# On-Site Hybrid Vehicle Investigation
Dynamic Science, Inc. (DSI), Case Number DS09018
2007 Toyota Prius
California
January 2009

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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 multiple side impacts. This three-vehicle crash occurred within a four-leg intersection. The subject vehicle was a 2007 Toyota Prius hybrid that was being driven by 49-year-old female. A 14-year-old male occupied the front row right seat position. The first other vehicle was a 2004 Toyota Camry that was being driven by a 22-year-old male. The second other vehicle was a 2009 Dodge Journey that was being driven by a 38-year-old male. The Prius was traveling eastbound in the uncontrolled left turn lane of an east/west roadway. The Camry was traveling westbound toward the intersection in the second lane from the right. The Journey was stopped in the north leg of the intersection in the southbound lane. The driver of the Prius intended to make a U-turn. As she began the turn, she observed the Camry and instead of completing the U-turn accelerated through a left turn. The front end of the Camry impacted the right side of the Prius. The impact resulted in sufficient lateral deceleration of the Prius to command the deployment of the right inflatable curtain (IC) air bag. The Prius was redirected northwest and the left side of the Prius impacted the front end of the Journey. During this impact, the Prius' left IC air bag and the seat-mounted side air bag deployed. The driver and front right occupant of the Prius did not report any injuries. An occupant in the Camry complained of pain and was transported to a local hospital. There were no other injuries reported. The Prius was towed due to damage and was later declared to be a total loss by the insurance company.

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**Dynamic Science, Inc.**
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## BACKGROUND

This investigation focused on a 2007 Toyota Prius hybrid vehicle that sustained multiple side impacts (**Figures 1-2**). This three vehicle crash occurred within a four-leg intersection. The subject vehicle was a 2007 Toyota Prius hybrid that was being driven by 49-year-old female. A 14-year-old male occupied the front row right seat position. The first other vehicle was a 2004 Toyota Camry that was being driven by a 22-year-old male. The second other vehicle was a 2009 Dodge Journey that was being driven by a 38-year-old male. The Prius was traveling eastbound in the uncontrolled left turn lane of an east/west roadway. The Camry was traveling westbound toward the intersection in the second lane from the right. The Journey was stopped in the north leg of the intersection in the southbound lane. The driver of the Prius intended to make a U-turn. As she began the turn, she observed the Camry and instead of completing the U-turn accelerated through a left turn. The front end of the Camry impacted the right side of the Prius. The impact resulted in sufficient lateral deceleration of the Prius to command the deployment of the right inflatable curtain (IC) air bag. The Prius was redirected northwest and the left side of the Prius impacted the front end of the Journey. During this impact, the Prius' left IC air bag and the seat-mounted side air bag deployed. The driver and front right occupant of the Prius did not report any injuries. An occupant in the Camry complained of pain and was transported to a local hospital. There were no other injuries reported. The Prius was towed due to damage and was later declared a total loss by the insurance company.

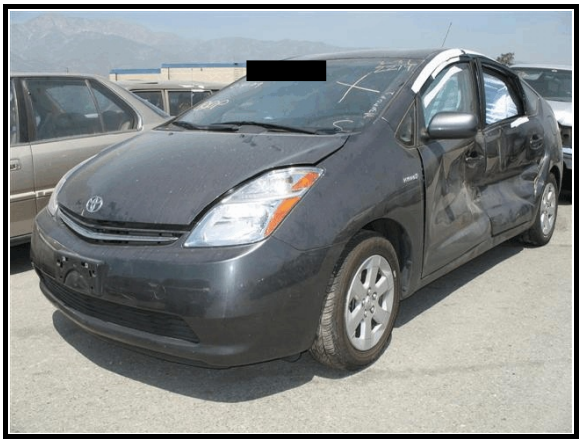

**Figure 1**. 2007 Toyota Prius, left side damage

**Figure 2**. 2007 Toyota Prius, right side damage

This investigation was initiated by the National Highway Traffic Safety Administration (NHTSA) during a search of an online vehicle auction. On March 23, 2009, DSI was forwarded the vehicle images and location with instructions to obtain cooperation. DSI obtained the police report on March 23, 2009 and obtained permission to inspect the subject vehicle and to remove the vehicle's Event Data Recorder (EDR). The case was assigned on March 30, 2009 and the vehicle was inspected on April 1, 2009. The EDR was removed and submitted to the NHTSA Crash Investigation Division (CID). The EDR was imaged by Toyota and a summary of the report is included in this report.

