TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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CALSPAN ON-SITE AIR BAG/CHILD PASSENGER FATALITY INVESTIGATION
CALSPAN CASE NO. CA97-045
VEHICLE: 1997 GEO METRO
LOCATION: FLORIDA
CRASH DATE: OCTOBER, 1997

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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 crash investigation focused on the injury mechanisms and cause of death of a 17 month old female child who was improperly restrained in a forward facing Evenflo child safety seat. The safety seat was positioned in the front right position of a 1997 Geo Metro that was equipped with frontal air bags for the driver and passenger positions. The air bag system deployed as a result of an undercarriage impact sequence with a driveway culvert. The child occupant was contacted by the deploying front right air bag which resulted in multiple soft tissue abrasions of the face, edema of the cerebral hemispheres, left leptomeningeal and subarachnoid hemorrhage. She was transported to a local hospital and transferred to a major medical center where she expired approximately 11.5 hours following the crash.			
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BACKGROUND

This on-site crash investigation focused on the injury mechanisms and cause of death of a 17 month old female child who was improperly restrained in a forward facing Evenflo child safety seat. The safety seat was positioned in the front right position of a 1997 Geo Metro that was equipped with frontal air bags for the driver and passenger positions. The air bag system deployed as a result of an undercarriage impact sequence with a driveway culvert. The vehicle subsequently overturned to its left prior to coming to rest on an upright attitude **(Figure 1)**. The child occupant was contacted by the deploying front right air bag which resulted in multiple soft tissue abrasions of the face, edema of the cerebral hemispheres, left leptomeningeal and subarachnoid hemorrhage. She was transported to a local hospital and transferred to a major medical center where she expired approximately 11.5 hours following the crash.

Figure 1. On-scene view of the crash site and final rest position of the Geo Metro.

The crash occurred in October 1997 and was identified by NHTSA through a search of the Fatal Analysis Reporting System (FARS). Notification was subsequently forwarded to Calspan's Special Crash Investigation Team on November 7, 1997. The insurance carrier for the rental agency of the Geo Metro scheduled a joint on-site inspection with representatives from Calspan, Evenflo (child safety seat manufacturer), ESIS (the insurance carrier for General Motors), and the plaintiff's attorney and his consultants. The inspection was delayed until early December to accommodate all parties. This investigation focused on the role of the deploying passenger side air bag with respect to the fatal outcome of the 17 month old female child passenger.

SUMMARY

Crash Site

This crash occurred during the early morning hours on a rural two-lane north/south state route. The dry asphalt road surface was straight with a negative grade of 3 percent with respect to the Geo's direction of travel **(Figure 2)**. Lighting conditions were dark with no artificial illumination. The travel lanes were bordered by 1.4 m (4.7') paved shoulders. Roadway markings consisted of a solid and

Figure 2. Overall view of the crash site.

broken yellow centerline with raised reflectors which allowed passing in the southbound direction of travel. The edgelines were solid white lines with no tactile warning devices present on the shoulder of the road. Private residential driveways intersected the travel lanes. The posted speed limit was 72 km/h (45 mph). A shallow drainage ditch paralleled the west (right) road edge and was located 5.2 m (17.0') outboard of the edgeline. A concrete drainage culvert for a private driveway was located 4.6-5.6 m (15'2"-18'4") west of the edgeline.

Vehicle Data

The involved1997 Geo Metro was a 2-door hatchback that was identified by vehicle identification number (V.I.N.) 2C1MR2296V6 (production number omitted). The vehicle was owned by a rental car company and was placed into the service fleet on July 31, 1997. The vehicle was rented by the driver's mother who permitted the driver to operate the vehicle.

