

INDIANA UNIVERSITY

TRANSPORTATION RESEARCH CENTER

ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN11006
LOCATION - MISSOURI
VEHICLE - 2010 TOYOTA PRIUS
CRASH DATE - December, 2010

Submitted:

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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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15. <i>Supplementary Notes</i> On-site side impact inflatable occupant protection investigation involving a 2010 Toyota Prius and a 2008 Ford Escape.					
16. <i>Abstract</i> The focus of this on-site investigation was the side impact air bag system of a 2010 Toyota Prius, which was involved in a side impact crash with a 2008 Ford Escape. The Toyota was occupied by a restrained 55-year-old female driver. She was southbound on a rural 2-lane state highway approaching a stop sign at the 4-leg intersection with a U.S. highway. The Ford was westbound on the U.S. highway. The Toyota entered the intersection and its left side plane was impacted by the front plane of the Ford (event 1). The force direction on the Toyota was within the 11 o'clock sector and the impact force triggered deployments of the driver's frontal air bag, knee air bag, left seat-mounted side impact air bag, and the left IC air bag. Both vehicles departed the southwest quadrant of the intersection and entered a ditch where the Toyota rolled over onto its left side (event 2) and touched down on top of the Ford (event 3). The driver of the Toyota was fatally injured and pronounced deceased at the crash scene. The restrained 53-year-old female driver of the Ford sustained incapacitating injuries and was transported by air ambulance to a hospital and admitted.					
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ON-SITE SIDE IMPACT INFLATABLE
OCCUPANT PROTECTION INVESTIGATION
CASE NUMBER - IN11006
LOCATION - MISSOURI
VEHICLE - 2000 TOYOTA PRIUS
CRASH DATE - December 2010

BACKGROUND

The focus of this on-site investigation was the side impact air bag system of a 2010 Toyota Prius (**Figure 1**). This crash was brought to the attention of the National Highway Traffic Safety Administration (NHTSA) on January 28, 2011 by Special Crash Investigation Team 2. The crash was identified through an on-line search of Missouri State Highway Patrol crash report abstracts. This investigation was assigned on February 9, 2011. The crash occurred in December, 2010, at 0605 hours, in Missouri and was investigated by the highway patrol. The Toyota and crash scene were inspected on February 15, 2011. The Ford was inspected on February 17, 2011.



Figure 1: The damaged 2010 Toyota Prius

The Toyota was involved in a side impact crash with a 2008 Ford Escape. The Toyota was a 4-door sedan equipped with frontal air bags, driver's knee air bag, front seat-mounted side impact air bags, and side impact inflatable curtain (IC) air bags. The driver's frontal air bag, knee air bag, front left seat-mounted side impact air bag, and IC air bag deployed as a result of a left plane impact by the front plane of the Ford. The Toyota was occupied by a restrained 55-year-old female driver. She sustained fatal injuries and was pronounced deceased at the crash scene. The Ford was a 4-door sport utility vehicle equipped with frontal air bags, front seat-mounted side impact air bags, and side impact IC air bags. The vehicle was occupied by a 53-year-old female driver. She sustained incapacitating injuries and was transported by air ambulance to a hospital and admitted.

CRASH SUMMARY

Crash Site: This crash occurred within the 4-leg intersection of a 2-lane U.S. highway and a rural 2-lane state highway during dark pre-dawn hours and cloudy weather conditions. The Toyota was traveling on the rural roadway, which traversed in a north-south direction. The roadway was bituminous with one lane in each direction and was bordered by gravel shoulders. The southbound lane was 3.5 m (11.5 ft) in width, while the northbound lane was 3 m (9.8 ft) in width. The west

shoulder was 2.6 m (8.5 ft) in width. The east shoulder was 1.9 m (6.2 ft) in width. The roadway pavement markings consisted of solid white edge lines and double yellow center lines. The roadway was controlled by a stop sign at the intersection. The grade for the Toyota on the approach to the intersection was positive 2%. The Ford was traveling on the U.S. highway, which traversed in an east-west direction. The roadway was uncontrolled and had one lane in each direction. Each lane was 3.6 m (11.8 ft) in width. The roadway was concrete and bordered by bituminous shoulders with a guardrail on the south side of the road. The south shoulder was 3.4 m (11.2 ft) in width, while the north shoulder was 3.2 m (10.5 ft) in width. The roadway pavement markings consisted of solid white edge lines and a broken yellow center line. The grade for the Ford was level. The speed limits for the Toyota and Ford were 89 km/h (55 mph) and 97 km/h (60 mph), respectively. The Scene Diagram is on page 15 of this report.

