**CRASH DATA RESEARCH CENTER**

Calspan Corporation

Buffalo, NY 14225

# CALSPAN ON-SITE AMBULANCE CRASH INVESTIGATION

**SCI CASE NUMBER: CA09040**

**VEHICLE: 2009 FORD E450 CHASSIS / OSAGE TYPE III AMBULANCE BODY**

**LOCATION: VERMONT**

**CRASH DATE: JUNE 2009**

Contract No. DTNH22-07-C-00043

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 system.

**TECHNICAL REPORT STANDARD TITLE PAGE**

| | | | |
|---|---|---|---|
| *1. Report No.*<br>CA09040 | *2. Government Accession No.* | *3. Recipient's Catalog No.* | |
| *4. Title and Subtitle*<br>Calspan On Site Ambulance Crash Investigation<br>Vehicle: 2009 Ford E450 Chassis/Osage Type III Ambulance Body<br>Location: State of Vermont | | *5. Report Date*:<br>September 2010<br>*6. Performing Organization Code* | |
| *7. Author(s)*<br>Crash Data Research Center | | *8. Performing Organization Report No.* | |
| *9. Performing Organization Name and Address*<br>Crash Data Research Center<br>Calspan Corporation<br>P.O. Box 400<br>Buffalo, New York 14225 | | *10. Work Unit No.*<br>*11. Contract or Grant No.*<br>DTNH22-07-C-00043 | |
| *12. Sponsoring Agency Name and Address*<br>U.S. Department of Transportation<br>National Highway Traffic Safety Administration<br>Washington, D.C. 20590 | | *13. Type of Report and Period Covered*<br>Technical Report<br>Crash Date June 2009<br>*14. Sponsoring Agency Code* | |
| *15. Supplementary Note*<br>This on-site investigation focused on the severity of an ambulance crash involving a 2009 Ford E450 chassis with an Osage Type III ambulance body and a 2008 Toyota Tundra pickup truck. | | | |
| *16. Abstract*<br>This on-site investigation focused on the severity of an ambulance crash involving a 2009 Ford E450 chassis with an Osage Type III ambulance body and a 2008 Toyota Tundra pickup truck. The crash resulted in the death of the restrained 48-year-old male paramedic driver and injury of three occupants in the patient compartment. The Advanced Life Support (ALS) ambulance was operating in a non-emergency mode, performing a general transport. An unrestrained 42-year-old male Advanced Emergency Medical Technician-Intermediate (AEMT-I) and an unrestrained 38-year-old female EMT/Paramedic student were responsible for the care of a restrained 62-year-old female patient. En route to their destination facility, the ambulance drifted to the right from its travel lane and struck the forward left side of the Toyota, which was stopped at an intersecting roadway. The Toyota rotated clockwise into a sign as the ambulance continued forward, departed the roadway, and impacted a large diameter tree with its front left area. The crash resulted in severe frontal damage to the ambulance cab and the deployment of its frontal air bag system. The paramedic driver was entrapped and fatally injured. The patient was transported via ground ambulance to a nearby helicopter landing zone and airlifted to a regional trauma center for treatment of serious injuries. The Emergency Medical Services (EMS) providers were transported by ground ambulance to a local hospital for treatment of minor severity injuries. The 57-year-old restrained male driver of the Toyota was uninjured. | | | |
| *17. Key Words*<br>2009 Ford E450 chassis Osage Type III ambulance body Fatal Injury Air bag deployment Driver extrication | | *18. Distribution Statement*<br>General Public | |
| *19. Security Classif. (of this report)*<br>Unclassified | *20. Security Classif. (of this page)*<br>Unclassified | *21. No. of Pages*<br>25 | *22. Price* |

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***BACKGROUND***

This on-site investigation focused on the severity of an ambulance crash involving a 2009 Ford E450 chassis with an Osage Type III ambulance body and a 2008 Toyota Tundra pickup truck. The crash resulted in the death of the restrained 48-year-old male paramedic driver and injury of three occupants in the patient compartment. **Figure 1** is an on-scene view of the ambulance at final rest.


**Figure 1: Final rest position of the ambulance.**

The Advanced Life Support (ALS) ambulance was operating in a non-emergency mode, performing a general transport. An unrestrained 42-year-old male Advanced Emergency Medical Technician-Intermediate (AEMT-I) and an unrestrained 38-year-old female EMT/Paramedic student were responsible for the care of a restrained 62-year-old female patient. En route to their destination facility, the ambulance drifted to the right from its travel lane and struck the forward left side of the Toyota, which was stopped at an intersecting roadway. The Toyota rotated clockwise into a sign as the ambulance continued forward, departed the roadway, and impacted a large diameter tree with its front left area. The crash resulted in severe frontal damage to the ambulance cab and the deployment of its frontal air bag system. The paramedic driver was entrapped and fatally injured. The patient was transported via ground ambulance to a nearby helicopter landing zone and airlifted to a regional trauma center for treatment of serious injuries. The Emergency Medical Services (EMS) providers were transported by ground ambulance to a local hospital for treatment of minor severity injuries. The 57-year-old restrained male driver of the Toyota was uninjured.

Notification of this crash was received by the Calspan Special Crash Investigations (SCI) team on Tuesday, June 16, 2009 from the National Highway Traffic Safety Administration's (NHTSA) Crash Investigation Division. The SCI team initiated telephone follow-up with the State EMS Director and the director of the involved parent ambulance service to gain full cooperation for this on-site investigation. The on-site investigation took place June 23 - 24, 2009, and involved the inspection and documentation of the ambulance, pickup truck, and incident scene. Detailed interviews were conducted with the involved EMS personnel, ambulance service director, and local police.

## *SUMMARY*

### *Crash Site*

This crash occurred at a controlled four-leg intersection during daytime hours. Weather conditions at the time of the crash were overcast with thunderstorm activity, with a temperature of 14 degrees Celsius (57 Fahrenheit) and easterly winds of 13 km/h (8 mph). The bituminous roadway was wet from heavy rain and hail associated with the aforementioned weather conditions. The ambulance was eastbound in the 3.7 m (12 ft) wide travel lane of a two-lane roadway, supported by a 1.3 m (4 ft) shoulder. The roadway followed a slight right curve with positive 3 percent grade before leveling off to a one percent grade and straightening out 50 m (164 ft) west of the intersection.

**Figure 2: Eastbound trajectory view of the ambulance.**

The north intersecting leg consisted of a two-lane roadway intersecting at a reverse 45 degree angle. The south leg intersected at an approximate right angle, and consisted of a 7.1 m (23.25 ft) wide two-lane roadway with a double yellow line 0.25 m (10 in) left of center. There was a stop sign with solid white stop line for the right lane.

To the southeast of the intersection was a wooded area, where the surface of the ground was raised 61 cm (24 in) in relation to the road. This area consisted of a soil base covered by grass and trees. A large 36 cm (14 in) diameter pine tree was centered 3.4 m (11.1 ft) south of the right edge of the roadway. This tree was the final impact point for the ambulance. A wooden community sign on a wood post with 76 cm (30 in) diameter concrete base was located off of the right side of the right leg, at the edge of the wooded area. This was the final impact point for the Toyota.

