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CALSPAN ON-SITE ROLLOVER CRASH INVESTIGATION

SCI CASE NO.: CA11009

VEHICLE: 2011 MERCEDES-BENZ ML350

LOCATION: NORTH CAROLINA

CRASH DATE: FEBRUARY 2011

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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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16. Abstract This on-site investigation focused on the rollover and source of occupant injury for the off-road, rollover crash of a 2011 Mercedes-Benz ML350. The crash occurred as the Mercedes was negotiating a left curve and departed the right side of the roadway. During the departure, the front right corner of the Mercedes impacted, fractured and displaced a utility pole. This impact redirected the Mercedes into a clockwise (CW) yaw off the right side of the roadway where the front plane of the Mercedes impacted a mailbox post. The Mercedes continued its CW yaw and tripped into a left side leading rollover. The vehicle rolled six-quarter turns coming to rest on its roof. The pole impact to the front right of the Mercedes and the subsequent rollover resulted in the deployment of the CAC frontal air bags, the right side impact air bags and both IC air bags. The Mercedes was occupied by a restrained 22-year-old male driver, an unrestrained 20-year-old male front right passenger and an unrestrained 24-year-old female second row left passenger. The driver reported no injuries and was not medically transported from the scene. The front right passenger was transported by personal vehicle directly to a regional trauma center and the second row left passenger was transported by ground ambulance to the same trauma center. The front right passenger was treated in the emergency department for minor soft tissue injuries and was released the same day. The female second row left passenger was admitted and hospitalized for the treatment of moderate severity fractures and internal injuries. She was released four days post-crash.			
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BACKGROUND

This on-site investigation focused on the rollover and source of occupant injury for the run-off-road, rollover crash of a 2011 Mercedes-Benz ML350 (**Figure 1**). This vehicle was identified by the Calspan Special Crash Investigations (SCI) team through a visit to a regional vehicle salvage facility on March 25, 2011. Based on the rollover of the late model year vehicle and the injured status of the passengers, this case was assigned by the Crash Investigation Division (CID) of the National Highway Traffic Safety Administration (NHTSA) for investigation on March 25, 2011. The on-site portion of the investigation was initiated on March 29, 2011 and involved the inspection and documentation of the Mercedes and the crash scene, and a detailed interview with the driver.

Figure 1: Front right oblique view of the 2011 Mercedes ML350.

The crash occurred as the Mercedes was negotiating a left curve and departed the right side of the roadway. During the departure, the front right corner of the Mercedes impacted, fractured and displaced a utility pole. This impact redirected the Mercedes into a clockwise (CW) yaw off the right side of the roadway where the front plane of the Mercedes impacted a mailbox post. The Mercedes continued its CW yaw and tripped into a left side leading rollover. The vehicle rolled six-quarter turns coming to rest on its roof. The Mercedes was equipped with the *Pre-Safe* occupant protection system, a Certified Advanced 208-Compliant (CAC) frontal air bag system, side impact air bags in the front and second row outboard seatbacks, and Inflatable Curtain (IC) air bags with rollover sensing. The pole impact to the front right of the Mercedes and the subsequent rollover resulted in the deployment of the CAC frontal air bags, the right side impact air bags and both IC air bags. The Mercedes was occupied by a restrained 22-year-old male driver, an unrestrained 20-year-old male front right passenger and an unrestrained 24-year-old female second row left passenger. The driver reported no injuries and was not medically transported from the scene. The front right passenger was transported by personal vehicle directly to a regional trauma center and the second row left passenger was transported by ground ambulance to the same trauma center. The front right passenger was treated in the emergency department for minor soft tissue injuries and was released the same day. The female second row

left passenger was admitted and hospitalized for the treatment of moderate severity fractures and internal injuries. She was released four days post-crash.

CRASH SUMMARY

Crash Site

This crash occurred during the early morning hours of February 2011. The environmental conditions at the time of the crash were clear, dry, and dark but lighted by overhead street lights. This crash occurred on a wide two-lane residential roadway that had legal roadside parking adjacent to the curb line. The roadway extended east/west and included a 122 m (400 ft) radius left curve in the direction of travel for the Mercedes. The eastbound travel lane was 6.2 m (20.3 ft) in width and the westbound travel lane was 6 m (19.7 ft) in width. The roadway had a grade of -3% in the pre-crash area, which transitioned to a grade of -1% in the area in which the Mercedes departed the roadway. The roadway was bordered by 8 cm (3 in) concrete barrier curbs. Outboard of the curbs, the roadside consisted of an 80 cm (31.5 in) wide grass area and a 1.4 m (4.6 ft) wide concrete sidewalk. Residential driveways intersected the main roadway at irregular intervals throughout the area of the crash, and landscaped residential yards extended outboard of the sidewalks. Utility poles, measuring 36 cm (14 in) in diameter, were located in the grass area between the curbs and the sidewalks on both roadsides. Outboard of the sidewalk, the slope of the south roadside increased to +4% perpendicular to the roadway. Along the vehicle's path of travel, the grade transitioned from -2% at the road departure, to a level grade at the trip point, and then to a +2% positive grade along the path to final rest. **Figure 2** is an eastbound trajectory view of the Mercedes approaching the roadway departure. **Figure 3** is a trajectory view of the Mercedes at the initiation of the rollover. A Scene Diagram is included at the end of this report.

