

**TRANSPORTATION SCIENCES
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**GENERAL DYNAMICS ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION
SCI TECHNICAL SUMMARY REPORT**

CASE NO. CA03-051

VEHICLE – 1994 PLYMOUTH VOYAGER

LOCATION - STATE OF GEORGIA

CRASH DATE – JULY 2003

Contract No. DTNH22-01-C-17002

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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.

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**GENERAL DYNAMICS ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION
SCI TECHNICAL SUMMARY REPORT
CASE NO. – CA03-051
SUBJECT VEHICLE – 1994 PLYMOUTH VOYAGER
LOCATION - STATE OF GEORGIA
CRASH DATE – JULY 2003**

BACKGROUND

This on-site investigation focused on the performance of an integrated forward-facing child safety seat (CSS) and the frontal air bag system that was present in a 1994 Plymouth Voyager. The Voyager (**Figure 1**) was occupied by a restrained 44-year-old female driver, a restrained 56-year-old male front right passenger, and a 3-year-old male passenger who was restrained in the integrated CSS in the second row right side. The Voyager was involved in an angled frontal collision with a 1994 Cadillac DeVille that hydroplaned and crossed the centerline of a four-lane roadway in a counterclockwise (CCW) yaw. The impact resulted in severe damage to the Voyager and was sufficient to



Figure 1. Damaged 1994 Plymouth Voyager

deploy the frontal air bag system. The Voyager was subsequently struck by a 1994 Ford Ranger pickup truck that was traveling behind the Voyager in the outboard lane. The Ford Ranger was an alternative fuel vehicle that was equipped with a Compressed Natural Gas (CNG) fuel system. The female driver of the Voyager was fatally injured and expired at the scene. The male front right passenger loaded the safety belt, which resulted in a chest contusion, a left 10th rib fracture, an abdominal contusion, and an abdominal abrasion. He also sustained a left fractured femur as an indirect result of left knee compression against the glove box door. Contact with the center instrument panel produced a left elbow contusion and abrasion. The front right passenger stated that the 3-year-old male child sustained a facial laceration. The male front right passenger and the 3-year-old child passenger were both transported by ambulance to a local hospital for treatment. The driver of the Voyager expired at the scene and did not receive medical treatment.

This crash was identified by the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) due to the use of an integrated CSS and the potential air bag-related driver fatality. The driver air bag-related fatality was ruled out due to the severity of the crash. An on-site investigation was assigned on September 5, 2003. A copy of the Police Accident Report (PAR) was obtained from the investigating agency and the on-site investigation was initiated on September 9, 2003.

CRASH SITE

This three-vehicle crash occurred during the daylight hours of July 2003 in the state of Georgia. At the time of the crash, rain was falling heavily and the concrete roadway surface was wet. The crash occurred on the westbound lanes of a four-lane roadway. The roadway was configured with two travel lanes in each direction that were separated by a center painted flush median that

measured 4.7 m (15.4') in width. West of the crash site, the painted median formed a center left turn lane. The roadway exhibited a gradual westbound right curve through the crash site and exhibited a slight positive westbound grade that began west of the crash site. The roadway was bordered by concrete shoulders that were configured with Continuous Shoulder Rumble Strips (CSRS). The roadside environment consisted of grassy and wooded areas. The westbound roadside had a negative embankment that led to a concrete drainage ditch, which measured 1.5 m (5.0') in width and was located 3.3 m (10.8') north of the westbound road edge. The posted speed limit for the roadway was 72 km/h (45 mph). There were no traffic control devices present at the crash site. The scene schematic is included as **Figure 19** of this narrative report.

VEHICLE DATA – 1994 PLYMOUTH VOYAGER

The 1994 Plymouth Voyager was identified by the Vehicle Identification Number (VIN): 2P4GH2537RR (production sequence omitted). The vehicle was a 3-door minivan equipped with a 3.0 liter, V-6 engine, front-wheel drive, a 3-speed automatic transmission, power brakes, power steering, and a tilt steering wheel. At the time of the vehicle inspection, the Voyager’s odometer read 305,791 km (190,015 miles). The table below summarized the tire data for the Voyager at the time of the vehicle inspection. The manufacturer’s recommended tire pressure was unknown.

