TRANSPORTATION SCIENCES
CRASH RESEARCH GROUP

Veridian
Calspan Operations
Buffalo, New York 14225

CALSPAN ON-SITE ROLLOVER INVESTIGATION
CALSPAN CASE NO. CA98-003
VEHICLE: 1998 MERCEDES-BENZ ML 320
LOCATION: ALABAMA
CRASH DATE: JANUARY, 1998

Contract No.
DTNH22-94-D-07058

Prepared for:

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

DISCLAIMER

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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

<table>
<tr><td colspan="2">1. Report No.
CA98-003</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="3" rowspan="2">4. Title and Subtitle
Calspan On-Site Rollover Investigation
Vehicle: 1998 Mercedes-Benz ML 320
Location: Alabama</td><td colspan="2">5. Report Date:
November, 1998</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="3">7. Author(s)
Crash Research Section</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="3" rowspan="2">9. Performing Organization Name and Address
Transportation Sciences
Crash Research Section
Calspan Operations
P.O. Box 400
Buffalo, New York 14225</td><td colspan="2">10. Work Unit No.
1115 (8240-8249)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
DTNH22-94-D-07058</td></tr>
<tr><td colspan="3" rowspan="2">12. Sponsoring Agency Name and Address
U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590</td><td colspan="2">13. Type of Report and Period Covered
Technical Report
Crash Date: January, 1998</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="5">15. Supplementary Notes
On-site investigation of a on-road rollover crash that involved a 1998 Mercedes-Benz ML 320 sport utility vehicle.</td></tr>
<tr><td colspan="5">16. Abstract
This on-site investigation focused on the rollover initiation type for a 1998 Mercedes-Benz ML 320 sport utility vehicle that was involved in a on-road rollover crash in Alabama. The driver initiated a rapid left-right steering input which induced a clockwise yaw. The left front alloy wheel subsequently gouged into the raised edge of the asphalt road surface which tripped the vehicle into a lateral side-over-side rollover event. The Mercedes completed seven (7) quarter turns prior to coming to rest on its right side. The belted female driver sustained soft tissue injuries and was treated at a local hospital and released. The ML 320 was equipped with frontal and side impact air bag systems. Both the left and right door-mounted side impact air bags deployed during the rollover event.</td></tr>
<tr><td colspan="3">17. Key Words
Sport utility vehicle
Tripped rollover
Seven quarter turns</td><td colspan="2">18. Distribution Statement
General Public</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
9</td><td colspan="2">22. Price</td></tr>
</table>

TABLE OF CONTENTS

CALSPAN ON-SITE ROLLOVER INVESTIGATION
CALSPAN CASE NO. CA98-003
VEHICLE: 1998 MERCEDES-BENZ ML320
LOCATION: ALABAMA
CRASH DATE: JANUARY 1998

BACKGROUND

This on-site investigation focused on the rollover initiation type for a 1998 Mercedes-Benz ML 320 sport utility vehicle that was involved in a on-road rollover crash in Alabama. The driver initiated a rapid left-right steering input which induced a clockwise yaw. The left front alloy wheel subsequently gouged the raised edge of the asphalt road surface which tripped the vehicle into a lateral side-over-side rollover event. The Mercedes completed seven (7) quarter turns prior to coming to rest on its right side **(Figure 1)**. The belted female driver sustained soft tissue injuries and was treated at a local hospital and released. The ML 320 was equipped with frontal and side impact air bag systems. Both front door mounted side impact air bags deployed during the rollover event.

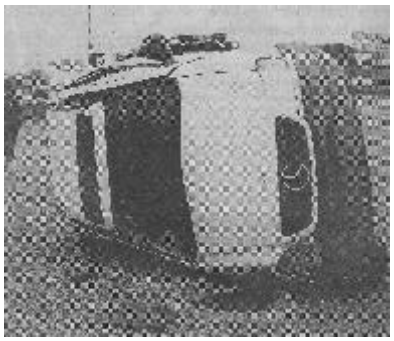


Figure 1. On-scene view of the ML 320 at final rest.

The crash occurred in January 1998, during daylight hours on an urban interstate in Alabama. The initial notification of the crash was provided to NHTSA by the NASS team leader at PSU 48 on January 15. The case was assigned to the Calspan Special Crash Investigation team on the same day and an on-site investigation was conducted on January 19-20.

