TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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ON-SITE ASYMMETRICAL AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA97-049

VEHICLE - 1993 MERCURY SABLE

LOCATION - OHIO

CRASH DATE - AUGUST, 1997

Contract No. DTNH22-94-07058

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

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

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17. *Abstract*

This task involved the on-site investigation of the asymmetrical deployment of a 1993 Mercury Sable's Supplemental Restraint System and the injury mechanisms of its fatally injured driver. The crash occurred in August, 1997 at approximately 1512 hours and involved a 1991 Oldsmobile Cutlass Ciera. The Mercury Sable was equipped with a Supplemental Restraint System (SRS) that consisted of driver and passenger side air bags. Only the front passenger air bag deployed in the crash.

The center and left frontal area of the Oldsmobile impacted the center and left frontal area of the Mercury in an offset frontal collision. At impact, the driver of the Mercury responded to the 12 o'clock direction of the impact force by initiating a forward trajectory and loading the lap and shoulder restraint. The forces generated by the impact caused the Mercury's left front structures to deform rearward and laterally to the right, into the driver's occupant space. The center of the steering wheel was displaced rearward 38 cm (15 in) and 28 cm (11 in) laterally. The driver contacted the rearward intruding components and suffered multiple trauma to the face, chest (AIS 4) and lower extremities. It is unlikely that the proper deployment of the driver air bag would have mitigated the driver's injuries. Reportedly, it took 50 minutes to extricate the driver from the vehicle. The driver was then life-flighted to a regional trauma center where she was pronounced dead in the emergency room 95 minutes post-crash. The cause of death was ruled Multiple Trauma.

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BACKGROUND

This task involved the on-site investigation of the asymmetrical deployment of a 1993 Mercury Sable's Supplemental Restraint System and the injury mechanisms of its fatally injured driver. The crash occurred in August, 1997 at approximately 1512 hours and involved a 1991 Oldsmobile Cutlass Ciera. The Mercury Sable was equipped with a Supplemental Restraint System (SRS) that consisted of driver and passenger side air bags. Only the front passenger air bag deployed in the crash. NASS Zone Center 2 notified the Field Operations Branch of the National Highway Traffic Safety Administration (NHTSA) of the crash on December 1, 1997. NHTSA in-turn assigned an investigative effort to the Calspan Special Crash Investigations (SCI) Team on that same day. Due to the circumstances of the crash, the Mercury Sable was stored by legal council representing the driver's family and the Oldsmobile Cutlass Ciera was impounded by the investigating authorities. The on-site investigation was conducted April 1 and 2, subsequent to cooperation with and coordination between all the involved parties. Calspan SCI inspected both vehicles in the course of this investigation. Technical and legal representatives for Ford Motor Company were present during the inspection of the Mercury Sable.

SUMMARY

Inspection of the crash scene revealed this two vehicle crash occurred on a level east/west two lane state route in a rural area of the state (**Figures 1 and 2**). A series of private residences bordered the south side of the roadway. The total width of the roadway was approximately 5.8 m (19.0 ft), with 0.6 m (2.0 ft) shoulders bordering each traffic lane. A "soft" right curve for westbound traffic ended approximately 61 m (200 ft) east of the point of impact. The impact point was identified by a series of gouge marks located on the south shoulder, outboard of the southern road edge line (**Figure 3**). **Figure 4** is an on-scene photograph taken of the crash site. There was no adverse weather, at the time of the crash, and the roads were dry. The speed limit in the area of the crash was 72 km/h (45 mph).

Figure 2: Westbound view 30 m (100 ft) from the POI.

Figure 1: Eastbound view 30 m (100 ft) from the POI.

Figure 3: Point of impact.

Figure 4: Westbound view of the crash scene.

