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Special Crash Investigations: On-Site Air Bag Inflator Rupture Investigation; Vehicle: 2002 Volvo S60; Location: Arkansas; Crash Date: April 2018

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16. Abstract This report documents the on-site investigation of a frontal air bag inflator rupture in a 2002 Volvo S60 involved in a crash fatal to the driver. The crash occurred in the evening in April 2018 in an urban area in Arkansas. The Volvo was driven southbound by an unbelted 22-year-old male. The other vehicle was a 2016 Buick Regal driven southbound by a belted 22-year-old female with a belted 30-year-old male front passenger. While attempting to pass the Buick, the Volvo's front and right planes struck the left plane of the Buick. The driver's frontal air bag deployed in the Volvo and ruptured, with components causing fatal injuries to the driver. He was pronounced deceased on-scene. Representatives from Volvo were present at the vehicle inspection and confirmed that the air bags and inflator were original to the vehicle and the inflator did rupture. Following the initial impact, the Volvo continued south, and struck a sign and metal rail before coming to rest. The occupants of the Buick were not injured. Both vehicles were towed due to damage.			
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Special Crash Investigations
On-Site Air Bag Inflator Rupture Investigation
Office of Defects Investigation
Case No. DS19026
Vehicle: 2002 Volvo S60
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Background

This report documents the on-site investigation of a frontal air bag inflator rupture (Figure 1) in a 2002 Volvo S60 involved in a crash in which the driver sustained fatal injuries. The case was initiated by the Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration in response to a notification reporting the driver frontal air bag deployed and debris from the air bag module struck the driver, causing fatal injuries. ODI was notified in August 2019. The Special Crash Investigations (SCI) group assigned the case to Dynamic Science in August 2019 and a vehicle inspection was completed that month in a secure facility in Texas. Representatives from Volvo and attorneys for the estate of the decedent were present at the inspection. The Volvo representatives confirmed that the air bags and inflator were original equipment and the inflator did rupture. Vehicle data from the air bag sensor module was imaged by Volvo during the inspection and shared with SCI. The interpretation of the data is discussed later in this report. A search of the NHTSA recall database using the Volvo's VIN showed the Volvo's air bags were not subject to any open or past recalls at the time of the crash. A vehicle history reported the vehicle had no crashes prior to this crash.

Figure 1. Driver frontal air bag, 2002 Volvo S60

The crash occurred in the evening in April 2018 in an urban area in Arkansas. Conditions were dusk, clear, and dry. The crash site was the intersection of a north/south U.S. highway and an east/west U.S. highway. The Volvo was being driven southbound by an unbelted 22-year-old male. The other vehicle was a 2016 Buick Regal being driven southbound by a belted 22-year-old female with a belted 30-year-old male front passenger. While attempting to pass the Buick, the Volvo's front and right planes struck the left plane of the Buick. The Volvo driver frontal air bag deployed and ruptured; the driver was struck in the neck by components from the air bag module, causing fatal injuries. He was pronounced deceased on-scene. Following the initial impact, the Volvo continued south, and struck a sign and metal rail before coming to rest. The Buick occupants were not injured. Both vehicles were towed due to damage.

Summary

Crash Site

The crash site was the intersection of a north/south U.S. highway and an east/west U.S. highway (Figure 2). Both vehicles were traveling southbound. The southbound asphalt roadway was straight and level with two southbound travel lanes and one northbound travel lane. The travel lanes were separated by double yellow painted lines. The intersection was controlled by three-phase overhead traffic signals. The speed limit was 56 km/h (35 mph) in all directions. The weather at the nearest reporting station was 20 °C (68 °F), 73 percent humidity, winds out of north/northeast at 8 km/h (5 mph), and cloudy. A crash diagram is included at the end of this technical report.

Pre-Crash

Both vehicles were initially traveling southbound at unknown speeds in the second lane from the right. As the vehicles entered the intersection, the Volvo driver attempted to pass the Buick on the left by entering the northbound lane. It should be noted that the Volvo was inspected in Texas. The crash scene was located in Arkansas and was not documented in person.