Roadway markings included double solid yellow center lines in all directions approaching the intersection. White fog lines delineated the shoulders. **Figure 2** is an eastbound trajectory view approaching the intersection. A schematic of the crash is attached as **Figure 15**.

***Vehicle Data***

***2009 Ford E450 Chassis***

The ambulance chassis was a 2009 Ford Econoline-450, manufactured August 2008 and identified by the Vehicle Identification Number (VIN): 1FDXE45P39D (production sequence deleted). The exact odometer reading could not be obtained at the time of SCI inspection due to the vehicle damage as seen in **Figure 3**, though the parent rescue squad reported that the ambulance had approximately 6,440 km (4,000 miles).

**Figure 3: Lateral view of the ambulance cab.**

The chassis was an incomplete chassis with the ambulance prep package, incorporating a two-door cutaway cab configured for a driver and front right passenger. This was similar to the exemplar shown in **Figure 4**. The chassis had a 401 cm (158 in) wheelbase and 180 cm (71 in) undeformed front-end width. Power for this 4x2 dual-wheel rear drive platform came from a turbocharged 6.0-liter V-8 diesel engine linked to a 5-speed automatic transmission. The service brakes were hydraulic four-wheel power-assisted discs with anti-lock. The Gross Vehicle Weight Rating (GVWR) was 6,577 kg (14,500 lb), with Gross Axle Weight Ratings (GAWR) of 2,268 kg (5,000 lb) front and 4,310 kg (9,500 lb) rear. The manufacturer's recommended tire size was 225/75R16E front and rear with cold tire pressures of 515 kPa (75 PSI) and 550 kPa (80 PSI), respectively. All tires were Michelin LTX of the recommended size, mounted on OEM steel wheels. Specific tire data at the time of SCI inspection was as follows:

**Figure 4: Exemplar ambulance chassis.**

| POSITION | TIN NUMBER | PRESSURE | TREAD DEPTH | DAMAGE |
|---|---|---|---|---|
| LF | B3JH FBXX 2708 | FLAT | 10 mm (12/32") | Flat, Sidewall abrasions |
| RF | Unknown | FLAT | 10 mm (13/32") | Flat, De-beaded, Cut in sidewall at bead |
| LR Outer | B3JH FBXX | 448 kPa (65 PSI) | 10 mm (12/32") | None |
| LR Inner | B3JH FBXX | 434 kPa (63 PSI) | 9 mm (11/32") | None |
| RR Outer | B3JH FBXX | 441 kPa (64 PSI) | 9 mm (11/32") | None |
| RR Inner | B3JH FBXX | 441 kPa (64 PSI) | 10 mm (12/32") | None |

The interior of the chassis was configured with two box-mounted deluxe high back captain's chairs with integrated head restraints and manual seat track and recline adjustment features. A folding armrest was on the inboard side of both seats. Both were adjusted to the full-rear track position. Seat back angles were deformed by the impact and deflection of the vehicle frame.

The steering wheel featured tilt adjustment, though its position could not be determined due to displacement from the crash. A center console with an array of switches and communications equipment related to the ambulance's emergency response activities was mounted below the instrument panel's stereo and climate controls.

The Ford chassis was equipped with 3-point lap and shoulder safety belts for both seating positions. This was supplemented by an advanced two-stage frontal air bag system that included a steering wheel hub-mounted driver air bag and instrument panel-mounted front right passenger air bag.

***Osage Type III Ambulance Body***

The ambulance body was manufactured by Osage Industries, Inc. and was identified as a model 2168 Super Warrior Type III, Class I ambulance. Overall dimensions of the ambulance body were 221 cm (87 in) in height, 244 cm (96 in) in width, and 427 cm (168 in) in length. The welded body construction consisted of aluminum roof and side panels on 5 cm (2 in) square aluminum tubing framework. There were five exterior storage compartments with pan-formed hinged doors, and two passenger access points.

**Figure 5: Ambulance right rear oblique view. (On-scene local police image)**

***Exterior***

On the right side (**Figure 5**) were two compartments and a passenger access door. This 175 cm (69 in) tall door was 84 cm (33 in) wide and centered 104 cm (41 in) aft of the front. A square sliding window was centered in the upper portion of the door. Immediately forward of this door was a 157 cm (62 in) tall by 46 cm (18 in) wide compartment, with roll out battery storage in the bottom. Above the rear axle and centered above the interior bench seat was a 41 cm (16 in) tall by 81cm (32 in) wide window. Another compartment 204 cm (80.5 in) tall and 56 cm (22 in) wide was at the rear corner, and served as storage for backboards and other equipment.

At the rear was a large 157 cm (62 in) tall by 127 cm (50 in) wide two-door opening. These doors opened toward either side of the body to allow for the easy loading and unloading of the patient compartment. A square window was centered toward the top of each door.

A shoreline power connection was located at the forward corner of the left side. Storage for the large on-board oxygen tank was found in the forward 204 cm (80.5 in) tall by 46 cm (18 in) wide compartment. To the rear was a 91 cm (36 in) tall by 117 cm (46 in) wide two-door compartment with an adjustable shelf. Aft of the rear axle was another 127 cm (50 in) tall by 69 cm (27 in) wide compartment with two adjustable shelves. The fuel filler cap was forward of this compartment, diagonally above and aft of the axle.

At the front of the ambulance body was a 137 cm (54 in) tall by 48 cm (19 in) wide opening with an affixed hinged door. This served as the passageway from the patient compartment to the cab of the ambulance.

All four exterior sides of the ambulance body were equipped with emergency warning and auxiliary lighting. A large light-bar spanned the top of the front, while clear scene lights and red emergency lights were mounted at the upper corners of the rear and side planes. Standard tail, brake, and marker light assemblies were mounted on all sides as required.

***Interior***

The interior of the ambulance body incorporated three separate seats, two countertops, controls, the patient stretcher, and numerous storage cabinets and compartments, as seen in **Figure 6**. Behind the passenger access door, the right side incorporated a 168 cm (66 in) long split-lid bench seat over the wheel-well with two 13 cm (5.25 in) tall by 78 cm (30.5 in) wide overhead storage compartments and under-seat bulk storage. An oxygen port was mounted to the wall above, forward of the side window. A large cushion was on the wall below the window, serving as the seatback for the bench seat. Lap belts were available to accommodate three passengers on the bench seat.

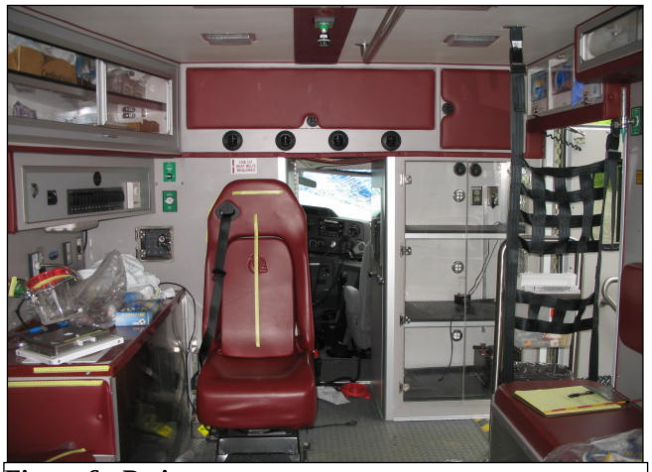

**Figure 6: Patient compartment.**

At the rear corner was the interior intrusion of the large exterior storage compartment. Storage for Personal Protective Equipment (PPE) was located above the access door. Safety strap webbing was at the forward end of the bench seat to prevent passengers from sliding forward into the access door opening during transit. The middle of the patient compartment was for the removable wheeled patient stretcher. The parent rescue squad had installed a Stryker anchoring system with serial number (SN) 081140891. A forward antler bracket straddled the wheels and frame at the head of the stretcher and a rail clamp secured the rear aspect of the stretcher. When loaded into the ambulance, an anchor pin located on the foot of the stretcher would insert into the rear bracket of the clamp and activate the spring-loaded mechanism, which would lock the stretcher in place for transit.