The 1991 Oldsmobile Cutlass Ciera was operated westbound by a 22 year old unrestrained male driver. The 1993 Mercury Sable was operated eastbound by a 48 year old female. She was restrained by the vehicle's manual 3-point lap and shoulder harness. The crash occurred when the westbound Oldsmobile failed to properly exit the right curve and traveled left of center directly into the path of the eastbound Mercury Sable. Refer to **Figure 14**, the crash schematic at the end of this narrative report.

The female driver of the Mercury recognizing the impending collision, steered right prior to the crash in an attempt to avoid the collision. The crash occurred outboard of the south road edge line referenced in Figure 3 above. The center and left frontal area of the Oldsmobile impacted the center and left frontal area of the Mercury in an offset frontal collision. The 12 o'clock direction of the impact force initiated the deployment sequence of the Mercury's SRS, however, only the vehicle's front passenger air bag deployed. The impact caused the Mercury to reverse its travel direction and rotate counterclockwise (CCW). The Mercury came to rest facing north in a driveway, approximately 4.0 m (13.0 ft) west of the point of impact and 5.8 m (19.0 ft) south of the road edge. The Oldsmobile rotated CCW and came to rest facing east on the roadway centerline, approximately 8 m (26 ft) west of the point of impact.

The Mercury Sable sustained 86 cm (34 in) of direct contact damage across the frontal width of the vehicle. The direct damage began 10 cm (4 in) right of center and extended to the left front corner. The measured crush profile was as follows: C1=118.9 cm (46.8 in), C2=105.1 cm (41.4 in), C3=85.1 cm (33.5 in), C4=62.2 cm (24.5 in), C5=40.9 cm (16.1 in), C6=3.3 cm (1.3 in). The right front corner of the vehicle was displaced laterally to the left 91.4 cm (36.0 in). The windshield was fractured and the left side window glazings shattered in the impact. The left front suspension deformed rearward foreshortening the left wheelbase 74 cm (29 in). Rearward deformation of the left A-pillar buckled the roof. The left front door was buckled and opened due to deformation of the latch mechanism. The left rear door was buckled and jammed shut by deformation. In order to attain access to the driver, the vehicle's left and right A-pillars were cut and the roof was pulled back. Additionally, the right B-pillar was cut and removed with the right rear door in the extrication process. The right front seat back and center console were removed as well. The Collision Deformation Classification (CDC) of the Mercury was 12-FYEW-5. The delta V calculated

by the Damage Algorithm of the WINSMASH model was 82.0 km/h (51.0 mph). The computed delta V was over estimated based on the vehicle's damage. The estimated delta V of the Mercury based on SCI was approximately 64 km/h (40 mph). **Figure 5 and 6** are front and left front views of the damaged Mercury Sable respectively.

Figure 6: Front view of the Mercury Sable.

Figure 5: Left side view of the Mercury Sable.

The Oldsmobile Cutlass Ciera (**Figure 7**) sustained 112 cm (44 in) of direct contact damage across the frontal width of the vehicle. The direct damage began 26.7 cm (10.5 in) right of center and extended to the left font bumper corner. The crush profile measured across the front plane of the vehicle was as follows. C1=157.5 cm (62.0 in), C2=143.3 cm (56.4 in), C3=124.0 cm (48.8 in), C4=99.6 cm (39.2 in), C5=70.1 cm (27.6 in), C6=35.6 cm (14.0 in). The right front corner was displaced laterally 86 cm (34 in) to the left. The deformation extended rearward along the left side of the vehicle to the C-pillar causing both left side doors to be buckled and jammed. The windshield was fractured and the left side window glazings were shattered. The left front suspension deformed rearward foreshortening the left wheelbase 88.6 cm (34.9 in). The left A-pillar was displaced rearward 57.9 cm (22.8 in) causing the roof to buckle. The left floor pan deformed rearward to the driver's seat cushion. The roof was cut at all the pillars and removed during the extrication of the driver. The CDC of the vehicle was 12-FYEW-6. The delta V calculated by the Damage Algorithm of the WINSMASH model was 92.0 km/h (57.2 mph). Forensic analysis of the Oldsmobile's damage and SCI experience indicated the delta V calculated by the SMASH program was overestimated. The Oldsmobile's damage appeared to be more consistent with a delta V of approximately 72 km/h (45 mph).

