TRANSPORTATION SCIENCES
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VERIDIAN ON-SITE AIR BAG RELATED ADULT DRIVER FATALITY INVESTIGATION
VERIDIAN CASE NO. CA97-024
VEHICLE: 1997 MITSUBISHI GALANT
LOCATION: DELAWARE
CRASH DATE: JUNE 1997

Contract No.
DTNH22-94-D-07058

Prepared For:

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

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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 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.* CA97-024	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* Veridian On-Site Air Bag Related Adult Driver Fatality Investigation Vehicle: 1997 Mitsubishi Galant Location: Delaware		5. *Report Date*: February 2002 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 Veridian Engineering P.O. Box 400 Buffalo, New York 14225		10. *Work Unit No.* C01115.0000.(7450-7459) 11. *Contract or Grant No.* DTNH22-94-D-07058	
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: June 1997 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* On-site investigation of a road-side departure crash that resulted in deployment of the frontal air bag system and fatal injuries to the belted 53 year old female driver.			
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17. *Key Word* Front impact with an impact attenuator Frontal air bag deployment Restrained adult female driver In-path of the deploying air bag		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

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BACKGROUND

This on-site crash investigation focused on the injury mechanisms and cause of death for a 53 year old female driver of a 1997 Mitsubishi Galant. The Galant was equipped with frontal air bags that deployed as a result of a frontal impact sequence **(Figure 1)** with an impact attenuator and subsequent left side engagement with a guardrail system. The driver was properly restrained by the manual 3-point lap and shoulder belt system and was seated in a mid track position. She had a history of hypertension, an enlarged heart, and was prescribed blood pressure medication by her physician. She was struck by the expanding driver air bag and module cover flap which resulted in numerous soft tissue injuries of the face and chest with bilateral subarachnoid and subural hemorrhage. The driver was transported by ambulance to a local hospital where she expired within minutes of arrival.

Figure 1. Frontal damage to the Mitsubishi Galant.

The Delaware State Police notified NHTSA of the crash through the Air Bag Hotline on the day following the June 1997 crash. The notification was immediately forwarded to the Veridian SCI team and assigned as an on-site investigation. The Veridian SCI investigator departed to the crash site on the day of notification. The vehicle was secured by the police and removed to an impound facility pending this SCI investigation.

SUMMARY

Crash Site

The crash occurred on the southbound lanes of an interstate roadway in a posted 89 km/h (55 mph) speed zone. On approach to the crash site, the southbound lanes consisted of five travel lanes. The right outboard lane transitioned into an exit ramp while the inboard lane terminated, merging the traffic flow into three lanes. A painted gore separated the exit lane from the through southbound lanes. A double guardrail system divided the through lanes from the exit ramp. This double system offered protection to traffic from both the through lanes and the exit ramp. The system utilized a W-beam rail mounted to strong I-beam posts with I-beam block-outs. The downstream blunt end of the guard system was protected from southbound traffic by sand-filled impact attenuators. The attentuator system consisted of a single row of four barrels followed by a double row of four barrels. **Figure 2** is an aerial view of the crash site.

Figure 2. Aerial view of the crash site.

The northbound lanes were separated by a wide median [estimated lateral distance of 0.8 km (0.5 miles)] that consisted of natural terrain features (e.g., trees, brush, grass, etc.) between the travel directions. South of the crash site, a left on-ramp merged into the southbound lanes. The new asphalt road surface was dry at the time of the nighttime crash. The ambient condition was clear with illumination adjacent to the dedicated exit lane. The Crash Schematic is attached as **Figure 13**.

Vehicle Data

The crash involved a 1997 Mitsubishi Galant ES, 4-door sedan. The vehicle was identified by vehicle identification number 4A3AJ56G8VE (production number deleted). The driver was not the owner of the Galant which was registered outside the state of Delaware. At the time of the crash, the vehicle's odometer reading was 4,490 km (2,790 miles).

The Galant was equipped with a 2.4 liter, 4-cylinder engine linked to a 3-speed automatic transmission with overdrive. The braking system consisted of power-assisted front disc/rear drum brakes without ABS. The interior of the vehicle was configured with front bucket seats with reclining seat backs and a rear bench seat with split, forward folding backrests. At the time of the crash, the rear seat backs were folded forward to accommodate cargo in the trunk of the vehicle.

