TRANSPORTATION SCIENCES
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VERIDIAN ON-SITE AIR BAG RELATED CHILD PASSENGER FATALITY INVESTIGATION
VERIDIAN CASE NO. CA98-049
VEHICLE: 1997 FORD EXPLORER
LOCATION: VIRGINIA
CRASH DATE: SEPTEMBER 1998

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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 injury mechanisms and cause of death of a 5 year old male front right passenger of a 1997 Ford Explorer. The Explorer was equipped with frontal air bags for the driver and front right passenger positions that deployed as a result of an off-set, front-to-rear crash with a 1988 Dodge Caravan. The 31 year old female driver of the Ford Explorer was distracted to her right as she approached the slower moving Dodge Caravan. As she redirected her attention forward, the driver detected the Caravan and braked in an attempt to avoid the crash. The front left area of the Explorer impacted the back right area of the Caravan resulting in moderate damage to both vehicles. The unrestrained child passenger was displaced forward by the pre-crash braking into the path of the deploying mid mount front right air bag. The cover flap and the expanding air bag membrane subsequently contacted the face, neck, and right upper extremity of the child passenger resulted in extensive abrasions of the right face, neck, arm, and a cervical fracture. He was transported by ambulance to a local hospital where he expired approximately 70 minutes post-crash. No autopsy was performed.			
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BACKGROUND

This on-site investigation focused on the injury mechanisms and cause of death of a 5 year old male front right passenger of a 1997 Ford Explorer. The Explorer was equipped with frontal air bags for the driver and front right passenger positions that deployed as a result of an off-set, front-to-rear crash with a 1988 Dodge Caravan. The 31 year old female driver of the Ford Explorer was distracted to her right as she approached the slower moving Dodge Caravan. As she redirected her attention forward, the driver detected the Caravan and braked in an attempt to avoid the crash. The front left area of the Explorer **(Figure 1)** impacted the back right area of the Caravan resulting in moderate damage to both vehicles. The unrestrained child passenger was displaced forward by the pre-crash braking into the path of the deploying mid mount front right air bag. The cover flap and the expanding air bag membrane subsequently contacted the face, neck, and right upper extremity of the child passenger resulted in extensive abrasions of the right face, neck, arm, and a cervical fracture. He was transported by ambulance to a local hospital where he expired approximately 70 minutes post-crash. No autopsy was performed.

Figure 1. Front left view of the damage to the Ford Explorer.

The September crash was reported to the Veridian Special Crash Investigation Team by the Virginia Crash Team on Wednesday, September 16, 1998. The notification was forwarded to NHTSA and an on-site investigative task was assigned on the day of notification. Cooperation with the investigating police agency was established on Thursday, September 17, 1998, and an on-site investigation was scheduled and initiated on Monday, September 21, 1998.

SUMMARY

Crash Site

This crash occurred during daylight hours on a four-lane roadway in an urban, residential area. In the vicinity of the crash site, the roadway was straight with an negative grade of one percent in the northbound direction that transitioned into a sag at the bottom of two negatives grades. The outboard northbound travel lane was 5.6 m (18.4') in width while the inboard lane was 3.9 m (12.8') wide. The southbound lanes were 5.7 m (18.7') and 3.8 m (12.4') respectively. The lanes were delineated by broken white lane lines and the center was marked with double yellow centerlines. Both edges of the roadway were bordered by

barrier curbs with lawns extending beyond the curblines. At the time of the crash, the asphalt road surface was dry and the weather was clear. The posted speed limit was 64 km/h (40 mph). The crash schematic is included as **Figure 12**.

Crash Sequence

Pre-Crash

The driver of the 1988 Dodge Caravan was traveling in a northerly direction on the inboard travel lane of the four-lane roadway **(Figure 2)**. She was decelerating for a left turn onto an intersecting street. The driver of the Caravan stated that there was no opposing traffic on her approach to the intersection. She further stated that she looked in her rearview mirror as she slowed for the left turn and did not detect the approaching Ford Explorer.