Figure 7: Left front three-quarter view of the Oldsmobile Cutlass Ciera.

The 48 year old female driver of the Mercury Sable had a reported height/weight of 168 cm (66 in) and 123 kg (271 lb). She was restrained by the vehicle's manual 3-point restraint. The left front seat was probably positioned in a mid to forward track position consistent with her stature. The forces of the impact initiated the deployment sequence of the vehicle Supplemental Restraint System. However, only the front passenger air bag deployed. At impact, the driver responded to the 12 o'clock direction of the impact force by initiating a forward trajectory and loading the lap and shoulder restraint. The forces generated by the impact caused the vehicle's left front structures to deform rearward and laterally to the right, into the driver's occupant space. The center of the steering wheel was displaced rearward 38 cm (15 in) and 28 cm (11 in) laterally. The driver contacted the rearward intruding components and suffered multiple trauma to the face, chest (AIS 4) and lower extremities. It is unlikely that the proper deployment of the driver air bag would have mitigated the driver's injuries. Reportedly, it took 50 minutes to extricate the driver from the vehicle. The driver was then life-flighted to a regional trauma center where she was pronounced dead in the emergency room 95 minutes post-crash. The cause of death was ruled Multiple Trauma.

The 22 year old male driver of the Oldsmobile was pinned in the vehicle due to its deformation. Reportedly, the driver's extrication took 45 minutes. The driver was then life-flighted to a regional trauma center. The driver was reportedly hospitalized for approximately 4 months during the course of his recovery.

AIR BAG VEHICLE

The 1993 Mercury Sable, 4 door sedan, was identified by a Vehicle Identification Number (VIN) of: 1MELM50U9PA (production sequence deleted). The power train consisted of a 3.0 liter V-6 engine linked to a 4-speed automatic transmission. The vehicle was equipped with a conventional braking system that consisted of front disc and rear drum brakes. The date of manufacture was 11/92 and the odometer read 94,796 km (58,905 miles) at the time of the inspection. Reportedly the vehicle was purchased used by the subject family in February, 1995 with an odometer reading of 47,993 km (29,822 miles).

INTERIOR DAMAGE

The Mercury's left front interior sustained significant impact damage as a result of the external forces generated in the crash (**Figure 8**). The left A-pillar and left corner of the instrument panel were displaced longitudinally approximately 51 cm (20 in). The steering column was displaced 38 cm (15 in) rearward and 28 cm (11 in) laterally to the right. The floor pan in the driver's foot well deformed rearward to the seat cushion.

The tilt mechanism of the steering wheel was fractured by occupant contact. The post-crash position of the steering wheel was rotated 180 degrees. The upper half (12 o'clock sector) of the rim was deformed approximately 15 cm (6 in) due to contact with the driver's abdomen/lower extremities (**Figure 9**). Due to the occupant loading, there was complete separation of the left side steering column shear capsule and the right aspect of the steering column's mount was fractured above the right shear capsule (**Figures 10 and 11**).

Figure 8: Right interior view.

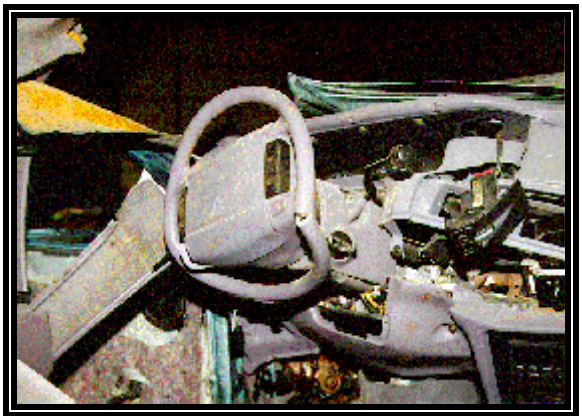

Figure 9: Steering wheel rim and steering column.