Figure 2: Eastbound trajectory view of the Mercedes approaching the road departure and the initial utility pole impact.

Figure 3: Eastbound trajectory view of the Mercedes at the initiation of the rollover.

Pre-Crash

The driver of the Mercedes was operating the vehicle eastbound, negotiating the left curve, at a police-reported speed of 56 km/h (35 mph). The Mercedes departed the roadway to the right in a tracking attitude at a shallow angle of approximately 3 degrees. The front right corner of the Mercedes approached the utility pole on the south roadside. Based on the SCI scene inspection, there was no evidence of braking or steering avoidance maneuvers prior to the initial impact with the utility pole **(Figure 4)**.

Figure 4: Eastbound trajectory view of the Mercedes at the initial (Event 1) point of impact.

Crash

The front right corner (front plane) of the Mercedes impacted the 36 cm (14 in) utility pole (Event 1). The pole was completely fractured by the impact and had been replaced at the time of the SCI scene inspection. The force of this impact caused the actuation of the first and second row outboard safety belt pretensioners and the deployment of the CAC driver and front right passenger's frontal air bags in the Mercedes. The impact with the utility pole induced a CW yaw to the vehicle. A yaw mark on the asphalt roadway was attributed to its rear left tire. The Mercedes was equipped with Electronic Stability Control (ESC); however, ESC was an ineffective countermeasure of the induced yaw due to the force of the impact. As the left front wheel crossed the curb, it produced a furrow in the grass area and a yaw mark across the concrete sidewalk. The total length of the yaw marks measured 17 m (55.8 ft) and 11.2 m (36.7 ft) for the left rear and left front tires, respectively.

The Mercedes traveled 9.3 m (30.5 ft) east of the utility pole and yawed 35 degrees CW at which point it impacted a mailbox post with its front plane (Event 2). The mailbox post sheared as a result of the impact. The Mercedes sustained only minor frontal damage from this impact. Subsequent to the Event 2 impact, the Mercedes continued its CW yaw and eastbound trajectory. The vehicle traversed a 5.5 m (18 ft) wide asphalt driveway that extended south, perpendicular to the main roadway and yawed an additional 30 degrees CW. The left front tire debeaded at the west edge of the driveway. The yaw mark on the concrete sidewalk and the furrow on the grass transitioned to a gouge mark on the asphalt driveway evidencing the vehicle's trajectory.

Adjacent to the east edge of the driveway was a narrow depression in the grass that measured 31 cm (12 in) in width and 8 cm (3 in) in depth. The left wheels of the Mercedes entered this depression, furrowed and tripped the vehicle into a left side leading rollover (Event 3). The rollover resulted in the deployment of the IC air bags on both sides of the Mercedes. The vehicle

rolled three-quarter turns and the right plane impacted the ground resulting in the deployment of the right side impact air bags. A 2 m (6.6 ft) gouge mark and a 1.8 m (5.9 ft) area of disturbed dirt in the residential yard south of the roadway evidenced the vehicle's ground contact. The Mercedes rolled a total of six-quarter turns over a distance of 20.4 m (67 ft) coming to rest on its roof facing west. Damaged landscape edging and plants indicated the final rest location of the Mercedes.

Post-Crash

The occupants of the Mercedes exited the vehicle under their own power. The second row left passenger attempted to walk to a nearby house for assistance, but reportedly lost consciousness a short distance away from the final rest position of the vehicle. The driver attempted to assist her, as well as the front right occupant. Police, emergency medical and tow personnel responded to the crash site. All three occupants were evaluated at the scene by EMS personnel and all three initially refused transport by EMS. The driver was not medically transported from the scene but was taken by police for testing to determine possible alcohol impairment. The front right passenger was transported by personal vehicle directly to a regional trauma center that was located in close proximity to the crash site. He was treated in the emergency department and released the same day. The second row left passenger was transported by ground ambulance to the regional trauma center where she was admitted and hospitalized four days for treatment of moderate severity injuries. The Mercedes was towed from the scene due to disabling damage. It was later transferred to a regional vehicle salvage facility for auction, where it was inspected.

