TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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ON-SITE AIR BAG RELATED CHILD PASSENGER FATALITY INVESTIGATION

VERIDIAN CASE NO: CA98-058

VEHICLE: 1996 GEO METRO

LOCATION: NORTH CAROLINA

CRASH DATE: OCTOBER 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 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 on-site investigation focused on the fatal injury mechanisms that resulted in the death of an unrestrained 4 year old male passenger seated in the front right position of a 1996 Geo Metro. The Geo was equipped with a Supplemental Restraint System consisting of driver and front right passenger air bags that deployed as a result of an in-line front-to-rear impact sequence with a 1987 Ford Aerostar. The unrestrained child passenger translated forward, with respect to the vehicle, in response to the driver's pre-crash braking and was positioned in the path of front right passenger air bag at impact. The expanding front right air bag hyper-extended the child's neck resulting in an atlanto-occipital fracture dislocation. The child was unresponsive at the scene and pronounced dead 65 minutes post-crash. The female driver of the Geo had a police reported complaint of pain. The eight occupants of the Ford Aerostar were uninjured.

The crash was identified through a media search by the Special Crash Investigations team at Veridian Engineering. Upon subsequent crash notification, the Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) assigned an crash on-site investigation to the Veridian SCI team. The vehicle was located through the investigating police agency and local cooperation was established.

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BACKGROUND

This on-site investigation focused on the fatal injury mechanisms that resulted in the death of an unrestrained 4 year old male passenger seated in the front right position of a 1996 Geo Metro. The Geo was equipped with a Supplemental Restraint System consisting of driver and front right passenger air bags that deployed as a result of an in-line front-to-rear impact sequence with a 1987 Ford Aerostar. The unrestrained child passenger translated forward, with respect to the vehicle, in response to the driver's pre-crash braking and was positioned in the path of front right passenger air bag at impact. The expanding front right air bag hyper-extended the child's neck resulting in an atlanto-occipital fracture dislocation. The child was unresponsive at the scene and pronounced dead 65 minutes post-crash. The female driver of the Geo had a police reported complaint of pain. The eight occupants of the Ford Aerostar were uninjured.

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SUMMARY

Crash-Site

This two-vehicle crash occurred during the evening hours of October 1998. At the time of the crash, it was dark, with overhead street lights, and the weather was not a factor. The asphalt road surface was dry. The crash occurred in the inboard northbound lane of a four lane north/south road located in an urban residential setting, **Figure 1**. The road was straight and had a positive 2 percent grade in the northbound direction. The respective travel directions were separated by double yellow center lines. The northbound pair of lanes was separated by broken white lines. The road was bordered by 15 cm (6 in) curbs, adjacent sidewalks, and private residences. A two lane road intersected the subject road approximately 37 m (120 ft) north of the point of impact forming a three-leg intersection. The speed limit in the area of the crash was 72 km/h (45 mph).

Figure 1: Trajectory view of the Geo 30 m (100 ft) south of the point of impact.

Pre-crash

The 1996 Geo Metro, 2 door hatchback, was traveling north on the inboard lane driven by a 30 year old restrained female. The front right seat was occupied by the 4 year old son of the driver. The child was seated in a full forward track position and was not restrained by the vehicle's 3 point manual belt system. The 1987 Ford Aerostar was northbound in the inboard traffic lane directly ahead of the Geo. The Ford was driven by a 24 year old male and occupied by seven additional passengers.

The Ford driver slowed the Aerostar in response to a non-contact vehicle ahead of him. This non-contact vehicle had stopped to turn left onto an intersecting street that was located north of the point of impact. The driver of the Geo did not initially detect the Ford's reduced speed but upon recognition of the impending crash, steered the vehicle to the right and locked the vehicle's brakes. The Geo skidded forward, in a tracking mode, to impact with the Ford. Inspection of the crash scene documented two pre-crash skid marks attributed to the front tires of the Geo. The left and right skid marks measured 7.0 m (23.0 ft) and 5.5 m (18.0 ft), respectively. **Figure 12,** page 10, is a schematic of crash.

