TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Advanced Information Engineering Services
A General Dynamics Company
Buffalo, NY 14225

GENERAL DYNAMICS REMOTE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

SCI TECHNICAL SUMMARY REPORT

NASS/SCI COMBO CASE NO. 03-48-222C

VEHICLE – 2001 VOLKSWAGEN BEETLE

LOCATION - STATE OF ALABAMA

CRASH DATE – NOVEMBER 2003

Contract No. DTNH22-01-C-17002

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

DISCLAIMER

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 are 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 STANDARD TITLE PAGE

1. Report No. 03-43-222C	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle General Dynamics Remote Side Impact Inflatable Occupant Protection Investigation Vehicle: 2001 Volkswagen Beetle Location: State of Alabama		*5. Report Date*: November 2004 *6. Performing Organization Code*	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Transportation Sciences Crash Data Research Center Advanced Information Engineering Services A General Dynamics Company P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* C00410.0000.0181 *11. Contract or Grant No.* DTNH22-01-C-17002	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: November 2003 *14. Sponsoring Agency Code*	
15. Supplementary Note This remote investigation focused on the performance of the side impact inflatable occupant protection system in a 2001 Volkswagen Beetle. And the presence of aftermarket seat covers that were over the front seats.			
16. Abstract This remote investigation focused on the performance of the side impact inflatable occupant protection system in a 2001 Volkswagen Beetle. The system consisted of seatback mounted side impact air bags for the front seating positions. The front seats of the Volkswagen were equipped with aftermarket seat covers. In addition, the Beetle was equipped with redesigned frontal air bags and retractor mounted safety belt pretensioners. The Volkswagen was involved in a multiple impact crash sequence with a 1999 Mercury Mountaineer and two driveway culverts. An unrestrained 32-year-old male driver and a restrained 20-year-old female front right occupant occupied the Beetle. The 1999 Mercury Mountaineer was occupied by a 29-year-old-male driver. The Volkswagen and the Mercury were traveling southbound on a four-lane north/south roadway. As the vehicles continued southbound, the front of the Volkswagen impacted the rear of the Mercury. This impact resulted in the deployment of the frontal air bag system and the firing of the safety belt pretensioners in the Volkswagen. The Volkswagen subsequently departed the west roadside and impacted a culvert with its right side and a second culvert with its front. The initial culvert impact resulted in the deployment of the right side impact air bag. The driver of the Volkswagen sustained minor severity injuries and was not transported to a hospital. The front right occupant of the Volkswagen sustained minor severity injuries and was transported to a local hospital. She obtained partial medical treatment and departed the hospital prior to the completion of her treatment. The Volkswagen and the Mercury sustained moderate damage and were towed from the crash site.			
17. Key Words Deployed Side Impact Air Bag Aftermarket Seat Cover		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 10	*22. Price*

TABLE OF CONTENTS

GENERAL DYNAMICS REMOTE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION
SCI SUMMARY TECHNICAL REPORT
NASS/SCI COMBO CASE NO. 03-48-222C
SUBJECT VEHICLE – 2001 VOLKSWAGEN BEETLE
LOCATION - STATE OF ALABAMA
CRASH DATE – NOVEMBER 2003

BACKGROUND

This remote investigation focused on the performance of the side impact inflatable occupant protection system in a 2001 Volkswagen Beetle **(Figure 1)**. The system consisted of seatback mounted side impact air bags for the front seating positions. The front seats of the Volkswagen were equipped with aftermarket seat covers. In addition, the Beetle was equipped with redesigned frontal air bags and retractor mounted safety belt pretensioners. The Volkswagen was involved in a multiple impact crash sequence with a 1999 Mercury Mountaineer and two driveway culverts. An unrestrained 32-year-old male driver and a restrained 20-year-old female front right occupant occupied the Beetle. The 1999 Mercury Mountaineer was occupied by a 29-year-old-male driver. The Volkswagen and the Mercury were traveling southbound on a four-lane north/south roadway. As the vehicles continued southbound, the front of the Volkswagen impacted the rear of the Mercury. This impact resulted in the deployment of the frontal air bag system and the firing of the safety belt pretensioners in the Volkswagen. The Volkswagen subsequently departed the west roadside and impacted a culvert with its right side and a second culvert with its front. The initial culvert impact resulted in the deployment of the right side impact air bag. The driver of the Volkswagen sustained minor severity injuries and was not transported to a hospital. The front right occupant of the Volkswagen sustained minor severity injuries and was transported to a local hospital. She obtained partial medical treatment and departed the hospital prior to the completion of her treatment. The Volkswagen and the Mercury sustained moderate damage and were towed from the crash site.