2011 MERCEDES-BENZ ML350

Description

The 2011 Mercedes was manufactured in August, 2010 and was identified by the Vehicle Identification Number (VIN): 4JGBB5GB4BAxxxxxx. The driver reported that the odometer reading was approximately 8,045 km (5,000 miles) at the time of the crash. The rear-wheel drive Mercedes was powered by a 3.5-liter V-6 engine linked to a seven-speed shiftable automatic transmission. The braking system consisted of power-assisted front and rear disc brakes with four-wheel antilock, electronic brakeforce distribution, emergency brake assist, and automatic brake drying. The Mercedes was also equipped with Electronic Stability Control (ESC), traction control, the Mercedes' *Pre-Safe* occupant protection system, post-collision safety system and a direct Tire Pressure Monitoring System (TPMS). The driver stated in the interview that there were no warning lights illuminated for the TPMS, check engine, or any other warning system prior to the crash. The Mercedes was equipped with four Continental 4x4 Contact tires, size P255/50R19, which matched the vehicle manufacturer recommended tire size. The vehicle manufacturer recommended cold tire pressure was 248 kPa (36 PSI) for the front and 262 kPa (38 PSI) for the rear. The specific tire data at the time of the SCI inspection was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	228 kPa (33 PSI)	7 mm (9/32 in)	No	None
LR	221 kPa (32 PSI)	7 mm (9/32 in)	No	None
RR	186 kPa (27 PSI)	6 mm (8/32 in)	No	None
RF	Unknown	Unknown	Unknown	Tire and wheel separated from the vehicle and not available for inspection.

The interior of the Mercedes was configured with leather-surfaced five-passenger seating. The front bucket seats were separated by a center console. All five seating positions were equipped with height adjustable head restraints, with the front row head restraints containing an automatic whiplash protection system. At the time of the SCI inspection, the driver's head restraint was 7 cm (2.8 in) above the full-down position. The front right head restraint was 10 cm (3.9 in) above the full-down position, and had been contacted but not compressed by the intruding right B-pillar and roof side rail. The second row left head restraint was 7 cm (2.8 in) above the full-down position, and the second row center head restraint was 10 cm (4.1 in) above the full-down position. The second row left and center head restraints were not damaged. The second row right head restraint was deformed by the intrusion of the right roof side rail. The inboard aspect of the head restraint was 8 cm (3.1 in) above the full-down position, and the outboard aspect of the head restraint was contacting the top of the right seatback. Both front seat tracks were in the full-rear position at the time of the SCI inspection. Both front seatbacks were at an angle 25 degrees aft of vertical. The second row consisted of a split bench seat with folding backs that were capable of folding flat to create a flat cargo floor from the rear hatch to the back of the front seatbacks.

The occupant safety systems consisted of 3-point lap and shoulder safety belts for all five designated seating positions, front row electric and pyrotechnic pretensioners, front row safety belt force limiters, second row safety belt pretensioners, CAC dual-stage frontal air bags, side impact air bags located in the upper outboard aspects of the front and second row outboard seats, and rollover-sensing IC air bags located in both roof side rails that provide protection to the four outboard seating positions. The manufacturer's literature indicated that the *Pre-Safe* occupant positioning system moved the front passenger seat rearward and upward, positioned the front head restraints to help prevent whiplash, and electrically pretensioned the front safety belts if vehicle movements and/or driver inputs were suggestive of an imminent crash. Additionally if severe lateral skidding was detected indicative of a rollover crash, the side windows and the sunroof automatically closed. The vehicle was also equipped with a post-collision safety system that reportedly shut off the engine and the fuel supply, unlocked the doors and moved the steering column upward away from the driver.

Exterior Damage

The front, left, and right planes of the Mercedes sustained moderate damage, and the top plane sustained severe damage in this multiple event crash sequence **(Figure 5)**. The Event 1 impact damage with the utility pole was located at the front right corner of the Mercedes. The direct contact damage began at the corner and extended rearward along the right side of the vehicle a length of 84 cm (33.1 in) and ended aft of the right front wheel well. On the front plane, the direct damage began 55 cm (21.7 in) right of the vehicle centerline and extended right 14 cm (5.5 in) to the front right bumper corner. The combined direct and induced damage extended along the full width of the front bumper. The maximum crush to the front bumper was located at C6, the right bumper corner, and measured 16 cm (6.3 in). A residual crush profile was documented along the full width of the front bumper reinforcement and was as follows: C1 = 0 cm, C2 = 2 cm (0.8 in), C3 = 4 cm (1.6 in), C4 = 1 cm (0.4 in), C5 = 1 cm (0.4 in) and C6 = 16 cm (6.3 in). The front right wheel separated from the vehicle and was not available for inspection. Based on the location of the remaining right front suspension components, the right wheelbase was shortened by 40 cm (15.7 in). The corner configuration and yielding of the utility pole for this Event 1 impact invalidated a full reconstruction with the WinSMASH program; however a Barrier Equivalent Speed (BES) of 14 km/h (8.7 mph) was calculated by the Barrier Algorithm of the program. The BES under-estimated the severity of the impact and the results were considered to be low. The CDC assigned to the initial impact was 12FREE4.

Figure 5: Front right oblique view of initial impact damage to the Mercedes.

The initial impact with the utility pole caused the Mercedes to initiate a Clockwise (CW) yaw. The shearing of the pole allowed the vehicle to maintain its trajectory to the east. The front plane of the Mercedes impacted a mailbox (Event 2). This frontal damage from the Event 2 impact was overlapped by the initial impact and subsequent rollover damage, and was not measured.