Figure 2. Overhead view of the Volvo's southbound travel into intersection (image source; Google Maps © 2022 Maxar Technologies)

Crash

The Volvo front and right planes struck the left plane of the Buick (Event 1). The right front tire and lower control arm were detached from the Volvo. The "missing vehicle" algorithm of the WinSMASH program calculated a total delta V of 17 km/h (11 mph) for the Volvo. The longitudinal and lateral components were -17 km/h (-11 mph) and -3 km/h) -2 mph), respectively. The results were considered borderline. The WinSMASH program calculated a total delta V of 16 km/h (10 mph) for the Buick. The longitudinal and lateral components were 15 km/h (9 mph) and 5 km/h (3 mph), respectively. The results were considered borderline. The Buick was displaced clockwise to the west and came to rest in the west leg of the intersection facing west (Figure 3). The Volvo was displaced to the east and continued through the intersection. The Volvo departed the roadway to the left, struck a metal fence with its front plane (Event 2), struck a metal pole/sign with its left plane (Event 3), returned to the roadway, and came to rest on the roadway approximately 59 m (193 ft) south of the intersection facing south (Figure 4).

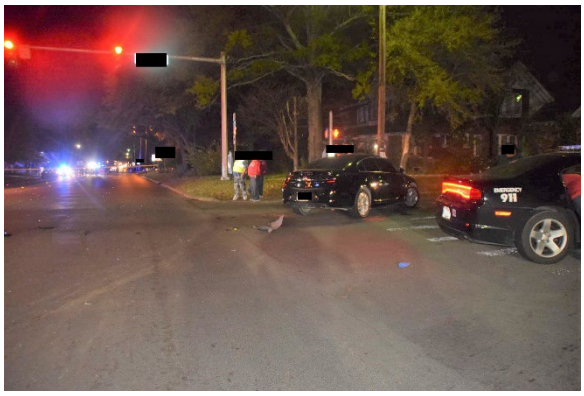


Figure 3. Final rest for the 2016 Buick Regal, looking southwest (police image)

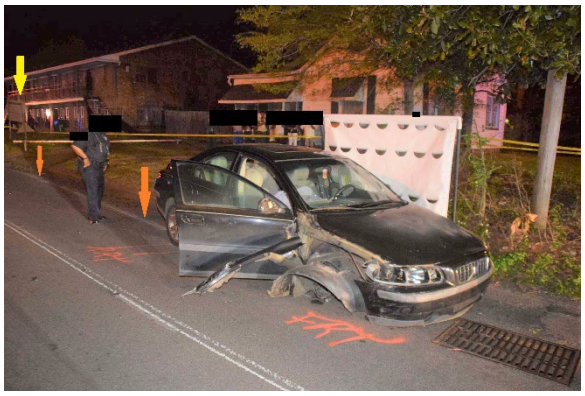


Figure 4. Final rest, 2002 Volvo S60, looking north (yellow arrow shows impacts 2 and 3, orange arrows show undercarriage gouge) (police image)

Post-Crash

The Volvo driver was pronounced deceased at the scene. He sustained major injuries to the neck and chest. The medical examiner reported the cause of death to be "blunt force injury." The Buick driver and front passenger did not report any injuries. Both vehicles were towed from the scene due to damage.

2002 Volvo S60

Vehicle Description

The Volvo was a 5-passenger, 4-door sedan identified by the VIN YV1RS61R222xxxxxx and manufactured in October 2001. The vehicle had a 2.4-liter, 5-cylinder, gasoline engine, automatic transmission, front-wheel drive, and 4-wheel ABS. The vehicle manufacturer recommended tire size was P195/65R15 for the front and rear. The vehicle had P205/55R16 tires for the left front, left rear, and right rear. The right front tire was not present during the inspection. The specific tire information was as follows.

Position	Measured Tread Depth	Restricted	Damage
LF	4 mm (5/32 in)	No	Flat/cut/torn
LR	3 mm (4/32 in)	No	None
RR	3 mm (4/32 in)	No	Unknown (flat at time of inspection)
RF	Missing		

Vehicle History

A Carfax report stated the vehicle had two previous owners. The first owner was in Florida and owned the vehicle for 1 year and 11 months. The second owner was in Arkansas and owned the vehicle for 15 years. There were no reports of crashes or damage to the vehicle. There were no indications of the air bags being serviced.

Exterior Damage

The Volvo sustained moderate front and right plane damage (Figure 5) from the impact to the left plane of the Buick (Event 1). The direct damage began at the right front corner and extended to the left 12 cm (4.7 in). The damage extended 118 cm (46.4 in) along the right side. The right front tire, right lower control arm and right fender were displaced from the vehicle. The Field L extended from bumper corner to bumper corner. Nineteen measurements were taken at bumper level by the Nikon Total Station and the Faro Blitz program computed crush measurement in six increments as follows: C1 = 6 cm (2.3 in), C2 = 4 cm (1.5 in), C3 = 0 cm, C4 = 0 cm, C5 = 0 cm, C6 = 0 cm. The Collision Deformation Classification (CDC) was 12FREE5.