Figure 1. Subject 2001 Volkswagen Beetle.

This crash was identified by the National Automotive Sampling System (NASS) PSU 48 during the weekly sampling of Police Accident Reports (PARs). This crash was selected and researched as CDS Case No. 03-48-222C. The NASS PSU performed the vehicle and scene inspections, and the driver interview. Due to the deployment of the side impact air bag and the presence of the aftermarket seat cover in the 2001 Volkswagen Beetle, NHTSA assigned the tasks of case review and report preparation to the General Dynamics SCI team.

SUMMARY

Crash Site

This multiple event crash occurred during the evening hours of November 2003 in the state of Alabama. At the time of the crash, there were no adverse weather conditions and the asphalt road surface was dry. The crash events occurred on a four-lane roadway and on the west roadside. The north/southbound roadway consisted of two travel lanes in each direction and was delineated by a double yellow centerline. The southbound travel lanes curved left and had a slight uphill grade. The west roadside consisted of a barrier curb, grass, trees, and driveway culverts. The posted speed limit for this roadway was 72 km/h (45 mph). **Figure 2** is a southbound view of the crash site. The NASS scene schematic is included as **Figure 15** of this report. Although it's not represented in the NASS scene schematic the southbound roadway has a slight left curve and a "T" intersection prior to the location of the initial impact.

Figure 2. Southbound view of the crash site.

Vehicle Data

2001 Volkswagen Beetle

The 2001 Volkswagen Beetle was identified by the Vehicle Identification Number (VIN): 3VWCK21C61 (production sequence omitted). The odometer reading was 63,273 kilometers (39,317 miles) at the time of the NASS inspection. The vehicle was a two-door hatchback that was equipped with a 2.0-liter, four-cylinder engine linked to a four-speed automatic transmission, front-wheel drive, four-wheel disc brakes with ABS, and daytime running lights. The tires on the Volkswagen were Goodyear GT II, size P205/55R16. The maximum pressure for these tires was 303 kpa (44 psi). The manufacturer recommended front and rear tire pressure was not reported. The specific tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	0 kpa	6 mm (8/32)	Yes	Unknown
LR	228 kpa (33 psi)	7 mm (9/32)	No	None
RF	0 kpa	6 mm (8/32)	No	Torn Sidewall
RR	234 kpa (34 psi)	6 mm (8/32)	No	None

The Volkswagen was configured with leather upholstered front bucket seats with height adjustable head restraints. Both front seat cushions and seatbacks were covered by form-fitting aftermarket seat covers. The manufacturer and type of material were unknown. The left head restraint was adjusted to the full-up position at the time of the NASS

inspection. The right head restraint adjustment could not be determined due to the placement of the aftermarket seat cover over the head restraint. The second row was configured with a leather upholstered two-passenger bench seat with height adjustable head restraints. No aftermarket seat covers were present on the rear seats. The head restraints were adjusted between the mid to full-down position.

1999 Mercury Mountaineer

The 1999 Mercury Mountaineer was identified by the VIN: 4M2ZU52P9X (production sequence omitted). The odometer reading was unknown. The NASS researcher reported the mileage to be 496,043 kilometers (308,226 miles) at the time of the inspection, which was probably coded incorrectly. The vehicle was a four-door sport utility vehicle that was equipped with a 5.0-liter, eight-cylinder engine, four-speed automatic transmission, and rear-wheel drive. The Mercury was equipped with Uniroyal Laredo tires size P235/75R15. The maximum pressure for these tires was 283 kpa (41 psi). The manufacturer recommended tire pressure for this vehicle was 179 kpa (26 psi). The specific tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	207 kpa (30 psi)	9 mm (11/32)	No	None
LR	207 kpa (30 psi)	2 mm (3/32)	No	None
RF	228 kpa (33 psi)	9 mm (11/32)	No	None
RR	0 kpa	3 mm (4/32)	Yes	Torn