Immediately forward of the stretcher was the rear-facing “Captain’s Chair”. Aptly named, this seating position provided the occupant with a view of the entire patient compartment and access to the ambulance module controls, with close proximity to the driver to enable crew coordination and communication. It also placed the patient’s head area immediately in front of the occupant, with respect to the stretcher, and thus was the best location to manage the patient’s airway during pre-hospital care.

The Captain's Chair seat could be adjusted forward or back, and was capable of rotating 180 degrees with positive stops both forward and backward. A 3-point lap and shoulder belt was available for manual restraint. Integrated into the seatback was a Child Restraint System (CRS) with an accompanying 5-point safety harness. Behind this chair was the center pass-through to the cab. To the immediate right of the pass-through were three stacked shelves for the stowage of large EMS bags and ALS equipment. The bulkhead provided the placement of the heating and air conditioning unit and the associated vents. A locking cabinet was located in the upper right corner.

The left side of the patient compartment served primarily for the stowage of EMS supplies required for patient care. A large 135 cm (53 in) wide by 51 cm (20 in) deep counter was located immediately to the left of the Captain's Chair. Mounted on the left wall above the countertop were oxygen, suction, and electrical outlets. An onboard suction unit was mounted in a metal bracket affixed to the counter, connected to the vacuum outlet on the wall. Mounted at the rear inboard corner of the counter was a square swivel base to support the ALS cardiac monitor. An overhang above served as the control center for the patient compartment, with an array of switches for lighting, a thermostat, radio volume controls, and electrical power controls. Above this overhang was a large 41 cm (16 in) tall by 123 cm (48.5 in) long compartment with clear sliding doors.

Immediately aft of the countertop, cardiac monitor, and control center was the cardio-pulmonary resuscitation (CPR) seat. The seat bottom was 69 cm (27 in) wide, with a two-piece seatback and a lap belt attached to the wall. This seat is so named as its location at the patient's chest area with respect to the stretcher places the occupant in a prime position to perform CPR. Overhead was a narrow storage compartment with clear sliding doors. Another small 39 cm (15.5 in) wide countertop was aft of the CPR seat, accompanied by an electrical outlet on the wall above. The remainder of the left wall space to the rear consisted of large storage compartments with clear sliding doors.

***2008 Toyota Tundra***

The 2008 Toyota Tundra pickup truck was manufactured in April 2008 and identified by the VIN: 5TFBT54128X (production sequence deleted). Shown in **Figure 7**, this four-wheel drive pickup truck was configured with a short bed and four-door crew cab. Power came from a 4.7-liter iForce V-8 gas engine linked to a 5-speed automatic transmission. The odometer reading could not be obtained at the time of SCI inspection because the electrical system had been disabled as a result of the collision.

**Figure 7: Left front oblique view of the Toyota.**

The Toyota was equipped with four-wheel, power-assisted disc brakes with anti-lock, electronic traction control, and electronic stability control. The GVWR was 3,125 kg (6,900 lb), with GAWR of 1,810 kg (4,000 lb) at the front and 1,855 kg (4,100 lb) at the rear. The manufacturer's recommended tire size was P255/70R18 front and rear with cold tire pressures of 210 kPa (30 PSI) and 230 kPa (33 PSI), respectively. The vehicle was equipped with the manufacturer's standard direct Tire Pressure Monitoring System (TPMS) and OEM alloy wheels. All tires were Bridgestone Dueler H/T of recommended size, with matching identification numbers (DOT 7XOP 658 0908).

At the time of SCI inspection, the left front tire was de-beaded and the outer bead was completely off of the rim. There were numerous scattered sidewall abrasions, and the wheel had a large dent on the inside bead. Some of this damage was incurred during recovery removal; however, the on-scene police investigation photographs show the tire was flat but still beaded, with a large dent on the inside rim of the wheel. Specific tire data at the time of SCI inspection was as follows:

| POSITION | PRESSURE | TREAD DEPTH | DAMAGE |
|---|---|---|---|
| LF | FLAT | 6 mm (8/32") | Sidewall abrasions, de-beaded |
| LR | 248 kPa (36PSI) | 6 mm (7/32") | None |
| RR | 255 kPa (37 PSI) | 6 mm (7/32") | None |
| RF | 248 kPa (36 PSI) | 6 mm (8/32") | None |

The interior of the pickup truck was equipped with a split driver/passenger bench seat. This featured a center seat with a seatback that folded down to serve as a combination armrest and center console with cup holders and convenience storage. The cloth seats were mounted on adjustable tracks with adjustable seatbacks. The second row was equipped with an asymmetrical non-adjustable three passenger split bench seat.

### *Crash Sequence*

#### *Pre-Crash*

The 48-year-old male paramedic had been an employee of the parent rescue squad since 2005. He and his 42-year-old male AEMT-I partner were working a 12-hour shift that had begun at 0600 hours. Their day had consisted of completing a routine mechanical check and supply inventory on the ambulance, getting coffee and breakfast, and completing one EMS run. The 38-year-old female EMT had joined the crew to complete field ride time for her paramedic coursework. The trio had been requested to complete a non-emergency transport of the 62-year-old female patient from a health center 19 km (12 mi) away to the local hospital for gastric tube replacement. This call did not require the use of the emergency warning lights or siren. The crew had responded to the health center where they loaded the female patient onto the stretcher and restrained her comfortably with the stretcher's leg, lap, and chest straps. The shoulder straps were not utilized due to the patient's position. The patient was moved into the ambulance on the stretcher, which was locked in place in the Stryker anchoring system.

En route to the local hospital, responsibilities associated with patient care had led the female EMT/Paramedic student to be seated unrestrained in the left sided CPR seat, and the AEMT-I was unrestrained in the Captain's Chair.

The 57-year old male Toyota driver was restrained by a 3-point lap and shoulder belt in the vehicle that had come to a stop at the intersection. He had just left his nearby place of employment and reached the intersection, coming to a controlled stop with his front wheels 0.6 m (2 ft) past the solid white stop line. His vehicle was positioned at a slight angle with respect to his travel lane, as he intended to make a right turn.

The ambulance was traveling eastbound on a winding state road. Approximately 14 minutes into the 22 minute trip, just as the AEMT-I completed his radio report to the destination hospital, the ambulance began to drift from its travel lane as it crossed over the white fog line and onto the shoulder. The driver of the Toyota, and other travelers in the immediate vicinity who witnessed the incident, reported that the ambulance drifted right without evasive maneuver. There were no visible tire marks prior to the impact, supporting this lack of avoidance of braking or steering action by the paramedic driver.

