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Veridian Engineering
Buffalo, New York 14225

SEAT BACK FAILURE/CHILD FATALITY INVESTIGATION

VERIDIAN CASE NO. CA01-032

VEHICLE: 1999 TOYOTA CAMRY

LOCATION: NEW YORK

CRASH DATE: MAY 2001

Contract No. DTNH22-94-07058

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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 be 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 of the involved vehicle(s) or their safety systems.

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17. *Abstract*

This investigation focused on the failure of the driver's seat back and the fatal injury mechanism of the left rear child passenger seated in a 1999 Toyota Camry. The Toyota was involved in a rear-end crash with a 1986 Pontiac 6000 station wagon. The Toyota was stopped, waiting to turn left, when struck from behind by the Pontiac. The Toyota was occupied by a 37 year old female driver and a 5 year old female left rear passenger. Both occupants of the Toyota were restrained at the time of the crash. The force of the 6 o'clock impact caused the occupants to initiate a rearward trajectory and load their respective seat backs. The driver's inertial loading of the seat back deformed the seat back rearward into the left rear occupant space. The child seated in this position suffered fatal skull fractures and underling brain injury, as a result of a rebound contact with the driver's head. The driver reportedly suffered a contusion to the back of her head, although she did not require medical attention.

The Special Crash Investigations team at Veridian Engineering was informed of the crash by the New York State Police (NYSP) Fatal Crash Reconstruction team. Veridian SCI passed the notification to the Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA). NHTSA's Office of Defects Investigation subsequently assigned an on-site crash investigation. The Toyota was located at an insurance salvage yard and was available for inspection.

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BACKGROUND

This investigation focused on the failure of the driver's seat back and the fatal injury mechanism of the left rear child passenger seated in a 1999 Toyota Camry. The Toyota was involved in a rear-end crash with a 1986 Pontiac 6000 station wagon. The Toyota was stopped, waiting to turn left, when struck from behind by the Pontiac. The Toyota was occupied by a 37 year old female driver and a 5 year old female left rear passenger. Both occupants of the Toyota were restrained at the time of the crash. The force of the 6 o'clock impact caused the occupants to initiate a rearward trajectory and load their respective seat backs. The driver's inertial loading of the seat back deformed the seat back rearward into the left rear occupant space. The child seated in this position suffered fatal skull fractures and underling brain injury, as a result of a rebound contact with the driver's head. The driver reportedly suffered a contusion to the back of her head, although she did not require medical attention.

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SUMMARY

Crash Site

This two-vehicle crash occurred during the morning hours of May, 2001. At the time of the crash, it was daylight and the weather was not a factor. The road surface was dry. The road was comprised of two asphalt lanes, oriented northwest/southeast in direction. The road was straight with a positive grade (est.<2 percent) in the northwest direction. The sight distance and visibility were not factors in the crash. Local businesses bordered both sides of the roadway. A parking lot and an access driveway to a local business were located on the south side of the road. The speed limit in the area of the was 72 km/h (45 mph). **Figure 1** is a northwest trajectory view of the crash scene with the vehicles at final rest. The photograph was taken during the police investigation.

Figure 1: Trajectory view at the crash scene.

Pre-crash

The 1999 Toyota Camry was stopped in the northwestbound lane waiting to turn left into the parking lot of a local business. This vehicle was driven by a 37 year old restrained female. The left rear seat was occupied by the driver's 5 year old daughter. The child was restrained by the vehicle's manual 3-point restrain system. The Toyota was stopped for an unknown duration, waiting for conflicting traffic to clear prior to initiating the left turn into the parking lot. Coincident to this, a 1986 Pontiac 6000 LE station wagon, driven by a 70 year old restrained male, was also northwestbound. The driver of the Toyota was unaware of the approaching Pontiac.

