

CRASH DATA RESEARCH CENTER
Calspan Corporation
Buffalo, NY 14225

CALSPAN ON-SITE HYBRID VEHICLE CRASH INVESTIGATION
SCI CASE NO: CA09057

VEHICLE: 2007 TOYOTA PRIUS

LOCATION: PENNSYLVANIA

CRASH DATE: JULY, 2009

Contract No. DTNH22-07-C-00043

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

DISCLAIMER

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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

<i>1. Report No.</i> CA09057	<i>2. Government Accession No.</i>	<i>3. Recipient's Catalog No.</i>	
<i>4. Title and Subtitle</i> Calspan On-Site Hybrid Vehicle Crash Investigation Vehicle: 2007 Toyota Prius Location: Pennsylvania		<i>5. Report Date:</i> May 2010	
		<i>6. Performing Organization Code</i>	
<i>7. Author(s)</i> Crash Data Research Center		<i>8. Performing Organization Report No.</i>	
<i>9. Performing Organization Name and Address</i> Calspan Corporation Crash Data Research Center P.O. Box 400 Buffalo, New York 14225		<i>10. Work Unit No.</i>	
		<i>11. Contract or Grant No.</i> DTNH22-07-C-00043	
<i>12. Sponsoring Agency Name and Address</i> U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		<i>13. Type of Report and Period Covered</i> Technical Report Crash Date: July 2009	
		<i>14. Sponsoring Agency Code</i>	
<i>15. Supplementary Note</i> An investigation of the rear end crash of a 2007 Toyota Prius and a 2007 Ford F150 pickup truck.			
<i>16. Abstract</i> <p>This investigation focused on the rear impact crash of 2007 Toyota Prius. The Toyota was stopped in a back-up of traffic and was struck by the front plane of a 2007 Ford F150 pickup truck. 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.</p> <p>The crash occurred on a two-lane east/west road in a suburban setting. The Toyota was westbound driven by a 41-year-old male. A 23-year-old female was the front right passenger. The Toyota came to a complete stop behind a westbound non-contact vehicle. The non-contact vehicle was stopped and intended to turn left. The Ford F150 was westbound driven by a 71-year-old male. The left aspect of the Ford's front plane impacted the right aspect of the Toyota's back plane. The driver and front passenger of the Toyota were transported with minor injuries.</p>			
<i>17. Key Words</i> Hybrid Vehicle Certified Advanced 208-Compliant frontal air bags		<i>18. Distribution Statement</i> General Public	
<i>19. Security Classif. (of this report)</i> Unclassified	<i>20. Security Classif. (of this page)</i> Unclassified	<i>21. No. of Pages</i> 9	<i>22. Price</i>

TABLE OF CONTENTS

BACKGROUND 1

SUMMARY 1

Vehicle Data..... 1

 2007 Toyota Prius..... 1

 2007 Ford F150 Pickup Truck..... 2

CRASH SITE..... 2

CRASH SEQUENCE 3

 Pre-Crash 3

 Crash..... 3

 Post-Crash..... 3

2009 TOYOTA PRIUS..... 3

 Exterior Damage..... 3

2007 FORD F150..... 4

 Exterior Damage..... 4

2009 TOYOTA PRIUS..... 5

 Interior Damage..... 5

 Federal Motor Vehicle Safety Standard No: 305 - Hybrid Battery Performance 5

 Manual Restraint Systems 6

 Air Bag Systems 6

DRIVER DEMOGRAPHICS 7

DRIVER INJURIES 7

DRIVER KINEMATICS 7

FRONT RIGHT PASSENGER DEMOGRAPHICS..... 7

FRONT RIGHT PASSENGER INJURIES 8

FRONT RIGHT PASSENGER KINEMATICS..... 8

CRASH SCHEMATIC 9

**CALSPAN ON-SITE HYBRID VEHICLE CRASH INVESTIGATION
SCI CASE NO: CA09057**

**VEHICLE: 2007 TOYOTA PRIUS
LOCATION: PENNSYLVANIA
CRASH DATE: JULY, 2009**

BACKGROUND

This investigation focused on the rear impact crash of 2007 Toyota Prius. The Toyota was stopped in a back-up of traffic and was struck by the front plane of a 2007 Ford F150 pickup truck. 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 crash occurred on a two-lane east/west road in a suburban setting. The Toyota was westbound driven by a 41-year-old male. A 23-year-old female was the front right passenger. The Toyota came to a complete stop behind a westbound non-contact vehicle. The non-contact vehicle was stopped and intended to turn left. The Ford F150 was westbound driven by a 71-year-old male. The left aspect of the Ford's front plane impacted the right aspect of the Toyota's back plane. **Figure 1** is an oblique view of the right rear damage. The driver and front passenger of the Toyota were transported with minor injuries.



