**TRANSPORTATION SCIENCES**
**CRASH DATA RESEARCH CENTER**

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# VERIDIAN ON-SITE AMBULANCE CRASH INVESTIGATION
# SCI TECHNICAL SUMMARY REPORT

## VERIDIAN CASE NO. CA02-033

## VEHICLE - 1995 FORD E-350 TYPE III AMBULANCE

## LOCATION - STATE OF MINNESOTA

## CRASH DATE - JULY 2002

Contract No. DTNH22-01-C-17002

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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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*<br>This on-site investigation focused on the crashworthiness issues and occupant protection systems of a chassis cab/box body Type III ambulance unit. The vehicle was a 1995 Ford E-350 that was equipped with a Horton ambulance body. The ambulance was en route to an emergency call with its lights and siren activated. The ambulance was occupied by a 23-year-old male driver with a Paramedic certification, a 21-year-old male front right passenger with an Emergency Medical Technician (EMT) certification, and a 19-year-old male patient care provider (PCP) with an EMT certification seated on the rear-facing technician seat in the patient compartment. The driver of the ambulance initiated a passing maneuver around a non-contact vehicle on approach to a sag on a two-lane undivided roadway. A 1996 Chevrolet Cavalier driven by a 17-year-old male was traveling in the opposite direction and both vehicles attempted to avoid the crash by steering in the same direction. The vehicles impacted in an angular head-on configuration on the shoulder adjacent to the ambulance's original travel lane. The Cavalier was redirected rearward in a counterclockwise (CCW) rotation and came to rest on the roadside. The ambulance traveled onto the roadside in a CCW rotation and rolled six quarter-turns down an embankment to final rest on its roof. After the ambulance came to rest, an engine compartment fire erupted which spread quickly to the patient compartment. The front right passenger of the ambulance assisted the two remaining occupants from the ambulance with the help of witnesses to the crash. The driver sustained multiple left femur fractures, and lacerations on the face and scalp. The front right passenger sustained a left rib contusion, facial abrasions, hand abrasions, and a right shoulder strain and contusion. The PCP sustained a posterior scalp laceration, mesentery injury, omental tear, abdominal abrasions and contusions, a frontal scalp contusion, and a right foot contusion. All of the ambulance occupants were transported by ambulance to a local hospital and admitted for treatment. The driver of the Cavalier sustained bilateral leg fractures, pelvic fractures, and an ankle fracture. He was transported by ambulance to a local hospital and admitted for treatment. | | | |
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***BACKGROUND***

This on-site investigation focused on the crashworthiness issues and occupant protection systems of a chassis cab/box body Type III ambulance unit. The vehicle was a 1995 Ford E-350 that was equipped with a Horton ambulance body. The ambulance was en route to an emergency call with its lights and siren activated. The ambulance was occupied by a 23-year-old male driver with a Paramedic certification, a 21-year-old male front right passenger with an Emergency Medical Technician (EMT) certification, and a 19-year-old male patient care provider (PCP) with an EMT certification seated on the rear-facing technician seat in the patient compartment. The driver of the ambulance initiated a passing maneuver around a non-contact vehicle on approach to a sag on a two-lane undivided roadway. A 1996 Chevrolet Cavalier driven by a 17-year-old male was traveling in the opposite direction and both vehicles attempted to avoid the crash by steering in the same direction. The vehicles impacted in an angular head-on configuration on the shoulder adjacent to the ambulance's original travel lane. The Cavalier was redirected rearward in a counterclockwise (CCW) rotation and came to rest on the roadside. The ambulance traveled onto the roadside in a CCW rotation and rolled six quarter-turns down an embankment to final rest on its roof. After the ambulance came to rest, an engine compartment fire erupted which spread quickly to the patient compartment **(Figure 1)**. The front right passenger of the ambulance assisted the two remaining occupants from the ambulance with the help of witnesses to the crash. The driver sustained multiple left femur fractures, and lacerations on the face and scalp. The front right passenger sustained a left rib contusion, facial abrasions, hand abrasions, and a right shoulder strain and contusion. The PCP sustained a posterior scalp laceration, mesentery injury, omental tear, abdominal abrasions and contusions, a frontal scalp contusion, and a right foot contusion. All of the ambulance occupants were transported by ambulance to a local hospital and admitted for treatment. The driver of the Cavalier sustained bilateral leg fractures, pelvic fractures, and an ankle fracture. He was transported by ambulance to a local hospital and admitted for treatment.

**Figure 1. On-scene photograph showing ambulance engulfed in flames**

NHTSA's Special Crash Investigation Division was alerted to the crash through an Emergency Medical Service web site. The news link was e-mailed to the Veridian SCI team. The Veridian SCI team initiated

telephone follow-up with the investigating police agency and the ambulance service. Cooperation was established with both agencies and an on-site investigation was initiated. This investigation was conducted by SCI in conjunction with the Center for Disease Control's (CDC) National Institute of Occupational Safety and Health (NIOSH).

## *SUMMARY*

### Crash Site

This two-vehicle crash occurred during daylight hours in July 2002. At the time of the crash, there were no adverse weather conditions and the asphalt roadway surface was dry. The crash occurred on a two-lane undivided north-south county roadway. The roadway was configured with one travel lane in each direction separated by a solid yellow centerline for southbound traffic and a broken yellow centerline for northbound traffic. The roadway was straight and the crash occurred near a sag between two small hills. Northbound traffic had a slight negative grade on approach to the crash site. The roadway was bordered by asphalt shoulders and the roadside environment consisted of agricultural fields. The east roadside had a negative sloped grassy ditch bank which began at the road edge. The slope descended at a rate of 1.0 m (3.3') over a length of 5.4 m (17.7') starting 10.0 m (32.8') east of the road edge. A steep grassy embankment began 14.0 m (45.9') east of the road edge with a decent of 5.0 m (16.4') over a length of 10.3 m (33.8'). There was no traffic control present at the crash site, and the posted speed limit was 89 km/h (55 mph). The scene schematic is included as **Figure 26** of this report.

### Pre-Crash

The 23-year-old driver began a 24-hour shift approximately one hour prior to the crash and stated that he was well-rested from a full-night's sleep. He had seven years of general driving experience, four years of experience driving ambulances, and had been operating the subject ambulance for approximately one year on a semi-regular basis. The driver did not have a CDL license, although a CDL license was not required for this class of vehicle. He completed an Emergency Vehicle Operation Course and a Defensive Driving Course within the previous year. The driver was restrained by the manual 3-point lap and shoulder belt.

