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CALSPAN ON-SITE ROLLOVER CRASH INVESTIGATION
SCI CASE NO.: CA09025

VEHICLE: 2009 FORD MUSTANG

LOCATION: NORTH CAROLINA

CRASH DATE: MARCH 2009

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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 a run-off-road rollover crash that involved a 2009 Ford Mustang. The vehicle was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system and seat back-mounted side impact air bags. The manufacturer of the Ford has certified that the vehicle is compliant with the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC system includes dual-stage frontal air bags for the driver and right front passenger positions, seat track positioning sensors, retractor pretensioners, and a front right occupant presence sensor. The vehicle departed the roadway to the right, rotated counterclockwise before traveling perpendicular to an embankment and rolling over 4-quarter turns coming to rest on its wheels. None of the available air bags deployed during the crash sequence. The 33-year-old restrained male driver was transported to a local hospital by ambulance, then transferred to a regional trauma center and admitted for treatment of moderate severity injuries. The 8-year-old male passenger was taken by a personal vehicle to a local hospital for evaluation.			
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TABLE OF CONTENTS

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BACKGROUND

This on-site investigation focused on a run-off-road rollover crash that involved a 2009 Ford Mustang **(Figure 1)**. The vehicle was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system and seat back-mounted side impact air bags. The manufacturer of the Ford has certified that the vehicle is compliant with the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC system includes dual-stage frontal air bags for the driver and right front passenger positions, seat track positioning sensors, retractor pretensioners, and a front right occupant presence sensor. The vehicle departed the roadway to the right, rotated counterclockwise before traveling perpendicular to an embankment and rolling over 4-quarters coming to rest on its wheels. None of the available air bags deployed during the crash sequence. The 33-year-old restrained male driver was transported to a local hospital by ambulance, then transferred to a regional trauma center and admitted for treatment of moderate severity injuries. The 8-year-old male passenger was taken by a personal vehicle to a local hospital for evaluation.

Figure 1: Left front oblique view of the Ford.

This crash was identified through a visit to a regional vehicle-salvage facility on April 21, 2009. Based on the rollover crash dynamics of the late model year vehicle, this case was assigned for on-site investigation on April 22, 2009. The on-site portion of this investigation was conducted on April 22-23, 2009. This investigation involved the inspection and documentation of the Ford and the crash site, and a detailed interview with the owner of the vehicle.

SUMMARY

Crash site

This crash occurred during daylight hours on the south roadside of a five-lane east/west roadway. The roadway was configured with two travel lanes in each direction and a center two-way left turn lane. The weather conditions were reported as clear and dry. The roadway was straight and level in the vicinity of the crash site. The road edges were bordered by concrete curbs that were 14 cm (5.5 in) in height. The outer eastbound lane measured 4.3 m (14.1 ft) in width, and the

inner eastbound lane measured 3.7 m (12.1 ft) in width. The center turn lane measured 4.9 m (16.1 ft) in width. Beyond the curb line bordering the eastbound lanes was a grass strip 0.6 m (2 ft) in width. Outboard the grass strip was a 2.3 m (7.5 ft) wide asphalt sidewalk bordered to the south by a grass embankment. The embankment began 3.7 m (12.1 ft) south of the south curb and extended south 3.1 m (10.2 ft) with a negative grade of 70 percent. At the bottom of the embankment was a fence line that bordered the rear of a residential neighborhood. One fence line was parallel to the roadway, 8.5 m (27.9 ft) south of the south barrier curb. A second fence line was constructed at an angle nearly perpendicular to the roadway and was struck during the crash. The struck fence consisted of a split-rail fence three rails high, with a height of 1.4 m (4.6 ft). Within the fenced area was natural growth consisting of pine trees with small brush. The posted speed limit for the roadway was 72 km/h (45 mph). The Crash Schematic is included as **Figure 9** of this report.

Vehicle Data

The case vehicle was a 2009 Ford Mustang two-door coupe. The Ford was manufactured in August, 2008 and was identified by the Vehicle Identification Number (VIN) 1ZVHT80N295 (production number deleted). The vehicle was purchased new by the owner/driver.