***Crash***

The first impact occurred when the front right of the ambulance collided with the left front corner of the Toyota. As the two vehicles engaged, the front right corner of the ambulance was crushed and displaced longitudinally by the 12 o'clock direction of force, displacing and deforming the headlight, fender, and underhood components above the bumper, and immediately deflating the right front tire. The left front corner of the Toyota, including the fender and underhood components, were crushed and displaced laterally by the 9 o'clock direction of force.

The Damage Algorithm of the WinSMASH model is used to calculate the severity of a crash (delta-V). Although the ambulance's GVWR is outside of the scope of the WinSMASH model, the missing vehicle algorithm was used to serve as a borderline reconstruction for this event. The resulting total delta-V of the ambulance was 7 km/h (4.4 mph). The longitudinal and lateral components were -6.9 km/h (-4.3 mph) and -1.2 km/h (-0.75 mph), respectively. The total calculated delta-V of the Toyota was 12 km/h (7.5 mph), with longitudinal and lateral components of -2.1 km/h (-1.3 mph) and 11.8 km/h (7.3 mph), respectively.

The ambulance continued on its eastbound trajectory, initiating a CW yaw as it departed the southeast quadrant of the intersection. This was evidenced by a 5.5 m (18 ft) tire mark on the road surface from the deflated right front tire, which extended from the point of impact to the edge of the bituminous surface and continued another 15.6 m (51.2 ft) as a gouge through the soil and grass of the inclining terrain.

The ambulance then impacted the 36 cm (14 in) diameter pine tree with its frontal plane, causing severe crush and displacement from the 11 o'clock sector. As the cab crushed during engagement with the tree, the rear axle lifted off of the ground.

An unknown object became airborne in the interior of the ambulance cab, struck the switch panel between the driver and passenger seats, and activated the emergency warning lights.

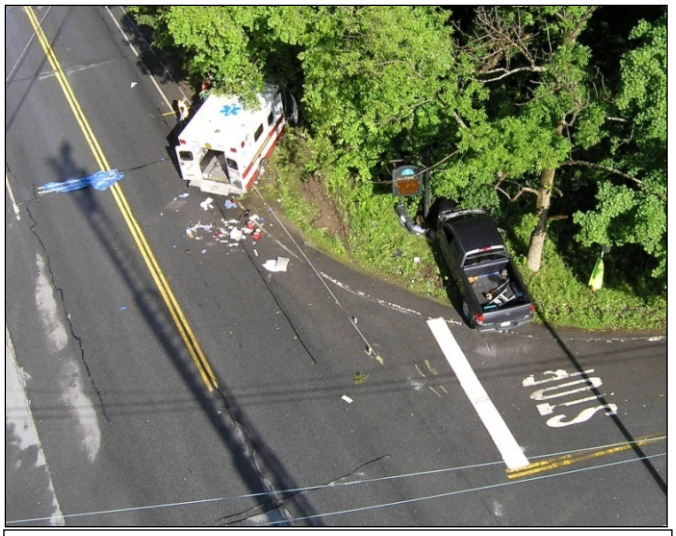


**Figure 8: Aerial Image of Incident Scene. (On-scene local police image)**

The ambulance rebounded and simultaneously rotated 40 degrees CW before the rear axle regained contact with the ground. Although the ambulance's GVWR is outside of the scope of the WINsmash model, a barrier equivalent delta-V of 52 km/h (32 mph) serves as a borderline reconstruction for this event. The longitudinal and lateral components were -51.2 km/h (-31.8 mph) and 9 km/h (5.6 mph), respectively. An aerial view of the vehicles in their final rest positions can be seen in **Figure 8**.

Due to the heading angles and physical dynamics of the vehicles at the first impact, the Toyota transitioned from its stationary position and began a clockwise (CW) rotation with eastward movement. The right front of the ambulance continued to engage the front of the Toyota, further damaging and displacing its frontal plane. As the Toyota continued its CW rotation, it exited the right side of the roadway and impacted the 76 cm (30 in) diameter concrete base of the wooden sign. This second impact had a 2 o'clock direction of force and penetrated the Toyota's frontal plane. The vehicle came to rest as the inside of the front left wheel and exposed undercarriage engaged the concrete sign base. This final rest position was at an angle perpendicular to the Toyota's pre-impact position, with 7.6 m (25 ft) total lateral displacement of the left front tire.

***Post-Crash***

The AEMT-I exited the ambulance without assistance and contacted the local 9-1-1 emergency response system. Police, fire, EMS, and helicopter medi-vac were dispatched to the scene at his request. The paramedic driver was unconscious, entrapped by intruding components, and did not have a palpable pulse. The female patient was concious but separated from the stretcher, lying left-lateral recumbent on the floor of the patient compartment, transverse, between the stretcher and the bench seat. The student was concious, and although injured herself, administered EMS care to the patient with the assistance of the AEMT-I. The driver of the Toyota was not injured.

Arriving EMS personnel assumed care of the patient, who was immobilized with a cervical collar and backboard, transported to a nearby helicopter landing zone, and airlifted to a regional trauma center for treatment of her serious head injuries. The AEMT-I and student were transported by ground ambulance to the local hospital for treament of minor injuries.

The entrapped paramedic driver had to be removed by fire department personnel through the use of hydraulic rescue tools. During the extrication process, the B-pillar mounted striker was cut and the door was moved forward. To disentangle the paramedic from the intruded steering column and instrument panel, the A-pillar was cut 17 cm (6.5 in) above the beltline and the hydraulic spreaders were used to push the instrument panel forward. Personnel cut the safety belt webbing, immobilized the paramedic on a backboard, and transported him to the local hospital. He was pronounced dead on arrival, approximately 40 minutes after the crash occured. The ambulance and pickup truck were towed to the local police department to be held in impound.

***Vehicle Damage***

***2009 Ford Chassis***

The front end of the ambulance had severe damage, with severe interior intrusion on the left side. The left front wheel and left side of the cab was significantly displaced rearward and vertically. There were two distinct areas of damage noted on either side of the frontal plane from the two separate impact events, as highlighted in **Figure 9**.

**Figure 9: Frontal damage patterns to the ambulance.**

Direct contact damage from the impact with the Toyota began 65 cm (25.5 in) right of center line and extended 28 cm (11 in) to the corner. The corner impact resulted in engagement on the right side plane extending rearward to the right front axle area. The right front fender crushed rearward, was pulled right laterally, and folded back over itself. The right headlight assembly was disintigrated, and the front right corner of the hood was crushed rearward. Under hood components were subsequently damaged. The right front tire aired out as the wheel was buckled and the tire debeaded. The Collision Deformation Classification (CDC) was 12FREE3.