Crash Sequence

Pre-Crash

The unrestrained 32-year-old male driver of the Volkswagen was operating the vehicle southbound negotiating the left curve on the inboard lane. The 29-year-old male driver of the Mercury was operating the vehicle southbound in front of the Volkswagen in the same lane. The Volkswagen was traveling at a higher speed than the Mercury, approaching the back of the SUV. As the Volkswagen approached the Mercury, the driver of the Volkswagen applied a right steering maneuver.

Crash

The front left aspect of the Volkswagen impacted the rear right aspect of the Mercury in the inboard lane **(Figure 3)**. The resultant directions of force were within the 12 o'clock sector for the Volkswagen and 6 o'clock for the Mercury. The WINSMASH damage algorithm was used to calculate a delta for this impact. The total delta V for the Volkswagen was 15.0 km/h (9.3 mph). The longitudinal and lateral components were -15.0 km/h (-9.3 mph) and

Figure 3. Area of impact between the Volkswagen and the Mercury.

0.0 km/h, respectively. The total calculated delta V for the Mercury was 11.0 km/h (6.8 mph). The longitudinal and lateral components were 11.0 km/h (6.8 mph) and 0.0 km/h, respectively. This impact resulted in the deployment of the frontal air bag system and the firing of the safety belt pretensioners in the Volkswagen.

The Volkswagen subsequently departed the west roadside and began to travel in a southwest direction initiating a counterclockwise yaw. The Volkswagen traveled off-road approximately 47.0 meters (154.0 feet) and impacted a shallow driveway culvert with its right side **(Figure 4)**. The resultant direction of force was within the 1 o'clock sector. The WINSMASH program was not used to calculate a delta V for this impact due to the lack of crush measurements. This impact resulted in the deployment of the right seatback mounted side impact air bag.

Figure 4. Area of impact between the Volkswagen and the first culvert.

The initial driveway culvert impact involved the right side and undercarriage and redirected the Volkswagen in clockwise rotation.

The Volkswagen traveled approximately 9.0 meters (30.0 feet) beyond the culvert and impacted a second driveway culvert with its lower frontal aspect **(Figure 5)**. The resultant direction of force for this impact was within the 12 o'clock sector. This impact resulted in minor damage to bumper fascia of the Volkswagen. Therefore, the WINSMASH program was not used to calculate a delta V for this impact. This impact arrested the Volkswagen's forward momentum and the vehicle came to rest against the culvert facing a southerly direction.

Figure 5. Second culvert impact and final rest for the Volkswagen.

Post-Crash

The unrestrained 32-year-old male driver of the Volkswagen sustained minor injuries as a result of the crash. The driver departed the crash site prior to the arrival of emergency personnel and was not transported to a hospital. The 20-year-old female front right occupant of the Volkswagen sustained minor injuries and was transported to a local hospital. She obtained partial medical treatment and departed the hospital prior to the completion of her treatment. The Volkswagen and Mercury sustained moderate severity damage and were towed from the crash site.

Vehicle Damage

Exterior – 2001 Volkswagen Beetle

Figure 6. Damage from the impact with the Mercury.

The 2001 Volkswagen Beetle sustained moderate severity damage as a result of the multiple event crash. The damage from the impact with the rear of the Mercury **(Figure 6)** consisted of longitudinal displacement of the front bumper; fractured composite left front fender, fractured left side mirror, and longitudinal displacement of the front left axle. The direct damage began at the front left corner and extended 21.0 cm (8.3") laterally right onto the bumper fascia. The maximum crush measured 2.0 cm (0.8") and was located at the front left bumper corner. Six equidistant crush measurements were documented along the bumper using a combined direct and induced damage width of 143.0 cm (56.3") and were as follows: C1 = 2.0 cm (0.8"), C2 = 2.0 cm (0.8"), C3 = 1.0 cm (0.4"), C4 = 1.0 cm (0.4"), C5 = 1.0 cm (0.4"), C6 = 0.0 cm. The Collision Deformation Classification (CDC) for this impact was 12-FLAE-7.