Figure 1: Right rear oblique view of the Toyota.

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 (CID) of the National Highway Traffic Safety Administration (NHTSA) forwarded the police report to the Calspan Special Crash Investigations (SCI) team on August 31, 2009 and assigned this on-site investigation the same day. The Toyota was considered a total loss and was available for inspection at an insurance salvage yard. The Ford F150 was repaired prior to SCI's involvement in the investigation and was not be inspected. Images of the Ford were obtained from its insurance carrier and were used to assess the vehicle's damage. The inspection of the Toyota and crash site took place on September 2, 2009.

SUMMARY

Vehicle Data

2007 Toyota Prius

The Toyota Prius was identified by the Vehicle Identification Number (VIN): JTDKB20U873 (production sequence deleted). The front-wheel drive, four-door hatchback was manufactured in

May 2007. The odometer reading, obtained from the insurance carrier, indicated the vehicle had registered 106,016 km (65,877 miles). The Toyota was powered by a 1.5-liter internal combustion engine that operated in series-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 vehicle was equipped with manual three-point safety belts in the five seat positions, Certified Advanced 208-Compliant (CAC) frontal air bags, front seat-mounted side impact air bags and side impact Inflatable Curtain (IC) air bags. The Toyota was equipped with Cooper CS4 Touring P185/65R15 tires mounted on OEM alloy rims. These tires were the proper size that was recommended by the vehicle manufacturer. 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	48 kPa (7 PSI)	3 mm (4/32 in)	No	Debeaded
LR	200 kPa (29 PSI)	4 mm (5/32 in)	No	None
RF	159 kPa (23 PSI)	3 mm (4/32 in)	No	None
RR	228 kPa (33 PSI)	4 mm (5/32 in)	Yes	None

2007 Ford F150 Pickup Truck

The 2007 Ford F150 was identified by the Vehicle Identification Number (VIN): 1FTRF12247N (production sequence deleted). The two-door, 4x2, ½ ton, regular cab pickup truck was powered by a 4.2-liter, V6 engine linked to a five-speed manual transmission. The service brakes were four-wheel disc with ABS. The manual restraint system consisted of three-point safety belts for the driver and front right passenger with a center lap belt. The air bag system consisted of Certified Advanced 208-Compliant (CAC) frontal air bags that did not deploy as a result of the crash.

CRASH SITE

The crash occurred during the daylight hours in July 2009. At the time of the crash, the weather was clear and the asphalt road surface was dry. The crash occurred on a straight and level, two-lane east/west road in a suburban setting. The traffic lanes were separated by a double-yellow center line and each lane measured 3.5 m (11.5 ft) in width. The traffic lanes were bordered by asphalt shoulders. The north shoulder measured 2.6 m (8.5 ft) in width. The south shoulder measured 2.2 m (7.2 ft) wide. A restaurant was located on the south side of the road. Two driveways for traffic entering/exiting the parking area of the business intersected the road from the south. The speed limit in the area of the crash was 64 km/h (40 mph).



Figure 2: Westbound view at the crash site.

CRASH SEQUENCE

Pre-Crash

The Toyota Prius was driven by a 41-year-old male and occupied by a 23-year-old female front right passenger. The westbound Toyota came to a complete stop behind a westbound non-contact vehicle. The non-contact vehicle was stopped, waiting for opposing traffic to clear and intended to turn left into the intersecting driveway of the restaurant. The Ford F150 was also westbound, driven by a 71-year-old male. The driver of the Ford braked and steered his vehicle to the right in an attempt to avoid the stopped Toyota. A schematic of the crash is attached to the end of this report as **Figure 10**.

Crash

The left aspect of the Ford's frontal plane struck the right aspect of the Toyota's back plane in a 12/6 o'clock impact configuration. The momentum of the Ford displaced the Toyota forward approximately 1 m (3 ft) and both vehicles came to rest facing west. The severity of the impact (delta-V) was calculated by the Damage Algorithm of the WinSMASH program. The total delta-V of the Toyota was 16.0 km/h (9.9 mph). The longitudinal and lateral components of the delta-V were 15.8 km/h (9.8 mph) and 2.8 km/h (1.7 mph), respectively. The total delta V of the Ford was 11.0 km/h (6.8 mph) with the longitudinal and lateral delta-V components of -11.0 km/h (-6.8 mph) and 0 km/h (0 mph), respectively.