Crash

The crash occurred with the front plane of the Geo impacting and underriding the back plane of the Ford in an in-line 12/6 o'clock impact configuration. The point of impact was evidenced by two gouge marks attributed to the undercarriage of the Geo. The force of the above-threshold impact caused the Supplemental Restraint System in the Geo to deploy. The delta V of the Geo calculated by the WINSMASH model was 22.0 km/h (13.7 mph). The longitudinal delta V component was -22.0 km/h (-13.7 mph). The calculated impact speed of the Geo was 46.8 km/h (29.1 mph). The WINSMASH calculated delta V and impact speeds of Ford were 11.0 km/h (6.8 mph) and 10.9 km/h (6.8 mph), respectively.

The northbound momentum of the Geo displaced the Ford forward (north) 15.5 m (50.9 ft) from the point of impact. The Ford came to rest on the inboard northbound lane facing north. The Geo came to rest on the northbound lane 14.2 m (46.6 ft) north of the POI. These final rest locations were documented during the police investigation and subsequent SCI on-site investigation. **Figure 2** is an on-scene police photograph of the vehicles at final rest.

Figure 2: On-scene police photograph of the vehicles at final rest.

Post-crash

The driver of the Geo removed the injured child from the vehicle through the driver's door. She carried him to the roadside, laid him down, and ran into a nearby residence to call 911. The police and EMS personnel responded to the crash and arrived on-scene approximately eight minutes after notification. The medical records available from the county medical examiner indicated the child was found pulseless and unresponsive at the scene. He was immediately transported via ambulance to a local trauma center.

Resuscitive measures were applied en route and the child's pupils were noted to be fixed and dilated upon arrival at the emergency department. A pulse was recovered for a short time at the hospital but was subsequently lost. The X-rays of the child's cervical spine identified a large atlanto-occipital fracture dislocation. The child was pronounced deceased 65 minutes post-crash.

The driver of the Geo was transported to the trauma center by the police in order to be with her son. The police report indicated she had no visible injury and she had an unspecified complaint of pain. The eight occupants of the Ford Aerostar were not injured and did not require medical attention.

1996 GEO METRO

The 1996 Geo Metro LSI was identified by the Vehicle Identification Number (2C1MR2292T6 production sequence deleted). The 2 door hatchback was front-wheel drive. Its power train consisted of a 1.3 liter, I-3 engine linked to a 3-speed automatic transmission. The manual restraint system consisted of 3-point lap and shoulder belts in the four outboard positions and a rear center lap belt. The Supplemental Restraint System (SRS) consisted of driver and front right passenger air bags that deployed as a result of the crash. The vehicle was manufactured in February 1996. The odometer read 55,955 km (34,770 miles) at the time of the inspection.

Exterior Damage

Figures 3 and 4 are the front and left lateral views of the Geo's exterior damage. The vehicle's front plane sustained 92.7 cm (36.5 in) of direct contact damage that began 29.2 cm (11.5 in) right of center and extending to the left corner. The width of the combined direct and induced damage extended across the vehicle's entire 127 cm (50 in) frontal end width. The exterior damage to the vehicle involved the front bumper, grille, hood, left headlamp assembly and left front fender. The bumper reinforcement bar was fractured and had separated from the left mounting bracket. The reinforcement bar fracture point was located 3.8 cm (1.5 in) left of center. The crush profile along the bumper reinforcement was as follows: C1=10.3 cm (4.1 in), C2=12.2 cm (3.8 in), C3=15.4 cm (6.1 in), C4=12.2 cm (3.8 in), C5=8.4 cm (2.3 in), C6=2.8 cm (1.1 in). There was no measurable change in the wheelbase dimensions. The doors remained operational and all glazings were intact. The Collision Deformation Classification (CDC) was 12-FDEW-2.