The rear-wheel drive Ford was powered by a 4.0 liter V-6 engine, linked to a five-speed manual transmission. The braking system consisted of power assisted four-wheel disc brakes with anti-lock. The Ford was also equipped with an indirect Tire Pressure Monitoring System (TPMS). It is unknown if the TPMS warning light was illuminated prior to the crash. The door window glazings were closed at the time of the crash. The Ford was equipped with BF Goodrich Traction TA P215/65R16 tires with a Tire Identification Number (TIN) of AP2H H111 2508. The vehicle manufacturer recommended tire size was P215/65R16. The recommended cold tire pressure was 241 kPa (35 PSI) front and rear. The tires were mounted on OEM five-spoke alloy wheels. The specific tire data at the time of the SCI inspection was as follows:

Position	Measured Tire Pressure	Measured Tread Depth	Tire/Wheel Damage
Left Front	214 kPa (31 PSI)	6 mm (8/32 in)	None
Left Rear	214 kPa (31 PSI)	6 mm (8/32 in)	None
Right Front	Flat	6 mm (8/32 in)	De-beaded/Rim deformed
Right Rear	207 kPa (30 PSI)	6 mm (7/32 in)	None

The interior of the Ford was configured with cloth-surfaced four-passenger seating. The front bucket seats were separated by a center console and equipped with adjustable head restraints. Both head restraints were found to be in the full-down position. The front left seat back was measured at an angle of 29 degrees rear of vertical with the front right seat adjusted to an angle of 31 degrees rear of vertical. The front left seat cushion was height adjustable and found to be

in the full-down position. The rear bench seat had 50/50 split folding backs with integral head restraints.

The interior safety systems consisted of three-point lap and shoulder belts for all four designated positions, a Certified Advanced 208-Compliant (CAC) frontal air bag system consisting of dual-stage frontal air bags for the driver and right front passenger positions, seat track positioning sensors, retractor pretensioners, and a front right occupant weight sensor, and side impact air bags located in the outboard aspect of the front seat backs.

Crash Sequence

Pre-crash

The restrained 33-year-old male driver of the Ford was traveling eastbound in the outboard lane on the five-lane roadway. The driver was en route to his residence with the 8-year-old male front right passenger. The driver was traveling on a straight, level section of the roadway at approximately 64 km/h (40 mph) due to traffic. The driver stated to the police investigator that another vehicle traveling on the inboard lane changed lanes to the right, encroaching into his lane. The non-contact vehicle's movement caused the Ford's driver to initiate an avoidance maneuver by steering to the right and braking. Consequently, the vehicle departed the roadway to the right traveling over the curb, grass strip and asphalt sidewalk. The driver attempted to return to the roadway by initiating a steering maneuver to the left. The combination of the left steering maneuver and the 70 percent grade of the embankment induced a counterclockwise yaw. The Ford rotated approximately 20 degrees counterclockwise within the south roadside area.

Crash

The Ford initiated a right side leading fall-over type rollover event down the embankment **(Figure 2)**. As the Ford rolled two-quarter turns, the top plane of the hood impacted the wood split-rail fence. The impact fractured the fence as the vehicle continued to roll. The Ford rolled over four-quarter turns coming to rest on its wheels. The vehicle came to rest in a residential back yard.

Figure 2: Steep slope of the grass-surfaced embankment.

Post-Crash

The police, emergency medical personnel, and tow personnel responded to the crash site. Both the driver and the front right passenger were removed from the vehicle by emergency medical personnel. Due to perceived serious injuries, the driver was transported by ambulance to a local hospital where he was treated for fractured cervical and thoracic vertebrae. The driver was transferred to a regional trauma center approximately 12 hours post-crash where he was admitted for further treatment. The front right passenger was transported by his grandmother in a personal

vehicle to a local hospital for evaluation. He was not injured and released from the emergency room the day of the crash.

2009 Ford Mustang

Exterior Damage

The exterior of the Ford sustained moderate severity damage to the right, top and left planes as a result of the rollover crash (**Figure 3**). The abrasions on the roof were longitudinally oriented indicating that the vehicle had rolled over one complete turn. The maximum vertical and lateral crush locations were separate. The maximum vertical crush was located on the windshield header, 56 cm (22 in) left of the junction of the right A-pillar and the right roof side rail (**Figure 4**). The resultant maximum vertical deformation was 20 cm (7.9 in). The direct damage to the top plane extended laterally from the left roof side rail to the right roof side rail. The lateral direct damage measured 115 cm (45.3 in). The direct damage to the top plane extended longitudinally from the front edge of the hood to the rear edge of the trunk lid and was 426 cm (167.7 in). The maximum lateral crush was located on the left roof side rail, 14 cm (5.5 in) forward of the B-pillar and measured 3 cm (1.2 in). The left and right door hinges were intact and remained attached to the A-pillars. Both door latches remained engaged as the doors remained closed during the crash. The windshield was cracked but remained in place. The left front and backlight glazing disintegrated during the ground contact. The left rear and right side glazing were not damaged. The Collision Deformation Classification (CDC) assigned for this rollover was 00TDDO4.

