On-scene Investigation / Vehicle versus Power Pole
Dynamic Science, Inc. / Case Number: DS01-011
2001 Toyota Prius Hybrid
California
March, 2001
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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 crash-worthiness performance of the involved vehicle(s) or their safety systems.
**Title and Subtitle**
In-Depth Accident Investigation

**Author(s)**
Dynamic Science, Inc.

**Performing Organization name and Address**
Dynamic Science, Inc.
530 College Parkway, Ste. K
Annapolis, MD  21401

**Sponsoring Agency Name and Address**
U.S. Dept. of Transportation (NRD-32)
National Highway Traffic Safety Administration
400 7th Street, SW
Washington, DC  20590

**Abstract**
This case was initiated because the case vehicle is a gas/electric hybrid vehicle. This single vehicle versus a power pole type collision occurred in March, 2001 at 0720 hours in an agrarian area of northern California. The crash occurred on a two-lane, straight and level, undivided asphalt roadway. The speed limit is 89 km/h (55 mph). There were no road defects or visual obstructions reported.

The case vehicle, a 2001 Toyota Prius Hybrid 4-door, was driven by a restrained 54-year-old female (168 cm-66 in./61 kg-135 lbs). The case vehicle was traveling eastbound at a driver reported 81 km/h (50 mph) while on her way to work. The driver reported that a coyote ran out onto the roadway from an unknown direction. She steered the case vehicle to the right to avoid running over the coyote, and lost control of the vehicle. The case vehicle ran off the south edge of the roadway and onto a dirt field. The driver then steered back to the left causing the case vehicle to begin rotating counterclockwise on the dirt field. The rear right fender of the case vehicle struck a power pole.

The case vehicle was assigned a Collision Deformation Classification (CDC) of 03RBEN3 with a Principle Direction of Force (PDOF) of 090 degrees. The combined direct and induced damage width was 80.0 cm (31.5 in.) [CRASH L = 80.0 cm (31.5 in.)], and the maximum crush depth was 48.5 cm (19.1 in.) located at C4. The Delta V for the case vehicle was computed using WinSmash version 2.12 and the pole option with size and stiffness coefficients derived from the case vehicle’s wheelbase. WinSmash calculated a total delta v of 29.0 km/h (18.0 mph), a longitudinal delta v of 0.0 km/h (0.0 mph) and a lateral delta v of -29.0 km/h (18.0 mph). The results fit the collision model and appear reasonable. The case vehicle was towed from the scene due to damage and was subsequently declared a total loss and sold as a salvage vehicle.

The driver of the case vehicle waited for fifteen minutes until a coworker drove by and drove her to her workplace and the driver checked in to her work. Her supervisor told her to seek medical treatment and a coworker drove her to a hospital. It is unclear at what time she arrived at the hospital. She sustained injuries consisting of abdominal pain and glass in her hands and legs.

**Key Words**
Injury, hybrid, electric

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Dynamic Science, Inc.
Accident Investigation
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BACKGROUND:

Description: This hybrid vehicle case was reported to the NHTSA by DSI on May 21, 2001 and the case was assigned on May 23, 2001. An on-scene investigation was conducted. All field work was completed on February 02, 2002.

Investigation Type: On-scene

Crash Location: California

Crash Date: March, 2001

Notification Date: May 21, 2001

Field Work Completed: February 2, 2002

SUMMARY:

This single vehicle collision occurred in March, 2001 at 0720 hours in an agrarian area of northern California. The crash occurred on a two-lane, straight and level, undivided asphalt roadway. There is a single lane for each direction of travel, east-west. The lanes are separated by a painted dashed yellow line. There is an asphalt paved shoulder on both sides of the roadway and dirt agriculture fields beyond that. The speed limit is 89 km/h (55 mph). There were no road defects or visual obstructions reported.