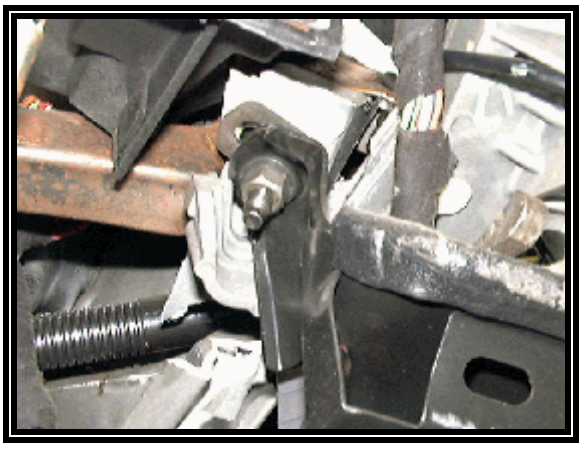

Figure 10: Left shear capsule complete separation.

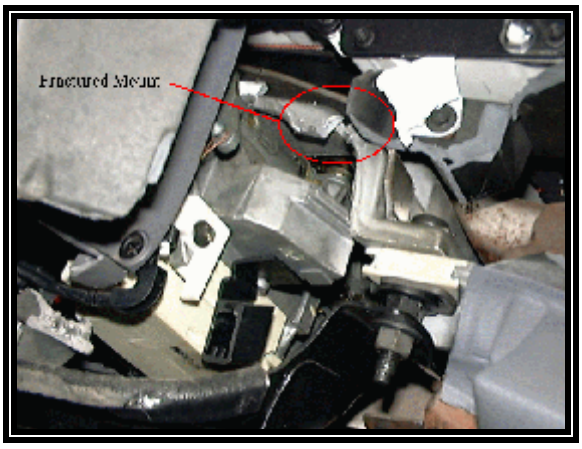

Figure 11: Fractured steering column mount.

Two areas of deformation were noted on the rigid left side knee bolster panel linked to contact with the driver's lower extremities. The areas measured approximately 7 cm x 7 cm (2.7 in x 2.7 in) and were centered 10.9 cm (4.3 in) left and 9.7 cm (3.8 in) right of the steering column centerline.

MANUAL RESTRAINT SYSTEM

The Mercury Sable was equipped with 3-point lap and shoulder belt systems in the 4 outboard seated positions. The center rear position was equipped with a lap belt. The front seat belt systems consisted of a continuous loop lap and shoulder belt webbing with a sliding latch plate. An inertia activated locking retractor was located in the base of each B-pillar. The restraint's upper anchorages (D-rings) were fixed. At inspection, the left front restraint webbing and the restraint's hardware surfaces exhibited signs of routine usage as well as witness marks indicative of usage in this crash. The left front restraint webbing was found extended and the retractor was locked. The webbing had been cut from the driver by the EMS during the rescue operations. The latch plate was found in the buckle.

SUPPLEMENTAL RESTRAINT SYSTEM

The Mercury Sable was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front passenger air bags. The driver air bag module was located in the typical manner in the center hub of the steering wheel. The passenger air bag module was configured as a mid mount on the right side of the instrument panel. **Figure 12** is a layout schematic of the SRS. The components and their respective locations are described in the table below.

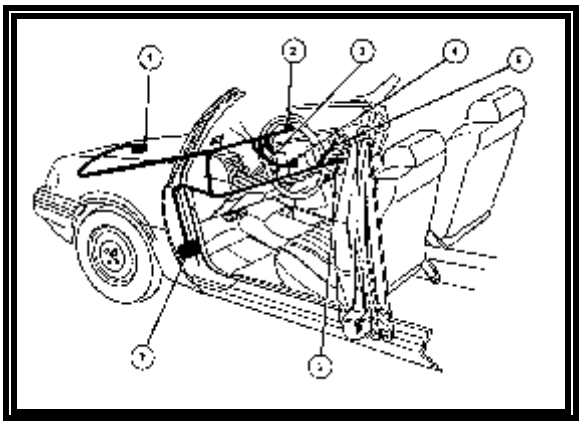

Figure 12: Mercury Sable SRS Components.