Pre-Crash: The Toyota was traveling south approaching the intersection (**Figure 2**) and the Ford was traveling west (**Figure 3**). The Toyota's Event Data Recorder (EDR) reported the Toyota traveling 108 km/h (67.1 mph) at 5 sec prior to the impact trigger decelerating to 96 km/h (59.7 mph) at 0.5 sec prior to the impact trigger. The brake was reported as "Off" from 5 sec to 2 sec prior to the impact trigger, "On" at 1 sec prior to the impact trigger, and "Off" at 0.5 sec prior to the impact trigger. The police crash schematic indicated that the Ford's driver applied hard braking in an attempt to avoid the crash. The toxicology results in the autopsy report for the driver of the Toyota were positive for opiates, analgesics, anticonvulsants, and antidepressants. Please see the Driver Demographics section on page 9 of this report for the toxicology results. The level of the antidepressant Venlafaxine was reported as over 24 times the maximum dosage and the autopsy reported the manner of death as suicide.

Crash: The Toyota entered the intersection and the front plane of the Ford (**Figure 4**) impacted the left plane of the Toyota (**Figure 5**, event 1). The force direction on the Toyota was within the 11 o'clock sector and the impact force triggered deployments of the driver's frontal air bag, knee air bag, left seat-mounted side impact air bag, and the left IC air bag. The WinSMASH program calculated the Toyota's total Delta V as 51 km/h (31.6 mph). The longitudinal and lateral velocity changes were -39 km/h (-24.2 mph) and 33 km/h (20.5 mph), respectively. The EDR reported the Toyota's longitudinal velocity change as 41 km/h (25.5 mph). The lateral velocity change at



Figure 2: Approach of the Toyota traveling south to the intersection



Figure 3: Approach of the Ford traveling west to the intersection

the B-pillar was reported as 96.2 km/h (59.8 mph). Following the impact, the Toyota rotated 230 degrees as it traversed 13 m (42.6 ft) and departed the southwest quadrant of the intersection into a 1.2 m (4 ft) deep ditch. The Ford rotated counterclockwise approximately 280 degrees as it traversed 22 m (72.2 ft) and departed the southwest quadrant of the intersection into the ditch. The Toyota became airborne as it entered the ditch and rolled over (event 2) onto its left side. The Toyota's left plane then impacted the top plane of the Ford (event 3) and the ground. The Toyota came to final rest on the top plane of the Ford heading northeast (**Figure 6**). The Ford was heading northwest at final rest. The Toyota traversed a total distance from impact to final rest of approximately 25 m (82 ft), while the Ford traversed a total distance of approximately 31 m (102 ft).

Post-Crash: The police were notified of the crash at 0610 hours and arrived at the crash scene at 0638 hours. Emergency medical and rescue services as well as an air ambulance also responded to the crash scene. Rescue personnel mechanically opened the left front door of the Toyota and removed the driver from the vehicle. She was pronounced deceased at the crash scene and transported to a local funeral home. The driver of the Ford sustained incapacitating injuries and was transported by air ambulance to a hospital where she was admitted. Both vehicles were towed from the crash scene due to damage.



Figure 4: Damage to the front plane of the Ford from impact with the Toyota



Figure 5: Damage on the left plane of the Toyota from the impact with the Ford



Figure 6: View southwest to the area of final rest of the Toyota and Ford

DESCRIPTION

The Toyota was a front wheel drive, 5-passenger, 4-door, sedan (VIN: JTDMN3DU8A0xxxxx) equipped with an 1.8-liter, 4-cylinder gasoline engine with a permanent-magnet AC-synchronous electric motor, a 201.6 volt sealed Nickel-Metal Hydride (NiMH) propulsion battery, a continuously variable automatic transmission, 4-wheel anti-lock disc brakes, traction control, and electronic stability control (ESC). The vehicle was equipped with driver and front right passenger dual stage frontal air bags, driver knee air bag, front seat-mounted side impact air bags, side impact IC air bags, and lap-and-shoulder safety belts. The windshield glazing was AS-1 laminated while the remainder of the glazing was AS-2 tempered. Prior to the crash, all of the glazing was either closed for adjustable windows or fixed for the others. The specified wheelbase was 271 cm (106.7 in). The odometer reading was unknown since the vehicle was equipped with an electronic odometer and was without power.