Figure 2. Northbound approach view of the crash scene.

The driver of the 1997 Ford Explorer was traveling in a northerly direction on the inboard travel lane of the four-lane roadway at a police reported speed of 56 km/h (35 mph). The subsequent analysis of the crash suggested that the Ford's initial velocity was approximately 72-80 km/h (45-50 mph). The driver stated to the investigating officer that as she crested the hill and was descending the negative grade, she did not see any other traffic in her vicinity of travel. The driver of the Ford Explorer became momentarily distracted to her driving task, and as she redirected her attention forward, she noted the Dodge Caravan directly ahead of her path of travel. The driver of the Explorer stated that she steered left and braked, however, based on the dynamics of the crash, she applied a right steering input immediately prior to impact. There were no skid marks at the scene to support the level of braking by the driver of the Explorer.

Crash

The front left area of the Ford Explorer impacted the back right area of the Dodge Caravan in an off-set impact configuration that resulted in impact forces of 12 o'clock for the Explorer and 6 o'clock for the struck Caravan. The damage and trajectory algorithm of the WinSMASH program computed impact speeds of 67.3 km/h (41.8 mph) for the Ford and 39.8 km/h (24.7 mph) for the struck Dodge Caravan. The total velocity changes were computed at 18.0 km/h (11.2 mph) for the striking Ford Explorer and 23.0 km/h (14.3 mph) for the struck Dodge Caravan. The longitudinal components were -18.0 km/h (-11.2 mph) for the Explorer and 23.0 km/h (14.3 mph) for the Caravan. It should be noted that the computer generated velocity changes appeared to be conservative, given the damage to the involved vehicles. This was attributed to the off-set impact configuration that involved the corner areas of the vehicles. As a result of the frontal impact, the Ford Explorer's frontal air bag system deployed.

The impact accelerated the Dodge Caravan in a forward direction as it free-rolled down the negative grade and traversed the centerline and the inboard southbound travel lane. During the post-crash spin-out, the Caravan turned in a CCW direction. The driver recovered from the initial impact force and brought the vehicle to a controlled stop approximately 82 m (269') north of the point of impact. At rest, the Caravan was facing in a northwesterly direction.

The left front tire of the Ford Explorer was displaced rearward due to the fracture of the steering spindle shaft. The deflection of this tire induced a counterclockwise steering input to the vehicle as it continued forward. The Explorer crossed the centerline into the southbound travel lanes where it came to rest diagonal to the roadway, approximately 15 m (49') north of the point of impact. At rest, the vehicle was facing in a westerly direction.

Post-Crash

The driver of the Ford Explorer immediately removed the child passenger from the vehicle and placed him on the road surface to await the arrival of medical and police assistance. The driver of the Dodge Caravan remained in her vehicle and used her cellular telephone to notify authorities of the crash.

The paramedics received the call two minutes following the police reported time of the crash. They departed their station within one minute and arrived on-scene within eight minutes of the call. On-scene, the paramedics found the child on the road unresponsive, without a pulse or respirations. CPR activities were immediately initiated and the child was prepared for ambulance transport to a local hospital. The unit departed the scene within eight minutes of their arrival and arrived at the hospital within eleven minutes. The child was evaluated which included an X-ray of the cervical region which identified a cervical fracture. He was pronounced deceased 70 minutes following the crash.

Vehicle Data - 1997 Ford Explorer

The subject vehicle in this crash was a 1997 Ford Explorer, four-door, four-wheel drive, sport utility vehicle with the Eddie Bauer trim package. The Explorer was powered by a 5.0 liter V-8 engine linked to a 4-speed automatic transmission with a column mounted transmission selector lever. The vehicle's braking system consisted of four-wheel, power-assisted disc brakes with four-wheel ABS. The Explorer's vehicle identification number was 1FMDU35P2VU (production number omitted).

