Hybrid Vehicle Investigation
Dynamic Science, Inc. (DSI), Case Number DS09013
2008 Toyota Prius
California
December 2008

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

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16. Abstract

This investigation focused on a 2008 Toyota Prius hybrid vehicle that sustained a back end impact. The crash occurred in the westbound lanes of a two-lane divided roadway. The Toyota was being driven in the inboard lane by a 48-year-old female. The other vehicle was a 2000 Chevrolet Silverado pickup that was being driven by a 23-year-old male. The Chevrolet was traveling behind the Toyota. The driver of the Toyota noticed that the Chevrolet was approaching her vehicle at a high speed. In an effort to avoid the crash, she initiated a lane change to the right. During the maneuver, the front of the Chevrolet struck the left rear of the Toyota. The driver of the Toyota did not sustain any injuries. The driver of the Chevrolet sustained a nasal fracture and a laceration above the right eye. He was transported to a local hospital where he was treated and then arrested for driving under the influence of alcohol. Both vehicles were towed from the scene due to damage. The Toyota was later declared a total loss by the insurance company.

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Dynamic Science, Inc.
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BACKGROUND

This investigation focused on a 2008 Toyota Prius hybrid vehicle that sustained a back end impact (**Figure 1**). The crash occurred in the westbound lanes of a two-lane divided roadway. The Toyota was being driven in the inboard lane by a 48-year-old female. The other vehicle was a 2000 Chevrolet Silverado pickup that was being driven by a 23-year-old male. The Chevrolet was traveling behind the Toyota. The driver of the Toyota noticed that the Chevrolet was approaching her vehicle at a high speed. In an effort to avoid the crash, she initiated a lane change to the right. During the maneuver, the front of the Chevrolet struck the left rear of the Toyota. The driver of the Toyota did not sustain any injuries. The driver of the Chevrolet sustained a nasal fracture and a laceration above the right eye. He was transported to a local hospital where he was treated and then arrested for driving under the influence of alcohol. Both vehicles were towed from the scene due to damage. The Toyota was later declared a total loss by the insurance company.

Figure 1. Subject vehicle, 2008 Toyota Prius

This on-site investigation was identified by the National Highway Traffic Safety Administration (NHTSA) during a search of an insurance auction lot. Images and data from the salvage facility were forwarded to DSI on March 6, 2009. DSI contacted the insurance company and obtained permission to inspect the vehicle and the inspection was completed on March 6, 2009. DSI was assigned the case that same day. Field work was completed on April 1, 2009 after the police report was obtained. The Chevrolet was not inspected.

SUMMARY

Crash Site

This two-vehicle crash occurred in December 2008 at 0155 hours. The crash occurred on a straight two-lane divided roadway (**Figure 2**). The inboard travel lane was bordered by a raised median; the outboard lane was bordered by raised concrete curb followed by a sidewalk. The asphalt roadway was dry and the streetlights in the area were illuminated. The posted speed limit was 40 km/h (25 mph).

Figure 2. Westbound approach to area of impact

Pre-Crash

The Toyota was being driven west in the inboard lane by a 48-year-old female. The Chevrolet was

traveling behind the Toyota. The driver of the Toyota noticed that the Chevrolet was approaching her vehicle at a high speed. In an effort to avoid the crash, she initiated a lane change to the right.

Crash

During the lane-change maneuver, the front of the Chevrolet struck the left rear of the Toyota. The Missing Vehicle algorithm of the WinSMASH program computed a Total Delta-V of 14 km/h (8.7 mph) for the Toyota. The longitudinal and lateral components were 14 km/h (8.6 mph) and -2 km/h (-1.5 mph), respectively. The left side impact inflatable curtain (IC) air bag in the Toyota deployed during the crash. For the Chevrolet, the program computed a Total Delta-V of 11 km/h (6.8 mph). The longitudinal and lateral components were -11 km/h (-6.8 mph) and 0 km/h, respectively.

Post-Crash

Both vehicles came to rest on the roadway but were driven to the side of the road prior to the arrival of the police. The driver of the Toyota did not sustain any injuries. The driver of the Chevrolet sustained a nasal fracture and a laceration above the right eye. He was transported to a local hospital where he was treated and then arrested for driving under the influence of alcohol. Both vehicles were towed from the scene due to damage. The Toyota was later declared a total loss by the insurance company. The status of the Chevrolet was not known.

