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CALSPAN ON-SITE HYBRID VEHICLE CRASH INVESTIGATION
SCI CASE NO: CA09033

VEHICLE: 2009 TOYOTA PRIUS

LOCATION: PENNSYLVANIA

CRASH DATE: APRIL, 2009

Contract No. DTNH22-07-C-00043

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract This investigation focused on the intersection crash of a 2009 Toyota Prius and a 1997 Ford Explorer. The Toyota Prius was a gasoline-electric hybrid vehicle powered by a 1.5 liter, in-line four cylinder internal combustion engine and a 50 kilowatt electric motor. The vehicle's electrical power was supplied by a stack of nickel-metal hydride batteries located behind the rear seat. The Toyota was equipped with Certified Advanced 208-Compliant (CAC) frontal air bags, seat back mounted side impact air bags and side impact Inflatable Curtain air bags (IC). The Ford was equipped with first-generation frontal air bags. The crash occurred when the front plane of the Ford struck the forward aspect of the Toyota's left side plane in a T-configuration. The force of the impact caused the left IC in the Toyota to deploy. The frontal air bags in the Ford also deployed. The impact caused the Toyota to rotate clockwise and the vehicles contacted again in a secondary side slap. The Toyota was driven by a 44-year-old restrained female. She sustained police reported minor severity injuries and was transported to a local hospital. The 24-year-old restrained male driver of the Ford was not injured and refused medical transport.			
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BACKGROUND

This investigation focused on the intersection crash of a 2009 Toyota Prius and a 1997 Ford Explorer. **Figure 1** is a left front oblique view of the Toyota. The Toyota Prius was a gasoline-electric hybrid vehicle powered by a 1.5 liter, in-line four cylinder internal combustion engine and a 50 kilowatt electric motor. The vehicle's electrical power was supplied by a stack of nickel-metal hydride batteries located behind the rear seat. The Toyota was equipped with Certified Advanced 208-Compliant (CAC) frontal air bags, seat back-mounted side impact air bags and side impact Inflatable Curtain (IC) air bags. The Ford was equipped with first-generation frontal air bags. The crash occurred when the front plane of the Ford struck the forward aspect of the Toyota's left side plane in a T-configuration. The force of the impact caused the left IC in the Toyota to deploy. The frontal air bags in the Ford also deployed. The impact caused the Toyota to rotate clockwise and the vehicles contacted again in a secondary side slap. The Toyota was driven by a 44-year-old restrained female. She sustained police reported minor severity injuries and was transported to a local hospital. The 24-year-old restrained male driver of the Ford was not injured and refused medical transport.

Figure 1: 2009 Toyota Prius

This crash was identified through the weekly sampling of police reported crashes conducted by the General Estimates System (GES) of the National Automotive Sampling System (NASS). The Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) forwarded the police report to the Calspan Special Crash Investigations (SCI) team on May 20, 2009. Calspan SCI initiated follow-up investigation and established cooperation with the insurance carrier for the Toyota. The Toyota was considered a total loss and was available for inspection at a salvage yard. The insurance carrier for the Toyota would only allow a visual inspection of the vehicle (measurements and photographs). The Prius could not be disassembled and its Event Data Recorder (EDR) could not be removed. The Ford was sold via an insurance auction prior to SCI involvement and was not inspected. The inspections of the Toyota and crash site took place May 28, 2009.

