TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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VERIDIAN ON-SITE AIR BAG NON-DEPLOYMENT INVESTIGATION

VERIDIAN CASE NO. CA01-025

VEHICLE - 2000 FORD EXPLORER XLS 4X4

LOCATION - STATE OF NEW JERSEY

CRASH DATE - APRIL, 2001

Contract No. DTNH22-94-D-07058

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.

TECHNICAL REPORT STANDARD TITLE PAGE

1. *Report No.* CA01-025	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* Veridian On-Site Air Bag Non-Deployment Investigation Vehicle - 2000 Ford Explorer XLS 4x4 Location - State of New Jersey		5. *Report Date*: June, 2002 6. *Performing Organization Code*	
7. *Author(s)* Crash Data Research Center		8. *Performing Organization Report No.*	
9. *Performing Organization Name and Address* Veridian Engineering Transportation Sciences Crash Data Research Center P.O. Box 400 Buffalo, New York 14225		10. *Work Unit No.* C01115.0349.(0000-0009) 11. *Contract or Grant No.* DTNH22-94-D-07058	
12. *Sponsoring Agency Name and Address* U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		13. *Type of Report and Period Covered* Technical Report Crash Date - April, 2001 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* On-site investigation of a frontal collision (into a fixed object) that involved a 2000 Ford Explorer XLS 4x4 sport utility vehicle equipped with redesigned frontal air bags for the driver and front right passenger positions.			
16. *Abstract* This on-site investigation focused on the non-deployment of the redesigned frontal air bag system of a 2000 Ford Explorer XLS 4x4 sport utility vehicle. The vehicle was equipped with redesigned frontal air bags for the driver and front right passenger positions which failed to deploy as a result of a frontal collision with a large diameter tree. The driver of the Ford Explorer was operating the vehicle northbound on a multi-lane divided state parkway when he allowed the vehicle to depart the left (west) pavement edge and enter a forested center median area. As the vehicle exited the west pavement edge, the front left area struck a W-beam guardrail which resulted in minor damage. The Ford continued in a northwesterly direction as the front center area impacted a large diameter tree resulting in severe damage. The WinSMASH computed velocity change was 67.4 km/h (41.9 mph). At impact with the tree, the unrestrained 20 year old male driver initiated a forward trajectory in response to the 12 o'clock impact force and loaded the steering wheel rim/column and knee bolster. Loading of the steering wheel rim resulted in unspecified liver and lung lacerations. He also sustained a fractured right foot from contact to the intruded toepan. The driver was transported to a local trauma center for treatment and admitted for an unknown duration. At impact with the tree, the unrestrained 26 year old male front right passenger initiated a forward trajectory in response to the 12 o'clock impact force and loaded the right instrument panel and passenger air bag module cover flap. Loading of the instrument panel resulted in multiple bilateral rib fractures *("flail chest")* along with underlying lacerations to the liver, spleen, and aorta. Loading of the passenger air bag module cover flap resulted in extensive basilar and vault skull fractures along with an underlying cerebral contusion, subarachnoid hemorrhage, and laceration of the brain stem. The front right passenger was pronounced deceased at the crash site.			
17. *Key Words* Collision Deformation Classification (CDC): 12-FCEN-4 WinSMASH damage algorithm: 67.4 km/h (41.9 mph) Passenger out-of-position Brain stem laceration		18. *Distribution Statement* General Public	
19. *Security Classif. (of this report)* Unclassified	20. *Security Classif. (of this page)* Unclassified	21. *No. of Pages* 10	22. *Price*