The Geo Metro was equipped with a Supplemental Inflatable Restraint (SIR) system which consisted of frontal air bags for the driver and front passenger positions. In addition to the frontal air bag system, the Metro was equipped with Takata 3-point manual lap and shoulder belt systems with fixed D-rings and energy management loops for the front outboard seated positions. The vehicle was configured with front bucket seats, a floor mounted 3-speed automatic transmission selector lever, manual rack-and-pinion steering, and power-assisted front disc/rear drum brakes (no ABS). At the time of the crash the odometer reading was 7,771 km (4,829 miles).

Pre-Crash

The Geo Metro was traveling in a southerly direction on the straight segment of roadway at a driver estimated speed of 72 km/h (45 mph). The driver successfully negotiated the transition from a four-lane roadway to the two-lane at a hillcrest located approximately 173 m (566') north of the impending crash site. On her descent of the negative grade, the driver reportedly fell asleep. The vehicle drifted off the right side of the road and traversed a sandy lawn area. The investigating officer documented a travel distance of 33 m (108') across the lawn area **(Figure 3)** which terminated at a driveway culvert. It should be noted that a pile of sand was located on the shoulder in the area of vehicle departure. The on-scene police photographs indicated the vehicle did not contact this sand pile as it departed the west (right) road edge.

Figure 3. Trajectory of the Geo Metro across the lawn area.

Figure 4. Struck driveway culvert.

Crash

As the Geo Metro continued forward, the right lower aspect of the bumper fascia, lower radiator support, the undercarriage tie-down

hook, and the right front tire and wheel assembly impacted the exposed edge of the driveway culvert **(Figure 4)**. The impact resulted in a 12 o'clock direction of force. The vehicle's damage pattern was outside the scope of the WinSMASH reconstruction program, therefore the velocity change was estimated at 13-16 km/h (8-10 mph). As a result of this impact sequence, the frontal air bag system deployed. It was probable the undercarriage contact produced an elongated crash pulse which delayed the deployment of the frontal air bag system.

The front right impact sequence induced a clockwise (CW) rotation to the Geo Metro as its center of gravity (CG) continued in a southerly trajectory. The Geo traveled a police reported distance of approximately 11 m (36') across the driveway and adjacent lawn area where the left side tires dug in to the sandy surface which tripped the Metro into a lateral rollover sequence, leading with its left side. The Metro completed four quarter turns over a longitudinal distance of approximately 33 m (109') before coming to rest in an upright attitude. At final rest, the vehicle was facing in a westerly direction approximately 6.7 m (22.0') off-road. The crash schematic is attached as **Figure 13**, Page 12.

Post-Crash

The driver stated that she came to rest restrained in the front left seat of the Geo Metro. The child passenger came to rest within the child safety seat in the front right position of the vehicle. The driver exited the vehicle from the left front door and removed the child passenger from the child safety seat. She noted the child was not crying. A passing motorist stopped at the crash site and offered to call for emergency assistance. A local ambulance arrived at the crash site and transported the injured child and the driver to a local hospital. The child was evaluated and prepared for air transport to a major medical center where she expired approximately 11.5 hours post-crash.

VEHICLE DAMAGE

Exterior

The driveway/culvert impact initially involved the lower aspect of the front bumper fascia. This flexible component was abraded from the culvert contact with the direct contact damage beginning 31.8 cm (12.25") right of center and extending 25.4 cm (10.0") to the right **(Figure 5)**. The deformation was below the level of the bumper reinforcement bar, therefore no residual crush occurred at bumper level. The impact with the driveway/culvert edge resulted in a 6.2 cm (2.4") longitudinal displacement of the lower radiator support located 36.0 cm (14.2") right of center and deformation of the tie-down hook. The right front tire and wheel subsequently impacted the culvert which dented the steel wheel and reduced the right wheelbase by 2.0 cm (0.8"). The Collision Deformation Classification (CDC) for this impact sequence was 12-FRLW-1.

Figure 5. Frontal view of the Geo Metro.

