

On-scene Investigation / Vehicle to Vehicle  
Dynamic Science, Inc. / Case Number: DS01-012  
2001 Toyota Prius  
California  
March, 2001

---

*This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.*

*The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.*

*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.*

---

**Technical Report Documentation Page**

1. Report No. DS01-012		2. Government Accession No.		3. Recipient Catalog No.	
4. Title and Subtitle In-Depth Accident Investigation				5. Report Date	
				6. Performing Organization Report No.	
7. Author(s) Dynamic Science, Inc.				8. Performing Organization Report No.	
9. Performing Organization name and Address Dynamic Science, Inc. 530 College Parkway, Ste. K Annapolis, MD 21401				10. Work Unit No. (TRAVIS)	
				11. Contract or Grant no. DTNH22-94-D-27058	
12. Sponsoring Agency Name and Address U.S. Dept. of Transportation (NRD-32) National Highway Traffic Safety Administration 400 7th Street, SW Washington, DC 20590				13. Type of report and period Covered [Report Month, Year]	
				14. Sponsoring Agency Code	
15. Supplemental Notes					
16. Abstract  This case was initiated because the case vehicle is a gas/electric hybrid vehicle. This crash occurred in March, 2001 at 1210 hours. The crash occurred on a six-lane divided roadway.  The case vehicle, a 2001 Toyota Prius four-door gas/electric hybrid driven by a restrained 46-year-old male, was traveling westbound at a driver reported speed of 56 km/h (35 mph). The front right seat was occupied by an unrestrained 46-year-old female. The first other vehicle, a 1996 Porsche 911 driven by a 36-year-old male, was traveling eastbound, just coming out of a right hand curve. The second other vehicle, a 1986 Nissan pickup driven by a 16-year-old male, was traveling eastbound behind the case vehicle. The front right seat of the Nissan was occupied by a restrained 18-year-old male. The third other vehicle, an unknown year Volkswagen Cabriolet driven by an 18-year-old male, was also traveling eastbound. This vehicle was in the far right hand lane. The driver of the Porsche lost control of his vehicle after hitting a patch of water in the roadway. The vehicle veered to the left, over-rode the center median and struck a narrow tree with its left side. The Porsche continued on and entered the westbound roadway. The rear of the Porsche struck the left front of the case vehicle. The forces were sufficient to deploy both frontal air bags and to fire the driver's seat belt pretensioner. The case vehicle was pushed to the right and struck the left side of the Volkswagen. The Porsche continued eastbound and contacted the third other vehicle—the Volkswagen Cabriolet. The Volkswagen was diverted to the right, rotated counterclockwise, and struck a curb with its right rear tire.  The driver of the case vehicle sustained a neck strain and a contusion to the right knee. The front right occupant sustained a fractured rib on the left side, abrasions to both hips, a contusion to the right side of the head, a contusion to the right ankle, an abrasion on the left knee, and a contusion on the right knee. The driver of the Porsche complained of pain to the left side of his head. He was transported to a local trauma center. All four vehicles were towed from the scene.					
17. Key Words Air bag, deployment, injury, hybrid, electric			18. Distribution Statement		
19. Security Classif. (of this report)		20. Security Classif. (of this page)		21. No of pages	22. Price

**Dynamic Science, Inc.**  
**Accident Investigation**  
**Case Number:DS01-012**

**TABLE OF CONTENTS**

Background .....	1
Description .....	1
Investigation Type .....	1
Crash Location .....	1
Crash Date .....	1
Notification Date .....	1
Field Work Completed .....	1
 Summary .....	 1
 Scene Diagram .....	 3
 Collision Measurements .....	 4
 Detailed Information .....	 5
Vehicles .....	5
Prius Hybrid-Electric System Discussion .....	6
Compliance with Sec.571.305 Standard No.305 .....	8
Responding Agency Training .....	9
Safety Features Discussion .....	9
Occupants .....	13
Injuries and Injury Mechanisms .....	17
Occupant Kinematics .....	19
 Attachment 1. Electrical Isolation Test .....	 20

**BACKGROUND:**

Description: This hybrid vehicle case was generated by DSI through existing insurance contacts. NHTSA was notified of the case on June 6, 2001. DSI was assigned the case on June 6, 2001. This case was conducted as an on-scene investigation.

