Hybrid Vehicle Investigation
Dynamic Science, Inc. (DSI), Case Number DS09014
2007 Toyota Prius
California
September 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 2007 Toyota Prius hybrid vehicle that sustained a back end impact. The crash occurred in the southbound lanes of a seven-lane north/south roadway that approached a four-leg intersection. The Toyota was being driven in the second lane from the right by a 52-year-old male. The other vehicle was a 2004 Jeep Wrangler Rubicon that was being driven by a 44-year-old male and occupied by a 42-year-old female front right passenger. The Jeep was traveling behind the Toyota. The driver of the Toyota saw and heard an ambulance in a parking lot to his right. He braked and came to a complete stop at the north limit line of the intersection. The driver of the Jeep braked but did not stop in time and the front end of the Jeep impacted the rear of the Toyota. The drivers of the two vehicles were not injured. The front right passenger of the Jeep complained of pain to her neck and right foot. The Toyota was towed from the scene due to damage and the Jeep was driven from the scene. The Toyota was later declared a total loss by the insurance company.

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Dynamic Science, Inc.
Crash Investigation
Case Number: DS09014

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BACKGROUND

This investigation focused on a 2007 Toyota Prius hybrid vehicle that sustained a back end impact (**Figure 1**). The crash occurred in the southbound lanes of a seven-lane north/south roadway that approached a four-leg intersection. The Toyota was being driven in the second lane from the right by a 52-year-old male. The other vehicle was a 2004 Jeep Wrangler Rubicon that was being driven by a 44-year-old male and occupied by a 42-year-old female front right passenger. The Jeep was traveling behind the Toyota. The driver of the Toyota saw and heard an ambulance in a parking lot to his right. He braked and came to a complete stop at the north limit line of the intersection. The driver of the Jeep braked but did not stop in time and the front end of the Jeep impacted the rear of the Toyota. The drivers of the two vehicles were not injured. The front right passenger of the Jeep complained of pain to her neck and right foot. The Toyota was towed from the scene due to damage and the Jeep was driven from the scene. The Toyota was later declared a total loss by the insurance company.

Figure 1. Subject vehicle, 2007 Toyota Prius

This investigation was initiated by the National Highway Traffic Safety Administration (NHTSA) during a search of auto auction facility. On March 6, 2009, DSI was forwarded the vehicle images, data and location with instructions to obtain cooperation. On March 10, 2009, DSI obtained permission to inspect the subject vehicle and the case was assigned. The vehicle was inspected at the auto auction facility on March 10, 2009. The police report was requested in March and obtained in April. The Jeep was not inspected.

SUMMARY

Crash Site

This two-vehicle crash occurred in September 2008 at 0930 hours. The crash occurred in the southbound lanes of a straight seven-lane, divided roadway (**Figure 2**). The roadway approaches a four-leg intersection and was comprised of three southbound travel lanes, a left turn lane, a painted median formed by two sets of double yellow lines, and three northbound travel lanes. The intersection was formed by the north/south roadway, an eastbound roadway, and a westbound entrance into a parking lot. The intersection was controlled by three-phase traffic signals that were green for southbound traffic at the time of the crash. The

Figure 2. Southbound approach for Toyota and Jeep

asphalt roadway was dry and level and had a posted speed limit of 64 km/h (40 mph).

Pre-Crash

The Toyota was being driven southbound in the second lane from the right. The Jeep was being driven southbound in the same lane behind the Toyota. A non-contact ambulance was facing east at the exit of the parking lot. The driver of the ambulance had activated his emergency lights and sirens in response to a medical call. He had been waiting for approximately 5 seconds for cross traffic to clear at the intersection before the crash. The driver of the Toyota saw and heard the ambulance. He braked and came to a complete stop at the north limit line of the intersection.

Crash

The driver of the Jeep braked but did not stop in time and the front end of the Jeep impacted the back end of the Toyota. The Missing Vehicle algorithm of the WinSMASH program computed a Total Delta-V of 26 km/h (16.2 mph) for the Toyota. The longitudinal and lateral components were 26 km/h (16.2 mph) and 0 km/h, respectively. The program computed a Total Delta-V of 21 km/h (13.0 mph) for the Jeep. The longitudinal and lateral components were -21 km/h (-13.0 mph), respectively.