The manual safety systems consisted of 3-point, continuous loop lap and shoulder belt systems for the four outboard seated positions. The center rear position was equipped with a lap belt. The front belt systems utilized adjustable D-rings and energy management loops incorporated into the lap belt webbing adjacent to the outboard aspect of the seat cushion. Both D-rings were adjusted to the full up positions. There was 9.5 cm (3.75") of vertical adjustment to both units. The management loops were concealed by vinyl sleeves. The driver was restrained by the manual belt system, however, her loading force against the belt system was minimal due her mid track position and the deployment of the frontal air bag system. As a result, the left management loop remained intact.

Crash Sequence

Pre-Crash

The 53 year old female driver was en route to her residence after working a double eight hour shift at a local medical facility. The driver had a history of hypertension and was under medication prior to the crash. She was traveling on the outboard right through lane of the interstate roadway, adjacent to the dedicated right exit lane, when the driver apparently fell asleep. The Mitsubishi Galant drifted over the right solid lane edge line and entered the asphalt gore area that delineated the through travel lane from the exit ramp. The vehicle traversed this area in a tracking mode **(Figure 3)** to impact with the impact attenuators that protected the blunt end of a double back-to-back parallel guardrail system. The impact attenuator consisted of Fitch and Energite type sand barrels which weighed 181 kg (400 lb)

Figure 3. Pre-crash approach of the Mitsubishi Galant.

each and measured 91.4 cm (36.0") in diameter and 106.7 cm (42.0") in height. The barrel placement pattern incorporated a single line of four barrels which preceded and centered on a dual parallel line of four barrels.

Crash

The front left area of the Mitsubishi Galant impacted the single line of attenuator barrels **(Figure 4)** and continued through the right side of the dual line of barrels, impacting and damaging a total of eight barrels **(Figure 4)**. The crash resulted in a 12 o'clock impact force and crushed the left corner of the upper radiator support panel to a depth of 30.5 cm (12.0"). Although the crash conditions were outside the scope of the WinSMASH reconstruction program due to the yielding object, the damage profile was used to compute a barrier equivalent speed of 18 km/h (11.2 mph). This impact deployed the vehicle's frontal air bag system. It should be noted that impact attenuators were engineered to gradually reduce the velocity of the vehicle, therefore the crash pulse experienced by the vehicle was elongated, resulting in a probable late deployment of the frontal air bag system.

Figure 4. Placement of the sand barrel attenuators.

Figure 5. Continued trajectory of the Galant.

The Galant yawed slightly in a counterclockwise (CCW) direction due to the off-set left frontal impact. It traveled approximately 16.6 m (54.4') and struck the W-beam guardrail located adjacent to the left side of the exit ramp with the left front fender area. The vehicle was redirected in a clockwise direction and continued along the ramp **(Figure 5)**, striking the guardrail four additional times before coming to rest adjacent to the guardrail 148.9 m (488.5') south of the initial point of impact with the impact attenuators. It was believed that the driver relinquished control of the vehicle immediately following air bag deployment and that the vehicle's front wheels were turned in a CCW direction which allowed the vehicle to continuously contact and "ride"along the guardrail system.

Post Crash

The Mitsubishi Galant came to rest with its left side against the guardrail. Rescue personnel cut the shoulder belt webbing and removed the driver from the vehicle through the right door. She was transported by ambulance to a local hospital where she expired within minutes of arrival.

