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CALSPAN ON-SITE HYBRID VEHICLE CRASH INVESTIGATION
SCI CASE NO.: CA09059

VEHICLE: 2006 HONDA CIVIC HYBRID

LOCATION: NORTH CAROLINA

CRASH DATE: SEPTEMBER 2009

Contract No. DTNH22-07-C-00043

Prepared for:

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

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

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

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. CA09059	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle Calspan On-Site Hybrid Vehicle Crash Investigation Vehicle: 2006 Honda Civic Hybrid Location: North Carolina		*5. Report Date*: October 2010 *6. Performing Organization Code*	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Calspan Corporation Crash Data Research Center P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* *11. Contract or Grant No.* DTNH22-07-C-00043	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: September 2009 *14. Sponsoring Agency Code*	
15. Supplementary Note An investigation of the rear impact crash of a 2006 Honda Civic Hybrid and a 1998 Ford F-150 Pickup truck.			
16. Abstract This on-site investigation focused on the hybrid system in a 2006 Honda Civic that was involved in a front-to-rear crash with a 1998 Ford F-150. The hybrid system included a high-voltage nickel-metal hydride battery pack using potassium hydroxide electrolyte. This battery pack had a total output rating of approximately 158 volts and was used for low speed acceleration and to assist the 1.3-liter gasoline engine in higher speed acceleration. The battery pack was located behind the second row seat of the vehicle. The Honda was equipped with a regenerative braking system to charge the hybrid battery. The Honda was also equipped with four-wheel anti-lock brakes; a Certified Advanced 208-Compliant frontal air bag system, front seat-mounted side impact air bags and side impact Inflatable Curtain (IC) air bags. The manufacturer of the Honda certified that the vehicle was compliant to the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC system included dual-stage frontal air bags for the driver and front passenger positions, front seat track positioning sensors, buckle switch sensors, retractor and buckle pretensioners, and a front right occupant presence sensor. The Honda was stopped in a line of standing traffic and struck on the back plane by a 1998 Ford F-150. The Honda was occupied by a restrained 49-year-old female driver, 15-year-old female front right passenger, 17-year-old female rear left passenger, and 15-year-old male rear right passenger. The driver and passengers of the Honda sustained police-reported minor injuries in this crash but refused medical transport from the scene and did not seek treatment.			
17. Key Words Front-to-rear impact Hybrid Battery Minor injury		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 12	*22. Price*

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BACKGROUND

This on-site investigation focused on the hybrid system in a 2006 Honda Civic that was involved in a front-to-rear crash with a 1998 Ford F-150. **Figure 1** is a rear oblique view of the Honda. The hybrid system included a high-voltage nickel-metal hydride battery pack using potassium hydroxide electrolyte. This battery pack had a total output rating of approximately 158 volts and was used for low speed acceleration and to assist the 1.3-liter gasoline engine in higher speed acceleration. The battery pack was located behind the second row seat of the vehicle. The Honda was equipped with a regenerative braking system to charge the hybrid battery. The Honda was also equipped with four-wheel anti-lock brakes; a Certified Advanced 208-Compliant frontal air bag system, front seat-mounted side impact air bags and side impact Inflatable Curtain (IC) air bags. The manufacturer of the Honda certified that the vehicle was compliant to the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC system included dual-stage frontal air bags for the driver and front passenger positions, front seat track positioning sensors, buckle switch sensors, retractor and buckle pretensioners, and a front right occupant presence sensor. The Honda was stopped in a line of standing traffic and struck on the back plane by a 1998 Ford F-150. The Honda was occupied by a restrained 49-year-old female driver, 15-year-old female front right passenger, 17-year-old female rear left passenger, and 15-year-old male rear right passenger. The driver and passengers of the Honda sustained police-reported minor injuries in this crash but refused medical transport from the scene and did not seek treatment.

Figure 1: Left rear oblique view of the 2006 Honda Civic.

The vehicle was identified through a visit to a regional vehicle salvage facility on September 10, 2009. An image of the Honda was forwarded to the Calspan Special Crash Investigations (SCI) team for review on the same day. Based on the rear end damage to this hybrid vehicle, this case was assigned for an on-site investigation on September 11, 2009. The on-site investigation was initiated on September 16, 2009. The investigation involved the inspection of the Honda, a

detailed interview with the driver of the Honda, and the documentation of the crash site. The driver of the Ford refused to cooperate in the SCI investigation; the Ford was not inspected.

