

On-Site Rollover Investigation
Dynamic Science, Inc. (DSI), Case Number DS10001
2008 Ford Escape Hybrid
California
November 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 <p>This investigation focused on a 2008 Ford Escape Hybrid that sustained multiple impacts and rolled over. This two-vehicle crash occurred in November 2009 at 1410 hours in an unincorporated area of California. The crash site was the four-leg intersection of a north/south roadway and an east/west roadway. The subject vehicle was being driven by a 37-year-old female. The other vehicle is a 2003 Chevrolet Cavalier that was being driven by a 23-year-old female. The Chevrolet was traveling north and slowed in preparation to turn left at the intersection. The Ford was traveling north directly behind the Chevrolet at a driver-estimated speed of 88-97 km/h (55-60 mph). The Chevrolet initiated a left turn and the driver of the Ford attempted to avoid impacting the Chevrolet by steering left. The right side of the Ford impacted the left front of the Chevrolet causing the driver of the Ford to lose control of her vehicle. The left and right inflatable curtain (IC) air bags deployed during the side impact. The vehicle then departed the northbound roadway on the right side, impacted a mail box unit, overturned five quarter-turns, and came to rest on its left side in a ravine. The Chevrolet came to rest in the intersection.</p> <p>The driver of the Ford did not sustain any codeable injuries and was not transported. The driver of the Chevrolet sustained a possible injury and was transported to a hospital.</p>				
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BACKGROUND

This investigation focused on a 2008 Ford Escape Hybrid that sustained multiple impacts and rolled over (**Figure 1**). This two-vehicle crash occurred in November 2009 at 1410 hours in an unincorporated area of California. The crash site was the four-leg intersection of a north/south roadway and an east/west roadway. The subject vehicle was being driven by a 37-year-old female. The other vehicle is a 2003 Chevrolet Cavalier that was being driven by a 23-year-old female. The Chevrolet was traveling north and slowed in preparation to turn left at the intersection. The Ford was traveling north directly behind the Chevrolet at an EDR-reported speed of 80.28 km/h (49.88 mph). The Chevrolet initiated a left turn and the driver of the Ford attempted to avoid impacting the Chevrolet by steering left. The right side of the Ford impacted the left front of the Chevrolet causing the driver of the Ford to lose control of her vehicle. The left and right IC air bags deployed during this side impact. The vehicle then departed the northbound roadway on the right side, impacted a mail box unit, overturned five quarter-turns, and came to rest on its left side in a ravine. The Chevrolet came to rest in the intersection.



Figure 1. Subject vehicle, 2008 Ford Escape Hybrid

The driver of the Ford sustained minor injuries and was not transported. The driver of the Chevrolet sustained a possible injury and was transported to a hospital.

This on-site rollover investigation was identified by a DSI investigator from a review of an auto auction internet site. Photographs of the subject vehicle were submitted to the National Highway Traffic Safety Administration (NHTSA) and on January 19, 2010 DSI was directed to commence the investigation. The police report was obtained, permission to inspect the subject vehicle was obtained, and the vehicle inspection was completed on January 20, 2010. Permission to remove the Ford's Event Data Recorder (EDR) was obtained and the EDR was forwarded to NHTSA for the purpose of submitting the EDR to Ford to image the crash data. A summary of the imaged data is included in this report. Field work was completed on February 5, 2010.

SUMMARY

Crash Site

The crash site was the intersection of a north/south roadway and an east/west roadway in an unincorporated area. The north/south roadway was configured with one northbound lane and one