Crash

For unknown reasons, the driver of the Pontiac failed to recognize the stopped Toyota precipitating the crash. The front of the Pontiac struck the rear of the Toyota in a co-linear 12/6 o'clock impact configuration. The direct contact damage extended across the full end-width of the respective vehicles. An analysis of the damage indicated the centerline of the Pontiac was offset approximately 15 cm (6 in) to the left of the Toyota's centerline. An imprint of the Pontiac's license plate into the rear bumper fascia of the Toyota was identified in the on-scene police photographs. (The rear fascia had separated from the vehicle post-crash and was not with the vehicle at the time of the SCI inspection.) The maximum crush of the Toyota measured 89 cm (35 in) and was located at the left rear corner. The Toyota's total delta V was determined to be 45 to 48 km/h (28 to 30 mph).

The Pontiac's momentum displaced both vehicle's 32 m (105 ft) forward, along the Pontiac's trajectory, to their final rest positions. The left offset orientation of the impact caused the Toyota to rotate 65 degrees clockwise as it slid to rest. The Toyota came to rest straddling the road's center line facing north. The Pontiac came to rest on the road's centerline, facing northwestward. The front of the Pontiac was in contact with the right rear quarterpanel of the Toyota, **Figure 2**.

Figure 2: Overhead view of the vehicles at final rest.

The police investigation identified tire and gouge marks that defined the point of impact. The post-crash trajectory of the vehicles was evidenced by tire marks and liquid debris. These evidences were documented by the police investigation using an electronic mapping system (i.e. a total station). That data was utilized in developing the crash schematic attached to this report, **Figure 16**, page 12. There were no pre-crash skid marks attributed to the Pontiac.

Post-crash

The police, fire and ambulance personnel responded to the crash. The driver of the Toyota had exited the vehicle under her own power. She was distraught and unclear regarding the details of the crash. She reportedly suffered a contusion to the posterior aspect of her head.

Several witnesses to the crash responded to the vehicles and forced open the Toyota's left rear door. The child was found restrained in the left rear position and slumped to the right. She was bleeding about the nose and right ear and was unresponsive. She was wearing a backpack. The emergency responders began applying resuscitation and first aid to the child. She was emergently transported to a local hospital, where she was pronounced deceased 90 minutes post-crash.

Figure 3: On-scene police photograph of the left rear interior.

Figure 3 is an on-scene view of the left rear interior. Inspection of the vehicle revealed a significant amount of blood noted in the left rear seat position, as well as on the upper right aspect of the driver's seat back. The driver's seat back in the Toyota deformed rearward and downward as a result of the dynamic loading by the driver. The child's shoe was observed to have been wedged and suspended between the driver's seat and the rear seat.

The driver of the Pontiac was found sitting sideways in the driver's seat with his feet out of the vehicle. He complained of a bloody nose and chest pains. He had no recollection of observing the Toyota pre-crash. He was transported to the emergency room of a local hospital. It was determined he suffered a broken nose as a result of steering wheel contact and a fractured sternum resultant to loading the 3-point restraint.

1986 PONTIAC 6000 LE STATION WAGON

Exterior Damage

The 1986 Pontiac 6000 LE station wagon was identified by the Vehicle Identification Number (VIN): 2G2AG35X2G9 (production sequence deleted). **Figures 4 and 5** are the left and right side views of the Pontiac taken during the police investigation. It was not available for SCI inspection.

The front plane of the Pontiac sustained direct contact damage that extended across its entire 152 cm (60 in) end width. The front structures of the vehicle deformed rearward and buckled down. The buckling appeared to have occurred in the area of the left and right front suspension. The vehicle's deformation was documented during the course of the police investigation and was used in the analysis of the crash. The crush profile measured along the front bumper was as follows: C1=34.0 cm (13.4 in), C2=44.0 cm (17.3 in), C3=47.0 cm (18.5 in), C4=52.0 cm (20.4 in), C5=54.0 cm (21.2 in), C6=59.0 cm (23.2 in). The Collision Deformation Classification (CDC) was 12-FDEW-3. The total delta V of the impact calculated by Damage model of the WINSMASH program was 53.0 km/h (32.9 mph). The impact speed of the Pontiac calculated by the Trajectory model was 105.2 km/h (65.4 mph).

Figure 4: Pontiac left side view.

Figure 5: Pontiac right side view.