The vehicle manufacturer's recommended tire size was P195/65R15. The vehicle was equipped with tires of the recommended size. The recommended cold tire pressure for the front and rear tires was 241 kPa (35 psi) and 228 kPa (33 psi), respectively. The tire data for the Toyota are presented in the table below.

<i>Position</i>	<i>Measured Pressure</i>	<i>Measured Tread Depth</i>	<i>Restricted</i>	<i>Damage</i>
LF	Flat (Flat)	6 mm (7/32 in)	No	Debeaded, tire tread torn
LR	228 kPa (33 psi)	5 mm (6/32 in)	No	None
RR	241 kPa (35 psi)	6 mm (7/32 in)	No	None
RF	241 kPa (35 psi)	6 mm (7/32 in)	No	None

The front row was equipped with cloth-covered bucket seats with adjustable head restraints. Both seat tracks were adjusted to between the middle and front position. The pre-crash position of the seat backs could not be determined since they were deformed rearward from intrusion. The second row was equipped with a cloth-covered split bench seat with folding backs and adjustable head restraints. The second row seat had fixed tracks.

EXTERIOR DAMAGE

Exterior Damage Event 1: The Toyota sustained left side plane damage during the impact with the Ford. The left fender, hood, A-pillar, B-pillar, and left side doors were directly damaged. The direct damage began 50 cm (19.7 in) forward of the left rear axle and extended 224 cm (88.1 in) forward along the left side plane. The crush measurements were taken at the mid-door level and the maximum residual crush was 68 cm (26.8 in) occurring 90 cm (35.4 in) forward of the left rear axle (**Figure 7**). The height of the maximum door crush was 72 cm (28.3 in) and the

door sill differential was 41 cm (16.1 in). The height of the sill was 28 cm (11 in). The vehicle's left side wheelbase was reduced 6 cm (2.4 in).

Damage Classification Event 1: The Collision Deformation Classification (CDC) was 11LYAW4 (320 degrees). The Damage algorithm of the WinSMASH program calculated the total Delta V as 51 km/h (31.7 mph). The longitudinal and lateral velocity changes were -39 km/h (-24.2 mph) and 33 km/h (20.5 mph), respectively. Based on the damage, the results appeared reasonable. The Toyota's EDR reported the longitudinal velocity change as 41 km/h (25.5 mph). The lateral velocity change at the B-pillar was reported as 96.2 km/h (59.8 mph).

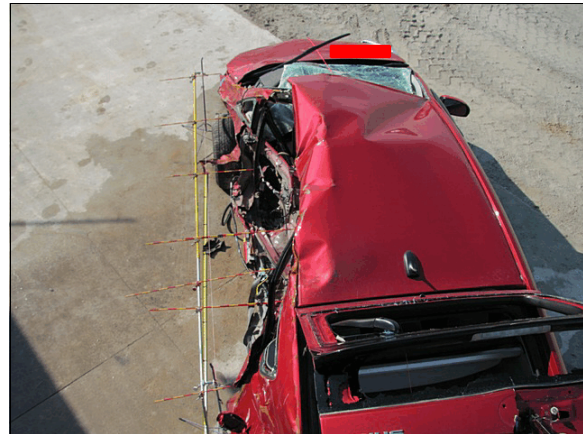


Figure 7: Top view of the left side plane crush to the Toyota; each increment on rods is 5 cm (2 in)

Exterior Damage Events 2 and 3: The left side plane of the Toyota simultaneously impacted the ground (event 2) and the back portion of the Ford's top plane (event 3) when the Toyota touched down from the rollover. Grass and mud were embedded in the Toyota's left front wheel and frame from the ground contact. The left quarter panel and back portion of the left rear door were damaged from the impact with the top plane of the Ford. The crush pocket from the event 1 impact did not appear to be significantly altered from these overlapping impacts.

Damage Classification Event 2 and 3: The CDC for the damage from the rollover (event 2) was 00LYAO2. The CDC for the left quarter panel impact (event 3) with the top plane of the Ford was 00LZAW3. The WinSMASH program could not be used on either of these impacts, since a rollover and non-horizontal impacts are out of scope for the program. The rollover damage was minor. The severity of the damage from the impact with Ford's top plane was moderate.