southbound travel lane that were separated by double yellow lines prior to the intersection (**Figure 2**). The asphalt roadway was straight and had an undulating profile. A hillcrest was located 82.9 m (272.0 ft) south of the intersection. At 60.9 m (200 ft) from the intersection the profile was a negative 5.4%, at 30.5 m (100.0 ft) the profile was a negative 2.9%, and at 15.2 m (50.0 ft) the profile was a negative 2%. At the intersection, the roadway began a positive grade and the profile was 1.5%. The posted speed limit was 89 km/h (55 mph). North of the intersection, the east edge of the roadway was delineated by a white stripe, followed by a 2.7 m (9.0 ft) asphalt shoulder, followed by a generally level area of dirt/gravel that terminated in a ravine that was located approximately 13.7 m (45.0 ft) from the road edge. The ravine was generally parallel with the roadway but had an irregular alignment and varying widths. The depth of the ravine ranged from 1.5m (5.0 ft) to 2.4 m (8.0 ft). East of the roadway there were three sets of group cluster mailbox units. The mailbox unit located furthest north measured 142.0 cm (55.9 in) in height and 143.0 cm (56.2 in) wide; it was supported by four 7.0 cm (2.8) diameter pipes that were embedded in a concrete base. The east/west intersecting roadways had an asphalt and dirt composition and were controlled by stop signs. The weather was clear and visibility in all directions was good.



Figure 2. Northbound approach

Pre-Crash

The Chevrolet was traveling north and slowed to a driver-estimated speed of 8 km/h (5 mph) in preparation to turn left at the intersection. The Ford was traveling north directly behind the Chevrolet at an EDR-reported 80.28 km/h (49.88 mph) five seconds before the event. The driver stated that she was 1-1/2 to 2 car lengths behind the Chevrolet. As the Chevrolet slowed, the driver of the Ford braked briefly and then accelerated and steered to the left into the southbound travel lane.

Crash

The right side of the Ford impacted the left front of the Chevrolet (Event 1), and the driver of the Ford lost control of her vehicle. The left and right IC air bags deployed and the driver's pretensioner actuated during this side impact. The EDR indicated that the driver began braking again. The Ford began a clockwise rotation, crossed the northbound travel lane, departed the northbound roadway on the right side (**Figure 3**) and impacted a metal mailbox unit (Event 2), and then began a left side leading rollover (Event 3). At one second prior to the rollover, the EDR reported that the vehicle speed was 25 km/h (16 mph). The Ford



Figure 3. Path to impact with mailbox unit

rolled five quarter-turns before coming to rest on its left side in the ravine (**Figure 4**). The Chevrolet came to rest facing north within the intersection.

Post-Crash

The driver of the Ford sustained minor lacerations to both hands and complained of pain to her neck and back. She was able to exit the vehicle under her own power and was examined at the scene by paramedics. She indicated that she would seek her own medical treatment. The driver of the Chevrolet complained of pain to his neck and back and was transported to a local hospital for treatment. Both vehicles were towed due to damage and the Ford was later declared a total loss by the insurance company. The mailbox unit was damaged and was replaced prior to the scene inspection.



Figure 4. Overview of final rest (south)

Vehicle Data - 2008 Ford Escape Hybrid

The 2008 Ford Escape Hybrid sport utility vehicle was identified by the Vehicle Identification Number (VIN): 1FMCU49H08Kxxxxxx. The vehicle date of manufacture was February 2008. The vehicle mileage was 71,754 kilometers (44,586 miles). The Ford was a gas/electric hybrid vehicle that was equipped with 2.3-liter, 4-cylinder gasoline engine, a hybrid electric motor alternator, a continuously variable transmission, front wheel drive, 4-wheel disc brakes, a regenerative braking system, and a tilt steering wheel. The Ford was equipped with Continental Contitrac P235/70R16 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). The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	207 kPa (30 psi)	6 mm (8/32 in)	No	None
LR	Tire Flat	6 mm (8/32 in)	No	De-beaded
RR	207 kPa (30 psi)	6 mm (8/32 in)	No	None
RF	200 kPa (29 psi)	7 mm (9/32 in)	No	None

The seating in the Ford was configured with front bucket seats with adjustable head restraints and rear 60/40 split bench seat with adjustable head restraints. The head restraint for the second row middle position was missing at the time of the inspection.

