On-Site Hybrid Vehicle Investigation
Dynamic Science, Inc. (DSI), Case Number DS09016
2008 Toyota Camry
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 2008 Toyota Camry hybrid vehicle that sustained a back end impact. This four-vehicle crash occurred in the fifth and sixth lanes of a six-lane divided state highway. The Toyota was being driven by a 31-year-old male. The first other vehicle was a 2006 Ford F350 that was being driven by a 24-year-old male. There were two additional occupants in the Ford, a 36-year-old male and a 21-year-old male. The second other vehicle was a 2001 Saab 9-5 that was being driven by a 39-year-old female. The third other vehicle was a 1997 BMW 740iL that was being driven by a 50-year-old male. All four vehicles were traveling westbound. The Toyota was initially traveling in the fifth travel lane. The Ford was traveling in the sixth lane to the left of the Toyota. The Saab was traveling in the fifth lane and was in front of the Toyota. The Saab was slowing and coming to a stop. The BMW was traveling in the fifth lane and was behind the Toyota. As the driver of the Toyota saw traffic slow, he attempted to change lanes to the left. The left front of the Toyota impacted the right rear of the Ford. The Toyota returned to the fifth lane and was impacted in the rear by the BMW. The Toyota was pushed forward, contacted the left side of the Saab, and began a counterclockwise rotation. The BMW continued forward and impacted the rear of the Saab. The Toyota continued its counterclockwise rotation, contacted the median barrier with its front end, and came to rest with its right rear against the barrier.

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Dynamic Science, Inc.
Crash Investigation
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BACKGROUND

This investigation focused on a 2008 Toyota Camry hybrid vehicle that sustained a back end impact (**Figure 1**). This four-vehicle crash occurred in the fifth and sixth lanes of a six-lane divided state highway. The Toyota was being driven by a 31-year-old male. The first other vehicle was a 2006 Ford F350 that was being driven by a 24-year-old male. There were two additional occupants in the Ford, a 36-year-old male driver and a 21-year-old male right front passenger. The second other vehicle was a 2001 Saab 9-5 that was being driven by a 39-year-old female. The third other vehicle was a 1997 BMW 740iL that was being driven by a 50-year-old male. All four vehicles were traveling westbound. The Toyota was initially traveling in the fifth travel lane. The Ford was traveling in the sixth lane to the left of the Toyota. The Saab was traveling in the fifth lane and was in front of the Toyota. The Saab was slowing and coming to a stop. The BMW was traveling in the fifth lane and was behind the Toyota. As the driver of the Toyota saw traffic slow, he attempted to change lanes to the left. The left front of the Toyota impacted the right rear of the Ford. The Toyota returned to the fifth lane and was impacted in the rear by the BMW. The Toyota was pushed forward, contacted the left side of the Saab, and began a counterclockwise rotation. The BMW continued forward and impacted the rear of the Saab. The Toyota continued its counterclockwise rotation, contacted the median barrier with its front end, and came to rest with its right rear against the barrier.

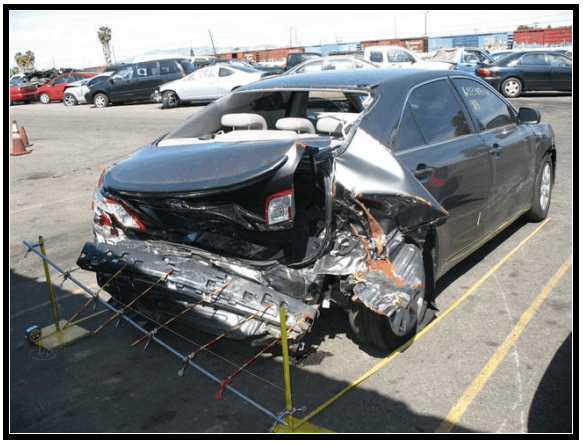

Figure 1. 2008 Toyota Camry Hybrid

This hybrid vehicle investigation was initiated by the National Highway Traffic Safety Administration (NHTSA) during an internet search of auto auction lots. On March 11, 2009, DSI was directed to commence the investigation. On March 12, 2009, DSI obtained permission to inspect the subject vehicle and the case was assigned. The vehicle was inspected on March 17, 2009.

SUMMARY

Crash Site

The crash occurred in September 2008 in the westbound lanes of a 6-lane divided state highway (**Figure 2**). The roadway was bordered on the left by a concrete median barrier. The sixth lane from the right was a High Occupancy Vehicle (HOV) lane that was bordered on the right by two solid double yellow lines. The remaining lanes were separated by dashed white lines and raised pavement markers. The straight asphalt roadway was dry and the weather was clear. The posted

Figure 2. Westbound approach

speed limit at this location was105 km/h (65 mph).