The top plane of the Mercedes sustained severe damage and the left and right planes sustained moderate damage as a result of the rollover (Event 3). This damage is depicted in **Figure 6**. On the top plane, the direct damage began at the

Figure 6: Overhead view of the Mercedes from the right rear corner.

leading edge of the hood and extended rearward 423 cm (166.5 in) to the backlight header encompassing the 132 cm (52 in) width of the roof from side rail to side rail. The greatest vertical deformation to the greenhouse area was located over the cargo area, at the junction of the right D-pillar and the backlight header. The residual vertical deformation measured 39 cm (15.4 in). Over the passenger compartment, the greatest vertical deformation was located on the right roof side rail 6 cm (2.4 in) aft of the right rear window quarter glass divider. The residual vertical deformation in this area measured 28 cm (11 in). The greatest lateral deformation was also located on the right roof side rail (C-pillar area) 6 cm (2.4 in) aft of the right rear window quarter glass divider. The residual lateral deformation was 5 cm (2 in). The CDC assigned for the rollover event was 00TDDO4.

Interior Damage

The Mercedes sustained moderate-severity interior damage that was attributed to passenger compartment intrusion, occupant contacts and air bag deployment. As a result of the rollover, the roof, right roof side rail and backlight header intruded vertically and the right B-pillar and roof side rail intruded laterally.

The front row lateral intrusion of the right roof side rail and B-pillar measured 8 cm (3.1 in). Combined with the right roof side rail 6 cm (2.4 in) vertical intrusion and the IC air bag deployment, the right roof side rail/headliner was contacting but not compressing the front right head restraint. The vertical intrusion of the roof in the second row was more severe. The left, center and right vertical intrusions measured 6 cm (2.4 in), 26 cm (10.2 in), and 31 cm (12.2 in), respectively. In the second row, the right roof side rail intruded vertically 25 cm (9.8 in). The vertical intrusion of the second row right roof and roof side rail allowed the roof to deform the second row right head restraint vertically 8 cm (3.1 in). The highest level of intrusion was over the rear cargo area. The roof intruded 7 cm (2.8 in), 25 cm (9.8 in) and 31 cm (12.2 in) from left to right. The backlight header intruded 7 cm (2.8 in), 23 cm (9.1 in) and 33 cm (13 in) vertically in the left, center and right positions. The right roof side rail adjacent to the cargo area also intruded 33 cm (13 in) vertically.

There was contact evidence attributed to the unrestrained front right passenger's head on the right sun visor, at the top of the windshield, and on the rear view mirror. The evidence on the sun visor consisted of a scuff mark located 0-8 cm (0-3.1 in) aft of the forward edge of the sun visor and 22-27 cm (8.7-10.6 in) inboard of the visor's right edge. The windshield was fractured and a 6 cm x 9 cm (2.4 in x 3.5 in) tissue transfer was located 24 cm (9.4 in) inboard of the right A-pillar. The rear view mirror was separated from the fractured windshield, but was attached to the header by electrical and data wiring. The rear view mirror was fractured with a blood transfer from a probable contact with the front right passenger's head. The unrestrained second row left passenger deposited scuff marks on the back of the driver's seatback, the upper left corner of the front right passenger's seat, the inboard side of the front right passenger's head

Figure 7: Left lateral view of the contacts within the Mercedes second row.

restraint, and the right roof slightly aft of the right B-pillar. The evidence on the back of the driver's seat was attributed to the second row passenger's left knee. This contact evidence was located 21-28 cm (8.3-11 in) below the top of the seat and 5-12 cm (2-4.7 in) inboard of the left edge of the seat. The scuff mark located on the upper left corner of the front right seatback measured 10 cm (3.9 in) in width and 12 cm (4.7 in) in height and was attributed to the passenger's chest. The scuff mark on the inboard aspect of the front right head restraint was located 0-8 cm (0-3.1 in) below the top of the head restraint and 0-7 cm (0-2.8 in) aft of the front of the head restraint. This contact was attributed to the passenger's head. The scuff mark on the interior of the roof was located 17-36 cm (6.7-14.2 in) aft of the right B-pillar and 15-26 cm (5.9-10.2 in) inboard of the right roof side rail. This contact was also attributed to the second row passenger's head. **Figure 7** is an interior view depicting the contacts within the second row of the Mercedes.

The AS1 windshield was completely fractured. It had separated across the full length of the header and sagged due its exposure to the elements in the salvage yard. The AS2 front windows were disintegrated in the crash sequence. The rear windows, rear quarter glass, rear windows adjacent to the cargo area, the backlight and the sunroof were AS3 deep tint glass. The left rear window was fully open prior to the initial impact and was not damaged. The sunroof was not damaged in the rollover. All other rear side windows and the backlight were disintegrated due to impact forces.

All four doors and the rear hatch remained closed and latched to their respective pillars or rear header throughout the crash sequence. The left doors were operational post-crash. Both right doors and the rear hatch were jammed shut post crash.