## SUMMARY

### Crash Site

This three-vehicle crash occurred within a four-leg intersection. At the time of the crash, there were no adverse weather conditions and the asphalt roadway surface was dry. Conditions were dark with streetlights illuminated. The west leg of the intersection was comprised of three eastbound through lanes, a left turn lane, a curbed median, and three westbound travel lanes (**Figure 3**). The east leg of the intersection was comprised of three westbound travel lanes, a left turn lane, a curbed median, and three eastbound travel lanes (**Figure 4**). There were no controls for the east/west roadway and the posted speed limit was 72 km/h (45 mph). The north leg of the intersection was comprised of a southbound travel lane and northbound travel lane. The roadway was controlled by a stop sign and the posted speed limit was 40 km/h (25 mph).

**Figure 3**. West leg of intersection

**Figure 4**. East leg of intersection

### Pre-Crash

The Prius was traveling eastbound in the uncontrolled left turn lane of an east/west roadway at a driver-reported speed of 32 km/h (20 mph). The Camry was traveling westbound toward the intersection in the second lane from the right. The Journey was stopped in the north leg of the intersection in the southbound lane. The driver of the Prius intended to make a U-turn. As she began the turn, she observed the Camry and instead of completing the U-turn accelerated through a left turn. The driver of the Camry tried to avoid the crash by steering to the right.

### Crash

The driver of the Camry was unable to avoid the crash and the front end of the Camry impacted the right side of the Prius. The Missing Vehicle algorithm of the WinSMASH program computed a Total Delta-V of 9.0 km/h (5.6 mph), based on the Pruis' right side crush profile. The longitudinal and lateral components were -3.1 km/h (-1.9 mph) and -8.5 km/h (-5.3 mph), respectively. The impact resulted in sufficient lateral deceleration of the Prius to command the deployment of the right IC air bag. The Prius was redirected in a clockwise direction to the northwest and the left side of the Prius impacted the front end of the stopped Journey. The Missing Vehicle algorithm of the WinSmash program computed a Total Delta-V of 21.0 km/h (13.0 mph), based on the Pruis' left side crush profile. The longitudinal and lateral components were 0 km/h and 21.0 km/h (13.0 mph), respectively. The results appear high. During this impact, the left IC air bag and the left seat-

mounted side air bag deployed.

**Post-Crash**

The driver and front right occupant of the Prius did not report any injuries. The driver of the Camry complained of pain to his upper right arm and was transported to a local hospital. There were no other injuries reported. The Prius was towed due to damage and was later declared 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): JTDKB20U273xxxxxx. The date of vehicle manufacture is not known. The Toyota was a gas/electric hybrid vehicle that was equipped with a 1.5-liter, 4-cylinder gasoline engine, electric drive motor, continuously variable transmission, front wheel drive, traction control, regenerative braking system, and 4-wheel ABS. The vehicle mileage was 65,505 km (40,703 miles). The Toyota was equipped with Federal Formoza FD-1 185/65R16 tires. The tire manufacturer's stated maximum pressure was 248 kPa (36 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 | 262 kPa (38 psi) | 5 mm (6/32 in) | No | None |
| LR | 207 kPa (30 psi) | 4 mm (5/32 in) | No | None |
| RR | 193 kPa (28 psi) | 5 mm (6 /32 in) | No | None |
| RF | 193 kPa (28 psi) | 4 mm (5/32 in) | No | None |

**Exterior Damage - 2007 Toyota Prius**

The Prius sustained minor right side plane damage from the impact with the Camry (**Figure 5**). The direct damage began 47.0 cm (18.5 in) aft of the rear axle and extended 140.0 cm (55.1 in) forward along the right side plane. The right rear tire was deformed and had a negative camber of 9 degrees. The combined direct and induced damage began 47.0 cm (18.5) aft of the rear axle and extended 168.0 cm (66.1 in) forward along the right side plane. Six crush measurements were documented at the mid-door level as follows: $C_1$ = 0 cm, $C_2$ = 2.0 cm (0.8 in), $C_3$ = 6.0 cm (2.4 in), $C_4$ = 11.0 cm (4.3 in), $C_5$ = 8.0 cm (3.1 in), $C_6$ = 0 cm. The height of the maximum lateral crush was 47.0 cm

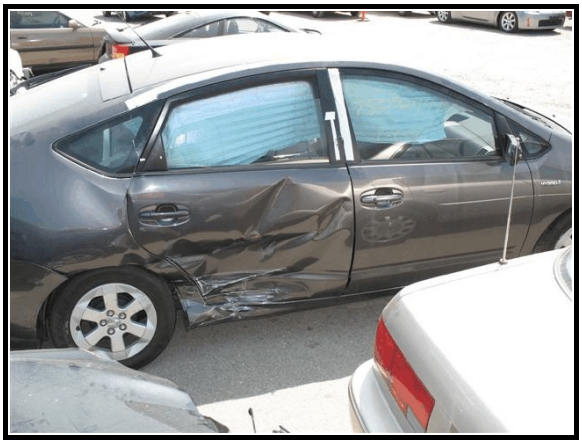

**Figure 5**. Right side damage

(18.5 in) from the ground and was located at C4. The Door Sill Differential (DSD) was 8.0 cm (3.1 in). The Collision Deformation Classification (CDC) for the impact with the Camry was 02RPEW2.