Pre-Crash

The Toyota was initially traveling in the fifth lane from the right at a police reported speed of 97 km/h (60 mph). The Ford was traveling in the HOV lane to the left of the Toyota at a police reported speed of 105 km/h (65 mph). The Saab was traveling in the fifth lane and was in front of the Toyota. The Saab was slowing and coming to a stop. The BMW was traveling in the fifth lane at a police reported speed of 56 km/h (35 mph) and was behind the Toyota. As the driver of the Toyota saw traffic slow, he braked and attempted to change lanes to the left.

Crash

The left front of the Toyota impacted the right rear of the Ford (Event 1). The Toyota returned to the adjacent lane and was impacted in the rear by the BMW (Event 2). The Missing Vehicle algorithm of the WinSMASH program computed a Total Delta-V of 26 km/h (16.2 mph) for the impact with the BMW. The longitudinal and lateral components were 26 km/h (15.9 mph) and 5 km/h (2.8 mph), respectively.

The Toyota was pushed forward, contacted the left side of the Saab (Event 3), and began a counterclockwise rotation. The BMW continued forward and impacted the rear of the Saab (Event 4). The Toyota continued its rotation, entered the HOV lane, contacted the median barrier with its front end (Event 5), and came to rest with its right rear against the barrier (Event 6).

Post-Crash

The driver of the Toyota was able to exit the vehicle under his own power. He sustained a neck strain and was transported to a local hospital where he was treated and released. The driver of the Saab complained of pain to the back and neck and was transported to a local hospital from treatment. The occupants of the Ford and the BMW did not report any injuries.

The Toyota, the Saab, and the BMW were towed from the scene. The Ford was driven from the scene. The Toyota was later declared a total loss by the insurance company.

Vehicle Data - 2008 Toyota Camry

The 2008 Toyota Camry Hybrid 5-passenger, 4-door sedan was identified by the Vehicle Identification Number (VIN): JTNBB46K783xxxxxx. The vehicle was manufactured in November 2007. The Toyota was a gas/electric hybrid vehicle that was equipped with a 2.4-liter, 4-cylinder gasoline engine, an electric drive motor, a continuously variable transmission, front wheel drive, traction control, and anti-lock brakes. The vehicle mileage was not known; there was no power to the vehicle and the key was not present.

The Toyota was equipped with Michelin Energy MXV4 P215/60R16 tires. The tire manufacturer's stated maximum pressure was 303 kPa (44 psi); the vehicle manufacturer's recommended cold pressure was 221 kPa (32 psi) for the front and rear tires.

The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	200 kPa (29 psi)	6 mm (7/32 in)	No	None
LR	145 kPa (21 psi)	6 mm (8/32 in)	No	None
RR	Tire Flat	6 mm (7/32 in)	Yes	Holed and torn
RF	214 kPa (31 psi)	6 mm (7/32 in)	Yes	None

Exterior Damage - 2008 Toyota Camry

The Toyota sustained damage to the front, right, and rear planes. There were five impacts documented. The first was a frontal impact between the Toyota and the right side of the Ford (**Figure 3**). The direct damage began 35 cm (13.7 in) left of the centerline and extended 46 cm (18.1 in) to the left front bumper corner. The plastic fascia at the left bumper corner was broken away. The damage extended 119 cm (46.8 in) longitudinally along the left fender and vertically onto the left side of the hood. The damage height was 91 cm (35.8 in) above the ground. The Collision Deformation Classification (CDC) for the first event was 12FLEW1.

Figure 3. Left front damage (Impact 1)

The second impact was between the rear of the Toyota and the front of the BMW (**Figure 4**). The direct damage began 11 cm (4.3 in) left of the centerline and extended 80 cm (31.5 in) to the right rear bumper corner. The right rear tire was damaged and restricted during this impact. There was a 36 cm (14.2 in) tear in the sidewall located 5 cm (1.9 in) from the bead, a 20 cm (7.9 in) tear at the area of restriction, and a 53 cm (20.9 in) tear to the inner sidewall. Six crush measurements were documented along the bumper as follows: C1 = 0 cm, C2 = 7 cm (2.8 in), C3 = 24 cm (9.4 in), C4 = 37 cm (14.6 in), C5 = 43 cm (16.9 in), C6 = 45 cm (17.7 in). The maximum crush was located at C6 and the CDC for the second event was 06BZEW4.

Figure 4. Rear damage (Impact 2)

The third impact was between the front of the Toyota and the left side of the Saab (**Figure 5**). The direct damage began at the right front bumper corner and extended 3 cm (1.2 in) to the left and 246 cm (96.8 in) longitudinally down the right side. The CDC for the third event was 12FRES9.

Figure 5. Front right damage (Impact 3)

The fourth and fifth impacts involved contacts to the concrete traffic barrier. The damage for the fourth impact was mostly masked by the third event. The direct contact began 17 cm (6.7 in) from the centerline and extended 25 cm (9.8 in) to the left. The CDC for the fourth event was 03FYES1. The damage for the fifth impact was masked by the second impact. No direct contact measurements were taken.