EVENT DATA RECORDER

The Toyota's EDR was imaged and reported using the manufacturer's EDR readout tool with software version 1.4.1.1. The EDR reported a side event and a frontal event. No rollover event was reported. The "Latest Pre-Crash Page.0" data block reported the driver's safety belt switch status as "Belted" and the driver's seat position as "RW," which is understood to indicate that the seat track was rearward of the switch point. The "Frontal Crash Page.0" data block reported the time from the pre-crash trigger as 3 ms and a "Lateral" previous event was reported. The frontal air bag and pretensioner deployment times were reported as 13 ms. The frontal air bag deployment stage was reported as "Low," which is understood to indicate a first stage deployment. There was 200 ms of longitudinal velocity change data reported and the maximum velocity change was reported as 41 km/h (25.5 mph) occurring at 200 ms. The "Side Crash Page.0" data block reported that the side air bag deployment trigger occurred at the B-pillar impact sensor and was reported as 7 ms. No previous event was reported. The time from the impact trigger to initial g was reported as 2 ms. The maximum lateral velocity change was reported as 96.2 km/h (59.8 mph) occurring at the B-pillar at 42 ms. The maximum lateral velocity change

at the C-pillar and floor were reported as 18 km/h (11.2 mph) at 34 ms and 27.2 km/h (-16.9) mph at 62 ms, respectively. The time limit of the recording was 74 ms. The pre-crash data was the discussed in the pre-crash section on page 2 of this report.

INTERIOR DAMAGE

The left front door had been mechanically cut and opened during extrication of the driver. The sheet metal and inner door panel were separated from the door and the rear portion of the door was jammed on the striker and B-pillar. The left front door was contacted by the driver, but the condition of the door prevented identification of specific occupant contact points. A small scuff from possible head contact by the driver was present on the left IC air bag located 45 cm (17.7 in) rearward of the front of the IC and 24 cm (9.4 in) above the bottom of the IC. There was no deformation of the steering wheel. Both front seats were deformed from intrusion. The left side of the second row seat was deformed from intrusion.

The left front door, left rear door, and rear hatch were jammed shut. The rear hatch had been mechanically opened. The right side doors remained closed and operational. The left front, left rear, second left rear, and backlight glazing were disintegrated from impact forces. The windshield was cracked from impact forces. It was separated from the windshield frame at the time of the inspection.

The vehicle sustained 21 intrusions of the passenger compartment. The most severe intrusions into the driver's space involved the B-pillar, upper rear quadrant of the left front door, and the left roof side rail. These components intruded laterally 39 cm (15.4 in), 44 cm (17.3 in), and 32 cm (12.6 in), respectively. The hood of the Ford also intruded into the driver's space an estimated 44 cm (17.3 in).

MANUAL RESTRAINT SYSTEMS

The front row was equipped with driver and front right passenger lap-and-shoulder safety belts. The driver's safety belt was equipped with continuous loop belt webbing, a sliding latch plate, an Emergency Locking Retractor (ELR), and an adjustable upper anchor that was in the full-up position. The front right passenger's safety belt was equipped the same as the driver, but had a switchable ELR/Automatic Locking Retractor (ALR). The adjustable upper anchor was in the full-down position. The front seat positions were equipped with retractor-mounted pretensioners, which actuated as a result of the event 1 impact. The second row was equipped with lap-and-shoulder safety belts. Lower Anchors and Tethers for Children (LATCH) were present at the outboard seat positions. The second row safety belts were equipped with continuous loop belt webbing, a sliding latch plate, switchable ELR/ALRs, and non-adjustable upper anchors.

Inspection of the driver's safety belt assembly revealed that the belt webbing was stretched and had been cut. The latch plate was found latched in the buckle. There were heavy load abrasions on the latch plate belt guide from the belt webbing. This evidence indicated that the driver was restrained at the time of the crash. The vehicle's EDR also reported the driver's safety belt switch status as "Belted." The remaining seat positions were unoccupied.

The Toyota was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of dual stage driver and front right passenger frontal air bags, driver seat position sensor, safety belt usage sensors, retractor mounted pretensioners and a front right passenger weight sensor. The vehicle also was equipped with a driver's knee air bag. Based on the 7th edition of Holmatro's Rescuer's Guide to Vehicle Safety Systems, the frontal air bag satellite sensors were located on the inner front fenders. The manufacturer has certified that the vehicle is compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The driver's frontal and knee air bags deployed in this crash. Deployment of the front right air bag was suppressed.