SUMMARY

VEHICLE DATA

2009 Toyota Prius

The Toyota Prius was identified by the Vehicle Identification Number (VIN): JTDKB20U197 (production sequence deleted). The front-wheel drive, four door sedan was manufactured in December 2008. The odometer reading was an estimated 966 km (600 miles). The mileage was reported by the insurance carrier. Twelve volt power could not be restored to the instrument panel during the SCI inspection. The Prius was powered by a 1.5 liter internal combustion engine that operated in parallel with a 50 kilowatt electric motor. The hybrid power train was linked to a Continuously Variable Transmission (CVT). The service brakes were a front disc/rear drum system with four-wheel ABS. The Toyota was equipped with Goodyear Integrity P185/65R15 tires mounted on OEM alloy rims. The vehicle manufacturer's recommended cold tire pressure was 240 kPa (35 PSI) front and 230 kPa (33 PSI) rear. The specific measured tire data at the time of the SCI inspection was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	Tire Flat	7 mm (9/32 in)	No	Debeaded
LR	255 kPa (37 PSI)	7 mm (9/32 in)	No	None
RF	262 kPa (38 PSI)	7 mm (9/32 in)	No	None
RR	262 kPa (38 PSI)	7 mm (9/32 in)	No	None

1997 Ford Explorer

The 1997 Ford Explorer was identified by the Vehicle Identification Number (VIN): 1FMDU34E5VU (production sequence deleted). The Explorer was manufactured in February 1997. The odometer had registered 207,426 (128,892 miles). The four-door, 4x4, sport utility vehicle was equipped with a 4.0 liter V6 engine linked to a four-speed automatic transmission. The service brakes consisted of front disc and rear drum system with ABS. The manual restraint system consisted of three-point lap and shoulder belts for the five seat positions. The air bag system consisted of driver and front right passenger air bags that deployed as a result of the crash.

CRASH SITE

The cash occurred during the evening hours of April 2009. At the time of the crash, it was raining and the roads were wet. The area was illuminated by overhead street lighting. The crash occurred at the four-leg intersection of a two-lane north/south road and a two-lane east/west road. The east/west traffic was controlled by stop signs. **Figure 2** is a northward view of the intersection from the southeast quadrant. The speed limit in the area of the crash was 40 km/h (25 mph). A street sign was located in the southeast quadrant of the intersection and was struck by the Ford Explorer as it traveled to

Figure 2: Northwest view of the intersection.

final rest. Tire marks were observed on the sidewalk immediately north of the road sign and were attributed to the Explorer. A schematic of the crash is attached to the end of this report as **Figure 12**.

CRASH SEQUENCE

Pre-Crash

The Toyota Prius was driven by the 44-year-old restrained female. The Prius was stopped at the intersection facing east. The driver intended to turn right and travel south. The Ford Explorer was southbound driven by the 24-year-old restrained male. The crash occurred when the Toyota accelerated forward into the path of the Ford.

Crash

The front right corner of the Ford impacted the forward left side of the Toyota in a 1/10 o'clock impact configuration. The force of the crash caused the Toyota's left IC air bag to deploy. The severity of the crash was calculated by the Missing Vehicle Algorithm of the WINSMASH model. The total delta V of the Toyota was 14.0 km/h (8.7 mph). The longitudinal and lateral delta V values were -5.0 km/h (-3.1 mph) and 13.0 km/h (8.1 mph), respectively. The total delta V of the Ford was 11.0 km/h (6.8 mph). The longitudinal and lateral delta V values were -10.0 km/h (-6.2 mph) and -6.0 km/h (-3.7 mph), respectively.

The impact force, located forward of the Toyota's center of gravity, caused the vehicle to rotate clockwise. The left quarterpanel of the Toyota struck the right quarterpanel of the Ford in a secondary side slap. The Toyota's delta V was 11.0 km/h (6.8 mph). The longitudinal and lateral delta V values were -2.0 km/h (-1.2 mph) and 11.0 km/h (6.8 mph), respectively. The delta V of the Ford was 10.0 km/h (6.8 mph) with longitudinal and lateral delta V values of 3.0 km/h (1.9 mph) and -9.0 km/h (-5.6 mph), respectively. The vehicles then separated with a southeast trajectory. The Toyota came to rest within the north/south leg of the road at an undetermined location. The Ford entered the southeast intersection quadrant evidenced by three tire marks across the sidewalk and struck a road sign with its left front corner. The Ford came to rest facing southwest on the road side grass.