Item	***Description***	***Location***
1	Primary Crash Sensor	Center radiator support
2	Primary Crash Sensor	Center cowl
3	Air Bag Indicator	Instrument cluster
4	Driver Air Bag Module	Center of steering wheel
5	Front Passenger Air Bag Module	Right aspect instrument panel
6	Diagnostic Module	Right instrument panel behind glove box
7	Safing Sensor	Left kick panel (driver foot well)

The SRS is designed to deploy both the driver and front passenger air bag modules when at least one primary crash sensor and the safing sensor close under vehicle specific parameters related to crash severity. The repair manual for the Mercury indicated the upper bound of the air bag deployment threshold was a barrier equivalent speed of 22.5 km/h (14.0 mph). In the subject crash, the SRS was properly triggered by the sensors, however, only the front passenger air bag deployed in the crash. Technical representatives from the Ford Motor Company were present during the inspection of the Mercury and were asked to participate in the inspection specifically to diagnose the cause of the driver air bag non-deployment. The following procedure was used to diagnose the SRS:

1. Removed the Diagnostic Module (DM);
2. Installed a breakout box - DM with umbilical that allows the user to read the electrical resistance of the SRS circuitry;
3. Took raw resistance data of the SRS as found;

4. Disconnected the deployed front passenger air bag module;
5. Installed front passenger air bag module resistor (simulated PAB module);
6. Took resistance readings;
7. Removed driver air bag module;
8. Installed driver air bag module resistor, (simulated DAB module);
9. Took resistance readings;
10. Applied voltage to the vehicle's electrical system;
11. Checked diagnostic flash codes stored in Diagnostic Module (read from indicator light in the instrument cluster), Stored Code = 32;
12. Removed steering wheel;
13. Removed clock spring;
14. Installed resistor (simulated DAB module and clock spring);
15. Took resistance readings.

The summation of the resistance readings taken during the Steps (1-6) of the inspection indicated that passenger air bag circuitry was intact and functioning properly. A fault was detected in the driver air bag circuitry Steps (8-9) and confirmed by the flash code (32) reading in Steps (10-11). During the check of the flash code (Step 11), upon ignition the air bag indicator illuminated steady for approximately 6 seconds, as the diagnostic module monitored the air bag system readiness. The indicator then flashed three times, paused one second, flashed two times, paused three seconds and then repeated the three flash, one second pause, two flash, three second pause sequence. This indicated a flash code 32. Flash code 32 represented a Driver Air Bag High Resistance or Open condition. This open condition in the Driver Air Bag circuitry resulted in the non-deployment of the driver air bag in the crash. Removing the clock spring and replacing it with a simulated load (resistor), Steps (12-15) isolated the fault in the circuitry to the clock spring. There were no other fault codes stored in the diagnostic module.

The purpose of the clock spring was to carry the electrical current from the stationary steering column through the rotating steering wheel to the driver air bag module, horn and cruise control. **Figures 13** is a view of the clock spring taken after its removal from the vehicle. The white electrical connector in the 10 o'clock sector of the figure was displaced from its designed location. The connector normally resides in the recess on the back side of the assembly. Additionally the flat wire conductor, wound internally in clock spring, had folded onto itself and was taut. The condition of the clock spring indicated that it had been improperly installed.