The vehicle was also equipped with a side impact air bag system that consisted of front seat-mounted side impact air bags and IC air bags. Based on the Holmatro Rescuer's Guide to Vehicle Safety Systems, the side impact sensors were located within the lower B- and C-pillars. The driver's seat-mounted side impact air bag and the left IC air bag deployed in this crash. The right seat-mounted side impact air bag and IC air bag did not deploy.

The driver's frontal air bag was located within the steering wheel hub and the module cover was a two flap configuration constructed of pliable vinyl. The top flap was 7.5 centimeters (3 in) in width at the top and 12 centimeters (4.7 in) in width at the bottom. The height of the cover flap was 8 cm (3.1 in). The bottom flap was 12 cm (4.7 in) in width at the top and 8 cm (3.1 in) in width at the bottom. The height of the cover flap was 6 cm (2.4 in). An inspection of the air bag module cover flaps revealed that they opened at the designated tear points and were undamaged. The deployed air bag was 53 cm (20.9 in) in diameter and had a 10 cm (3.9 in) wide internal tether. There were two vent ports 4 cm (1.6 in) in diameter on the back of the air bag at the 3 and 9 clock positions. Inspection of the air bag revealed no damage and no discernable evidence of occupant contact.

The driver's knee air bag was located within the lower left instrument panel. The module cover was a two flap configuration constructed of pliable vinyl. The top flap was 25 cm (9.8 in) in width and 3.5 cm (1.4 in) in height. The bottom flap was 25 cm (9.8 in) in width and 4 cm (1.6 in) in height. The cover flaps opened at the designated tear points. Both flaps were deformed by the intrusion of the left lower A-pillar, which deformed the instrument panel. The deployed knee air bag was 51 cm (20.1 in) in width and 22 cm (8.7 in) in height. There were two vertical cuts 5 cm (2 in) and 3 cm (1.2 in) in length on the front of the air bag located 27 cm (10.6 in) from the left side of the air bag. There were several dark transfers and scuffs on the front of the air bag from components placed in the vehicle following the crash.

The deployed left IC air bag (**Figure 8**) was 168 cm (54.3 in) in width and 38 cm (14.9 in) in height and was attached to the A-pillar by a nylon tether 22 cm (8.7 in) in length. Inspection of the IC revealed a small scuff from probable contact by the driver's head. The scuff was located 45 cm (17.7 in) rear of the front of the IC and 24 cm (9.4 in) above the bottom of the IC. The IC was not damaged during the crash.

The deployed left seat-mounted side impact air bag was entrapped between the intruded left B-pillar and the deformed driver's seat back. It was not accessible for inspection.

CONFORMANCE WITH FMVSS 305, SECTION 571, ELECTRIC POWERED VEHICLES

The Toyota's propulsion battery was located in the back cargo area immediately rear of the second row seat. The battery pack consisted of 28, 7.2 volt NiMH modules connected in series and located in a water resistant stainless steel case. Each module contains 6 cells. The cells contain

an alkaline of potassium and sodium hydroxide, which is absorbed into the battery cell plates and will form a gel. The gel will not normally leak in the event of a crash¹. Inspection of the propulsion battery revealed no evidence of leakage. The back of the battery case and the two rear mounting flanges appeared to be slightly deformed due to the induced deformation of the floor of the trunk. The battery was equipped with a high voltage service disconnect switch, which was located on the back right corner of the battery. The switch was in the locked position. The high voltage wiring that was accessible for inspection was not damaged. There was no evidence of electrical arcing at the visible electrical connections on the battery. The voltage inverter/converter and associated wiring in the engine compartment were not damaged and there was no evidence of electrical arcing at the visible electrical connections. An electrical isolation test was not conducted.



Figure 8: The Toyota's left IC air bag; yellow tape show location of probable occupant contact scuff

ROLLOVER MITIGATION

The NHTSA has given the 2010 Toyota Prius a four star rollover rating on a five star scale². The Toyota was equipped with ESC. It was not equipped with rollover sensing. ESC uses sensors to detect a loss of steering control and selectively applies the brakes to minimize the control loss and keep the vehicle on the intended path. The control loss in this crash occurred post-impact and was caused by impact forces. There was no steering input by the driver following the impact.

Following the impact with the Ford, the Toyota rotated counterclockwise approximately 230 degrees to the area it departed the southwest quadrant of the intersection. The vehicle became airborne as it departed the roadway it entered a 1.2 m (4 ft) deep ditch. As the vehicle was airborne, it rolled over one quarter turn onto its left side and touched down partially on top of the back of the Ford and partially on the ground where it came to final rest heading northeast. The distance traversed during the rollover was estimated to be 8 m (26.2 ft).