Figure 3: Front view of the Geo.

Figure 4: Left lateral view of the Geo.

The Geo's total delta V calculated by the Damage algorithm of the WINSMASH model was 22 km/h (13.7 mph). The longitudinal and lateral components were -22.0 km/h (-13.7 mph) and 0 km/h, respectively. The WINSMASH trajectory algorithm calculated an impact speed of 46.9 km/h (29.1 mph). These analyses were consistent with the damage the vehicle and dynamics of the crash.

1987 FORD AEROSTAR

The 1987 Ford Aerostar XL was identified by the Vehicle Identification Number (1FMCA11U1HZ production sequence deleted). The minivan was configured with the seven passenger optional seating package. Its power train consisted of a 3.0 liter V6 engine linked to a 3-speed automatic transmission. The date of manufacture was October 1986 and the odometer read 315,000 km (195,737 miles) at the inspection.

Exterior Damage

Figures 5 and 6 are the Aerostar. The vehicle's back plane sustained 117 cm (46 in) of direct contact damage which began 33 cm (13 in) left of center and extended to the right corner. The width of the combined direct and induced damage extended across the vehicle's entire 168 cm (66 in) entire width. The exterior damage was limited to the rear bumper with some minor paint transfers and abrasions to the rear lift gate. The impact force caused the rear bumper to rotate downward (clockwise) when viewed from the left, Figure 6. The crush profile measured along the bumper was as follows: C1=0, C2=0, C3=1.3 cm (0.5 in), C4=2.4 cm (0.9 in), C5=3.2 cm (1.2 in), C6=4.1 cm (1.6 in). There was no change in the wheelbase dimensions. All the doors remained operational and there was no glazing damage. The CDC of the Aerostar was 06-BDEW-1. The Aerostar sustained a WINSMASH computed delta V of 11.0 km/h (6.8 mph) and had a calculated speed at impact of 10.9 km/h (6.8 mph). These calculated values were consistent with the extent of the vehicle's damage and the crash dynamics.

Figure 5: Aerostar left rear three-quarter view.

Figure 6: Left side view of the Aerostar.

1996 GEO METRO

Interior Damage

The Geo's interior damage was attributed to the deployment of the Supplemental Restraint System (SRS) and occupant contacts. There was no occupant compartment intrusion or interior damage associated to the exterior forces of the crash.

The driver seat track was adjusted to a rear track position measuring 6.8 cm (2.7 in) forward of full rear. The total seat track travel measured 22.9 cm (9.0 in). The driver seat back angle measured 43 degrees from vertical. The horizontal measurement from the driver air bag module to the seat back was 80.0 cm (31.5 in). There was no deformation of the four spoke steering wheel rim. Examination of the steering column shear capsules determine there was no shear capsule displacement. The driver's knee bolster exhibited two minor contacts related to the driver's lower extremities. The outboard aspect of the plastic bolster was stressed (whitened plastic) over a 2.5 cm (1.0 in) square area adjacent to the left door from contact with the left knee. A 5 cm (2 in) long scuff resultant to a right lower extremity contact was located on the bolster 20 cm (8 in) left of vehicle center. The left aspect of the windshield was fractured from contact by the driver's left hand. The fracture site was located 21.6 cm (8.5 in) below the header and 48.3 cm (19 in) left of vehicle center.

The passenger seat track was adjusted to a full forward position. The passenger seat back angle measured 21 degrees (aft of vertical). The horizontal distance from the rearward edge of the passenger air bag module to the seat back measured 66.0 cm (26 in). Contact evidence to the front right interior components resulted primarily from expansion contacts with the expanding passenger air bag during its altered deployment. The altered deployment of the passenger air bag was a result of the forward position of the front right child passenger. These contacts consisted of heavy abrasion to the interior trim panel of the right door, grab handle window crank and door release, **Figure 7**. The surface of the instrument panel immediately surrounding the passenger air bag module exhibited numerous minor scuffs and abrasions from the bag expansion. A tissue transfer to the right sunvisor, near its leading edge, was attributed to contact by the child passenger following the expansion of the passenger side air bag. Bodily fluid residue was located along the right aspect of the front passenger seat cushion and sill area and indicated the probable final rest location of the child.