Position	Tire	Tread Depth	Measured Pressure	Damage
LF	Cordovan CR-10 P205/75R14	4.0 mm (5/32")	0.0 kPa	Sidewall lacerated and tire debaded
LR	Solution SPR P195/75/R14	3.2 mm (4/32")	0.0 kPa	None
RF	Cordovan CR-10 P205/75R14	4.0 mm (5/32")	234.4 kPa (34.0 PSI)	None
RR	Kelly Explorer P195/75R14	3.2 mm (4/32")	110.3 kPa (16.0 PSI)	None

The front seating positions in the Voyager were configured with box-mounted bucket seats with integrated head restraints. The driver’s seat was positioned 15.9 cm (6.3") rear of the full-forward track position and 4.4 cm (1.8") forward of the full-rear track position. The front right passenger’s seat was found jammed 5.1 cm (2.0") rear of the full-forward track position and 10.2 cm (4.0") forward of the full-rear track position at the time of the vehicle inspection. The second row was configured with a two-person bench seat with integrated CSS’s and a folding back. The third row was configured with a three-person bench seat with a folding back. The second and third row bench seats had low seat backs, no head restraints, and were removable.

At the time of the crash, a loose vehicle battery was present in the vehicle, and found on the floor forward of the third row bench seat at the time of the vehicle inspection. An unrestrained full-size tire (P195/75R14) mounted on a steel wheel was present in the cargo area behind the third bench seat. Two plastic wheel covers were also present in the rear cargo area.

VEHICLE DATA – 1994 CADILLAC DEVILLE

The 1994 Cadillac DeVille was identified by the VIN: 1G6KD52B5RU (production sequence omitted). The vehicle was a four-door sedan that was equipped with a 4.9 liter V-8 engine, 4-

speed automatic transmission, power brakes with ABS, power steering, and a tilt steering wheel. The vehicle's odometer reading was unknown. The manufacturer's recommended tire pressure was 210 kpa (30 psi). The tire data also stated to add 28 kpa (4 psi) to the recommended tire pressure if the tires were hot. A separate label located above the manufacturer's information stated that the tire inflation pressure for high speed usage was 240 kPa (35 PSI). At the time of the vehicle inspection, both front tire treads measured 5.6 mm (7/32") and both rear treads measured 3.2 mm (4/32"). The table below summarized the tire data for the DeVille at the time of the vehicle inspection.

Position	Tire	Tread Depth	Measured Pressure	Damage
LF	Michelin X Radial Plus P215/70R15	5.6 mm (7/32")	151.7 kPa (22.0 PSI)	None
LR	Michelin X Radial Plus P215/70R15	3.2 mm (4/32")	193.1 kPa (28.0 PSI)	None
RF	Michelin X Radial Plus P215/70R15	5.6 mm (7/32")	241.3 kPa (35.0 PSI)	None
RR	Michelin X Radial Plus P215/70R15	3.2 mm (4/32")	0.0 kPa	None

The front seating positions in the DeVille were configured with a split bench seat with power track adjustments. The rear seating positions were configured with a bench seat.

VEHICLE DATA – 1994 FORD RANGER

The 1994 Ford Ranger was identified by the VIN: 1FTCR10U5RT (production sequence omitted). At the time of the vehicle inspection, the odometer read 106,721 km (66,315 miles). The vehicle was a two-door pickup truck configured with a 1.8 m (6.0') long bed. The pickup truck was equipped with an aftermarket Compressed Natural Gas (CNG) fuel system. The CNG system was identified by lettering present on the top aspects of the left and right fenders, which read: "Natural Gas Powered." The table below summarized the tire data for the Ranger at the time of the inspection. The manufacturer's recommended tire pressure was 241 kpa (35 PSI).