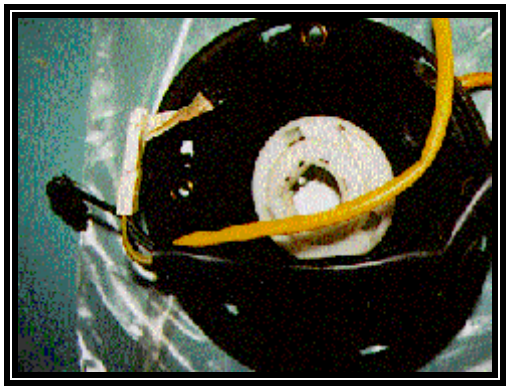

Figure 13: View of the back side of the clock spring.

As reported by Ford Motor Company's service records, the steering column of the Mercury Sable had a history of having been removed from the vehicle for ignition

service. This service reportedly occurred in July, 1995. The vehicle's mileage at the time of the service was 57,396 km (35,665 miles). This service would have required the removal of the clock spring. It was probable that the clock spring was improperly reinstalled during this repair.

As noted earlier in this report, during the diagnosis of the SRS, the diagnostic module, driver air bag module, steering wheel and clock spring were removed from the vehicle. The Office of Defects Investigations has requested those components for further analysis. Refer to the ODI report for further information regarding the non-deployment issue.

DRIVER INJURIES

Injury	***Severity (AIS 90)***	***Injury Mechanism***
Left ribs 1-10 fractured, right rib #1 fractured, left hemothorax	Severe (450232.4,3)	Steering wheel
Contusions of both lungs	Severe (441410.4,3)	Steering wheel
Proximal fracture left fibula	Moderate (851605.2,2)	Intruding left knee bolster/ instrument panel
Proximal fracture left tibia	Moderate (853404.2,2)	Intruding left knee bolster/ instrument panel
Distal fracture of the right tibia and fibula	Moderate (851612.2,1)	Intruding left knee bolster/ instrument panel
8.9 cm x 5 cm (3.5 in x 2 in) stellate laceration left side forehead	Minor (290602.1,7)	Intruding left A-pillar
Multiple facial abrasions and contusions	Minor (290202.1,0) Minor (290402.1,0)	Intruding left A-pillar
5 cm (2 in) contusion of chin	Minor (290402.1,8)	Steering wheel rim
Two 5 cm (2 in) linear abrasions left side of neck	Minor (390202.1,2)	Inertial loading of 3-point restraint
Scattered faint contusions anterior abdomen	Minor (590402.1,0)	Inertial loading of 3-point restraint/steering wheel rim
Multiple abraded contusions right upper extremity	Minor (790202.1,1) Minor (790402.1,1)	Intruding instrument panel

Injury	*Severity (AIS 90)*	*Injury Mechanism*
Multiple abraded contusions both lower extremity	Minor (890202.1,3) Minor (890402.1,3)	Intruding left knee bolster/ instrument panel
30 cm (12 in) laceration above left knee and 5 cm (2 in) laceration medial aspect left calf	Minor (890602.1,2)	Intruding left knee bolster/ instrument panel

DRIVER KINEMATICS

The 48 year old female driver had a reported height/weight of 168 cm (66 in) and 123 kg (271 lb). The driver was initially seated with a presumed normal posture with the seat adjusted to a mid to forward track position. This placed the driver in close proximity to the steering wheel due to her stature. At impact, the restrained driver initiated a forward trajectory in response to the 12 o'clock direction of the impact forces and loaded the 3-point restraint. The minor neck abrasions and abdominal contusions occurred due to this inertial loading. The driver's upper torso, neck and head then began to pitch forward. Coincident to this, the left A-pillar and left side of the instrument panel were deforming rearward due to the forces of the impact. The driver contacted the intruding left A-pillar and steering wheel with her head and chest respectively. The chest injuries occurred due to a combination of the intrusion and her forward kinematics. The driver's abdomen and upper extremities contacted and deformed the steering wheel rim. The intruding knee bolster/instrument panel contacted and fractured her lower extremities.