SUMMARY

Crash Site

The crash occurred during the daylight hours of September 2009 in the northbound lane of a two-lane undivided roadway (**Figure 2**). The roadway extended in a north/south direction and had a shallow right curve in the area of the crash. The grade transitioned from a downhill grade of -3.2 percent in the pre-crash area to an uphill grade of 1.6 percent near the point of impact. An intersecting two-lane roadway extended west from the area of the crash. The weather conditions at the time of the crash were dry and clear. The traffic lanes were surfaced with asphalt and were 3.3 m (10.6 ft) in width. A grass shoulder extended beyond the east fog line. The west roadside consisted of a paved shoulder, for future expansion of the roadway, surfaced in asphalt and bordered by a grass shoulder. Tire marks at the scene evidenced the area of the crash and the post-impact travel of the vehicles. The posted speed limit was 72 km/h (45 mph). The Crash Schematic is included as **Figure 8** of this report.

Figure 2: Northbound trajectory view of the Honda at the area of the impact.

Vehicle Data

2006 Honda Civic Hybrid

The 2006 Honda Civic Hybrid four-door sedan was manufactured in August 2006 and identified by the Vehicle Identification Number (VIN): JHMFA36226S (production number deleted). The vehicle was purchased new by the driver in December 2006. The odometer reading was 73,394 km (45,615 mi) at the time of the SCI inspection.

The front-wheel drive Honda was powered by a 1.3-liter transverse-mounted 4-cylinder gasoline engine linked to a hybrid electric motor and a Continuously Variable Transmission (CVT). The hybrid motor was powered by a 158 volt nickel-metal hydride battery pack. The hybrid battery was located behind the rear seat of the vehicle, slightly forward of the rear axle. The hybrid battery was concealed by an aluminum cover and a carpeted panel that formed the front of the trunk area. The service brakes were front-wheel disc and rear drum with four-wheel anti-lock. All four windows were closed at the time of the crash. The Honda was equipped with four Michelin X Radial tires in size P195/65R15. The vehicle manufacturer recommended tire size was P195/65R15 with 221 kPa (32 PSI) of cold tire pressure for the front and rear tires. The tires

were mounted on OEM alloy wheels. The specific tire data at the time of the SCI inspection was as follows:

Position	Measured Tire Pressure	Measured Tread Depth	Damage
Left Front	214 kPa (31 PSI)	8 mm (10/32 in)	None
Left Rear	207 kPa (30 PSI)	8 mm (10/32 in)	None
Right Front	214 kPa (31 PSI)	8 mm (10/32 in)	None
Right Rear	Tire flat	8 mm (10/32 in)	Tire puncture in tread

The interior of the Honda was configured with cloth-surfaced five-passenger seating. The front bucket seats were separated by a center console and equipped with adjustable head restraints. The front head restraints were equipped with a whiplash-protection system. The driver head restraint was located 4 cm (1.6 in) above the full-down position. The front right head restraint was in the full-down position at the time of the SCI inspection. The driver seat track was adjusted to a mid-to-rear track position 5 cm (2 in) forward of full-rear. Post-crash, the driver seat back angle measured 24 degrees aft of vertical. The front right seat track was adjusted to a mid-to-rear track position that measured 8 cm (3.1 in) forward of the full-rear position. The post-crash front right seat back angle was 20 degrees aft of vertical. The second row was a bench seat with adjustable head restraints. The rear left head restraint was adjusted 3 cm (1.2 in) above the full-down position, the center and rear right head restraints were in the full-down position

The interior occupant safety systems consisted of 3-point lap and shoulder belts for all five designated seating positions, front retractor and buckle pretensioners, dual-stage CAC frontal air bags, front seat-mounted side impact air bags, front seat track position sensors, buckle switch sensors, and side impact IC air bags that provided protection for the four outboard seating positions.

1998 Ford F-150

The 1998 Ford F-150 was a 4x2 regular-cab pickup truck. The Ford was identified by the VIN 1FTYF1760WN (production sequence deleted). The rear-wheel drive Ford was powered by a 4.6-liter, V-8 engine linked to a 4-speed automatic transmission. The service brakes were front and rear disc with four-wheel antilock. The owner of the Ford refused an inspection of the vehicle and photographs of the damaged vehicle were not available.

