TRANSPORTATION RESEARCH GROUP
CRASH RESEARCH SECTION

VERIDIAN ENGINEERING
(FORMERLY CALSPAN SRL CORPORATION)
BUFFALO, NEW YORK 14225

REMOTE AIR BAG DEPLOYMENT INVESTIGATION

VERIDIAN CASE NO. CA99-013

FRONT RIGHT AIR BAG RELATED INJURY

VEHICLE #1 - 1994 PLYMOUTH GRAND VOYAGER MINIVAN

LOCATION - STATE OF FLORIDA

CRASH DATE - DECEMBER, 1997

Contract No. DTNH22-94-D-07058

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.* CA99-013	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* Veridian Engineering Remote Redesigned Air Bag Deployment Investigation Vehicle #1 - 1994 Plymouth Grand Voyager Minivan Location - State of Florida		5. *Report Date*: September 1999 6. *Performing Organization Code*	
7. *Author(s)* Crash Research Section		8. *Performing Organization Report No.*	
9. *Performing Organization Name and Address* Transportation Research Group Crash Research Section Veridian Engineering P.O. Box 400 Buffalo, New York 14225		10. *Work Unit No.* C01115.0229.(0000-0009) 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: December 1997 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* Remote investigation of a dual frontal air bag deployment crash that resulted in serious injuries to the right front occupant.			

16. *Abstract*

This crash which involved a 1994 Plymouth Grand Voyager (Vehicle #1) equipped with dual front air bags that occurred during the late evening hours in the month of December, 1997. The 47 year old female driver was traveling on a local roadway and entered a public parking lot roadway system. As she proceeded in the parking lot, the frontal plane of the vehicle struck a curbed parking lot divider which resulted in the deployment of the air bag system.

The assigned Collision Deformation Classification (CDC) code for the Plymouth was 12-FDLW-1. The damage routine of the WinSMASH algorithm was utilized which resulted in a computed total delta V of 13.6 km/h (8.5 mph). Given this computed delta V and the engagement of a rigid vehicle component (i.e., engine mounting bracket), it appeared that the SRS system function appropriately.

The 16 year old female right front occupant right front occupant, who was 165.1 cm (65.0") tall and weighed 47.6 kg (105.0 lbs.), moved forward during precrash braking and was within the expansion zone of the front right air bag at the time of the SRS deployment sequence. She was looking slightly to the right at the time of the SRS actuation as noted by the heavy concentration of abrasions along the left side of her face and neck which was attributed to air bag contact. Her head was simultaneously rotated in a clockwise direction and rearward from the expanding air bag which resulted in brain trauma (AIS-3) and a left brachial plexus injury at C6 - T1 (AIS-2).

Rescue arrived and noted that the girl had a Glasgow Coma Scale (GCS) of 13. She was life flighted to a trauma center where her GCS was assessed at 9. She was admitted and treated for a closed head injury, a left brachial plexus trauma, a fracture of the left clavicle, and soft tissue injuries. She was subsequently transferred to a rehabilitation facility four days later.

17. *Key Words* Front dual air bag deployment, Delta V 13.6 km/h (8.5 mph) 16 year old female right front occupant, AIS-3 (Serious)		18. *Distribution Statement* General Public	
19. *Security Classification (of this report)* Unclassified	20. *Security Classification (of this report)* Unclassified	21. *No. of Pages* 8	22. *Price*

TABLE OF CONTENTS

September, 1999

FINAL CASE REPORT
VERIDIAN ENGINEERING CASE NO. CA99-013
FRONT RIGHT AIR BAG RELATED INJURY
1994 PLYMOUTH GRAND VOYAGER
STATE OF FLORIDA
DECEMBER, 1997

BACKGROUND

Veridian Engineering (formerly Calspan Operations of Veridian) was notified of a single vehicle crash involving a 1994 Plymouth Grand Voyager by the Field Operations Branch (FOB) of the National Highway Traffic Safety Administration (NHTSA). The Veridian Engineering investigation team was requested to conduct a remote investigation to determine the relationship between the vehicle's deployed air bag system and injuries sustained by the 16 year old female seated in the right front seat. A initial contact summary which included preliminary data from the attorney representing the family was forwarded to NHTSA the same day of notification.