Post-Crash

The police and ambulance personnel responded to the crash. Both drivers exited their respective vehicles under their own power. The driver of the Toyota sustained a police reported scalp contusion. She was transported by ground ambulance to a local hospital, treated and released. The driver of the Ford was not injured and declined medical services. Both vehicles were towed from the crash scene and deemed total losses by their respective insurance companies.

2009 TOYOTA PRIUS

Exterior Damage

The Toyota Prius sustained left side damage consistent with the multiple event crash sequence, **Figures 3 and 4**. The primary impact damage (Event 1) was located on the left fender. The total length of the direct and induced damage measured 116.8 cm (46.0 in). The induced damage began at the trailing edge of the fender and left front door seam that was located 39 cm (15.4 in) aft of the left front axle. The direct damage measured 54.1 cm (21.3 in) in length. The direct

contact damage began at the left front corner and ended 23.1 cm (9.1 in) forward of the left front axle. The force of the impact crushed the front structure approximately 14 cm (5.5 in) to the right. The residual crush profile along the mid door elevation was as follows: C1 = 0, C2 = 2.0 cm (0.8 in), C3 = 5.0 cm (2.0 in), C4 = 7.0 cm (2.8 in), C5 = 35.0 cm (13.8 in), C6 = 28.0 cm (11.0 in). There was a 51 cm x 71 cm (20 in x 28 in) area of direct contact to the forward left aspect of the hood. The left wheelbase was reduced 1.0 cm (0.4 in). The right wheelbase was unchanged. The windshield was not fractured. All the side glazing was intact, except the disintegrated left rear quarter window. The Collision Deformation Classification (CDC) was 10LFEW3.

The side slap impact damage (Event 2) was located on the left quarterpanel and extended to the mid aspect of the left rear door panel. The combined length of the direct and induced damage measured 170 cm (66.9 in). The induced damage began 96 cm (37.8) forward of the left rear axle and ended at the left rear bumper corner. The direct contact damage measured 117 cm (46.0 in), began 43 cm (16.9 in) forward the left rear axle and ended at the left rear corner. The residual profile along the mid-door elevation was as follows: C1 = 8.0 cm (3.1 in), C2 = 20.0 cm (7.9 in), C3 = 17.0 cm (6.7 in), C4 = 11.0 cm (4.3 in), C5 = 5.0 cm (2.0 in), C6 = 0. The maximum crush was located 8.0 cm (3.1 in) forward of C2 and measured 21.0 cm (8.3 in). The CDC of this impact was 09LZAW3.

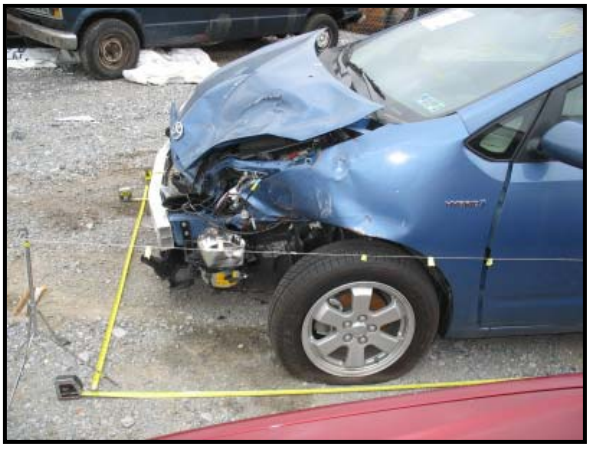

Figure 3: Left fender damage.

Figure 4: Left quarterpanel damage.

1997 FORD EXPLORER

Exterior Damage

The Ford Explorer was sold prior to SCI involvement in this investigation and was not inspected. Insurance company images were obtained and reviewed. **Figures 5 and 6** are a front right oblique and a right rear oblique view of the Ford, respectively. The Ford Explorer sustained frontal and right side damage as a result of the intersection crash. The direct contract damage from the initial impact (Event 1) began at the front right corner and extended rearward along the right fender to the leading edge of the front right door. The maximum crush of the fender was located over the front right tire and was an estimated 13 cm (5 in). The front right tire was involved in the impact and was debeaded. The frontal air bags in the Explorer deployed. The CDC of this impact was 01FREE5.