The second impact caused severe damage to the chassis. Due to the inclined terrain and the angle at which the ambulance impacted the tree, the entire impact area was crushed rearward, and buckled vertically. Direct damage began on the hood 17 cm (6.5 in) left of center and extended 44 cm (17 in) to the left corner, and began at the bumper height 39 cm (15 in) left of center and extended 40 cm (16 in) to the left corner. The combined induced and direct damage extended from corner to corner across the 180 cm (71 in) end-width. The residual crush measured along the bumper was as follows: C1 = 115 cm (45 in), C2 = 86 cm (34 in), C3 = 55 cm (22 in), C4 = 27 cm (10.5 in), C5 = 9 cm (3.5 in), and C6 = 0 m (0 in). Maximum crush was located at the front left corner (C6). The CDC associated with this second damage pattern was 32FYEN05. The direction of force was incremented by a factor of 20 to account for vertical shift of the left frame rail, which was displaced upward approximately 15 cm (6 in).

Direct damage from the second impact included crush and displacement of the entire bumper, hood, grille, headlight assembly, radiator, fluid reservoirs, and other underhood components. The bumper was also separated from its left mount. The narrow impact caused distinct U-shaped damage in the hood, which matched the diameter of the tree. The crush extended to the inboard side of the left wheel and wheel opening, and reduced the left wheelbase by 64 cm (25 in) to 338 cm (133 in). Consequently, the right wheelbase was lengthened 1 cm (0.5 in) to 403 cm (158.5 in). The vertical displacement of the frame rail vertically upheaved the left sill and induced rearward crush, folding the left running board.

The A-pillar was deformed to a near vertical orientation, which fractured the windshield glazing. The driver's door glazing disintegrated as the door was buckled outward at its center, though the latch remained engaged. Further damage was induced as the roof buckled vertically and the junction of the roof side rail and B-pillar separated. To document the longitudinal displacement of the A-pillar, measurements between the A- and B-pillar of the ambulance were compared to an exemplar chassis cab. These longitudinal measurements highlighted rearward displacements of 46 cm (18 in) at sill level, 39 cm (15 in) at the beltline, and 61 cm (24 in) at the hydraulic rescue tool cut point located 17 cm (6.5 in) above the beltline.

**Figure 10: Driver intrusion. (On-scene local police image)**

Due to the displacement of the left front suspension and wheel, the floor, pedals, and toe pan were also displaced and intruded into the interior. There was gross deformation and deflection to the floor under and surrounding the driver's seat. Combined, the intrusion and deformation had crushed the left front corner of the driver's seat, and displaced the entire seat cushion upward and rearward. The outer layer of the plywood wall behind the driver's seat had separated and was bowed outward.

The severe interior intrusion of the ambulance cab was heavily biased to the left side. The entire instrument panel and steering column were intruded significantly. The steering wheel was displaced vertically and longitudinally and was engaged against the right side of the driver's head restraint. It was also displaced laterally to the right by 32 cm (12.5 in), measured at the 12 o'clock position with respect to the centerline of the head restraint. The severe deformation surrounding the driver's seat is shown in **Figure 10**. (Note the vertical and longitudinal displacements of the instrument panel, steering wheel, and left front tire.) Measurements of the longitudinal distance between the plane of the driver and passenger seatbacks (adjusted to the furthest rear position) and the aformentioned components are found in the following table, which compares the involved vehicle at the time of SCI inspection to an undeformed exemplar chassis:

| POSITION | INTRUDED COMPONENT | DIRECTION | MAGNITUDE |
|---|---|---|---|
| LEFT | Mid-line of instrument panel | Longitudinal | 50 cm (19.5 in) |
| | Steering wheel hub | Longitudinal | 39 cm (15.5 in) |
| | Brake pedal | Longitudinal | 51 cm (20 in) |
| | Toe pan at wheelwell | Longitudinal | 39 cm (15 in) |
| CENTER | Mid-line of instrument panel | Longitudinal | 36 cm (14 in) |
| | Engine cowl | Longitudinal | 44 cm (17.5 in) |
| RIGHT | Outboard instrument panel | Longitudinal | 3 cm (1 in) |
| | Inboard instrument panel | Longitudinal | 15 cm (6 in) |
| | Engine cowl | Longitudinal | 14 cm (5.5 in) |

Occupant contact points were located on the knee bolster from engagement with the driver during the crash. There was an area of deformation and scuffing located toward the right edge, 46-53 cm (18-21 in) left of the vehicle centerline and 30-46 cm (12-18 in) below the top of the instrument panel. A second area of deformation and scuffing was located above the parking brake release lever, 0-10 cm (0-4 in) inboard and 33-46 cm (13-18 in) below the top of the instrument panel. The emergency brake pedal was also displaced and deformed.

***Osage Type III Ambulance Body***

Overall rearward longitudinal displacement of the cab caused deformation to the frontal exterior area of the ambulance body, with a maximum rearward deflection of 6 cm (2.5 in) at sill level. There was 6 cm (2.25 in) of deflection at striker level on the B-pillar, as depicted in **Figure 11**. There was also 5 cm (2 in) of deflection at the belt line, though there was no deformation at the roofline.

**Figure 11: Ambulance body crush.**

The remainder of the exterior of the ambulance body including the sides, rear, top, and glazing were intact and undamaged. All doors were undamaged and remained operational. Deformation was evident on the interior of the patient compartment at the bulkhead. The underside of the bulkhead above the pass-through to the cab was buckled and deflected downward, exposing the plywood and framework.

The wall behind the Captain's Chair had contact evidence from the upper seatback of the chair. This was located from 94-122 cm (37-48 in) above the floor, at 41-61 cm (16-24 in) left of centerline. The Captain's Chair was not deformed, and the integral CRS remained stowed within the seatback. This is depicted in **Figure 12**.


**Figure 12: Captain's Chair contact evidence.**

On the left side, the onboard suction container was fractured from its countertop mount. The forward of two oxygen ports mounted on the wall above the counter had been displaced from its plastic mount. The swivel base for the cardiac monitor was sheered off at the center swivel bolt, and the edge had gouged the countertop surface. The compartment wall adjacent to the CPR seat bottom below the countertop was deflected forward 3 cm (1 in).

***Manual Safety Belt Systems***

The Ford chassis was equipped with manual 3-point lap and shoulder safety belts for both front occupant positions. The driver's belt was equipped with a sliding latch plate, an Emergency Locking Retractor (ELR) and a buckle pretensioner. The front right belt system was equipped with a sliding latch plate, an ELR and Automatic Locking Retractor (ALR) and a buckle pretensioner. The driver was restrained by the manual safety belt, evidenced by loading on the latchplate, D-ring, and belt webbing.

At the time of SCI inspection, it was observed that the driver's safety belt had been cut 27 cm (10.5 in) above the floor anchor. This had occurred during the fire and rescue personnel's extrication process. The latch plate was still in the buckle at inspection and the retractor was still operational. The webbing remained threaded through the latch plate with the stop button against the latch plate hardware. The remainder of the webbing was under the tension of the retractor's return spring. There was 24 cm (9.5 in) of webbing below the stop button to the cut point. A 48 cm (19 in) length of loading evidence was visible on the webbing that began 2 cm (1 in) above the cut extending through the latch plate. The pretensioner actuated as evidenced by the compression of the buckle stalk.

All seats in the patient compartment of the Osage ambulance body were equipped with manual safety belt restraints. The Captain's Chair was equipped with a manual 3-point lap and shoulder safety belt, and integrated into the seatback was a stow-away CRS with accompanying 5-point safety harness. The CPR seat was equipped with a lap belt anchored on the wall. The bench seat was equipped with three lap belts. None of these belts were utilized at the time of the crash. At the time of SCI inspection, all belts were stowed and had no evidence of loading.