Figure 7: Expansion contacts to right door interior panel.

Manual Restraint System

The Geo's manual restraint system consisted of 3-point lap and shoulder belt systems for the four outboard positions. The front restraints had a continuous loop webbing, sliding latch plate, dual mode locking retractors and fixed D-rings. The rear center position was a lap belt.

The driver's belt was stowed at inspection and operational. The latch plate evidenced historical use marks. Inspection of the webbing and the surfaces of the hardware (D-ring and latch plate) was unremarkable for usage marks, however, the severity of the crash may not have been great enough to generate belt evidence during the driver ride down. Based on the lack of driver injuries and the lack of shear capsule displacement, and lack of significant occupant contacts to the interior or driver air bag, the driver was probably restrained at the time of the crash.

The front passenger belt was stowed in its retractor and was operational at the time of the inspection. The latch plate exhibited marks of historical use. Inspection of the webbing and hardware surfaces did not identify any at-crash use indicators. The energy management loop at the outboard anchor was not released. The nature of the child's injuries were all air bag related. There were no seat belt related abrasions or contusions consistent with belt use. It was probable the child was unrestrained at the time of the crash.

Supplemental Restraint System

The driver air bag, **Figure 8**, was designed in the typical manner and located in the center hub of the steering wheel rim. The driver air bag module I-configuration cover flaps were symmetrical and measured 15 cm x 6.9 cm (6 in x 2.7 in), width by height. The vinyl flaps were not damaged and exhibited no contact evidence. The deployed driver air bag measured 61 cm (24 in) in its deflated state and was tethered by four internal straps sewn to the face of the bag. It was vented by two 3.8 cm (1.5 in) diameter ports on the back side of the bag in the 10/2 o'clock positions. The face of the bag exhibited no contact evidence. The driver bag was identified by the following: *PE5114100-01 TBS6039B1736*.

Figure 8: Driver air bag.

The front right passenger air bag was a top mount design located in the right instrument panel. The rigid vinyl cover flap measured 36 cm x 18 cm (14 in x 7 in). There was no contact evidence to the flap. The face of front right passenger air bag measured 47.0 cm (18.5 in) square and it extended rearward 48 cm (19 in) from the module, **Figure 9**. The bag was not tethered and was not externally vented. No manufacturer's identifiers were found on the passenger bag.

Figure 9: Rearward excursion of the PAB.

Inspection of the deployed front right passenger air bag revealed evidence of direct contact to the child passenger. Two heavy tissue transfers, **Figures 10 and 11**, were noted on the top horizontal surface of the bag. These transfers measured 6.4 cm x 21.6 cm (2.5 in x 8.5 in) and 3.8 cm x 29.2 cm (1.5 in x 11.5 in), width by length, and were located on the right inboard and center aspects of the bag, respectively. The center transfer extended onto the face of the bag 29.2 cm (11.5 in). The tissue transfers were consistent with the large facial and neck abrasions noted by the medical examiner. A blue fabric transfer was located adjacent to the tissue transfer of the bag's face and was associated to the child's clothing. The bag was initially folded in an accordion pattern. It was noted the heaviest tissue and fabric transfers occurred at the pleats of the folds. The location and nature of the transfers indicated the child was contacted by the air bag very early in its expansion sequence.

Figure 10: View of the tissue transfers to the top surface of the PAB.

Figure 11: Close-up view of the tissue transfers.