Crash Sequence

Pre-crash

Prior to the crash, the Honda and Ford F-150 were both traveling northbound on the two-lane roadway. Traffic ahead of their position had stopped for a non-contact vehicle that was waiting

to turn left onto the intersecting roadway. The Ford was traveling at a police-estimated speed of 72 km/h (45 mph) prior to the crash. The driver of the Honda braked her vehicle and stopped in a line of standing traffic in the northbound travel lane. The driver of the Ford did not recognize the stopped the traffic ahead and approached the rear of the Honda.

Crash

The front of the Ford impacted the rear of the Honda in a 12/6 o'clock impact configuration. The Honda was displaced forward 17.1 m (56.1 ft) and slightly to the right. A skid mark that measured 15.7 m (51.5 ft) in length was deposited on the roadway by the left rear wheel of the Honda and denoted its movement. The Honda came to rest partially off the right roadside straddling the east fog line. The Ford continued its northbound trajectory and came to rest on the roadway 15.5 m (50.9 ft) north of the impact.

The Missing Vehicle algorithm of the WinSMASH program was used to calculate the severity of the crash (delta-V). The total delta-V of the Honda was 30 km/h (18.6 mph). The longitudinal and lateral components of the Honda's delta-V were 30 km/h (18.6 mph) and 0 km/h, respectively. The total delta-V of the Ford was 24 km/h (14.9 mph) with a longitudinal component of -24 km/h (-14.9 mph); the lateral component was 0 km/h. No air bags in the Honda deployed during the rear-end crash event.

Post-Crash

The driver of the Honda called the 9-1-1 emergency response system from her cellular phone. Police, emergency medical, and tow personnel responded to the crash site. The driver and front right passenger exited the vehicle through the front doors. The rear doors were jammed shut post-crash. The rear passengers exited by climbing over the center console and exiting through the front right door. There was a 50 minute wait until the police and emergency personnel arrived at the crash scene. During this time, the driver attempted to move the vehicle completely off the roadway. The gasoline engine started as normal but the vehicle was unable to move due to a restricted left rear wheel. The driver stated in the interview that no warning or check engine lights were illuminated on the dash as she attempted to move the vehicle. The driver then turned off the ignition, removed the key, and exited the vehicle a second time.

The driver and all passengers of the Honda refused medical treatment at the scene and were not transported to a medical facility. Both vehicles were towed from the scene due to disabling damage. The Honda was transferred from the tow yard to a regional vehicle salvage facility, where it was inspected. The Ford was towed from the scene to a local body shop. The owner of the Ford refused to cooperate with the SCI investigation.

2006 Honda Civic Hybrid

Exterior Damage

The rear of the Honda Civic sustained moderate-severity damage. The impact involved the rear bumper, trunk, and rear quarter panels of the Honda **(Figure 3).** The combined width of the direct and induced damage (Field L) extended across the entire 140 cm (55.1 in) end width of the vehicle. Longitudinal crush was present to the bumper beam, trunk area, spare tire well, and both rear quarter panels of the Honda. A crush profile measured along the damaged rear bumper was as follows: C1 = 19 cm (7.5 in), C2 = 25 cm (9.4 in), C3 = 34 cm (13.4 in), C4 = 33 cm (13 in), C5 = 30 cm (11.8 in), C6 = 33 cm (13 in). The maximum crush was located at C3; 13 cm (5.1 in) left of the centerline of the vehicle and measured 34 cm (13.4 in). The residual longitudinal distance from the deformed bumper to the hybrid battery was 54 cm (21.3 in) at the C3 location. This distance is depicted in **Figure 4.** The crash-related damage to the back of the Honda did not extend forward to the location of the hybrid battery. The battery was located forward of the carpeted panel in Figure 4.

Figure 3: Back view of the damaged Honda.

