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VERIDIAN ON-SITE AIR BAG RELATED CHILD PASSENGER FATALITY INVESTIGATION VERIDIAN CASE NO. CA99-050 VEHICLE: 1998 CHEVROLET TRACKER LOCATION: MICHIGAN CRASH DATE: DECEMBER 1999

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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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TABLE OF CONTENTS

VERIDIAN ON-SITE AIR BAG RELATED CHILD FATALITY INVESTIGATION
VERIDIAN CASE NO CA99-050
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BACKGROUND

This on-site investigation focused on the injury mechanisms and the cause of death for a 7 year old female front right passenger of a 1998 Chevrolet Tracker **(Figure 1)**. The Tracker was equipped with frontal air bags for the driver and right passenger positions that deployed as a result of an intersection crash with a 1995 Ford Thunderbird. The WinSMASH program computed total delta V of 23.0 km/h (14.3 mph) for the Chevrolet and 18.4 km/h (11.4 mph) for the Ford. The 7 year old front right passenger of the Tracker was displaced forward by pre-crash braking. She was contacted by the front right air bag module cover flap and air bag membrane during the deployment sequence. Air bag deployment resulted in a dislocation of the atlanto-occipital joint with transection of the upper cervical spinal cord (AIS-6). She was transported to a pediatric medical facility where she was pronounced deceased shortly after arrival.

Figure 1. Subject vehicle, 1998 Chevrolet Tracker.

The Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) was informed of this crash by a representative of General Motors. The notification was forwarded to the Veridian SCI team as an on-site investigation. The investigating Police Department was contacted and cooperation was established for this investigation. An on-site inspection of both vehicles was completed at the police impound lot where the vehicles were stored pending the continuation of the police investigation.

SUMMARY

Crash Site

The crash occurred at a signalized four-leg intersection of two city roadways during daylight hours under overcast skies. The environmental surfaces were dry. The Tracker was traveling in an easterly direction on a six lane divided concrete road surface **(Figure 2)**. The eastbound travel lanes were bordered by a curbed south edge line and a curbed grass median. The travel lanes were delineated by broken white lane lines. The Ford Thunderbird was traveling in a westerly direction on the same roadway. The east leg of the intersection consisted of three through lanes in each direction inclusive of designated inboard left turn lanes. The speed limit in the vicinity of the crash was 56 km/h (35 mph).

Figure 2. Overall view of the crash site from the Tracker's path of travel.

Vehicle Data

1998 Chevrolet Tracker

The subject vehicle in this crash was a 1998 Chevrolet Tracker 4x4, two-door sport utility vehicle. The Tracker was equipped with a convertible top that spanned rigid upper A- and B-pillars with contiguous side rails. The convertible top was in the up position at the time of this winter crash. This Tracker was equipped with a 1.6 liter engine linked to a 3-speed automatic transmission. The vehicle's braking system consisted of power-assisted front wheel disc with rear drum brakes without anti-lock (ABS). The Tracker was manufactured in 10/97 and was identified by vehicle identification number 2CNBJ1865W6 (production number deleted). At the time of the crash, the vehicle's odometer reading was 50,133 km (31,152 miles).

The interior of the Tracker was configured with front bucket seats with adjustable head restraints and a two person folding rear bench seat. The Chevrolet Tracker was designed as a four passenger vehicle with manual continuous loop lap and shoulder belts with belt sensitive/inertial locking retractors at each seat position. The driver and front right passenger positions were equipped with frontal air bags. It should be noted that this air bag system did not include redesigned (reduced force) inflators.

1995 Ford Thunderbird

The struck vehicle in this crash was a two-door Ford Thunderbird. The Ford was manufactured in 8/94 and was identified by vehicle identification number 1FALP6248SH (production number deleted). The Thunderbird was equipped with manual belts and frontal air bags for the driver and right passenger positions. The frontal air bags did not deploy as a result of this side impact crash.

Crash Sequence

Pre-Crash

The 35 year old female driver of the Chevrolet was en route to her residence and was transporting her two daughters, ages 7 (front right passenger) and 15 (left rear passenger) years of age, and a 16 year old male seated in the right rear position. Food related artifacts noted in the vehicle suggested that they were returning from a fast food restaurant prior to the crash. The Chevrolet was traveling on the center eastbound lane en route from the downtown area of a large metropolitan region during rush hour traffic **(Figure 3)**.