SUMMARY

This crash which involved a 1994 Plymouth Grand Voyager (Vehicle #1) equipped with dual front air bags that occurred during the late evening hours in the month of December, 1997. The 47 year old female driver was traveling on a local roadway and entered a public parking lot roadway system. As she proceeded in the parking lot, the frontal plane of the vehicle struck a curbed parking lot divider which resulted in the deployment of the air bag system. The 16 year old right front occupant was contacted by the expanding air bag and suffered injuries of the face, head, chest and shoulder. She was taken to a trauma center where she was admitted and transferred to a rehabilitation facility four days later.

Figure 1- Trajectory of the Plymouth approaching the concrete barrier curb parking lot divider

Prior to the crash, the 1994 Plymouth Grand Voyager was traveling north on a local roadway within a public parking lot which was designed to provide access between several businesses within a shopping area. The roadway appeared to have provided two way travel with an implied travel lane in each direction **(refer to Figure 1)**. The straight, level, wet asphalt roadway was designed with a jog to the right (northbound) as it appeared

to intersect with another east/west parking lot roadway. The jog to the right was accomplished by a concrete barrier curb parking lot divider which was located at the northwest corner of the intersection and was oriented in an east/west direction. From the driver's perspective, the curbed divider occluded approximately two thirds of the roadway's northbound travel at the point of the jog. There were no traffic controls at the intersection of the two roadways **(refer to Figure 2)**.