Post-Crash

The Toyota was pushed forward but remained in the north leg of the intersection. Both vehicles came to rest on the roadway facing south. All occupants were able to exit their respective vehicles under their own power. The driver of the Toyota did not sustain any injuries and reported he barely felt the impact. The driver of the Jeep did not report any injuries and the front right passenger complained of pain to her neck and right foot. She refused any medical treatment and indicated that she would seek medical attention later if necessary.

The Toyota was towed from the scene due to damage. The Jeep was driven from the scene. The Toyota was later declared to be a total loss by the insurance company.

Vehicle Data - 2007 Toyota Prius

The 2007 Toyota Prius 5-passenger, 4-door hatchback was identified by the Vehicle Identification Number(VIN): JTDKB20U773xxxxxx (**Figure 3**), and was manufactured in May 2007. The Toyota 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, a regenerative braking system, and a 4-wheel anti-lock brake system. According to the auction facility, the vehicle mileage was 31,970 km (19,866 miles).

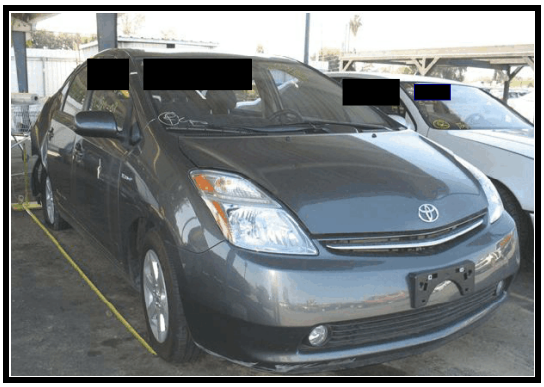

Figure 3. 2007 Toyota Prius

The Toyota was equipped with Goodyear Integrity

P185/65R15 tires. 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	193 kPa (28 psi)	6 mm (8/32 in)	No	None
LR	159 kPa (23 psi)	7 mm (9/32 in)	No	None
RR	Tire Flat	6 mm (7/32 in)	Yes	Gouge and abrasion to sidewall
RF	193 kPa (28 psi)	6 mm (7/32 in)	No	None

Vehicle Damage - 2007 Toyota Prius

Exterior Damage

The Toyota sustained moderate back end damage from the impact with the Jeep (**Figures 4-5**). The direct damage began at the right bumper corner of the bumper fascia and extended 77 cm (30.3 in) to the left. The Field L began at the right bumper corner and extended 130 cm (51.1in) to the left bumper corner. The bumper fascia was displaced from the vehicle and the bumper reinforcement had rotated forward; the crush measurements were taken to the mid-point of the reinforcement. Six crush measurements were documented along the rear bumper reinforcement as follows: C1 = 5 cm (1.9 in), C 2= 13 cm (5.1 in), C3 = 21 cm (8.3 in), C4 = 28 cm (11.0 in), C5 = 30 cm (11.8 in), C6 = 33 cm (12.9 in). The Collision Deformation Classification (CDC) for the impact with the Jeep was 06BZEW3.

Figure 4. Rear end damage

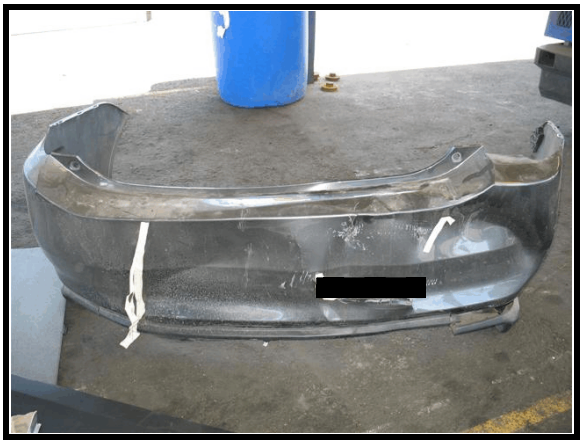

Figure 5. Contact to rear bumper fascia

Interior Damage

The Toyota did not sustain any damage to the passenger area related to intrusion or occupant contacts. According to the interviewee, the rear hatch was jammed shut after the crash, but was later forced open. The lower backlight was disintegrated during the impact.