Figure 7. Residual damage from the first culvert impact.

The damage from the first culvert impact consisted of a cut front right tire, lateral abrasions on the right sill, and lateral crush to the right sill **(Figure 7)**. A crush profile was not documented for this impact; therefore the direct damage width and crush measurements were unknown. Based on the images of the damage, the crush appeared to be approximately 2.5 cm (1.0") at the sill level. The NASS researcher documented a CDC for this impact of 00-U999-9. Based on the SCI damage evaluation the CDC was revised for this report as follows: 01-RYLS-1.

Figure 8. Frontal damage from the second culvert impact.

The Volkswagen sustained minor severity damage as a result of the second driveway culvert impact **(Figure 8)**. The damage consisted of a fractured grille that was mounted to lower front bumper fascia. The NASS researcher measured the direct damage at 63.0 cm (24.8") along the bumper. A crush profile was not obtained for this impact. The vehicle did not appear to have sustained crush as a result of this impact. The NASS researcher documented a CDC for this impact of 00-F9LW-9. Based on the SCI damage evaluation

the CDC was revised for this report as follows: 12-FDLW-1.

Interior – 2001 Volkswagen Beetle

The Volkswagen Beetle sustained no interior damage **(Figure 9)** as a result of passenger compartment intrusion. The NASS researcher documented an occupant contact to the front right safety belt that consisted of stretching to the upper portion from occupant loading. Also noted was the torn seam on the right side of the aftermarket seat cover.

Figure 9. Overall view of the interior front row.

Exterior – 1999 Mercury Mountaineer

The 1999 Mercury Mountaineer sustained moderate severity damage to the rear aspect as a result of the impact with the Volkswagen **(Figure 10)**. The direct damage measured 33.0 cm (13.0") and began at the rear right bumper corner and extended left. The maximum crush was 24.0 cm (9.4") and was located at the rear right bumper corner. The damage involved longitudinal displacement of the rear bumper, tailgate, right rear fender, and the right rear axle. Six crush measurements were documented at the rear bumper using a combined direct and induced damage width of 150.0 cm (59.1"), and were as follows: C1 = 4.0 cm (1.6"), C2 = 3.0 cm (1.2"), C3 = 5.0 cm (2.0"), C4 = 4.0 cm (1.6"), C5= 6.0 cm (2.4"), C6= 24.0 cm (9.4"). The CDC for this impact was 06-BREE-4.

Figure 10. Resultant damage from the impact with the Volkswagen.

Side Impact Air Bags – 2001 Volkswagen Beetle

The 2001 Volkswagen Beetle was equipped seatback mounted side impact air bags for the front seating positions. The sensors for the side impact air bags were located under the front seats. In the subject crash, the right side impact air bag deployed **(Figure 11)**. Aftermarket seat covers were installed on the front bucket seats of the Volkswagen. The seatback was completely covered on all four sides of the seat back. The aftermarket seat cover appears to be one-piece and was stretched over the OEM seatback completely covering the side impact air bag module. However, the aftermarket seat cover did not appear to impede the deployment of the air bag **(Figure 12)**. The aftermarket seat cover seam and the seam of the front right seatback appeared to overlap which may have contributed to the unimpeded deployment. The seam of the aftermarket seat cover and seatback were torn open by the deploying air bag. The air bag measured 27.0 cm (10.6") in height and 55.0 cm (21.7") in width. The air bag contained no tethers or vent ports. No occupant contacts or failures were noted to the air bag.

Figure 11. Deployed front right side impact air bag.

Figure 12. Side impact air bag cover flap. Note the aftermarket seat cover seam and the seam of the seat appear to overlap.

Redesigned Frontal Air Bag System – 2001 Volkswagen Beetle

The 2001 Volkswagen Beetle was equipped with redesigned frontal air bags that deployed in the subject crash. The driver's air bag was housed in the center of the steering wheel hub **(Figure 13)**. The air bag module consisted of H-configuration cover flaps. The air bag measured 58.0 cm (22.8") in diameter in its deflated state and contained three tethers. A single vent port that was located at the 12 o'clock position on the rear aspect vented the air bag. The NASS researcher noted black smudges on the face of the air bag. No damage or failures were noted to this air bag.