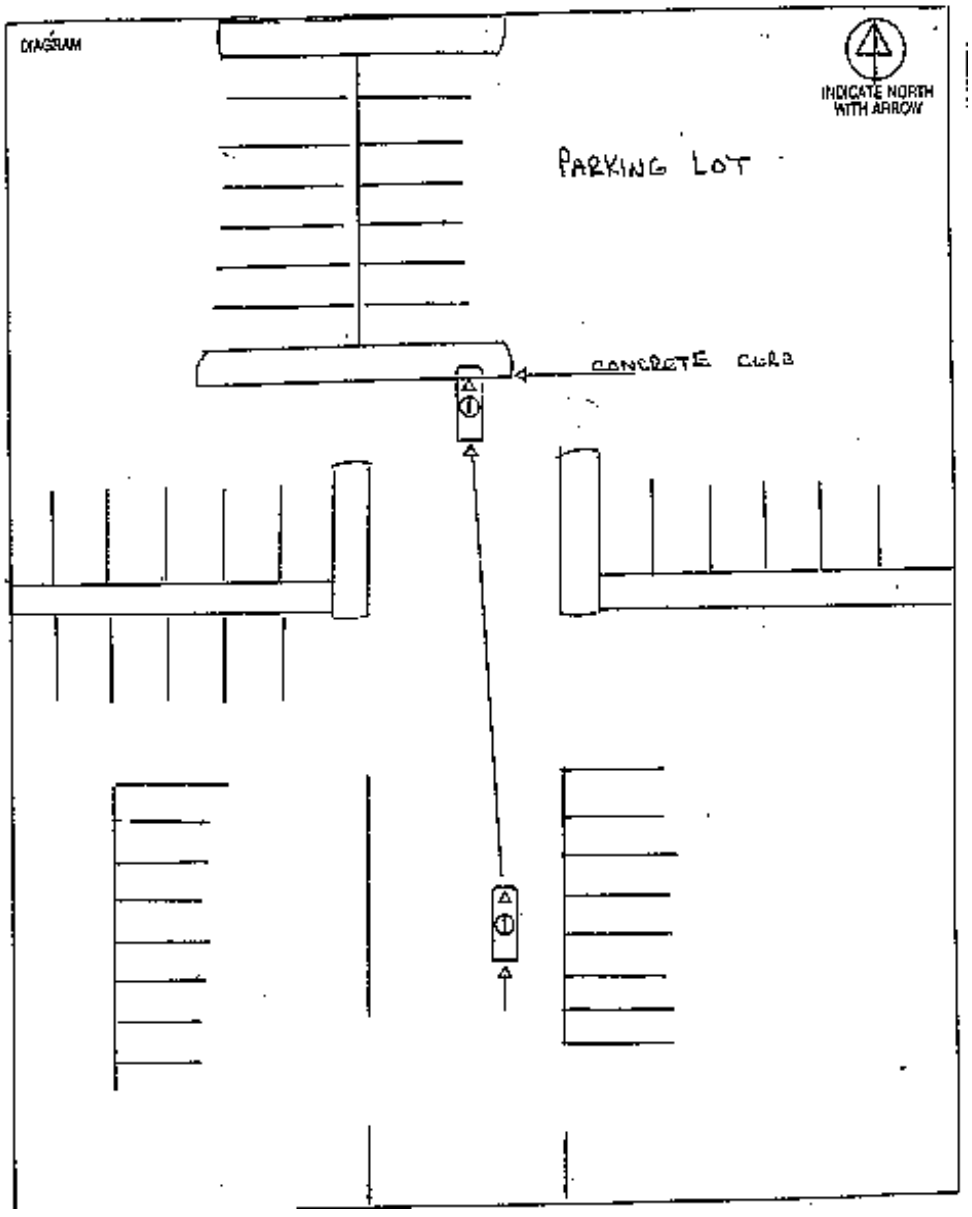

Figure 2- Police crash report scene sketch

The height of the barrier curb parking lot divider visually appeared to be approximately 15.2 cm - 17.8 cm (6.0"-7.0"). Impact type evidence to the top and vertical surfaces of the curb were associated with contact by the lower frontal surface of the Dodge **(refer to Figure 3)**.

Leading up to the curb, there appeared to be a faint tire skid mark which was associated with the right front tire. It appeared to be at least 1.5 m (5.0') in length **(refer to Figure 4)** with an overall length not known due to the limited scope of the photographs provided by the attorney. The vehicle came to the final rest position (FRP) with the front wheels against the curb face and the vehicle's heading angle perpendicular to the curb.

Figure 3- View of the curb showing impact evidence with the lower frontal area of the Plymouth

Figure 4- View of the Plymouth's trajectory showing a faint right front skid mark

The center engine mounting bracket of the Plymouth as well as the lower radiator support bracket contacted the curb during the impact sequence as noted in **Figure 5**. Although the rearward deformation of the lower radiator support appeared to be minor (2.5 cm - 5.0 cm), the contact sequence to the stiffer engine mounting bracket apparently resulted in a sufficient delta V to have triggered the supplemental restraint system (SRS) deployment sequence.

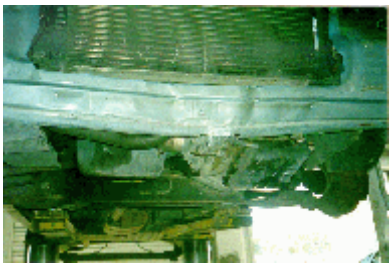

Figure 5- Close-up view of the contact damage to lower radiator support and center engine mount bracket

An exemplar vehicle revealed that the clearance between the bottom of the center engine mounting bracket and the ground measured 21.6 cm (8.5") while the ground clearance between the transmission and engine oil pans was 15.9 cm (6.25"). Although these static dimensions were higher than the estimated 15.2 cm - 17.8 cm (6.0"-7.0") vertical height of the curb, the front of the vehicle more than likely pitched downward due to pre-impact braking and placed the lower portion of the frontal plane below the top edge of the curb. A fluid deposit at the scene which was located adjacent to the barrier curb indicated that either the engine or transmission oil pan also sustained damage during the crash.