Figure 3. Trajectory of the Chevrolet prior to the POI

Figure 4. Trajectory of the Ford in the left turn lane.

The 48 year old female driver of the Ford was traveling westbound **(Figure 4)** and was reportedly stopped in the designated left turn lane for the red traffic light. The intersection was controlled by overhead mounted and curbside pole mounted traffic lights which were not equipped with designated left turn arrows. The driver of the Ford proceeded to make a left turn reportedly under the green light and was unaware of the Chevrolet's approach. She was transporting an 84

year old female hospice patient to the grocery store as part of a volunteer effort.

As the driver of the Tracker detected the left turning Ford Thunderbird, she braked in an attempt to avoid the impending impact. There were no visible skid marks on the concrete road surface to support the extent of braking. It was unknown if the driver of the Ford initiated avoidance actions. The Crash Schematic is attached as **Figure 15**, Page 11 of this Summary Report.

Crash

The full frontal area of the Tracker impacted the right passenger compartment area of the Thunderbird. The damage and trajectory algorithm of the WinSMASH program computed impact speeds of 39.3 km/h (24.5 mph) for the Tracker and 26.4 km/h (16.4 mph) for the Ford Thunderbird. Resultant directions of force were within the 11 o'clock sector for the Tracker and 2 o'clock for the struck Ford. The crash induced velocity changes (averages of the trajectory and damage algorithms) were 22.7 km/h (14.1 mph) and 18.1 km/h (11.25 mph) for the Tracker and the Ford respectively. The respective longitudinal components were -21.25 km/h (-13.2 mph) and -11.5 km/h (-7.2 mph) with respective lateral components of 7.8 km/h (4.9 mph) and -14.0 km/h. The computed values appeared to be representative of the vehicle damage and indicative that the frontal air bag deployment was within the anticipated deployment threshold. The WinSMASH outputs are identified in the following table:

WinSMASH 1.02.001		**1998 Chevrolet Tracker**	**1995 Ford Thunderbird LX**
Impact Speed		39.3 km/h (24.5 mph)	26.4 km/h (16.4 mph)
Total delta V	Damage	23.0 km/h (14.3 mph)	18.4 km/h (11.4 mph)
	Trajectory	22.3 km/h (13.8 mph)	17.8 km/h (11.1 mph)
Longitudinal delta V	Damage	-21.6 km/h (-13.4 mph)	-11.8 km/h (-7.3 mph)
	Trajectory	-20.9 km/h (-13.0 mph)	-11.2 km/h (-7.0 mph)
Lateral delta V	Damage	7.9 km/h (4.9 mph)	-14.1 km/h (-8.7 mph)
	Trajectory	7.7 km/h (4.8 mph)	-13.8 km/h (-8.6 mph)
Energy dissipated		17,963 joules (13,255 ft-lb)	49,265 joules (36,352 ft-lb)
Barrier equivalent speed		15.3 km/h (9.5 mph)	24.9 km/h (15.5 mph)

Post-Crash

The Tracker continued approximately 2.9 m (9.5') forward and rotated approximately 30 degrees in a clockwise direction before coming to rest straddling the outboard eastbound travel lanes. The Ford was deflected approximately 45 degrees in a clockwise direction as the engagement occurred rearward of its center of gravity. The Ford came to rest approximately 2.6 m (8.5') south of its at-impact position.

Police arrived on-scene and transported the 7 year old front right passenger of the Tracker to a pediatric hospital where she arrived 27 minutes after the police reported time of the crash. She was pronounced deceased 40 minutes later. The driver of the Chevrolet indicated to police that everyone in her vehicle was using their manual lap and shoulder restraint system at the time of the crash. The lack of occupant contact evidence to interior components by the driver and the rear seat occupants as well as the lack of reported injury by the driver and rear left occupant supported the driver's statement of restraint usage.

The driver of the Ford indicated to police that both her and the front right occupant were wearing their manual lap and shoulder belt at the time of the crash. The driver was not injured while her passenger suffered internal injuries (fractured ribs, contusion of both lungs) and was transported to a local medical treatment facility where she underwent emergency surgery. The passenger of the Ford subsequently expired due to crash related injuries.

Both vehicles were towed from the scene due to damage and were stored at a police impound lot pending the continuation of the police investigation and SCI inspection.