The front right passenger and the rear-facing PCP in the patient compartment had also come on-duty approximately one hour prior to the crash. Both the front right passenger and PCP had responded to an emergency call previous to the crash and had been in service for approximately 20 minutes between the earlier call and the crash. The PCP had completed his EMT training four weeks prior to the crash and was scheduled to work an 8-hour shift due to his new-hire status. The front right passenger was restrained by the manual 3-point lap and shoulder belt and the PCP was restrained by the manual lap belt.

The driver of the ambulance was operating the vehicle in a northbound direction on the county roadway, with lights and siren activated. He stated that he was very familiar with the road and its characteristics and noted that traffic flow was somewhat heavy. There were no distractions within the ambulance and there was no two-way radio traffic prior to the crash. The front right passenger was operating the siren, writing on a clipboard, and referencing a map before the crash. The 17-year-old male driver was operating the Chevrolet Cavalier in a southbound direction on the county roadway.

**Figure 2. Northbound approach for the ambulance**

**Figure 3. Southbound approach for the Cavalier**

As the ambulance approached the crash site, the ambulance encountered four vehicles ahead of it in the northbound lane. The last three vehicles pulled onto the right shoulder and allowed the ambulance to pass. The lead vehicle did not immediately detect the approaching ambulance, and the driver of the ambulance initiated a passing maneuver around the vehicle as the ambulance approached a hillcrest. The ambulance driver estimated the speed of the ambulance to be approximately 113 - 121 km/h (70 - 75 mph) as it passed the non-contact vehicle. The non-contact vehicle attempted to move to the right as the ambulance passed. The driver of the ambulance detected the oncoming Cavalier traveling in the southbound lane as the ambulance crested the hill in the southbound lane **(Figures 2 and 3)**. The driver of the ambulance described the Cavalier's movement as hesitant, as if the Cavalier's driver was not sure which way to steer. The ambulance driver steered right into the northbound lane, and the driver of the Cavalier steered left into the northbound lane in an attempt to avoid the collision. The driver of the ambulance stated that he removed his foot from the accelerator pedal when he detected the approaching vehicle, and applied the brakes in full lock-up when he realized the impending crash. Skid marks that measured 50.5 m (165.7') in length were present in the ambulance's pre-crash trajectory, and the right side tire marks began in the southbound lane adjacent to the centerline. There were no pre-impact skid marks in the Cavalier's trajectory indicative of pre-crash braking, however, the vehicle's post-crash travel distance suggested that it may have been slowing prior to impact.

## Crash

The Ford E-350 ambulance impacted the Chevrolet Cavalier in an agular head-on configuration. The impact resulted in severe damage to both vehicles and was sufficient to deploy the frontal air bag system in the Cavalier. The impact resulted in vehicle debris to be scattered over a large section of the roadway **(Figure 4)**. The principal direction of force was in the 12 o'clock sector for the ambulance and in the 1 o'clock sector for the Cavalier. The driver of the ambulance stated that the ambulance lost power immediately after the impact, as the vehicle battery was located in the front left aspect of the engine compartment. The ambulance deflected the Cavalier 160 degrees in a rapid CCW rotation. The ambulance continued in its forward direction of travel past the Cavalier and the right rear side aspect of the Cavalier impacted the left rear wheel area of the ambulance in a sideslap configuration. Multiple gouge marks were present at the point of impact from the displacement and rotation of the Cavalier. The disproportionate weight of the ambulance relative to the weight of the Cavalier resulted in the total rearward displacement of the Cavalier 63.0 m (206.7'). The Cavalier rotated an additional 190 degrees in a CCW direction while it traveled along the shoulder evidenced by post-impact skid marks **(Figure 5)**. As the rear wheels of the Cavalier left the right roadside, the rotation was reversed and the Cavalier rotated 190 degrees in a CW direction and came to rest facing north east on the roadside. The ambulance traveled onto the roadside and down the ditch bank with the left front aspect creating a large gouge in the grass that measured 1.0 m (3.3') in width. The front left area of the ambulance impacted the bottom aspect of the ditch bank and the ambulance pivoted 130 degrees in a rapid clockwise (CW) direction on the front left corner. Multiple analysis of delta-V's were performed, but considering the multiple events, masking damage, and post-impact travel, the computed delta-V's appeared unreasonable. The vehicles did not reach a common velocity during the initial impact and the damage profile on the ambulance resulted from multiple impacts, which could not be reasonably separated. Therefore, the static crush measured on the ambulance overstated the severity of the Cavalier impact and due to the damage pattern of the Cavalier, the Cavalier's crush profile understated the initial impact severity.

**Figure 4. View of vehicle debris on roadway**

**Figure 5. Post-impact skid marks from the Cavalier**

The rear aspect of the ambulance impacted the ground evidenced by large gouges from the rear dual wheels. The ambulance tipped onto the left side and began a rollover down the grassy embankment. The top left corner of the patient compartment created a gouge at the top of the embankment and two linear gouges were present in the ambulance's trajectory along the embankment from the roof side rails of the patient compartment. The ambulance came to rest on its roof facing southeast. Final rest positions are shown in **Figure 6.**

**Figure 6. Northeast view showing final rest of both vehicles**

**Post-Crash**

The front right passenger exited the ambulance under his own power, although, he could not recall his method of egress. He walked to the rear of the ambulance and opened the rear doors to check the status of the PCP. He saw the PCP hanging upside down from the lap belt and heard him moaning. Since he confirmed that the PCP was breathing, he walked around the left side of the ambulance to check on the driver. At that point, he detected an engine compartment fire in the ambulance. He stated that a passer-by attempted to put the fire out with a fire extinguisher, but after a few minutes, the fire flared up again. The driver was suspended upside down by the manual 3-point lap and shoulder belt. The driver stated that he was conscious and had considered using the ambulance's two-way radio to call for another ambulance, but realized that there was no power to the ambulance due to the crash. His right leg was pinned in the left aspect of the floor pan due to the intrusion, and he had attempted to cut the seat belt with a multi-function tool that was in his pocket. The front right passenger assisted the driver in cutting the seat belt and after freeing the driver's leg, pulled him out of the driver's window by his legs with the help of a passer-by. The engine compartment fire began to spread and the front right passenger returned to the back of the ambulance to assist the PCP. He cut the lap belt and attempted to break the fall of the PCP as he fell onto the roof of the overturned ambulance. He helped to remove the PCP through the rear doors of the ambulance and was assisted by three people who stopped at the crash. The fire had spread to the cab when the PCP was removed from the ambulance. The front right passenger returned to the ambulance and retrieved the Lifepack defibrillator which was on the ceiling near the technician seat, thinking it might be needed. All of the ambulance occupants were moved away from the ambulance where they received treatment from rescue personnel. As they were being evaluated on-scene, one of the oxygen tanks in the ambulance discharged due to the fire, which caused the fire to intensify and spread to the patient compartment **(Figure 7)**. The occupants of the ambulance were transported by ambulance to a local hospital and admitted for treatment. The 17-year-old male driver of the Chevrolet Cavalier was pinned in the vehicle due to intrusion of the passenger compartment. A witness

**Figure 7. On-scene photograph showing the extent of fire damage**

to the crash assisted the driver of the Cavalier until rescue personnel arrived to remove him from the vehicle. He was transported by ambulance to a local hospital and admitted for treatment.