Investigation Type: On-scene

Crash Location: California

Crash Date: March, 2001

Notification Date: June 6, 2001

Field Work Completed: June 8, 2001

**SUMMARY:**

This crash occurred in March, 2001 at 1210 hours. The crash occurred on a six-lane divided roadway. There are three westbound and three eastbound travel lanes. The travel lanes are separated by a raised concrete median. There is parking on both sides of the street. The speed limit is 72 km/h (45 mph). There is a 5% down grade for westbound traffic and a 5% up grade for eastbound traffic.

The case vehicle, a 2001 Toyota Prius four-door gas/electric hybrid driven by a restrained 46-year-old male (180 cm/71 in., 69 kg/152 lbs), was traveling westbound at a driver reported speed of 56 km/h (35 mph). The front right seat was occupied by an unrestrained 46-year-old female (168 cm/66 in., 57 kg/125 lbs.).

The first other vehicle, a 1996 Porsche 911 driven by a 36-year-old male, was traveling eastbound, just coming out of a right hand curve. The second other vehicle, a 1986 Nissan pickup driven by a 16-year-old male, was traveling westbound behind the case vehicle. The front right seat of the Nissan was occupied by a restrained 18-year-old male.



**Figure 1.** Struck tree in foreground, final rest for Porsche in background.



**Figure 2.** Final rest, case vehicle.

The third other vehicle, an unknown year Volkswagen Cabriolet driven by an 18-year-old male, was also traveling westbound. This vehicle was in the far right hand lane.

The driver of the Porsche lost control of his vehicle after hitting a patch of water in the roadway. The vehicle veered to the left, over-rode the center median and struck a narrow tree with its left side. The Porsche continued on and entered the westbound roadway. The rear of the Porsche struck the left front of the case vehicle (11FLEE9). The case vehicle sustained a longitudinal delta v of -10.9 km/h (-6.8 mph) and a lateral delta v of 6.3 km/h (3.9 mph)<sup>1</sup>. The forces were sufficient to deploy both frontal air bags and to fire the driver's seat belt pretensioner.

The case vehicle was pushed to the right and struck the left side of the Volkswagen (01FREE6). The Porsche continued eastbound and contacted the third other vehicle—the Volkswagen Cabriolet. The Volkswagen was diverted to the right, rotated counterclockwise, and struck a curb with its right rear tire.

The driver of the case vehicle sustained a neck strain and a contusion to the right knee. He was transported by ambulance to a local hospital where he was treated and then released two hours later. The neck pain continued for several weeks. The front right occupant sustained a fractured rib on the left side, abrasions to both hips, a contusion to the right side of the head, a contusion to the right ankle, an abrasion on the left knee, and a contusion on the right knee. She was transported by ambulance to a local hospital where he was treated and then released two hours later.

The driver of the Porsche complained of pain to the left side of his head. He was transported to a local trauma center.

All four vehicles were towed from the scene.

---

<sup>1</sup>Calculated using WinSmash version 2.06, stiffness values calculated from NCAP test results. Results appear low. Damage was likely altered by the second impact.