Vehicle Damage

1998 Chevrolet Tracker - Exterior

The frontal area of the Tracker sustained moderate damage **(Figure 5)** that was limited to the front bumper, hood, and the right front fender of the vehicle. The maximum crush to the front of the Chevrolet measured 9.2 cm (3.625") located at the right corner of the front bumper **(Figure 6)**. The direct contact damage extended across the entire front bumper and measured 149.9 cm (59.0"). The documented crush profile was as follows: C1 = 6.7 cm (2.6"), C2 = 3.5 cm (1.375"), C3 = 6.4 cm (2.5"), C4 = 7.0 cm (2.75"), C5 = 6.0 cm (2.375"), C6 = 9.2 cm (3.625"). The Collision Deformation Classification (CDC) was11-FDEW-1.

Figure 5. Frontal view of the 1998 Chevrolet Tracker.

Figure 6. Lateral view of the Chevrolet showing the longitudinal crush profile.

1995 Ford Thunderbird - Exterior

The right side of the Ford Thunderbird sustained moderate damage as a result of the intersection crash with the Chevrolet Tracker. Maximum crush was 31.1 cm (12.25") located on the right door, 116.8 cm (46.0") forward of the right rear axle location. The direct damage began 52.1 cm (20.5") forward of the referenced axle and extended 162.6 cm (64.0") forward to the leading edge of the front door. The combined induced and direct damage length was 203.8 cm (80.25") which began at the leading edge of the door and terminated 24.1 cm (9.5") forward of the right rear axle **(Figure 7)**. The crush profile at mid door level was as follows: C1 = 0 cm, C2 = 21.0cm (8.25"), C3 = 29..2 cm (11.5"), C4 = 28.6 cm (11.25"), C5 = 23.2 cm (9.1"), C6 = 0 cm. The CDC for this damage pattern was 02-RPEW-3.

Figure 7. Right side damage to the Ford Thunderbird.

1998 Chevrolet Tracker - Interior

The interior damage to the Tracker was rated as moderate and was associated with occupant contact and frontal air bag deployment. There was no damage associated with exterior damage or intrusion of interior components.

The driver's right knee contacted the right aspect of the knee bolster. A 7.6x16.5 cm (3.0x6.5") scuff mark evidenced the contact point. There were no fracture points to the rigid plastic panel. Although she loaded the deployed air bag, there was no contact evidence or damage to the bag. Her loading force was transmitted into the steering column which resulted in 0.6 cm (0.25") of steering column compression.

The front right child passenger was positioned forward on the seat cushion and was displaced forward into the path of the air bag module cover and bag membrane. Her lower chin area was struck by the left aspect of the module cover flap. A 5.1 cm (2.0") diameter tissue transfer was surrounded by scuff marks in a 10x13 cm (4x5") area of scuffs and abrasions **(Figure 8)**. The full width of the leading edge of the front right cover flap was abraded from windshield contact.

Figure 8. Child passenger contact with the cover flap.

The forward position of the child passenger altered the deployment path of the front right air bag. The bag membrane initially expanded against the module cover flap as the child restricted the path of the flap. The left aspect of the front right air bag membrane exhibited a narrow band of black vinyl transfers from its expansion against the module cover. The combination of occupant contact and bag expansion deformed the cover flap. Additionally, the bag expanded within the module assembly and deformed the mounting brackets and fractured the instrument panel at the lower left corner of the module location. On the right side of the bag membrane, a wide band of pink fabric transfers were noted from contact against the child passenger's clothing.

The front right passenger was wearing a series of 1.9 cm (0.75") diameter beads in her hair. As the front right air bag deployed against the forward positioned child, these beads separated from her hair and were thrust against the windshield resulting in a series of isolated fracture points to the glazing. At each site, a transfer was noted that was consistent with color of the beads **(Figure 9)**.

Figure 9. Bead and fracture point to the windshield.

The child passenger's left leg contacted and scuffed the left aspect of the glove box door and the adjacent center console. The 5.1 cm (2.0") wide contact contained fragments of tissue. A 5.1 cm (2.0") diameter fabric transfer was also noted to the mid instrument panel, directly below the air bag module cover flap. The transfer was located 40.6 cm (16.0") right of the vehicle's centerline.

The rear view mirror was displaced to the left and rotated vertically by the expanding front right air bag. This resulted from the altered path of bag by the forward positioned child passenger.