An analysis of the Pontiac's damage indicated the calculated WINSMASH delta V overestimated the vehicle's speed change. This overestimation may have been caused by inappropriate stiffness values utilized by the model (considering the age and condition of the Pontiac) coupled with the unverified crush profile measured by the police investigators. A delta V in the 40 to 45 km/h (25 to 28 mph) range was more consistent with the vehicle's damage, crash dynamics and driver injury. The recalculated impact speed of the Pontiac based on linear momentum would have been in the range of 85 to 93 km/h (53 to 58 mph).

1999 TOYOTA CAMRY LE

The 1999 Toyota Camry LE was identified by the Vehicle Identification Number (VIN): 4T1BG22K5XU (production sequence deleted). The 4-door sedan was equipped with a power train that consisted of a 2.1 liter/I4 engine linked to a 4-speed automatic transmission. The vehicle's date of manufacture was 08/98. The electronic odometer could not be read at the time of the inspection. The vehicle's manual restraint system consisted of 3-point lap and shoulder belts for the five seat positions. The Supplemental Restraint System (SRS) consisted of frontal air bags for the driver and front right passenger.

Figure 6: Rear view of the Toyota.

Exterior Damage

The back plane of the Toyota sustained 147 cm (58 in) of direct contact damage that extended across the vehicle's entire end width, **Figure 6**. **Figures 7 and 8** are the left side and right lateral views of the damage, respectively. The nature of the damage was indicative of a direct bumper to bumper impact with a subsequent override as the vehicles reached maximum engagement. The crush profile measured at the rear bumper reinforcement bar was as follows: C1=89.0

cm (35.0 in), C2=75.0 cm (29.5 in), C3=69.0 cm (27.2 in), C4=64.0 cm (25.2 in), C5=60.0 cm (23.6 in), C6=56.0 cm (22.0 in). The 6 o'clock direction of the impact force deformed the rear structures of the vehicle forward to the C-pillars. The truck space was collapsed. The roof was buckled above the left and right B-pillars. The left wheelbase reduction measured 9.1 cm (3.6 in). The right wheelbase measurement was unchanged. The backlight disintegrated during the impact. The glazing of all the side windows were intact. All the doors were operational at inspection. The Collision Deformation Classification (CDC) was 06-BDEW-6. The total delta V of the impact calculated by the Damage Model of the WINSMASH program was 53.0 km/h (32.9 mph). The longitudinal and lateral components of the delta V were +53.0 km/h (+32.9 mph) and 0 km/h (0 mph), respectively. This calculation overestimated the speed change in this crash due to the magnitude of crush, the default stiffness values used by the model and the input data describing the Pontiac 6000.

An analysis of the crash using the conservation of linear momentum calculated the delta V of the Toyota was approximately 45 to 48 km/h (28 to 30 mph). This calculation was more consistent with the dynamics of the crash and the vehicle's damage based on SCI experience. The Toyota was stopped at the time of the impact; its impact speed was 0 km/h (0 mph).

Figure 7: Left view of the Toyota.

Figure 8: Right lateral view.

Interior Damage

The interior damage to the Toyota was limited to the deformation of the driver's seat back and blood evidence located within the left rear occupant space. There was no measurable intrusion into the occupant compartment caused by the exterior crash forces.

The driver seat, **Figure 9 and 10**, was adjusted to a mid to rear track position measured at 8.9 cm (3.5 in) forward of full rear. The seat was jammed in this position due to the deformation of the seat and could only be moved forward one notch (approximately 0.75 in). The total seat travel measured on the right front seat was 22.9 cm (9.0 in). The seat back was deformed to an angle of 45 to 50 degrees, referenced to vertical. The deformed seat back angle was measured 51 cm (20 in) above the seat bight. The seat back

could be reclined approximately 5 degrees further (50 to 55 degrees total) by using the recline mechanism but could not be raised to a more vertical position. The anti-submarine angle of the seat cushion measured 30 degrees. The majority of the seat back deformation occurred in the upper aspect of the seat back frame (in comparison with the right front seat back). A 5 cm (2 in) square area of blood evidence was identified on the upper rear inboard aspect of the seat back, **Figure 11**. The head restraint was raised approximately 2.5 cm (1 in). This blood evidence had deteriorated as compared to the on-scene photographs, refer to Figure 3.