Vehicle Data - 2008 Toyota Prius

The 2008 Toyota Prius 4-door hatchback was identified by the Vehicle Identification Number (VIN): JTDKB204287xxxxxx. The Toyota was manufactured in March 2008. It was a gas/electric hybrid vehicle that was equipped with a 1.5-liter, 4-cylinder gasoline engine, an electric drive motor, a continuously variable transmission, front wheel drive, traction control, and antilock brakes. The vehicle mileage was not known; there was no power to the vehicle and the key was missing.

The Toyota was equipped with Goodyear Integrity P185/65R15 tire. The tire manufacturer's stated maximum pressure was 303 kPa (44 psi); the vehicle manufacturer's recommended cold pressure was 241 kPa (35 psi) for the front tires and 228 kPa (33 psi) for the rear tires.

The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	179 kPa (26 psi)	6 mm (8/32 in)	No	None
LR	172 kPa (25 psi)	6 mm (8/32 in)	Yes	Bulge on sidewall.
RR	165 kPa (24 psi)	6 mm (8/32 in)	No	None
RF	165 kPa (24 psi)	7 mm (9/32 in)	No	None

The seating in the Toyota was configured with front bucket seats with adjustable head restraints

and a rear bench seat with separate back cushions.

Vehicle Damage - 2008 Toyota Prius

Exterior Damage

The Toyota sustained moderate back end damage from the impact with the Chevrolet (**Figure 3**). The direct damage began at the rear left bumper corner and extended 27 cm (10.6 in) to the right. The bumper fascia was displaced from the vehicle. There was direct contact damage up the left side of the vehicle that began at the left bumper corner and extended forward 173 cm (68.1 in). Vertically, the direct damage terminated 114 cm (44.8 in) above the ground. The sheet metal above the left rear tire was displaced laterally 24 cm (9.4 in). The gas cap top was torn away but the filler neck remained sealed.

Figure 3. Back end, left side

Six crush measurements were documented along the back bumper reinforcement as follows: C_1 = 17 cm (6.7 in), C_2= 12 cm (4.7 in), C_3 = 10 cm (3.9 in), C_4 = 7 cm (2.7 in), C_5 = 6 cm (2.4 in), C_6 = 3 cm (1.2 in). The Collision Deformation Classification (CDC) for the impact with the Chevrolet was 06BLEE7.

Interior Damage

The Toyota sustained minor interior damage as a result of passenger compartment intrusion and occupant contacts. Possible contacts were located to the driver's seat back and the driver's door. There was longitudinal intrusion to the second row seat back, lateral intrusion to the left rear door and C pillar, and vertical intrusion to the seat cushion.

The specific passenger compartment intrusions were documented as follows:

Position	Intruded Component	Magnitude of Intrusion	Direction
Second row left	Seat back	5 cm (1.9 in)	Longitudinal
Second row left	Door, rear lower quadrant	5 cm (1.9 in)	Lateral
Second row middle	Seat back	3 cm (1.2 in)	Longitudinal
Second row left	Seat cushion	3 cm (1.2 in)	Vertical
Second row left	C-pillar	3 cm (1.2 in)	Lateral

The left second row door and the rear hatch were jammed shut. The vehicle sustained integrity loss to the left rear/left rear 2 sideglass and the glazing strip beneath the backlight.

There was damage to the left cargo area aft of the rear seat. The left side panel of the cargo area was deformed inward 20 cm (7.8 in) and it deformed and fractured the left side of the rear deck floor box (**Figure 4**).

Figure 4. Cargo area intrusion

Manual Restraints

The Toyota was configured with 3-point manual lap and shoulder belts for all five seating positions. The vehicle was equipped with driver and front right passenger safety belt retractor pretensioners. The driver's safety belt anchorage adjustment was in the full-up position; the front right passenger's safety belt anchorage adjustment was in the full-down position. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR); there was evidence of historical usage. The police reported that the driver was restrained.