Manual Belt Systems

The four outboard manual restraint systems consisted of continuous loop 3-point lap and shoulder belt webbings with sliding latchplates and fixed D-rings. All retractors were emergency locking and belt sensitive. The front right and rear retractors were switchable into the automatic locking mode for securing child safety seats. All latchplates exhibited routine wear marks that were consistent with routine usage for the mileage of the vehicle. The front seat belt systems were equipped with energy management loops that were concealed within the vinyl sleeves at the lower aspect of the lap belt, above of the outboard anchorage point. The management loops did not deploy in this crash.

Although the driver was belted in this crash, there was no loading evidence of the belt system. The front right child passenger was improperly resrained with the shoulder belt webbing positioned behind her back. The edges of the belt were frayed from historical use, however, there was no distinct loading evidence. The left rear shoulder belt webbing contained fabric transfers from occupant loading during the crash. The right rear belt system did not yield loading evidence. The lack of contact evidence to the front seat backs supported belt usage.

Frontal Air Bag System - Chevrolet Tracker

The Chevrolet Tracker was equipped with a frontal air bag system that deployed **(Figure 10)** as a result of the impact sequence with the Ford Thunderbird. The system consisted of a single point Sensing and Diagnostic Module (SDM) that was located on the top of the center transmission tunnel under the center console, an instrument panel mounted air bag indicator lamp, and the driver and front right passenger air bag modules. The SDM measured the severity of the crash, provided a deployment command to the frontal air bag modules, performed diagnostic checks and recorded faults in the system,

Figure 10. Deployed frontal air bags.

provided back-up power to deploy the air bag system, and record crash data through its event data recording (EDR) capabilities. It should be noted that at the time of this SCI investigation, Veridian did not have the capabilities to download the Tracker's EDR.

The driver air bag module was located within the four spoke steering wheel rim **(Figure 11)** and concealed by I-configuration module cover flaps. The spokes were located at the 3 and 9 and 5 and 7 o'clock sectors. The flaps were symmetrical in size and measured 7.6 cm (3.0") horizontally and 12.7 cm (5.0") vertically. The thickness of the vinyl flaps was approximately 0.3 cm (0.125"). Two small abrasions were noted to the right cover flap, however, these abrasions were not believed to be crash or occupant related. The driver air bag membrane was approximately 66.0 cm (26.0") in diameter and was vented by two 3.8 cm (1.5") ports located on the back side of the bag at the 10 and 2 o'clock positions. The bag was tethered internally by two straps located at the 12 and 6 o'clock positions. A vinyl transfer was noted to the 1 o'clock sector of the air bag face from expansion within the module cover flaps. There was no loading evidence or damage to the driver's air bag.

Figure 11. Deployed driver's air bag.

The front right passenger air bag was concealed by a single cover flap in the top of the upper right instrument panel. The cover flap was hinged at the forward aspect and separated from the instrument panel at the designated tear points at both sides and the bottom (leading) edge. The cover flap measured 17.8 cm (7.0") fore and aft and 36.8 cm (14.5") horizontally. A 5.1 cm (2.0") diameter tissue transfer was located on the left aspect of the cover flap. The transfer was centered 10.2 cm (4.0") above the leading edge and adjacent to the left edge. A 12.7 cm (5.0") diameter abrasion pattern extended below the tissue transfer, terminating at the leading edge. The leading edge of the cover flap contacted the windshield which fractured the glazing and abraded the edge of the flap. It should be noted that the cover flap was deformed from contact against the child passenger.

Figure 12. Transfers to the front right passenger air bag.

The front right passenger air bag membrane was rectangular in shape and measured approximately 44.5 cm (17.5") in width and 73.7 cm (29.0") in height. The top aspect of the bag extended approximately 50.8 cm (20.0") rearward from the module assembly. The bag was not tethered, however, two 6.4 cm (2.5") diameter vent ports were located on the side panels of the bag at the 3 and 9 o'clock positions. A narrow black vinyl transfer was noted to the left side of the top panel of the bag membrane from expansion within the module cover. The transfer was 33.0 cm (13.0") in length and originated 17.8 cm (7.0") rearward of the inflator. A large pink fabric transfer from the child's jacket was noted on the right aspect of the top panel **(Figure 12)**. The transfer was 15.2 cm (6.0") in width and extended 50.8 cm (20.0") longitudinally on the bag membrane. In addition to the contact evidence, a small 5.1 cm (2.0") tear was located at the

upper left corner of the bag. This tear probably resulted from snagging with the module as the path of the expanding bag was restricted by the forward positioned passenger.