The interior was configured with leather wrapped high-back front bucket seats with integral head restraints and a fixed center console. The second set was a bench with a split forward folding backrest. The four outboard seated positions were equipped with continuous loop 3-point lap and shoulder belts with sliding latchplates and inertia activated locking retractors. The front belt systems were equipped with adjustable D-rings. It should be noted that the driver's D-ring was adjusted to the full-down position while the front right position was adjusted to the full-up position. In addition to the manual belt systems, the Explorer was equipped with frontal air bags for the driver and right passenger positions. The frontal air bag system deployed as a result of the front-to-rear impact sequence with the Dodge Caravan.

Vehicle Damage

Exterior - 1997 Ford Explorer

The Ford Explorer sustained moderate severity frontal damage from its impact sequence with the rear of the Dodge Caravan. Maximum crush was 35.6 cm (14.0") located at the left corner of the front bumper. The direct contact damage began at the front left corner and extended 44.4 cm (17.5") inboard **(Figure 3)**. The damage deformed the full frontal width of the bumper profile resulting in a combined direct and induced damage length of 136.5 cm (53.75"). The crush profile at bumper level **(Figure 4)** was as follows:

C1 = 35.6 cm (14.0"), C2 = 8.9 cm (3.5"), C3 = 5.1 cm (2.0"), C4 = 2.5 cm (1.0"), C5 = 0.6 cm (0.25"), C6 = 0 cm.

The damage extended rearward into the leading edge of the left front fender, the left front suspension, and the left front tire and wheel assembly. The crash forces transmitted into the left front suspension fractured the steering spindle. The components damaged by the impact included the front bumper, left headlamp assembly, grille, hood, radiator support, left front fender, and the left front suspension. The Collision Deformation Classification (CDC) for this impact was 12-FLEW-2.

Figure 3. Frontal view of the Ford Explorer.

Figure 4. Profile view of the damage pattern to the Ford Explorer.

Interior - 1997 Ford Explorer

The interior damage to the Ford Explorer was minor and was associated with air bag deployment and occupant contact. There was no intrusion of interior components or damage due to exterior deformation. The frontal air bag system deployed as designed. The driver air bag deployed from a typical steering wheel mount while the front right passenger air bag deployed from the mid mount position in the right instrument panel.

The driver's left knee contacted and scuffed the plastic knee bolster 36.8 cm (14.5") left of center and 11.4 cm (4.5") above the lower aspect of the rigid plastic panel. Her face loaded the deployed driver air bag as evidenced by make-up transfers on the upper right quadrant of the bag. A horizontally oriented lipstick transfer was located within a 12.7x11.4 cm (5.0x4.5") flesh-tone make-up transfer. The larger make-up transfer originated 10.2 cm (4.0") right of the vertical centerline and 5.1 cm (2.0") above the horizontal centerline.

Several longitudinally oriented scuff marks were present on the fabric headliner above the driver's seated position. The left leading edge of the center console cover was abraded.

The front right child passenger was displaced forward by the pre-crash braking and was in a close proximity to the front right air bag module cover at deployment. The cover flap initially contacted the child as evidenced by a two closely spaced subtle, semi-circular scuff marks along the leading edge of the flap. The scuff marks began at the lower left corner of the flap and extended 22.9 cm (9.0") laterally to the right, extending 2.5 cm (1.0") vertically onto the face of the flap.

A large probable vinyl transfer was located on the left side panel of the air bag and extended onto the face of the bag membrane. The transfer originated 10.2 cm (4.0") below the top surface of the bag and extended 16.5 cm (6.5") vertically downward. The overall width of the transfer was 3.8 cm (1.5"). A second vinyl transfer was located on the mid face area of the bag, at the left side. This transfer was horizontally oriented and measured approximately 26.7 cm (10.5") square. Both transfers appear to have resulted from expansion against the cover flap and/or instrument panel.