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BACKGROUND

This on-site investigation focused on the non-deployment of the redesigned frontal air bag system of a 2000 Ford Explorer XLS 4x4 sport utility vehicle. The vehicle was equipped with redesigned frontal air bags for the driver and front right passenger positions which failed to deploy as a result of a frontal collision with a large diameter tree. The driver of the Ford Explorer was operating the vehicle northbound on a multi-lane divided state parkway when he allowed the vehicle to depart the left (west) pavement edge and enter a forested center median area. As the vehicle exited the west pavement edge, the front left area struck a W-beam guardrail which resulted in minor damage. The Ford continued in a northwesterly direction as the front center area impacted a large diameter tree resulting in severe damage. The WinSMASH computed velocity change was 67.4 km/h (41.9 mph). At impact with the tree, the unrestrained 20 year old male driver initiated a forward trajectory in response to the 12 o'clock impact force and loaded the steering wheel rim/column and knee bolster. Loading of the steering wheel rim resulted in unspecified liver and lung lacerations. He also sustained a fractured right foot from contact to the intruded toepan. The driver was transported to a local trauma center for treatment and admitted for an unknown duration. At impact with the tree, the unrestrained 26 year old male front right passenger initiated a forward trajectory in response to the 12 o'clock impact force and loaded the right instrument panel and passenger air bag module cover flap. Loading of the instrument panel resulted in multiple bilateral rib fractures *("flail chest")* along with underlying lacerations to the liver, spleen, and aorta. Loading of the passenger air bag module cover flap resulted in extensive basilar and vault skull fractures along with an underlying cerebral contusion, subarachnoid hemorrhage, and laceration of the brain stem. The front right passenger was pronounced deceased at the crash site.

The crash notification was provided to NHTSA by the investigating police officer on Thursday, April 19, 2001 and immediately assigned to the Veridian SCI team as an on-site investigative effort. Cooperation was immediately established with local law enforcement as the on-site investigator departed on April 23 and completed field activities Tuesday, April 24, 2001.

SUMMARY

Crash Site

This single vehicle crash occurred during the early morning hours of April, 2001. At the time of the crash, it was dark (street not lighted) with no adverse conditions as the road was dry. The crash occurred off the west pavement edge of a straight and level north/south multi-lane state parkway which was divided by a forested center median area **(see Figure 10 - page 10)**. The northbound (asphalt) travel lanes were bordered by tactile warning devices (rumble strips) and narrow paved shoulders. A W-beam guardrail was documented 32.8 meters (107.6 feet) south of the final impact point and located 4.4 meters (14.4 feet) off the west pavement edge. I-beam strong posts, spaced at 92.0 cm (36.2 in) apart, supported the structure with block-outs between the post and W-beam. No traffic control was present at the scene which had a posted speed limit of 80 km/h (50 mph).

Pre-Crash

The 20 year old male driver of the 2000 Ford Explorer XLS was operating the vehicle northbound **(Figure 1)** on the inboard lane when he apparently fell asleep and allowed the vehicle to depart the left (west) pavement edge in a forward tracking mode. The police reported no pre-impact tire marks at the scene indicative of driver avoidance maneuvers.

Figure 1. Northbound approach for the 2000 Ford Explorer XLS 4x4.

Crash

As the Ford Explorer exited the west pavement edge, the front left area impacted a W-beam guardrail **(Figure 2)** resulting in minor damage. At this point, contact separation occurred as the left side surface struck the W-beam guardrail resulting in minor damage. The vehicle sustained contact with the guardrail 4.0 meters (13.1 feet) prior to final separation at the north end post. The Ford continued in a northwesterly direction approximately 32.3 meters (106.0 feet) as the front center area impacted a 41.0 cm (16.1 in) diameter tree resulting in severe damage **(Figure 3)**. Impact speeds and velocity changes were computed utilizing the WinSMASH reconstruction program. The trajectory algorithm computed a speed *at impact* of 73.6 km/h (45.7 mph) as the damage algorithm computed an overall velocity change of 67.4 km/h (41.9 mph) with a matching negative longitudinal component. At this point, the Ford rebounded 1.5 meters (4.9 feet) off the tree and came to rest in close proximity to the point of impact (in the center median) facing northwest.

Figure 2. West view of struck W-beam guardrail.

Figure 3. Northwest view of impacted tree.

Post-Crash

Both occupants were removed from the vehicle by rescue personnel. The driver was transported by ambulance to a local trauma center for treatment and admitted for an unknown duration. The front right passenger was pronounced deceased at the scene. The vehicle was towed from the crash site with disabling damage.