The patient stretcher was equipped with manual shoulder, chest, lap, and leg safety restraint straps. The ambulance crew reported to the SCI team that at the time of the crash the patient was semi-Fowler's, a medical position where the head of the stretcher is reclined between 45 and 60 degrees to optimize comfort and improve breathing in immobile patients. The patient was "loosely" restrained by the chest, lap, and leg straps in order to maximize patient comfort and avoid interference with patient care. The shoulder straps were not utilized due to the patient's pre-existing health conditions and associated positioning and care requirements. The stretcher was not available for SCI team inspection.

### *Air Bag System*

The Ford chassis was equipped with an advanced two-stage frontal air bag system that consisted of a steering wheel hub-mounted driver air bag and a mid-instrument panel-mounted front right passenger air bag. The frontal air bags deployed as a result of the crash. However, intrusion and crush prevented complete inspection of the air bag as the steering wheel hub was displaced into the upper quadrant of the seatback as seen in **Figure 13**. Contact evidence could be seen on the air bag, marked by bodily fluid discoloration.

**Figure 13: Driver air bag and displaced steering assembly of the ambulance.**

The passenger air bag was mounted beneath two 7 cm (3 in) tall by 23 cm (9 in) wide flaps, was not tethered, and had a 2.5-5 cm (1-2 in) vent at the 3 o'clock position. No contact evidence was found on this bag.

### *2008 Toyota Tundra*

### *Exterior*

The stationary Toyota was impacted by the ambulance on the left front side (**Figure 14**). Direct contact damage from this impact began 61 cm (24 in) forward of the left A-pillar and extended 41 cm (16 in) to the left front bumper corner. The associated Field L was 102 cm (40 in), and began 7 cm (2.6 in) forward of the leading edge of the left front door and extended to the front corner. The accompanying crush profile included the following six equidistant values documented along the plane: C1 = 0 cm (0 in), C2 = 7 cm (3 in), C3 = 14 cm (5.5 in), C4 = 26 cm (10.5 in), C5 = 37 cm (15 in), and C6 = 44 cm (17 in). Maximum crush was located at the front left corner (C6). The CDC of this impact was 09LFEW3.

**Figure 14: Final rest position of the Toyota. (On-scene local police image)**

The initial impact caused moderate damage to the front of the vehicle, crushing the left front fender laterally into the hood and underhood components. This deformation damaged and displaced the battery, headlight assemby, hood, grille, and bumper. The left front tire lost air pressure as a result of the impact, though photographs taken on-scene by police officers show that the tire remained mounted on the wheel rim and did not debead. As the ambulance engaged the Toyota, the front bumper of the pickup truck was separated from its mounts. Both the bumper and the pickup truck transitioned into eastward CW rotations. The bumper completed a full 360 degree lateral

rotation and 180 degree vertical rotation before coming to rest 7.6 m (25 ft) east of impact, centered 1 m (3.3 ft) north of the concrete community sign base.

The second impact for the Toyota occurred when it impacted the concrete sign base during its CW rotation. This frontal impact damage began left of the centerline, engaging the left bumper mount and frame. Minor crush was sustained to the metal frame and tow hook mounted on the frame rail. As the engagement with the concrete base continued, the left tie rod and the inside front left wheel came in contact with the concrete. This fractured the tie rod from the wheel, rotating the wheel counterclockwise (CCW) slightlty outward as the vehicle came to rest. The CDC associated with this impact damage was 02FLLE3.

***Manual Safety Belt System – 2008 Toyota Tundra***

All six seats in the Toyota were equipped with manual 3-point lap and shoulder belts. The four outboard positions were shoulder height-adjustable at their pillar anchor points. The driver belt was equipped with an ELR, while the remaining positions had ELR/ALR retractors. A retractor pretensioner was equipped on both the driver and right front passenger belts. All six seats had adjustable head restraints, which were all in the full down position at the time of SCI inspection. The driver was restrained by the 3-point lap and shoulder belt at the time of the crash. This was evidenced by subtle loading and belt abraision at the lap plate and D-ring.

***Air Bag Systems – 2008 Toyota Tundra***

The Toyota was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system, Inflatable Curtain (IC) air bag system, and seatback-mounted side impact air bag system. This frontal air bag system was certified by the manufacturer of the Toyota to be compliant with the advanced air bag requirements of Federal Motor Vehicle Safety Standard No. 208. The IC system consisted of curtain airbags mounted on the roof side rail for the four outboard positions. The side impact air bag system consisted of front seatback-mounted air bag. None of the air bag systems deployed in the crash.

***Occupant Data – Ambulance Driver Demographics***

| | |
|---|---|
| Age / Sex: | 48-year-old / Male |
| Height: | 178 cm (70”) |
| Weight: | 99 kg (218 lb) |
| Seat Track Position: | Full-rear |
| Safety Belt Usage: | Restrained by the 3-point lap and shoulder safety belt |
| Usage Source: | SCI vehicle inspection |
| Egress from Vehicle: | Entrapped; extricated by emergency response personnel |
| Type of Medical Treatment: | Transported by ground ambulance to a local hospital where he was pronounced deceased 40 minutes after the crash |

***Driver Injuries***

| Injury | Injury Severity (AIS 90/Update 98) | Injury Source |
|---|---|---|
| Multiple lacerations of the heart (small lacerations of the left and right atrium; the largest laceration of the heart measures approx. 8 cm and extends through the right ventricle) | Maximum (441016.6,4) | Steering wheel |
| Brainstem laceration at the ponto-medullary junction | Maximum (140212.6,8) | Steering wheel |
| Left pulmonary vein laceration (with greater than 20% blood loss, 1500 ml total blood loss) | Critical (421206.4,4) | Steering wheel |
| Bilateral flail chest (Left ribs 1-12 and Right ribs 2-9, fractured anteriorly, laterally and posteriorly) | Critical (450266.5,3) | Steering wheel |
| Left hemidiaphragm laceration (10 cm) with traumatic herniation of the stomach and the spleen into the left hemithorax | Severe (440606.4,8) | Steering wheel |
| Spleen laceration (4cm) of the splenic helium | Severe (544226.4,2) | Steering wheel |
| Subarachnoid hemorrhage at the base of the brain near the foramen magnum | Serious (140684.3,9) | Steering wheel |
| Sacroilium fracture (left sacroiliac joint separation) | Serious (852800.3,6) | Induced by loading of intruded instrument panel |
| Symphysis Pubis separation (fracture) | Serious (853000.3,5) | Induced by loading of intruded instrument panel |
| Lung lacerations NFS | Serious (441414.3,9) | Steering wheel |
| Pleural lacerations | Moderate (441800.2,9) | Steering wheel |
| Complete atlanto-occipital dislocation | Moderate (650208.2,6) | Steering wheel |
| Sternum fracture (transverse fracture at the level of the manubrium) | Moderate (450804.2,4) | Steering wheel |
| Urinary bladder avulsion off of the anterior pelvic wall (bladder is intact) | Moderate (540699.2,8) | Seatback |
| Pericardial lacerations | Moderate (441602.2,4) | Steering wheel |
| Liver capsule lacerations at the level of the falciform ligament | Moderate (541822.2,1) | Steering wheel |
| Left tibia fracture NFS | Moderate (853404.2,2) | Parking brake pedal |
| Left fibula fracture NFS | Moderate (851605.2,2) | Parking brake pedal |
| Left elbow laceration (posterior aspect) | Minor (790602.1,2) | Left front door |
| Left elbow abrasion (posterior aspect) | Minor (790202.1,2) | Left front door |
| Right eyebrow abrasion | Minor (290202.1,1) | Air bag |
| Right cheek abrasion | Minor (290202.1,1) | Air bag |
| Right lower lip abrasion | Minor (290202.1,8) | Air bag |
| Scalp contusion (10cm occipital region) | Minor (190402.1,6) | Windshield header |
| Left shoulder abrasion (top) | Minor (790202.1,2) | Safety belt webbing |
| Large contusion of the left testicle | Minor (544610.1,8) | Seat cushion |
| Chest contusions | Minor (490402.1,9) | Steering wheel |
| Abdominal contusions | Minor (590402.1,9) | Steering wheel |