### Scene Diagram

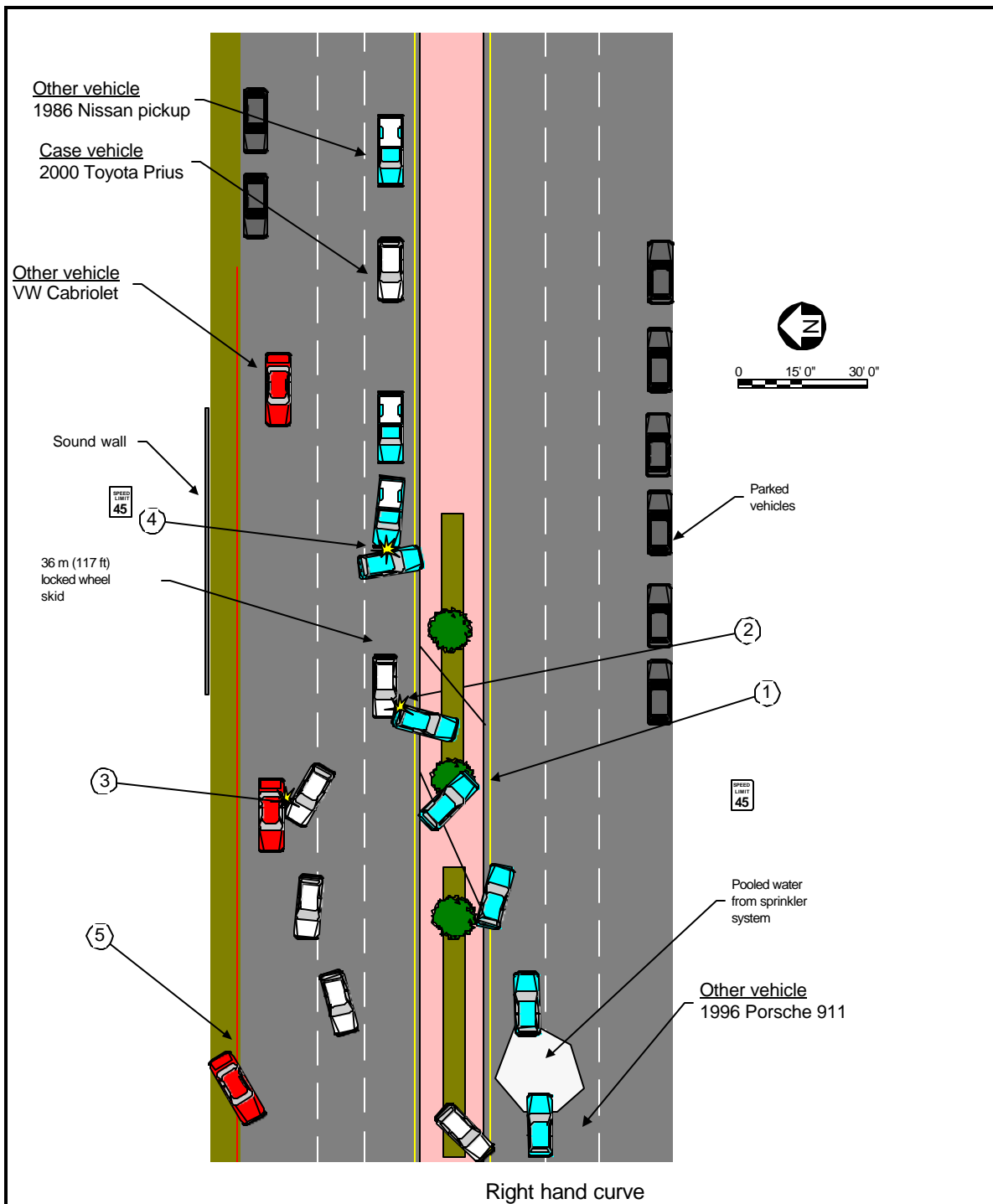


Figure 3. Scene diagram

<b>COLLISION MEASUREMENTS</b>						
<b>Reference point:</b>	Break in median					
<b>Reference line:</b>	Median edge					
<b>Data Point</b>	<b>Distance and Direction from RP</b>			<b>Distance and Direction from RL</b>		
	ft	m	d	ft	m	d
End skid A (Porsche)	56	17	W	15	4.5	S
Tree 1	59	17.9	W	7.5	2.3	S
Start skid A (Porsche)	74	22.5	W	0	0	S
End skid B (Porsche)	84	25.6	W	15	5.5	S
Tree 2	89	27.1	W	7.5	2.3	S
Start skid B (Porsche)	120	36.6	W	0	0	S



