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Forensic Engineering Determination of Who Was Driving

by Jeffrey D. Armstrong, P.E. (NAFE 644F)

Abstract

The investigation of vehicle crashes occasionally presents a question of who was driving a vehicle at the time of a collision. Many accidents result in drivers and passengers being thrown about the passenger compartment, or being completely ejected from their vehicle. In such cases, driver, passenger, and witness statements are often in conflict with one another; especially when the driver could potentially be charged with a crime, or be held liable for damages resulting from a crash. In many cases, physical evidence can provide the forensic engineer with information to conduct a proper reconstruction of the crash, to perform an occupant kinematic analysis, and to make a determination and render an opinion regarding who was driving the vehicle at the time of the crash.

This paper will address methodologies for data collection and crash reconstruction that can be used in determining who was driving a vehicle at the time of a crash. It will include instruction to the at-scene investigator as to data that can be helpful in such analyses and determinations. Two case studies will be presented in which the author analyzed the crash data to determine who was driving.

Introduction

When investigating and reconstructing a collision in which there is some question as to who was driving at the time of a crash, special care must be taken during the investigation and reconstruction phases in order to collect proper data and information, and then properly analyze that information. The investigating forensic engineer will need to search for information and clues regarding the positioning and motion of the driver and occupants as they conduct the vehicle inspection. Vehicle damage must be carefully analyzed to determine the principal direction of force of a collision or collisions. During the reconstruction phase, a careful analysis of vehicle movement must be conducted, from initial contact, through maximum engagement and separation, and finally through the post-separation movement of the vehicle to its final rest. An understanding of and an ability to calculate collision forces, rotational movement, and rollover rates will greatly aid in the determination of who was driving.

Vehicle Inspection

The sooner that a vehicle can be inspected after a collision, the more information will be available to assist in the determination of who was driving the vehicle. The vehicle inspection will consist of two phases; an exterior inspection and an interior inspection.

Jeffrey D. Armstrong, P.E., 17844 North U.S. Highway 41, Lutz, Florida 33549

During the exterior inspection, the engineer or assigned investigator will need to document all damage to the vehicle which resulted from the accident. Damage areas should be measured and photographed, and an initial assessment of the Principal Direction of Force (PDOF) should be performed. Areas of contact damage and induced damage should be identified and documented. The investigator should look for areas of secondary impact between vehicles, or evidence of impacts with other objects which may be present at the accident location. In the case where a vehicle has rolled over, evidence of contact with the ground should be carefully documented. The location and direction of scratch marks on the vehicle, in combination with an analysis of the evidence at the accident scene, will help to identify rollover locations, rollover rates, and the number of times a vehicle rolled. Any collapsing or crushing of the support pillars or the roof must be documented. The identification of what parts of the vehicle came in contact with the ground can assist in determining how occupants were ejected from the vehicle. Various data collection techniques, such as laser mapping of an accident vehicle using a total station or a 3-D scanner will provide the engineer with detailed information which will assist in the determination of how and where contact forces were applied to the vehicle. All points of contact damage should be carefully analyzed to determine whether they came from contact with another vehicle, the roadway, barrier walls, guardrails, drainage structures, trees, or other objects at the accident location.

During the interior vehicle inspection, the engineer or investigator should look for and identify evidence of occupant contact with the interior of the vehicle. When occupants are ejected from the vehicle, the engineer must look for evidence of where and how occupants were ejected from the vehicle. The steering wheel should be inspected for contact damage. When passengers are unrestrained, damage to the windshield can occur when struck by occupants' heads. The inspection of the "headstar" damage on the windshield should include a search for hair fibers or traces of bodily fluids such as blood. It may be necessary to preserve such samples for future analysis. The engineer should contact a forensic laboratory for specific instructions regarding how such samples should be gathered, documented, and preserved. Seat positions should be documented and measured. Knee bolsters should be inspected for contact damage. Deployed airbags should be inspected for traces of bodily fluids, lipstick and makeup stains, or other evidence of contact with occupants. Seat belts should be inspected to see if they were in use at the time of a crash, and to see if they were functioning properly. Door panels, roofs, headliners, dash boards, and other interior surfaces should be inspected for evidence of occupant contact. In some cases, it may be helpful to dust various surfaces for fingerprints. Fabric imprints matching clothing worn by occupants can sometimes be seen by the careful investigator on interior vehicle surfaces.