The rollover event resulted in vertically oriented abrasions to the left rear quarter panel, lateral abrasions to the roof and hood, and vertical abrasions to the right side of the Geo. The right A-pillar and adjacent side rail area sustained 7.0 cm (2.75") of lateral displacement and approximately 5 cm (2") of vertical displacement. The leading edge of the right front fender and hood at the headlamp area was displaced 7.6 cm (3.0") in both the vertical and lateral directions **(Figure 6)**. The rollover damage resulted in a CDC of 00-TDDO-3.

Figure 6. Rollover damage.

Interior

The interior of the Geo Metro sustained moderate damage that was associated with exterior deformation, frontal air bag deployment, and occupant contact. The mid point of the right upper A-pillar intruded 7.0 cm (2.75") laterally into the passenger compartment. As a result of the lateral displacement of the pillar and crush to the roof side rail, the roof buckled downward into the front right passenger compartment. The vertical displacement of the roof, side rail, and windshield header at the front right position was 5.7 cm (2.25").

The deployment of the front right air bag resulted in separation of the interior mounted rear view mirror. An air bag fabric transfer was noted to the right side of the mirror housing. Although the frame separated from the mounting stem, the mirror glass remained intact.

The driver's knees contacted the knee bolster on each side of the steering column. Faint scuff marks identified the contact points. The left knee contact was located 41.9 cm (16.5") left of center and 33.0 cm (13.0") above the floor pan. The right contact point was located 22.9 cm (9.0") left of center and 32.4 cm (12.75") above the floor.

The lower aspect of the improperly restrained child safety seat moved forward during the crash sequence and contacted the lower mid instrument panel evidenced by a scuff mark with plastic transfers **(Figure 7)**. The contact point was located 10.2-38.1 cm (4.0-15.0") right of center and was 7.0 cm (2.75") in height. The transfer was located 3.2-10.8 cm (1.25-4.25") below the leading edge of the front right air bag module cover flap. Additional transfers from the base of the CSS were noted to the front right seat cushion. These transfers resulted from the forward movement of the CSS during the crash sequence.

Figure 7. CSS contact to the mid instrument panel.

MANUAL RESTRAINT SYSTEMS

The 1997 Geo Metro was equipped with manual 3-point lap and shoulder belts for the four outboard seated positions. The front belt systems consisted of continuous loop webbings with sliding latchplates,

emergency locking retractors, and fixed D-rings. The front right and rear seat belt systems incorporated a switchable mode in the retractors which locked the retractor for use with child safety seats. Both front belt systems utilized an energy management loop to provide a ridedown effect to the occupant in crashes on sufficient magnitude. The loops were incorporated into the lap belt webbing located 14.0-20.3 cm (5.5-8.0") above the floor. These loops were concealed by the vinyl sleeve at the base of the lap belt. Both front management loops remained intact and were not deployed as a result of this crash.

The front left latchplate did yield evidence of routine usage, however, being a rental car, this could not be related to this driver. There was no impact induced loading evidence on the front left belt system.

The front right belt was routed through the proper belt path of the CSS. The belt webbing was twisted behind the shell of the CSS from improper installation. The twist began 33.0 cm (13.0") below the D-ring and extended into the belt path of the CSS. There was no loading evidence on the front right belt system although the belt was routed through the CSS at the time of the crash.

A label affixed to the front right lap belt warned against the use of rear facing child safety seats in this position. It advised the following:

> *A child in a rear facing child restraint can be badly injured by the passenger air bag if it inflates. Never put a child in a rear facing child restraint in the front seat of this vehicle. Secure a rear facing child restraint in the rear seat.*
>
> *Before securing a forward facing child restraint, ALWAYS move the front passenger seat as far back as it will go. Then pull the safety belt out all the way to lock the belt, so you can use it with the forward facing child restraint. Or, secure the child restraint in the rear seat. For more information, see your Owner's Manual and the instructions that came with your child restraint.*

AUTOMATIC RESTRAINT SYSTEM

The frontal Supplemental Inflatable Restraint (SIR) system consisted of a single-point sensing and diagnostic module (SDM) which also utilized an outboard (to the passenger compartment) discriminating sensor that was mounted to the forward aspect of the mid radiator support panel, adjacent to the hood latch assembly, a driver air bag and a front right passenger air bag. The SDM recorded events related to the deployment sequence. The Calspan SCI team requested the services of GM/ESIS to download the hexidecimal codes and interpret the data. They complied and dispatched a team which downloaded the data on the day of the joint inspection of the vehicle. The interept were not forwarded to the Calspan SCI team following numerous requests for the data.

