TRANSPORTATION SCIENCES
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VERIDIAN ON-SITE AIR BAG RELATED CHILD DRIVER FATALITY INVESTIGATION VERIDIAN CASE NO. CA98-042 VEHICLE: 1994 MERCURY SABLE STATION WAGON LOCATION: PENNSYLVANIA CRASH DATE: JULY 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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BACKGROUND

This on-site crash investigation focused on the injuries and injury mechanisms that resulted in the death of a 7 year old male who entered the family's 1994 Mercury Sable station wagon and deliberately drove the vehicle from the residence. The Sable was equipped with frontal air bags for the driver and right passenger positions. The child driver drove the vehicle approximately 150 m (500') from a parked position at roadside and negotiated a left curve with a downgrade. As he approached a 3-leg T intersection, the Sable drifted to the left and impacted a tree with the front right area of the vehicle **(Figure 1)**. The moderate severity crash **(Figure 2)** deployed the vehicle's frontal driver and right passenger air bag system. The child driver was positioned within close proximity to the steering assembly and was contacted by the deploying front left air bag module cover flaps and air bag membrane. He sustained a dislocation of the cervical spine at C1 with a brain stem injury (AIS 5) from air bag deployment. The child was transported to a regional trauma center where he expired within 50 minutes of the crash.

Figure 1. Stuck spruce tree.

Figure 2. Front right damage resulting from the tree impact.

This crash was identified through an Internet search by NHTSA of air bag related crashes. The child driver fatality and air bag deployment crash were confirmed by telephone follow-up with the investigating police agency and the case was assigned to Veridian's Special Crash Investigation Team on Friday, July 30th. An on-site investigation was conducted on August 3-4.

SUMMARY

Crash Site

The crash occurred on a two lane local street in a residential neighborhood of single family residences. The asphalt road surface was curved to the left with a one percent grade, negative to the Sable's direction of travel. The asphalt surface was in new condition with no markings on the pavement surface. The travel

lanes were bordered by lawns (no curbs or shoulders) with vehicles parked along both road sides. The surface was dry with a posted speed limit of 40 km/h (25 mph). The light conditions were reported by the investigating officer as dusk.

Vehicle Data

The involved vehicle was a 1994 Mercury Sable LS station wagon. The Sable was manufactured on 8/93 and was identified by vehicle identification number 1MELM5844RA (production number deleted). The Mercury was equipped with a Supplemental Restraint System (SRS) that consisted of frontal air bags for the driver and right passenger positions. In addition, the Sable was equipped with manual 3-point lap and shoulder belt systems for the four outboard seated positions and center lap belts for the front and rear seats. The drive train consisted of a 3.8 liter V-6 engine linked to a four-speed automatic overdrive transmission with a column mounted shift lever. The braking system consisted of 4-wheel power-assisted disc brakes with anti-lock (ABS). Optional equipment included a keyless entry system that consisted of a touch pad system on the exterior of the left front door, power windows and door locks, steering wheel mounted cruise control, tilt wheel, and a front split bench seat with separate back rests. The driver's seat was electrically adjusted (6-way) while the passenger side was manually adjusted. It should be noted that the Sable was equipped with a brake inter-lock system that required brake application to disengage the transmission from the park position. (This system could not be tested post-crash due to the compression of the energy absorbing steering column).

Pre-Crash Sequence

A 16 year old sister to the child driver was using the Mercury Sable to practice parallel parking between two trash containers at the road side in front of the family residence. She was supervised by a male friend who was seated in the front right position of the vehicle. A second sister exited the residence to inform the 16 year old female that she had a telephone call. The vehicle was parked with the key left in the column mounted ignition switch. The 16 year old had difficulty removing the key from the ignition and left the vehicle with the key in the ignition and the doors unlocked.

A 14 year old sister of the child driver noted the key in the ignition and attempted to remove the key. She was assisted by the male friend and placed the key on the front seat of the vehicle. She subsequently locked the doors and walked back to the residence. The 16 year old exited the residence and decided to go for a walk with her male friend, leaving the vehicle unattended at road side with the key on the seat cushion and the doors locked. The father of the children confirmed this habit of leaving the keys in the vehicle and using the keyless (touch pad) entry system to unlock the vehicle.

