Injury Mechanism	Confidence Level
Abrasion, left side of head, 10.1 x 5.0 cm (4.0 x 2.0 in).	110202.1,2	Roof	Probable
Contusion, left shoulder	710402.1,2	Seat belt webbing	Certain

Front Row Right Occupant: Injury obtained from interviewee.

Injury	Injury Severity (AIS 2005)	Injury Mechanism	Confidence Level
Broken blood vessel inside eye (coded as vitreous hemorrhage)	241601.1,2	Unknown	Unknown

Second Row Right Occupant: Injury obtained from interviewee.

Injury	Injury Severity (AIS 2005)	Injury Mechanism	Confidence Level
Contusion, left chest	410402.1,2	Seat belt webbing	Certain

OCCUPANT KINEMATICS

Driver Kinematics

The 23-year-old male driver of the BMW was seated in an upright posture and was restrained by the vehicle's lap and shoulder belt. The seat was adjusted to the full-rearward track position and the seat back was slightly reclined. The driver was actively steering and braking the vehicle as it departed the roadway onto the right shoulder. Once on the shoulder the driver began steering sharply to the left and the vehicle began a counterclockwise rotation. During rotation the driver was displaced to the right and then was displaced in all directions as the vehicle tripped and began rolling over. During the right side leading rollover the driver loaded the safety belt. He likely contacted the roof and windshield visor with his head, causing a head abrasion. He sustained minor lacerations to his arms that were likely caused by broken glass as he extricated himself from the vehicle. He sought treatment later that day at a walk-in clinic where he was treated and released.

Front Right Occupant Kinematics

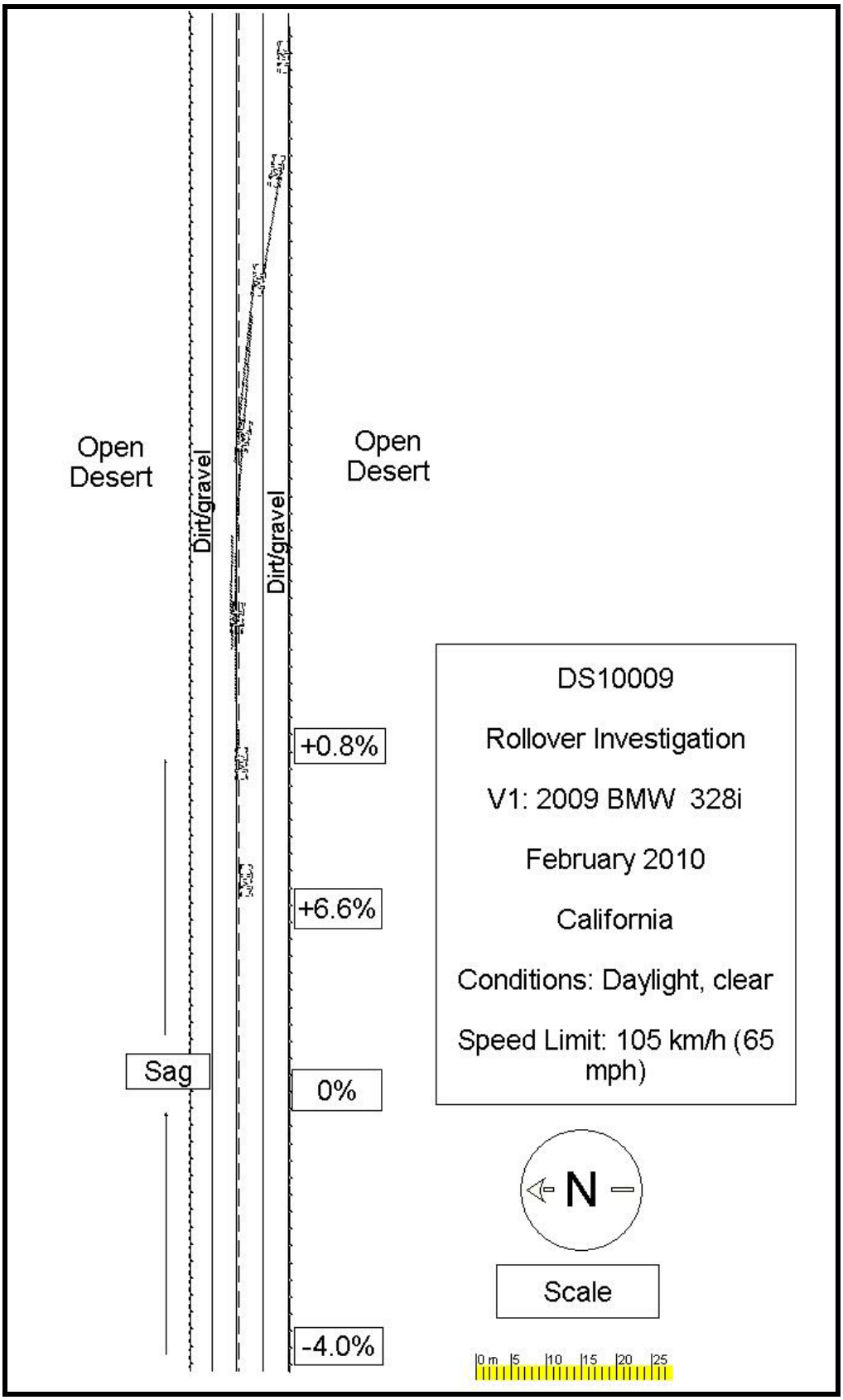
The 36-year-old male front right occupant was seated in an upright posture and was restrained by the vehicle's lap and shoulder belt. The seat was adjusted to the full-rearward track position and the seat back was slightly reclined. During rotation this occupant was displaced to the right and then was displaced in all directions as the vehicle tripped and began rolling over. During the right side leading rollover he loaded the safety belt. The were no indications of loading or contacts in his immediate seating area. There was blood on the IC curtain module cover above the B-pillar. The blood was located 45.0 cm (17.7 in) aft of the windshield header and measured 24.0 cm (9.4 in) in length and 8.0 cm (3.1 in) in width. This occupant complained of pain to his head and back and sustained minor lacerations as he exited the vehicle. The interviewee reported that this occupant did sustain a "popped" blood vessel in his left eye and sought treatment later that day at a walk-in clinic where he was treated and released.