Figure 9: Right interior view.

Figure 10: Left interior view.

Figure 11: Blood evidence to upper seat back.

For reference, the track position and seat back angle of the right front seat were measured. The right front seat was adjusted to a rear track position. The right front seat back angle was 19 degrees measured 51 cm (20 in) above the seat bight.

The rear seat was configured as a bench with split forward folding seat backs. The bench measured 147 cm x 43 cm (58 in x 17 in) width by length. The antisubmarine angle measured 17 degrees. The width of

the left rear seat back measured 46 cm (18 in). The width of the rear seat back spanning the center and right positions measured 61 cm (24 in). The outboard aspects of the rear seat back were comprised of 20 cm (8 in) wide bolsters. The upper aspects of the folding seat backs were detached from the package shelf. The left rear seat back angle was 20 degrees measured 46 cm (18 in) above the seat bight.

An area of dried blood evidence was located on the left central aspect of the seat cushion immediately right of the left rear seat belt buckle, **Figure 12**. This area was the final rest position of the child's head. The blood evidence measured 23 x 28 cm (9 in x 11 in) width by length. A blood smear measuring 6.4 cm x 7.6 cm (2.5 in x 3.0 in) was located on the left outboard seat back bolster and was centered 6 in above the seat bight. This contact evidence probably resulted during the removal of the child from the vehicle.

Figure 13 is a right interior views depicting the residual interior space at the left rear position.
The horizontal distance from the rear seat back to the driver's head restraint measured 39.4 cm (15.5 in). A comparison measurement taken from the right rear seat to right front seat measured 73.7 cm (29.0 in). The horizontal distance from the left rear seat bight to the deformed driver seat back measured 51 cm (20 in).

Figure 12: View of the left rear seat position.

Figure 13: Measurements of the residual left rear interior space.

Manual Restraint System

The 1999 Toyota Camry was equipped with manual 3-point lap and shoulder belts in all five seat positions. The restraints consisted of sliding latch plates, continuous loop webbings and dual mode locking retractors. The drivers belt was stowed upon inspection and was operational. Examination of the latch plate revealed evidence of historical use. Inspection of the webbing and the frictional surfaces of the hardware exhibited no evidence indicative of use during this crash. However, given the 6 o'clock direction of force evidence of occupant loading would not be expected.

An interview with the driver's husband revealed the family was habitual seat belt users. Inspection of the vehicle revealed frequent usage marks in all five belt positions. The seat fabric in the right rear seat was worn from the long term use of a child safety seat in that position. Considering the historical evidence, interview, and the driver's statements, the driver was restrained during the crash.

The observations of the first responders indicated the left rear child occupant was restrained by the 3-point lap and shoulder belt, as they approached the vehicle. Upon SCI inspection, the left rear restraint was in the stowed position and was operational. Examination of the latch plate revealed historical usage marks. Examination of the extended webbing and hardware was unremarkable. However, considering the initial rearward kinematics and the size of the child loading evidence would not be expected. The fabric stalk of the left rear buckle, adjacent to the blood evidence on the bench, was stained with blood.

The New York State Police Collision Reconstruction Report submitted by the NYSP Fatal Investigation Unit indicated a blood transfer was noted on the webbing in the area of the buckle, when the webbing was extended to the buckled condition. **Figure 14** is the only on-scene police photograph that depicts this blood evidence. **Figure 15** is a photograph of the webbing taken at the time of the SCI inspection. The on-scene blood evidence had deteriorated between the time of the May crash date and the June SCI inspection. It should be noted that the blood evidence on the driver's seat back and head restraint had also deteriorated between the date of the crash and the SCI inspection.

Based upon the observations of the first responders, the historical usage evidence, the police investigation and in consideration of the occupant kinematics the left rear occupant was restrained by the 3-point lap and shoulder belt during the crash.

Figure 14: Police photograph of the left rear restraint.

Figure 15: Left rear restraint webbing.