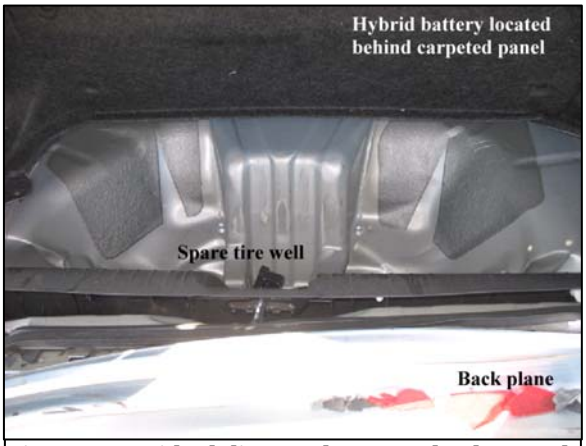

Figure 4: Residual distance between the damaged rear of the trunk and the hybrid battery.

The backlight, all side windows and the windshield were undamaged. The left front and right front doors remained closed during the crash and were operational post-crash. The right rear and left rear doors were jammed shut post-crash. The Collision Deformation Classification (CDC) assigned for this impact was 06BDEW4.

Interior Damage

The Honda Civic sustained minor-severity interior damage that was attributed to occupant loading. A scuff mark to the left bolster of the driver seat was identified during the SCI inspection. This scuff mark was located 0-9 cm (0-3.5 in) right of the left edge of the seat back and 35-49 cm (13.8-19.3 in)

Figure 5: Interior view of the driver seat depicting the seat deformation.

below the top of the seat (**Figure 5**). The seat back angle adjustment was jammed. The outboard track of the driver was damaged by the driver loading and allowed the left side of the seat to be displaced rearward 10 cm (3.9 in). This resulted in a 15 degree counterclockwise (CCW) rotation of the driver's seat. This rotation resulted in the 16 cm (6.3 in) intrusion of the left corner of the seat back into the area occupied by the rear left passenger.

The rear impact resulted in trunk deformation. A spare tire well was located in the center of the trunk area below the level of the floor aft of the hybrid battery. The spare tire was located in the storage well at the time of the crash. A 15 cm (6 in) section of the spare tire's rim edge deformed during the impact. There was no intrusion of the rear seat back; however, some movement of the upper package tray above the rear seats was evidenced by the movement of the plastic trim panel concealing the right C-pillar.

Manual Restraint Systems

The Honda was equipped with manual 3-point lap and shoulder belts for the five designated seating positions. All belt systems utilized continuous loop webbing with sliding latch plates. The driver's belt retracted onto an Emergency Locking Retractor (ELR) with both a retractor and buckle-mounted pretensioner. The upper D-ring was adjustable and set to the full-up position. The driver and front right passenger were using the safety belts at the time of the crash. The front right passenger's belt retracted onto a switchable ELR/Automatic Locking Retractor (ALR) and the system also contained a buckle and retractor mounted pretensioner. The adjustable upper D-ring was set to the full-up position. The front pretensioners did not actuate in this rear-end crash. All second row safety belt systems utilized a switchable ELR/ELR. The outboard seats were occupied and the second row passengers were using the safety belts at the time of the crash. The SCI inspection of all the belt systems was unremarkable for crash-related evidence.

Frontal Air Bag System

The Honda was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of dual stage driver and front right passenger air bags, seat track positioning sensors, a front right occupant presence sensor, safety belt pretensioners, and safety belt buckle switches. The manufacturer of the Honda certified that the vehicle was compliant to the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

The driver/owner stated that the Honda had not been involved in any previous crashes and the air bags were all original to the vehicle. The driver's air bag was concealed within the center hub of a 3-spoke steering wheel. The front right passenger's frontal air bag was concealed within the upper aspect of the front right instrument panel. The CAC frontal air bag system did not deploy in this rear-end crash.

Side Impact Air Bag System

The Honda was equipped with front seat-mounted side impact air bags and roof side rail-mounted side impact IC air bags. No side impact air bags deployed in this rear-end crash.

Hybrid Battery System

The 2006 Honda Civic was equipped with a hybrid battery system used to drive an electric motor that assisted, and in some cases supplanted, the gasoline engine. This system improved fuel efficiency while the gasoline engine was in use and provided power for vehicle movement at lower speeds without use of the gasoline engine. The nickel-metal hydride battery pack was manufactured by Panasonic and had a 158-volt, 5.5 Ah capacity. The battery was located behind the rear seat back, centered and slightly forward of the rear axle.