Figure 3: Rollover damage of the Ford Mustang from overhead left.

Figure 4: Maximum vertical crush of the roof of the Ford Mustang.

During the rollover event, the front aspect of the hood impacted the wood fence. The direct damage from the fence was identified by a subtle paint transfer and scratching to the vehicle. There was no crush to the hood. The direct damage measured 62 cm (24.4 in) longitudinally and began at the front edge of the hood, extending rearward **(Figure 5)**. The CDC was 00TFDW1.

Figure 5: Secondary impact damage to the top of the hood of the Ford Mustang.

Interior Damage

The Ford Mustang sustained moderate severity interior damage that was attributed to intrusion and occupant contact. The roof and windshield header were displaced vertically to a higher magnitude in the center than the outboard aspects. The roof side rails were displaced laterally, drawn inward by the action of the roof displacing downward. The nearest and highest severity intrusion in the direction of an occupant was the roof over the front right seat position, where the roof displaced to within 3 cm (1.2 in) of the front right head restraint. The intrusion of the Ford is listed on the following table:

Position	Component	Direction	Magnitude
Row 1 Left	Windshield	Longitudinal	8 cm (3.1 in)
Row 1 Center	Windshield	Longitudinal	18 cm (7.1 in)
Row 1 Right	Windshield	Longitudinal	15 cm (5.9 in)
Row 1 Left	Windshield	Vertical	10 cm (3.9 in)
Row 2 Left	B-pillar	Lateral	3 cm (1.2 in)
Row 2 Right	B-pillar	Lateral	2 cm (0.8 in)
Row 1 Left	Roof	Vertical	6 cm (2.4 in)
Row 1 Center	Roof	Vertical	15 cm (5.9 in)
Row 1 Right	Roof	Vertical	8 cm (3.1 in)
Row 2 Left	Roof	Vertical	5 cm (2 in)
Row 2 Center	Roof	Vertical	7 cm (2.8 in)
Row 2 Right	Roof	Vertical	2 cm (0.8 in)
Row 1 Left	Windshield header	Vertical	4 cm (1.6 in)
Row 1 Center	Windshield header	Vertical	15 cm (5.9 in)
Row 1 Right	Windshield header	Vertical	8 cm (3.1 in)
Row 2 Left	Backlight header	Vertical	1 cm (0.4 in)
Row 2 Center	Backlight header	Vertical	4 cm (1.6 in)
Row 2 Right	Backlight header	Vertical	3 cm (1.2 in)

The interior of the Ford sustained damage attributed to occupant contact. There was a scuff mark on the headliner that began over the front left seating position. This scuff mark began 51 cm (20.1 in) aft of the windshield header and ended at the backlight header. Laterally this scuff mark was located from 20 cm (7.9 in) to 40 cm (15.7 in) inboard of the left roof side rail. This contact was attributed to the driver's head. There was a scuff mark on the forward aspect of the center armrest/console. This scuff resulted from contact with the driver's right hip. A scuff mark from the front right passenger's head was present on the roof over the front right seating position beginning 60 cm (23.6 in) rear of the windshield header and 55 cm (21.7 in) inboard of the right roof side rail. This contact terminated 68 cm (26.8 cm) rear of the windshield header and 63 cm (24.8 in) inboard of the right roof side rail. **Figures 6 and 7** depict the occupant contact damage to the interior of the Ford.

Figure 6: Head contacts to the headliner.

Figure 7: Hip contact to the center console.

Manual Restraint Systems

The Ford was equipped with a manual three-point lap and shoulder belt in each of the four designated seating positions. All belt systems utilized continuous loop webbing with sliding latch plates. The driver's belt retracted onto an Emergency Locking Retractor (ELR) with a retractor pretensioner. The upper D-ring was fixed and equipped with a belt positing device **(Figure 8)**. The driver's retractor pretensioner did not actuate during this rollover crash sequence. The driver used the safety belt during the crash; however, no crash related evidence was present on the belt system.

Figure 8: OEM belt positioning device.

The front right safety belt was equipped with a switchable ELR/Automatic Locking Retractor (ALR), fixed height D-ring, and a retractor pretensioner. Additionally, the front right belt system

contained a belt positing device. The front right retractor pretensioner did not actuate during the crash. Although the safety belt was used by the 8-year-old passenger, there was no loading evidence on the front right safety belt. The second row safety belt systems utilized a switchable ELR/ALR retractor. These positions were unoccupied at the time of the crash.