Interior Damage - 2008 Toyota Camry

The Toyota did not sustain any damage to the passenger area related to intrusion or occupant contacts. The right rear door was jammed shut and the backlight was disintegrated.

There was damage to the cargo area aft of the rear seat and the traction battery (**Figure 6**). The rear portion of the cargo area was deformed forward. The longitudinal distance from the traction battery to the rear portion of the cargo area measured 44 cm (17.3 in) on the left and 26 cm (10.2 in) on the right. Since the left was largely undamaged, the depth of crush was 18 cm (7.0 in). 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.

Figure 6. Trunk and service battery damage

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 mid- to full-down 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 were indications 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, a driver's

knee air bag, left and right side curtain air bags modules, left and right seat mounted side air bags, and front outboard safety belts with retractor pretensioners. There were no air bag deployments and the seat belt prentensioners did not actuate.

Hybrid Electrical System

The Toyota 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 Toyota was designed with a 2.4-liter 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 battery system was a 244-volt Nickel Metal-Hydride (NiMH) battery that was mounted in the rear cargo floor, aft of the second row seat (**Figure 7**). 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 of the vehicle. An air intake vent was located on the right side of rear deck for the purpose of cooling the traction battery. Orange colored power cables carry high voltage direct current between the HV battery pack and the inverter/converter. The cables extended along the center of the vehicle, under the vehicle floor pan, from the cargo area to the engine compartment.

Figure 7. Traction battery

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.

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

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

The service plug was located on the right 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, the positive and negative high voltage cables connected to the battery are controlled by a 12 volt normally open relate. When the vehicle is shut off, the relays stop electrical flow from leaving the battery pack. The battery pack relays will automatically open to stop the electrical flow in a collision sufficient to activate the supplemental restraint system.

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 - 2006 Ford F350

The 2006 Ford F350 was identified on the police report. The Ford was occupied by an unknown age male driver and a 21-year-old male front right passenger. The vehicle sustained minor damage to the right side plane and was driven from the scene. There were no reported injuries for either occupant.

Vehicle Data - 2001 Saab 9-5

The 2001 Saab 9-5 was identified on the police report. The Saab was equipped with front-wheel drive, rack and pinion steering, and 4-wheel disc brakes. The vehicle was occupied by a 39-year-old female driver. The vehicle sustained damage to left and back planes and was towed from the scene. The driver complained of pain to her neck and back and was transported to a local hospital for treatment.

Vehicle Data - 1997 BMW 740iL

The 1997 BMW 740i was identified on the police report. The BMW was equipped with a 4.4-liter, 8-cylinder engine, rear-wheel drive, and 4-wheel disc brakes with ABS. The vehicle was occupied by a 50-year-old male driver. The vehicle sustained damage to the frontal plane and was towed from the scene. There were no reported injuries to the occupant.

OCCUPANT DEMOGRAPHICS

	Driver
Age/Sex:	31/Male
Seated Position:	Front left
Seat Type:	Bucket
Seat track position:	Mid-track. Located 38 cm (14.9 in) aft of A-pillar.
Height:	175 cm (69 in)
Weight:	82 kg (180 lbs)
Alcohol/Drug Involvement:	None
Body Posture:	Upright
Hand Position:	Both hands on steering wheel, 10 and 2 o'clock position.
Foot Position:	Right foot on accelerator, left on floor.
Restraint Usage:	Lap and shoulder
Air bags:	Driver air bag, seat-mounted side air bag, and knee air bag available. There were no deployments.

OCCUPANT INJURIES

Driver Injuries: Injuries obtained from interviewee.

Injury	OIC Code	Injury Mechanism	Confidence Level
Cervical strain	640278.1,6	Impact forces	Certain

OCCUPANT KINEMATICS

Driver Kinematics

The 31-year-ld male driver was seated in an upright posture and was using the lap and shoulder belt. His right foot was on the accelerator prior to the initial impact. As traffic began to slow, the driver steered to the left. The front left of the Toyota contacted the right side of the Ford. The driver braked and steered back to the right. As the vehicle approached the Saab, it was struck in the rear by the BMW. At impact, he was displaced rearward into the seat back and sustained a cervical

strain. The Toyota was pushed forward and began a counterclockwise rotation as it engaged the left side of the Saab. This was a minor impact and had minimal effect on the driver's kinematics. The vehicle continued its counterclockwise rotation as it contacted the median barrier. This was also a minor impact with little driver movement. The vehicle continued its rotation until it came to rest with the rear of the vehicle in contact with the barrier. The driver was able to exit the vehicle under his own power. He initially complained of pain to the neck and back and was transported to a local hospital for treatment.

Attachment 1. Scene Diagram