Vehicle Damage

Exterior Damage

The Ford sustained direct and induced damage to the right side from the impact with the Chevrolet (**Figure 5**). The direct damage began at the left rear bumper corner and extended forward 412.0 cm (162.2 in). The Field L measurement was identical to the direct damage measurement. Six crush measurements were taken at the frame level as follows: $C_1 = 3.0$ cm (1.2 in), $C_2 = 0$ cm, $C_3 = 1.0$ cm (0.4 in), $C_4 = 2.0$ cm (0.8 in), $C_5 = 1.0$ cm (0.4 in), $C_6 = 1.0$ cm (0.4 in). Maximum crush was located 120.0 cm (47.2 in) forward of rear bumper corner and measured 5.0 cm (1.9 in). The Collision Deformation Classification (CDC) for Event 1 was 01RDES1.



Figure 5. Right side crush profile (Event 1)

The Ford sustained minor front end damage from the impact with the mailboxes (**Figure 6**). The damage extended from bumper corner to bumper corner. Six crush measurements were taken at the bumper level as follows: $C_1 = 1.0$ cm (0.4 in), $C_2 = 1.0$ cm (0.4 in), $C_3 = 0$ cm, $C_4 = 0$ cm, $C_5 = 0$ cm, $C_6 = 0$ cm. Maximum crush was located at C1. The CDC for Event 2 was 12FDLW1.



Figure 6. Frontal damage

The Ford sustained moderate damage to the top plane during the rollover event (**Figure 7**). The direct damage to the top of the vehicle extended laterally from roof side rail to roof side rail and measured 142.0 cm (55.9 in). The damage extended from the backlight header forward 374.0 cm (147.2 in). The maximum vertical crush was located 53.0 cm (20.9 in) from the vehicle centerline at the right roof 3.0 cm (1.2 in) from the right A-pillar and measured 28.0 cm (11.0 in). The maximum lateral crush on the right roof side rail was located 127.0 cm (50.0 in) aft of the front axle and measured 5.0 cm (1.9 in). The CDC for Event 3 was 00TDDO4.



Figure 7. Top rollover damage (Event 3)

Interior Damage

The Ford sustained moderate interior damage as a result of intrusions, occupant loading, and contact. Vertical intrusion was located in the front row at the right A-pillar, windshield header, roof, and left

A-pillar (**Figure 8**). Lateral intrusion was located in the front row at the roof side rail and B-pillar. Vertical intrusion was located in the second row at the roof. Evidence of occupant loading and contacts were documented to the driver's safety belt, the safety belt latch plate, the rear view mirror, and the left IC air bag.

The doors and the rear hatch remained closed and operational. All the window glazing was either fixed or closed. The windshield was holed and out of place. The left front, right front, right rear, and right rearmost glazing was disintegrated.

Manual Restraints

The front row seating positions were equipped with 3-point manual lap and shoulder belts with sliding latch plates, adjustable D-ring anchorage assemblies, and buckle/retractor pretensioners. The driver's safety belt had an Emergency Locking Retractor (ELR) and the front right passenger's safety belt had a switchable ELR/Automatic Locking Retractor (ALR).



Figure 8. Roof intrusion

The driver's safety belt D-ring anchorage was set in the full-down position. The latch plate showed scratching indicative of historical usage. The retractor pretensioner actuated and the safety belt was locked in place. There was no discernible movement of the buckle pretensioner.

The front right and second row left safety belt latches showed evidence of historical usage and the safety belt components were otherwise unremarkable. The second row center and right safety belts did not show indications of usage.

Supplemental Restraint Systems

This vehicle's Supplemental Restraint System (SRS) included a Restraint Control Module (RCM), driver and passenger frontal air bags, seat-mounted side air bags for the front row, combination rollover/side impact IC air bags, and safety belt pretensioners for the front row. The Ford was a Certified Advanced 208-Compliant (CAC) vehicle and was equipped with advanced frontal 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 driver's air bag was located within the steering wheel hub and the front right passenger air bag was located within the middle of the right instrument panel. During the side impact, the left and right IC air bags deployed (**Figure 9**). The frontal and seat-mounted side air bags did not deploy.