Post-Crash

The police and ambulance personnel responded to the crash site. The driver of the Toyota complained of neck pain and a loss of sensation. He was transported via helicopter to a trauma center as a precaution. After examination in the trauma bay, his diagnosis was downgraded and he was discharged through the Emergency Room with a diagnosis of cervical strain and a right knee abrasion. The front right passenger of the Toyota was transported by ground ambulance to a local hospital with a complaint of back and neck pain. She was diagnosed with an unspecified head injury, and cervical and thoracic strain. The driver of the Ford was not injured and declined medical services. Both vehicles were towed from the crash scene.

2009 TOYOTA PRIUS

Exterior Damage

The Toyota Prius sustained moderate severity damage to its back plane as a result of the impact. **Figure 3** is a rear view of the Toyota's back plane damage. **Figure 4** is a lateral view at the back plane depicting the extent of crush. The direct contact damage began 41 cm (16 in) right of center and extended 25 cm (10 in) to the right rear bumper corner. The combined width of the direct and induced damage extended across the full 132 cm (52 in) end width of the vehicle. The rear bumper fascia separated during the impact and was not available for inspection. The exposed rear bumper reinforcement beam was a 6 cm x 10 cm (2.5 in x 4 in) aluminum box section 132 cm (52 in) in length. The reinforcement beam was mounted to the chassis by two 6 cm (2.5 in) stand-offs mounted 97 cm (38 in) apart. The reinforcement beam was not deformed by the corner impact. Rather, the force of the impact was distributed through the beam and into the frame and floor pan of the Toyota. The right rear body structure was crushed which buckled

the floor pan. The reinforcement beam was displaced forward and down. The crush profile at the bumper elevation was as follows: C1 = 1 cm (0.4 in), C2 = 0, C3 = 5 cm (2 in), C4 = 8 cm (3.1 in), C5 = 10 cm (3.9 in), C6 = 13 cm (5.1 cm). The maximum crush was located above the rear bumper elevation at the right rear corner of the Toyota. The maximum crush measured 16 cm (6.3 in). The right rear wheelhouse crushed forward and was in contact with the right rear tire. The right wheelbase was shortened 3 cm (1.2 in). The rear hatch was jammed shut. The backlight glazing was fractured. The Collision Deformation Classification (CDC) was 06-BRAE3.



Figure 3: Rear view of the damage to the Toyota's back plane.



Figure 4: Right lateral view of the depicting the extent of crush at the rear corner.

2007 FORD F150

Exterior Damage

The Ford F150 was repaired prior to SCI's involvement in this investigation. Digital images of the frontal damage were obtained from its insurance carrier and were used to evaluate the vehicle's damage. **Figures 5 and 6** are the front and left oblique views of the Ford. The frontal damage was confined to the front left corner. The damaged components included the front bumper, left fender, hood and left headlamp assembly. The direct contact damage began an estimated 52 cm (21 in) left of center and extended left 30 cm (12 in). The estimated crush profile at the bumper elevation was as follows: C1 = 15 cm (6 in), C2 = 5 cm (2 in), C3 = 0, C4 = 0, C5 = 0, C6 = 0. There was no reduction in left wheelbase. The CDC of the damage was 12-FLEE1.



Figure 5: View of the Ford's frontal damage. Image obtained from the insurance carrier.



2009 TOYOTA PRIUS

Interior Damage

There was no damage or intrusion to the vehicle's occupant compartment. Minor intrusion was identified to the right rear aspect of the cargo area, **Figure 7**. The longitudinal dimension from the row 2 seat back to the back wall of the cargo area was reduced 11 cm (4.5 in) on the right. The right floor was deformed over a 48 cm x 20 cm (19 in x 8 in) area and buckled vertically approximately 5 cm (1.8 in).

The driver seat was located in a full-rear track position. The total seat track travel was 24 cm (9.5 in). The seat back was reclined 20 degrees aft of vertical. There was no deflection or deformation to the seat back. The horizontal distance from the seat back to the driver air bag module in the center hub of the steering wheel measured 74 cm (29 in). The head restraint was adjusted 5 cm (2 in) above the seat back. 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. There were no contacts within the driver's occupant space.

The front right seat was adjusted to a full-rear track position. The seat back was reclined 22 degrees aft of vertical. There was no seat back deflection. The horizontal distance from the seat back to the face of the instrument panel measured 86 cm (34 in). The head restraint was in the full-down position. A 13 cm (5 in) long scuff mark to the headliner was the only identified potential occupant contact. The scuff was located directly above and rearward of the front right passenger's head restraint. The scuff began 15 cm (6 in) aft of the B-pillar and extended rearward. The scuff was ruled out as an occupant contact due to its rearward location.