Frontal Air Bag System

The Ford 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 weight sensor, retractor pretensioners, and safety belt buckle switches. The manufacturer of the Ford certified that this vehicle was compliant to the advanced air bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) Number 208.

The driver stated that the vehicle had not been involved in any previous crashes and the air bags were all original to the vehicle. The driver's air bag was concealed within the center hub of a three-spoke steering wheel. The driver's air bag did not deploy.

The front right passenger's frontal air bag was concealed within the mid aspect of the front right instrument panel. The front right passenger's air bag did not deploy during the rollover crash sequence.

Side Impact Air Bag System

The Ford was equipped with seat back-mounted side impact air bags located in the outboard aspect of the front seat backs. The front left and right seat back air bags did not deploy in this crash.

Driver Demographics/Data

Age/Sex:	33-year-old/Male
Height:	178 cm (70 in)
Weight:	109 kg (240 lb)
Eyewear:	None
Seat Track Position:	Full-rear
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from vehicle:	Removed by EMS due to perceived serious injuries
Mode of Transport from Scene:	Ambulance
Type of Medical Treatment:	Treated at a local hospital and transferred to a regional trauma center where he was admitted for two days

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
C2 odontoid (dens) fracture (comminuted base of dens)	Serious (650228.3,6)	Intruding roof (indirect)
C6 left lamina fracture	Serious (650224.3,6)	Intruding roof (indirect)
C6 left pedicle fracture	Serious (650226.3,6)	Intruding roof (indirect)
C7 right lamina fracture (avulsion of anterior endplate)	Serious (650224.3,6)	Intruding roof (indirect)
C6 left facet fracture	Moderate (650220.2,6)	Intruding roof (indirect)
C6 spinous process fracture	Moderate (650218.2,6)	Left front head restraint (direct)
T1 spinous process fracture (minimally displaced)	Moderate (650418.2,7)	Left front head restraint (direct)
T3 vertebral body fracture (no loss of height)	Moderate (650432.2,7)	Intruding roof (indirect)
T4 vertebral body fracture (no loss of height)	Moderate (650432.2,7)	Intruding roof (indirect)
Left eyelid hematoma	Minor (297402.1,2)	Separated left roof side rail trim (direct)
Right side facial abrasions	Minor (290202.1,1)	Right head restraint (direct)
Right parietal scalp hematoma	Minor (190402.1,1)	Intruding roof/headliner (direct)
Right hand laceration (1 cm over dorsal aspect)	Minor (790602.1,1)	Mirror (direct)
Lower abdominal contusion, across abdomen – 8 cm (3 in) high	Minor (590402.1,8)	Safety belt

Source - Hospital medical records

Driver Kinematics

The 33-year-old male driver was seated in a full-rear track position and was restrained by the manual three-point lap and shoulder belt system. During the Ford's rollover sequence to the right, the driver loaded the center console with his right hip. Although the console was scuffed, this contact did not result in injury. The driver loaded the manual safety belt system resulting in a contusion across his abdomen. The roof and headliner intruded into the passenger

compartment. The driver's head contacted the roof and headliner resulting in compressive-type fractures of the cervical and upper thoracic vertebrae. The posterior aspect of the driver's neck impacted the left head restraint resulting in impact fractures of the spinous process of C6 and T1.

During the intrusion of the roof, the left roof side rail trim separated from its mounting points. This trim panel contacted the driver resulting in a left eyelid contusion. There was no contact evidence on the plastic trim panel. The driver's head moved laterally right and impacted the right head restraint. A small area of body fluid evidenced the contact area which resulted in a right facial abrasion. His right scalp impacted the headliner resulting in a hematoma. A large area of scuff marks with a right lateral direction was noted on the headliner during the SCI inspection supporting the driver's contact to the intruding roof/headliner.

The driver sustained a right hand laceration from probable contact with the interior rear view mirror. The mirror separated from the windshield mount and was not damaged.

The driver was removed from the vehicle by the first responders and was transported by ambulance to a local hospital. Following a diagnosis of his injuries, the driver was transferred by ground ambulance to a regional trauma center and admitted for two days.

Front Right Passenger Demographics/Data

Age/Sex:	8-year-old/Male
Height:	135 cm (53 in)
Weight:	25 kg (56 lb)
Eyewear:	None
Seat Track Position:	Full rear
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from vehicle:	Removed by EMS
Mode of Transport from Scene:	Personal vehicle
Type of Medical Treatment:	Evaluated in the ER of a local hospital and released.