Figure 9. Left IC air bag

The left and right IC air bags deployed from modules in roof rails above the front and second rows. The IC air bags measured 138.0 cm (54.3 in) in length and 50.0 cm (19.7 in) in height. The bottom edge of the air bag was located 7.0 cm (2.8 in) below the side window frame. The air bags were configured without vent ports or internal tethers. The front of the air bag was attached to the A-pillar by a 38.0 cm (14.9 in) tether; the rear was attached to the C-pillar by a 6.0 cm (2.4 in) tether. There was 30.0 x 35.0 cm (11.8 x 13.8 in) area of window not covered.

The left IC air bag inboard panel revealed a skin oil/skin deposit covering an area measuring 46.0 cm (18.1 in) in length and 18.0 cm (7.0 in) in height. There was a vertical area of contact from the B-pillar that measured 33.0 cm (12.9 in) in height and 3.0 cm (1.2 in) in width. There was no damage to the outboard panel. There was no damage or contact to the right IC air bag.

Event Data Recorder

The restraint control module analysis reported the following:

Event Data Record 1

- A side event was recorded.
- The driver's retractor pretensioner fire time was 55 milliseconds (ms).
- The driver's pretensioner fire time was 60 ms.
- The left IC air bag deployment time was 55 ms.
- The right IC air bag deployment time was 55 ms.
- There were 3.75 minutes from key-on until rollover algorithm wakeup.

Event Data Record 2

- A rollover event was recorded.
- The roll rate was 152.5 degrees per second.
- The roll angle was 22.218 degrees.
- The restraints did not deploy since they already deployed from the previous event.

Pre-Crash Data from Event Data Record 1

- The driver seat belt status was buckled and the seat track position was rearward.
- The passenger seat belt status was unbuckled. The seat track position was not reported.
- The vehicle speed was 80.28 km/h (49.88 mph) at 5 seconds prior to the event. The brake pedal was reported as being active at this time. At 3 seconds prior to the event, the vehicle began accelerating and the brake pedal was no longer active. At 1 second prior to the event, the vehicle has accelerated to 84.73 km/h (52.65 mph).

Pre-Crash Data from Event Data Record 2

- The seat belt status and seat track positions remained unchanged.
- The vehicle speed at 5 second prior to the rollover event was 82.17 km/h (51.06 mph). At 3 seconds prior to the event, the brake pedal and ABS were recorded as

being active and vehicle began decelerating. At 1 second prior to the event, the vehicle had decelerated to 24.98 km/h (15.52 mph).

Hybrid System - 2008 Ford Escape

The Ford 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 Ford was designed as a full hybrid vehicle, meaning that the gasoline engine and the electric motor can both operate separately, or they can run at the same time. The Ford was designed with a 2.3-liter, 4-cylinder gasoline engine which was linked to a 3-phase permanent magnet electric motor. An overview of the hybrid components and their locations is shown in Attachment 2.

The high-voltage battery pack consists of 50 battery modules with each module comprised of 5 Nickel Metal-Hydrate (NiMH) 1.3-volt batteries welded together. The battery cells contain a base electrolyte consisting of potassium hydroxide as the dominant active ingredient. The total voltage of the battery pack is approximately 300 volts DC. The battery pack is mounted below the rear cargo floor, aft of the second row seat (**Figure 10**). The battery pack 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. The battery is electrically isolated from the rest of the vehicle when the key is OFF. When the key is turned ON, high voltage contactors inside the battery are closed to make the electricity available to the motor/generator and enable the vehicle to drive¹. There was an orange-colored service disconnect plug located on the right side of the battery. It was in the locked position at the time of the vehicle inspection.