The vehicle sustained minor damage from the impact with the metal rail (Figure 6). There was direct contact to the front left bumper that was 3 cm (1.1 in) wide and extended 41 cm (16.1 in) along the left plane. The left front tire was holed from the rail. The CDC was 12FLEE3.

Figure 5. Front/right damage, 2002 Volvo S60

Figure 6. Front/left damage, 2002 Volvo S60

The vehicle also sustained minor damage from a probable impact with a sign/pole. There was direct contact to the left rear door that measured 21 cm (8.2 in) in width and was located 46 cm (18.1 in) forward of the left rear axle. The CDC was 12LPMS1.

Event Data Recorder

The Volvo had an air bag module located in the center console. The module contained a limited amount of crash data. The module was imaged by Volvo during the vehicle inspection. The downloaded data included the part numbers of the unit, part 1 of crash recorder (crash data), and part 1a of crash recorder (fault data). Volvo indicated that it does not possess the numerical values that correspond to the threshold levels associated with the decision to activate the driver air bag with either high output (both stages in rapid succession) or low output (both stages with a longer delay in between). The actual low level information resides with the system supplier of the SRS.

Volvo provided interpretations for the downloaded data. These are summarized below.

The stage 1 threshold levels are described as follows.

F1: frontal algorithm

F2: unbelted threshold level

F3: belted threshold level

There is a function call SMINC that is used for detecting higher-severity events. The stage 2 threshold levels for this function are described as follows.

S1: unbelted threshold level

S2: belted threshold level

The crash counter indicated that a crash was recorded. There were firing requests issued. For the driver frontal air bag stage 1 was requested on threshold F2 and stage 2 was requested on threshold S1. The firing time was at 18 ms. The frontal thresholds for F1, F2, and F3 were reached.

None of the thresholds intended for side or algorithms were met in this crash.

NHTSA Recalls and Investigations

There was one recall associated for this vehicle when the NHTSA recall database was queried with the Volvo's VIN in August 2022. NHTSA Recall #20V681 was dated November 2020. The recall date was after the crash date in this case. The recall focused on the driver frontal air bag and the possibility of injury by metal fragments during deployment. The corrective action was to replace the driver frontal air bag with a new air bag.

Interior Damage

The Volvo sustained moderate interior damage related to the air bag module rupture. Portions of the module and the module cover were located in several places in the vehicle. There was no deformation of the steering wheel rim or compression of the column. There were no deformations to any of the seats. All the doors remained closed and operational. The windshield was fractured from the air bag deployments. There was no intrusion. There was blood on the driver seat cushion, center console, front passenger air bag, and front right seat cushion.

Manual Restraint Systems

The front row had driver and front right passenger lap and shoulder seat belts. The driver's belt had continuous loop belt webbing, a sliding latch plate, an emergency locking retractor (ELR), and a fixed upper anchor. Based on the SCI vehicle inspection, the driver's seat belt was not in use during this crash. It is unknown if the pretensioner actuated.

Supplemental Restraints System

The Volvo had supplemental restraint systems (SRS) consisting of dual-stage driver and passenger frontal air bags and retractor tensioners for all seat positions. The air bag system was controlled by an air bag sensor module. The dual-threshold, dual-stage air bags use special sensors that are integrated with the front seat buckles. According to the owner's manual, the point at which the air bag deploys is determined by whether the seat belt is being used, as well as the severity of the collision. Driver's frontal air bag stage 1 was requested on threshold F2, which was the unbelted threshold level. Collisions can occur where only one of the air bags deploys. If the impact is less severe, but severe enough to present a clear injury risk, the dual-stage air bags are triggered at just 70 percent of their total capacity. If the impact is more severe, the dual-stage air bags are triggered at full capacity. The vehicle was also equipped with side impact protection system (SIPS) air bags. The SIPS air bag system consists of air bag modules built into the outboard sides of both front seat backs, wires, and gas generators/sensor units.