The expanding air bag membrane subsequently contacted the face and neck area of the forward positioned child passenger. The forward positioned child altered the deployment path of the front right air bag. The air bag subsequently contacted the windshield as evidenced by an air bag fabric transfer to the glazing, directly above the module location. An additional scuff/air bag fabric transfer was noted to the right front door glazing. There was no damage to the windshield or side glazing. The expanding air bag was deflected into the rear view mirror and the overhead console that was mounted to the headliner immediately aft of the mirror. As a result of the contact, the mirror was displaced left from its adjusted position. A scuff mark was noted to the left leading edge of the center console of the Ford Explorer. The scuff mark wrapped 7.6 cm (3.0") around the corner of the console cover and extended 1.3 cm (0.5") onto the plastic shell of the component.

The child's knees/lower legs contacted the glove box door and the heater box. Two distinct scuff/tissue transfers were noted to the plastic surfaces. The glove box contact was located 22.9 cm (9.0") right of the vehicle's centerline and extended 10.2 cm (4.0") laterally to the right. The contact extended 2.5-7.6 cm (1.0-3.0") above the bottom edge of the door. The right knee/leg contacted the heater box 26.7-31.8 cm (10.5-12.5") right of center. The scuff mark was located 30.4-33.0 cm (12.0-13.0") above the height of the floor.

Exterior - 1988 Dodge Caravan

The right rear of the Dodge Caravan sustained moderate damage with a maximum crush value of 36.8 cm (14.5") located at the right bumper corner **(Figure 5)**. The direct contact damage began at the corner and extended 55.9 cm (22.0") inboard. The combined direct and induced damage was 157.4 cm (62.0") that included the full width of the rear plane. The crush profile at bumper level **(Figure 6)** was as follows: C1 = 0 cm, C2 = 0 cm, C3 = 5.1 cm (2.0"), C4 = 16.5 cm (6.5"), C5 = 26.0 cm (10.75"), C6 = 36.8 cm (14.5"). The CDC for this impact was 06-BREW-3.

The front left corner of the Explorer crushed the bumper, liftgate, right D-pillar, and the right quarter panel. The damage also shattered the backlight and the right quarter window glazing.

Figure 5. Right rear view of the Caravan's damage.

Figure 6. Overhead view of the Caravan's crush profile.

Frontal Air Bag System - 1997 Ford Explorer

The 1997 Ford Explorer was equipped with a frontal air bag system for the driver and right passenger positions. The system consisted of two crash sensors mounted to the upper radiator support panel, a safing sensor that was located in the front left kick panel, a control/diagnostic module located in the center instrument panel, a steering wheel mounted driver air bag module, and the front right passenger air bag module located in the right mid instrument panel. The system deployed **(Figure 7)** as a result of the impact sequence with the rear of the Dodge Caravan.

Figure 7. Deployed frontal air bag system.

The driver air bag module was mounted within the four spoke steering wheel rim with the spokes located at the 10/2 and the 5/7 o'clock positions. The H-configuration module cover flaps were nearly symmetrical in size and both opened at the designated tear seams. The deployed driver air bag membrane was a tethered design with four internal tether straps sewn to the face of the bag with a 17.1 cm (6.75") diameter reinforcement. The bag was 67.9 cm (26.75") in diameter in its deflated state and was vented by two 1.3 cm (0.5") diameter ports located at the 11 and 1 o'clock positions. The driver air bag module was identified by the following bar coded number: 1ZGJ254J20157.

The driver's face contacted the deployed air bag as evidenced by make-up and lipstick transfers on the upper right quadrant of the bag. There was no damage to the driver air bag membrane or module assembly.

The front right air bag deployed from a single cover flap **(Figure 8)** that was 16.5 cm (6.5") in height and 37.1 cm (14.625") in width. The flap was hinged at the top surface, therefore it opened in an upward direction. The front right air bag membrane was a non-tethered design that measured 55.9 cm (22.0") in height and approximately 81.3 cm (32.0") in width. The bag was vented by two 5.1 cm (2.0") diameter ports located at the lateral aspects of the bag.