Vehicle Damage

Exterior

The Mitsubishi Galant sustained moderate frontal damage and minor left side damage from impacts with the impact attenuator and guardrail system, respectively. The initial impact with the attenuator system produced damage at the bumper and radiator support levels. The direct contact damage on the bumper fascia began 13.3 cm (5.25'") left of center and extended 58.4 cm (23.0") to the left corner **(Figure 5)**. The impact deformed the full frontal width of the vehicle resulting in a combined induced and direct damage length of 144.1 cm (56.75"). The crush profile at bumper level was as follows: C1 = 7.8 cm (3.1"), C2 = 3.6 cm (1.4"), C3 = 0 cm, C4 = 0 cm, C5 = 0 cm, C6 = 0 cm. Maximum crush was 30.5 cm (12.0") located at the left corner of the radiator support panel. The crush profile at the level of the radiator support was as follows: C1 = 30.5 cm (12.0"), C2 = 29.8 cm (11.75"), C3 = 11.4 cm (4.5"), C4 = 2.5 cm (1.0"), C5 = 1.9 cm (0.75"), C6 = 0 cm. These profiles **(Figure 6)** were averaged for input into the damage algorithm of the WinSMASH program. The Collision Deformation Classification (CDC) for the first impact with the impact attenuator was 12-FYEW-2.

The multiple impact sequence with the guardrail system was combined and assigned a single CDC of 11-LDMS-2. The maximum crush to the left front fender from this impact measured 22.9 cm (9.0"). The combined induced and direct contact damage length was 369.6 cm (145.5") which extended from the left corner rearward to a point 50.8 cm (20.0") aft of the left rear axle position **(Figure 7)**. Damage to the vehicle was estimated by police at $5,000.

Figure 6. Profile view of the frontal crush.

Figure 7. Left side guardrail damage.

Interior

The interior damage to the Mitsubishi Galant was rated as minor and was associated with driver contact and deployment of the frontal air bag system. There was no interior damage associated with exterior deformation or intrusion to the passenger compartment. The frontal air bag system deployed as designed from the respective driver and passenger modules. **Figure 8** is a profile view of the driver's compartment of the Mitsubishi Galant.

Figure 8. Overall view of the driver's compatment.

The driver was out-of-position forward as the frontal air bag system deployed. The leading edge of the driver air bag module cover flap contacted the driver's torso area as evidenced by a horizontally oriented scuff/abrasion to the cover flap. This interaction momentarily restricted the expansion of the air bag membrane as evidenced by black vinyl transfers on the bag membrane from contact against the interior aspect of the horn pad. The bag subsequently expanded against the driver's torso and face. A make-up transfer was noted to the center of the bag within the tether reinforcement area.

The forward position of the driver, in combination with her forward trajectory, displaced the deployed driver air bag in a forward direction. Air bag fabric scuff marks were noted to the upper edge of the steering wheel rim. The bag contacted the leading edge of the sun visor which abraded the edge of the fabric covered component. Several strands of loose hair (presumably from the driver) were noted to the sun visor. At the time of the SCI investigation, the visor was rotated forward against the laminated windshield.

The driver's knees contacted the mid instrument panel and the left aspect of the knee bolster. Superficial scuff marks and a tissue transfer evidenced the contacted areas. There was no damage to these components. There was no deflection of the steering wheel rim or compression of the energy absorbing steering column.

The right corner of the front right air bag module cover flap contacted and fractured the windshield 52.1 cm (20.5") right of the vehicle's centerline. A 5.1 cm (2.0") vertically oriented vinyl transfer was noted to the glazing at the fracture point.

Frontal Air Bag System

The 1997 Mitsubishi Galant was equipped with a frontal air bag system for the driver and right passenger positions. The system deployed as a result of the vehicle's frontal impact sequence with the impact attenuator. The air bag system consisted of two crash sensors that were mounted to the forward aspect of the inner fenders, a diagnostic and control module that was mounted under the center console between the front bucket seats, an instrument panel air bag indicator lamp, a steering wheel mounted driver air bag module, and a right instrument panel mounted passenger air bag module.

The driver air bag module consisted of a single cover flap that was hinged at the top surface of the module assembly. The vinyl flap material measured 12.7 cm (5.0") vertically and 17.5 cm (6.9") laterally with a measured thickness of 3.1 mm (0.125"). The module cover exhibited a scuff pattern along the bottom leading edge **(Figure 9)** that measured 5.7 cm x 5.1 cm (2.25" x 2.0"). The scuff was attributed to driver contact during the air bag deployment sequence. Located behind the module cover flap was the horn activation pad which measured 9.5 mm (0.375") thick.

Figure 9. Driver air bag module cover flap.