Manual Restraint Systems

The Mercedes was equipped with 3-point lap and shoulder safety belts for the five designated seating positions. All belt systems utilized continuous loop webbing and sliding latch plates. The upper D-rings for the front seats were height adjustable. The front left height adjustment was 3 cm (1.2 in) below the full-up position and the front right height adjustment was in the full-down position at the time of the SCI inspection. The driver's belt retracted onto an Emergency Locking Retractor (ELR), all other belts retracted onto switchable ELR/Automatic Locking Retractors (ALR). The four outboard seat belts utilized retractor pretensioners which actuated during the crash sequence. The front seats also included buckle pretensioners which actuated

during the crash sequence and pulled the buckles downward a distance of 4 cm (1.6 in). The driver's safety belt was in use at the time of the crash and was locked in its spooled out position. The length of the exposed webbing measured 142 cm (55.9 in). There was also contact evidence on the belt webbing. This evidence consisted of a 3 cm (1.2 in) frictional abrasion attributed to the latch plate located 68 cm (26.8 in) above the lower seat anchor. The front right and all three second row seat safety belts were not in use at the time of the crash. The front right safety belt had been pulled taut against the right B-pillar by the actuation of the retractor pretensioner. A small amount of slack [<3 cm, (<1 in)] was present in the front right belt webbing, indicating that the pretensioner had actuated prior to the intrusion to the right B-pillar and roof side rail. Both outboard second row seat retractor pretensioners had actuated, pulling their respective safety belts taut against the left and right second row seatback.

Supplemental Restraint Systems

The Mercedes was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of dual-stage driver and front right passenger air bags, seat track positioning sensors, a front right occupant presence (weight) sensor, front seat retractor and buckle pretensioners, and safety belt buckle switch sensors. The manufacturer of the Mercedes certified this vehicle was compliant with the advanced air bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. Both of the frontal air bags deployed during the crash.

The Mercedes was also equipped with side impact air bags in the upper outboard aspects of the front row and second row seats, and rollover-sensing IC air bags in the vehicle's roof side rails. Both IC's and the two right side impact air bags deployed during the crash sequence. The side air bags on the left side (front and second row) did not deploy.

The driver's frontal air bag was mounted within the center hub of the four-spoke steering wheel by a five-flap design. The upper center cover flap measured 6 cm (2.4 in) in width and 8 cm (3.1 in) in height. The upper left and right flaps were triangular in shape and measured 3 cm (1.2 in) in width and height. The lower flaps measured 6 cm (2.4 in) in height and 8 cm (3.1 in) in width. There was no damage present to the cover flaps. The driver's air bag measured 68 cm (26.8 in) in diameter in its deflated state. It was vented by two ports in the upper rear aspect of the air bag that were located at the 11 and 1 o'clock positions. There were two internal tethers that attached to the 12 and 6 o'clock positions of a 14 cm (5.5 in) circular tether sewn to the center face of the air bag. The deployed-shape of the air bag was also controlled by two lines of tear threads on the front of the air bag. These threads were arranged in stitch pattern, 3 cm (1.2 in) apart, which extended from the 6 o'clock sector of the air bag to 3 and 9 o'clock positions, respectively. There was no crash-related damage to the driver's air bag. Two small areas of post-crash blood droplets were observed on the air bag. One was located in the front upper right quadrant of the

air bag and the other located in the upper left quadrant on the back side of the air bag. The deployed frontal air bag is depicted in **Figure 8**.

Figure 8: Overall view of the driver's frontal air bag in the Mercedes.

Figure 9: Overall view of the Mercedes front right passenger's air bag.

The front right passenger's frontal air bag **(Figure 9)** was mounted within the upper aspect of the right instrument panel by a single cover flap. This flap measured 25 cm (9.8 in) in width and 12 cm (4.7 in) in height. The deflated air bag was 60 cm (23.6 in) in height and 38 cm (15 in) in width. It was vented by a single vent port at the upper right side of the air bag, and had no internal tethers. There was no crash related damage to the front right air bag. There was an area of post-crash blood located at the lower right on the side of the air bag that measured 15 cm (5.9 in) in width and 28 cm (11 in) in height.

The left and right IC air bags deployed from their respective roof side rails during the crash sequence. The air bags were symmetrical and had the same dimensions. The IC's measured 164 cm (64.6 in) in length, 46 cm (18.1 in) in height at the forward seating positions and 50 cm (19.7 in) in height at the second row seating positions and provided protection from the C-pillars forward to a location 25 cm (9.8 in) aft of the A-pillars. There were no tethers or vent ports in the IC air bags. The air bag was not equipped with a sail panel. The post-crash void at the A-pillar measured 25 cm (9.8 in) wide and 25 cm (9.8 in) high. Both IC's were labeled with the nomenclature: *340190950*

Figures 10 and 11 depict the inboard sides of the left and right IC air bags, respectively. The inboard side of the left IC contained a scuff mark that was attributed to the left side of the driver's head in an area adjacent to the front left seating position. This scuff mark was located 6-41 cm (2.4-16.1 in) below the top of the left IC and 24-34 cm (9.4-13.4 in) aft of the front edge of the air bag. A scuff mark was also present on the inboard side of the right IC, adjacent to the front right seating position. This scuff mark was located 3-32 cm (1.2-12.6 in) below the top of the IC and 31-43 cm (12.2-16.9 in) aft of the front edge of the air bag and was attributed to the

Figure 10: View of the Mercedes left IC, including the driver contact.