The right quarterpanel of the Explorer sustained an area of damage that began at the trailing edge of the right rear door extending to the right rear bumper corner as a result of the side slap impact (Event 2). The maximum crush was an estimated 5 cm (2 in) and was located approximately 10 cm (4 in) rearward of the right rear axle. The CDC of the impact was 03-RBEW1.

Figure 5: Right front oblique view of the Ford supplied by the insurance carrier.

Figure 6: Right rear oblique view of the Ford supplied by the insurance carrier.

2009 TOYOTA PRIUS

Interior Damage

The interior damage to the occupant compartment of the Toyota was limited to the deployment of the left curtain air bag and driver interior contact to the left front door panel. There was no intrusion into the occupant space.

The driver seat was located in a full-rear track position. The total seat track travel was 23 cm (9 in). The seat back was reclined 15 degrees aft of vertical. The horizontal distance from the seat back to the driver air bag module in the center hub of the steering wheel measured 66 cm (26 in). The head restraint was adjusted 7 cm (2.8 in) above the seat back. It could not be verified if this was the position of the seat at the time of the crash. The four-spoke steering wheel was mounted to a tilt column that was adjusted to the full-up position. There was no steering wheel rim deformation or steering column compression.

The driver's left hip contacted the door panel evidenced by a compression displacement of the arm rest. The displaced area measured 23 cm x 5 cm (9 in x 2 in) and was located in the upper rear quadrant of the door panel. There was an induced fracture of the forward aspect of the plastic panel. **Figure 7** is a view of the door panel.

Figure 7: Left door panel

As a result of the side slap impact, the cargo area behind the second row seats sustained approximately 8 cm (3 in) of intrusion damage. The intrusion was located 46 cm (18 in) forward of the hatch opening on the left side plane, approximately 24 cm (9.5 in) aft of the hybrid battery compartment. Upon initial inspection, the OEM plastic storage container positioned over the spare tire well was found displaced and ajar, **Figure 8**. The cargo area was bell-shaped. At the rear seat back, the area measured 97 cm x 43 cm (38 in x 17 in) width by length. The cargo space then expanded to 140 cm (55 in) wide over an additional 46 cm (18 in). The total length from the seat back to the rear hatch opening measured 89 cm (35 in).

Figure 8: View of the cargo area.

Federal Motor Vehicle Safety Standard No: 305 - Hybrid Battery Performance

The hybrid battery compartment measured 30 cm x 76 cm x 15 cm (12 in x 30 in x 6 in) length x width x height. The battery compartment was located approximately over the rear axle, 70 cm (27.5 in) forward of the hatch opening [81 cm (32 in) forward of the rear bumper]. It was mounted to the floor of the cargo space, forward and above the 66 cm (26 in) diameter spare tire well. Heating, ventilation, and cooling (HVAC) duct work was located along the right side of the cargo area. There was no damage to, or leakage from, the hybrid battery compartment. **Figures 9 and 10** are additional views of the cargo area and hybrid battery. The battery appeared to be in compliance with Federal Motor Vehicle Safety Standard (FMVSS) No: 305.

Figure 9: Cargo area and hybrid battery location.

Figure 10: Hybrid battery location.

Manual Restraint System

The driver's manual restraint consisted of a three-point lap and shoulder safety belt with continuous loop webbing, sliding latch plate, an adjustable D-ring and an Emergency Locking Retractor (ELR). The D-ring was adjusted to the full-down position. The ELR was equipped with a pretensioner that did not actuate during the crash sequence. The webbing was stowed on the retractor at initial inspection. Examination of the webbing and the hard surfaces of the D-ring and latch plate was unremarkable for crash related evidence. However, in general the occupant loading of the safety belt in a lateral crash event does not result in strong usage indicators. Minor historical use evidence was observed on the latch plate that was consistent with the new condition of the vehicle.