OCCUPANT DEMOGRAPHICS

	Driver	Left Rear Child Passenger
Age/Sex:	37 year old/Female	5 year old/Female
Height:	178 cm (70 in)	124 cm (49 in)
Weight:	75 kg (165 lb)	30 kg (66 lb)
Restraint Use:	Manual 3-pt. lap and shoulder	Manual 3-pt. lap and shoulder
Usage Source:	Historical use, police investigation, interview, occupant kinematics	Observations of the first responders, historical use, police investigation, interview, occupant kinematics
Medical Treatment:	No treatment	Fatally injured

DRIVER INJURY

Injury	Injury Severity (AIS 98 Update)	Injury Mechanism
Contusion to the posterior aspect of the head, NFS	Minor (190402.1,6)	Contact to the head of the left rear occupant

Note: this injury was identified during an interview with the driver's spouse.

DRIVER KINEMATICS

Immediately prior to the crash, the driver was restrained and seated with a presumed normal posture. The driver's seat was adjusted in a mid-to-rear track position. Upon impact, the driver initiated a rearward trajectory in response to the 6 o'clock direction of the impact. The driver's upper body loaded the driver's seat back and the seat back began to deform. The upper aspect of the seat back frame deformed rearward into the left rear occupant space. As the seat back deformed rearward, the driver continued to load the frame and also ramped up the seat back. The manual restraint would have offered little resistance, as the driver would have slipped out from under the restraint during the rearward trajectory. Given the driver's stature, it was probable her head moved above the level of the head restraint during the rearward trajectory. The driver sustained a posterior head contusion as a result of her contact with the right temporal region of the rebounding left rear occupant.

LEFT REAR PASSENGER INJURY

Injury	Injury Severity (AIS 98 Update)	Injury Mechanism
Punctate abrasion on the right side of the face at the top of the forehead	Minor (290202.1,7)	Rebound contact to the head of the driver
2.5 cm (1.0 in) diameter contusion on the right side of the face along the mid mandible	Minor (290402.1,1)	Rebound contact to the deformed driver seat back/head restraint
Large area of subgaleal hemorrhage within the right temporal scalp	Minor (190402.1,1)	Rebound contact to the head of the driver
Small left subgaleal hemorrhage associated with a fracture of the skull	Minor (190402.1,2)	Rebound contact to the head of the driver
Massive skull fractures beginning on the right side and communicating to the top and base of the skull	Serious (150404.3,1)	Rebound contact to the head of the driver
Separate smaller basilar skull fractures involving the anterior and posterior cranial fossa	Severe (150206.4,8)	Rebound contact to the head of the driver
Diffuse subarachnoid hemorrhage	Serious (140684.3,9)	Rebound contact to the head of the driver
Subdural hematoma at the base of the skull adjacent to the foramen magnum near the posterior cranial fossa fractures	Severe (140438.4,6)	Rebound contact to the head of the driver
Brain contusions predominately in the right frontal and temporal lobes along the inferior aspect	Serious (140612.3,1)	Rebound contact to the head of the driver
Multiple small abrasions and contusions to the anterior right leg in the mid to upper portion	Minor (890202.1,1) (890402.1,1)	Contact to the deformed driver seat back

The above injuries were identified in the Autopsy Records for the left rear passenger.

LEFT REAR PASSENGER KINEMATICS

Immediately prior to the crash, the child passenger was restrained and seated in the left rear position. She was wearing a backpack which would have placed her slightly forward of the seat back. This forward position may have introduced some slack into the restraint system.

Upon impact, the child initiated a rearward trajectory in response to the 6 o'clock direction of the impact and loaded the rear seat back. Due to the fixed nature of the rear seating system, it was stiffer than the front buckle seats with a non-yielding frame. As the Toyota accelerated to its post-impact speed, the child rebounded with a forward trajectory. The child translated forward and her pelvic region loaded the lap portion of the manual restraint system. As her pelvic region became restrained, the child's forward momentum caused her to bend forward about the waist. Her head would have moved forward and down. The head was probably turned to the left exposing the right aspect. As a result of this kinematic patten, the right temporal region of her head impacted the posterior aspect of the driver's head. The head contact resulted in a scalp abrasion to the right side of the forehead near the hairline and a massive skull fracture. This rebound contact also resulted in the described underlying brain injuries. The child then rebounded rearward from this contact and came to rest in the left rear position slumped to the right.