The driver was en route to a video rental store late in the evening presumably to return video tapes. The right front occupant was reportedly asked by her mother to accompany her and was attired in bedtime clothes. Although the attorney indicated that his client was wearing the manual lap and shoulder belt, medical records, the police crash report, and the injury pattern indicated that the right front occupant was unrestrained at the time of the crash.

The right front occupant, who was 165.1 cm (65.0") tall and weighed 47.6 kg (105.0 lbs.), moved forward during precrash braking and was within the expansion zone of the front right air bag at the time of the SRS deployment sequence. She was looking slightly to the right at the time of the SRS actuation as noted by the heavy concentration of abrasions along the left side of her face which was attributed to air bag contact. Her

head was simultaneously rotated in a clockwise direction and rearward from the expanding air bag which resulted in brain trauma and a left brachial plexus injury at C6 - T1.

The right front occupant also suffered a fracture of the left mid clavicle. Due to the lack vehicle interior information, the association of this injury with an injury source could only be speculative. Even though the air bag interaction was not ruled out as an injury source, it appeared unlikely that this injury was the result of contact with the expanding air bag. The occupant was more than likely propelled rearward by the air bag and contacted some other interior component (e.g., seat back support, etc.).

The assigned Collision Deformation Classification (CDC) code for the Plymouth was 12-FDLW-1. The damage routine of the WinSMASH algorithm was utilized which resulted in a computed total delta V of 13.6 km/h (8.5 mph). This computation was based on observational crush and should be viewed as an approximate delta V value. Given the computed delta V and the engagement of a rigid vehicle component (i.e., engine mounting bracket), it appeared that the SRS system functioned appropriately.

According to the police crash report, the driver was listed as unrestrained. The attorney indicated that she suffered unspecified trauma to her teeth. The driver hastily exited the vehicle through the driver's door due to smoke and ran around the front of the vehicle. She opened the passenger's door and according to the attorney took the child's restraint belt off and removed her from the vehicle. The mother was reportedly a nurse.

Rescue arrived and noted that the girl had a Glasgow Coma Scale (GCS) of 13. She was life flighted to a trauma center where her GCS was assessed at 9. She was admitted and treated for a closed head injury, a left brachial plexus trauma, a fracture of the left clavicle, and soft tissue injuries. She was subsequently transferred to a rehabilitation facility four days later.

VEHICLE Data

Exterior -1994 Plymouth Grand Voyager

The 1994 Plymouth Grand Voyager was equipped with a dual front Supplemental Restraint System (SRS) which deployed as the result of the impact with the concrete barrier curbed parking lot divider. Exterior damage to the vehicle involved the center engine mounting bracket as well as the lower radiator support bracket. The right front fender was removed, but its condition was not known. The windshield was cracked with a concentrated fracture pattern located in the right upper third. This was associated with contact from the expanding front right air bag **(refer to Figure 6)**. The attorney indicated that the front bumper was not damaged and was reused after the front damage had been repaired.

Figure 6- View of the damaged windshield glazing from contact with the expanding front right air bag

Crush values were visually determined from photographs and are contained in the following table **(refer to Figures 7 & 8)**.

Vehicle #1 Crush			
Impact with barrier curb	C_1 = cm	C_2 = 2.5 cm (1.0")	C_3 = 5.1 cm (2.0")
	C_4 =5.1 cm (2.0")	C_5 =2.5 cm (1.0")	C_6 = 0

Figure 7- View of the frontal damage from the right side

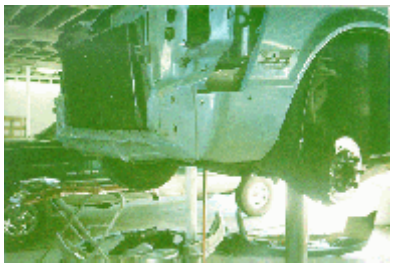

Figure 8- View of the damage from the left side of the vehicle

The transmission oil pan showed signs of oil residue along the bottom surface. The appearance of the oil appeared somewhat fresh, however, the front and right gasket surfaces appeared dry. The engine oil pan appeared to be intact and exhibited oil residue which was judged to have been a precrash residue.