Air Bag Systems

The Toyota Prius was equipped with a CAC frontal air bags, front seat-mounted side impact air bags for the driver and front right passenger and IC air bags. A CAC vehicle is certified by the vehicle manufacturer to be compliant with the advanced air bag portion of Federal Motor Vehicle Safety Standard No 208. The air bag systems were controlled by an Air Bag Control Module (ACM) that was located within the occupant compartment under the center console. The ACM was reported to have Event Data Recorder (EDR) capabilities. The Toyota's insurance carrier declined a request from SCI to remove the ACM for EDR imaging. The insurance carrier would not allow disassembly of the vehicle.

The CAC frontal air bag modules for the driver and front right passenger were located in the center hub of the steering wheel and the right aspect of the instrument panel, respectively. The side impact air bags were mounted within the outboard aspects of the front seat backs. The frontal air bags and seat back side impact air bags did not deploy as a result of the crash. The reason the left front seat back side impact air bag did not deploy in this side impact crash was unknown.

The left IC air bag deployed from the left roof side rail as a result of the crash, **Figure 11**. The curtain provided coverage from the A- to C-pillars. The membrane was rectangular in shape and measured 163 cm x 38 cm (64 in x 15 in). The curtain provided 66 cm (26 in) of coverage forward of the left B-pillar and provided full vertical coverage of the side glazing to the belt line in both rows. A 30 cm x 32 cm (12 in x 12.5 in) area forward of the curtain's leading edge at the A-pillar junction was not covered by the membrane. This area was partially covered by an 18 cm x 18 cm (7 in x 7 in) triangular sail panel that was attached to the leading aspect of the curtain. No occupant contacts were observed on the deployed curtain.

Figure 11: Deployed left inflatable curtain.

DRIVER DEMOGRAPHICS/DATA

Age/Sex:	44-year-old/Female
Height:	Unknown
Weight:	Unknown
Manual Safety Belt Use:	Three-point lap and shoulder belt system
Usage Source:	Vehicle interior inspection
Seat Track Position:	Rear track
Egress from Vehicle:	Exited vehicle unassisted
Type of Medical Treatment:	Treated and released

DRIVER INJURIES

Injury	Injury Severity (AIS90/Update 98	Injury Source
Scalp contusion	Minor (190402.1,9)	Unknown

Source – Police Report. Medical records were not available.

DRIVER KINEMATICS

The 44-year old female driver of the Toyota Prius was seated in a presumed rear track position based on the seat position at the time of the SCI investigation. The adjustable head restraint was set 7.1 cm (2.8 in) above the seat. The driver was police reported as restrained by the manual safety belt system. The Toyota was a new vehicle and the safety belt system displayed only minimal historical usage evidence. The left side impact did not significantly displace the driver, therefore there was no loading evidence on the belt system.

At the initial impact with the Ford Explorer, the left IC air bag deployed. The driver responded to the 10 o'clock direction of force by initiating a left lateral and slightly forward trajectory. Her left flank/hip area impacted the left door panel and armrest area. The contact compressed the plastic panel resulting in a partial separation of the armrest from the panel. No apparent injury resulted from this contact.

The driver's left shoulder and head probably contacted the deployed IC air bag. The left front door window was closed and remained intact during the crash. The deployed curtain air bag prevented potential head contact to the glazing and the hard surfaces surrounding the glazing. There was no evidence of driver contact to the curtain air bag. The subsequent side slap impact was closely spaced to the initial impact. The driver initiated a secondary response to her left. She again loaded the deployed curtain air bag that would have remained inflated during this interval between the impacts.

The driver sustained a police reported soft tissue contusion to an unspecified area of the scalp. The source of this contusion is currently unknown. There were no other occupant contact points noted within the vehicle. The driver exited the vehicle unassisted, was taken to a local hospital and treated and released.