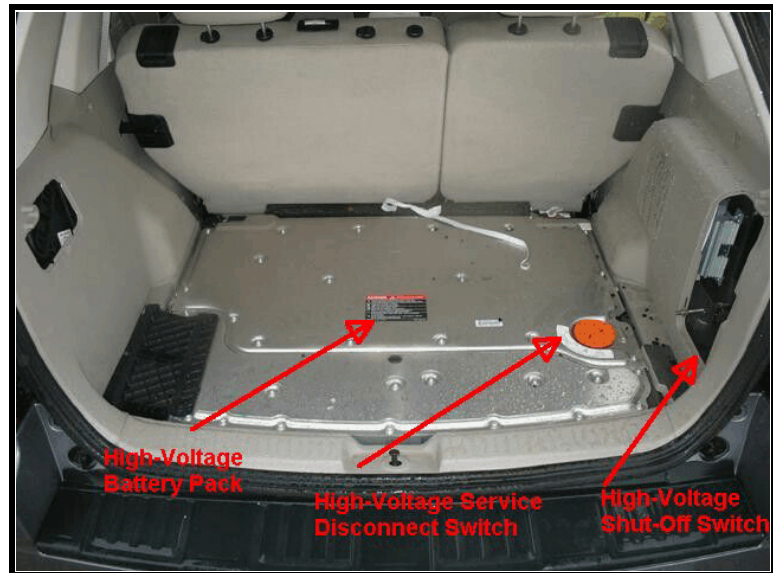


Figure 10. High-Voltage Battery

In the event the vehicle receives a substantial physical jolt the high voltage shut-off switch shuts off power from the high voltage battery. The shut-off switch was located in the cargo area on the passenger side of the vehicle in the jack compartment, behind the jack access door. The switch is located behind the jack. At the time of the inspection, the jack had already been removed and the switch had apparently been reset.

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 than 48

¹2008 Ford Escape Hybrid Owner's Manual

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.² 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.

The Ford was examined to assess compliance with the performance requirements listed above.

- There were no indications of electrolyte spillage from the propulsion battery either outside or inside the passenger compartment.
- There was no movement of the battery module.
- The isolation test was not conducted. There were no indications of any arcing, fire or component meltdown.

External power was applied to the vehicle service battery but the vehicle would not start. The electronic odometer and other controls were illuminated and the power door locks were activated. The center video screen on the IP displayed systems and maintenance details pertaining to the vehicle.

Rollover Discussion

The Ford had a Static Stability Factor (SSF) of 1.14. The SSF of a vehicle is an at-rest calculation of its rollover resistance, which is based on its track width and center of gravity. The vehicle had a rollover resistance rating of 3 out of 5 stars, and had a 22% chance of rollover³. The vehicle was equipped with anti-lock brakes but no additional traction or braking features.

After the initial impact with the Chevrolet, the Ford began a clockwise rotation. As the Ford departed the roadway, the front end impacted the mail box units. The clockwise rotation continued and as the left side tires engaged the ground the vehicle Ford tripped and began a left side leading rollover. The EDR recorded a rollover event with a rate of 152.5 degrees per second and a roll angle of 22.218 degrees. During the rollover, the Ford rolled across the level ground and then fell into the ravine. The Ford rolled five quarter-turns before coming to rest on its left side. The estimated distance from the trip point to final rest was 15 m (49 ft).

²U.S. Department of Transportation, 49CFR 571.305

³www.safercar.gov

Vehicle Data - 2003 Chevrolet Cavalier

The 2003 Chevrolet Cavalier was identified from the police report. The VIN was not listed on the report and specific features and specifications were not known. The Chevrolet was a 4-door sedan that sustained moderate damage to the left side. The vehicle came to rest in the intersection and was moved to the side of the road by the driver. The driver was assisted from the vehicle by paramedics and was transported to a local hospital after complaining of pain to her neck and back. The Chevrolet was towed from the scene and was not inspected.