As a result of the front-to-side impact with the Buick, both frontal air bags deployed. The driver frontal air bag deployed at full capacity according to data from the air bag module. The driver frontal air bag deployed from an H-configuration module cover located in the hub of the steering wheel rim (Figure 7). The air bag was circular and measured 61cm (24.0 in) in diameter in its deflated state. The air bag had rear panel vent ports and was not tethered. The air bag inflator ruptured during the air bag deployment (Figure 8). The air bag face was holed at the 7 o'clock position. The hole measure 6 cm (2.3 in) and was located 20 cm (7.8 in) above the bottom edge and 23 cm (9.0 in) to the right of the left edge.

Figure 7. Driver frontal air bag, 2002 Volvo S60

Figure 8. Driver frontal air bag inflator, attached to the vehicle, 2002 Volvo S60

The passenger frontal air bag deployed from the top of the instrument panel. There was no indication of occupant contact and the air bag was not damaged. There was no occupant in this seat position.

Air Bag Inflator Rupture Discussion

The driver frontal air bag inflator was manufactured by Autoliv/Temic Automotive and was reported by Volvo to be original to this vehicle. At the time of the inspection, the bottom portion of the module was still attached to the vehicle (Figure 9). The top cap of the module (Figure 10) and other pieces were found in the vehicle in several locations. The top cap of the inflator was located on the right front floor. The wiring harness was located on the upper instrument panel near the windshield. The air bag module cover flaps were located on the left front floor. The container mesh on the back of the module was damaged (Figures 11-12). Two metal fragments were extracted from the driver's neck during the autopsy (Figure 13).

Figure 9. Driver frontal air bag, 2002 Volvo S60

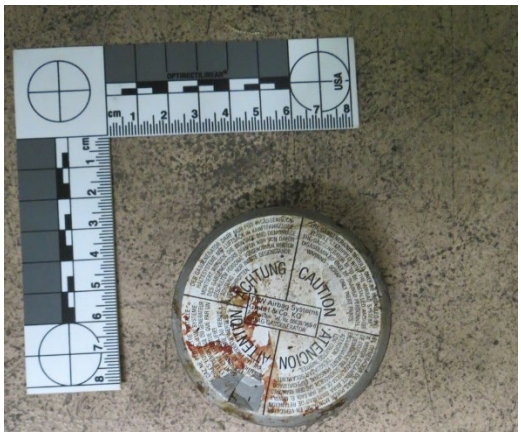


Figure 10. Air bag module cap, 2002 Volvo S60

Figure 11. Back of air bag, air bag module, 2002 Volvo S60

Figure 12. Back of air bag module (close up), 2002 Volvo S60

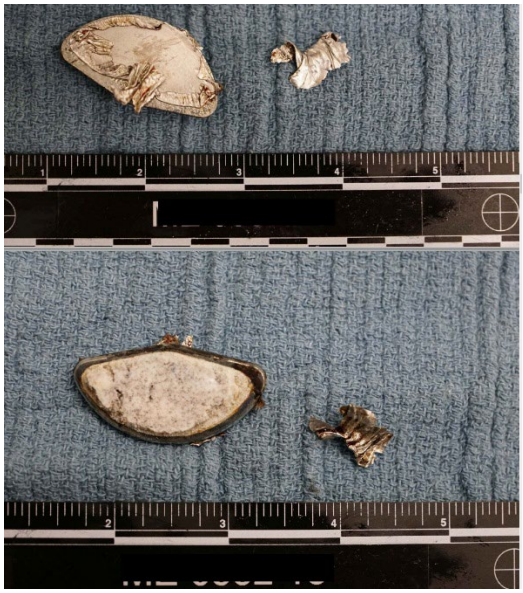


Figure 13. Metal fragments extracted from the driver's neck during autopsy

The Volvo was labeled with an informational warning stating the vehicle air bags were to be serviced or replaced by October 2012 (Figure 14). Based on available information, the air bags were never replaced. It is unknown if they were serviced in any way.

Figure 14. Air bag labeling, 2002 Volvo S60

Based on available evidence, it was determined that the driver frontal air bag inflator ruptured during its deployment and displaced inflator components rearward toward the driver. The Volvo representatives agreed with this assessment. The components penetrated the air bag fabric and struck the driver in the neck and chest, resulting in the fatal injuries.