Accident Scene Inspection

As with the investigation of any accident where a reconstruction will be required, careful documentation of the accident scene is important. Documentation and mapping of all skid marks, tire marks, scrapes, gouges, vehicle fluid stains, and other evidence will aid in the analysis of the post-collision vehicle trajectories. Investigators should identify and map locations of broken glass and other vehicle debris. In the case of a vehicle rollover, investigators should attempt to determine contact points between the ground and the vehicle, and to match damage areas on the vehicle with contact areas on the ground. Roadway grades and cross-slopes should be measured, and all topographic features that might have affected the vehicle trajectories must be documented. The scene investigator should look for any physical features that may have had the effect of altering the trajectory of the vehicles, such as curbs, fire hydrants, trees, fences, varying surface materials, drainage swales, sign posts, or any other object that may have come in contact with the vehicles.

Evidence From Occupants

In some cases the engineer may be provided with autopsy reports and/or photographs. These can provide valuable information to assist in the reconstruction. It may be possible to match trauma such as head, chest, or knee injuries with damage inside the vehicle. Scratches on the bodies may indicate the direction that an ejected occupant exited the vehicle. Bruising and abrasions from contact with the steering wheel or other interior features may assist in determining the seating positions of occupants.

Forensic Engineering Accident Reconstruction

In cases where the forensic engineer has the task of determining who was driving at the time of the accident, many of the same steps must be taken as with any other accident reconstruction. Information from the vehicles must be matched with information from the roadway to assess the movement of the vehicles from the point of contact to final rest. Pre-impact and post-impact speeds need to be calculated. The PDOF for each vehicle must be determined. In rollover accidents an attempt should be made to determine the number of times a vehicle rolled over, and where various parts of the vehicle struck the roadway during the rollover. It may also be necessary to calculate the roll rate of a vehicle at various points along the roll path to determine when during a rollover the occupants were ejected, and to determine the speed and direction that the occupants were traveling when they were ejected. The engineer can then compare the ejection locations with the final rest locations of the occupants to assist in determining seating positions.

Occupant Movement Analysis

Newton's first law states that, "*Every body persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.*" In the field of accident reconstruction engineering, this means that when a collision occurs, an unrestrained occupant will continue to move in the same direction and at the same speed they were moving before the collision, until some object interferes with or changes their motion. Once the body comes in contact with interior areas of the vehicle, then the occupants' speed and direction of travel will be altered by the forces applied by the vehicle surfaces. For example, if a vehicle is driven straight into a solid wall, the vehicle will begin to decelerate very rapidly as the front is crushed against the wall. While the vehicle is decelerating, unrestrained occupants will continue to move forward at the same speed and in the same direction they were traveling prior to the impact with the wall, until they strike the steering wheel, dash board, windshield, or other areas of the vehicle's interior. The movement of the occupants will typically be directly opposite of and parallel to the PDOF.

Inasmuch as occupants move opposite of and parallel to the PDOF, the identification of the PDOF is critical to a proper occupant analysis. By identifying points of occupant contact within the vehicle, and by knowing the direction of the PDOF, the forensic engineer will often be able to determine the seating position of occupants prior to the collision.

When occupants are ejected, a careful analysis must be performed to determine what events in the crash may have caused the ejections. Ejections often occur at points where there is a sudden change in the speed and/or direction of the vehicle, such as the initial impact or secondary impacts with structures such as trees or poles.

Occupant Ejections In Rollover Accidents

During rollovers, vehicle occupants are exposed to additional centrifugal forces caused by the rolling of the vehicle. An assessment of these forces requires an analysis of the number of times a vehicle rolled, the roll rate of the vehicle, and the orientation of the rolling vehicle on the road at all points in the rolling phase of the accident.

Figure 1 illustrates the forces to which a driver would be subjected during a vehicle rollover, and the subsequent path an ejected driver would take. The forward motion of the vehicle results in a forward velocity vector. The centrifugal force created by the rolling of the vehicle points away from the center of rotation. This centrifugal force will tend to pull an un-belted driver out of his/her seat, and can potentially be strong enough to eject the driver through the side window. Once ejected, the resultant velocity vector created by the forward motion of the vehicle and the rolling of the vehicle will throw the driver up and over the top of the vehicle as indicated by the dashed line. Once the ejected occupant lands on the ground, their forward velocity will cause them to slide or tumble on the ground to a final rest position.