The case vehicle, a 2001 Toyota Prius Hybrid 4-door, was driven by a restrained 54-year-old female (168 cm-66 in./61 kg-135 lbs). The case vehicle was traveling eastbound at a driver reported 81 km/h (50 mph) while on her way to work. The driver reported that a coyote ran out onto the roadway from an unknown direction. She steered the case vehicle to the right to avoid running over the coyote, and lost control of the vehicle. The case vehicle ran off the south edge of the roadway and onto a dirt field. The driver then steered back to the left causing the case vehicle to begin rotating counterclockwise on the dirt field. The rear right fender of the case vehicle struck a power pole.

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results fit the collision model and appear reasonable. The case vehicle was towed
from the scene due to damage and was subsequently declared a total loss and sold
as a salvage vehicle.

The driver of the case vehicle waited for fifteen minutes until a coworker drove by
and drove her to her workplace and the driver checked in to her work. Her
supervisor told her to seek medical treatment and a coworker drove her to a
hospital. It is unclear at what time she arrived at the hospital. She sustained injuries consisting of abdominal pain and glass in her hands
and legs.

At 1000 hours of the same morning, the responding police officer was dispatched to the hospital
for a report of a minor injury traffic collision. He arrived at the scene of the collision at 1018
hours and did a scene inspection and noted that the power pole did not appear to sustain any
damage. He then went to the hospital and spoke to the driver of the case vehicle.
Coyote ran out in front of case vehicle from an unknown direction

Driver steers right to avoid coyote

Power pole 1.8 miles east of Interstate 49 cm (19 in.) diameter

Final rest heading at unknown distance from impact with pole

Driver steers left and goes into counterclockwise rotation

Asphalt shoulder

Case vehicle 2001 Toyota Prius Hybrid 4-door

Figure 3. Scene diagram
DETAILED INFORMATION

Vehicles

Case vehicle

Description: 2001 Toyota Prius four-door hybrid electric

VIN: JT2BK12U0100xxxxxx

Odometer: 36,264 kilometers (22,534 miles)

Engine: Engine: 1.5 L 4 cylinder gasoline

Electric motor type: Permanent magnet

Battery type: 38 sealed Nickel-metal Hydride modules

Reported Defects: None

Cargo: None at the time vehicle inspected

Damage Description: Severe lateral crush to the right rear fender beginning just forward of the right rear axle and extends rearward to the right rear bumper corner. Both rear door jammed shut. Rear left door forced open by investigator. Minor longitudinal intrusion of the 2nd seat back.

CDC: 03RBEN3

Delta V:

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>29.0 km/h (18.0 mph)</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>0.0 km/h (0.0 mph)</td>
</tr>
<tr>
<td>Latitudinal</td>
<td>-29.0 km/h (-18.0 mph)</td>
</tr>
</tbody>
</table>

Energy: 139,370 joules (102,794 ft-lbs)
**Prius hybrid-electric system discussion**¹

The Toyota Prius is a standard-production hybrid-electric vehicle. The Prius' hybrid powertrain consists of a 70 horsepower 1.5 liter four cylinder gasoline-fueled internal combustion engine, a 33 KW (44 horsepower) permanent magnet electric motor, a generator, a 274 volt nickel metal-hydride battery (the battery pack is comprised of 38 sealed Nickel-Metal Hydride modules that are completely sealed in a carbon composite case and positioned behind the rear seat within the protective unibody of the car), an electronic controller (Advanced Control System), and a 'power split device' which functions as a continuously variable (automatic) transmission. The Prius operates on both the engine and electric motor/battery - one or both of these power sources can drive the Prius depending on load and road conditions - the electronic controller makes that decision with no input from the driver.

Standard equipment includes ABS and regenerative brakes, an eight-year/100,000-mile battery and hybrid-related component warranty.