The driver air bag measured 66.7 cm (26.25") in diameter in its deflated state and was designed with two tethers located at the 9 o'clock and 3 o'clock positions. The two air bag vent ports measured 2.5 cm (1.0") in diameter and were located 36.8 cm (14.5") apart at the 3 and 9 o'clock positions. The expanding driver air bag membrane contacted the driver's face as evidenced by a cosmetic transfer that measured 4.4 cm x 1.3 cm (1.75" x 0.5") and was located within the boundary of the tether stitching in the center of the bag. Additionally, there were black vinyl transfers located above and to the left of the cosmetic transfer area which were attributed to expansion within the air bag module cover during the deployment sequence.

The front right passenger air bag system consisted of an air bag module assembly that was mounted in the mid aspect of the right instrument panel and concealed by a single cover flap. The flap measured 22.2 cm (8.75") vertically and 35.6 cm (14.0") horizontally. The air bag was not tethered and was approximately square in shape with perimeter dimensions of 45.7 cm (18.0"). The air bag was designed with two 7.0 cm (2.75") diameter vent ports that were located on the side surfaces of the air bag. The maximum rearward excursion of the passenger bag was 68.6 cm (27.0") from the face of the mid panel. The module cover was abraded along the lower right corner as the result of the contact against the windshield. There was no evidence of driver contact on the air bag.

Manual Restraint Systems

The front outboard seated positions of the Galant were equipped with 3-point lap and shoulder belt systems. The systems consisted of continuous loop webbings with sliding latch plates and retractors that were emergency locking and belt sensitive. The B-pillar mounted D-rings were adjustable and both were adjusted to the full-up position. The outboard aspect of the lap belt webbings were equipped with energy management loops that were located above the outboard anchorages. The loops were concealed within a vinyl sleeve and although the driver was belted, her loading force against the system was minimal as the loop remained intact **(Figure 10)**. There was no loading evidence on the driver's belt system. Rescue personnel cut the shoulder belt webbing at the level of the shoulder as they provided treatment to the driver **(Figure 11)**.

Figure 10. Non-deployed management loop.

Figure 11. Cut shoulder belt webbing.

The rear seat of the Galant was equipped with 3-point lap and shoulder belts for the outboard positions and a center lap belt.

Driver Demographics

Age/Sex:	53 year old female
Height:	162.6 cm (64.0")
Weight:	75.8 kg (167.0 lb)
Manual Restraint Usage:	3-point lap and shoulder belt system
Usage Source:	Observations of first responders, vehicle inspection
Seat Track Position:	Mid track
Type of Medical Treatment:	Transported by ambulance to a local trauma center where she expired shortly after arrival

Driver Injuries

Injury	Severity (AIS 90/Update 98)	Injury Source
Thin subdural hemorrhage over the left cerebral hemisphere and moderately on the right cerebral hemisphere	Critical (140654.5,3)	Expanding driver air bag membrane
Focal subarachnoid hemorrhage of the inferior aspect of the bilateral frontal brain lobe	Serious (140684.3,1; 140684.3,2)	Expanding driver air bag membrane
Abrasion over the tip of the nose	Minor (290202.1,4)	Expanding driver air bag membrane
1.5 x 1.5" area of superficial abrasion extending down the midline and over the end of the chin	Minor (290202.1,8)	Expanding driver air bag membrane
Contusion of the outer border of the lower lip	Minor (290402.1,8)	Expanding driver air bag membrane
Upper frenula torn and hemorrhagic	Minor (290600.1,8)	Expanding driver air bag membrane
Marked mucosal hemorrhage in the lower jaw that extends from the vermillion border of the lip to the level of the mandible; minute hemorrhages in the mucosa of the mouth	Minor (243202.1,8)	Expanding driver air bag membrane