**DETAILED INFORMATION****Vehicles**Case vehicle

Description:	2001 Toyota Prius four-door hybrid electric	
VIN:	JT2BK12U0100xxxxxx	
Odometer:	Unknown	
Engine:	Engine: 1.5 L 4 cylinder gasoline Traction battery: Nickel hydride metal	
Reported Defects:	None	
Cargo:	None	
Damage Description:	Moderate crush to left side beginning at left front corner and extending to driver's door. Driver's door jammed shut. Moderate crush to right side beginning at front corner and extending along most of the fender. Vehicle declared a total loss by insurance company.	
CDC:	Impact 1 (Porsche): 11FLEE9 Impact 2 (Volkswagen): 01FREE6	
Delta V (Impact 1):	Total	12.6 km/h (7.9 mph)
	Longitudinal	-10.9 km/h (-6.8 mph)
	Latitudinal	6.3 km/h (3.9 mph)
	Energy	14,152 joules (10,438 ft-lbs)



**Figure 4.** Front left, showing first impact.



**Figure 5.** Right side, case vehicle, showing second impact.

## **Prius hybrid-electric system discussion**

The Toyota Prius is one of the world's first standard-production hybrid-electric vehicles. The name Prius is Latin for "to go before". The Prius' hybrid powertrain consists of a 70 horsepower 1.5 litre 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, an electronic controller, 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.

### 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 the electric motor stands ready to power up the Prius. This conserves fuel and eliminates exhaust emissions caused by idling.

### Specifications

Standard equipment includes ABS brakes, thermostat-controlled air conditioning, power windows, door locks and mirrors, an cassette stereo, an eight-year/100,000-mile battery and hybrid-related component warranty, roadside assistance and three-year basic maintenance programs.

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 11.9 gallon gas tank has a plastic bladder which reduces gasoline vapors. The EPA fuel

economy is 52 miles per gallon for the city and 45 miles per gallon for the highway.

The electric drive motor is a permanent-magnet design. It produces its maximum power of 33 kW (44 horsepower) from 1,040-5,600 rpm, and maximum torque of 350 N-m (258 lb./ft.) from 0-400 rpm.

Prius' lightweight battery pack is comprised of 38 sealed Nickel-Metal Hydride modules with a nominal voltage of 274 volts. For matters of safety, it is completely sealed in a carbon composite case and positioned behind the rear seat within the protective unibody of the car. It is also a safer alternative to lead-acid batteries because it is essentially inert, non-flammable and non-caustic.

### Recalls

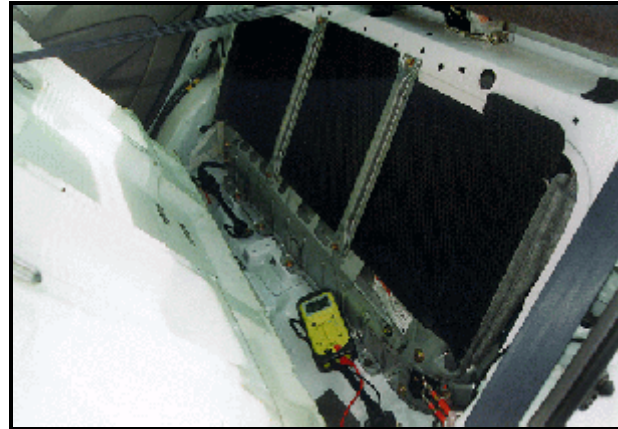
There is one recall in place that might affect this vehicle (NHTSA Campaign ID Number: 00V285000). This potentially affects 1,772 vehicles manufactured between May 2000 and July 2000. On certain passenger vehicles, insufficient electrical contact can occur in the torque sensor that controls the power 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 of the battery module.
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, the initial impact had gone through the left hand fuse block and there was no internal 12v power available. There was also no key available. 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.



**Figure 6.** Front side of traction battery



**Figure 7.** Engine fuse block



**Figure 8.** Traction battery voltage

### Responding agency training

The responding police agency was contacted. Responding officers had received academy training with regard to issues related to hazardous material spillage.

### **Safety features discussion**

The case vehicle was equipped with driver and front right passenger air bags. 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 drivers 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 but the front right passenger was not. At impact, the pretensioner for the driver's belt fired. Since the front right passenger was not belted, the pretensioner on the right side did not fire.