Collision Deformation Classification (CDC)

The CDC for the front impact was assigned as follows: 12-FDLW-1.

Interior -1994 Plymouth Grand Voyager

Interior damage data of the 1994 Plymouth Grand Voyager was not available for this report. From a supplied photograph, it was noted that the windshield glazing was fractured with a focused fracture pattern located in the upper third of the glazing and aligned with the right front seat area. The fracture pattern appeared to be the result of contact by the expanding front right air bag (as observed in other similar type deployment related crashes). The lap and shoulder restraint belts for the front seat occupants were visible in the photographs **(refer to Figure 6)**.

SPEED RECONSTRUCTION

The WinSMASH speed reconstruction algorithm was used to compute relative delta V values. The output from the damage routine indicated that the vehicle experienced a total delta V of 13.6 km/h (8.5 mph) as shown in the following table. This value was considered an approximation due to the visually estimated crush values, but appears to be within an acceptable range of 8-16 km/h (5-10 mph).

Total delta V	13.6 km/h (8.5 mph)
Longitudinal delta V	-13.6 km/h (-8.5 mph)
Lateral delta V	0

Energy dissipated	12,820 joules (9,460 ft-lb)
Barrier equivalent speed	13.6 km/h (8.5 mph)

SUPPLEMENTAL RESTRAINT SYSTEM (SRS)

The Supplemental Restraint System (SRS) in the 1994 Plymouth Grand Voyager was designed with a single point sensor system and dual front air bags which deployed during the impact sequence with the barrier curb parking lot divider. The contact damage to the vehicle appeared to be relatively minor which at first glance appeared to have been a below threshold deployment event. However, the impact sequence included direct contact to the center front engine mount which was a stiffer component than the surrounding sheet metal components. It was theorized that this stiffness resulted in a transmission of a an energy spike to the single point sensor which was sufficient to actuate the SRS deployment sequence.

Front Right Passenger Air Bag

The attorney representing the family indicated that the front right air bag had a 61.0 cm (24.0") excursion. Soft tissue injuries to the right front occupant's face and neck indicated that she was within the expansion zone of the air bag during the deployment actuation sequence. A pattern type abrasion was noted over her left eye which was attributed to contact with an air bag seam line during deployment.

The front right air bag in a similar type vehicle was top mounted, tethered with no visible vent ports. The air bag module cover flap was constructed of rigid vinyl and hinged at the forward aspect of the module. It measured 32.4 cm (12.75") laterally and ranged from 14.9 cm (5.875) to 15.9 cm (6.25") longitudinally in the exemplar vehicle.

Front Left Driver Air Bag

The front left air bag module in an exemplar vehicle had "H" configuration cover flaps that were symmetrical in design. The air bag was a nontethered design with two vent ports in the 12 o'clock sector. It was not known whether the driver came in contact with the deploying air bag as the limited injury information indicated that she suffered trauma to her teeth.

The attorney indicated that the air bags were replaced against the wishes of the owner. The vehicle reportedly is still in-service and used every day by the family.

Injury Data

The right front occupant, who was 165.1 cm (65.0") tall and weighed 47.6 kg (105.0 lbs.), moved forward and was within the expansion zone of the front right air bag at the time of the SRS actuation. This was noted by the heavy patterned abrasion along the left side of her face and the injury of the left brachial plexus. Rescue assessed the girl's vital signs and assigned a Glasgow Coma Scale (GCS) of 13. They transported her via life flight to a trauma center where her GCS score was listed as a 9. She was admitted for treatment of head trauma, a brachial plexus injury, a fracture of the left clavicle, and multiple soft tissue injuries. The following

table summaries the injuries identified in related medical records along with the respective AIS-90 injury code and correlating injury source.