The front right air bag was a top mount design on the front right instrument panel. The air bag module contained a single cover flap. The air bag measured 60.0 cm (23.6") in height and 84.0 cm (33.0") in width and contained one tether **(Figure 14)**. Two vent ports that were located at the 1 and 5 o'clock positions on the right aspect vented the air bag. The NASS researcher noted black smudges on the face of the air bag. No damage or failures were noted to this air bag.

Figure 13. Deployed driver's frontal air bag. Note the steering wheel is rotated 180 degrees therefore the top of the air bag is at the bottom of the picture.

Figure 11. Deployed front right frontal air bag.

Manual Restraint Systems – 2001 Volkswagen Beetle

The 2001 Volkswagen Beetle was equipped with manual 3-point lap and shoulder safety belts for the four seating positions. The driver's safety belt was configured with a sliding latch plate, Emergency Locking Retractor (ELR), and a retractor mounted pretensioner. The driver did not utilize his safety belt in the crash, which was evidenced by the fired status of the retractor pretensioner that restricted the safety belt in the stowed position against the B-pillar. The front right safety belt was configured with a sliding latch plate, switchable Emergency Locking Retractor/Automatic Locking Retractor (ELR/ALR), and a retractor mounted pretensioner. The front right occupant utilized her safety belt in the crash that was evidenced by the fired status of the retractor pretensioner that restricted the safety belt in the used position. The rear safety belts were configured with sliding latch plates, and switchable ELR/ALR.

Occupant Demographics – 2001 Volkswagen Beetle

Driver

Age/Sex:	32-year-old male
Height:	188.0 cm (74.0")
Weight:	91 kgs (200 lbs)
Seat Track Position:	Full rear
Manual Restraint Use:	None Used
Usage Source:	Vehicle inspection
Eyewear:	None
Type of Medical Treatment:	None

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Right eyelid contusion	Minor (297402.1,1)	Steering wheel rim

Source- Front right occupant

Driver Kinematics

The 32-year-old male driver of the 2001 Volkswagen Beetle was seated in a presumed upright driving posture and was not restrained by the manual 3-point lap and shoulder belt. The seat was adjusted to a rear-track position. The initial impact with the rear of the Mercury resulted in the driver's frontal air bag deployment and the firing of the safety belt pretensioner. The driver initiated a forward trajectory and loaded the deployed air bag which prevented possible injury. At impact with the first culvert the driver was probably not displaced, as this was a minor impact.

At impact with the second culvert the driver initiated a forward trajectory and as a result contacted the steering wheel rim which resulted in the right eyelid contusion. The driver departed the crash site prior to the arrival of emergency personnel. He did not seek medical attention.

Front Right Occupant

Age/Sex:	20-year-old female
Height:	160.0 cm (63.0”)
Weight:	54 kgs (119 lbs)
Seat Track Position:	Full rear
Manual Restraint Use:	Manual 3-point lap and shoulder belt
Usage Source:	Vehicle inspection
Eyewear:	Contact Lenses
Type of Medical Treatment:	Transported to a hospital. Departed emergency room prior to completion of treatment.

Front Right Occupant Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Closed head injury with no loss of consciousness	Minor (160402.1,0)	*Frontal air bag
Cervical spine strain	Minor (640278.1,6)	*Extension over safety belt
Left facial contusion	Minor (290402.1,2)	Frontal air bag

Source – *Emergency room records, and occupant interview

Front Right Occupant Kinematics

The 20-year-old female front right occupant of the 2001 Volkswagen Beetle was seated in a presumed upright posture and was restrained by the manual 3-point lap and shoulder belt. The seat was adjusted to a rear-track position. The initial impact with the rear of the Mercury resulted in the frontal air bag deployment and the firing of the safety belt pretensioner. She initiated a forward trajectory and loaded the manual safety belt system. Her head extended over the shoulder belt which resulted in the cervical spine strain. The deploying air bag contacted the left side of her face which resulted in the left facial contusion and the closed head injury. The impacts with the culverts did not significantly displace the occupant, due to her belted status, fired pretensioner, and right side impact air bag deployment. Due to minor right side impact the front right occupant had no significant interaction with the deploying side impact air bag.