Injury	Severity (AIS 90/Update 98)	Injury Source
Stellate, blotchy red/blue contusion of the left breast above the nipple 3 x 3" with soft hemorrhage	Minor (490402.1,2)	Air bag module cover flap
1.25 x 1.75" rectangular abrasion on the anterio-lateral left forearm distal to the antecubital fossa	Minor (790202.1,2)	Expanding driver air bag membrane
Two contusions (0.5 and 1.0" respectively) of the dorsal left hand, proximal to digit nos. 4 and 5	Minor (790402.1,2)	Probable fling injury to the left upper A-pillar
Marked hemorrhage into the deep tissues under the chin and into the strap muscles of the neck, laryngeal mucosa with multiple petechial hemorrhages as well as a few larger confluent hemorrhages	Minor (390402.1,2)	Expanding driver air bag membrane
Petechial hemorrhages over the left shoulder	Minor (790402.1,2)	Shoulder belt webbing
Sclerae of the eyes are hemorrhagic	N/A, not codeable	Expanding driver air bag membrane

** Source of Injuries - Autopsy report*

Driver Kinematics

The female driver of the Mitsubishi Galant relinquished directional control of the vehicle and was seated in a mid track position. The driver seat was located 14.0 cm (5.5") rear of full forward over a seat adjustment range of 22.2 cm (8.75"). The seat back was adjusted to a near vertical position with six degrees of recline measured in its cash position. The seat placement was reportedly undisturbed from the time of the crash as the driver was removed by rescue through the right front door area. The horizontal distance between the seat back support and the mid point of the driver's air bag module cover flap was 47.6 cm (18.75"). The 53 year old female driver was restrained by the manual 3-point lap and shoulder belt system.

At impact with the sand barrel impact attenuator, the frontal air bag system in the Mitsubishi Galant deployed late in the crash sequence due to the graduated stacking of the impact attenuators. The late deployment allowed the driver to move forward in response to the 12 o'clock direction of force impact into

the path of the driver air bag module **(Figure 12)**. Although restrained by the 3-point lap and shoulder belt system, the driver's mid track seat position combined with her forward movement prior to air bag deployment, positioned her torso with the deployment range of the single air bag module cover flap. It should be noted that the driver loaded the manual belt system as she initiated her forward trajectory, however, her loading force was not sufficient to deploy the energy management loop that was incorporated into the outboard aspect of the lap belt webbing, above the lower anchorage point. She did sustain petechial hemorrhages over the left shoulder from loading against the belt webbing.

Figure 12. View of the driver's trajectory.

The single module cover flap contacted the driver's chest as the air bag membrane deployed. A horizontally oriented scuff mark was present on the face of the flap bordering the tear seam. The driver sustained a large stellate contusion of the left breast with soft tissue hemorrhage from the flap contact. The expanding air bag membrane contacted the driver's face and chest, accelerating her head rearward into the seat back. The bag contact produced multiple facial abrasions, contusions, and lacerations, with hemorrhage into the deep tissues under the chin and into the strap muscles of the neck. Additionally, the air bag expansion against the driver's face and head resulted in focal subarachnoid hemorrhage of the inferior aspect of the bilateral frontal lobes of the brain. The combination of direct air bag contact and the rearward acceleration of the head induced by the air bag resulted in thin subdural hemorrhage over the cerebral hemispheres bilaterally.

The driver probably had her left hand positioned on the steering wheel rim in the 9-11 o'clock sector. As the driver air bag deployed, the bag membrane expanded against her anterior left forearm resulting in an abrasion of the anterio-lateral left forearm. The continued bag expansion displaced her hand from the steering wheel rim into the upper left A-pillar (fling). The dorsal aspect of her hand impacted the pillar which resulted in contusions proximal to the 4^{th} and 5^{th} digits.

The driver came to rest in a seated position slumped against the seat back. Emergency responders cut the shoulder belt webbing at the height of her left shoulder and removed the driver from the vehicle on a back board. She was transported by ambulance to a local hospital where she expired within minutes of her arrival.

The driver had an enlarged heart which weighed 740 grams. To put the size of this heart in prospective, the medical examiner indicated that the normal size of a heart was roughly equal to the size of her fist. The size of the driver's heart was described as being equivalent to size of four fists. The driver reportedly was on blood pressure medication. The driver also suffered from hypertensive heart disease with left ventricular hypertrophy. The autopsy revealed that the driver did not suffer any skeletal trauma of the ribs, spinal column, face, or head. The Medical Examiner's conclusion for cause of death was multiple blunt force injuries to the head, neck, and chest.