Supplemental Restraint Systems

The Toyota's supplemental restraint system consisted of driver and passenger air bags, left and right side IC air bags, and left and right seat-mounted side air bags. The vehicle was configured with front electronic side impact sensors mounted near the base of the B-pillars and rear side impact sensors mounted near the base of the C-pillars (**Figure 5**). According to Toyota reference material:

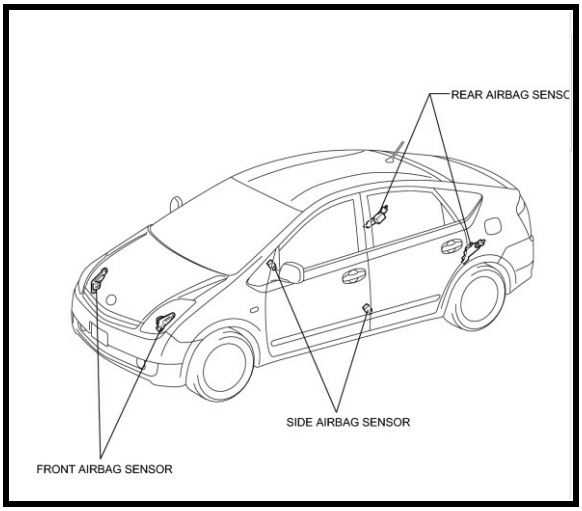

Figure 5. Impact sensor locations (Supplemental Restraint System - Air Bag System RS-1)

- Frontal collisions are detected by the air bag electronic control unit and two front air bag sensors. The driver and front passenger air bags and the seat belt pretensioners then operate simultaneously.
- Side collisions are detected by the side air bag sensor installed in the bottom of the center pillar and the rear air bag sensor installed in the bottom of the rear pillar.
- Front side collisions are detected by the side air bag sensor, causing the front seat air bag and curtain shield air bag to deploy simultaneously.
- Rear side collisions are detected by the rear air bag sensor to deploy only the curtain shield air bag.

The left side IC air bag deployed during this crash. While this was not a side impact, it is probable that the air bag deployed as a result of contact to the sensor during the rear end impact. There were no other air bag deployments, and the pretensioners did not actuate.

The left side impact IC air bag deployed through the roof rail cladding (**Figures 6-7)**. The air bag was generally rectangular and measured 167 cm (65.7 in) in length and 45 cm (17.7 in) in height. The forward aspect of the bag was attached to the left A-pillar by a sail panel that measured 22 cm (8.7 in) in length and was 25 cm (9.8 in) in height at the point it attached to the air bag; the rear aspect of the bag was attached to the left D-pillar. The longitudinal area of coverage began near the midpoint A-pillar and extended to the D-pillar. The bag's vertical coverage began at the roof rail and extended to approximately 7.0 cm (2.8 in) below the bottom of the side glass. The bag was configured with 20 pleats and did not have any internal tethers or ports. There were no contacts or damage to the air bag. The interior A-pillar cover was displaced 3 cm (1.2 in) laterally. There was a 13 cm (5.1 in) tear in the roof cladding at the rear aspect of the driver's grab handle.

Figure 6. Second row IC air bag

Figure 7. Front row IC air bag

Hybrid System - 2008 Toyota Prius

The Prius was specifically designed as a hybrid power train vehicle. The hybrid system consisted of a gasoline engine and an electric motor that when combined, produced low emissions and high fuel economy without the need to externally charge the battery system.

The Prius was designed with a 1.5-liter, transversely mounted gasoline engine which was linked to a permanent magnet AC electric motor. Both units were mounted in the front of the vehicle and linked to an electronically controlled continuously variable transmission (CVT). An inverter/converter in the engine compartment boosts and inverts the high voltage electricity from the traction battery pack to 3-phase AC electricity that drives the electric motor. The gasoline engine was positioned on the right side of the engine compartment with the electric motor mounted left of the engine.

The battery system was a 201-volt Nickel Metal-Hydride (NiMH) battery that was mounted in the rear cargo floor, aft of the second row seat (**Figure 8**). This high-voltage (HV) battery system was mounted laterally in the vehicle and was concealed and protected by an aluminum cover that was bolted to the rear floor. Orange -color power cables carry high voltage direct current between the HV battery pack and the inverter/converter. The cables extended along the left side of the vehicle, from the cargo area to the engine compartment. The Prius was equipped with a regenerative braking system that utilized the motor to decelerate the vehicle and convert power back into the batteries for recharging purposes.