Front Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Lower abdominal contusion	Minor (590402.1,8)	Safety belt

Source - Driver interview; the emergency room records indicated the child was not injured.

Front Right Passenger Kinematics

The 8-year-old male front right passenger was seated in a full-rear track position and was restrained by the manual three-point lap and shoulder belt system. During the rollover sequence, the front right passenger loaded the safety belt system. The combination of the passenger's size and the use of the safety belt system prevented significant contact with interior components. His loading of the safety belt system resulted in a lower abdominal contusion (reported by interview).

The front right passenger was transported by a family member in a personal vehicle to a local hospital. He was evaluated in the emergency department and released.

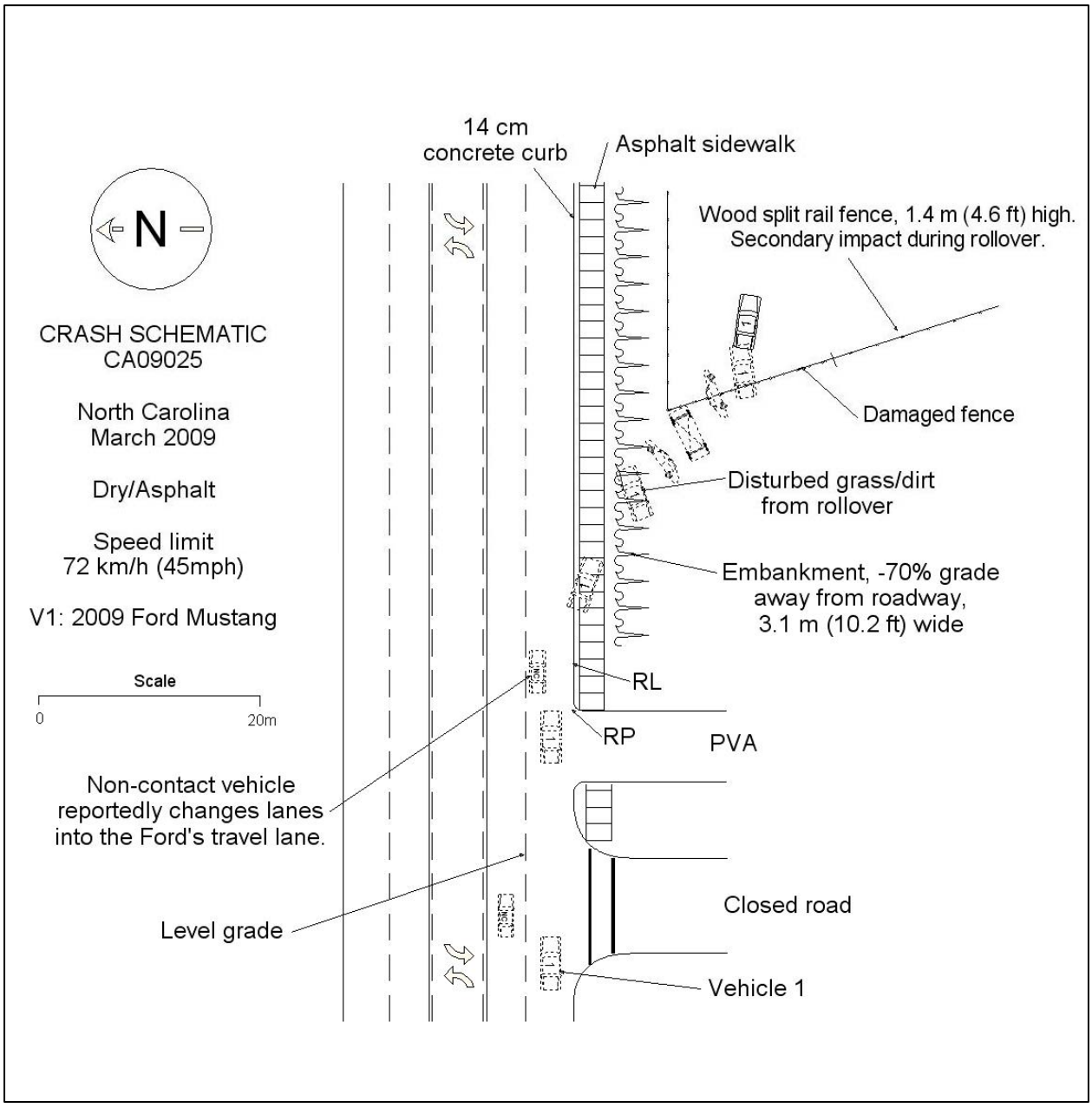

Figure 9: Crash Schematic