Other vehicle 1

Description:	1996 Porsche 911	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Moderate lateral crush along entire rear bumper. Moderate lateral crush to left side, primarily the driver's door. According to interviewee, vehicle was declared a total loss.	
CDC:	Impact 1 (tree): 09LFEN1 Impact 2 (Prius): 07BDEW1 Impact 4 (Nissan): 09LPEW1	
Delta V (Impact 2):	Total	12.5 km/h (7.8 mph)
	Longitudinal	8.9 km/h (5.5 mph)
	Latitudinal	8.9 km/h (5.5 mph)
	Energy	19,081 joules (14,073 ft-lbs)



**Figure 9.** Exterior, rear and right side.

Other vehicle 2

Description:	Unknown year Volkswagen Cabriolet	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Light contact damage to left side. Right rear wheel pushed inward due to contact with the curb.	
CDC:	Impact 3 (Prius): 07LPEW1 Impact 5 (curb): 02RPWN1	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown



**Figure 11.** Exterior, right side.



**Figure 10.** Exterior, left side.

Other vehicle 3

Description:	1986 Nissan pickup	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Moderate frontal contact to bumper and grille. Towed from the scene.	
CDC:	Impact 4 (Porsche): 12FDEW1	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown



Figure 12. Exterior, front left.



**Occupants**

<u>Case vehicle</u>	Occupant 1	Occupant 2
Age/Sex:	46/Male	46/Female
Seated Position:	Front left	Front right
Seat Type:	Fabric covered bucket seat, adjusted to between middle and rear most track position.	Fabric covered bucket seat, adjusted to rear most track position.
Height:	180 cm/71 in.	168 cm/66 in.
Weight:	69 kg/152 lbs	57 kg/125 lbs
Occupation:	Unknown	Unknown
Pre-existing Medical Condition:	None noted	None noted
Alcohol/Drug Involvement:	None	NA
Driving Experience:	Unknown, presumed to be greater than 20 years	NA
Body Posture:	Normal, upright	Normal, upright
Hand Position:	Both on steering wheel, unknown placement	Unknown
Foot Position:	Right on accelerator, left on floor	Unknown
Restraint Usage:	Lap and shoulder belt available, used	Lap and shoulder belt available, <u>not</u> used
Air bag:	Steering wheel mounted driver's air bag deployed	Top mounted front right passenger's air bag deployed

Other vehicle (Porsche)

Age/Sex:	36/Male
Seated Position:	Front left
Seat Type:	Bucket
Height:	183 cm (72 in)
Weight:	84 kg (185 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Unknown
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt used, per police report

Other vehicle (Volkswagen)

Age/Sex:	28/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	178 cm (70 in)
Weight:	75 kg (165 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Unknown
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt used, per police report

Other vehicle (Nissan)

Age/Sex:	16/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	170 cm (67 in)
Weight:	64 kg (142 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	Unknown
Driving Experience:	Unknown
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt used, per police report

**Injuries and Injury Mechanisms**

Case vehicle (Toyota Prius)

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Neck strain	640278.1,6	847.0	Air bag
	Contusion, right knee	890402.1,1	924.11	Left lower instrument panel
Front right occupant:	Rib fracture, lower left side	450212.1,2	807.01	Unknown
	Bilateral hip abrasions	590202.1,1 590202.1,2	916.0 916.0	Center console / right door
	Contusion, right side of head	190402.1,1	920.0	Side glass
	Contusion, right ankle	890402.1,1	924.21	Right door, near base
	Abrasion, left knee	890202.1,2	916.0	Right lower instrument panel
	Contusion, right knee	890402.1,1	924.11	Right lower instrument panel

Other vehicle (Porsche)

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Complained of pain to left side of head			

Other vehicle (Nissan)

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Complained of pain to back			

Other vehicle (Volkswagen)

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Complained of pain to head			

## Occupant Kinematics

The 46-year-old male driver of the case vehicle was seated in the front left position. He was seated in a bucket seat in a normal, upright position. The seat was adjusted to the rear-most track position. He was wearing the available lap and shoulder belt. Both of his hands were on the steering wheel. His right foot was on the accelerator. The 46-year-old female occupant was seated in the front right position. She was seated in a bucket seat in a normal, upright position. The seat was adjusted to between the middle and rear-most track position. She was not wearing the available lap and shoulder belt. The seat belt anchorage was adjusted to the full up position.