Figure 11: View of the Mercedes right IC including the front right passenger contact.

front right passenger's head. On the outboard side of the right IC, at the right front window, were two abrasions from contact with the ground. The first was in the upper left quadrant of the right front window, 6-16 cm (2.4-6.3 in) below the top of the IC and 2-17 cm (0.8-6.7 in) forward of the right B-pillar. The second ground contact abrasion was located 18-40 cm (7.1-15.7 in) below the top of the right IC and 19-41 cm (7.5-16.1 in) aft of the front edge of the right IC.

The two right side impact air bags of the Mercedes also deployed during this crash sequence (**Figures 12 and 13**). The front right side air bag deployed from a 32 cm (12.6 in) tear seam in the upper outboard aspect of the front right seatback. The deflated air bag measured 18 cm (7.1 in) in width and 26 cm (10.2 in) in height. It was vented by one port located slightly below the forward 3 o'clock position on the air bag. The right side air bag was not tethered. It was not damaged and did not contain any crash related evidence. The second row right side air bag deployed from a 36 cm (14.2 in) tear seam in the upper outboard aspect of the seatback.

Figure 12: Lateral view of the front row right side impact air bag.

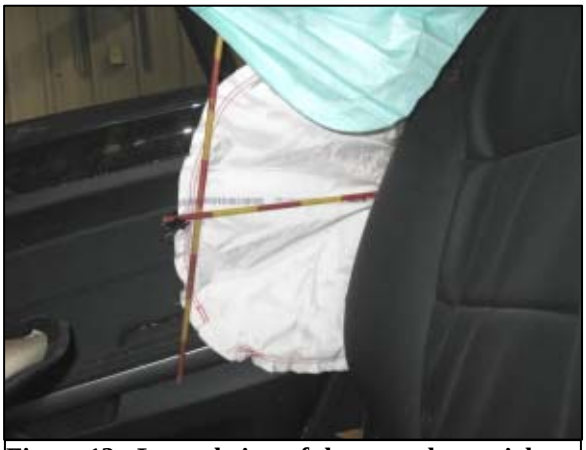

Figure 13: Lateral view of the second row right side impact air bag.

This air bag was 22 cm (8.7 in) wide and 32 cm (12.6 in) in height. It was vented by a single vent port at the forward 4 o'clock position. No crash related evidence was identified on this air bag during its inspection.

Pre/Post-Collision Safety Systems

The Mercedes-Benz ML350 was equipped with a pre-collision occupant protection system known under the proprietary trade name *Pre-Safe*. The Mercedes-Benz website reported the following information regarding the operation of this system.

In the event that sensors within the Electronic Stability Control (ESC) system or Emergency Brake Assist systems detected vehicle movements that indicate an imminent crash, the following reversible preparations were made in the vehicle:

- the front right passenger seat is moved rearward and upward, and the seatback is moved to an upright position;
- both front head restraints move upward and open forward to protect against whiplash;
- both front safety belts are electrically pretensioned to remove slack from the safety belts;
- if the system senses that a rollover is imminent due to lateral skidding, the front windows are raised and the sunroof closes.

At the time of the SCI inspection, the front right seat was found in the full-rear position. Both front head restraints were in a raised position and had opened forward on a spring-loaded mechanical hinge **(Figure 14)**. The SCI inspection revealed that the front windows were closed before disintegrating as a result of the crash due to the presence of glazing fragments in the tracks and seals of the window frames. The sunroof was closed post-crash. The driver stated that he had no recollection of the crash during his interview. He was unaware of the pre-crash position of the windows or sunroof.

Figure 14: Front row head restraints raised and hinged forward.

The Mercedes was also equipped with a post-collision safety system. As reported by the Mercedes-Benz website, in the event of a crash this system was designed to turn the ignition and engine off, turn off the fuel pump, unlock the doors and raise the tilt steering column to its full-up position. At the time of the SCI inspection, all four doors were unlocked and the steering column was in the full-up position. It was not possible to check the status of the fuel pump and ignition.

Rollover Mitigation

The 2011 Mercedes-Benz ML-Class Sport Utility Vehicle (SUV) was tested by the NHTSA for Rollover safety and earned a 4-star rating. In the agency's Dynamic 80 km/h (50 mph) Reverse Steer Test, the Mercedes-Benz ML-Class SUV did not "Tip-up" and the rollover risk was determined to be 17.43%.

The Mercedes-Benz was equipped with Electronic Stability Control (ESC); however, ESC was ineffective as a counter-measure during this crash due to the vehicle's shallow road angle and the Event 1 frontal impact that occurred prior to the rollover. The IC air bags were designed with roll-sensing capabilities and deployed at the onset of the rollover.