***VEHICLE DATA - 1995 Ford E-350 Ambulance***

The 1995 Ford E-350 ambulance could not be identified during the vehicle inspection due to fire damage. The Vehicle Identification Number (VIN) was obtained from the ambulance company records and was as follows: 1FDKE30F8SH (production sequence omitted). The odometer reading could not be determined due to damage. The ambulance was configured with a Ford E-350 Super Duty 4 x 2 cutaway chassis that was equipped with the Ford Ambulance Prep package that included a 7.3 liter, turbo-charged V-8 diesel engine, a single 133 liter (35 gal) fuel tank, front disc and rear drum brakes, a four-speed automatic transmission with overdrive, and original equipment manufacturer (OEM) low-mount RV style mirrors with convex mirrors. The ambulance was configured with LT225/75R16 16 x 6 wheels. The tire data for the ambulance was as follows:

| Position | Tire | Pressure | Tread |
|---|---|---|---|
| LF | Unknown (burned) | N/A | N/A |
| LR (inboard dual) | Unknown | 0.0 kpa | 7.9 mm (14/32") |
| LR (outboard dual) | Unknown (burned) | 0.0 kpa | 11.1 mm (10/32") |
| RF | Mastercraft LT225/75R16 | 0.0 kpa | 9.5 mm (12/32") |
| RR (inboard dual) | Unknown | 458.5 kpa (66.5 psi) | 7.9 mm (10/32") |
| RR (outboard dual) | Mastercraft LT225/75R16 | 542.2 kpa (78.5 psi) | 7.9 mm (10/32") |

The Ford E-350 ambulance package was produced by Horton Emergency Vehicles. The ambulance model was a 523 Type III. The patient compartment dimensions measured 399 x 216 x 244 cm (157 x 85 x 96"). The ambulance was configured with two rear entry doors with an opening that measured 137 x 124 cm (54 x 49"), and a single entry door on the right front side aspect that measured 76 x 198 cm (30 x 78"). The entry doors had paddle type latches equipped with interior and exterior accessible locks. The ambulance had three exterior compartments on the left side and two exterior compartments on the right side. Each compartment was equipped with a paddle type locking latch. Compartment specifications are included in **Appendix A** at the end of this report. The ambulance was also equipped with an electronic siren and emergency lighting which included body warning lights, flashing lights, grille lights, intersection lights, load lights, and scene lights. A center console was present between the front seats which housed controls for the sirens, emergency lights, and two-way radios.

The forward exterior compartment on the left aspect housed an H-sized oxygen cylinder that measured 110.5 cm (43.5") in height and 17.8 cm (7.0") in diameter. The oxygen cylinder was reported to have contained 10,342 kpa (1,500 psi) at the time of the crash. The H-cylinder was secured with four heavy-

duty steel brackets which were affixed to the interior wall of the cabinet. The intensity of the fire melted the interior walls of the cabinet which allowed the brackets to disengage from the wall. The oxygen cylinder was found lying laterally across the interior aspect of the cabinet with the top aspect protruding through the forward left corner of the patient compartment which had burned away completely. Two additional D-sized oxygen cylinders that measured 41.9 cm (16.5") in length and 11.1 cm (4.4") in diameter were located in the patient compartment. One was originally positioned in a soft-shell EMS equipment bag which was located on the second shelf of the front right compartment, and the second was originally located in a vertical mount on the forward aspect of the right side bench seat, adjacent to the right side door. The occupants suggested that this cylinder may have become dislodged during the rollover event, as they suggested that the cylinder may have been able to slide out. The driver stated that both D-sized oxygen cylinders were full and contained 13,790 kpa (2,000 psi) prior to the crash.

**Figure 8. View of exemplar patient compartment**

**Figure 8** illustrates the approximate configuration of the Horton ambulance patient compartment interior. A center-mount Ferno ambulance cot fastener system was installed in the ambulance. The fastening system consisted of a front "antler" bracket mounted to the center aspect of the floor that secured the front wheels of the cot and a rear spring-loaded fastener rail mounted on the left aspect of the floor that fastened directly to the cot frame. A non-padded stainless steel assist rail was located on the ceiling above the ambulance cot area. The front right side exterior cabinet was accessible from the interior of the patient compartment by two sets of plexiglass doors hinged on the outboard aspects. The remaining interior cabinetry consisted of sliding plexiglass doors configured with full-length aluminum pull handles. Each cabinet with plexiglass doors was configured with an aluminum trim picture frame with 45 degree angles at the corners. Two cabinets with plexiglass doors were located along the left wall on the rear aspect and measured 45.7 cm (18.0") in depth. The rear left side cabinets were vertically oriented and the combined measurements were 64.8 cm (25.5") in width and 121.9 cm (48.0") in height. Additional cabinets with plexiglass doors were located forward of the rear cabinets at the top and bottom aspects of the wall. The top cabinet was hinged at the top aspect and the bottom was configured with sliding doors. Both cabinets measured 53.3 cm (21.0") in width and 30.5 cm (12.0") in height. A Lifepack 12 defibrillator was located on the top aspect of the lower center cabinet. The defibrillator was secured to the shelf with a 2.5 cm (1") wide strap which was routed through the defibrillator's handle on the top aspect. Two additional cabinets that measured 127.0 cm (50.0") in width and 30.5 cm (12.0") in height were located over and under the work space area on the forward aspect of the left wall. The specific cabinet locations are illustrated in the ambulance interior schematic in **Appendix A**.

The seating in the cab of the Ford E-350 ambulance was configured with box-mounted bucket seats with integral head restraints and folding armrests. Due to the fire damage, positions of the seats could not be determined, although, the driver and front right passenger stated that the seat tracks were adjusted to the

full-rear position at the time of the crash.