2002 Volvo S60 Occupant

Driver Demographics

Age/sex:	22 years/male
Height:	183 cm (72 in)
Weight:	71 kg (156 lbs)
Eyewear:	Unknown
Seat type:	Bucket
Seat track position:	Between middle and rear most track position
Manual restraint usage:	Lap and shoulder belt not used
Usage source:	Vehicle inspection
Air bags:	Frontal air bag deployed/inflator ruptured, outboard mounted side impact air bag not deployed
Alcohol/drug data:	Negative for alcohol, positive for THC/cannabinoids per autopsy report
Egress from vehicle:	Fatal at scene
Transport from scene:	NA
Type of medical treatment:	None

Driver Injuries

Inj. No.	Injury	Injury Severity AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
1 2 3	Lacerations, left vertebral artery, left subclavian artery, left jugular vein	122802.5 421404.3 320802.2	Driver air bag module components	Certain
4	Left hemothorax, 1700 ml	442200.3	Driver air bag module components	Certain
5 6	Fractures, 6th and 7th cervical vertebrae	650216.2 650216.2	Driver air bag module components	Certain
7	Contusions, bilateral lung apices (upper lung)	441410.3	Driver air bag module components	Certain
8	Blunt force tissue damage and hemorrhage anterior strap muscles	310099.1	Driver air bag module components	Certain
9	Lower lip, abrasion	210202.1	Driver air bag	Certain
10	Left upper chest contusion	410402.1	Driver air bag	Certain
11	Abrasions, dorsum of right forearm	710202.1	Driver air bag	Certain

Inj. No.	Injury	Injury Severity AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
12 13	Abrasion, left anterior fore-arm, contusion distal left fore-arm, abrasion dorsum left hand	710202.1 710402.1	Driver air bag	Certain
14	Laceration, 8 x 9 cm, anterior neck	310602.1	Driver air bag module com-ponents	Certain
15	Contusion, 1 x 3 cm, left cheek	210402.1	Driver air bag	Probable

Source: Medical examiner report/autopsy

Driver Kinematics

The 22-year-old male driver was seated in an unknown posture. He was unbelted and his seat was adjusted to between the middle and rear-most track position. As the Volvo was passing the Buick, the Volvo front plane struck the left plane of the Buick. The severity of the crash resulted in the deployment of the Volvo's frontal air bag system. During deployment, the driver frontal air bag inflator ruptured and portions of the inflator penetrated through the air bag fabric and struck the driver's neck and chest. He was declared deceased on scene. His death was originally reported as a possible homicide due to the visible type of injury sustained. The manner of death was later changed to accident.

2016 Buick Royal

Vehicle Description

The 2016 Buick Regal was a 4-door, 5-passenger sedan identified by the VIN 2G4GK5EX0G9xxxxxx and was manufactured in December 2015. It had a 2.0-liter, 4-cylinder, E85 engine, automatic transmission, and front-wheel drive.

Exterior Damage

The Buick sustained moderate left plane damage (Figures 15 and 16). The damage began aft of the left A-pillar and extended forward to the left front bumper corner. According to insurance photos, it appears that the vehicle sustained drive axle and wheel damage. The CDC was 07LYEW2.

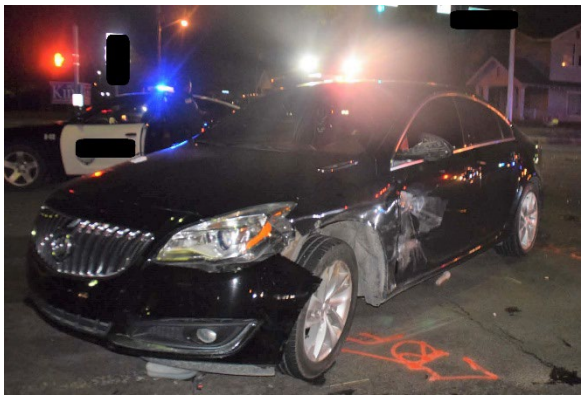


Figure 15. Left front, 2016 Buick Regal (police image)