VEHICLE DATA

The 2000 Ford Explorer XLS 4x4 was manufactured in June, 2000 and identified by the vehicle identification number (VIN): 1FMZU72X7YZ (production number deleted). The front right passenger was reported by police as the owner of the vehicle. The vehicle was a 4-door sport utility equipped with four-wheel drive, ABS and a 4.0 liter, V-6 engine. At the time of the crash, the odometer had recorded approximately 14,484 km (9,000 miles). The seating was configured with front bucket and a rear split bench seat (with folding backs). Previous crashes or maintenance on the Ford's frontal air bag system were unknown.

VEHICLE DAMAGE

Exterior

The 2000 Ford Explorer XLS 4x4 sustained severe frontal damage as a result of the impact with the large diameter tree **(Figure 4)**. The direct contact damage began 4.0 cm (1.6 in) right of the end plane centerline and extended left 40.0 cm (15.7 in). The impact deformed the full frontal width resulting in a combined direct and induced damage length (Field L) of 49.0 cm (19.3 in). Six crush measurements were documented at the level of the reinforcement bar *(bumper fascia separation)*: C1= 18.5 cm (7.3 in), C2= 68.0 cm (26.8 in), C3= 83.0 cm (32.7 in), C4= 81.0 cm (31.9 in), C5= 72.0 cm (28.3 in), C6= 13.5 cm (5.3 in). The Collision Deformation Classification (CDC) for this impact to the Ford was 12-FCEN-4 with a principal direction of force of 0 degrees. The hood was deformed up and rearward from engagement against the tree. The bumper corners were pulled inward by the narrow contact damage. Induced contact damage produced longitudinal shifting of the A-pillars which buckled the roof and side rails. The windshield was fractured from (exterior) impact forces and (interior) right instrument panel occupant loading. Extensive passenger loading of the right instrument panel area also resulted in an 8.0 cm (3.1 in) x 50.0 cm (19.7 in) slit to the windshield, contributing to passenger compartment integrity loss. The right rear tempered glazing was disintegrated by cargo shift during the crash. Reduction in the left wheelbase measured 21.0 cm (8.3 in) as the right wheelbase was elongated 11.0

Figure 4. Frontal damage to the 2000 Ford Explorer XLS 4x4.

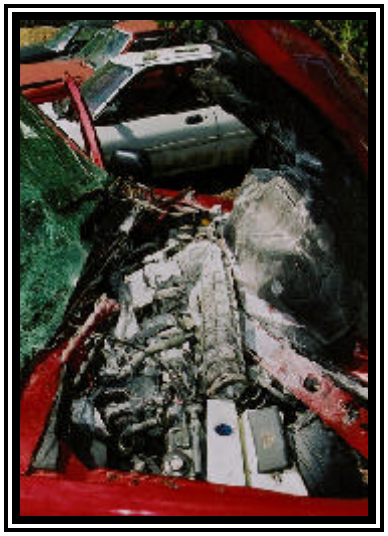

Figure 5. Fire damage to the engine compartment.

cm (4.3 in). The left front axle fractured and resulted in complete separation of the left front wheel/tire. This damage was not attributed to the W-beam guardrail impact given consistent rotating tire marks documented at the scene; but related to the severe frontal crash forces. Although the fuel tank was deformed by undercarriage movement during the crash, snagging occurred during post-crash vehicle extrication activities which resulted in minor fuel leakage. Minor fire damage was also noted in the engine compartment area **(Figure 5)**.

Direct contact damage was also identified at the front left area and left side surface attributed to the W-beam guardrail impact. The direct contact damage began at the front left bumper corner and extended 11.0 cm (4.3 in) inboard. This contact pattern also extended 392.0 cm (154.3 in) rearward along the left side surface **(Figure 6)**; at and below the level of the frame. Contact separation documented along the guardrail during the SCI scene inspection necessitated assignment of two separate events for this damage pattern. Induced contact damage above the level of the frame jammed the left front door opening and produced outward buckling of the upper window frame. The CDC's for the guardrail impacts to the Ford were 12-FLEE-9 and 12-LZES-1, respectively.

Figure 6. Left side surface damage to the 2000 Ford Explorer XLS 4x4.