The seating in the patient compartment of the ambulance was configured with a single rear-facing technician's bucket seat mounted on a wood base in the forward left position with an adjustable fore and aft seat track position. The PCP stated during the interview that the technician seat track was adjusted to the full-rear position in the rear-facing orientation. An HVAC vent panel was located on the forward interior wall above the seat back. A three-person bench seat was located along the right wall with a lid hinged on the outboard aspect. Additional storage space was located under the bench seat lid. A window that measured 91.4 cm (36.0") in width and 39.4 cm (15.5") in height was located on the right side aspect of the patient compartment above the bench seat.

## *VEHICLE DAMAGE*

### Exterior Damage - *1995 Ford E-350 Ambulance*

The 1995 Ford E-350 ambulance sustained severe damage as a result of the initial impact with the Chevrolet Cavalier. Due to the nature of the impact with the ditch bank, the damage resulting from the initial impact was partially masked. The impact and pivot of the front left aspect of the ambulance on the ditch bank caused severe frontal damage to the ambulance. The cab was crushed between the weight of the patient compartment and the ditch bank, and the left rear aspect of the cab penetrated the front left aspect of the patient compartment, evidenced in the on-scene photographs **(Figures 9 and 10)**. After the ambulance was uprighted, the partial restitution of the cab and frame resulted in the separation between the cab and the patient compartment and understated the static crush measurements. The direct contact damage along the frontal plane began 36.8 cm (14.5") right of center and extended laterally 132.1 cm (52.0") to the front left corner. Abrasions were noted on the bumper from contact with the Cavalier. The grille area and head lamp assemblies were displaced and separated. The combined direct and induced damage involved the entire frontal width of the vehicle and measured 129.5 cm (51.0").

**Figure 9. Post-crash view of left side of ambulance**

**Figure 10. Post-crash view of right side of ambulance**

The front left aspect of the cab sustained severe crush, deformation, and lateral shift to the right **(Figure 11)**. The centerline of the bumper was located 71.2 cm (28.1") to the right of the centerline of the windshield header **(Figure 12)**. The left A-pillar was displaced rearward and inward. The bottom aspect of the left A-pillar was located 24.1 cm (9.5") rear of the top aspect. The entire left front door was twisted approximately 100 degrees in a CW direction and was crushed rearward. The base of the right A-pillar was displaced to the right. The ambulance frame was deformed laterally to the right and vertically upward, more severely on the left side. The upper and lower radiator supports were crushed rearward on the left side and the front axle was displaced rearward on the left side. The left wheelbase was reduced by 48.3 cm (19.0"). Six crush measurements were documented along the front bumper which represented the combined residual damage from the impact with the Cavalier and the impact with the ditch bank and were as follows: C1 = 91.4 cm (36.0"), C2 = 64 cm (26.0"), C3 = 62.2 cm (24.5"), C4 = 19.3 cm (7.6"), C5 = 10.4 cm (4.1"), C6 = 3.8 cm (1.5"). The Collision Deformation Classification (CDC) for the initial impact with the Cavalier was 12-FDEW, but the extent zone was unknown due to masking damage. The CDC for the impact with the ditch bank was 72-FDEW with an unknown extent zone (the CDC was incremented by 60 to denote the lateral shift to the right which resulted from the impact with the ditch bank). The combined damage for both impacts was an extent zone of 6.

**Figure 11. View of damaged ambulance after it was uprighted**

**Figure 12. View showing the centerline variance between the windshield header and upper radiator support**

The damage associated with the secondary sideslap impact was partially masked from the fire damage on the left side aspect. The left rear outboard tire was scuffed from contact with the Cavalier and the rim exhibited faint abrasions. The CDC for the sideslap event was 09-LBEW-1.

The rear of the ambulance impacted the ground after the impact with the ditch bank and CW rotation. The impact caused both dual wheels to impact the undercarriage and top aspects of the wheel wells. Abrasions and scuffs were present on the interior aspect of the right wheel well from contact with the right rear wheels and tires. The left side wheel well area was destroyed by the fire. The rear diamond plate step was displaced upward and induced buckling was present on the right rear aspect of the patient compartment from contact with the ground and the rear right vertical seam of the patient compartment was separated slightly at the bottom aspect **(Figure 13)**. The separation began at the bottom corner and extended 14.0 cm (5.5") vertically. The center flip-up portion of the rear step was separated from the ambulance at the time of the vehicle inspection. The CDC for the undercarriage impact was 00-UBDW-2.

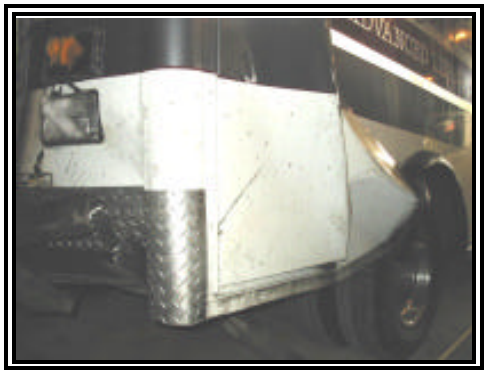

**Figure 13. Right rear damage from the ground impact**

The rollover event resulted in moderate damage to the ambulance. Dirt and grass were present along the entire right side top aspect of the patient compartment along the drip rail. Dirt deposits extended vertically down the right side aspect 64.8 cm (25.5") and pieces of grass were noted in the compartment door frames. Grass and dirt were embedded in the right front wheel. Both side mirror assemblies were separated from the ambulance, and lateral abrasions were present on the right side door and right front fender. The left front diamond plate running board was separated. The right aspect of the roof and windshield header were crushed vertically. The vertical distance between the base of the right A-pillar and the top of the right A-pillar measured 5.1 cm (2.0"). The front right door was buckled outward. Left side separation of the rear aspect of the cab and the forward aspect of the patient compartment measured 13.0 cm (5.1") on top aspect and 24.1 cm (9.5") on the bottom aspect **(Figure 14)**. The left front corner of the patient compartment was resting on the ground. The right side separation of the cab and patient compartment measured 14.0 cm (5.5") at the top aspect and 3.8 cm (1.5") at the bottom aspect. The patient compartment sustained minor deformation as a result of the rollover, and the top aspect exhibited minimal crush. The post-crash dimensions measured 398.8 x 212.1 x 235.0 cm (157 x 83.5 x 92.5"). The left front aspect sustained induced buckling. The exterior compartment doors were operational with the exception of the left front (oxygen cylinder compartment) which was jammed shut and burned through, and the right rear compartment which was jammed shut and buckled. The right side door leading into the patient compartment was jammed shut. The rear doors of the ambulance did not open during the crash, however, the rear left door was separated from the vehicle at the time of the vehicle inspection. The rear right door was operational. The CDC for the rollover event was 00-TDDO-4.