¹ Source: Toyota Prius Emergency Response Guide

² www.safercar.gov, 02/24/10

DRIVER DEMOGRAPHICS

Age/Sex: 55 years/female
 Height: Unknown
 Weight: Unknown
 Eyewear: Unknown
 Seat Type: Bucket
 Seat Track Position: Between middle and forward position
 Manual Restraint Usage: Lap-and-shoulder
 Usage Source: Vehicle inspection and EDR data
 Air Bags: Frontal, knee, seat-mounted side impact, and IC, deployed
 Alcohol/Drug Involvement: Toxicology results from the autopsy were positive for opiates, analgesics, anticonvulsants, and anti depressants³, no alcohol was reported
 Egress from Vehicle: Rescue personnel mechanically opened the left front door to extricate the driver
 Transport from Scene: Transported to local funeral home
 Medical Treatment: None, pronounced deceased at crash scene

DRIVER INJURIES

Injury Number	Injury	AIS 2005/08	Injury Source	Confidence Level
1	Laceration (separation), complete, pontomedullary junction from internal decapitation ⁴	140218.6,8	Exterior of other motor vehicle: hood edge	Probable
2	Dislocation, atlanto-occipital ⁴ , in all directions of mobility ⁵	650208.2,6	Exterior of other motor vehicle: hood edge	Probable
3 4	Contusions brainstem and at base of cerebellum, not further specified	140204.5,8 140402.3,6	Exterior of other motor vehicle: hood edge	Probable
5 6	Hemorrhage, small, intraventricular in lateral ventricles	140678.2,1 140678.2,2	Exterior of other motor vehicle: hood edge	Probable

³ Opiates: Oxycodone [271 ng/ml (normal dosage: 10-100)], Oxymorphone (39.8 ng/ml); Analgesics: Cyclobenzaprine [122 ng/ml (normal dosage: 3-36)]; Anticonvulsants: Gabapentine [42.3 ug/ml (normal dosage: 2-20)]; Antidepressants: Amitriptyline [109 ng/ml (normal dosage: 10-250)]; Trazodone [0.1 ug/ml (normal dosage:0.8-1.6)]; Venlafaxine [12,160 ng/ml (normal dosage: 100-500)]; Norvenlafaxine [759 ng/ml (normal dosage: 200-400)]; The driver suffered from fibromyalgia.

⁴ The autopsy indicated that this lesion resulted in immediate death and, based upon the toxicology and the level of drugs in her system, death would have resulted from the level of drug use. "We know that the actual cause of death for ... is an atlanto-occipital dislocation, causing an internal decapitation. However, these levels of drugs in her system cannot be ignored. One would wonder if she was unconscious prior to the accident or even perhaps at death prior to the accident. The levels also indicate a purposeful ingestion of *venlafaxine*; therefore, we cannot exclude suicide from the manner of death. These levels do not happen by chance or accident." The autopsy concluded: the cause of death is atlanto-occipital dislocation and the manner of death is a complex suicide. "A complex suicide is one in which an individual will kill themselves while putting others in harm's way. In this case, ... drove into oncoming traffic with a high level of drug(s) in her system with the intention of killing herself."

⁵ According to the autopsy, the patient's neck was unstable and the skull was mobile in lateral directions.