Interior

Interior damage to the Ford Explorer was severe and attributed to component intrusions and occupant contact **(Figures 7 & 8)**. The left knee bolster was heavily deformed and scuffed. The steering column was displaced approximately 12.0 cm (4.7 in) upward and 17.0 cm (6.7 in) to the left from driver loading. Steering wheel rim deformation measured 12.0 cm (4.7 in) along the top portion as shear capsule movement measured 3.0 cm (1.2 in). The accelerator pedal fractured with the brake pedal displaced to the left. The rear view mirror separated from the windshield undamaged. The right knee bolster and glove compartment door were deformed and scuffed. Tissue, blood, scratch marks and indentations were identified on the front right passenger air bag module cover flap. Blood spattering was noted along the right roof side rail and B-pillar. Cargo movement in the vehicle resulted in extensive deformation to the second row seat back along with minor abrading and scuff marks to the rear aspect of the front right seat back. Longitudinal intrusions into the front left occupant space involved 27.0 cm (10.6 in) of toepan intrusion and 10.0 cm (3.9 in) of instrument panel intrusion with 8.0 cm (3.1 in) of vertical floor intrusion. Longitudinal intrusions into the front right occupant space involved 33.0 cm (13.0 in) of toepan intrusion, 5.0 cm (2.0 in) of instrument panel intrusion and 5.0 cm (2.0 in) of cargo intrusion.

Figure 7. Interior damage to the 2000 Ford Explorer XLS 4x4.

Figure 8. Second row seat back deformation from cargo movement within the vehicle.

MANUAL RESTRAINT SYSTEMS

The interior of the Ford Explorer consisted of a five passenger seating configuration with front bucket and a rear split bench seat (with folding backs). The driver 3-point manual lap and shoulder belt system consisted of a continuous loop belt webbing with a sliding latchplate and dual mode retractors (inertial lock/belt sensitive). The front right 3-point manual lap and shoulder belt system consisted of a continuous loop belt webbing with a sliding latchplate and a retractor equipped with an inertial and switchable lock mechanism. No frequent usage indicators were identified on the latchplates of the front restraints. No loading evidence was identified on any of the restraint webbings or D-rings to support belt usage by either occupant. The rear outboard seated positions were equipped with 3-point manual lap and shoulder belt systems which consisted of continuous loop belt webbings with sliding latchplates that retracted into inertial sensitive and switchable locking retractors. The rear center seat was equipped with a 2-point manual lap belt which consisted of a sewn-on latchplate which retracted into an inertial sensitive and switchable locking retractor.

SUPPLEMENTAL RESTRAINT SYSTEMS

The 2000 Ford Explorer XLS 4x4 was equipped with redesigned frontal air bags for the driver and front right passenger positions which did not deploy as a result of the crash. The driver air bag was housed in the center of the steering wheel with a horizontally oriented flap tear seam (H-configuration). Contact evidence to the driver air bag module cover flap consisted of small scuff marks and indentations. The front right passenger air bag was housed in the right mid-instrument panel area with a single cover flap design hinged at the top aspect. The cover flap was rectangular in shape and measured 37.0 cm (14.6 in) in width and 17.4 cm (6.9 in) in height. Contact evidence to the passenger air bag module cover flap consisted of skin tissue, scratch marks and indentations.

The Ford Explorer frontal air bag system utilized the ball and tube sensor design with the primary sensors mounted on "hat brackets" located on the upper left/right radiator area. The air bag system also utilized an electro-mechanical safing sensor integral to the restraints control module (RCM) located in the right kick panel area. The primary sensors were inspected and documented carefully. The left primary sensor was identified by Ford part number: XL2A-14B005-AA with a bar coded lot number of: *CB13200589*. The sensor was found inboard of the contact damage and rotated 16 degrees inward as a result of the impact force. The right primary sensor was identified by Ford part number: XL2A-14B004-AA with a bar coded lot number of: *CA11801497*. The sensor was found outboard of the contact damage and rotated 38 degrees inward as a result of the impact force. The connections were examined for evidence of owner deactivation (tampering), however, the connectors were found uniformly clean and intact. The instrument cluster had been removed by police, therefore, flash codes could not be identified. The SCI investigator also observed electrical continuity tests by police investigators. Electrical continuity was confirmed on the air bag system (to include the primary sensors).