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

The hybrid battery stack was housed in an aluminum compartment that 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 behind the second row seat backs 58 cm (23.5 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. **Figures 8** is an overhead view into the cargo area depicting the deformation and the hybrid location behind the second row seat backs. **Figure 9** is a view of the hybrid battery and the buckled right aspect of the floor. 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. The battery appeared to be in compliance with Federal Motor Vehicle Safety Standard (FMVSS) No: 305.

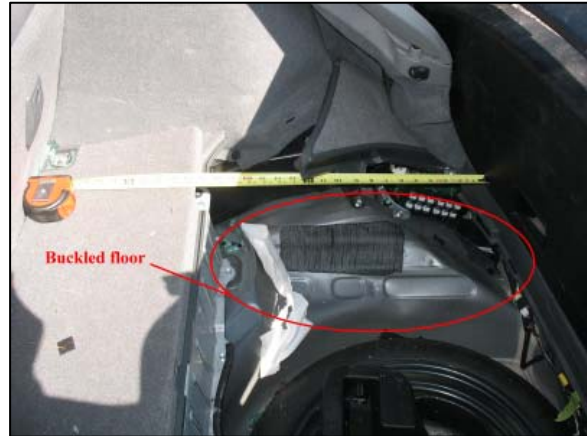


Figure 7: Left lateral view into the cargo area.

Figure 6: Front left oblique view of the Ford. Image obtained from the insurance company.



Figure 8: Overhead view into the cargo area depicting the hybrid battery location.



Figure 9: View of the hybrid battery and the buckled floor on right.

Manual Restraint Systems

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 2 cm (0.8 in) above 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. Historical use evidence was observed on the latch plate that was consistent with the mileage of the vehicle.

The front right restraint was a three-point safety belt utilizing continuous loop webbing, a sliding latch plate, an adjustable D-ring and a switchable Automatic Locking Retractor/ELR (ALR/ELR). The retractor was equipped with a pretensioner that did not actuate during the crash. The adjustable D-ring was in the full-down position. The webbing was stowed on the retractor at initial examination and the retractor was operational. Examination of the belt system was unremarkable for crash related evidence. Historical use evidence was observed on the latch plate.

Air Bag Systems

The Toyota Prius was equipped with CAC frontal air bags, seat-mounted side impact air bags for the driver and front right passenger, and side impact inflatable curtain air bags. A CAC vehicle is certified by the vehicle manufacturer to be compliant with the advanced air bag portion of FMVSS No 208. None of the air bags deployed as a result of the crash.

DRIVER DEMOGRAPHICS

Age/Sex: 41-year-old / Male
Height: Unknown
Weight: Unknown
Manual Safety Belt Use: Three-point lap and shoulder belt system
Usage Source: Vehicle interior inspection, PAR
Seat Track Position: Full-rear track
Type of Medical Treatment Treated and released

DRIVER INJURIES

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Cervical strain	Minor (640278.1,6)	Head restraint
Right knee abrasion	Minor (890202.1,1)	Right knee abrasion

Source: Emergency Room Records

DRIVER KINEMATICS

The 41-year-old male driver was restrained at the time of the crash and was seated in a full-rear seat track position. The vehicle was stopped behind a non-contact vehicle at the time of the impact.

At impact, the safety belt retractor locked in response to the sudden acceleration of the impact. The driver responded to the 6 o'clock direction of the impact force by initiating a rearward trajectory. The driver loaded the seat back with his torso. His head contacted and loaded the head restraint. He sustained a cervical strain as a result of the contact. The seat back and head restraint compressed as a result of the loading and the driver rode down the force of the impact. He then rebounded with a forward trajectory and loaded the locked safety belt system. The driver's right knee contacted the knee bolster resulting in an abrasion. The driver complained of a loss of sensation to the ambulance personal and was transported via helicopter to a trauma center as a precaution. The extent of the driver's injuries was downgraded after evaluation and he was treated and released from the Emergency Department.