The Prius sustained moderate left side plane damage from the impact with the Journey (**Figure 6**). The direct damage began 28.0 cm (11.0 in) forward of the rear axle and extended 199.0 cm (78.3 in) forward along the left side plane. The combined direct and induced damage began 9.0 cm (3.5 in) forward of the rear axle and extended 219.0 cm (86.2 in) forward along the left side plane. Six crush measurements were documented at the mid-door level as follows: $C_1$ = 0 cm, $C_2$ = 14.0 cm (5.5 in), $C_3$ = 19.0 cm (7.4 in), $C_4$ = 17.0 cm (6.7 in), $C_5$ = 9.0 cm (3.5 in), $C_6$ = 0 cm. The height of the maximum lateral crush was 60.0 cm (23.6 in) from the ground and was located 119.0 cm (46.8 in) forward of the rear axle at the B-pillar. The DSD was 12.0 cm (4.7 in). The CDC for the impact with the Journey was 09LPEW2.

**Figure 6**. Left side damage

**Interior Damage - 2007 Toyota Prius**

The Prius sustained minor interior damage as a result of passenger compartment intrusion **(Figure 7**). The left front and rear doors and B-pillar sustained lateral intrusion. The specific intrusions were as follows:

| Row | Position | Intruded Component | Magnitude of Intrusion | Direction |
|---|---|---|---|---|
| 1 | Left | B-pillar | 9.0 cm (3.5 in) | Lateral |
| 1 | Left | Door, rear upper quadrant | 8.0 cm (3.1 in) | Lateral |
| 2 | Left | Door, forward upper quadrant | 7.0 cm (2.8 in) | Lateral |
| 1 | Left | Seat back | 1.0 cm (0.4 in) | Lateral |

The right rear door was jammed shut and the right rear window frame was bowed outward. There was a gap located along the right window frame with a maximum opening of 4.0 cm (1.6 in). Both left side doors were jammed shut and the left front window was bowed outward. There was a gap located along the left window frame with a maximum opening of 4.0 cm (1.6 in). The left rear window glazing was disintegrated due to impact damage.

**Figure 7**. Left interior intrusion

**Manual Restraints**

The Prius 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-down position. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR). The remaining safety belts were configured with sliding latch plates and switchable ELR/Automatic Locking Retractors (ALR); the belts were set in ELR mode. All safety belts in the vehicle showed indications of historical usage. The police reported that the driver and front right occupant were restrained

**Supplemental Restraint Systems (SRS)**

The Toyota was equipped with advanced occupant protection systems including multi-stage Certified Advanced 208-Compliant driver and front right passenger air bags. The multi-stage air bags were certified by the manufacturer to be compliant with the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The frontal air bags did not deploy.

The vehicle was also equipped with left and right side IC air bags, and left and right seat-mounted side air bags. The vehicle was configured with side impact sensors mounted near the lower B- and C-pillars.

**Figure 8**. Right side curtain air bag

The right IC air bag deployed during the impact with the Camry (**Figure 8**). The right seat-mounted side air bag did not deploy. This was probably because the damage was located primarily near the C-pillar sensor. The right IC air bag deployed vertically from roof cladding. The curtain measured 172.0 cm (67.7 in) in length and 45.0 cm (17.7 in) in height. It provided coverage for both the first and second row of the vehicle and extended vertically 4.0 cm (1.6 in) below the side glass. The curtain was attached to the left A-pillar by a 27.0 cm (10.6 in) sail. There was a smear, which was suspected to be a hair oil transfer, that measured 16.0 cm (6.3 in) in width and 20.0 cm (7.9 in) in

height; the transfer was located at the B-pillar and extended down to the bottom edge of the air bag. A 6.0 cm (2.4 in) longitudinal transfer was located 49.0 cm (19.2 in) aft of the front aspect of the air bag and 4.0 cm (1.6 in) below the roof cladding.

**Figure 9**. Left IC air bag and side air bag

The left IC air bag and the left seat-mounted side air bag deployed during the impact with the Journey (**Figure 9**). The left IC air bag deployed vertically from the roof cladding and was of the same dimensions as the right IC air bag. There were no indications of damage or contact to the curtain. The side air bag deployed longitudinally from the driver's seat back. The air bag extended 40.0 cm (15.7 in) in length and 40.0 cm (15.7 in) in height. Three vent ports were located at the forward aspect of the air bag. A 2.0 x 4.0 cm (0.8 x 1.6 in) scuff was located 7.0 cm (2.8 in) aft of the forward aspect of the air bag.