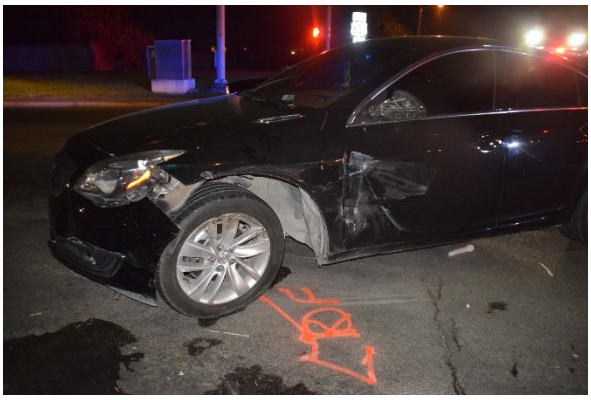
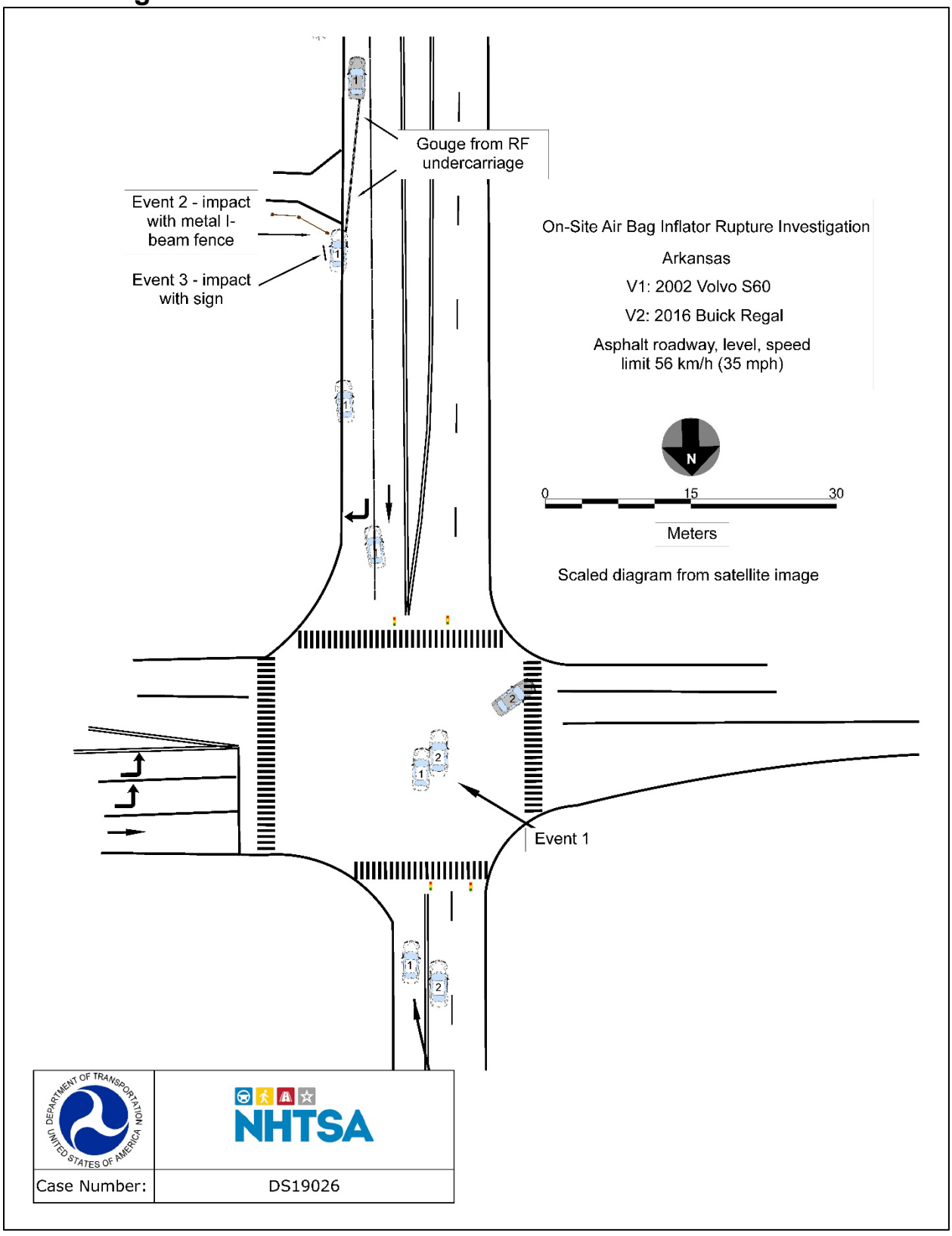


Figure 16. Left front, 2016 Buick Regal (police image)

Occupant Data

The 2016 Buick Regal was being driven southbound by a 22-year-old female with a 30-year-old male front passenger . According to the police report, both were belted. There were no reported injuries.

Crash Diagram



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