The 7 year old brother knew the keyless entry code and opened the driver's door with the touch pad system. (His father later noted to the investigating officer that the 7 year old had attempted to start the vehicle on a previous occasion.) The child apparently placed the key in the ignition and started the vehicle. The driver's seat was adjusted to a police reported forward track position. It was presumed that the child driver was seated on the forward aspect of the seat cushion to depress the brake pedal and shift the vehicle from park to drive. It was doubtful that the child driver depressed the accelerator pedal based on the low velocity of the vehicle at the impending crash. The pre-crash velocity was probably obtained by the idle

speed of the Sable in combination with the downhill grade of the roadway.

The child driver maneuvered the Mercury Sable onto the travel lanes of the local residential street. **Figure 10** is the schematic of the crash scene. He successfully negotiated a moderate left curve as the vehicle was accelerated by the one percent negative grade. The child drove the vehicle approximately 150 m (500') narrowly avoiding several parked vehicles on the sides of the street **(Figure 3)**. As he approached the 3-leg T intersection, his intentions were unknown as to turning left at the intersection or proceeding straight ahead. The vehicle subsequently drifted across the mouth of the intersection and departed the northwest corner of the intersection. It should be noted that the 16 year old sister and her friend observed the Mercury Sable pass them as they walked along the edge of the road in a northerly direction. They attempted to run after the vehicle, however, were unsuccessful in catching up to it.

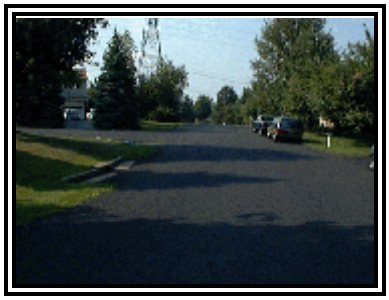

Figure 3. Trajectory of the Mercury Sable.

Crash

The Mercury Sable departed the northwest corner of the intersection and penetrated the lower branches of a spruce tree which shielded the trunk of the tree from view. The front right area of the vehicle subsequently impacted the trunk of the tree that was 25 cm (10") in diameter. The trajectory algorithm of the WinSMASH program computed an impact speed of 19.7 km/h (12.2 mph) for the Mercury Sable. The 12 o'clock direction of force impact crushed the front bumper to a maximum depth of 15.9 cm (6.25") **(Figure 4)** which resulted in a WinSMASH generated velocity change of 17.9 km/h (11.1 mph) with a longitudinal component of -17.9 km/h (-11.1 mph). The impact induced deceleration was sufficient to deploy the Sable's frontal air bag system. The vehicle came to rest engaged against the struck tree with the ignition in the on-position and the engine stalled. The investigating officer noted during a post-crash inspection of the vehicle that the emergency fuel cut-off switch was not tripped.

Figure 4. Profile view documenting the crush profile.

Vehicle Damage

Exterior

The 1994 Mercury Sable station wagon sustained moderate frontal damage as a result of the impact sequence with the tree. Maximum crush was 15.9 cm (6.25") located on the front bumper fascia 51.4 cm (20.25") right of center **(Figure 5)**. The direct contact damage consisted of abrasions and transfers from both the trunk of the struck tree and the lower branches which extended to the ground. The direct contact damage on the fascia began 13.3 cm (5.25") right of center and extended 69.9 cm (27.5") to the right

bumper corner. Direct damage on the hood face and grille began 21.6 cm (8.5") right of center and extended 69.9 cm (27.5") to the right corner. The specific damage that resulted from the trunk of the tree began 41.9 cm (16.5") right of center and extended 24.8 cm (9.75") to the right. The combined induced and direct contact damage was 142.2 cm (56.0") which involved the full width of the bumper system. The crush profile was documented at bumper level and was as follows: C1= 0 cm, C2 = 1.9 cm (0.75"), C3 = 5.6 cm (2.2"), C4 = 9.5 cm (3.75"), C5 = 14.2 cm (5.6"), C6 = 15.2 cm (6.0"). The Collision Deformation Classification (CDC) for the tree trunk impact sequence was 12-FREN-1.

Figure 5. Damage to the front right area of the Sable.