SUMMARY

Crash Site

The crash occurred on the northbound lanes of a six lane divided interstate roadway in a posted speed zone of 105 km/h (65 mph) during daylight hours **(Figure 2)**. The northbound travel lanes consisted of three (3) lanes of equal width of 3.7 m (12.0'). A continuous pour concrete median barrier physically divided the trafficway. The northbound travel lanes were bordered by a 3.4 m (11.1') paved outboard shoulder and a 3.3 m (10.7') paved inboard shoulder. In the vicinity of the crash site, the interstate was curved to the left with respect to the Mercedes' northbound path of travel. The radius of curvature was calculated at 1,375 m (4,513'). At the point of rollover, the grade was 1.0 percent, positive to the north. The superficial elevation was measured at 1.6 percent. The asphalt travel lanes were raised 2.5 cm (1.0") over the level of the shoulder. It should be noted that the asphalt surface of the travel lanes was in good condition with no visible defects. The surface, however, was coarse with a No. 1-type stone protruding above the asphalt mixture. The surface of the shoulders was a coarser mixture of asphalt with fewer protruding stones. These stones appeared to extend higher above the tar

Figure 2. Overall view of the northbound travel lanes.

base. The coefficient of friction for these surfaces was estimated at 0.85. The surface was dry at the time of the crash.

VEHICLE DATA

Figure 3. Frontal view of the involvedMercedes-Benz ML 320 sport utility vehicle.

The involved vehicle was a 1998 Mercedes-Benz ML 320, 4-door sport utility vehicle **(Figure 3)**. The vehicle was leased by a Mercedes employee. His wife was the primary driver of the vehicle and she was responsible for the majority of the estimated (4-5,000 miles) on the odometer. The Mercedes was manufactured in July 1997, and was identified by vehicle identification number 4JGAB54EXWA (production number deleted). The Mercedes-Benz was equipped with a full-time all wheel drive system with an electronic traction system. Power was transferred from the 3.2 liter gasoline V-6 engine by an electronically controlled 5-speed automatic transmission. Braking was obtained through four-wheel power disc brakes with anti-lock (ABS). The vehicle's suspension system was a four-wheel independent system with front and rear anti-sway bars. The Mercedes-Benz was equipped with General Grabber ST 255/65R16 mud and snow tires mounted on five spoke aluminum-alloy wheels.

Pre-Crash

The 30 year old female driver was traveling in a southwesterly direction on a divided interstate with a posted speed limit of 105 km/h (65 mph). She merged onto a two lane exit ramp which provided access to a north/southbound interstate. The driver traveled approximately 1.6 km (1.0 miles) in an northerly direction on the outboard lane of the interstate. On her approach to the impending crash site, the driver noted a puppy entering the roadway from the grassy area adjacent to the right (outboard) shoulder. She estimated her travel speed at approximately 113 km/h (70 mph) in the posted 105 km/h (65 mph) speed zone. The driver applied a rapid counterclockwise (CCW) steering input to avoid the small animal which redirected the vehicle to the left, traversing the center travel lane. The driver subsequently applied a rapid clockwise (CW) steering input in an attempt to redirect the Mercedes in a controlled eastbound direction.

Figure 4. Initiation of the yaw marks on the inboard travel lane.

The CW steering reversal induced a clockwise yaw as the vehicle broke traction on the inboard travel lane. The yaw was evidenced by left front and left rear tire marks which began on the inboard travel lane 1.5 m (5.0') right of the yellow inboard edge line **(Figure 4)**. The yaw marks crossed the yellow edge line onto the paved left shoulder as the vehicle continued to yaw CW. The yaw marks began to arc back toward the travel lane as the Mercedes-Benz yawed approximately 47 degrees CW **(Figure 5)**. The maximum lateral separation **(Figure 6)** between the left front and left rear yaw marks was 206 cm (81"). The total length of the yaw marks were 24.7 m (81.2') and 23.3 m (76.3') respectively for the left front and left rear tires. A calculated speed of 101.4 km/h (63.0

mph) was derived from the yaw marks using the critical curve speed formula. The aggressive asphalt surface of the shoulder in combination with the extent of CW yaw allowed the sidewalls of the left side tires to roll under the aluminum-alloy wheels. As the left front tire mounted a 2.5 cm (1.0") rise in the pavement from the shoulder to the travel lane, the alloy left front wheel of the Mercedes gouged the asphalt surface **(Figure 7)**. The gouge extended for a total length of 2.1 m (7.0') and was approximately 7.6 cm (3.0") in width. At this point, the left front tire was probably aired out due to the rotation and wheel engagement with the road surface. The aired out left front tire continued to mark on the asphalt surface adjacent to the gouge mark. The wheel was subsequently deformed to a depth of 0.6 cm (0.25") over a length of 17.8 cm (7.0"). Asphalt was embedded in the outer aspect of the bead at the area of deformation.