The front left driver air bag module was concealed within a four-spoke steering wheel rim and deployed from symmetrical H-configuration module cover flaps. The deployed front left air bag was 62.2 cm (24.5") in diameter in its deflated state. The bag was tethered by two wide-band internal tether straps

located at the 3 and 9 o'clock sectors. Two 3.8 cm (1.5") diameter vents ports were located at the 10 and 2 o'clock sectors. There was no contact evidence on the bag (i.e. tissue, makeup transfers), however, several blood spatters were noted to the upper left quadrant of the bag. These appeared to have resulted following the deployment and deflation of the bag.

The front right passenger air bag deployed from a top mounted module assembly that was incorporated within the upper right instrument panel. The single cover flap was hinged at the forward edge and opened in an upward direction toward the windshield. The flap was 34.5 cm (13.6") in width and 15.6 cm (6.1") in depth. The leading edge of the cover flap was positioned 4.4 cm (1.75") forward of the protruding mid instrument panel. The word AIRBAG was embossed into the mid area of the flap.

The passenger side air bag was constructed of a typical nylon-type fabric and was not damaged by the deployment sequence or occupant involvement. The bag was not tethered or manufactured with vent ports. Venting was achieved either through the use of a porous fabric, or back venting through the manifold/inflator assembly. Overall dimensions of the bag in its deflated state were 44.4 cm (17.5") in width, 53.3 cm (21.0") in height, and approximately 40.6 cm (16.0") in depth.

The maximum rearward excursion of the non-tethered passenger side air bag was 64.8 cm (25.5") from the leading edge of the module assembly, or 60.3 cm (23.75") rearward of the mid panel. Vertically oriented black vinyl transfers were present on the top panel of the bag located 8.9-14.0 cm (3.5-5.5") rearward of the cover flap. These transfers resulted from bag expansion against the inside surface of the module cover flap. Faint tissue transfers were noted to the face of the bag, located slightly right of the bags center line **(Figure 8)**. The vertically oriented transfers consisted of tissue fragments from bag expansion against the face of the child passenger.

Figure 8. Tissue and vinyl transfers on the face of the front right air bag.

The sunvisors contained the yellow, black, and white warning labels that advised the occupants about the hazards associated with child and front right air bags. The labels warned against the following:

- Death or Serious Injury Can Occur
- Children 12 and under can be killed by the air bag
- The back seat is the safest place for children
- Never put a rear facing child restraint in the front seat
- Sit as far back as possible from the air bag
- Always use Seat Belts and Child Restraints

The driver stated that she was not aware of the risks associated with air bag deployment and child passengers and was not aware of the above warning labels.

CHILD SAFETY SEAT

The 17 month old female passenger was seated in a forward facing Evenflo Scout convertible child safety seat (CSS) that was positioned in the front right of the vehicle. The CSS was manufactured on September 26, 1995, and was identified by Model No. 225117 J1 **(Figure 9)**. The restraint consisted of a molded plastic shell with an adjustable strut on the base of the CSS. This strut was folded up into the shell which is the proper position when used in a rear facing mode. The strut should have been extended to the down position to maintain a vertical profile to the seat in the forward facing position. The harness system consisted of a three-point belt system with an abdominal shield with an integral latchplate. The shoulder harness straps were properly routed through the upper slots for this forward facing position. The chest positioning clip was affixed to the left shoulder harness strap. This model did not utilize a fold-up tray shield. The history of this CSS was unknown.