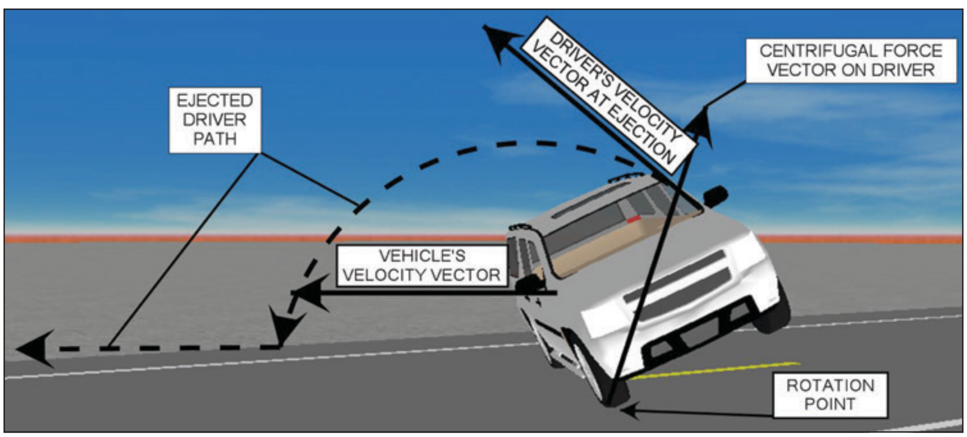

Figure 1
Diagram illustrating velocity vectors and force vectors present during a vehicle rollover and subsequent ejected occupant path.

Sample Case Number 1

A 2006 Ford Taurus was traveling north when it entered an intersection and struck a 1996 Chevrolet Lumina. Both vehicles rotated clockwise and traveled to the northeast corner of the intersection. The Chevrolet Lumina rolled over onto its roof and came to rest against the front porch of a house at the northeast corner of the intersection. The driver of the Lumina was partially ejected from his vehicle

Figure 2
Front view of Ford Taurus.

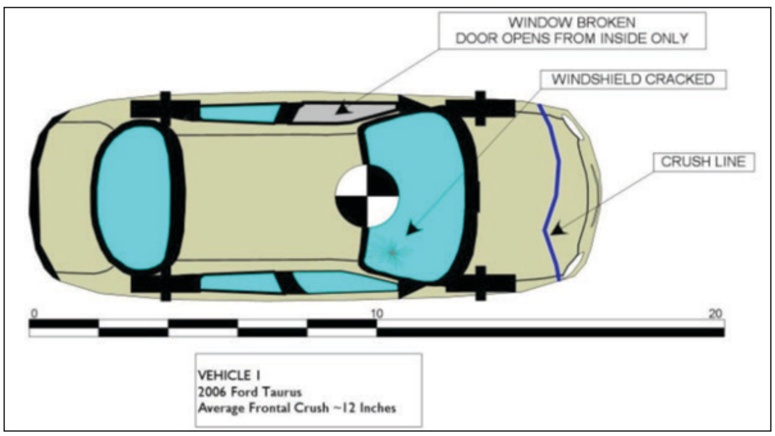

Figure 3
Crush Diagram for Ford Taurus.
Average crush depth 12 inches.

Figure 4
Passenger-side view of Chevrolet Lumina.

which came to rest on top of his torso, resulting in his fatal injuries. The Ford Taurus came to rest against a fire hydrant at the northeast corner of the intersection. When the police and paramedics arrived at the scene, a young woman was unconscious and unrestrained (not wearing a seat belt) in the driver's seat of the Ford Taurus. The reconstruction of this crash indicated that the Ford Taurus had run through a stop sign while traveling well above the posted speed limit. The young woman was subsequently charged with vehicular homicide.

The Ford Taurus had severe contact damage to the front of the vehicle as seen in Figure 2. A damage diagram for the Ford Taurus was prepared as shown in Figure 3. The average crush depth across the front of the Taurus was 12 inches. The driver and passenger airbags were deployed, and the driver's seat belt was latched with the lap belt resting on the seat and the shoulder harness was resting against the seat back. Rescue personnel indicated that they had to retrieve the young woman through the passenger's door because the driver's door would not open. During our inspection we confirmed that the driver's door would not open from the outside. However, during our interior inspection it was discovered that the door could be easily opened from the inside.