Prius’ primary power is provided by an all-aluminum 1.5-liter 4 cylinder gasoline engine with a peak 70 horsepower at 4,500 rpm and peak torque of 82 lb./ft. at 4,200 rpm. Variable valve timing maximizes efficiency. The 45 liter (11.9 gallon) gas tank has a plastic bladder which reduces gasoline vapors. The EPA fuel economy is 83.7 kilometers (52 miles per gallon) for the city and 72.4 kilometers (45 miles per gallon) for the highway.

**System modes**

The Prius system works in six main modes:

1. When accelerating from a stop, the Prius is powered by the battery/electric motor only.
2. As more acceleration is needed, the engine will turn on automatically and run by itself or in conjunction with the electric motor and the battery.
3. Under full acceleration, the electric motor is supplemented by power from the battery. At high speeds the gas engine is the primary source of power. The electric motor will assist to varying degrees.
4. When the engine is running it uses a generator to charge the battery, and when braking, a regenerative braking system also charges the battery, so there is never a need to recharge the battery separately. When the vehicle is coasting or the brakes are applied, the motor is turned into a generator, capturing energy that would normally be lost as heat or kinetic energy and transforming it into electricity to recharge the batteries.
5. The battery is regulated to maintain a constant charge. When the charge is low, the electric generator routes power to charge the battery.
6. During coasting or braking, the electric motor functions as a generator to charge the battery. When the vehicle is stopped, the gas engine shuts off automatically and

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¹ Prius specifications and System modes data obtained from the Internet @ http://www.toyota.com/html/shop/vehicles/prius/technology/prius_technology.html
the electric motor stands ready to power up the Prius. This conserves fuel and eliminates exhaust emissions caused by idling.

Recalls

There is one recall in place that might affect this vehicle (NHTSA Campaign ID Number: 00V285000). This potentially affects 1,772 vehicles manufactured between May 2000 and July 2000. On certain passenger vehicles, insufficient electrical contact can occur in the torque sensor that controls the power assist operation of the electric power steering gear box. The torque sensor could output improper electrical signals. If this occurs, the power steering warning icon will be displayed on the center panel, and the driver could experience higher than normal steering effort depending upon vehicle speed.
Compliance with Sec.571.305 Standard No.305; Electric-powered vehicles: electrolyte spillage and electrical shock protection

The case vehicle was examined to determine compliance with the 305 standards.

1. There were no indications of electrolyte spillage from the propulsion battery.

2. There was no movement or damage of the battery pack. The frame directly in front of the traction battery—behind 2nd seat back was damaged.

3. The electrical isolation test was partially conducted. There is a circuit near the power cable that prevents access to power unless the ignition switch is in the “ON” position and the vehicle is running. In this case, internal 12v power was available and the engine did crank over but would not start. The net result was that there was no propulsion battery voltage external of the battery system. There were no indications of any arcing, fire, or component meltdown.

An overview of the electrical isolation test is included as Attachment 1.
Safety features discussion

The case vehicle was equipped with a driver’s steering wheel mounted air bag and front right passenger top instrument panel mounted air bag. According to data found in the NCAP test files, these are not advanced, multistage air bags. The case vehicle was also equipped with 3-point seat belts in all five seating positions. The driver’s belt was equipped with an emergency locking retractor while the other seat positions are equipped with switchable retractors. The driver and front passenger seat belts are equipped with pretensioners with force limiters.

In this crash, the driver was wearing the lap and shoulder belt. At impact, the pretensioner for the driver’s belt did not fire and neither of the frontal air bags deployed.
### Occupants