Figure 9. Overall view of the Evenflo Scout CSS.

Although not in violation of manufacturers recommendations, the forward facing CSS was positioned in the front right seat of the Geo Metro. The manufacturers label on the front right belt webbing advised that the seat track must be adjusted to the full rear position when using a forward facing CSS. The seat track was positioned in a mid track position, set 10.4 cm (4.1") forward of the full rear position. The CSS was improperly restrained by the vehicle's manual 3-point lap and shoulder belt system. The belt webbing was routed through the proper belt path of the shell, however, the retractor was not placed in the switchable mode, therefore the CSS was not properly secured to the vehicle. In this position, the emergency locking retractor allowed the CSS to move free within the front right position **(Figure 10)**. The investigating police officer indicated that the child safety seat after the crash could be lifted approximately 30 cm (12") above the seat cushion while secured by the manual belt system.

Figure 10. Loose position of the CSS in the front right seated area.

Damage to the CSS was limited to superficial abrasions to the lower front aspect of the shell from contact against the lower/mid instrument panel. Blood stains were noted to the harness straps and front shield.

A second CSS was in the rear seat of the vehicle. This CSS was an older Fisher Price convertible seat with no identifying labels remaining on the shell of the restraint. This seat was not restrained in the vehicle and was found in an inverted position on the right aspect of the rear seat cushion.

DRIVER DEMOGRAPHICS

Age/Sex:	23 year old female
Height:	170.2 cm (67.0")
Weight:	72.5 kg (160.0 lb)
Manual Restraint Usage:	3-point lap and shoulder belt system
Usage Source:	Vehicle inspection/driver statements
Eyeware:	Prescription eyeglasses
Mode of Transport From Scene:	Ambulance with injured child passenger
Type of Medical Treatment:	Not medically treated

DRIVER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanisms
*Left neck abrasion	Minor (390202.1,2)	Shoulder belt webbing
*Multiple contusions, not specified	Minor (990400.1,9)	Deployed front left air bag (per driver)
*Lip lacerations, not specified	Minor (290600.1,8)	Deployed front left air bag

** These injuries were obtained from interview data as the driver refused medical attention.*

DRIVER KINEMATICS

The driver of the vehicle was a 23 year old female with a reported height of 170.2 cm (67.0") and weight of 72.5 kg (160.0 lbs). At the time of the crash, she was driving with a restricted license which required a licensed driver over the age of 21 years accompany her. Although there was no loading evidence on the manual belt system, the driver stated that she was restrained by the 3-point lap and shoulder belt system.

The manually operated driver's seat track was adjusted to a mid track position, 9.7 cm (3.8") rearward of the full forward position **(Figure 11)**. The seat back support was adjusted to the most vertical position at the time of inspection. Contact evidence within the driver's compartment of the vehicle consisted of two abrasions/scuff marks to the knee bolster.

Figure 11. Adjusted seat rack position and the deployed front left air bag.

During the impact with the driveway culvert, the driver moved

forward in response to frontal impact force and contacted the knee bolster with her knees which produced the abrasions/scuff marks. No injury resulted from this contact sequence. Due to her mid track seat position, her face and torso loaded the deployed front left air bag which resulted in lip lacerations and contusions of an unspecified body area. The use of restraint systems prevented her from contact with the steering wheel and/or windshield.

The manual belt system provided the driver with sufficient restraint during the rollover sequence. She remained in her seated area during the rollover event as determined by the lack of rollover related occupant contact evidence on adjacent interior surfaces. She sustained an abrasion to the left lateral neck from interaction against the belt webbing during the crash sequence.