**Figure 13.** Driver's seated area

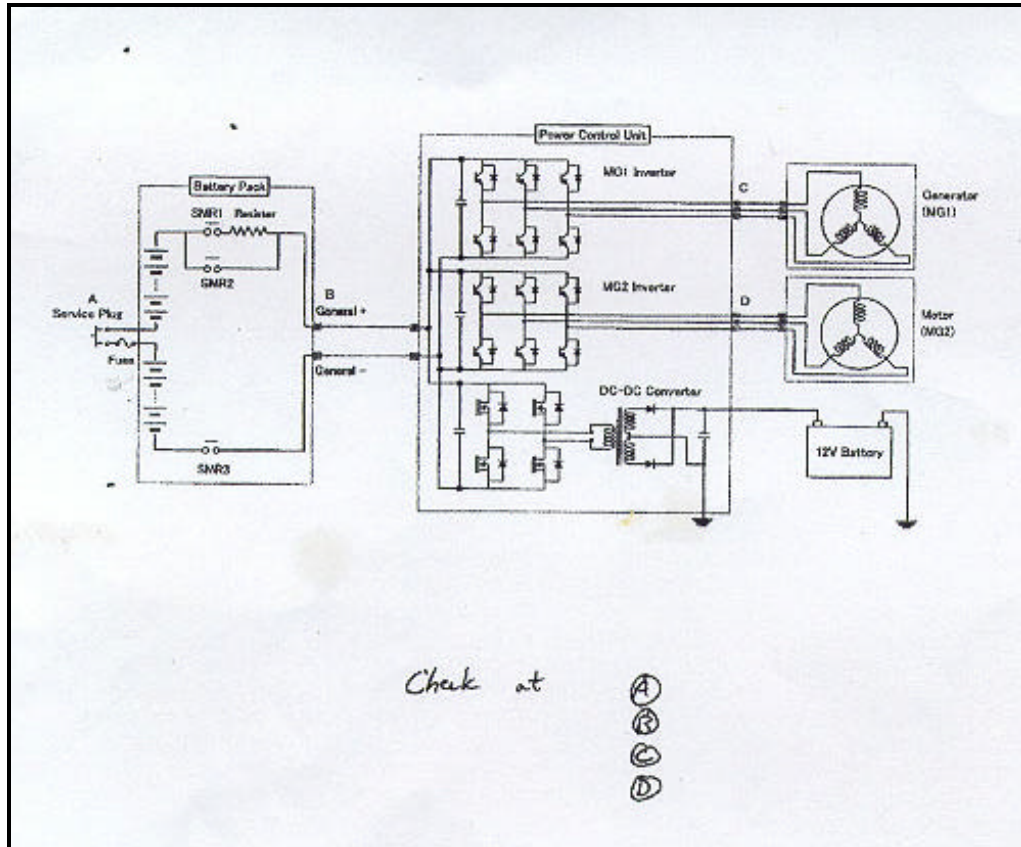
At the first impact, the restrained driver responded to the 11 o'clock direction of force by moving forward and to the left. The seat belt pretensioner fired. The driver engaged the deployed air bag with his face—causing the neck strain. His right knee contacted the lower instrument panel—causing a small contusion. At the second impact, he responded to the 1 o'clock direction of force by moving forward and to the right.

At the first impact, the unrestrained front right occupant responded to the 11 o'clock direction of force by moving forward and to the left. Her left side contacted the center console, causing the left hip abrasion and possibly the rib fracture on the left side. At the second impact, she responded to the 1 o'clock direction of force by moving forward and to right. Her right side contacted the door and right side glass, causing the head contusion and right hip abrasion. As she moved forward, both knees struck the instrument panel, causing the abrasion to the left knee and the contusion to the right knee.