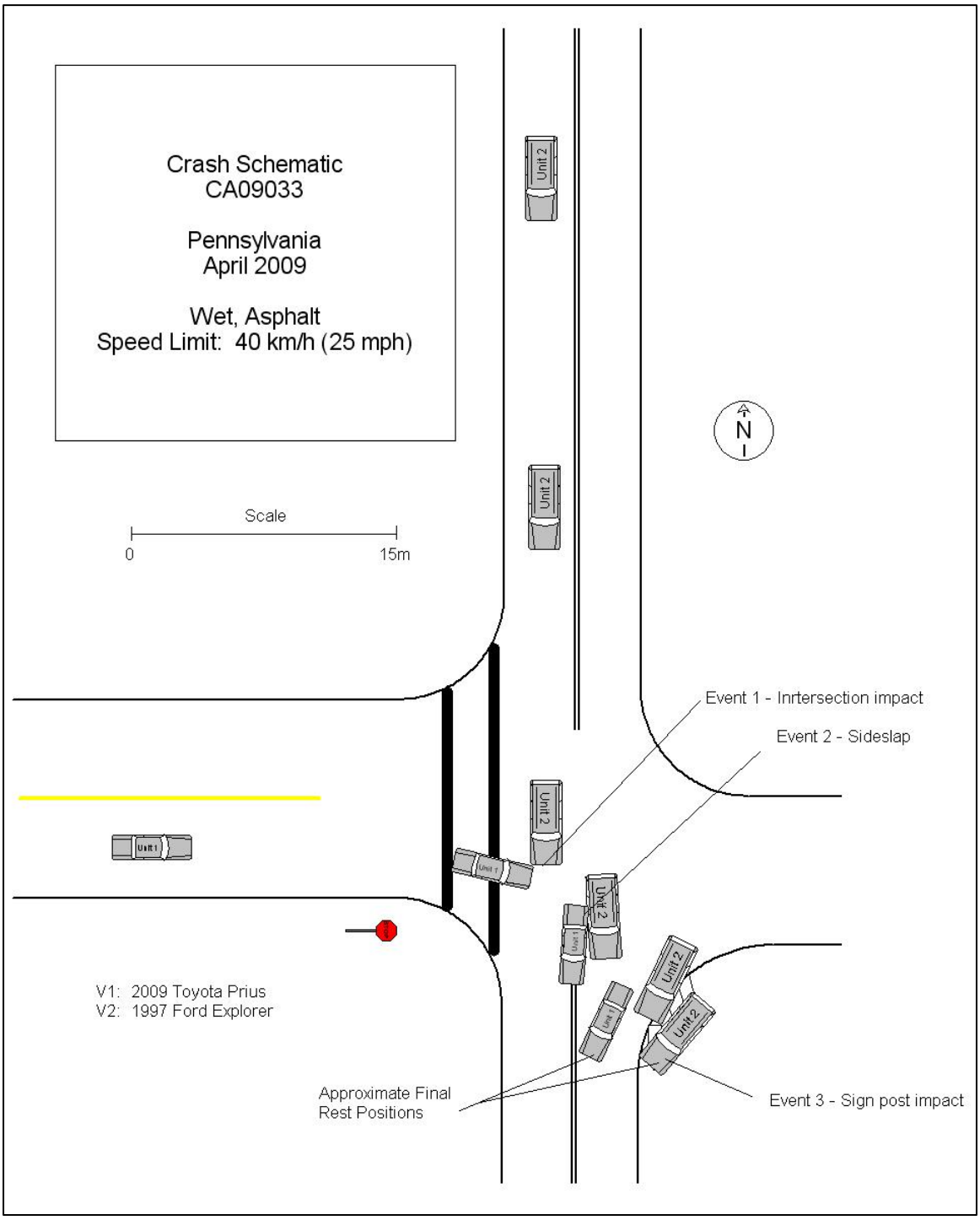

Figure 12: Crash Schematic.