Figure 8. Front right air bag cover flap.

The forward positioned child passenger contacted the cover flap at deployment and was subsequently contacted by the expanding air bag membrane. As a result of the later contact sequence, the child altered the deployment path of the bag. The bag expanded against the windshield and the mid instrument panel, below the location of the module cover. Air bag fabric transfers identified the expansion points.

The sunvisors of the Ford Explorer contained warning labels **(Figure 9)** that advised the following:

WARNING To Avoid Serious Injury

- For maximum safety protection in all types of crashes, you must always wear your safety belt.
- Do not install rearward-facing child seats in any front passenger seat position.
- Do not sit or lean unnecessarily close to the air bag.
- Do not place any objects over the air bag or between the air bag and yourself.

*See Owner's Manual for further information and explanation.

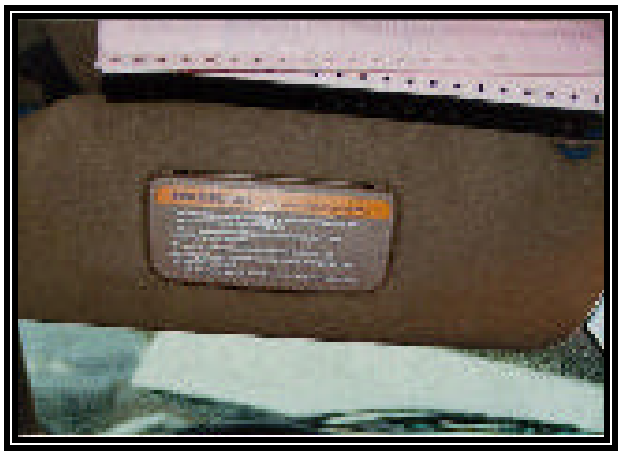

Figure 9. Sunvisor Air Bag Warning Label

Driver Demographics - 1997 Ford Explorer

Age/Sex:	31 year old female
Height:	Unknown
Weight:	Unknown
Manual Restraint Usage:	None, 3-point lap and shoulder belt was available
Usage Source:	Vehicle inspection
Seat Track Position:	Mid track position
Mode of Transport From Scene:	Ambulance to a local hospital
Type of Medical Treatment:	Treated and released

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Chin abrasion	Minor (290202.1,8)	Driver air bag membrane

** Source of injury - police*

Driver Kinematics

The driver of the Ford Explorer was seated in a presumed normal driving posture with her seat adjusted to a mid track position. The driver was not restrained by the manual belt system. At impact, the frontal air bag system deployed. The driver initiated a forward trajectory in response to the 12 o'clock impact force and loaded the deployed driver air bag with her face and torso. The driver's facial contact was evidenced by make-up transfers located at the upper right quadrant of the bag membrane. This contact sequence resulted in an abrasion of the driver's chin.

The deployed air bag did provide the driver with adequate crash protection as it prevented her from direct contact with the steering assembly. Her thoracic loading force of the air bag did not result in steering wheel rim deformation or compression of the energy absorbing steering column.

The driver subsequently rebounded into the front left seat back support where she came to rest. She immediately exited the vehicle and removed her injured child from the front right position of the Ford Explorer. She laid the child on the asphalt road surface and waited for rescue personnel to arrive on-scene.

Front Right Child Passenger Demographics

Age/Sex:	5 year old male
Height:	Unknown
Weight:	Unknown
Manual Restraint Usage:	None, 3-point lap and shoulder belt was available
Usage Source:	Vehicle inspection
Seat Track Position:	Mid track position
Mode of Transport From Vehicle:	Ambulance
Type of Medical Treatment:	Transported to a local hospital where he was evaluated and expired approximately 70 minutes following the crash