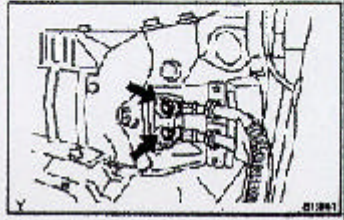
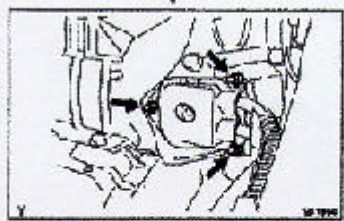
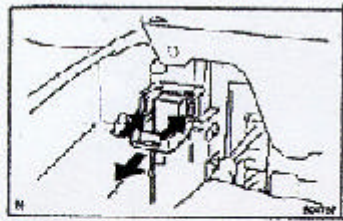
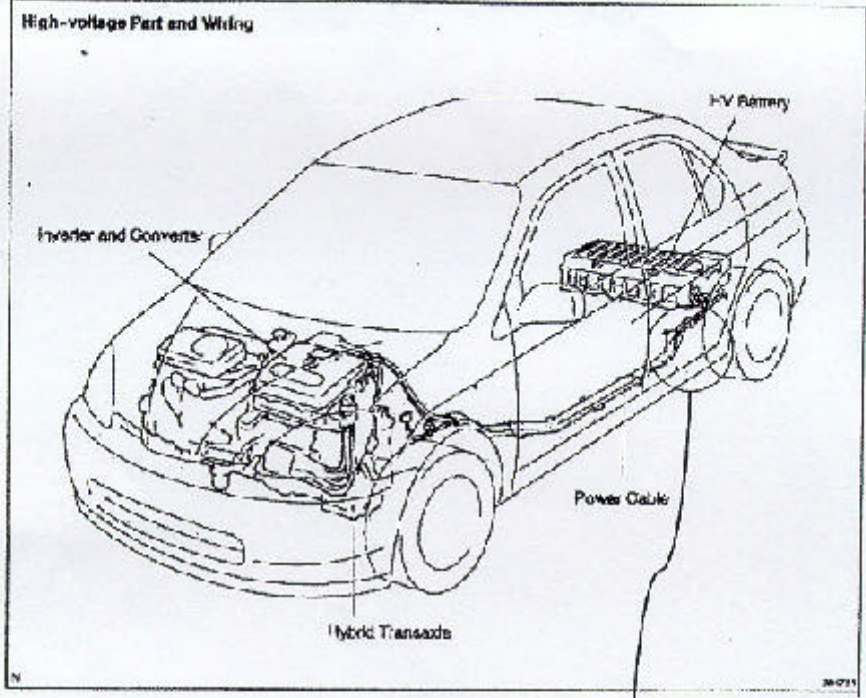


**Figure 14.** Front right passenger seating area

Attachment 1. Electrical Isolation Test







Page: HV-1 of repair manual

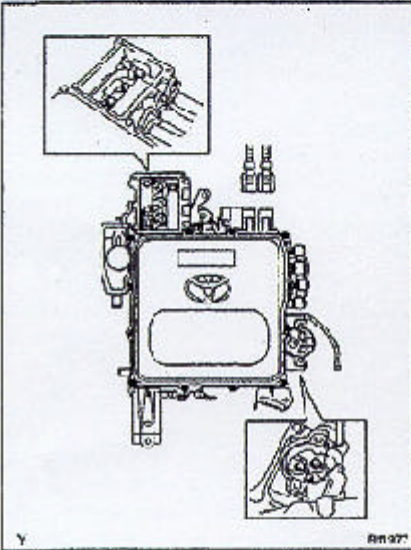
HV-10

HYBRID VEHICLE CONTROL - CONVERTER AND INVERTER ASSEMBLY

**REMOVAL**

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

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



4. VERIFY 0 V

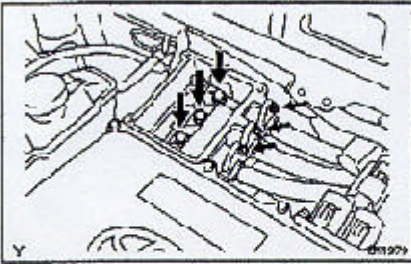
**NOTICE:**

- 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.

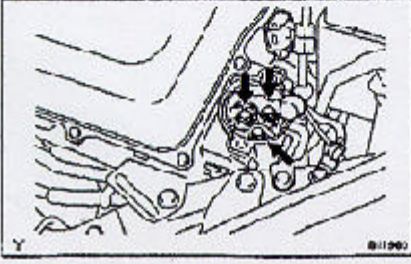
**NOTICE:**  
Be careful to prevent foreign matter from entering the inside of connector cover.