Injury Number	Injury	AIS 2005/08	Injury Source	Confidence Level
7	Hemorrhage, subarachnoid, diffusely, not further specified	140693.2,9	Exterior of other motor vehicle: hood edge	Probable
8	Laceration posterior right atrium, not further specified	441008.3,4	Left front door panel, rear upper quadrant	Probable
9	Laceration (torn) vena cava, adjoining right atrium, not further specified	421802.3,4	Left front door panel, rear upper quadrant	Probable
10	Laceration (torn) lower left pulmonary vein, not further specified	421202.3,2	Left front door panel, rear upper quadrant	Probable
11	Fractured ribs, bilaterally, including anterior right 2 nd -4 th , lateral right 2 nd , 5 th through 9 th , and posterior right 1 st through 4 th , 9 th , and 10 th ; left anterior 1 st , lateral left 4 th through 6 th , and posterior left ribs 1 st through 12 th	450203.3,3	Left front door panel, rear upper quadrant	Certain
12	Hemothorax bilaterally, not further specified	442200.3,3	Left front door panel, rear upper quadrant	Certain
13	Laceration (not intact) parietal pleura due to rib fractures, and laceration left visceral pleura	441800.2,3	Left front door panel, rear upper quadrant	Certain
14	Laceration (rupture) both hemidiaphragms with abdominal contents herniated into chest cavity	440610.4,0	Left front door panel, rear upper quadrant	Certain
15	Dislocation left clavicle at sternoclavicular joint	770530.2,2	Torso portion of safety belt system	Certain
16	Fracture, complex, pelvis involving separation of pubic symphysis and right sacroiliac joint, fracture left pubic ramus, left ishium, and right sacrum, completely	856161.3,4	Left front door panel, rear lower quadrant	Certain
17	Fracture left acetabular region, not further specified	856200.2,2	Left front door panel, rear lower quadrant	Certain
18 19	Fractures (palpable), midshaft left tibia and fibula, not further specified	854221.2,2 854471.2,2	Left front door panel, forward lower quadrant	Certain
20	Lacerations, multiple, liver: horizontally on anterior right lobe, vertically x 4 on anterior left lobe, and medial left lobe, including a laceration of inferior vena cava at liver, not further specified	541828.5,1	Left front door panel, rear lower quadrant	Certain
21	Laceration splenic capsule, not further specified, with hemoperitoneum	544220.2,2	Left front door panel, rear lower quadrant	Certain

Injury Number	Injury	AIS 2005/08	Injury Source	Confidence Level
22	Contusion (bruise) cecum, not further specified	540810.2,8	Lap portion of safety belt system	Probable
23	Injury (unstable on palpation) medial and lateral collateral ligaments left knee	840405.2,2	Left front door panel, forward lower quadrant	Probable
24	Hemorrhage, subgaleal, in scalp extending into temporal muscles	110402.1,9	Exterior of other motor vehicle: hood edge	Probable
25 26 27	Abrasions, dicing type, on hairline, left nasal area, and left facial-16.5 x 15.2 cm (6.5 x 6 in) area	210202.1,7 210202.1,4 210202.1,2	Noncontact injury: flying glass, left front glazing	Certain
28	Lacerations x 2, gaping, 1.3 cm (0.5 in), at jaw line, not further specified	210602.1,8	Exterior of other motor vehicle: hood edge	Probable
29 30 31	Abrasion and contusion, 7.6 x 7.6 cm (3 x 3 in) over left acromioclavicular joint with surrounding extensive contusions, including contusion (bruise) of left pectoralis muscle, not further specified	710202.1,2 710402.1,2 410402.1,2	Torso portion of safety belt system	Certain
32 33	Abrasion contusion, 14.0 cm (5.5 in), diagonally, from right upper quadrant to upper pericardium	410402.1,4 510402.1,1	Torso portion of safety belt system	Certain
34 35	Abrasion contusion, 10.2 x 6.4 cm (4 x 2.5 in) from right anterior superior iliac spine toward umbilicus	510202.1,1 510402.1,1	Lap portion of safety belt system	Certain
36	Abrasion from above left iliac wing toward the umbilicus with a thicker abrasion at the umbilicus	510202.1,8	Lap portion of safety belt system	Certain
37	Abrasions, dicing type, posterior right upper arm, not further specified	710202.1,1	Noncontact injury: flying glass, left front glazing	Certain
38	Abrasions x 2, 10.2 cm (4 in) on dorsum left hand, below ⁶ 5 th digit	710202.1,2	Left front door panel, forward upper quadrant	Probable
39	Contusions (bruising), diffuse, palmer surface left forearm and one, 9.5 cm (3.75 in) over distal left ulna	710402.1,2	Left front door panel, forward upper quadrant	Probable
40	Laceration, gaping, 2.5 x 1.3 cm (1 x 0.5 in), over base left 5 th metacarpal	710602.1,2	Left front door panel, forward upper quadrant	Probable
41	Contusions (bruising), diffuse, dorsum right hand, not further specified	710402.1,1	Center instrument panel	Probable

⁶ This contractor believes they mean proximal to the little finger.

Injury Number	Injury	AIS 2005/08	Injury Source	Confidence Level
42	Avulsion, 27.9 cm (11 in), of skin and muscle from left mid thigh to left upper calf exposing bone ⁷	810802.1,2	Left front door panel, rear lower quadrant	Certain
43	Contusions, confluent, over lateral aspect of left side of body affecting most surfaces	910400.1,9	Unknown	Unknown
44	Contusions (bruising), diffuse, anterior lower extremities, bilaterally, not further specified	810402.1,3	Left lower instrument panel (includes knee bolster)	Probable

Source(s): Autopsy Records.