The control module was harvested by SCI for further analysis by Ford Motor Company's Design Analysis Department. Following the SCI on-site investigation, Ford also conducted an inspection of the vehicle and its safety systems. A tentative analysis by Ford revealed that the primary sensors were designed to close within 7.5 microseconds of the event, as the safing sensor was designed to close either immediately, or within 40 milliseconds after the primary sensors to get a "deployment decision". The RCM looks for the safing sensor to close within the specified time period, or it senses a problem and writes a fault code ("low resistance to ground") to deactivate the air bag system *for that key cycle only*. The Ford sustained a localized impact (guardrail impact #1) to the front left area, which was considered a threshold impact. This initial impact closed the left primary sensor but the safing sensor closure did not follow within the specified time period. The above mentioned diagnostic code was found written into memory after the guardrail impact. Therefore, the RCM deactivated the air bag system for that key cycle. It should be noted that further closure of the primary sensors will not write into memory. Ford performed an in-house test to verify this scenario, which matched this crash perfectly. Ford also found the safing sensor to be working properly while electrical continuity tests were conducted.

DRIVER DEMOGRAPHICS

Age/Sex:	20 year old male
Height:	173 cm (68 in)
Weight:	73 kg (160 lb)
Seat Track Position:	Mid-to-rear position
Manual Restraint Use:	None
Usage Source:	Vehicle inspection, police report
Eyeware:	None
Type of Medical Treatment:	Transported to a local trauma center and admitted for an unknown duration

Driver Injuries

Injury	*Severity (AIS 90)*	*Injury Mechanism*
*Lung laceration (not further specified)	Serious (441414.3,9)	Steering wheel rim
*Liver laceration (not further specified)	Moderate (541820.2,1)	Steering wheel rim
*Right foot fracture (not further specified)	Moderate (852000.2,1)	Left toepan
*Right foot contusion (not further specified)	Minor (890402.1,1)	Left toepan

**Source - police*

Driver Kinematics

The 20 year old male driver of the 2000 Ford Explorer XLS 4x4 was unrestrained (3-point manual lap and shoulder belt system available) and presumed to be seated upright and out-of-position with a slight lean to the right *(asleep)*. This posture was evidenced by the kinematic response and associated contact pattern to the right of the steering column. The seat track was adjusted to a mid-to-rear position with the seat back angled 22 degrees aft of vertical. The lack of belt usage was determined by the trajectory of the driver and contact points within the vehicle relative to the absence of loading evidence on the restraint webbing or D-ring.

At first impact with the W-beam guardrail, the driver probably initiated little if no forward trajectory in response to the 12 o'clock impact force. Although this initial impact resulted in closure of the left primary air bag sensor, vehicle deceleration was minimal as the structure of this sport utility absorbed most of the crash energy easily. At second impact with the W-beam guardrail, the above kinematic scenario would have repeated itself with only the driver awakening as the expected reaction. Whether the driver awoke at this point is unclear, however, scene evidence suggested the vehicle continued in a forward tracking mode into the large diameter tree.

At impact with the tree, the driver initiated a forward trajectory in response to the 12 o'clock impact force and loaded the steering wheel rim/column and knee bolster. Interaction with the steering wheel rim resulted in an unspecified liver/lung laceration as evidenced by 12.0 cm (4.7 in) of deformation documented to the upper portion of this component. Loading of the knee bolster was evidenced by the deformation documented to this component, however, no injury was reported as a result. He also sustained a contusion and fracture of the right foot from contact to the (intruded) toepan. This injury mechanism was evidenced by fractured accelerator pedal and placement of the driver's right foot on this pedal during pre-crash control loss. The driver was removed from the vehicle by rescue personnel due to perceived serious injury and subsequently transported by ambulance to a local trauma center for treatment and admitted for an unknown duration. Use of the available 3-point manual lap and shoulder belt system would have mitigated the injuries sustained by the driver, in lieu of a redesigned driver air bag deployment.