FRONT RIGHT PASSENGER DEMOGRAPHICS

Age/Sex: 23-year-old / Female
Height: Unknown
Weight: Unknown
Manual Safety Belt Use: Three-point lap and shoulder belt system
Usage Source: Vehicle interior inspection, PAR
Seat Track Position: Full-rear track
Type of Medical Treatment: Treated and released

FRONT RIGHT PASSENGER INJURIES

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Unspecified head injury	Minor (160402.1,0)	Head restraint
Cervical spine strain	Minor (640278.1,6)	Head restraint
Thoracic spine strain	Minor (640478.1,7)	Seat back support

Source: Emergency Room Records

FRONT RIGHT PASSENGER KINEMATICS

The 23-year-old female front right passenger was seated in a full-rear track position and was restrained by the vehicle's safety belt. At impact, she initiated a rearward trajectory and loaded the front right seat back. Her head loaded the head restraint. She sustained an unspecified head injury, cervical and thoracic spine strain as a result of the contact. The seat back compressed and the passenger rode down the force of the impact. She then rebounded forward and loaded the locked safety belt with her chest. She was transported to a local hospital via ground ambulance where she was treated and released on the day of the crash.

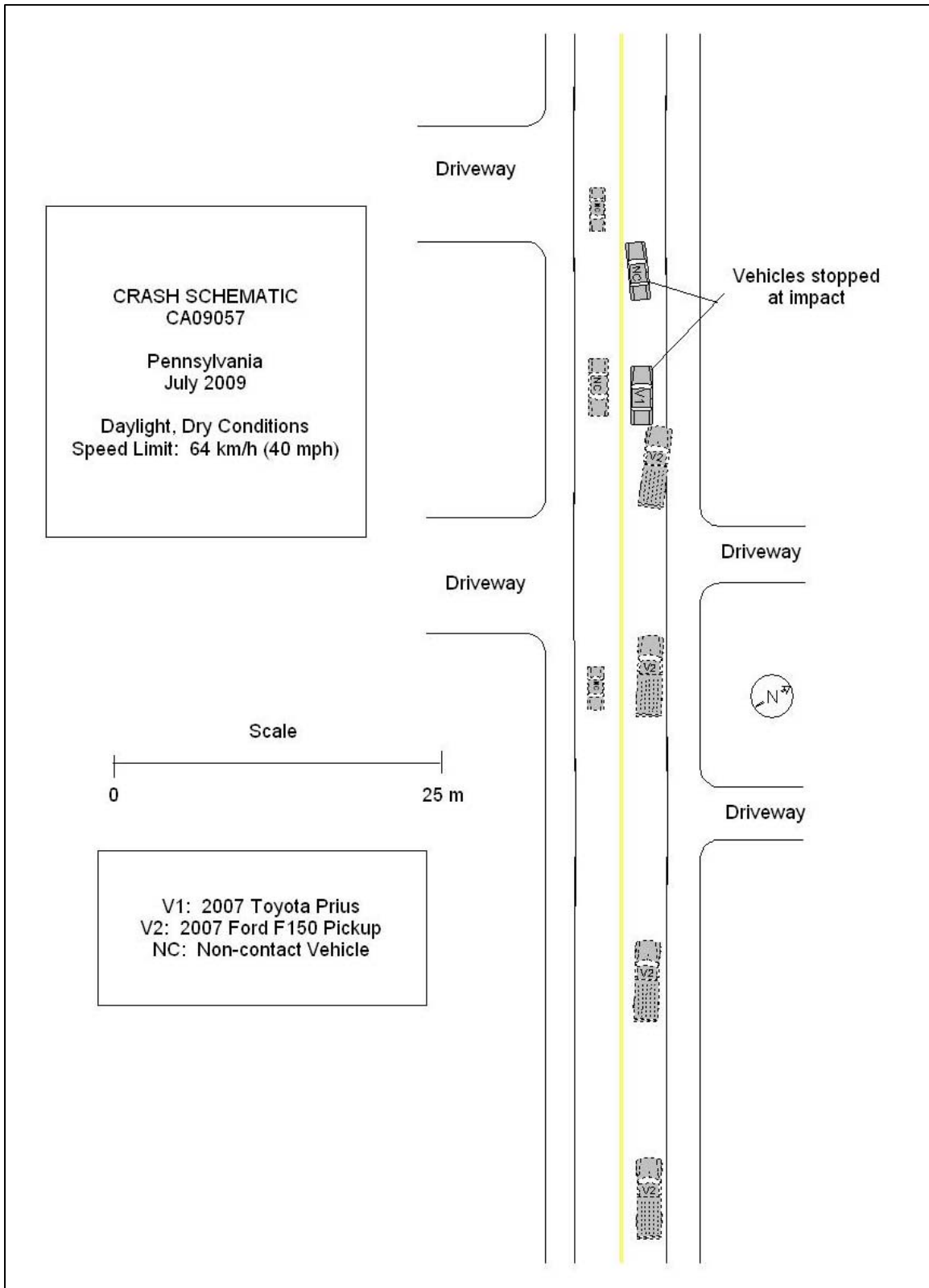


Figure 10: Crash schematic.