Components damaged by the crash included the front bumper fascia and reinforcement beam, right headlamp assembly, grille, hood face, and the right front fender. Superficial sideswipe-type damage extended the full length of the right side of the vehicle, however, the damage was not associated with this event.

Interior

The interior of the 1994 Mercury Sable sustained minor damage that was associated with air bag deployment and occupant contact. There was no intrusion or damage resulting from exterior deformation.

The child driver was positioned within a close proximity to the steering assembly as the vehicle impacted the tree. The upper cover flap of the front left (driver) air bag module contacted the child's anterior neck and chin areas which resulted in a large tissue transfer to the cover flap **(Figure 6)**. The transfer was located on the lower right corner of the cover flap. His forward position impeded the deployment path of the expanding air bag membrane. As a result, the bag expanded against the interior surfaces of the module assembly which produced black/gray vinyl transfers to the top, right

Figure 6. Tissue transfer on the upper cover flap.

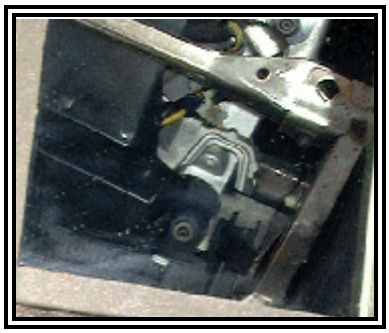

Figure 7. Shear capsule separation.

side panel, and the upper right quadrant of the face of the bag. The continued expansion of the bag displaced the cruise control touch pads from between the spokes of the steering wheel.

Diagonally oriented transfers (probable tissue transfers) were noted to the center face of the front left air bag on the tether reinforcement. The transfers ranged in width from 3.2-6.4 mm (0.125-0.25") and involved an area that was 12.7 cm (5.0") horizontally and 11.4 cm (4.5") vertically.

The child driver's froward trajectory in response to the frontal impact force in combination with air bag expansion against his body resulted in compression of the energy absorbing steering column. The shear capsules were completely separated with 4.1 cm (1.625") of left separation and 4.4 cm (1.75") of right bracket displacement **(Figure 7)**. There was no deformation to the steering wheel.
The deployment of the front right passenger air bag resulted in damage to several areas of the front right passenger compartment. Several vinyl-type scuff marks were present on the right side of the windshield from possible contact with the separated cruise control components and a 10.2 x 12.4 cm (4.0 x 4.9") panel that separated from the upper right quadrant of the top instrument panel adjacent to the windshield.

The expanding membrane of the front right passenger air bag contacted the laminated windshield which fractured the glazing 21.0 cm (8.25") right of center and 12.1 cm (4.75") above the upper instrument panel. There were no scuff marks or air bag fabric transfers surrounding the star-like crack. The bag subsequently contacted the right aspect of the rear view mirror and displaced the mirror on an upward and forward direction. The upper right corner of the mirror frame contacted and fractured the windshield 7.9 cm (3.125") right of center and 1.3 cm (0.5") below the windshield header.

Automatic Restraint System

The supplemental frontal air bag system deployed as a result of the tree impact sequence. The system consisted of three front mounted electro-mechanical crash sensors, an interior mounted control module, a steering wheel mounted clock spring and driver air bag module assembly, and a right instrument panel mounted front passenger air bag module. The system's status was displayed by a instrument panel mounted air bag indicator lamp. The SRS system's indicator lamp was tested during the inspection of the vehicle. This was accomplished by turning the ignition key to the on-position and observing the status of the indicator lamp. At key, the light illuminated for a six second interval followed by a repetitive flash sequence of 3 and 2 indicating a flash code of 32. This code indicates deployment of the frontal driver and passenger air bags.

The front left (driver) air bag module was mounted within the four-spoke steering wheel rim and concealed by asymmetrical H-configuration module cover flaps. The spokes were positioned at the 3 and 9 and 5 and 7 o'clock sectors. The cover flaps opened at the designated tear points. The upper flap was 17.8 cm (7.0") in width at the horizontal tear seam with a maximum width at the spokes of 24.4 cm (9.6"). The overall height of the flap was 10.4 cm (4.125"). A large tissue transfer was located on the lower right quadrant of the upper flap **(Figure 6)**. The tissue transfer was located 2.9 cm (1.125") right of center and extended 7.0 cm (2.75") to the right. The transfer began at the leading edge of the flap and extended 8.3

cm (3.25") vertically onto the face of the vinyl flap.