| | | |
|---|---|---|
| Lower extremity abrasions | Minor (890202.1,9) | Knee bolster |

*Source- Internal Autopsy*

***Driver Kinematics***

The driver of the ambulance was seated in a full-rear track position and restrained by the manual 3-point lap and shoulder safety belt system. Evidence of loading on the belt system components and actuation of the pretensioner confirmed belt use. The inertia-activated retractor locked at the on-set of the initial impact with the Toyota and the frontal air bag system deployed. The driver responded to the frontal impact events by initiating a forward trajectory. Loading of the belt system and occupant contact points could not be separated by event. Frictional abrasions were found on the latch plate. During the crash sequence, his torso loaded the safety belt system. His knees contacted the knee bolster, evidence by scuffing and deformation to the bolster panel. He also loaded the deployed air bag, compressing the air bag against the steering wheel. As the vehicle engaged the tree, direct crush and induced deformation resulted in the severe longitudal and vertical intrusion of the toe pan, floor, instrument panel, and steering wheel. The driver was compressed into the deformed seatback by the aforementioned intruding components. This contact and engagement resulted in severe injury to the driver's torso, head, and internal organs.

The driver was found entrapped, without a palpable pulse. Responding fire and rescue personnel utilized hydraulic rescue tools during the extrication process to free him from the intruded components and remove him from the vehicle. He was then immobilized on a backboard and transported from the scene by EMS ground ambulance to a local hospital where he was pronounced deceased on arrival.

***Patient Compartment – Captain's Chair Passenger Demographics***

| | |
|---|---|
| Age / Sex: | 42-year-old / Male |
| Height: | 178 cm (70") |
| Weight: | 114 kg (251 lb) |
| Seat Track Position: | Rear-facing, adjustment unknown |
| Safety Belt Usage: | Unrestrained |
| Usage Source: | SCI vehicle inspection; interview |
| Egress from Vehicle: | Exited without assistance |
| Type of Medical Treatment: | Transported by ground ambulance to local hospital where he was treated for minor severity injuries and released |

***Captain's Chair Passenger Injuries***

| Injury | Injury Severity (AIS 90/Update 98) | Injury Source |
|---|---|---|
| Right parietal scalp abrasion (size of a dime) | Minor (190202.1,1) | Patient compartment ceiling |
| Right scalp laceration (over mastoid area) | Minor (190600.1,1) | Patient compartment ceiling |
| Mid upper back abrasion | Minor (690202.1,6) | Captain's Chair seatback |

*Source- Hospital Medical Records*

***Captain's Chair Passenger Kinematics***

The rear facing Captain's Chair passenger was seated unrestrained, occupied with patient care responsibilities. He initiated a forward trajectory with respect to the vehicle in response to the frontal impacts, though resulting loading and contact points could not be separated by event.

During the crash sequence, the AEMT-I loaded the seatback of the Captain's Chair. This resulted in contact damage to the front wall as the seatback deflected forward. As the vehicle engaged the tree, objects in the patient compartment became airborne. The AEMT-I was separated from the Captain's Chair and contacted the front wall and ceiling with his back and head. The unrestrained patient was ejected from the stretcher and contacted him in the chest. He was displaced to the right side as the vehicle rebounded, coming to rest on the floor in front of the right side passenger access door. This sequence caused abrasion and laceration injuries to his scalp. After the vehicle came to rest, he exited the vehicle without assitance. He was transported by EMS ground ambulance to a local hospital where he was treated for minor severity injuries and released the same day.

***Patient Compartment – CPR Seat Passenger Demographics***

| | |
|---|---|
| Age / Sex: | 38-year-old / Female |
| Height: | 162-165 cm (64 – 65") |
| Weight: | 59-68 kg (130-150 lb) |
| Position: | Right-facing, seated |
| Safety Belt Usage: | Unrestrained |
| Usage Source: | SCI vehicle inspection; interview |
| Egress from Vehicle: | Exited without assistance |
| Type of Medical Treatment: | Transported by ground ambulance to local hospital where she was treated for minor severity injuries and released |

***CPR Seat Passenger Injuries***

| Injury | Injury Severity (AIS 90/Update 98) | Injury Source |
|---|---|---|
| Right scalp laceration (at hairline) | Minor (190600.1,1) | Cardiac monitor |
| Posterior scalp contusion | Minor (190402.1,6) | Overhead storage compartment |
| Forehead contusion | Minor (290402.1,7) | Control panel |
| Right mid forearm contusion (anterior aspect) | Minor (790402.1,1) | Cardiac monitor |
| Right thigh contusion (inner aspect) | Minor (890402.1,1) | Patient stretcher |
| Bilateral buttock and left lateral thigh contusion | Minor (890402.1,3) | CPR seat cushion, compartment wall |
| Right shoulder strain | Minor (751020.1,1) | Cardiac monitor |

*Source-Interview*

***CPR Seat Passenger Kinematics***

The right facing CPR seat passenger was seated unrestrained, occupied with patient care responsibilities. She initiated a forward trajectory with respect to the vehicle in response to the frontal impacts, though resulting loading and contact points could not be separated by event.

During the crash sequence, the EMT/Paramedic student loaded the short compartment wall below the counter, forward of the CPR seat bottom. This resulted in contact damage and forward displacement of the compartment wall.

As the vehicle engaged the tree, the cardiac monitor was fractured from its mount and displaced forward, striking the CPR seat occupant in her right arm. This caused minor injuries to her right side. Her head struck the overhead compartment and patient compartment control switch panel. She was then separated from the CPR seat as the vehicle rebounded, and landed partially on the rear of the stretcher. After the vehicle came to rest, she was able to exit the vehicle without assitance through the rear doors. She was then transported by EMS ground ambulance to a local hospital where she was treated for minor severity injuries and released the same day.