Figure 5. CCW arc of the left side yaw marks.

Figure 6. Lateral separation of the yaw marks.

Figure 7. Raised pavement surface and the gouge mark.

Crash

The lateral yaw of 47 degrees and the subsequent engagement of the alloy left front wheel into the asphalt road surface resulted in a tripped side-over-side rollover event **(Figure 8)**. The Mercedes-Benz rolled onto its left side initially contacting the left roof side rail area. The first gouge mark on the asphalt surface was located at the inboard edge line of the travel lane 9.2 m (30.3') north of the end of the wheel gouge. The vehicle continued to overturn in a side-over-side attitude, completing seven (7) quarter turns prior to coming to rest on its right side diagonally across the center and inboard travel lane **(Figure 9)**. Numerous gouge marks were present on the road surface to track the trajectory and quarter turns of the vehicle. A semi-circular gouge mark was present on the inboard travel lane 24.2 m (79.8') north of the trip point which initiated the rollover event. The gouge was located 2.7 m (8.7') inboard of the yellow edge line and resulted from contact with the right front wheel. Asphalt was embedded into the bead between the alloy wheel and the inflated tire.

Figure 8. Asphalt embedded into the left front wheel which tripped the ML 320.

Figure 9. Rollover trajectory of the ML 320.

The Mercedes-Benz came to rest on its right side with its CG straddling the lane delineations approximately 41.8 m (137.0') north of the trip

point of the rollover. Final rest was determined from a fluid spill on the asphalt road surface and from additional gouges incurred during the removal of the vehicle from the scene.

VEHICLE DAMAGE

Exterior

Damage to the Mercedes-Benz ML 320 consisted of vertically oriented abrasions along both sides which extended the full length of the vehicle. The heaviest concentration of abrasions occurred to the roof side rail/upper door window frame areas. Maximum crush was 4.4 cm (1.75") located at the junction of the right upper A-pillar and the right roof side rail **(Figure 10)**. The roof did not sustain direct contact damage between the roof rack rails that were affixed directly inboard of the side rail area. The front and rear bumper fascias were damaged at the left side corners, however, there was no underlying damage to the structural components. The laminated windshield was cracked adjacent to the left A-pillar. The left rear door glazing, left rear quarter glazing, backlight glazing **(Figure 11)**, and the right front door glazing was shattered during the rollover. The remaining door and quarter window glazing, in addition to the sunroof, remained intact. All four doors remained closed and operational.

Figure 10. Rollover damage to the right side area of the vehicle.

Figure 11. Left rear three-quarter view of the rollover damage.

Tire and Wheel Damage

The left front wheel was embedded with asphalt from its contact and tripping action with the asphalt road surface **(Figure 12)**. During the rollover, additional impact damage (abrasions and deformation) occurred to the tire and wheel assembly which resulted in separation of the lower left ball joint from the lower control arm. The sidewall area of the left front tire was abraded from contact with the road surface and the outer aspect of the tire tread was abraded from the initial yaw. The left rear alloy wheel was abraded 300 degrees circumferentially with a 43.2 cm (17.0") area of the bead fractured from the wheel. The left rear suspension was damaged due to wheel contact during the rollover. Suspension damage consisted of separation of the lower ball joint, fracturing of the axle spindle, and a large fracture of the inner aspect of the alloy wheel. Both left side tires were completely aired out and separated from the beads, however, the tires remained on the wheels.

Figure 12. Close-up view of the embedded asphalt into the left front alloy wheel.