The lower cover flap maintained the same tear seam width as the upper flap with an overall height of 4.4 cm (1.75"). The acronym SRS was molded into the upper center are of the lower flap. There was no damage or contact evidence to the lower flap.

The front left (driver) air bag was constructed of two separate fabrics and sewn with an internal peripheral seam. The panel exposed to the driver was a typical neoprene lined woven fabric while the forward panel consisted of an unlined tight weave fabric. The overall diameter of the bag in its deflated state was 64.8 cm (25.5"). The bag was vented by two 1.3 cm (0.5") diameter vent ports located on the forward panel at the 11 and 1 o'clock positions. The ports were centered 7.9 cm (3.1") forward of the peripheral seam and spaced on 16.5 cm (6.5") centers. The bag was tethered by four internal tether straps that were sewn to the face of the bag with a 17.8 cm (7.0") diameter reinforcement. The internal tethers were located at the 12/6 and 3/9 sectors.

The child driver's forward position impeded the deployment path of the expanding front left (driver) air bag membrane. As a result, the air bag was restricted within the module and subsequently expanded against the interior surface of the cover flaps and the mounting bracket. The cruise control switches that were mounted between the spokes of the steering wheel rim were fractured and displaced from the wheel assembly. The investigating officer noted these components were scattered across the front seat and floor of the vehicle.

The expanding air bag within the module assembly resulted in a large area of black/gray vinyl transfers to the right side area of the bag **(Figure 8)**. The transfer pattern was approximately 40.6 cm (16.0") vertically and 24.1 cm (9.5") horizontally. A second area of less pronounced vinyl transfers were located on the left side of the forward panel of the driver air bag. This transfer pattern measured 22.9 cm (9.0") vertically and 17.8 cm (7.0") horizontally. A third area of vinyl transfers was located on the upper right quadrant of the face of the bag. The transfers began 2.5 cm (1.0") right of the vertical center line and extended 17.8 cm (7.0") to the right. The pattern began 1.3 cm (0.5") above the horizontal center line and extended upward 19.1 cm (7.5").

Figure 8. Vinyl transfers on the right side of the front left air bag.

Driver contact evidence on the bag consisted of diagonally oriented transfers (possible tissue transfers) that extended across the tether reinforcement. The transfer pattern consisted of narrow bands that were 3.2-6.4 mm (0.125-0.25") in width over an area that was 12.7 cm (5.0") horizontally and 11.4 cm (4.5") vertically.

The front right passenger air bag deployed from a mid mount module assembly in the right instrument panel. The H-configuration module cover consisted of symmetrical rectangular flaps that were 28.6 cm (11.25")

in width and 5.7 cm (2.25") in height. The deployment deformed the right instrument panel which resulted in separation of the right vent louver from the mid instrument panel and an access panel from the top right instrument panel adjacent to the base of the windshield.

The front right passenger air bag was a non-tethered design with two 6.4 cm (2.5") diameter vent ports located on the inboard (left) side panel of the bag at the 9 o'clock sector. The vertically positioned ports were centered 27.9 cm (11.0") apart and located 45.7 cm (18.0") rearward of the module assembly. The face of the bag membrane was approximately 71.1 cm (28.0") in width and 58.4 cm (23.0") in height. The side profile of the bag extended 8.6 cm (3.25") outward from the module assembly then flared vertically an additional 34.3 cm (13.5") to form the rectangular shape of the bag.

The front right passenger air bag expanded against the windshield and the rear view mirror. The windshield glazing was cracked directly above the module assembly in a star-like pattern. The crack was located 21.0 cm (8.25") right of center and 12.1 cm (4.75") above the upper instrument panel. The bag subsequently contacted the rearview mirror in an upward and forward direction. The upper right corner of the mirror contacted the windshield and fractured the glazing 7.9 cm (3.1") right of center directly below the header. There was no damage or contact evidence on the deployed air bag.