CRASH SCHEMATIC
VERIDIAN CASE NO. CA97-024

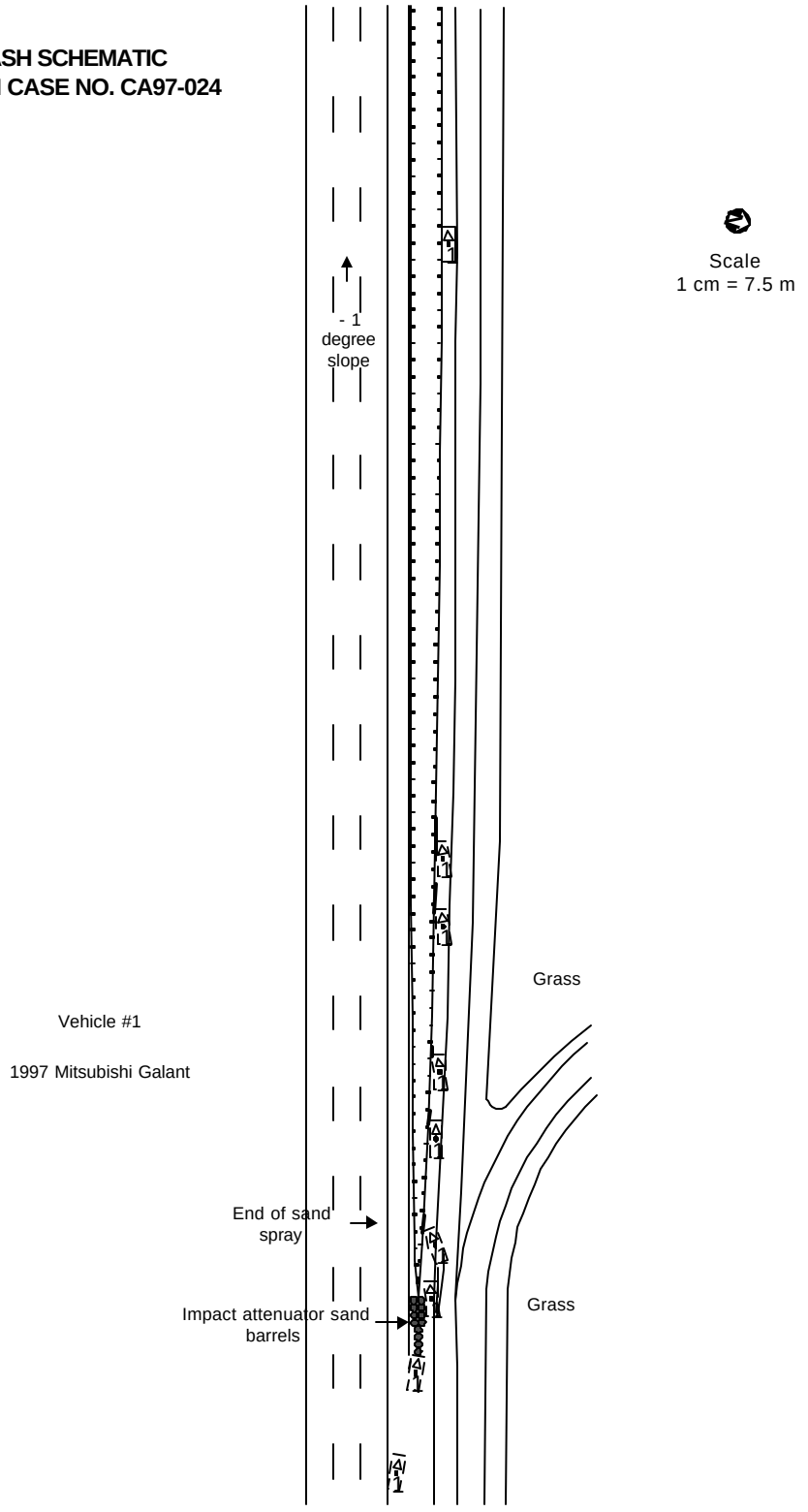

Figure 13. Crash Schematic.