FRONT RIGHT PASSENGER DEMOGRAPHICS

Age/Sex:	26 year old male
Height:	170 cm (67 in)
Weight:	70 kg (154 lb)
Seat Track Position:	Middle position
Manual Restraint Use:	None
Usage Source:	Vehicle inspection, police report
Eyeware:	None
Type of Medical Treatment:	Pronounced deceased at the scene

Front Right Passenger Injuries

Injury	*Severity (AIS 90)*	*Injury Mechanism*
*Brain stem laceration	Maximum (140212.6,8)	Non-deployed passenger air bag module cover flap (indirect contact injury)
*Transected aorta (total circumferential)	Critical (420216.5,4)	Right instrument panel
*Flail chest (bilateral rib fractures) with massive hemothorax	Critical (450266.5,3)	Right instrument panel
*Basilar skull fracture (hinge and ring FX) with copious amount of blood coming out of ear canals bilaterally and moderate amount from nostrils and mouth	Severe (150206.4,8)	Non-deployed passenger air bag module cover flap
*Cerebral subarachnoid hemorrhage	Serious (140684.3,2)	Non-deployed passenger air bag module cover flap
*Contusion left cerebrum	Serious (140602.3,2)	Non-deployed passenger air bag module cover flap
*Laceration liver (extensive/linear/horizontal)	Serious (541824.3,1)	Right instrument panel
*Vault skull fracture (right temporal and parietal)	Moderate (150402.2,1)	Non-deployed passenger air bag module cover flap
*Vault skull fracture (left temporal and parietal)	Moderate (150402.2,2)	Non-deployed passenger air bag module cover flap
*Fracture bilateral occipital bones	Moderate (150402.2,6)	Non-deployed passenger air bag module cover flap
*Laceration spleen	Moderate (544222.2,2)	Right instrument panel
*Laceration upper/lower lip (superficial - corresponds with incisor teeth)	Minor (290602.1,8)	Non-deployed passenger air bag module cover flap (indirect contact injury)
*Bilateral abrasions anterior shin (identical/symmetrical @ 2x3cm)	Minor (890202.1,3)	Glove compartment door

*Source - autopsy report**

Front Right Passenger Kinematics

The 26 year old male front right passenger of the 2000 Ford Explorer XLS 4x4 was unrestrained (3-point manual lap and shoulder belt system available) and presumed to be seated upright and out-of-position leaned slightly to the left against the center arm rest. This posture was evidenced by the kinematic response and associated concentration of contact points to the left of the front right occupant space. The seat track was adjusted to the middle position with the seat back angled 22 degrees aft of vertical. The lack of belt usage was determined by the trajectory of the passenger and contact points within the vehicle relative to the absence of loading evidence on the restraint webbing or D-ring.

Figure 9. Contact evidence to the non-deployed front right passenger air bag module cover flap.

At first (and second) impact with the W-beam guardrail, the front right passenger probably initiated little if no forward trajectory in response to the 12 o'clock impact force.

At impact with the tree, the passenger initiated a forward trajectory in response to the 12 o'clock impact force as the lower extremities loaded the glove compartment door and knee bolster resulting in bilateral abrasions to the anterior shins. This injury mechanism was evidenced by the extensive deformation documented to these components. The torso impacted the mid-instrument panel resulting in multiple bilateral rib fractures *("flail chest")* with an associated massive hemothorax. Underlying internal trauma consisted of a liver/spleen laceration and a complete circumferential aortic transection, evidenced by the indentations identified on the mid-instrument panel area. The head/face struck the (non-deployed) front right passenger air bag module cover flap which resulted in multiple basilar (bilateral "hinge" temporal) and vault (bilateral temporal, parietal, and occipital) skull fractures. Underlying trauma involved a cerebral contusion/subarachnoid hemorrhage and (indirect contact) brain stem laceration. These injury mechanisms were evidenced by the type of injury sustained in conjunction with the skin tissue, scuff marks and indentation documented on the passenger air bag module cover flap **(Figure 9)**. In addition, this extensive loading pattern displaced the upper right instrument panel through the windshield producing the noted slit in the windshield. He also sustained a superficial laceration of the upper and lower lip (corresponding to the incisor teeth) which was an indirect result of head contact to the passenger air bag module cover flap *("bit lip")*. The front right passenger was removed from the vehicle by rescue personnel and pronounced deceased at the scene. Use of the available 3-point manual lap and shoulder belt system would have mitigated the injuries sustained by the passenger, in lieu of a redesigned passenger air bag deployment.