The right side tires and wheels were superficially damaged, however, both tires remained inflated to a recorded pressure of 29 psi. The right front wheel contained asphalt embedded between the bead of the wheel and tire which resulted in a separation of 1.2 cm (0.5") of the tire bead. This occurred during the rollover event as the vehicle impacted the pavement during the third (3rd) quarter turn. All tires were in new condition with a tread depth of 11/32nds.

Manual Restraint Systems

The interior of the Mercedes-Benz consisted of a five passenger seating configuration with two front bucket seats and three individual rear seat positions. The four outboard seated positions were equipped with 3-point manual lap and shoulder belt systems. The front belt systems consisted of continuous loop belt webbings with sliding latchplates that retracted onto dual mode locking retractors. In addition, the upper anchorages (D-rings) were adjustable and the lower attachment points were affixed to the seat frame. The driver's side D-ring assembly was adjusted to the full-down position. A label affixed to the webbing at the lower anchorage point identified the belt as follows:

A1638600185 (On opposite side of label)
TRW 887001
Ar 4mp 212971L
E13 e H98-27
040096

The driver's belt system did not yield evidence of loading (i.e., D-ring transfers, fabric transfers), however, the latchplate was abraded that was consistent with routine usage. The lack of occupant contact evidence outside of the driver's space supported the driver's statement of belt usage during the crash.

Automatic Restraint Systems

The Mercedes-Benz ML 320 was equipped with a Supplemental Restraint System (SRS) that consisted of frontal air bags for the driver and right front passenger positions and front door mounted side impact air bags. An additional component to the frontal air bag system were pyrotechnic emergency tensioning retractors (ETRs) that were incorporated into the B-pillars for the front seat belt systems. The ETRs activate at deployment of the frontal air bag system and spool-up the slack in the shoulder belt webbing. The frontal air bag system did not deploy (as designed) during the rollover crash, however, the front door mounted side impact air bags deployed during the rollover event. It should be noted that the ML 320 was equipped with a dual threshold deployment system for the frontal air bag system that was based on front seat belt usage.

Figure 13. Deployed left side impact air bag.

The side impact air bag system consisted of an abdominal/thoracic bag that deployed from a module assembly installed in the rear third area of the front door panels **(Figure 13)**. Deployment of the side impact air bags was triggered by a sensor located within the passenger compartment area of the vehicle. The left and right side impact air bags

subsequently deployed as a result of side contact with the asphalt road surface during the rollover event which involved seven (7) quarter turns. The air bags deploy independently of each other, therefore the bags deployed at different intervals within the rollover event.

The side air bags deployed from modules with two nearly symmetrical H-configuration cover flaps. The flaps were 24.1 cm (9.5") in width at the horizontal tear seam and 7.0 cm (2.75") in height. The units were identified with SRS AIR BAG molded into the lower right aspect of the upper module flap. The side impact air bag membrane was constructed of a typical nylon-type fabric that was 50.9 cm (20.0") in overall length and 25.4 cm (10.0") in height at the end seams. The bag was not vented, however, an internal tether limited the inward excursion of the bag to approximately 12.7 cm (5.0"). The wide band internal tether was sewn to the face of the side bag with a 21.1 cm (4.75") long stitch pattern at the mid point of the bag. In its deflated state, the side impact air bag involved the rear two-thirds of the respective door panels.

At deployment of the side impact air bag system, the upper module cover flaps opened 180 degrees into the upper aspect of the door panel. Both door panels were scuffed with similar patterns from the flap contact. The lower module cover flap opened 90 degrees against the integral door armrest. Scuff marks from the outer edges of the lower cover flaps were present on the armrest fabric. There was no contact evidence on the deployed side impact air bag membrane.

DRIVER DEMOGRAPHICS

Age/Sex:	30 year old female
Height:	154.9 cm (61.0")
Weight:	54.4 kg (120.0 lb)
Manual Restraint Usage:	3-point lap and shoulder belt system
Usage Source:	Vehicle inspection, interview data
Eyeware:	None
Mode of Transport From Scene:	Ambulance
Type of Medical Treatment:	Treated at a local hospital and released

Driver Injuries

Injury	Injury Severity (AIS 90)	Injury Mechanisms
Contusion with abrasion over the lateral aspect of the left thigh	Minor (890402.1,2 890202.1,2)	Left door armrest
Vertically oriented contusion with abrasion of the medial aspect of the right lower leg	Minor (890402.1,1 890202.1,1)	Knee bolster