2011 MERCEDES ML350 OCCUPANTS

Driver Demographics

Age / Sex:	22 years / Male
Height:	183 cm (72 in)
Weight:	79 kg (175 lb)
Eyewear:	None
Seat Type:	Bucket
Seat Track Position:	Full-rear
Manual Restraint Usage:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Air Bags:	Frontal and IC deployed
Alcohol/Drug involvement:	Police reported 0.15 BAC for driver
Egress from Vehicle:	Exited under his own power through the left front window
Transport from Scene:	Not medically transported
Medical Treatment:	None

Driver Injuries

Inj. No.	Injury	AIS 2005/08	Injury Source	Confidence Level
1	Upper chest contusion	410402.1,7	3-point safety belt	Probable
2	8 cm (3 in) contusion on left elbow, dorsal side	710402.1,2	Left door panel rear upper quadrant	Probable
3	Small cuts on palms of both hands	N/A	Fractured glass, during post-crash egress	N/A

Source: Driver interview data

Driver Kinematics

The 22-year-old male driver of the Mercedes was seated in a rear-track position and was restrained by the manual 3-point lap and shoulder belt system. The Mercedes departed the

roadway to the right for an unknown reason. There was no evidence at the scene which indicated that the driver initiated an avoidance maneuver prior to the initial impact with the utility pole.

At initial impact with the utility pole, the driver's retractor and buckle pretensioners actuated and the driver's frontal air bag deployed. The driver initiated a forward trajectory within the front left seating position in response to the frontal impact. The driver loaded the safety belt webbing which resulted in a chest contusion as he rode down the force of the initial impact. The Mercedes rotated CW as it separated the utility pole from its base. This vehicle then slid across the driveway and tripped into a left side leading rollover. At the initiation of the rollover, the IC air bags deployed. The vehicle rolled 6-quarter turns until arriving at final rest with its roof against the ground. During the rollover sequence, the driver's lower body remained retrained by the safety belt system. His upper body initiated a lateral trajectory and loaded the left IC and door panel. A scuff mark was observed on the left IC. The driver sustained an elbow contusion from contact with the door panel. At final rest, the driver was restrained upside down within the front left seating position. He released his safety belt and exited the vehicle through the disintegrated left front window opening. During egress the driver sustained small cuts on palms of both hands from coming into contact with the disintegrated glazing within the vehicle. He refused medical transport at the crash scene and did not require follow-up treatment.

Front Right Occupant Demographics

Age / Sex:	20 years / Male
Height:	178 cm (70 in)
Weight:	79 kg (175 lb)
Eyewear:	None
Seat Type:	Bucket
Seat Track Position:	Full-rear
Manual Restraint Usage:	None used
Usage Source:	Vehicle inspection
Air Bags:	Right frontal, IC and side impact air bags deployed
Alcohol/Drug Involvement:	Yes, BAC not reported
Egress from Vehicle:	Exited under his own power
Transport from scene:	Refused ambulance transport, transported by personal vehicle to a trauma center
Medical Treatment:	Treated and released the day of the crash

Front Right Occupant Injuries

Inj. No.	Injury	AIS 2005/08	Injury Source	Confidence Level
1	Contusion across forehead	210402.1,7	Sun visor	Probable
2	8 cm (3 in) abrasion on right forehead (above right eye)	210202.1,7	Right roof side rail	Probable

Inj. No.	Injury	AIS 2005/08	Injury Source	Confidence Level
3	Right eyelid abrasion (outer corner of eye)	210202.1,1	Windshield	Probable
4	Right arm contusion on dorsal side from shoulder to wrist	710402.1,1	Ground	Probable
5	Right hip abrasion	810202.1,1	Right front door	Possible
6	Left hip abrasion	810202.1,2	Anterior aspect of right front seatback	Possible
7	Right hip ecchymosis	810402.1,1	Right front door	Possible
8	Left hip ecchymosis	810402.1,2	Anterior aspect of right front seatback	Possible
9	Epistaxis (bloody nose)	251004.1,4	Windshield	Probable

Source: Driver interview data and Medical Records

Front Right Occupant Kinematics

The 20-year-old male front right occupant was unrestrained and seated in a rear-track position. At initial impact with the utility pole, the retractor and buckle belt pretensioners actuated and the front right frontal air bag deployed. The unused safety belt webbing was pulled taut against the B-pillar. The front right occupant initiated a forward trajectory in response to the 12 o'clock direction of force and loaded the frontal air bag with his chest. He contacted the right sun visor with his forehead which caused a scuff mark to the visor's cloth surface. This contact resulted in a contusion across his forehead. This occupant's nose contacted the upper aspect of the windshield causing an epistaxis. The sun visor and windshield contact were vertically in line and adjacent to each other. Dermal tissue was noted in the windshield contact. This was associated with a right eyelid abrasion.

The Mercedes rotated CW as it separated from the utility pole, slid across the driveway, and tripped into a left side leading rollover. At the initiation of the rollover, the IC air bags deployed. During the rollover, the unrestrained front right occupant initiated a lateral trajectory within the interior compartment. As the vehicle rolled 3-quarter turns, the right plane of the vehicle impacted the ground. This ground impact resulted in the deployment of the right seatback-mounted side impact air bags. The occupant responded to the ground impact with a right lateral trajectory and loaded the right IC with his upper body and right shoulder/arm. This loading compressed the IC against the ground resulting in a right, dorsal arm contusion extending from his shoulder to his wrist. Abrasions, consistent with ground contact, were noted on the outboard surface of the IC. Abrasions of this nature were not observed on the outboard surface of the IC's at the second row right window area or either of the left window areas.