**Figure 14. Left side view showing cab/patient compartment separation**

Damage to the ambulance was severe as a result of the fire. The fire appeared to have started in the engine compartment and spread quickly as reported by on-scene personnel and evidenced by **Figure 1** of this report. The fire was fueled by a suspected diesel fuel leak and a crash-induced rupture of the on-board oxygen system, evidenced by the complete burn-through of the compartment housing the cylinder and the melted steel on the top of the displaced cylinder. The fire engulfed the cab after the occupants were removed. As the fire spread to the patient compartment, one of the oxygen tanks discharged which intensified the fire. The exterior and interior of the cab were completely burned. The interior of the patient compartment was burned throughout, and the intensity of the fire resulted in a complete burn-through of left side aspect of the patient compartment **(Figure 15)**. The left side hole that resulted from the fire measured 230.5 cm (90.8") and 188.0 (74.0") in height. The left front tire was completely destroyed by the fire and the left rear tires were partially melted. The exterior door and interior diamond-plate walls of the left front cabinet (oxygen cylinder compartment) were completely burned through. The burn hole in the exterior left front cabinet door measured 29.8 cm (11.8") in width and 101.6 cm (40.0") in height. The exterior top aspect and exterior right side aspect of the patient compartment exterior sustained minor fire damage.

**Figure 15. Left side fire damage**

**Interior Damage** - ***1995 Ford E-350 Ambulance***

Interior damage to the 1995 Ford E-350 ambulance was severe and was attributed to passenger compartment intrusion and fire damage. The windshield laminate was separated and all glazing had disintegrated as a result of the multiple impacts and fire. Integrity loss through glazing could not be determined due to the masking damage. The integrity of both front doors was compromised due to deformation and distortion of the doors resulting from direct and induced damage. The left front door disengaged from the latch/striker due to the rearward and lateral displacement of the forward aspect and was twisted approximately 100 degrees in a CW direction.

**Figure 16. Frontal view of the left A-pillar - Incremented sticks show the lateral displacement of the lower aspect**

Intrusion into the cab of the ambulance was catastrophic. Longitudinal intrusions included the steering assembly, entire instrument panel, right and left toe pans, right and left A-pillars, windshield header, and both floor pans. Both front seat cushion frames were buckled as a result of the intrusion. Lateral intrusions included both A-pillars, left side panel forward of the A-pillar, left front door, and left roof side rail. **Figure 16** shows the lateral displacement of the left A-pillar. Vertical intrusions included the windshield header, and the roof which was most severe on the right aspect where there was a 5.1 cm (2.0") distance between the windshield header and the base of the windshield.

Contact evidence in the cab of the ambulance could not be determined due to fire damage. The steering wheel was found vertically oriented in the left side of the windshield opening at the time of the vehicle inspection. Both front seat back frames were deformed, both rotated slightly CW.

The interior damage to the patient compartment was severe and attributed to fire damage. All interior surfaces were charred **(Figure 17)** and the left side wall of the patient compartment was completely burned through. Based on the exterior post-crash dimensions of the patient compartment, intrusion appeared to be minimal. The glazing of the patient compartment windows had disintegrated as a result of the multiple impacts and fire. Charred and displaced equipment was present on the floor of the patient compartment. The Ferno cot appeared to have been dislodged from the fastener system at some point during the crash sequence. The cot appeared to have been displaced onto the ceiling of the patient compartment adjacent to the longitudinal assist handle. What appeared to be the charred remains of the Ferno cot were on the ceiling of the patient compartment on the left aspect of the assist rail. A charred D-size oxygen cylinder was found in the left rear aspect of the patient compartment, although it's original position was not known.

**Figure 17. Interior of patient compartment looking forward through the rear door frame**

***MANUAL RESTRAINT SYSTEM - 1995 Ford E-350 Ambulance***

The 1995 Ford E-350 ambulance was configured with manual 3-point lap and shoulder belts for the driver and front right passenger positions. The specific design of the seat belts and loading evidence could not be determined due to the fire damage. The patient compartment was configured with 2-point lap belts with automatic locking retractors (ALR's) and sewn latch plates for the rear-facing technician seat and each of the three seating positions on the right side squad bench seat. The retractor for the technician seat was located on the inboard aspect of the seat. The charred retractors were the only identifiable restraint components in the patient compartment.

***VEHICLE DATA - 1996 Chevrolet Cavalier LS***

The 1996 Chevrolet Cavalier was identified by the Vehicle Identification Number (VIN): 1G1JF5243T7 (production sequence deleted). The date of manufacture could not be identified due to extrication damage on the left front door. The 4-door sedan was equipped with a 2.2 liter/I4 engine, a 4-speed automatic transmission, power steering, and power brakes. The four-wheel anti-lock braking system was standard equipment. The manual restraint system consisted of 3-point lap and shoulder belts in the four outboard positions with a center rear lap belt. The Supplemental Restraint System (SRS) consisted of frontal air bags for the driver and front right passenger. The vehicle was also equipped with an Event Data Recorder (EDR). The EDR was removed during the police investigation prior to SCI involvement and was in transit to a State Police laboratory for analysis. It was not available for download.

**Exterior Damage - *1996 Chevrolet Cavalier***

**Figures 18 and 19** are the front and left lateral of the Chevrolet, respectively. The vehicle sustained severe frontal damage that extended across the entire 137 cm (54") undeformed frontal end width. The impact damage was biased to the vehicle's right side indicative of the angular head-on impact configuration. The bumper fascia and front body panels separated from the vehicle during the impact exposing the bumper reinforcement bar and forward sub-frame. The bumper reinforcement had separated from the right sub-frame and was cantilevered from the left sub-frame attachment. The separation of the bumper reinforcement precluded measuring the crush profile to this component. The vehicle's crush profile was documented by longitudinal measurements to the deformed locations of the left and right sub-frame, resulting in only two C-locations. The residual crush of the sub-frame was as follows: C1=12.7 cm (5.0"), C2=15.7 cm (6.2"). The residual crush underestimated the severity of the impact. The Collision Deformation Classification (CDC) of the frontal impact was 12-FDEW-1.