Injury	Injury Severity (AIS 90)	Injury Mechanisms
Abrasion over right hand and wrist	Minor (790202.1,1)	Non-deployed driver air bag module cover
Cervical strain	Minor (640278.1,6)	Headliner
Contusion over the left scapular area	Minor (690402.1,2)	Seat back support

Driver Kinematics

The driver of the Mercedes-Benz was a 30 year old female with a height of 154.9 cm (61.0") and weight of 54.4 kg (120.0 lbs). She was not wearing prescription lenses or protective eyeware. The driver stated that she was properly restrained by the manual 3-point lap and shoulder belt system Although there was no direct loading evidence on the belt system, belt usage was supported by the lack of occupant contacts outboard the immediate area of her seated position. The latchplate yielded several faint superficial abrasions that were consistent with routine usage. The D-ring was found adjusted to the lowest position that was consistent with her small stature of 154.9 cm (61.0").

The driver was seated in an upright driving posture with the power seat adjusted to a forward track position. The seat back was slightly reclined and the adjustable head restraint was positioned 7.0 cm (2.75") above the top of the seat back support.

During the lateral overturn sequence, the driver contacted the knee bolster, center console, steering wheel air bag module cover, left upper A-pillar, left side impact air bag, and the left door panel. The driver's lower extremities contacted the bolster, the base of the steering column, and the left side of the console **(Figure 14)**. The bolster contact was evidenced by a vertically oriented patterned fabric transfer/scuff that was located 46.4-52.1 cm (18.25-20.5") left of center and 27.9-36.8 cm (11.0-14.5") below the upper instrument panel. Two additional small scuff marks were located on the vertical transfer. On the base of the column at the outboard edges were two scuff marks that probably resulted from contact with the upper aspect of the knees. The driver's right lateral leg contacted the lower left corner of the mid instrument panel and the left side of the center console. Both contact points were evidenced by patterned transfers. As a result of bolster contact, the driver sustained a vertically oriented contusion with abrasion over the medial aspect of the right lower leg.

Figure 14. Lower extremity contacts to the knee bolster.

Figure 15. Scuff marks on the non-deployed driver air bag module cover.

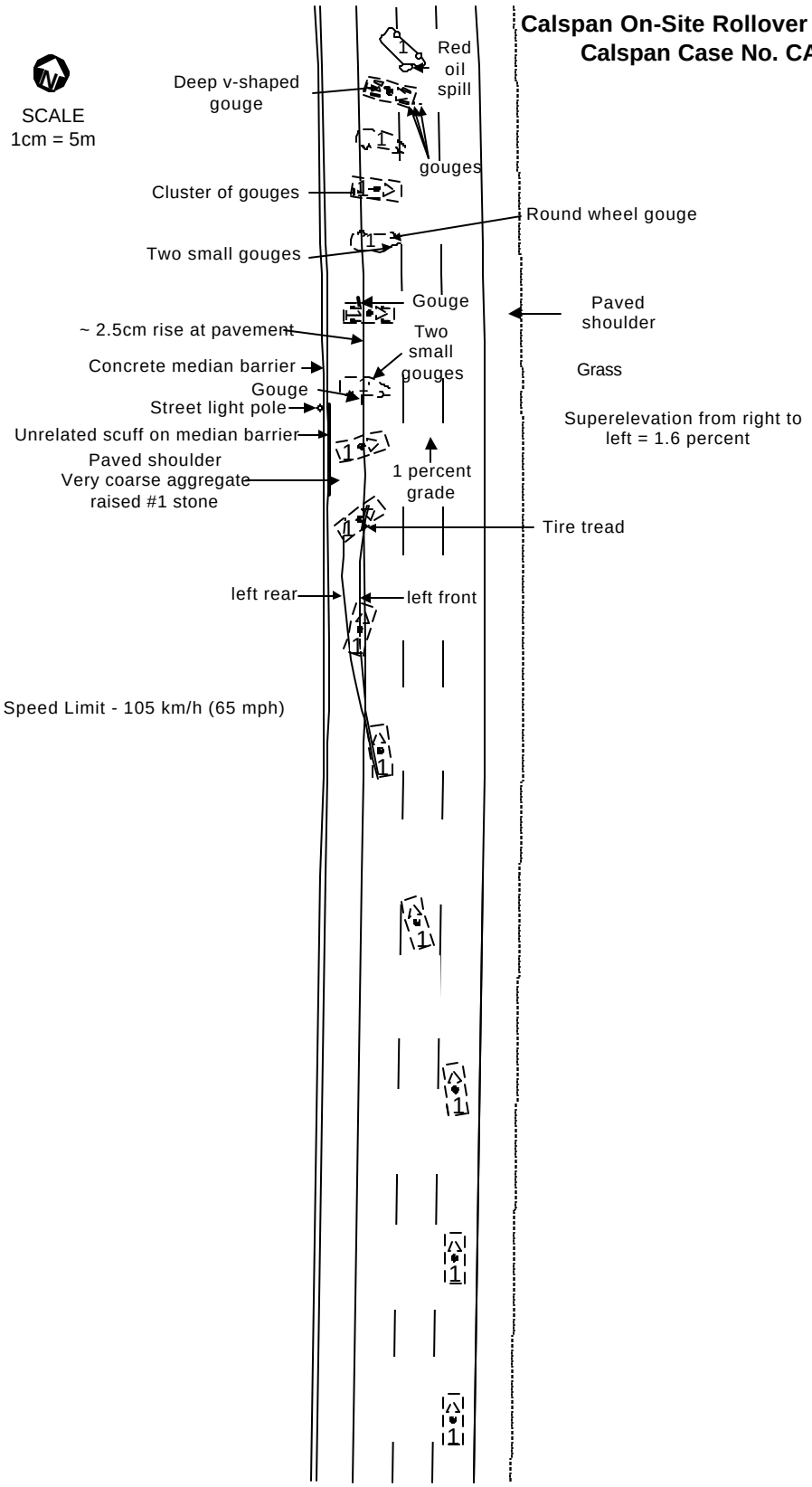
A large horizontally oriented scuff mark extended across the right upper aspect of the driver's side air bag module cover. The scuff mark