The Chevrolet Lumina received severe contact damage on the passenger-side of the vehicle as shown in Figure 4. A damage diagram for the Chevrolet

Lumina was prepared and is shown in Figure 5. The maximum depth of the crush was approximately 21 inches. The airbags in this vehicle did not deploy.

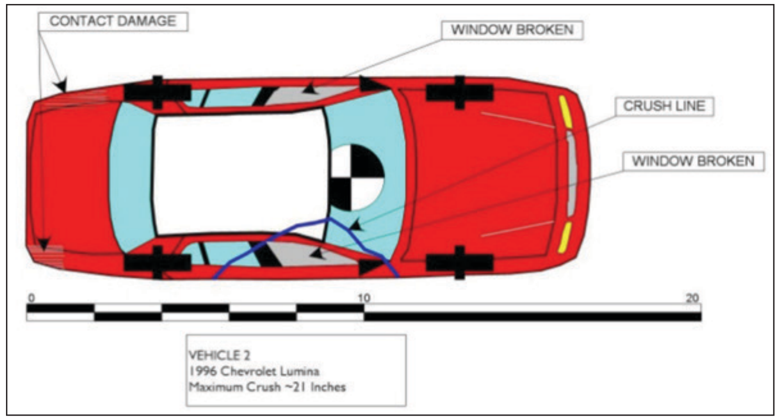

Figure 5
Crush Diagram for Chevrolet Lumina.
Maximum crush depth 21 inches.

During the investigation of this crash, information was presented to investigators suggesting that the boyfriend of the young woman who was found in the Ford Taurus had been in the vehicle at the time of the crash and had fled the scene prior to the arrival of rescue personnel. Traces of bodily fluids were found near the center of the driver's airbag. The airbag was removed from the vehicle by investigators, with the area of the fluids being cut out and sent to a lab for analysis. Figure 6 shows the airbag that was removed from the vehicle and the area that was cut out of the airbag. An analysis of the DNA which was found on the airbag matched that of the boyfriend. However, since the young woman was found passed out in the driver's seat at the scene, the State continued to charge the young woman with vehicular homicide. The author was retained to analyze the physical evidence and the dynamics of the collision to determine who was driving the Ford Taurus at the time of the collision.

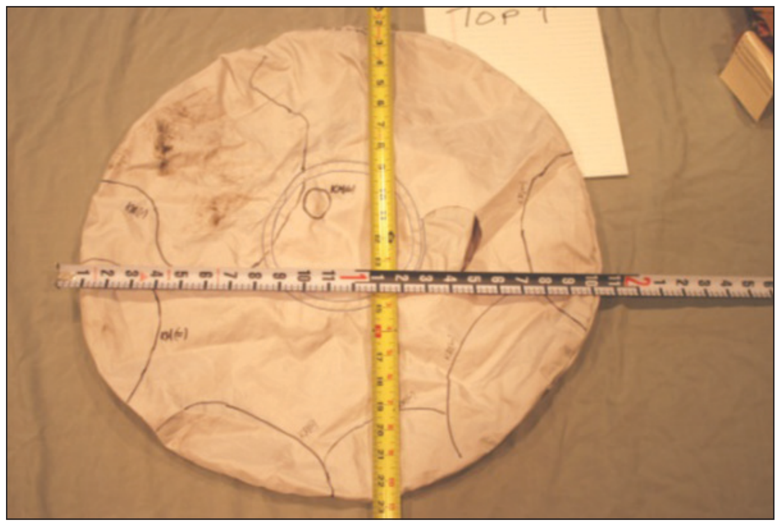

Figure 6
Driver's Airbag from the Ford Taurus.

A reconstruction of the collision was performed which indicated that the Ford Taurus was traveling at a speed of 54 to 63 miles per hour (mph) at the time of impact, and the Lumina was traveling at a speed of 30 to 38 mph at impact. The speed of the Taurus indicates that it did not stop at the stop sign prior to entering the intersection. A reconstruction diagram was prepared and is shown in Figure 7.