OCCUPANT DEMOGRAPHICS

	Driver	**Front Right Child Passenger**
Age/Sex:	30 year old/Female	4 year old/Male
Height:	Unknown	110.5 cm (43.5 in)
Weight:	Unknown	20 kg (45 lb) estimated
Restraint Use:	3 point lap and shoulder	Unrestrained
Usage Source:	SCI inspection/Occupant Kinematics	SCI inspection/Occupant Kinematics
Medical Outcome:	Not injured	Fatal

DRIVER INJURY

Injury	Injury Severity (AIS 98 Update)	Injury Mechanism
None/Unspecified complaint of pain	Not AIS codeable	Force of the crash/Contact to deployed driver air bag

DRIVER KINEMATICS

The restrained driver was seated in a presumed normal posture with her seat adjusted to a rear track position. Immediately prior to the crash, the driver reacted to the impending impact by steering clockwise (right) and locking the vehicle's brakes. She probably braced against the steering wheel rim with her arms for the impact.

At impact, the inertial retractor of the manual belt system locked and the frontal air bags deployed. The driver responded to the 12 o'clock direction of the impact force by initiating a forward trajectory. Her left hand lost its grip of the steering wheel rim and, projecting forward, contacted and fractured the right aspect of the windshield. The driver's torso contacted and loaded the webbing of the 3-point manual restraint. The driver's head and chest then contacted the deployed driver air bag, as she rode down the force of the crash. The use of the 3-point manual restraint maintained the driver "in-position" to benefit from supplemental protection offered by the driver air bag. She then rebounded back into her seat.

FRONT RIGHT CHILD PASSENGER INJURIES

Injury	Injury Severity (AIS 98 Update)	Injury Mechanism
Large areas of facial abrasion over the right side of the face, forehead, nose, lips, chin	Minor (290202.1,0)	Expanding front right passenger air bag
Large areas of abrasion over the right side neck and the anterior neck with an apparent deep hematoma within the anterior region	Minor (390202.1,1) (390202.1,5) (390402.1,5)	Expanding front right passenger air bag
Faint contusion over the right retro-clavicular area	Minor (790202.1,1)	Expanding front right passenger air bag

Large atlanto-occipital fracture dislocation	Minor (650216.2,6)	Expanding front right passenger air bag

Note: the above injuries were identified in the *"Report of Investigation by Medical Examiner"*. This examination was only external in nature. An invasive autopsy was not conducted.

FRONT RIGHT CHILD PASSENGER KINEMATICS

The unrestrained 4 year old male child passenger was seated in presumed normal posture with the front right seat adjusted to a full forward track position. The child passenger initiated a forward and slightly leftward trajectory in response to the driver's pre-crash steering and braking actions. He was positioned in-close proximity to the passenger air bag at the time of the impact.

At impact, the frontal air bag system deployed. The expanding front right passenger air bag contacted the child's face and neck early in deployment sequence. The forward position of the child altered the normal deployment path of the bag. The altered deployment was evidenced by the scuffs and abrasions to the instrument panel surrounding the passenger module and the expansion scuffs to the right door panel.

Direct contact to the expanding air bag was evidenced by the large areas of tissue transfer to the bag membrane and the associated abrasions to the child face and neck. The child's head was turned to the left exposing the right side of his face at the time of the contact. The expansion of the air bag applied an upward and rearward force to the child's head, hyper-extending the neck. This hyper-extension resulted in a fracture/dislocation of the atlanto-occipital joint. The continued bag expansion lifted the child from the seat as evidenced by the tissue transfer to the right sunvisor. The child then rebounded back into the passenger seat and came to rest along its right aspect evidenced by the bodily fluid transfers to the right sill and right aspect of the cushion.

The child was removed from the vehicle by the driver (his mother) and laid on the ground. The child was unresponsive upon arrival of the emergency responders. He was pronounced dead 65 minutes post-crash at a trauma center local to the crash.