***Patient Compartment – Patient on Stretcher Demographics***

| | |
|---|---|
| Age / Sex: | 62-year-old / Female |
| Height: | Unknown |
| Weight: | 73-91 kg (160-200 lbs) |
| Position: | Semi-fowler's on stretcher; rear facing |
| Safety Belt Usage: | Loosely restrained by chest, lap, and leg straps |
| Usage Source: | Ambulance crew interview |
| Egress from Vehicle: | Not entrapped, immobilized and removed by emergency response personnel |
| Type of Medical Treatment: | Transported by ground ambulance to nearby helicopter landing zone and air-lifted to regional trauma center; hospitalized for 15 days for treatment of serious injuries |

***Patient on Stretcher Injuries***

| Injury | Injury Severity (AIS 90/Update 98) | Injury Source |
|---|---|---|
| Bilateral comminuted sacral fractures | Serious (852604.3,6) | Patient compartment front wall |
| Right comminuted proximal humeral (neck) fracture | Serious (752604.3,1) | Occupant to occupant contact |
| Comminuted right palate (maxilla) fracture ( the bone is sheared centrally to the right and the fragment is rotated in a counter clockwise location) | Moderate (250800.2,1) | Patient compartment front wall |
| Alveolar ridge fracture (with teeth fracture, avulsion and loosening. One tooth was aspirated into the left bronchus, one into the stomach) | Moderate (250200.2,8) | Patient compartment front wall |
| Grade 1 splenic laceration | Moderate (544222.2,2) | Patient compartment front wall |

| | | |
|---|---|---|
| L1 left transverse process fracture | Moderate (650620.2,8) | Patient compartment front wall |
| L2 left transverse process fracture | Moderate (650620.2,8) | Patient compartment front wall |
| L3 right and left transverse process fractures | Moderate (650620.2,8) | Patient compartment front wall |
| L4 right and left transverse process fractures | Moderate (650620.2,8) | Patient compartment front wall |
| L5 right and left transverse process fractures | Moderate (650620.2,8) | Patient compartment front wall |
| Right non-displaced distal clavicle fracture | Moderate (752200.2,1) | Occupant to occupant contact |
| Multiple right sided posterior rib fractures | Moderate (450210.2,1) | Patient compartment front wall |
| Multiple facial abrasions | Minor (290202.1,9) | Patient compartment floor |
| Large deep chin laceration extending upwards to the lip (through and through on the lip portion) | Minor (290602.1,8) | Patient compartment floor |
| Neck contusions | Minor (390402.1,9) | Patient compartment floor |
| Left upper anterior chest abrasion | Minor (490202.1,2) | Patient compartment floor |
| Bilateral shoulder contusions | Minor (790402.1,3) | Patient compartment floor |

*Source-Medical Records*

***Patient on Stretcher Kinematics***

The patient on the rear facing stretcher was semi-Fowler's and loosely restrained by chest, lap, and leg straps. As the vehicle engaged the tree, she iniated a forward trajectory with respect to the vehicle. She ramped up the back of the semi-reclined stretcher and was separated from it. She contacted the AEMT-I in the chest, deflecting off of his left side. She then contacted the front wall of the patient compartment. This caused moderate and severe injuries to her head and torso. As the vehicle rebounded, she was displaced to the rear of the patient compartment. She landed transverse, left laterally on the floor, between the stretcher and bench seat. This resulted in several facial injuries. She was immobilized and removed from the patient compartment by responding emergency response personnel. She was transported by EMS ground ambulance to a nearby helicopter landing zone and air-lifted to a regional trauma center, where she was hospitalized for 15 days for treatment of severe injuries. She received a total of four units of transfused blood.

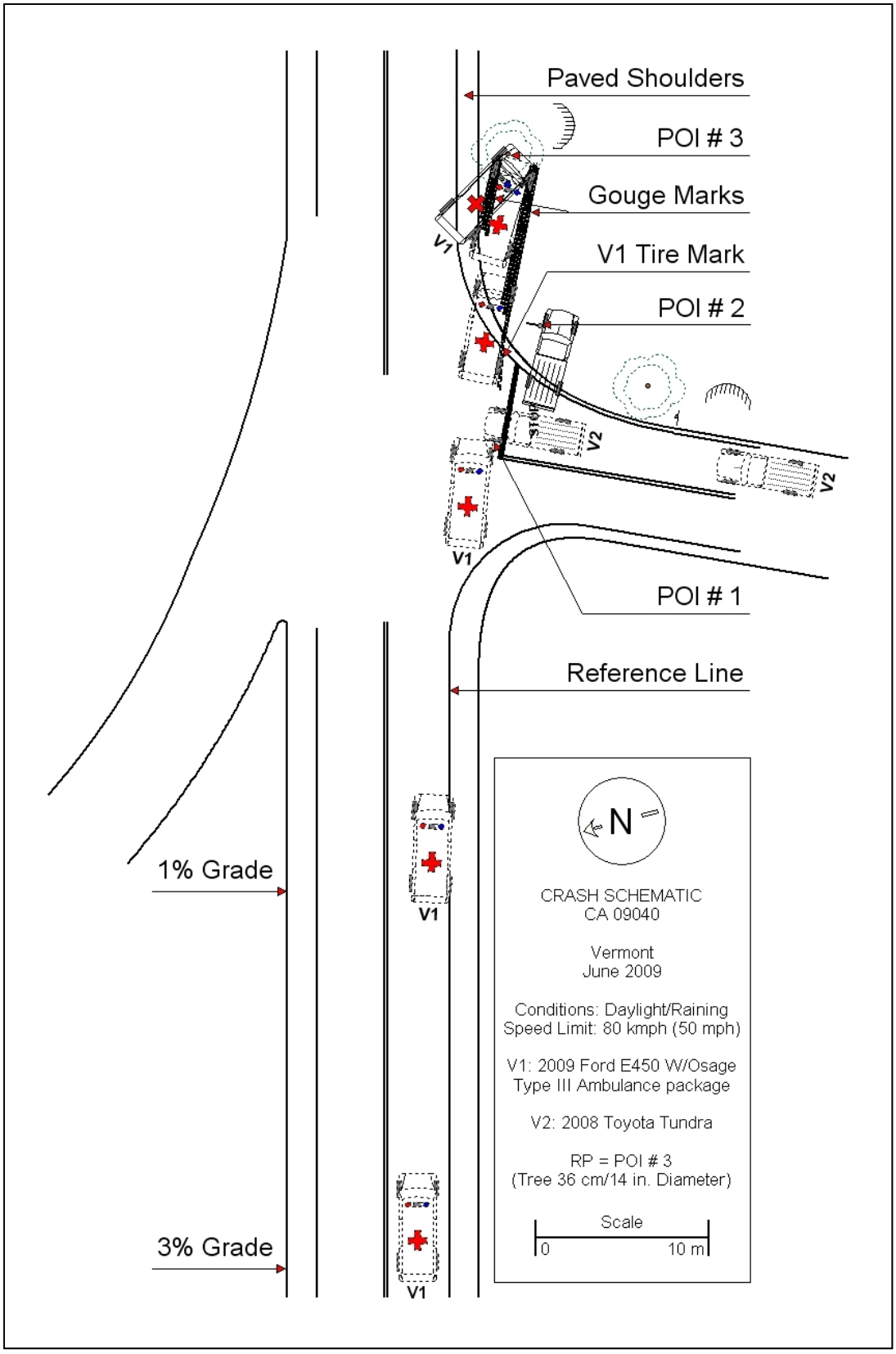


**Figure 15: Crash Schematic**