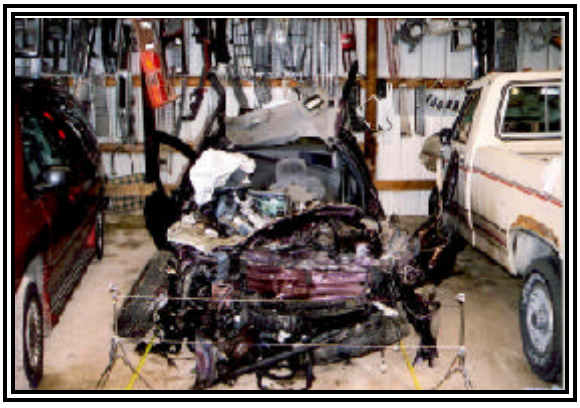

**Figure 18: Front view of the Chevrolet**

**Figure 19: Left lateral view**

The A-pillars were cut and the roof was retracted during the driver extrication. The windshield was fractured in multiple locations. The right front door buckled approximately 20 cm (8") rear of the A-hinge pillar, **Figure 20**, as a result of its compression into the right B-pillar. The right front door and right rear doors were jammed shut. The location of the right B-pillar measured 5 cm (2") rearward compared to the left B-pillar location. The right wheelbase measurement was foreshortened 13 cm (5"). The left front door was jammed shut by the impact and then pried open during the extrication of the driver. The left rear door was operational but restricted. The damage to the left front suspension precluded a meaningful measurement of the left wheelbase. The floor pan appeared to have twisted (deformed) CCW. Referring to **Figure 20**, note that the right front seat back contacts the right B-pillar as a result of the floor pan deformation.

A 66 cm (26") region of the right rear quarter panel was damaged as a result of a secondary side slap, **Figure 21**. This contact pattern began 74 cm (29") rear of the right rear axle and ended 8 cm (3") rear of that axle location. The lateral displacement of the quarterpanel collapsed the trunk space. The maximum displacement measured 41 cm (16"). Immediately aft of the right rear wheel opening, an arcing scuff and abrasion was identified on the lower fascia. This damage pattern was associated to direct contact with the left rear tire and rim of the ambulance. The CDC of this contact was 03-RBEW-3.

**Figure 20: Right side view**

**Figure 21: Side slap damage**

**Interior Damage** - ***1996 Chevrolet Cavalier***

The vehicle's interior sustained moderate damage and intrusion consistent with the exterior forces of the crash, deployment of the Supplemental Restraint System, and occupant interior contacts. The right side bias of the impact damage reduced the front right occupant space. The intrusion of the right corner of the instrument panel measured 16.5 cm (6.5"). The driver's interior space remained intact.

**Figure 22: View of the deformed steering wheel rim**

During the ride down of the impact, the driver loaded the 3-point manual restraint system, the deployed driver air bag/steering assembly and the knee bolster. The steering wheel was found separated from the steering column upon initial inspection. The casting that comprised the tilt mechanism fractured above the upper steering column knuckle. It was reported by the fire department personnel that the steering wheel separation occurred during the extrication process. The two-spoke steering wheel rim was deformed throughout its unsupported upper sector, **Figure 22**. The maximum deformation measured approximately 8.9 cm (3.5") in the 12 o'clock sector. The steering wheel rim was rotated approximately 160 counterclockwise relative to the column. There was complete separation of the left and right shear capsules indicative of driver loading.

The left bolster exhibited two contacts related to the driver's lower extremities **(Figure 23)**. A left lower extremity contacted the bolster 8.3 cm (3.3") left of the steering column center line evidenced by a 5 cm (2") scuff. The right lower extremity pocketed into the right aspect of the bolster 15 cm (6") right of the steering column center line. The metal backer panel behind the bolster was deformed in this region.

**Figure 23: Left forward interior**

The driver seat was adjusted to a full rear track position at the time of the inspection. It was not verified that this was the at-crash position. It was possible the seat may have been altered during the driver's removal.

***MANUAL RESTRAINT SYSTEM - 1996 Chevrolet Cavalier***

The webbing of the driver's restraint was extended from the retractor upon initial inspection and the retractor was locked. Examination of the latch plate revealed historical usage marks consistent with the vehicle's age. The cinch bar of the latch plate was fractured due to an overload. A section of the webbing, in the area of the latch plate when the restraint was buckled, was abraded and stressed over a 13 cm (5") length. This stressed webbing section began 66 cm (26") above the outboard anchor. A 2.5 cm (1.0") abrasion in the torso section of the webbing from frictional contact with the D-ring was located 152 cm (60") above the anchor point. All the evidence identified during the inspection indicated the driver was restrained at the time of the crash. The driver's manual restraint is shown in **Figure 24.**

**Figure 24: Driver's restraint**

***SUPPLEMENTAL RESTRAINT SYSTEM - 1996 Chevrolet Cavalier***

The driver air bag was designed in the typical manner and housed within the center hub of the steering wheel. The driver air bag measured 61 cm (24") in its deflated state and was not tethered. It was vented through two 3.3 cm (1.3") diameter ports located in the 3/9 o'clock sectors on the back side of the bag. The face of the driver air bag was soiled from post-crash handling. There was no direct evidence of occupant contact to the bag.

The front right passenger air bag was a top mount design located in the right aspect of the instrument panel. The face of the passenger air bag measured 51 cm x 46 cm (20" x 18") in its deflated state. The bag was tethered and it vented internally back through the instrument panel. There was no occupant contact evidence noted to the bag.

***OCCUPANT DEMOGRAPHICS - 1995 Ford E-350 Ambulance***

Due to the lack of interior contact evidence which resulted from the fire damage, specific injury mechanisms could not be determined with certainty. Possible injury mechanisms were identified based on probable occupant trajectories and occupant interviews.

**Driver**

| | |
|---|---|
| Age/Sex: | 23-year-old male |
| Height: | 173 cm (68") |
| Weight: | 107 kg (235 lb) |
| Seat Track Position: | Full-rear |
| Manual Restraint Use: | Manual 3-point lap and shoulder belt |
| Usage Source: | Injury data, interview |
| Eyewear: | Prescription glasses |
| Type of Medical Treatment: | Transported by ambulance to a local hospital and admitted for six days |

**Driver Injuries**

| Injury | Injury Severity (AIS 90/Update 98) | Possible Injury Mechanism |
|---|---|---|
| Left comminuted 13 cm (5") transverse midshaft femur fracture with a 10 - 12 cm (4-5") split in the proximal fragment | Serious (851814.3,2) | Loading of intruded left instrument panel, left door, left side panel |
| Left comminuted distal femur fracture in the supracondylar area | Serious (851822.3,2) | Loading of intruded left instrument panel, left door, left side panel |
| Small 2 cm (1") minimally gaping laceration just over the left eyebrow | Minor (290602.1,7) | Possible contact with prescription eyeglasses as a result of facial contact with the steering wheel rim |
| Superficial lacerations on the dorsal skull | Minor (190602.1,6) | Flying glass |