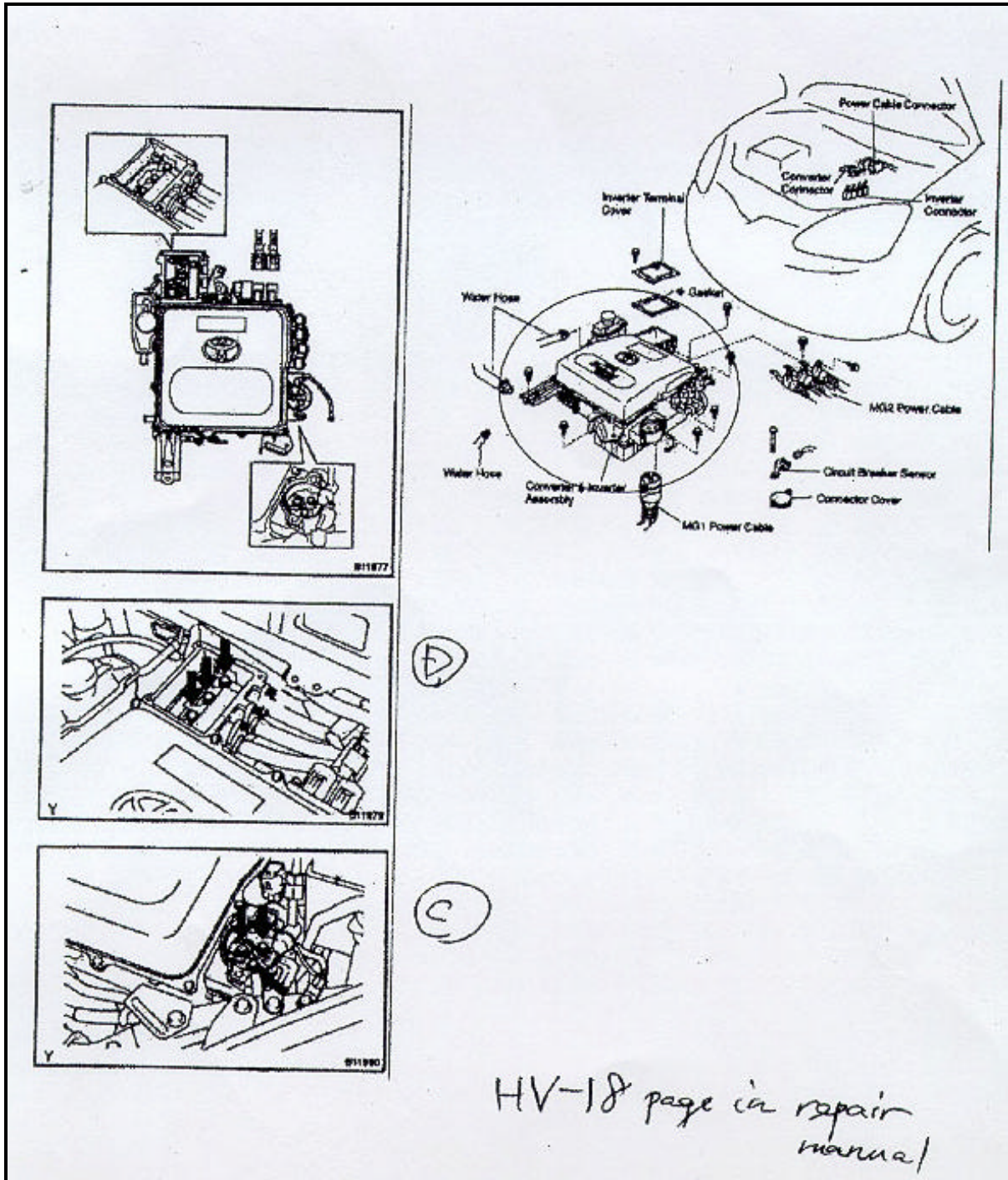
- (b) Remove the 3 bolts and power cable for MG1.

**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