<table>
<thead>
<tr>
<th>Case vehicle</th>
<th>Occupant 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age/Sex:</strong></td>
<td>54/Female</td>
</tr>
<tr>
<td><strong>Seated Position:</strong></td>
<td>Front left</td>
</tr>
<tr>
<td><strong>Seat Type:</strong></td>
<td>Fabric covered bucket seat, adjusted to rear most track position.</td>
</tr>
<tr>
<td><strong>Height:</strong></td>
<td>168 cm (66 in.)</td>
</tr>
<tr>
<td><strong>Weight:</strong></td>
<td>61 kg (135 lbs)</td>
</tr>
<tr>
<td><strong>Occupation:</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Pre-existing Medical Condition:</strong></td>
<td>None noted</td>
</tr>
<tr>
<td><strong>Alcohol/Drug Involvement:</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Driving Experience:</strong></td>
<td>Unknown, presumed to be greater than 30 years</td>
</tr>
<tr>
<td><strong>Body Posture:</strong></td>
<td>Assumed normal, upright</td>
</tr>
<tr>
<td><strong>Hand Position:</strong></td>
<td>Both on steering wheel, unknown placement</td>
</tr>
<tr>
<td><strong>Foot Position:</strong></td>
<td>Right on accelerator, left on floor</td>
</tr>
<tr>
<td><strong>Restraint Usage:</strong></td>
<td>Lap and shoulder belt available, used</td>
</tr>
<tr>
<td><strong>Air bag:</strong></td>
<td>Steering wheel mounted driver’s air bag did not deploy</td>
</tr>
</tbody>
</table>
Injuries and Injury Mechanisms

Case vehicle (Toyota Prius)

<table>
<thead>
<tr>
<th>INJURY</th>
<th>OIC CODE</th>
<th>ICD-9</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver: Complained of abdominal pain. Glass in her hands (blood found near driver’s seat belt buckle) and legs. Injuries are not codeable.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Occupant Kinematics

The 54-year-old female driver of the case vehicle was seated in the front left position. She was seated in a bucket seat in an assumed normal, upright position. The seat was adjusted to the rear-most track position. She was wearing the available lap and shoulder belt and the shoulder belt upper anchorage adjustment was in the full up position. Both of her hands were probably on the steering wheel. Her right foot was on the accelerator.

On impact with the power pole, the restrained driver responded to the 03 o’clock direction of force by moving to the left. The driver loaded the seat belt—causing the abdominal pain. Her lateral movement to the right also deformed the seat back. Flying glass from the disintegrated backlight contacted her hands and probably caused a laceration to her right hand and as she un-buckled the seat belt, blood was deposited on the center console area.

Figure 9. Driver’s seat—deformed seat back and blood deposited on center console.
Attachment 1. Electrical Isolation Test
High-voltage Part and Wiring

Inverter and Converter

Power Cable

Hybrid Transaxle

Page: HV-1 of repair manual
REMOVAL

1. REMOVE SERVICE PLUG (See page HV-1)
2. DRAIN HV COOLANT (See page HT-6)
3. REMOVE COWL TOP PANEL (See page DO-27)

You do not need to conduct steps 2 and 3 just to reach the MG terminals.

4. VERIFY 0 V

NOTICE:
- Before starting step (a), 5 minutes or more should be passed after removing the service plug.
- Be careful to prevent foreign matter from entering the inside of connector cover.

(a) Disconnect the connector of the battery power cable and insulate it with packaging tape.
(b) Using a torx socket wrench (T30), remove the 4 screws and inverter terminal cover.
(c) Using a torx socket wrench (T40), remove the 2 screws, circuit breaker sensor and connector cover.

HINT:
Slide the connector cover to disconnect the circuit breaker sensor connector.
(d) Using a voltmeter, measure the voltage between terminals of 3 phases (U→V, V→W, U→W) and each terminal and body ground to verify them to be approx. 0 V.

5. REMOVE CONVERTER & INVERTER ASSEMBLY

(a) Remove the 6 bolts and 3 power cables for MG2.

NOTICE:
Be careful to prevent foreign matter from entering the inside of connector cover.

(b) Remove the 3 bolts and power cable for MG1.

NOTICE:
- Remove the power cable for MG1 together with converter & inverter assembly.
- Be careful to prevent foreign matter from entering the inside of connector cover.
(c) Remove the bolt and ground cable.
HV-18 page in repair manual