Front Right Occupant Medical Treatment

The front right occupant stated to the NASS researcher that she and was transported to a local hospital. However, she obtained partial medical treatment and departed the hospital prior to the completion of her treatment.

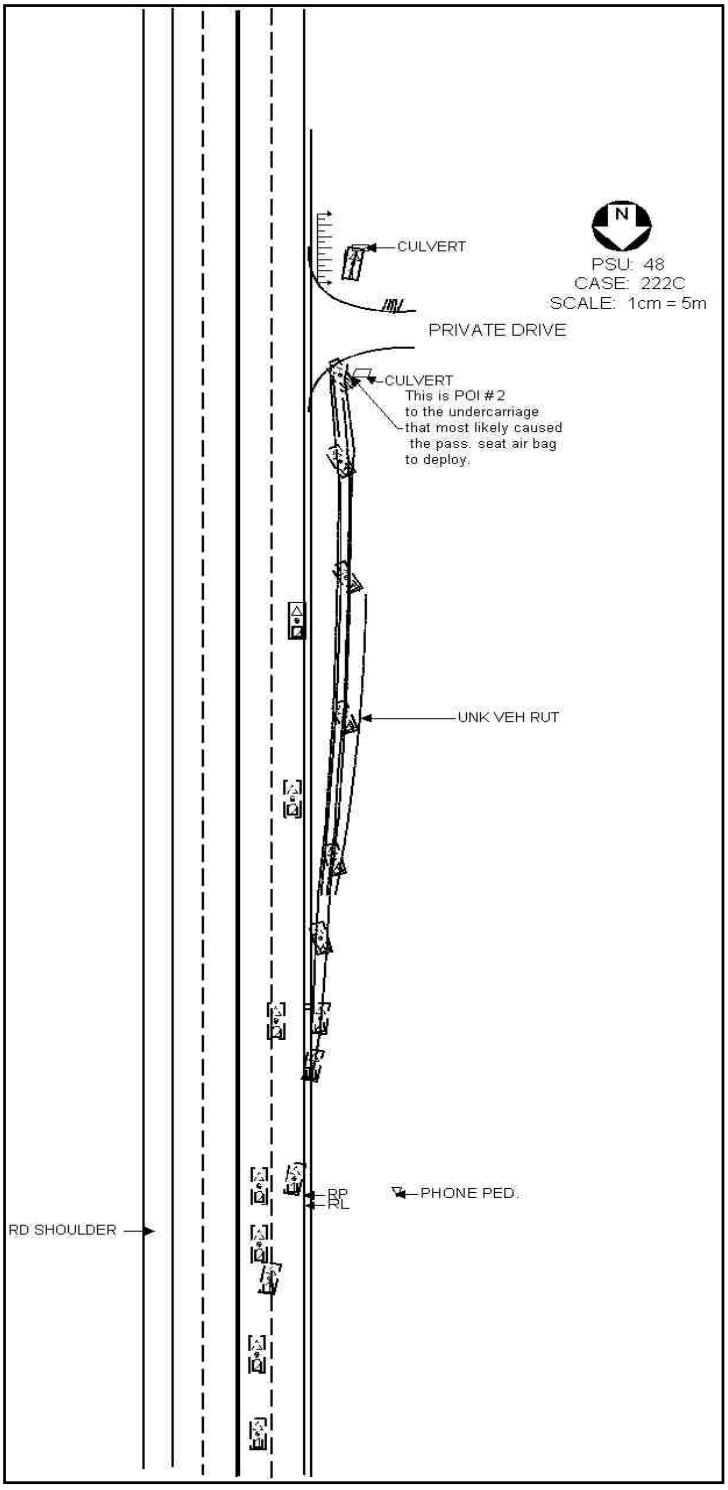

Figure 15. NASS Scene Schematic