INJURY	AIS-90	INJURY SOURCE
1-3. Fracture of three teeth, #7, #8, & #9	251404.1,8 251404.1,8 251404.1,8	Front right passenger air bag
4. Laceration of the right lower lip	290602.1,8	Front right passenger air bag
5. Multiple superficial abrasions of the face	290202.1,0	Front right passenger air bag
6,7. Avulsion of the small nerves at C7-T1 with stretching at C6	630216.2,6 630212.2,6	Front right passenger air bag
8. Defuse cerebral edema	140668.3,0	Front right passenger air bag
9. Abrasions of the anterior neck	390202.1,5	Front right passenger air bag
10. Abrasions of the upper chest, clavicular area	490202.1,2	Front right passenger air bag
11. Contusions of the upper chest, clavicular area	490402.1,2	Unknown
12. Nondisplaced mid shaft fracture of the left clavicle	752200.2,2	Unknown

The girl was transferred to a rehabilitation facility four days after being admitted to the trauma center. She was later released and underwent surgery eight months later in an attempt to restore function of her left arm. The surgical procedure was described as rare and complex with the outcome initially rated as 30-50 percent functional recovery. Per the attorney, the girl has not demonstrated a marked improvement since the surgery.

The girl was in her second year of high school at the time of the crash and due to her physical limitations and other factors did not attend the remainder of her high school years. She was instructed at home, however, through a tutor program and apparently met the requirements for graduation.

OCCUPANT KINEMATICS

The driver and her 16 year old daughter were en route to a video rental store presumably to return video tapes late in the evening. Photographs of the scene indicated that the driver applied full brakes prior to the crash as noted by the right front skid mark approaching the curb and ending at the curb face.

The attorney representing the family indicated that both the driver and the right front occupant were using their three point manual lap and shoulder restraint at the time of the crash. Injuries sustained by the right front occupant in addition to police and medical data indicated that the girl was not restrained at the time of the crash.

Right Front Occupant

The 16 year female right front occupant was sitting in the seat and looking slightly to her right just prior to impact. During the braking action, the girl moved forward and was within the expansion zone of the front right air bag during the SRS actuation sequence. The air bag contacted the girl's facial area resulting in multiple abrasions over the left eye brow, left cheek, nose, chin, and right cheek. A well defined lateral line pattern over the left eyebrow was attributed to the stitched seam area of the air bag. As the air bag continued to expand, it contacted the girl's chin area and forced her jaw closed. This action resulted in the fracture of three frontal teeth. She also experienced a perforation of her lip which was attributed to the protrusion of her teeth during the air bag contact sequence.

Her head and neck were displaced rearward in a clockwise rotation by the expanding air bag which resulted in a brachial plexus injury where the nerve roots were avulsed at C7-C8, T1 and stretched at C6. The 16 year old female passenger was displaced rearward by the expanding air bag into the front right seat back. She sustained a non-displaced mid shaft fracture of the left clavicle from an unknown source. It was not known what her body position or location was at final rest other than it was reported that the driver removed her daughter from the vehicle through the right front door.

Driver

Vehicle damage and scene evidence indicated that the driver applied full brakes just prior to impact with the barrier curb parking lot divider. She suffered unknown injury to her teeth which suggested that her face may have been within the expansion zone of he front left driver air bag and that the interaction with the air bag resulted in the rapid closure of her jaw and subsequent injury. The police indicated that the driver was not using the manual lap and torso belt at the time of the crash which would have allowed the driver to move forward into the path of the air bag during the SRS late deployment sequence.

The driver was conscious following the crash and exited the vehicle through her door. She went around the vehicle to the right front door and removed her daughter from the vehicle.