Federal Motor Vehicle Safety Standard (FMVSS) No. 305: Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection is the standard applied to vehicles that use more than 48 nominal volts of electricity as propulsion and whose speed on a level paved surface is more than 40 km/h (25 mph). FMVSS No. 305 specifies performance requirements of electrolyte spillage, retention of propulsion batteries, and electrical isolation of the chassis from the high-voltage system during a crash event. The standard test requirements are summarized as follows:

- Not more than 5.0 liters (1.3 gal) of electrolyte from propulsion batteries shall spill outside the passenger compartment, and none shall spill in the passenger compartment, within 30 minutes after a barrier impact test.
- No propulsion battery system component located inside the passenger compartment shall move from its installed location.
- No propulsion battery system component located outside the passenger compartment shall enter the passenger compartment.
- Electrical isolation shall exist between the propulsion battery system and the vehicle electricity-conducting structure.

The Honda was visually inspected for compliance with FMVSS No. 305. The rear impact damage did not involve the area of the propulsion battery. The carpet panels at the front of the trunk were removed to expose the hybrid battery and its ventilation system during the SCI inspection. The battery pack was visually inspected for damage and leakage. None was found. No damage was evident to the battery pack itself, the mounting points, or the attachment brackets. The intake and output ducts of the ventilation system were properly aligned. There was no apparent damage to the electrical connectors or wiring. The electrical isolation test was not conducted. **Figures 6 and 7** depict the hybrid battery in the trunk of the Honda.

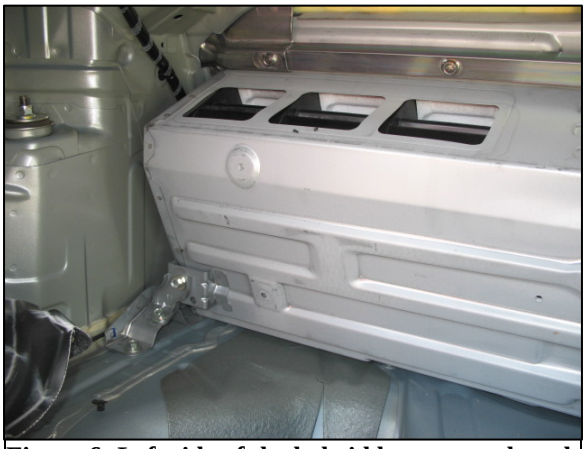

Figure 6: Left side of the hybrid battery pack and ventilation intake with the duct removed.

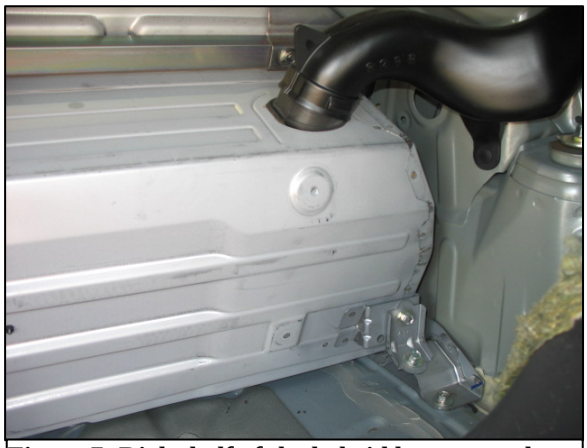

Figure 7: Right half of the hybrid battery pack and the ventilation exhaust.

2006 Honda Civic Hybrid Occupant Demographics/Data

Driver Data

Driver Age/Sex:	49-year-old/Female
Height:	160 cm (63 in)
Weight:	61 kg (135 lb)
Eyewear:	None
Seat Track Position:	Mid-to-rear track
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from vehicle:	Exited under own power through left front door
Mode of Transport from Scene:	None
Type of Medical Treatment:	None

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
0.9 cm (0.3 in) laceration to center of inside lower lip	Minor (290602.1,8)	Steering wheel rim
8 cm (3 in) wide contusion to inside of lower lip	Minor (290402.1,8)	Steering wheel rim

Source = Driver interview

Driver Kinematics

The restrained 49-year-old female driver of the Honda was seated with an upright posture in a mid-to-rear track position and was restrained by the manual 3-point lap and shoulder belt system.