Front Right Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Cervical fracture, NFS	Moderate (650216.2,6)	Front right air bag module cover flap and the expanding air bag
Right lower lip abrasion	Minor (290202.1,8)	Expanding air bag membrane
Continuous abrasion of the right anterior chin, right anterior neck, and the right face terminating at the level of the ear	Minor (290202.1,1; 290202.1,1; 390202.1,5)	Front right air bag module cover flap and the expanding air bag
Abrasion of the right anterior shoulder that continues onto the anterior right upper arm	Minor (790202.1,1; 790202.1,1)	Expanding air bag membrane
Laceration of the right upper arm within the abrasion	Minor (790600.1,1)	Expanding air bag membrane

** Source of injury - Hospital reported injuries and police photographs. No autopsy was performed.*

Front Right Child Passenger Kinematics

The front right child passenger of the Ford Explorer was in a presumed upright seated position with the seat adjusted to a mid track position. The seat back was adjusted to an angle of 19 degrees aft of vertical. The seat cushion sloped rearward at an angle of 19 degrees of horizontal. With the seat adjusted to this position, the horizontal distance between the seat back support and the vertical profile of the mid mount passenger air bag module cover **(Figure 10)** was 74.9 cm (29.5"). The leather seat covering probably resulted in a reduced friction coefficient between the child's clothing and the cushion as compared to a fabric seat covering. The child was not restrained by the manual belt system.

Figure 10. Excursion of the passenger air bag and adjusted position of the seat.

Figure 11. Child passenger trajectory and air bag contact points.

Prior to impact with the Dodge Caravan, the driver of the Ford Explorer braked which displaced the child passenger in a forward direction. He slid forward on the leather seat cushion and was in close proximity to the mid mount front right passenger air bag at impact. As a result of the crash, the Explorer's frontal air bag system deployed.

The leading edge of the front right air bag module cover flap impacted the lower facial area of the out-of-position child passenger. Semicircular scuff marks evidenced the contact to the cover flap. This contact began to displace the child's head in an upward and rearward direction. Additionally, this contact momentarily impeded the upward motion of the cover flap which allowed the air bag membrane to expand against the interior aspect of the cover flap. This interaction produced vinyl transfers to the air bag and abraded the inside surface of the flap.

The child initiated a forward trajectory in response to the 12 o'clock impact force as the air bag membrane expanded from the module **(Figure 11)**. The air bag membrane expanded against his lower lip, anterior chin, neck, and right face resulting in a heavy tissue abrasions. The expanding air bag subsequently contacted his anterior right shoulder and upper arm which resulted in a continuous abrasion pattern of the

right upper extremity with a laceration located within the abrasion pattern. Based of the location of these injuries, the child passenger was probably turned to his left, thus exposing the right side of his body to the air bag module.

The combination of module cover flap contact and air bag expansion under the child passenger's chin and anterior neck, hyperextended his head and displaced him in an upward and rearward direction. The child sustained an unspecified cervical fracture. It was unknown if cord damage occurred.

His forward motion, combined with his forward position, altered the deployment path of the expanding air bag membrane in a forward direction. The air bag membrane expanded against the windshield and mushroomed outward, contacting the right door window glazing, the interior rear view mirror, and the overhead console. Air bag fabric transfers and scuff marks evidence the contacted areas.

The child passenger possibly contacted the sliding cover to the sunroof with his left upper extremity as he was displaced vertically upward and rearward by the deploying air bag. He fell to rest on the center console, scuffing the top left aspect of the console cover. No injury resulted from the console contact.

As the vehicle came to rest, the driver removed the child from the vehicle and placed him on the asphalt road surface and waited for emergency personnel to arrive on-scene.

Medical Treatment

The front right child passenger of the Ford Explorer was removed from the vehicle immediately following the crash by the driver. She positioned the child on the asphalt road surface adjacent to the final rest position of the Explorer and waited for rescue personnel to arrive on scene. The emergency medical technicians responded to the crash scene within one minute of the call. They arrived on-scene within eight minutes and were met by an EMT who was administering cardiac-pulmonary resuscitation (CPR) to the injured child. The ambulance EMTs established an airway and inserted an IV of natural saline into the child's left upper extremity. They applied a heart monitor patch to the child's chest and connected the monitor which showed the child as asystole; no heart rate. They positioned a cervical collar on the child and placed him on a backboard. The child was loaded into the ambulance and the unit departed the scene within eight minutes of arrival.