DRIVER KINEMATICS

The impact with the Ford displaced the driver to the left and forward opposite the 11 o'clock direction of force and she loaded the safety belt. The left side of her body contacted the intruding left front door and her head loaded through the left IC air bag and contacted the hood of the Ford. The driver sustained multiple brain and brain stem injuries from contacting the hood. The contact to the intruding left front door caused multiple bilateral rib fractures, internal thoracic injuries, abdominal injuries, multiple pelvic fractures, and lower left leg fractures. The driver also sustained a left clavicle dislocation and contused cecum from loading the safety belt. The intrusion of the left front door and left B-pillar deformed the driver's seat and rotated the seat back counterclockwise entrapping the driver between the intruded left front door and the deformed seat back. The driver contacted the left front door again when the vehicle rolled over onto its left side and touched down on the top back portion of the Ford and the ground. Rescue personnel mechanically removed the left front door and cut the safety belt to extricate the driver from the vehicle.

2008 FORD ESCAPE

DESCRIPTION

The 2008 Ford Escape was a front wheel drive, 5-passenger, 2-door coupe (VIN 1FMCU03198K-----) equipped with a 3.0 liter, V-6 engine, a 4-speed automatic transmission, 4-wheel, anti-lock brakes with electronic brake force distribution, traction control, and electronic stability control. The vehicle was equipped with lap-and-shoulder safety belts, front safety belt pretensioners, driver and front right passenger dual stage frontal air bags, front seat-mounted side impact air bags, and side impact IC air bags. The manufacturer has certified that the vehicle is compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The specified wheelbase was 262 cm (103.1 in).

⁷ According to the autopsy, the exposed bone was not fractured.

The vehicle manufacturer’s recommended tire size was P235/70R15. The vehicle was equipped with tires of the recommended size. The recommended cold tire pressure for the front and rear tires was 221 kPa (32 psi). The tire data for the Ford are presented in the table below.

<i>Position</i>	<i>Measured Pressure</i>	<i>Measured Tread Depth</i>	<i>Restricted</i>	<i>Damage</i>
LF	Flat (Flat)	6 mm (8/32 in)	No	Debeaded
LR	241 kPa (35 psi)	8 mm (10/32 in)	No	None
RR	Flat (Flat)	8 mm (10/32 in)	No	None
RF	Flat (Flat)	6 mm (8/32 in)	No	Debeaded

EXTERIOR DAMAGE

Exterior Damage Event 1: The Ford sustained front plane damage during the impact with the Toyota. The front bumper, headlamp/turn light assemblies, hood, and both fenders were directly damaged. The direct damage began at the front left bumper corner and extended across the entire frontal plane. The crush measurements were taken at the bumper bar and the maximum residual crush was 31 cm (12.2 in) occurring 14 cm (5.5 in) right of C₃. Each frame rail was shifted to the left 20 cm (7.9 in).

Damage Classification Event 1: The CDC was 82FDEW2 (50 degrees). The force direction was incremented by 80 since each frame rail was shifted to the left 20 cm (7.9 in) The Damage algorithm of the WinSMASH program calculated the total Delta V as 46 km/h (28.6 mph). The longitudinal and lateral velocity changes were -30 km/h (-18.6 mph) and -35 km/h (-21.7 mph), respectively. Based on the damage to both vehicles, the results appeared reasonable.

Exterior Damage Event 2: The Ford sustained top plane damage (**Figure 11**) when the Toyota touched down on the top of the Ford as the vehicle’s came to final rest. The top of the back hatch, roof, right roof side rail, right C-pillar, and right D-pillar were directly damaged. The direct damage extended 102 cm (40.2 in) across the roof. The maximum crush to the roof was 38 cm (15 in).



Figure 11: Damage to the top plane of the Ford from the impact by the Toyota

Damage Classification Event 2: The CDC was 00TBDW4. WinSMASH could not be used on this impact since non-horizontal impact are out of scope for the program. Based on the extent of crush to the roof, the severity of the damage was severe.

OCCUPANT DATA

IN11006

Based on the police crash report, the driver of the Ford (53-year-old female) was restrained by the lap-and-shoulder belt. She sustained incapacitating injuries and was transported by ambulance to a hospital.