Child Driver Demographics

Age/Sex:	7 year old male
Height:	Not reported (reported as tall for his age)
Weight:	Not reported (Coroner listed the body as small framed and thin)
Manual Restraint Usage:	None, 3-point lap and shoulder belt was available
Usage Source:	Observation of first responders and vehicle inspection
Eyeware:	None reported
Mode of Transport From Scene:	Ambulance to a parking church parking lot located three blocks from the crash site and transferred to a helicopter for air transport to a regional trauma center
Type of Medical Treatment:	Expired 50 minutes following the crash

Child Driver Injuries

Injury	Injury Severity (Update 98)	Injury Mechanism
* Dislocation of the cervical spine at C1	Moderate (650208.2,6)	Upper air bag module cover flap and expanding air bag membrane

Injury	Injury Severity (Update 98)	Injury Mechanism
* Brain stem injury reported as incompatible with life (NFS)	Critical (140299.5,8)	Upper air bag module cover flap and expanding air bag membrane
+ Facial edema	Minor (290402.1,9)	Upper air bag module cover and expanding air bag membrane
+ Periorbital edema (NFS)	Minor (297402.1,9)	Upper air bag module cover and expanding air bag membrane
~ Laceration with abrasion over the right anterior neck	Minor (390600.1,1; 390202.1,1)	Upper air bag module cover and expanding air bag membrane
+ Massive swelling of the head and facial areas with hemorrhage from both ears and the nose	N/A, not codeable	Result of unknown head or a result of the neck injuries

Injury Sources - ** Hospital records*
+ Coroner's report
~ Observations of the investigating officer

Child Driver Kinematics

The child driver was in a presumed seated position on the forward aspect of the seat cushion based on his age, physical size, and resulting injury. In this position, the child driver was probably looking through the upper aspect of the steering wheel rim to see out of the windshield. Although the driver's seat had been moved prior to this on-site SCI investigation, the police officer recorded measurements of the seat location. Based on these measurements, it was determined the seat track was adjusted approximately 4.4 cm (1.75") rearward of the full forward position, or 17.8 cm (7.0") forward of the full rear track position. He was not restrained by the manual belt system. The lack of belt usage was determined from observations of the first responders to the crash scene and the stowed position of the belt system. There was no loading evidence of the belt system or air bag fabric transfers on the webbing. The child was dressed in a T-shirt and shorts with no reports of eyeware.

At impact, the child's face was positioned within a close proximity to the steering wheel mounted driver air bag module cover. As the frontal air bag system deployed, the asymmetrical module cover flaps opened at the designated seams. The right aspect of the upper module cover flap contacted the child driver under the chin area which resulted in a large tissue transfer on the flap. The investigating officer noted the child

sustained a laceration and abrasion of the right anterior neck. (The Coroner failed to note this injury as the body was received with a cervical collar in place. He did not remove the collar since no autopsy was performed.) The cover flap and subsequent expansion of the air bag membrane hyper-extended the neck which resulted in a dislocation of cervical vertebra at C1 with a brain stem injury. The brain stem injury was unspecified, however, the medical report noted that it was incompatible with life. Additionally, the Coroner noted edema of the face and periorbital areas with massive swelling of the head and face. These were probably related to an unknown closed head injury or related to the cervical/brain stem injuries. The Coroner also reported hemorrhage from both ears and the nose.

Figure 9. Vertical and rearward displacement of the child driver.

The forward position of the child driver, in combination with the deployment of the driver air bag against his body and his response to the 12 o'clock impact force, resulted in compression of the energy absorbing steering column. The shear capsule brackets were separated from the stationary blocks 4.1 cm (1.625") on the left and 4.4 cm (1.75") on the right. This compression resulted in complete separation of the shear bracket assemblies.

The continued expansion of the driver air bag membrane displaced the child driver in an upward and rearward direction **(Figure 9)** into the headliner. Scuff marks on the headliner evidence his displacement by the expanding driver's air bag. He came to rest in a slumped seated position in the driver's seat with his back resting against the seat back.

Medical Treatment

The child driver was removed from the vehicle and transported by ambulance to a landing site where he was flown by helicopter to a regional trauma center. He was in full cardiac arrest with CPR in progress throughout the medical transport. The child arrived at the hospital with continued CPR efforts. The trauma staff ordered an X-ray of the cervical spine which revealed the dislocation and the brain stem injury. CPR was discontinued and the child was pronounced deceased at approximately 50 minutes following the crash. No autopsy was performed due to the medical diagnosis at the hospital.