Following the collision the Chevrolet Lumina rotated clockwise approximately 360 degrees. It continued to rotate as it traveled across the curb, sidewalk, and the front yard of the residence. The Chevrolet Lumina rolled over, coming to rest on its roof. The driver of the Lumina was partially ejected through the driver's window of his vehicle, with the vehicle coming to rest on top of the driver's upper body. The Ford Taurus rotated clockwise approximately 90 degrees (¼ turn), coming to rest at the corner of the intersection.

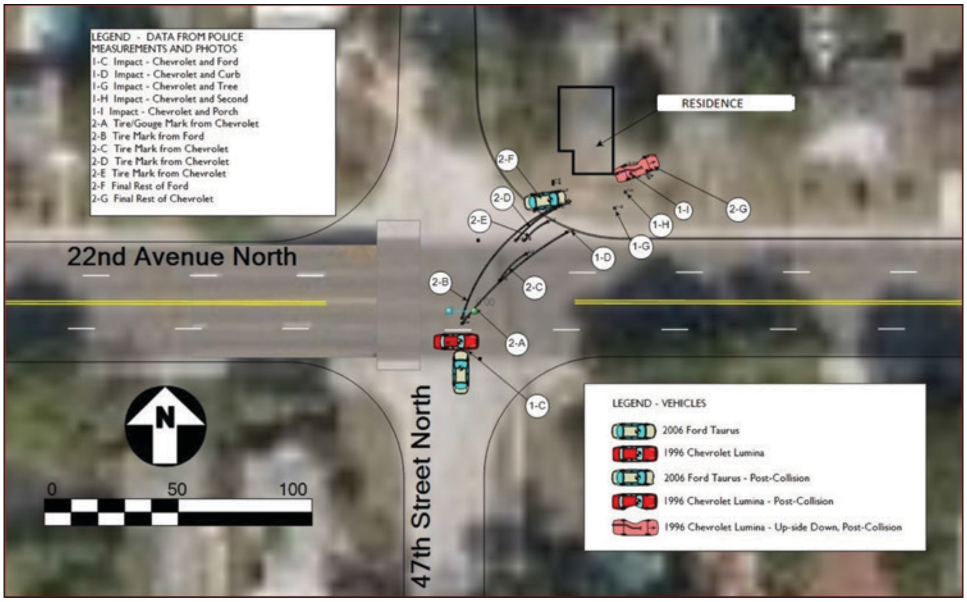

Figure 7
Accident Reconstruction Diagram.

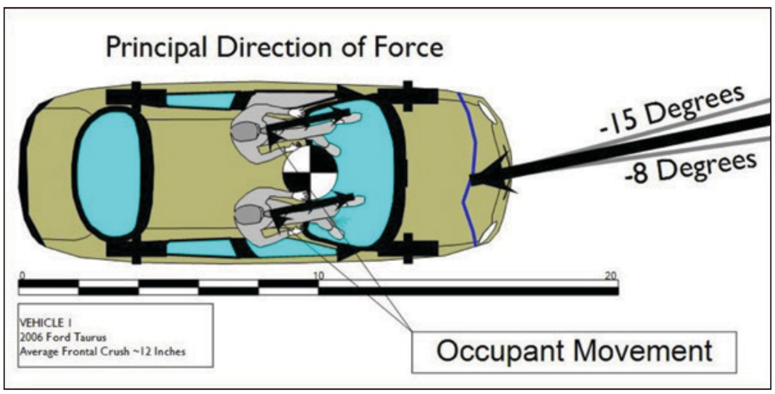

Figure 8
Principal Direction of Force (PDOF) and
Occupant Movement Diagram for Ford Taurus.

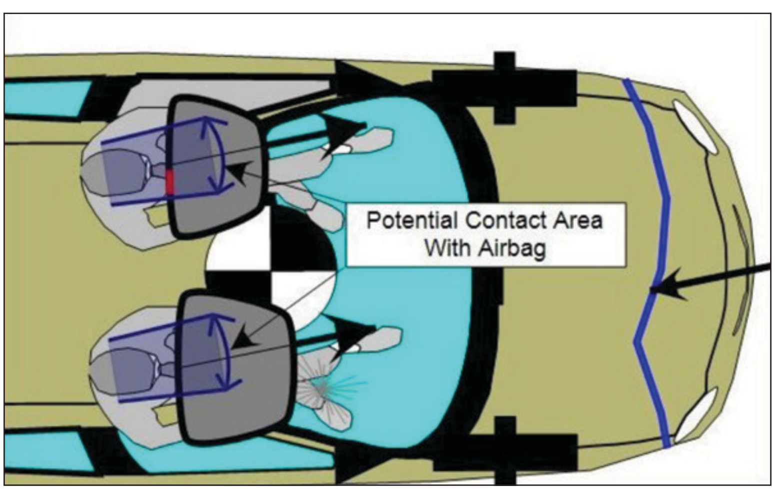

Figure 9
Passenger-Airbag contact diagram.