As the Mercedes continued to rotate about its longitudinal axis, the front right occupant loaded the anterior aspect of the right front seatback. This contact caused a left hip abrasion with prominent bruising. He was then redirected towards the right side of the vehicle where he made

contact with the right roof side rail and right front door panel. This occupant sustained an 8 cm (3 in) abrasion to his right forehead from the right roof side rail and a right hip abrasion with significant bruising from contact with the right front door.

The separated rear view mirror contacted the front right occupant's bloody nose during the roll sequence resulting in the blood transfer. When the Mercedes-Benz came to final rest, in its inverted position, the front right occupant fell onto the interior first row roof area. He was not ejected during the rollover sequence and exited the vehicle under his own power through an unidentified window.

The front right occupant was evaluated by EMS at the scene but refused transport by ground ambulance. He was transported by a personal vehicle to a regional trauma center, where he was treated in the emergency department for minor soft tissue injuries and released the same day.

Second Row Left Occupant Demographics

Age / Sex:	24 years / Female
Height:	168 cm (66 in)
Weight:	54 kg (120 lb)
Eyewear:	Prescription glasses
Seat Type:	Split-bench with folding back
Seat Track Position:	Not adjustable
Manual Restraint Usage:	None used
Usage Source:	Vehicle inspection
Air Bags:	IC deployed
Alcohol/Drug Involvement:	Yes, BAC not reported
Egress from Vehicle:	Exited the vehicle under her own power
Transport from scene:	Ground ambulance
Medical Treatment:	Admitted to a regional trauma center for four days.

Second row Left Occupant Injuries

Inj. No.	Injury	AIS 2005/08	Injury Source	Confidence Level
1	C3 left pars fracture that extends posteriorly to involve the left lamina	650217.2,6	Roof	Probable
2	Grade 1-2 liver laceration (3-4 cm diameter)	541822.2,1	Inboard aspect of posterior front right seatback	Probable
3	Right small apical pneumothorax (2.5cm at the greatest thickness)	442202.2,1	Inboard aspect of posterior front right seatback	Probable
4	Loss of consciousness NFS	161003.2,0	Roof	Probable
5	Left cheek contusion	210402.1,2	Roof	Possible

Inj. No.	Injury	AIS 2005/08	Injury Source	Confidence Level
6	Right cheek contusion	210402.1,1	Inboard aspect of posterior front right head restraint	Probable
7	Left cheek abrasion	210202.1,2	Roof	Possible
8	Lower lip abrasion	210202.1,8	Inboard aspect of posterior front right head restraint	Probable
9	Left hand small abrasion	710202.1,2	Roof	Possible
10	Left flank abrasions	510202.1,2	Posterior aspect of driver's seatback	Possible
11	Left flank contusions	510402.1,2	Posterior aspect of driver's seatback	Possible
12	Right thigh abrasion	810202.1,1	Posterior aspect of driver's seatback	Probable
13	Bilateral lower leg and ankle (medial aspect) abrasions	810202.1,3	Posterior aspect of driver's seatback	Probable
14	Bilateral knee and lower leg contusions	810402.1,3	Posterior aspect of driver's seatback	Certain

Source: Driver interview data and Medical Records

Second Row Left Occupant Kinematics

The 24-year-old female second row left occupant was unrestrained and seated in the second row left position. As a result of the initial impact with the utility pole, she initiated a forward trajectory and her lower body loaded the posterior aspect of the driver's seatback. This contact with the seatback resulted in bilateral knee and lower leg contusions and abrasions as well as a right thigh abrasion. Her upper body was redirected laterally right from the driver seatback and her torso loaded the inboard aspect of posterior front right seatback. This contact resulted in the liver laceration and the right apical pneumothorax.

The Mercedes rotated CW as it separated the utility pole from its base. This vehicle then slid across the driveway and tripped into a left side leading rollover. At the initiation of the rollover, the IC air bags deployed. As the Mercedes continued to rotate about its longitudinal axis, the second row left occupant loaded the interior second row roof area, which caused a C3 left pars fracture, loss of consciousness and abrasions and contusions to her left cheek and hand.

The second row left occupant was then redirected towards the second row seating area of the vehicle where she made contact with the inboard aspect of the posterior, front right head restraint and the posterior aspect of the driver's seatback. This occupant sustained a right cheek contusion and a lower lip abrasion from contact with the front right head restraint. She also sustained left flank abrasions and contusions from contact with the driver's seatback. During the rollover, this unrestrained occupant loaded the deployed right IC with her upper body and was contained within the vehicle.

When the Mercedes came to final rest, the second row left occupant was laying on the roof of the inverted vehicle. She was conscious and exited the vehicle through an unknown disintegrated window. She attempted to reach a nearby house for help, but reportedly lost consciousness a short distance from the vehicle. The female occupant was evaluated by EMS at the scene of the crash and reportedly regained consciousness during the course of the examination. She initially refused transport, but then agreed to be taken by ground ambulance to a regional trauma center. She was hospitalized for four days and treated for her numerous injuries.

SCENE DIAGRAM