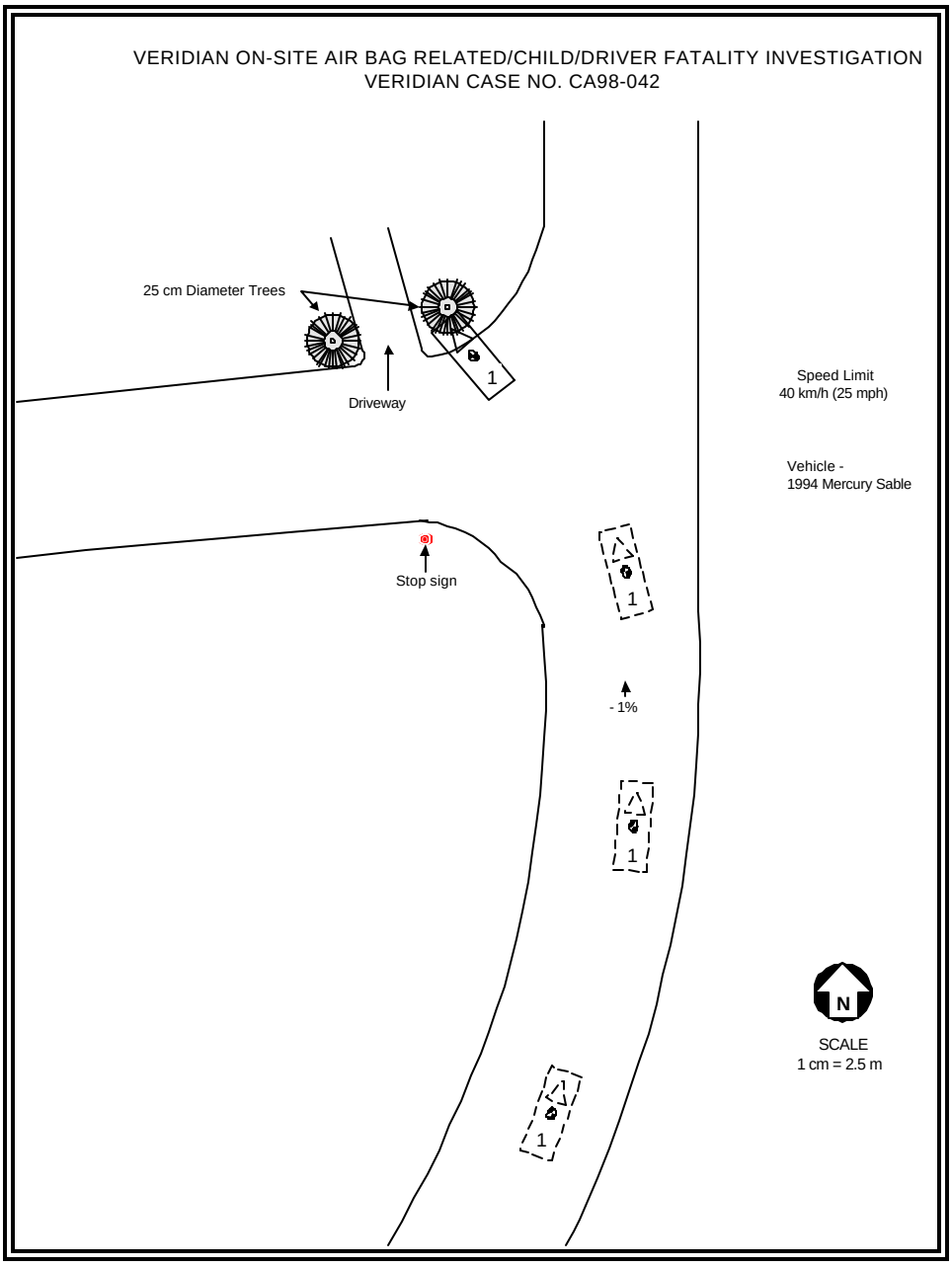

Figure 10. Crash Schematic