The mounting bracket for the front right air bag inflator was deformed by the bag expansion. This resulted from the forward positioned child passenger at deployment. The air bag membrane's deployment path was restricted and altered as she responded to the impact force.

Driver Demographics - Chevrolet Tracker

Age/Sex:	35 year old female
Height:	173 cm (68") police estimate
Weight:	136 kg (300 lb) police estimate
Manual Restraint System Usage:	3-point lap and shoulder belt system
Usage Source:	Vehicle inspection
Seat Track Position:	Full rear track position
Mode of Transport From Scene:	Police vehicle to the local hospital
Type of Medical Treatment:	None, not injured

Driver Injuries

Injury	Injury Severity AIS 90/Update 98	Injury Source
Not injured	N/A	N/A

Driver Kinematics

The 35 year old female driver of the Chevrolet Tracker was seated in an upright driving posture with the seat track adjusted to a full rear position. The seat back was reclined to a measured angle of 10 degrees. In this adjusted position, the horizontal distance between the seat back support and the center of the driver air bag module was 61 cm (24").

At impact with the Ford Thunderbird, the Tracker's frontal air bag system deployed. The driver initiated a forward trajectory and loaded the manual belt system and the deployed driver's air bag. There was no loading evidence on the belt system or the deployed air bag membrane. Her right knee contacted the right edge of the knee bolster at the edge of the lower instrument panel. Although no injury occurred from the contact sequence, a scuff mark evidence the contact sequence. Immediately following the crash, the driver unbuckled the belt system and exited the vehicle from the left door.

Front Right Child Passenger Demographics

Age/Sex:	7 year old female
Height:	132.1 cm (52.0")
Weight:	32.7 kg (72.0 lb)
Manual Restraint System Usage:	Improper use of the 3-point lap and shoulder belt (shoulder belt webbing was positioned behind her back)
Usage Source:	Vehicle inspection
Seat Track Position:	Mid track, 14.0 cm (5.5") rearward of full forward
Mode of Transport From Scene:	Police vehicle to a local hospital
Type of Medical Treatment:	Evaluated and treated at the local hospital, however, she expired within 67 minutes of the crash.

Front Right Child Passenger Injuries

Injury	Injury Severity (AIS90/Update 98	Injury Source
*Transection of the upper spinal cord with extensive hemorrhage into the bilateral neck soft tissue and posterior mediastinum	Maximum (640274.6,6)	Front right air bag module cover flap and the expanding air bag membrane
*Atlanto-occipital dislocation	Moderate (650208.2,6)	Front right air bag module cover flap and the expanding air bag membrane
*17.8 x 1.3 cm band-like abrasion of the underside of the chin	Minor (290202.1,0)	Expanding front right air bag membrane
*Diffuse right frontal and parietal subgaleal hemorrhage with no internal head injuries	Minor (190402.1,1)	Center console (Probable)
+Abrasion over the mid anterior neck	Minor (390202.1,5)	Expanding front right air bag membrane

** Source of Injury Data - Autopsy Report*

+ Autopsy photograph, not listed in autopsy report

Front Right Passenger Kinematics

The front right child passenger was seated in a mid track position with the seat track adjusted 14.0 cm (5.5") rearward of the full forward position and 17.8 cm (7.0") forward of the full rear track position. The seat back support was reclined 10 degrees aft of vertical. She was improperly restrained by the manual belt system. The lap belt was positioned across her hips, however, the shoulder belt webbing was positioned behind her back **(Figure 13)** which produced slack in the belt system. Based on the known seat track position and the improper belt usage, the child was probably positioned forward on the seat cushion, placing her in close proximity to the right instrument panel. She was wearing a pink jacket over a pink sweater with black stretch pants and white athletic shoes.

Figure 13. 3-point lap and shoulder belt system improperly worn by child passenger.

The child responded to the pre-crash braking by moving forward. Her forward motion was partially arrested by the lap belt webbing of the manual belt system. The loading of the lap belt webbing would have induced a jackknife motion of the head and torso, pitching these body areas forward in close proximity to the top mount air bag module.

At impact, the frontal air bag system deployed. The top mounted air bag module cover opened in a vertical rotational motion and contacted the child's anterior neck and chin area **(Figure 14)**. There was 12.7 cm (5.0") wide abrasion pattern on the surface of the flap which included a 5 cm (2") area of heavy tissue concentration. This correlated with the 17.8 cm (7.0") long and 1.3 cm (0.5") linear abrasion noted by the medical examiner on the undersurface of the chin.