Occupant Demographics - 2008 Ford Escape Hybrid

Driver

Age/Sex:	37/Female
Seated Position:	Front left
Seat track position:	Between middle and rear-most
Height:	168 cm (66 in)
Weight:	61 kg (135 lbs)
Seat track position:	Between middle and rear-most
Manual restraint use:	Lap and shoulder belt
Type of medical treatment:	Treated at scene

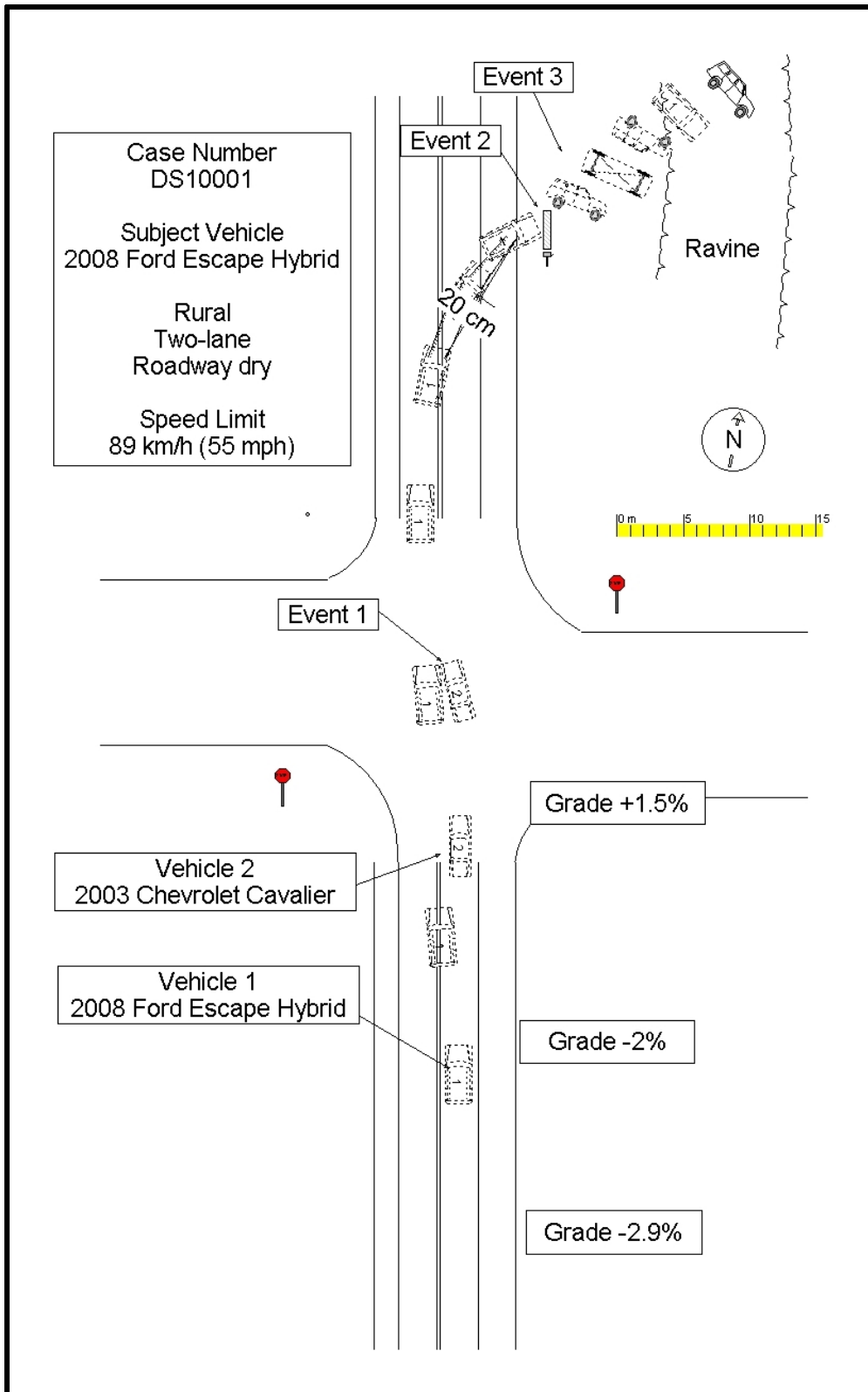
Driver Kinematics

The 37-year-old female driver was seated in an unknown posture. Based on the vehicle inspection, she was wearing the manual lap and shoulder belt and the bucket seat was adjusted to between the middle and rear-most track position. As the Ford approached the Chevrolet, the driver steered to the left in an attempt to avoid the Chevrolet. The right side of the Ford impacted the left front of the Chevrolet. This was a sideswiping, low Delta-V event and there was little driver movement. According to the EDR, the left and right IC air bags deployed and the driver's seat belt pretensioner actuated during this side impact. After impact, the Ford began a clockwise rotation and the driver was displaced to the left. As the Ford departed the roadway, the front of the vehicle impacted the mailbox unit. This was also a low Delta-V event and there was little driver movement. As the Ford tripped and began to roll, the driver was held in place by the pretensioned safety belt. She contacted the left IC air bag but there were no resultant injuries. The vehicle rolled five quarter-turns and came to rest on its left side. The driver sustained small lacerations to her hands that were likely a result of extrication. She also complained of pain to her neck and back. She was treated at the scene by paramedics but was not transported. She indicated that she would seek her own medical treatment if necessary.

Occupant Injuries

No crash related injuries.

Attachment 1. Scene Diagram



Attachment 2. Hybrid Component Location and Identification⁴

HYBRID COMPONENT LOCATION AND IDENTIFICATION

This chart provides the location, description and basic function of the Hybrid system components. Refer to the Hybrid Component Location illustration on the following page.

	COMPONENT	LOCATION / DESCRIPTION	FUNCTION