Figure 8. Traction battery

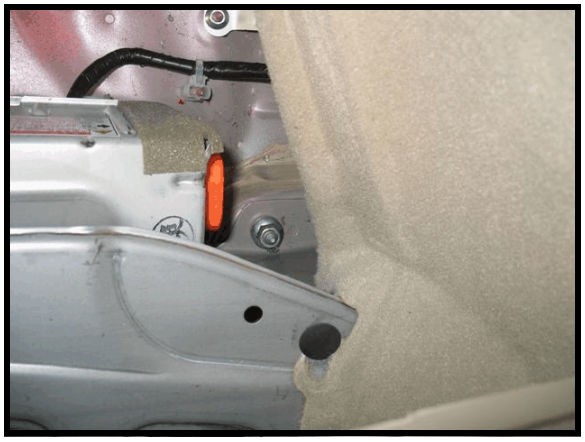

Figure 9. Traction battery service plug

Federal Motor Vehicle Safety Standard (FMVSS) 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection is the standard applied to vehicles that use more that 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.[1] 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 battery 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 Toyota was examined to assess compliance with FMVSS No. 305.

- There were no indications of electrolyte spillage from the propulsion battery.
- There was no movement of the battery module.
- The isolation test was not conducted; there was no power to the vehicle or to the traction battery.

[1]U.S. Department of Transportation, 49CFR 571.305

- There were no indications of any arcing, fire or component meltdown.

The service plug was located on the left side of the battery and was in place at the time of the vehicle inspection (**Figure 9**). The service plug shuts off the high voltage circuit of the HV battery when this plug is removed for vehicle inspection or maintenance.

According to Toyota service personnel, there are two possible locations to test for power when vehicle power is available and the ignition is on: the System Master Relay (SMR) and at the cables leading into the inverter. In newer models, the SMR is located within the battery box cover and is not accessible without removing the cover and pulling the service plug. If there is no service battery power or the key is not on or the ignition is off, the SMR is in an open condition and there will be no power past the SMR. There will be no power to the high power cable or to the inverter. While in the open condition, the SMR shuts down both the ground and power sides.

This moderate severity crash was isolated to the left rear of the vehicle. There was no damage to the battery pack area or any visible damage to the area of the left side harness. The engine compartment was not damaged. There was no evidence of damage or procedures by the first responders to the crash site.

Vehicle Data - 2000 Chevrolet Silverado

The 2000 Chevrolet C1500 Silverado pickup was identified from the VIN: 1GCEC14W2YZxxxxxx. The Chevrolet was equipped with a 4.3-liter, 6-cylinder engine, rear-wheel drive, 4-wheel ABS, and power steering. The Chevrolet sustained moderate damage to the front right end from the impact with the rear of the Toyota and was towed from the scene.

Occupant Demographics

	Driver
Age/Sex:	48/Female
Seated Position:	Front left
Seat Type:	Bucket
Seat track position:	Unknown
Height:	163 cm (64 in)
Weight:	61 kg (135 lbs)
Alcohol/Drug Involvement:	None
Body Posture:	Normal, upright
Hand Position:	Both hands on steering wheel, unknown clock direction.
Foot Position:	Right foot on accelerator, left on floor.

Restraint Usage:	Lap and shoulder belt used per interviewee.
Air bags:	Frontal and seat-mounted side air bag, did not deploy. Side impact IC air bag deployed.

Occupant Injuries

Driver was not injured.

Driver Kinematics

The 48-year-old female driver was seated in an upright posture and was restrained by the 3-point lap and shoulder belt. The seat back was slightly reclined. The seat track was position at the time of the crash is not known. The driver was actively steering with both hands and was attempting to change lanes to the right. At impact with the Chevrolet, the driver initiated a rearward trajectory and impacted the seat back. There was a scuff located on the right upper area of the seat back. She did not sustain any injuries and was able to exit the vehicle under her own power.

Attachment 1. Scene Diagram