The driver stated to the SCI investigator that she did not see the approaching Ford and did not initiate an avoidance maneuver or brace her body prior to the impact.

At impact, the driver responded to the 6 o'clock direction of force by initiating a rearward trajectory within the front left seating position. The driver loaded the seat back with her torso evidenced by the scuffed bolster. This loading caused the left seat track to release and resulted in a rearward CCW rotation of the driver's seat. The driver's loading of the seat back's lumbar region actuated the whiplash-protection system in the driver's seat. The driver's head restraint traveled upward and forward toward the back of the driver's head. The driver's head contacted the head restraint and rode down the crash forces. In the interview, the driver did not complain of any "whiplash-related" neck injuries.

The force of the impact displaced the Honda forward and the driver initiated a forward rebound trajectory within the front left seating position. The driver loaded the belt system with her chest and abdomen. The driver's head extended forward, beyond her torso which was held in place by the belt system. The driver's jaw and lower lip contacted the steering wheel rim, resulting in the laceration and contusion to the inside of her lower lip and pain in her jaw. The driver rebounded from this contact and came to rest in the driver's seat.

The driver of the Honda turned off the ignition, removed the key and exited the vehicle through the left front door without assistance. She refused treatment at the scene and was not transported to a medical facility.

Front Right Passenger Data

Age/Sex:	15-year-old/Female
Height:	160 cm (63 in)
Weight:	52 kg (115 lb)
Eyewear:	None
Seat Track Position:	Mid-to-rear track
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from vehicle:	Exited under own power through right front door
Mode of Transport from Scene:	None
Type of Medical Treatment:	None

Front Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
8 cm (3 in) contusion on right side of neck	Minor (390402.1,1)	Safety belt

Source = Driver interview

Front Right Passenger Kinematics

The front right passenger was seated in a mid-to-rear track position in an upright posture and was restrained by the 3-point lap and shoulder belt. The passenger responded to the rear impact force by initiating a rearward trajectory. The passenger loaded the seat back with her torso and actuated the whiplash protection system of the head restraint. The head restraint moved up and forward towards the back of the passenger's head. The passenger's head contacted the head restraint and rode down the crash. The front right passenger then initiated a rebound trajectory, traveling forward within the front right seating position. She loaded the belt system with her torso and sustained a contusion to the right side of her neck. The passenger came to rest in the front right seat and exited the vehicle through the right front door. She refused medical transport from the scene and did not seek later treatment.

Second Row Left Passenger Data

Age/Sex:	17-year-old/Female
Height:	155 cm (61 in)
Weight:	52 kg (115 lb)
Eyewear:	None
Seat Track Position:	Not adjustable
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from vehicle:	Exited under own power through right front door after climbing over front row center console.
Mode of Transport from Scene:	None
Type of Medical Treatment:	None

Second Row Left Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
8 cm (3 in) contusion across lower abdomen	Minor (590402.1,8)	Safety belt

Source = Driver interview

Second Row Left Passenger Kinematics

The second row left passenger was seated in an upright posture and was restrained by the 3-point lap and shoulder belt system. As a result of the rear impact, the second row left passenger initiated a rearward trajectory. She loaded the seat back with her torso, compressed the seat back and then initiated a forward rebound trajectory within her seating position. The passenger loaded the belt system with her chest and abdomen resulting in a contusion across her abdomen. She came to rest within the second row left position. Due to the jammed rear doors, the passenger climbed over the front row center console and exited the vehicle through the right front door. She declined medical transport and did not seek later treatment.

Second Row Right Passenger Data

Age/Sex:	15-year-old/Male
Height:	178 cm (70 in)
Weight:	68 kg (150 lb)
Eyewear:	None
Seat Track Position:	Not adjustable
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from vehicle:	Exited under own power through right front door after climbing over front row center console.
Mode of Transport from Scene:	None
Type of Medical Treatment:	None

Second Row Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Contusion across lower abdomen	Minor (590402.1,8)	Safety belt

Source = Driver interview

Second Row Right Passenger Kinematics

The second row right passenger was seated in an upright posture and was restrained by the 3-point lap and shoulder belt system. As a result of the rear impact, the passenger initiated a rearward trajectory and loaded the seat back with his torso. The passenger compressed the seat back and then initiated a forward rebound trajectory. He loaded the belt system with his chest and abdomen resulting in an abdominal contusion. The passenger came to rest within the second row right position and exited the vehicle through the right front door after climbing over the center console. He declined medical transport and did not seek later treatment.