The Principal Direction of Force (PDOF), or thrust, was -8 to -15 degrees on the Taurus as illustrated in Figure 8. The PDOF defines the direction of force at the point of maximum engagement of the two vehicles.

In a vehicular collision, the occupants will tend to move in a direction opposite of and parallel to the PDOF. Therefore, at the point of maximum engagement, the occupants of the Taurus would move forward with respect to the interior of the vehicle, in a direction 8 to 15 degrees to the left of straight ahead. In a frontal collision, the air bags would typically begin to deploy approximately 25 to 50 milliseconds (0.025 to 0.05 seconds) after the collision begins. During this brief time, passengers will begin to move in the direction of the PDOF, while not yet experiencing the effects of vehicular rotation that may occur after separation.

Figure 8 is an occupant movement diagram that illustrates the direction that the driver and passenger would move during the initial stages of the crash. Figure 9 is an occupant-airbag contact diagram showing where the heads of a driver and occupant would contact the airbags. The location of the DNA sample matching the boyfriend fell within the expected contact area. The diagram clearly indicates that the driver's face would come in contact with that area of the airbag where the boyfriend's DNA was found. The analysis also showed that during the post-collision phase of the accident as the Ford Taurus traveled from the point of separation to the point of final rest, rotational forces were insufficient to have carried a person from the passenger seat to the point where they would come in direct contact with the deflating driver's airbag.

There were suggestions that after the collision, the boyfriend had gotten out of the car and dragged the young woman into the driver's seat. Rescue personnel had been unable to open the driver's door from the outside. This led them to believe that it would have been difficult or impossible for the boyfriend to have quickly escaped the car and then move the young woman to the driver's seat. However, our inspection of the Ford Taurus showed that the driver's door opened easily from the inside, making it possible for the boyfriend to have exited the vehicle through the driver's door and then drag the young woman in the driver's seat. Additionally, the center console and arm rest in the front seat was broken in a manner that would be consistent with dragging a person across the front seat. The damage to the center console would not have normally occurred as a result of the crash.

The evidence clearly indicated that the boyfriend had been in the front seat and in contact with the driver's airbag after it deployed. The occupant movement analysis showed that only the driver of the vehicle was likely to have come in contact with that portion of the airbag that contained the boyfriend's DNA. Our inspection uncovered evidence that supported the theory that the boyfriend had exited the car following the collision and moved his unconscious girlfriend into the front seat.

After our report was submitted to the State, the State dropped the charges against the young woman. The State subsequently charged the boyfriend with vehicular homicide.

Sample Case Number 2

A full-size Sport Utility Vehicle (SUV) carrying a male and a female occupant was driving down a dark country road late at night when the vehicle drifted off the side of the road. The SUV struck the end of a drainage culvert, causing the vehicle to go airborne and roll over. Both occupants were ejected, and were killed. For purposes of resolving the insurance claims related to the two fatalities, it was important to the insurance company to determine who was driving the SUV at the time of the collision. The author was retained to investigate and reconstruct the accident, and to attempt to determine who was driving. When first retained, the client stated that, "I don't need you to do an accident reconstruction. I just need you to figure out who was driving." It was necessary to explain to the client that the determination of who was driving requires a detailed reconstruction in order to properly assess the movement of the occupants relative to the vehicle throughout the crash sequence.

Figures 10 and 11 are photographs taken by the investigating police officers. Figure 10 shows the area where the SUV struck the paved roadway shoulder as it was rolling over. Figure 11 shows the final

Figure 10
Accident scene photograph showing area where SUV rolled over.

Figure 11
Accident scene photo showing SUV at final rest.

Figure 12
Accident location. SUV struck the culvert, rotated, and rolled over.