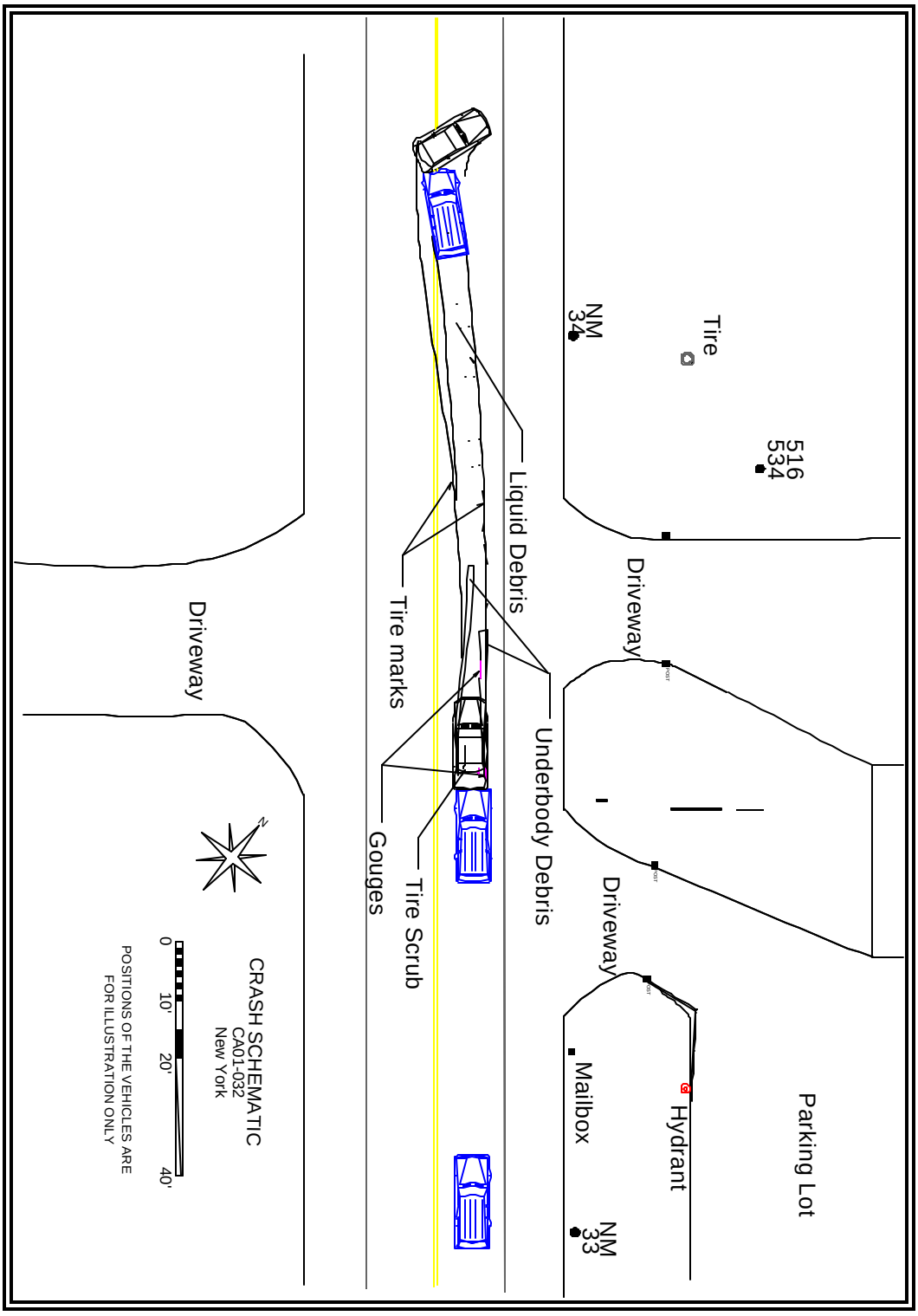

Figure 16: Crash Schematic.