**Event Data Recorder**

The initial data table reported the following:

- There was no frontal air bag deployment time and the driver and passenger deployment stages were listed as Not Fired.

The individual data, pre-crash data, and post-crash data for the first reported event included the following:

- The driver's seat position was rearward.
- The belt switch status for the driver and front right passenger was belted.
- The writing flag indicated that the writing had been finished.
- The data in the pre-crash section reported no vehicle speed, no engine RPM, and both accelerator and brake as Off.
- The velocity change was reported as 0.6 km/h (0.4 mph ) at 10 milliseconds (ms) and declining to -0.2 km/h (-0.1 mph ) at 150 ms.

The individual data, pre-crash data, and post-crash data for the second reported event included the following:

- The driver's seat position and the belt switch for the front seat was the same as in the first reported event.
- The pre-crash data was the same as in the first reported event.
- The velocity change was reported as 0.6 km/h (0.4 mph ) at 10 ms and ascending to 4.0 km/h (2.5 mph ) at 150 ms.

**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 (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.

**Figure 10**. Traction battery

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 10**). 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 color power cables carry high voltage direct current between the HV battery pack and the inverter/converter.

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.

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

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.
- 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 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. The battery pack relays will automatically open to stop electricity flow in a collision sufficient to activate the frontal air bags.

This moderate severity crash was isolated to the left and right sides 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 - 1994 Toyota Camry**

The 1994 Toyota Camry was identified on the police report but was not inspected. Camry sedans and coupes were designed with seating for five. The vehicle sustained frontal damage and was towed from the scene.

**Vehicle Data - 2009 Dodge Journey**

The 2009 Dodge Journey was identified on the police report but was not inspected. The Journey was a four-door, cross-over sport utility vehicle with seating for five, or six if the vehicle was configured with the optional third row seat. The vehicle was equipped with a 2.4-liter, 4-cylinder engine in its base configuration. The vehicle sustained frontal damage and was driven from the scene by the driver.

## OCCUPANT DEMOGRAPHICS

| | Driver | Front Right |
|---|---|---|
| Age/Sex: | 49/Female | 14/Male |
| Seated Position: | Front left | Front right |
| Seat Type: | Bucket | Bucket |
| Seat track position: | Between forward and mid-track | Mid-track |
| Height: | 163 cm (64 in) | 170 cm (67 in) |
| Weight: | 54 kg (130 lbs) | 54 kg (119 lbs) |
| Alcohol/Drug Involvement: | None | N/A |
| Body Posture: | Upright | Upright |
| Hand Position: | 10/2 o'clock positions on steering wheel | Unknown |
| Foot Position: | Right foot on accelerator, left on floor | Both feet on floor |
| Restraint Usage: | Lap and shoulder belt | Lap and shoulder belt |
| Air bags: | Steering wheel mounted frontal air bag, did not deploy. Side IC air bag and seat-mounted side air bag deployed. | Instrument panel mounted frontal air bag and seat-mounted side air bag, did not deploy. Side IC air bag deployed. |

## OCCUPANT INJURIES

The driver and front right passenger were not injured.

## OCCUPANT KINEMATICS

### Driver Kinematics

The female driver was seated in an upright posture and was restrained by the 3-point manual lap and shoulder belt. The bucket seat was positioned between the forward and mid-track position. The seat back was positioned 21 degrees from vertical and the seat cushion was positioned 12 degrees from horizontal. At impact with the Camry, the right IC air bag deployed. The driver was displaced laterally and slightly forward to the right. There were no indications of loading to the seat belt webbing. The vehicle began a clockwise rotation and the left side of the vehicle impacted the Journey. At impact with the Journey, the left IC air bag and the left seat-mounted side air bag

deployed. The driver likely engaged both air bags to some degree. A small scuff was located on the side air bag. There was no damage to the air bags and the driver did not report any injuries.

**Front Right Occupant Kinematics**

The 14-year-old was seated in an upright posture and was restrained by the 3-point manual lap and shoulder belt. The bucket seat was positioned at the mid-track position. The seat back was positioned 21 degrees from vertical and the seat cushion was positioned 12 degrees from horizontal. At impact with the Camry, the right IC air bag deployed. This occupant was displaced laterally the right and his head contacted the deployed air bag, depositing a hair oil transfer. The vehicle began a clockwise rotation and the left side of the vehicle impacted the Journey. This occupant was displaced to the left but was held in place by the lap and shoulder belt. There were no reported injuries to this occupant

**Attachment 1. Scene Diagram**