Figure 14. Expansion of the front right air bag into the closely positioned child passenger.

The air bag module cover and the expanding air bag exerted a force under the child's chin which lifted her head upward toward the windshield. The lap belt restricted the vertical motion of the child which probably accentuated the injury to the child's spinal column. The beads braided in her hair beading contacted the windshield as noted by the focal fracture points in the windshield. The air bag also interacted with the child's upper torso as noted by the heavy pink transfer in the air bag fabric that was attributed to contact with the child's pink coat. She was displaced rearward and came to rest with her head located on the console between the front seat backs. The child passenger sustained diffuse right frontal and parietal subgaleal hemorrhages that probably resulted from her rebound trajectory into the console.

Medical Treatment

The front right child passenger was removed from the vehicle by an unknown individual. She was placed on the pavement adjacent to the vehicle and administered CPR by a civilian witness. The investigating officer was located approximately 30m (100') from the scene of the crash. He heard the crash

and responded on foot to the intersection. As he arrived on-scene, the officer requested an ambulance and assisted the civilian with the CPR activities. A delay in ambulance arrival was transmitted to the officer via police radio. A police vehicle arrived on-scene and the officers decided to transport the injured passenger to the hospital in the police unit. CPR activities were continued as the child was transported to the hospital, arriving approximately 27 minutes after the police reported time of the crash. The child passenger expired 67 minutes following the crash.

Rear Seated Occupants

The rear seat of the Chevrolet Tracker was occupied by a 15 year old female in the left rear position and a 16 year old male seated in the right rear position of the vehicle. Both were police reported as restrained by the manual belt systems. The lack of contact evidence to the front seat backs supported the restraint usage. In addition, the left rear belt webbing contained faint fabric transfers from occupant loading during the crash. The right rear belt system did not yield loading evidence, however, both latch plates exhibited historical use wear marks. The left rear female passenger was not injured while the right rear male passenger sustained police reported (C-level) possible injuries.

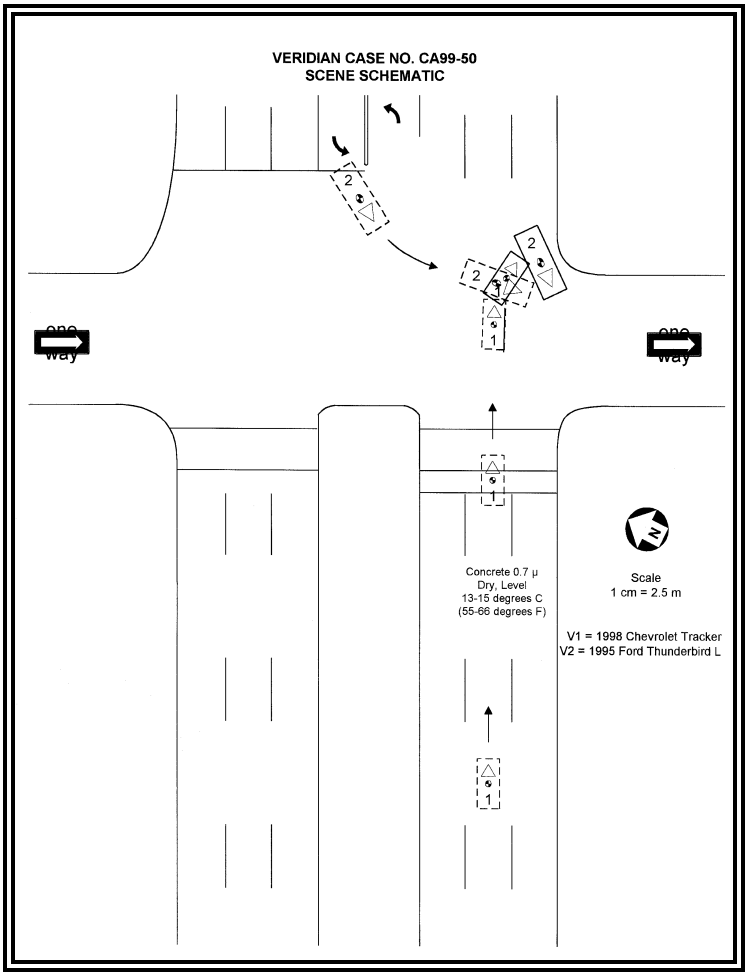

Figure 15. Crash scene schematic