Injury source: Medical records

**Driver Kinematics**

The 23-year-old male driver was seated in an upright posture with the seat track adjusted to the full-rear position and the seat back slightly reclined. He stated the seat back made contact with the rear aspect of the cab in that position. His hands were positioned at the 9 and 3 o'clock positions on the steering wheel rim. His clothing consisted of a white button-down short-sleeved shirt, grey pants, and 23 cm (9") high boots (no safety toe). He was operating the Ford E-350 ambulance in a northbound direction in an

emergency mode with lights and sirens activated. When he detected the Cavalier approaching in the opposite direction, he steered right and braked in full-lockup in an attempt to avoid the collision. At impact with the Cavalier, the driver initiated a forward trajectory and loaded the manual restraint. His legs most likely loaded the lower instrument panel. He continued in a forward direction as the front left corner of the ambulance impacted the ditch bank. His head may have flexed forward and struck the steering wheel rim. His eyeglasses may have compressed against his face resulting in a small 2 cm (1") minimally gaping laceration just over the left eyebrow. He stated that his prescription eyeglasses flew off during the ditch bank impact. The combination of the forward and slightly lateral loading of his legs to the instrument panel and the severe intrusion of the instrument panel, toe pan, floor pan, left front door, and left side panel resulted in a left comminuted 13 cm (5") transverse midshaft femur fracture with a 10 - 12 cm (4-5") split in the proximal fragment and a left comminuted distal femur fracture in the supracondylar area. The driver stated that the impact with the Cavalier did not seem as severe as the impact with the ditch bank. He was redirected in a lateral motion to the left as the ambulance rotated in a CW direction, and probably displaced vertically in the seat as the rear of the ambulance impacted the ground. As the ambulance rolled down the grassy embankment, he was again redirected laterally. Throughout the crash sequence, the manual 3-point lap and shoulder belt mitigated additional movement throughout the cab of the ambulance. He sustained superficial lacerations on the dorsal skull as a result of flying glass. He came to rest upside down suspended from the seat belt, and could not move his left leg, as it was pinned under instrument panel near the left front side panel. He stated that he was initially short of breath, and he attempted to cut the seat belt with a tool from his pocket, as he detected the engine compartment fire. The front right passenger had exited the vehicle and assisted the driver by cutting the seat belt with a pair of scissors. He assisted the driver down and pulled the driver out of the ambulance through the driver's window area by his feet with the assistance of a passer-by. The driver was pulled to a safe area as the ambulance became engulfed in fire, and was transported by ambulance to a local hospital for treatment. He was admitted for six days and released.

**Front Right Passenger**

| | |
|---|---|
| Age/Sex: | 21-year-old male |
| Height: | 198 cm (78") |
| Weight: | 82 kg (180 lb) |
| Seat Track Position: | Full-rear |
| Manual Restraint Use: | Manual 3-point lap and shoulder belt |
| Usage Source: | Injuries, interview |
| Eyewear: | None |
| Type of Medical Treatment: | Transported by ambulance to a local hospital and admitted for two days |

**Front Right Passenger Injuries**

| Injury | Injury Severity (AIS 90/Update 98) | Possible Injury Mechanism |
|---|---|---|
| Facial abrasions (NFS) | Minor (290202.1,9) | Unknown |
| Contusion of posterolateral aspect of the left 7th rib | Minor (450202.1,2) | Shoulder belt loading |
| 2 cm (1") abrasion at the top of the right shoulder/scapula | Minor (790202.1,1) | Indirect - frictional interaction of clothing due to shoulder belt loading |
| Bilateral hand abrasions (NFS) | Minor (790202.1,3) | Unknown |
| Right shoulder strain | Minor (740402.1,0) | Shoulder belt loading |
| Right shoulder contusion | Minor (790402.1,1) | Shoulder belt loading |

Injury source: Medical records

**Front Right Passenger Kinematics**

The 21-year-old front right passenger was seated in an upright posture with the seat track adjusted to the full-rear position. He stated the seat back was slightly reclined and that it contacted the rear aspect of the cab. He was restrained by the manual 3-point lap and shoulder belt. His clothing consisted of a short-sleeve shirt, grey pants, and 20 cm (8") tall duty boots (no safety toe). Prior to impact, he was writing on a clipboard, checking a map, and operating the siren. At impact with the Cavalier, he initiated a forward trajectory and loaded the manual restraint. His knees struck the glove box door and lower instrument panel which were in close proximity due to his height. He continued in a forward direction as the front left corner of the ambulance impacted the ditch bank and loaded the manual restraint again. The forward loading against the manual restraint during both frontal impacts resulted in right shoulder strain and contusion. The frictional interaction of his shirt against his shoulder due to loading the manual restraint resulted in a 2 cm (1") abrasion at the top of his right shoulder. He was redirected laterally as the ambulance rotated CW and may have been displaced vertically and contacted the roof as the ambulance impacted the ground. He continued to be redirected in a lateral direction as the ambulance rolled down the grassy embankment, but additional movement was mitigated due to the use of the manual 3-point lap and shoulder belt. He also sustained facial abrasions and bilateral hand abrasions during the multiple events. The front right passenger came to rest upside down suspended by the seat belt. He could not recall how he exited the vehicle, although, he did so under his own power. He assisted the other occupants of the ambulance out of the vehicle and was transported by ambulance to a local hospital. He was admitted for two days and released.

**Patient Compartment Rear-Facing Technician Seat Passenger (PCP)**

| | |
|---|---|
| Age/Sex: | 19-year-old male |
| Height: | 185 cm (73") |
| Weight: | 88 kg (195 lb) |
| Seat Track Position: | Full-rear (rear-facing) |
| Manual Restraint Use: | 2-point lap belt |
| Usage Source: | Injuries, interview |
| Eyewear: | Prescription contact lenses |
| Type of Medical Treatment: | Transported by ambulance to a local hospital, transferred to a regional trauma center and admitted for six days |