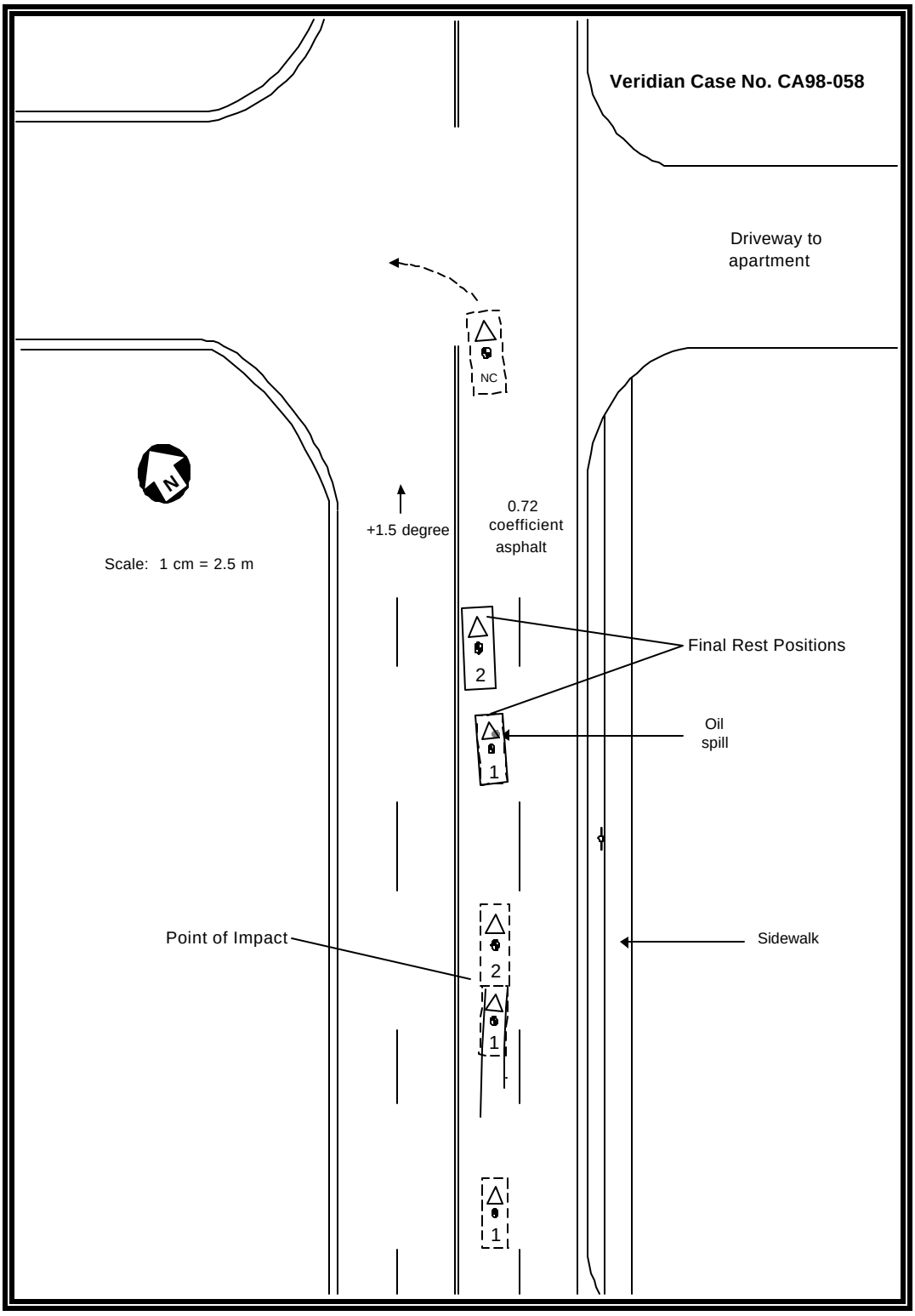

Figure 12: Crash Schematic.