The ambulance arrived at a local non-trauma hospital and the child was rushed into the emergency room where no pulse or heart rate was detected. The hospital staff administered treatment for 51 minutes prior to pronouncing him deceased at 70 minutes following the crash. A cervical X-ray was taken which revealed an unspecified cervical fracture. No autopsy was performed, therefore it was unknown if cord damage was present.

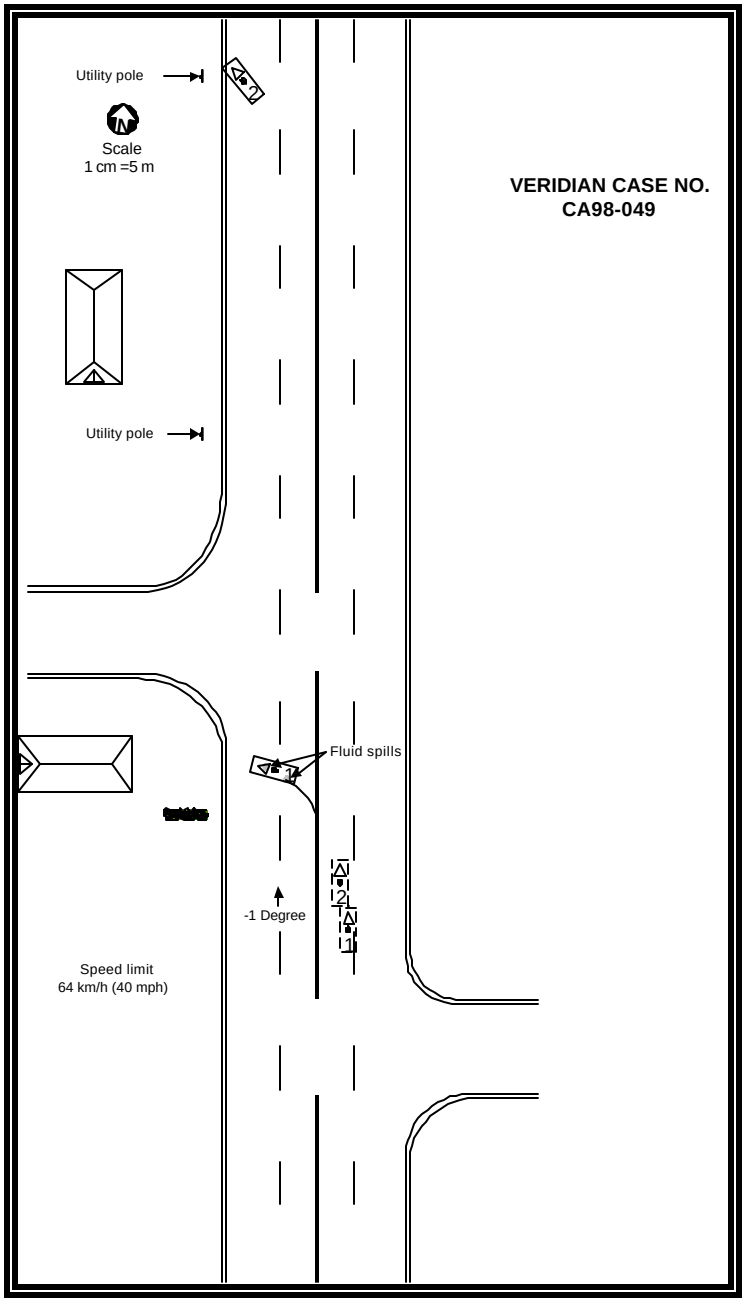

Figure 12. Scene Schematic.