There was damage to the cargo area aft of the rear seat and the traction battery (**Figure 6**). Aft of the battery, the Toyota was configured with a plastic liner that was situated above the spare tire. The liner was normally covered by a deck lid. The lid was located in the rear of the vehicle. The plastic liner was cracked and deformed forward, primarily on the right. The aft portion of the cargo area was deformed forward. The longitudinal distance from the seat back to the aft portion of the cargo area measured 90 cm (35.4 in) on the left and 53 cm (20.8 in) on the right. Since the left side was largely undamaged, the depth of crush was 37 cm (14.6 in). The distance between the aft portion of the battery and aft portion of the cargo compartment measured 46 cm (18.1 in) on the left and 19 cm (7.5 in) on the right.

Figure 6. Damage to cargo area

The vehicle's lead-acid service battery was located in the right rear of the cargo compartment. It was fractured during the crash and the battery had leaked the acid/water solution.

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 and front right passenger's safety belt anchorage adjustment were in the full-up position. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR); there were indications of historical usage.

Supplemental Restraint Systems

The Toyota's supplemental restraint system consisted of driver and passenger air bags, left and right side curtain air bags, left and right seat mounted side air bags, and front outboard safety belts with retractor pretensioners. The vehicle was configured with side impact sensors mounted near the base of the B-pillars and near the base of the C-pillars. There were no air bag deployments and the safety belt prentensioners did not actuate.

Hybrid System - 2007 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. 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 (**Figure 7**).

Figure 7. Engine compartment configuration

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 lateral to lateral in the vehicle and was concealed and protected by an aluminum cover that was bolted to the rear floor of the vehicle. Orange-colored 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.

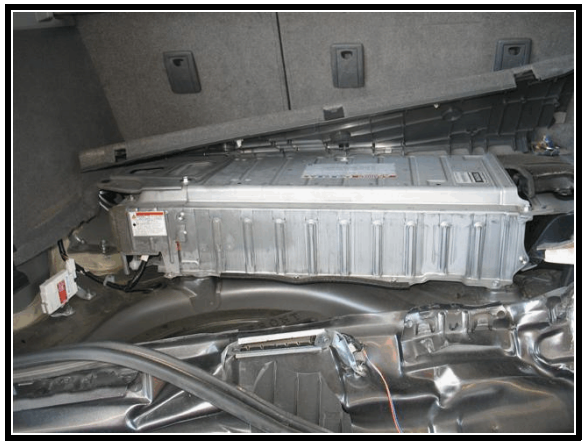

Figure 8. Traction battery

Conformance to Sec. 571.305 Standard No. 305; Electric-powered vehicles: electrolyte spillage and electrical shock protection

The vehicle was examined to determine compliance with FMVSS 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.
- 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. 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 right rear of the vehicle. There was no damage to the battery pack area and the battery had not moved. The engine compartment was not damaged. There was no evidence of damage by the first responders to the crash site.

Vehicle Data - 2004 Jeep Wrangler Rubicon

The 2004 Jeep Wrangler Rubicon was identified in the police report. The Jeep was equipped with a 4.0-liter, 6-cylinder engine, 4-wheel drive, and disc brakes. The vehicle sustained moderate frontal damage and was driven from the scene.

Occupant Demographics

	Driver
Age/Sex:	52/Male
Seated Position:	Left front
Seat Type:	Bucket
Seat track position:	Mid-track
Height:	183 cm (72 in)
Weight:	84 kg (195 lbs)
Alcohol/Drug Involvement:	None
Body Posture:	Normal
Hand Position:	Both hands on wheel, unknown clock positions.
Foot Position:	Right foot on brake, left on floor.
Restraint Usage:	Lap and shoulder belt
Air bags:	Driver frontal air bag, seat-mounted side air bag, and side-impact IC air bag. There were no deployments.

Occupant Injuries

Driver not injured.

Driver Kinematics

The 52-year-old male driver was seated in an upright posture and was wearing the lap and shoulder belt. Prior to impact, the driver had brought the vehicle to a stop. His right foot was on the brake, the left on the floor. At impact, he was displaced rearward into the seat back. There were no indications of loading to the seat back and the driver did not report any injuries. The vehicle came

to rest slightly forward of its original position. The driver was able to exit the vehicle under his own power.

Attachment 1. Scene Diagram