Figure 13
Accident location, showing landing area of SUV.

rest position of the SUV on the side of the roadway. An inspection of the accident scene was conducted in which the roadway and the evidence from the accident were mapped using a total station. Figure 12 shows the drainage culvert that was struck by the SUV, and which caused it to rotate, go airborne, and ultimately roll over. Figure 13 shows the area where the SUV came to rest.

Based on the mapping of the accident location and on a careful review and analysis of the photographs taken by the investigating police officers, a scale diagram of the accident scene was prepared which showed the roadway configuration, roadway grade, cross slopes on the roadside, the location of the drainage culvert, the location of marks on the roadway that were left by the SUV as it was rolling over, the location of final rest of the SUV, and the final rest locations of the male and female occupants. The accident scene diagram is shown in Figure 14.

The SUV was inspected, photographed, and measured. Significant contact damage was observed in the area of the front-left (driver's) side tire, which had been separated from the vehicle during the crash as seen in Figure 15. There was severe contact damage to the left-front corner of the SUV. It was also observed that the left (driver's) side of the roof had partially collapsed during the rollover phase of the crash as seen in Figure 16. A careful inspection of the interior of the vehicle and the exit point revealed no hair or clothing fibers that might have assisted in determining who was driving. The interior of the vehicle was dusted for fingerprints, but no prints were found; probably because the soft surfaces of the vehicle interior could not hold fingerprints.

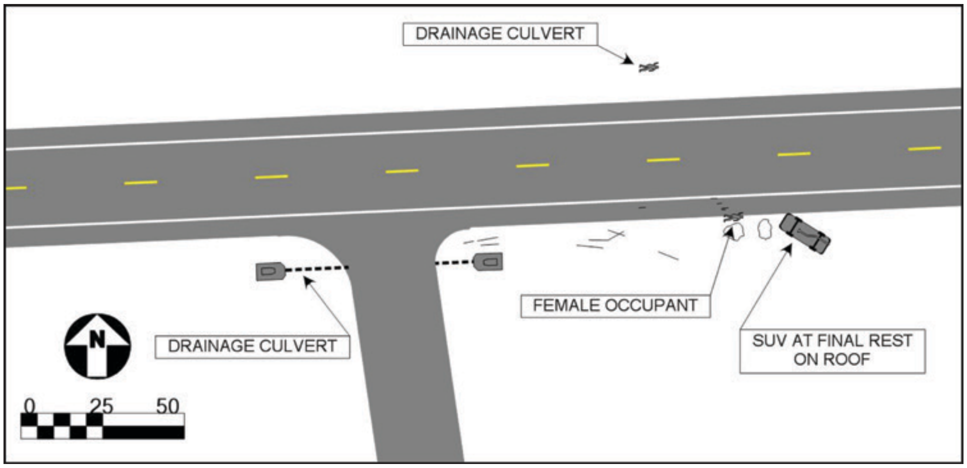

Figure 14
Accident Scene Diagram.

The evidence that was documented at the accident scene and on the SUV was used to reconstruct the collision. A scale model of the SUV was marked to show damage areas using a permanent marker. A scale drawing of the accident location, plotted at the same scale as the scale model SUV was prepared to assist in the analysis.

Figure 15
Vehicle inspection photo.

The SUV was equipped with an airbag control module which was capable of recording crash information. Among the helpful information contained in the module was the recording of the pre-crash speed approximately 10 mph above the posted speed limit, and an indication that the driver's seat belt was not in use at the time of the collision. The pre-crash speed that was reported by the airbag control module was verified by the engineer-

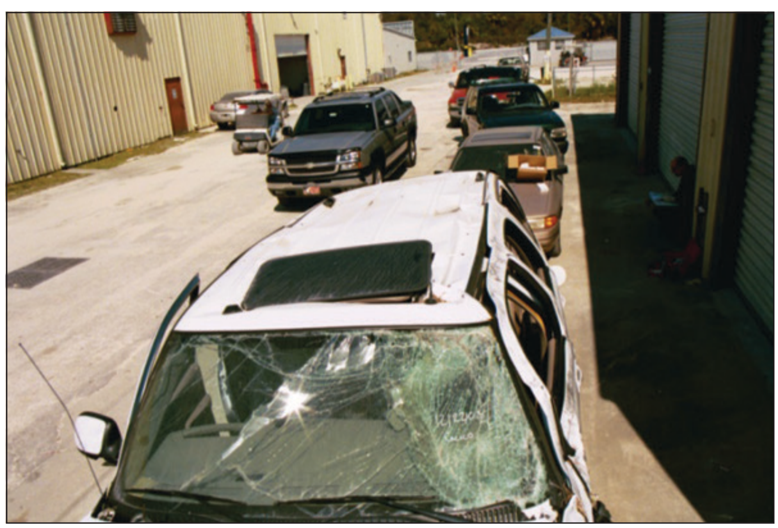

Figure 16
Vehicle inspection photo.