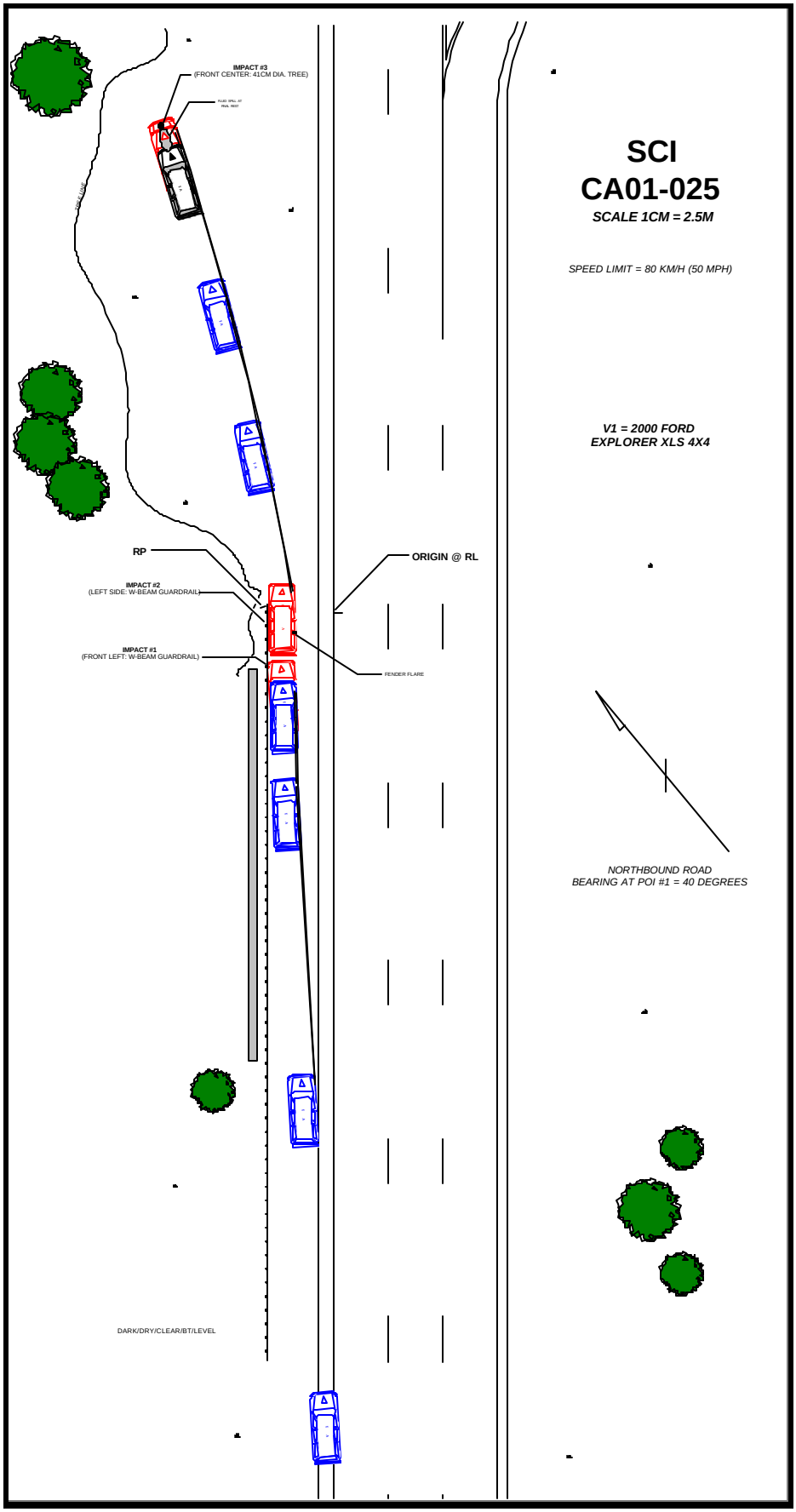

Figure 10. Scene Diagram.