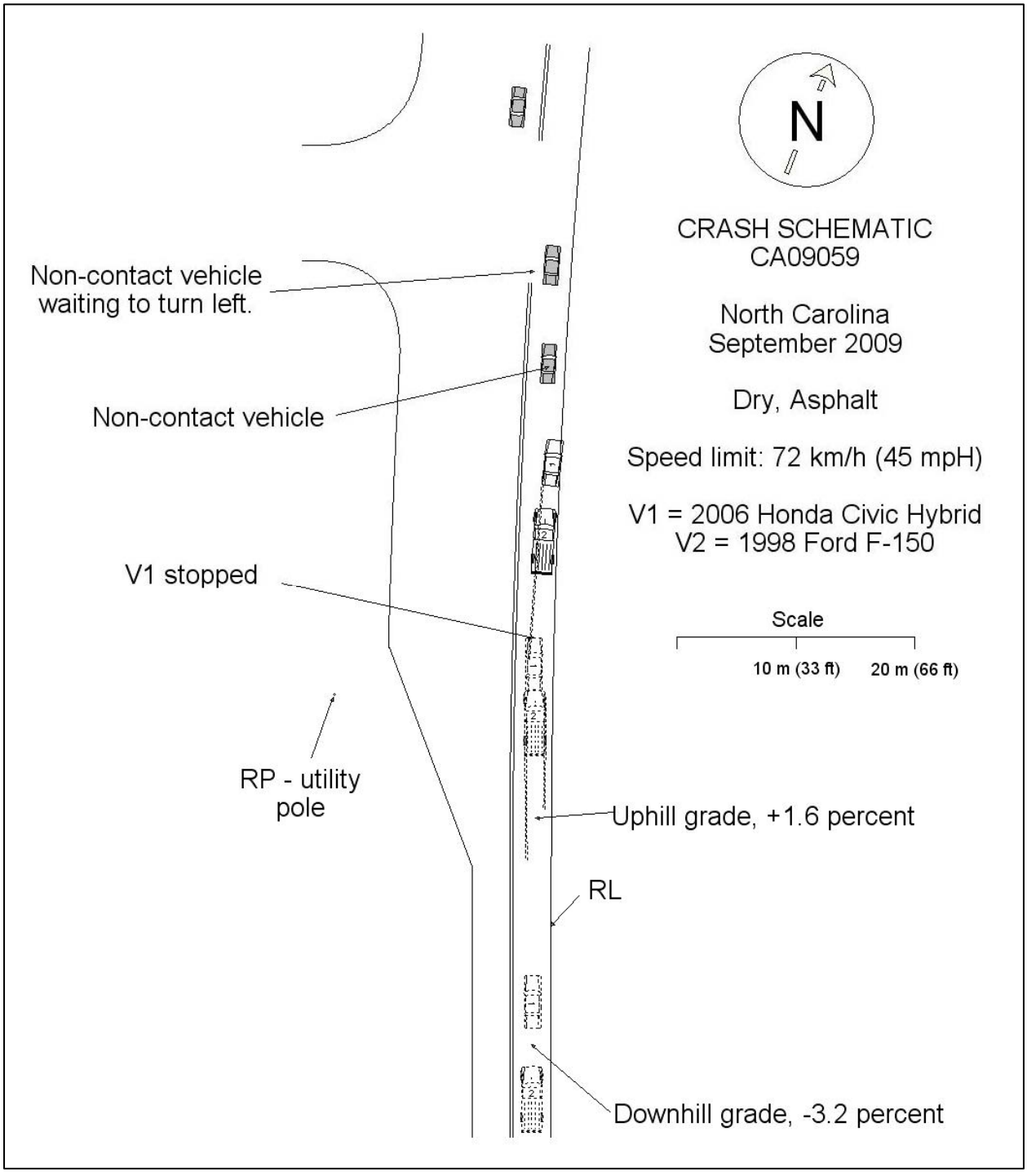

Figure 8: Crash Schematic