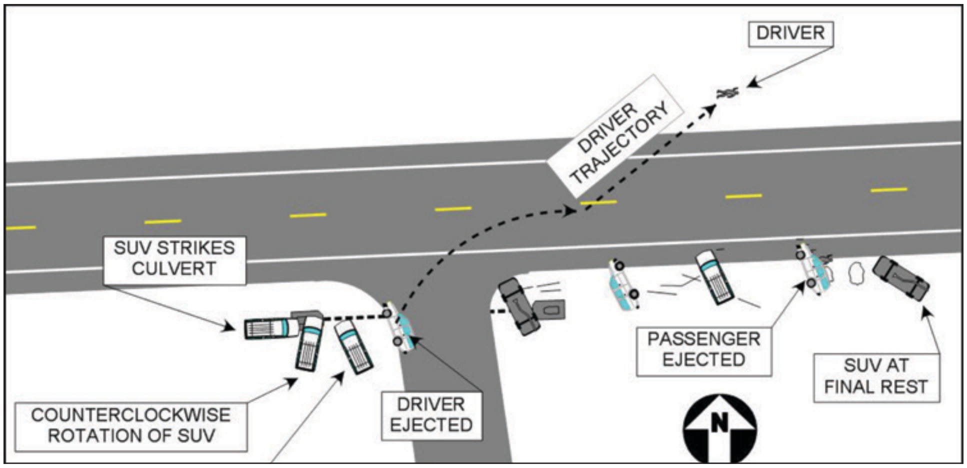

Figure 17
Accident sequence diagram.

ing reconstruction of the crash. The seat belts were inspected during our vehicle inspection. There was no evidence on the seat belts to suggest that they had been in use at the time of the collision, consistent with the report from the airbag control module.

After drifting off the roadway, the SUV struck the end of the drainage culvert that is seen in Figure 12. The left front tire struck the opening in the culvert, causing the SUV to rotate in a counterclockwise direction. Once the SUV rotated to the point where it was approximately perpendicular to its direction of travel it began to roll over, leading with the right (passenger) side of the vehicle. The vehicle went airborne during the rollover, striking the ground with the edge of the roof on the left (driver's) side of the vehicle. As the vehicle rolled over, the extreme centrifugal forces caused by the rolling of the vehicle ejected the driver through the driver's side window, throwing him up and over the rolling vehicle in a direction across the road. The driver then struck the ground and tumbled to a final rest position on the north side of the road as shown in Figure 17. Calculations were performed to determine the speed at which this occupant would have exited the vehicle. Calculations were also performed to determine the speed required for a human body to travel from the point where it was determined that the ejection occurred to the point of final rest on the opposite side of the road. Each calculation resulted in the same speed for the ejected body, supporting the determination of the ejection location. Since the body of the male occupant was found on the north side of the road, it was determined that he was driving at the time of the crash.

The SUV continued to roll parallel to the roadway, coming to rest on its roof. Just prior to rolling onto its roof, the right (passenger) side of the vehicle rolled over the grass, now at a much lower speed and roll rate, where the occupant of the passenger seat essentially fell out the window of the passenger's (right side) door. The body of the female occupant was found at the location where the passenger-side window would have rolled over the ground. Therefore it was determined that the female occupant had been seated in the passenger seat. The rollover sequence and the ejection events are illustrated in Figure 17.

Conclusion

Careful inspection of the accident scene and the interior and exterior of accident vehicles can often provide useful clues in the determination of who was driving. Whenever a question exists as to who was driving a vehicle at the time of a crash, accident reconstructionists must use great care to specifically look for such clues. An understanding of the forces related to the crash, and of the expected occupant movements during the crash event are essential tools in the analysis. The examples that have been shown demonstrate many of the tools that can assist in the determination of who was driving.

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