**Patient Compartment Rear-Facing Technician Seat Passenger (PCP) Injuries**

| Injury | Injury Severity (AIS 90/Update 98) | Possible Injury Mechanism |
|---|---|---|
| Distal terminal ileum injury with complete disruption of the mesentery with approximately 20 cm (8") of avascular small bowel, a complete muscular disruption of a 5 cm (2") segment of the sigmoid colon with associated mesenteric rent, and small retroperitoneal hematoma | Severe (542026.4,8) | Lap belt loading |
| Omental tear | Moderate (542220.2,8) | Lap belt loading |
| Unknown loss of consciousness, awake at scene, no memory of crash details | Minor (160499.1,0) | Head strike to inboard aspect of front right cabinetry in the patient compartment |
| Left frontal scalp contusion | Minor (190402.1,5) | Head strike to inboard aspect of front right cabinetry in the patient compartment |
| Two 4 cm (2") lacerations on the right posterior parietocciptal region with a distracted central piece about 4 cm (2") wide | Minor (190602.l,6) | HVAC vent on forward wall of the patient compartment above the rear-facing seat back |
| Abdominal abrasions | Minor (590202.1,0) | Frictional interaction of clothing as a result of lap belt loading |

| Injury | Injury Severity (AIS 90/Update 98) | Possible Injury Mechanism |
|---|---|---|
| Abdominal contusions | Minor (590402.1,0) | Lap belt loading |
| Right foot contusion | Minor (890402.1,1) | Left wall of patient compartment |

Injury source: Medical records

**Patient Compartment Rear-Facing Technician Seat Passenger (PCP) Kinematics**

The 19-year-old PCP was seated in the rear-facing technician seat in the patient compartment of the ambulance **(Figure 25)**. The adjustable seat track was adjusted to the full-rear position and the fixed seat back was upright. The PCP was wearing a short-sleeve polo shirt, black EMS pants, and low-cut duty boots with a steel safety toe. He was restrained by the two-point lap belt with an ALR. He stated that he did not actively pull excess webbing into the retractor to tighten the fit of the lap belt. His height allowed his head to clear the top of the seat back. At impact with the Cavalier, he initiated a rearward trajectory toward the front of the patient compartment. He rebounded forward, possibly jack-knifing over the lap belt and was redirected rearward at the impact with the ditch bank. During the frontal impacts, his head extended over the seat back and struck the HVAC vent which resulted in two 4 cm (2") lacerations on the right posterior parietocciptal region with a distracted central piece about 4 cm (2") wide. As the ambulance rotated CW, he was redirected in a lateral direction and loaded the lap belt. He was probably displaced vertically as the rear of the ambulance impacted the ground. He was redirected laterally as the ambulance rolled down the grassy embankment and loaded the lap belt. His upper torso jack-knifed over the lap belt which resulted in a distal terminal ileum injury with complete disruption of the mesentery with approximately 20 cm (8") of avascular small bowel, a complete muscular disruption of a 5 cm (2") segment of the sigmoid colon with associated mesenteric rent, and small retroperitoneal hematoma. He also sustained an omental tear, abdominal contusions and abdominal abrasions. As he moved laterally, his head possibly contacted the inboard aspect of the front right cabinetry in the patient compartment which resulted in a left front scalp contusion and a concussion. During the rollover event, he sustained a right foot contusion from possible contact with the floor, seat base, or left interior wall of the patient compartment. The PCP came to rest upside down suspended from the lap belt. The front right passenger cut the lap belt and assisted the PCP down onto the ceiling of the ambulance. The PCP was reportedly semi-conscious and assisted out of the rear doors by the front right passenger and witnesses to the crash. He was transported by ambulance to a local hospital and transferred to a regional trauma center for treatment. He was admitted for six days and released.

**Figure 25. View of PCP in exemplar ambulance illustrating his pre-crash position**

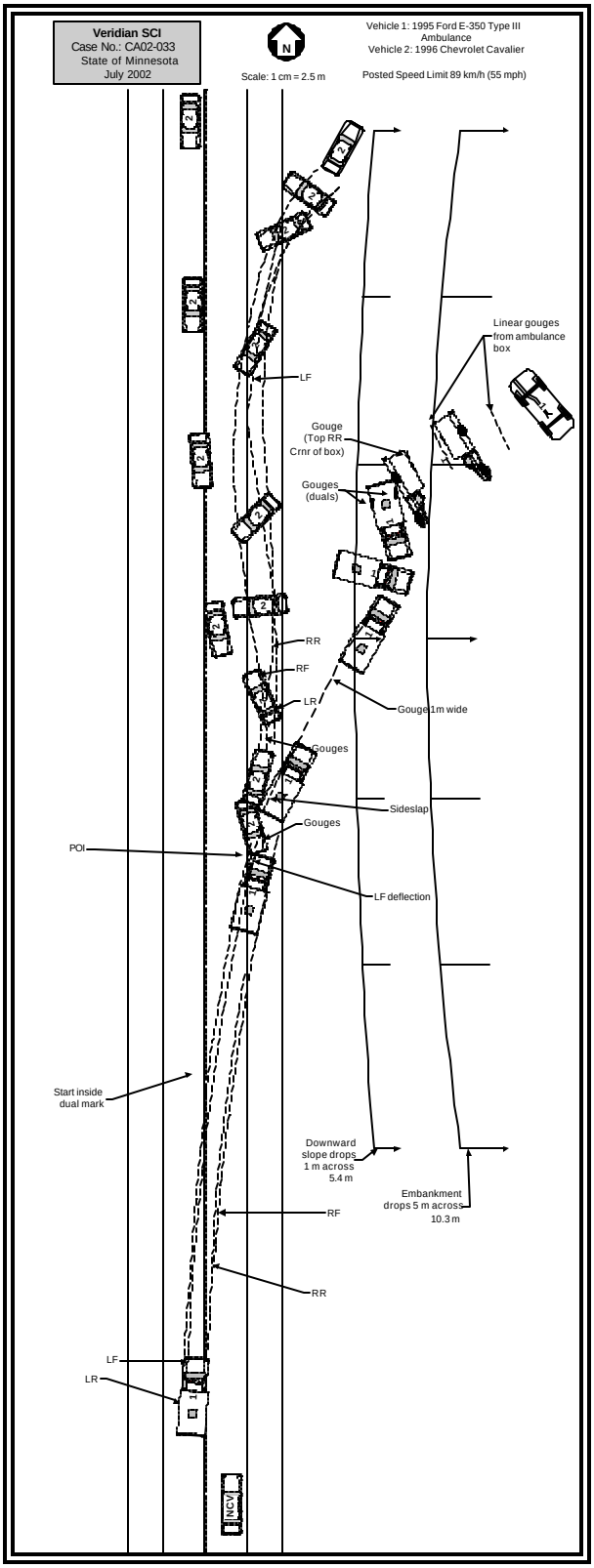


**Figure 26. Scene schematic**

**APPENDIX A (Horton 523d specification sheet)**