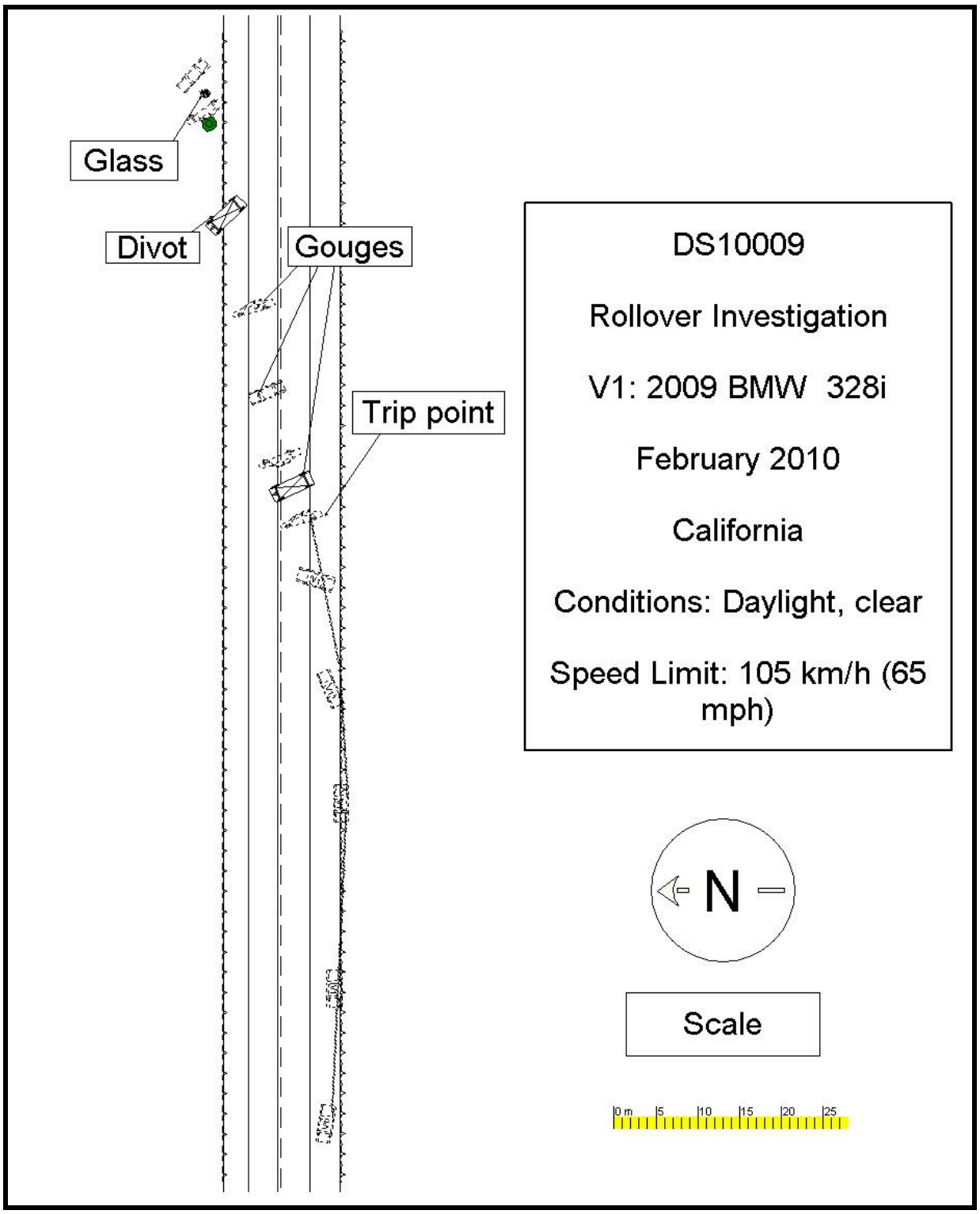
Second Row Right Occupant Kinematics

The 24-year-old male second row right occupant was seated in an upright posture and was restrained by the vehicle's lap and shoulder belt. During rotation this occupant was displaced to the right and then was displaced in all directions as the vehicle tripped and began rolling over. During the right side leading rollover he possibly contacted the roof with his head. A possible contact was located on the roof. It was located 36.0 cm (14.1 in) forward of the backlight, 23.0 cm (9.0 in) lateral of the roof side rail, and measured 7.0 x 6.0 cm (2.8 x 2.4 in). This occupant sustained a left side chest contusion which was attributed to the safety belt. He sought treatment

later that day at a walk-in clinic where he was treated and released.

Attachment 1. Scene Diagram




Glass
Divot
Gouges
Trip point
DS10009
Rollover Investigation
V1: 2009 BMW 328i
February 2010
California
Conditions: Daylight, clear
Speed Limit: 105 km/h (65 mph)
N
Scale
0 m
5
10
15
20
25