CHILD PASSENGER DEMOGRAPHICS

Age/Sex:	17 month old female
Seated Position:	Front right
Height:	81.3 cm (32.0")
Weight:	12.7 cm (28.0 lb)
Restraint Usage:	Improperly restrained in a forward facing Evenflo Scout forward facing child safety seat
Usage Source:	Vehicle inspection/child injuries
Mode of Transport From Scene:	Transported by ambulance to a local hospital then transferred by air to a major medical center (non-trauma)
Medical Outcome:	Expired approximately 11.5 hours following the crash

CHILD PASSENGER INJURIES

Injury	Injury Severity (AIS 90)	Injury mechanism
Moderate edema of the cerebral hemispheres	Severe (140672.4,1 140672.4,2)	Deploying front right passenger air bag
Leptomeningeal hemorrhage over the left superior temporo-parietal region with left subarachnoid hemorrhage	Serious (140684.3,2)	Deploying front right passenger air bag
Scalpular hemorrhage in the mid frontal region, 1.25" in size	Minor (190402.1,5)	Deploying front right passenger air bag

Extensive non-patterned abrasions of the anterior forehead, nose lips, cheeks, and chin	Minor (290202.1,0)	Deploying front right passenger air bag
Ecchymosis of the mucosal surface of the left upper and lower lips	Minor (290402.1,8)	Deploying front right passenger air bag
Non-patterned abrasions over the left medial thigh	Minor (890202.1,2)	Deploying front right passenger air bag
Abrasions over the left superior lower leg, and left ankle, and left 1st- 3rd toes	Minor (890202.1,2)	Right mid instrument panel
Non patterned abrasions over the right medial leg	Minor (890202.1,1)	Deploying front right passenger air bag
Small linear abrasions over the dorsum of the right foot	Minor (890202.1,1)	Deploying front right passenger air bag
Ecchymosis over the left 1st - 3rd toes	Minor (890402.1,2)	Right mid instrument panel
Ecchymosis over the right forearm proximally and dorsally, 2.5 cm in size	Minor (790402.1,1)	Deploying front right passenger air bag
Non patterned abrasions over the base of the right neck and shoulder	Minor (390202.1,1 790202.1,1)	Deploying front right passenger air bag
Slight dependent edema of the right lung	N/A (not codeable under AIS 90 rules)	Deploying front right passenger air bag
Perivertebral hemorrhage of the soft tissue overlying the ventral cervical vertebral column from C2-C5	N/A (not codeable under AIS 90 rules)	Deploying front right passenger air bag

Note: All injuries listed above were documented and coded from the autopsy report. The mother of the child (driver) refused through her attorney to sign a medical release form to allow the SCI team to gain access to the child's hospital medical records.

CHILD PASSENGER KINEMATICS

The 17 month old child passenger was asleep, seated in a forward facing Evenflo Scout child safety seat that was positioned in the front right of the Geo Metro. The CSS was improperly secured by the vehicle's 3-point lap and shoulder belt system. The belt was loosely routed through the belt path which allowed forward excursion of the CSS. The emergency locking retractor was not placed in the switchable mode, therefore the driver could not secure the CSS firmly into the front right seat position. The investigating police officer indicated that the child safety seat could be lifted approximately 30 cm (12") above the seat cushion while secured by the manual belt system. The child was secured by the integral harness of the CSS, however, the adjustment of the harness was unknown. The harness positioning clip was on the belt webbing, however, the at crash adjustment status of this clip was unknown.

The right front seat track was adjusted to a mid track position that was located 10.5 cm (4.1") forward of the full rear position with the seat back reclined 30 degrees rearward of vertical at the time of the vehicle inspection. The horizontal distance between the leading edge of the front right air bag module cover flap and the seat back support was 81.3 cm (32.0").

In response to initial frontal impact forces, the CSS moved in a forward direction due to the improper installation of the CSS. The child and CSS moved forward within the expansion zone of the front right air bag at the time of the frontal air bag deployment. It was unknown whether the driver awoke prior to the impact and attempted to apply the brakes which resulted in the forward movement of the child or whether the contact between the driveway and the vehicle's undercarriage produced an elongated crash pulse which delayed the SIR deployment sequence.