extended from the midpoint of the Mercedes logo to the right upper spoke and measured 14.0 cm (5.5") horizontally and 1.2 cm (0.5") in width. A second scuff mark was noted to the right mid area of the module cover **(Figure 15)**. The driver's right hand/wrist probably contacted the non-deployed module cover during the rollover which resulted in an abrasion over right hand and wrist. The driver's left arm probably contacted the left upper A-pillar as evidenced by scuff marks 13.3-15.2 cm (5.25-6.0") above the upper instrument panel and at the juncture with the side rail area. No injury occurred from the A-pillar contact. Her head probably contacted the headliner at the left rear corner area of the sun roof. The trim was compressed against the headliner and a single strand of hair was embedded into the fabric headliner. The driver sustained cervical strain that was induced from the head contact against the headliner. She probably rebounded into the left seat back support during the rollover event which resulted in a contusion over the left scapular area.

The driver's left abdominal/thoracic area probably loaded against the deployed left side impact air bag during the overturn. There was no direct contact evidence on the air bag, however, the inner door panel was displaced in an outward direction.

As a result of forces associated with the overturn event and her contact with the interior components, the driver sustained a contusion with abrasion over the lateral aspect of the upper left thigh, a vertically oriented contusion of the medial aspect of the right lower leg, a contusion over the scapular area, and an abrasion of the right wrist.

Immediately following the overturn as the vehicle came to rest, the driver unbuckled the manual belt system and fell onto the right door area of the vehicle. She reached to turn off the compact disc player and attempted to open the left front door. She was unable to open the door and subsequently crawled through the left rear door window opening where she was assisted by passing motorists who stopped at the crash scene. She was transported by ambulance to a local hospital where she was X-rayed for possible injury and released.


Calspan On-Site Rollover Investigation
Calspan Case No. CA98-003
SCALE
1cm = 5m
Red
oil
spill
Deep v-shaped
gouge
gouges
Cluster of gouges
Round wheel gouge
Two small gouges
Gouge
Paved
shoulder
~ 2.5cm rise at pavement
Two
small
gouges
Concrete median barrier
Grass
Gouge
Street light pole
Superelevation from right to
left = 1.6 percent
Unrelated scuff on median barrier
Paved shoulder
Very coarse aggregate
raised #1 stone
1 percent
grade
Tire tread
left rear
left front
Speed Limit - 105 km/h (65 mph)