1	High-Voltage Shut-Off Switch	<ul style="list-style-type: none"> Located in the jack stowage compartment, passenger side in the cargo area. 	Disconnects high-voltage battery in the event of a collision.
2	High-Voltage Service Disconnect Switch	<ul style="list-style-type: none"> Located on top of the high-voltage battery, passenger side in the cargo area under carpet. Orange in color with molded plastic handle, about 100 mm (4 inch) in diameter. 	Provides means to disconnect high-voltage battery for safely servicing vehicle.
3	High-Voltage Battery — 300+ Volts	<ul style="list-style-type: none"> Located in the cargo area under carpet. Sealed nickel-metal hydride. 	Provides high-voltage storage (300+ V) for vehicle propulsion requirements.
4	High-Voltage Wiring	<ul style="list-style-type: none"> Runs along underside of vehicles cab floor from high-voltage battery to electronically controlled continuously variable transaxle (eCVT) then to DC-to-DC converter. All high-voltage wiring has orange-colored insulation. 	Provides physical path for high-voltage circuitry.
5	12-Volt Battery	<ul style="list-style-type: none"> Located under the hood on driver side of the vehicle. Typical automotive 6-cell lead/acid design. 	Provides 12-volt power for vehicle accessories.
6	Electronically Controlled Continuously Variable Transaxle (eCVT)	<ul style="list-style-type: none"> Transverse-mounted design similar to the non-Hybrid Escape/Mariner vehicles. Contains the traction motor, generator motor and Hybrid electronics. 	Provides delivery of power to wheels for vehicle propulsion, generates electricity to recharge the batteries during braking and coasting, and contains certain Hybrid electronics.
7	DC/DC Converter	<ul style="list-style-type: none"> Located under the hood on the passenger side forward of the strut tower. 	Provides 12 volts of power to charge the 12-volt battery and run vehicle accessories.
8	Fuel Shut-Off Inertia Switch	<ul style="list-style-type: none"> Located behind the flip-up panel in the passenger front foot well. 	Disables power supply to the gasoline fuel pump and the HV shut-off switch in the event of a collision.

NOTE: All high-voltage wires and harnesses are wrapped in orange-colored insulation.

⁴Escape Hybrid/Mariner Hybrid Emergency Response Guide

Hybrid Component Location