Figure 12. Excursion of the front right air bag into the CSS.

At the time of air SIR deployment, the child was within the deployment path of the front right air bag **(Figure 12)** with her head turned slightly to the right. The child sustained extensive facial abrasions that extended vertically from the underside of the chin to the mid forehead and laterally from the left ear to the outboard aspect of the right eye (refer to SENSITIVE IMAGES, **Figures 14 and 15,** Page 14). Tissue transfers on the bag evidence her interaction with the deploying membrane. The head was accelerated by the deploying air bag which resulted in a frontal scalpular hemorrhage, cerebral edema, and leptomeningeal hemorrhage over the left superior temporao-parietal region with left subarachnoid hemorrhage. In addition to the face and closed head injuries, the child sustained abrasions of the lower legs from air bag deployment. Her feet impacted the mid right instrument panel as the lower aspect of the child restraint contacted and scuffed the mid instrument panel.

The child was removed from the CSS by the driver. She was transported from the scene of the crash

to a local hospital for stabilization and prepared for helicopter transfer to a major medical facility where she expired 11.5 hours post-crash.

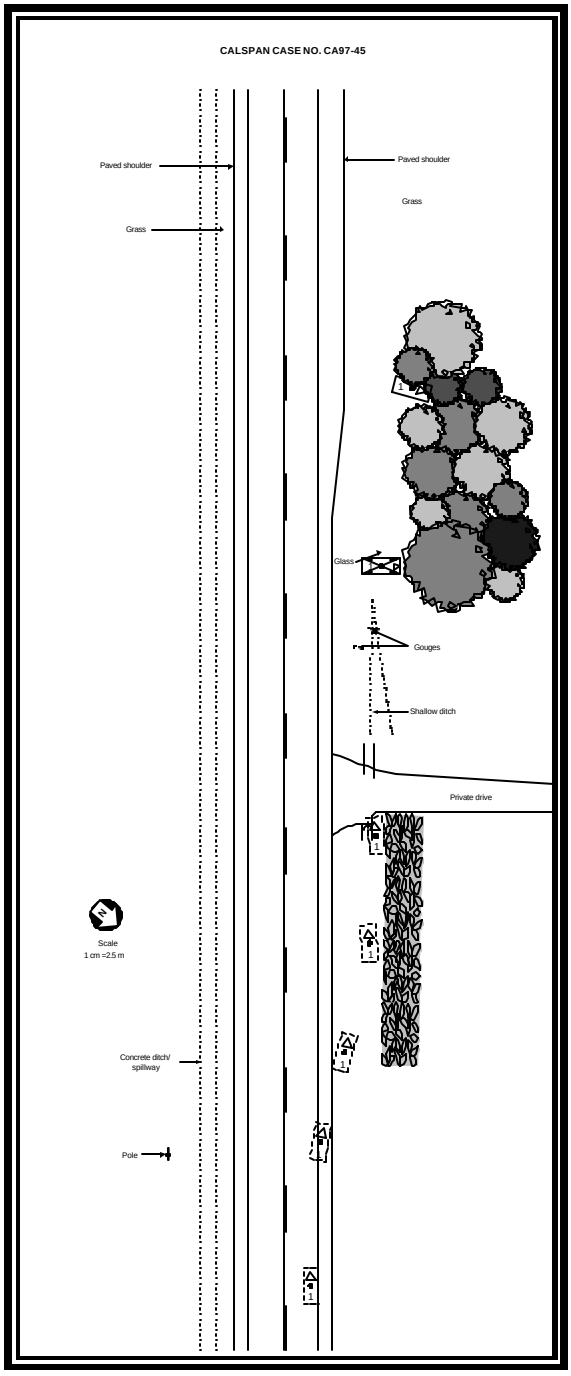

Figure 13. Crash Schematic