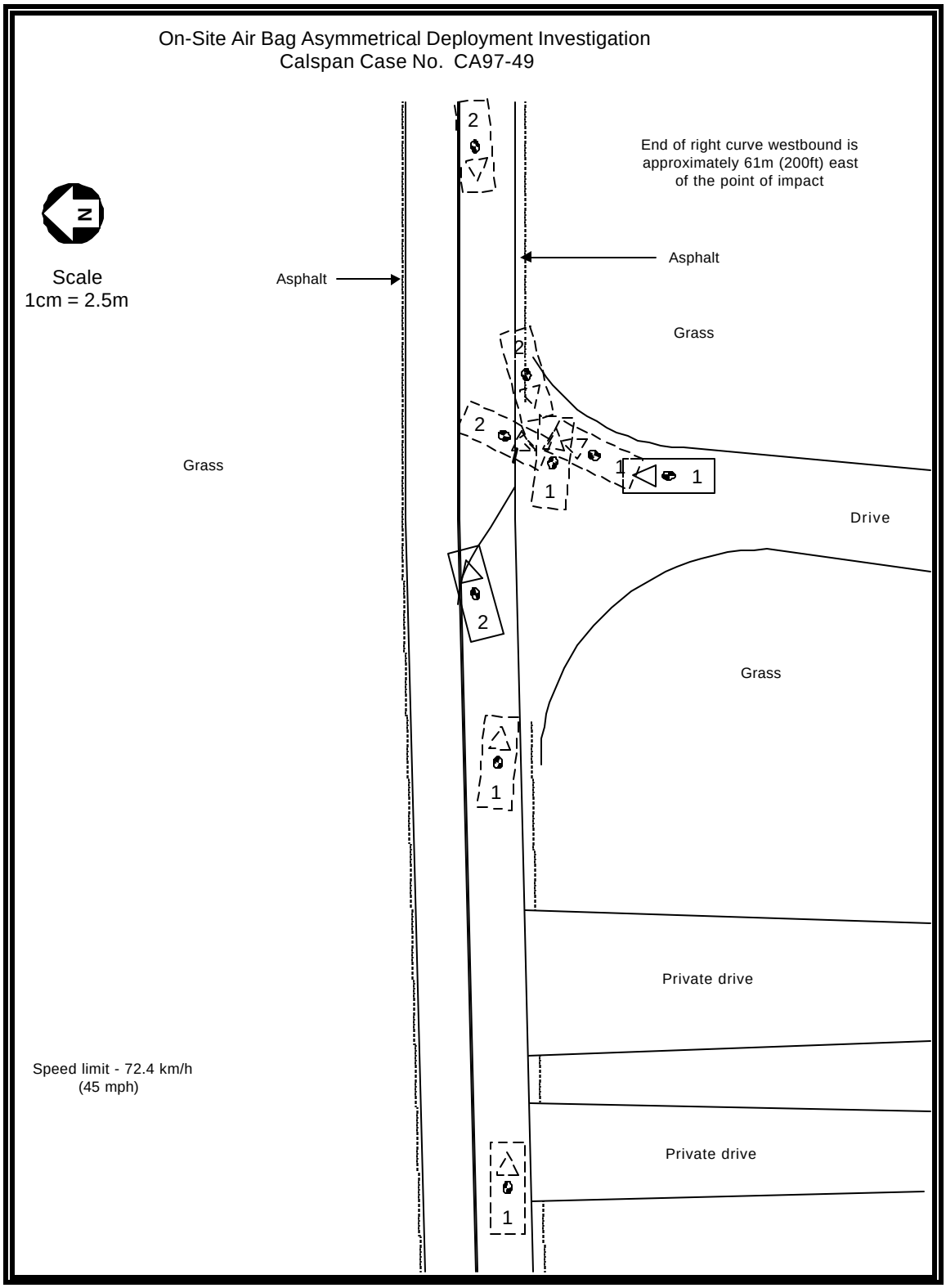

Figure 14: Crash Schematic.