Position	Tire	Tread Depth	Measured Pressure	Damage
LF	Cooper Trendsetter SE P215/75R14	5.6 mm (7/32")	231.0 kPa (33.5 PSI)	Minor 1.3 cm (0.5") tear in sidewall
LR	Cooper Trendsetter SE P215/75R14	2.4 mm (3/32")	248.2 kPa (36.0 PSI)	None
RF	Cooper Trendsetter SE P215/75R14	4.0 mm (5/32")	255.1 kPa (37.0 PSI)	None
RR	Cooper Trendsetter SE P215/75R14	4.0 mm (5/32")	210.3 kPa (30.5 PSI)	None

The seating positions in the Ranger were configured with a single bench seat.

CRASH SEQUENCE

Pre-Crash

The 44-year-old female driver was operating the Plymouth Voyager on the inboard westbound lane and entered the slight right curve (**Figure 2**). Her pre-crash travel speed was unknown. The 34-year-old male driver of the 1994 Cadillac DeVille was operating the vehicle at a high rate of speed in the inboard eastbound lane (**Figure 3**). As the DeVille descended the slight downgrade and entered the left curve on approach to the crash site, the vehicle began to hydroplane on the wet roadway surface. The driver lost control of the vehicle and the DeVille initiated a CCW yaw. The Cadillac departed the travel lane and crossed the paved median while it continued to rotate. The DeVille had rotated a total of approximately 110 degrees in a CCW direction, exposing its right side, when it encroached into the inboard westbound lane into the path of the oncoming Plymouth Voyager. It was unknown if the driver of the Voyager attempted any avoidance maneuvers prior to the crash. The 1994 Ford Ranger was traveling behind the Voyager in the outboard lane.



Figure 2. Westbound approach for the Plymouth Voyager and Ford Ranger



Figure 3. Eastbound approach for the Cadillac DeVille

Crash

The front left aspect of the Plymouth Voyager struck the right front side aspect of the DeVille as the DeVille encroached into the westbound travel lane. The impact resulted in severe damage to the Voyager, moderate damage to the DeVille, and was sufficient to deploy the frontal air bag system in the Voyager. The Cadillac exhibited greater momentum, evidenced by the severe damage to the Voyager and continuation of the Cadillac's trajectory after the initial impact. The damage algorithm of the WinSMASH program computed a total delta-V of 34.0 km/h (21.1 mph) for the Voyager and 32.0 km/h (19.9 mph) for the Cadillac based on the respective crush profiles. Given the severe damage to the Voyager, the WinSMASH output appeared low, and the Barrier Equivalent Speed of 53.0 km/h (32.9 mph) appeared more reasonable. A second WinSMASH model was run using the Missing Vehicle routine, which yielded a total delta-V of 76.0 km/h (47.2 mph) for the Voyager and 72.0 km/h (44.7 mph) for the DeVille. The Missing Vehicle output appeared high for both vehicles, supported by the lack of serious injury to the 3-year-old child in the Voyager.

The impact redirected the Voyager rearward and induced a clockwise (CW) rotation of the DeVille and a CCW rotation of the Voyager, which resulted in a secondary sideslap between both vehicles. The damage algorithm of the WinSMASH program computed a total delta-V of 19.0 km/h (11.8 mph) for the Voyager and 18.0 km/h (11.2 mph) for the Cadillac, based on the respective side crush profiles. The vehicles separated and the Voyager rotated in a CW direction

onto the roadside. The Cadillac rotated CCW as it continued in its trajectory across the travel lanes.

The driver of the Ford Ranger pickup truck observed the initial collisions and steered right in an attempt to depart the roadway and avoid a secondary crash. As the Ranger departed the right roadside, the left front aspect of the Ranger struck the right rear side aspect of the rotating Cadillac in a glancing sideswipe configuration. The impact intensified the CCW rotation of the Cadillac. The right rear corner of the Cadillac rotated CCW against the Ranger's left front fender and left side aspect as the Ranger continued forward in a tracking mode onto the roadside embankment. The Ranger departed the right roadside and the front right corner struck the right aspect of the Voyager as it traveled down the embankment. The negative slope allowed the front left corner of the Ranger to slightly underride the forward aspect of the left sill on the Voyager. The damage algorithm of the WinSMASH program computed a total delta-V of 17.0 km/h (10.6 mph) for the Voyager and a total delta-V of 18.0 km/h (11.2 mph) for the Ford Ranger, based on the respective crush profiles. The forward momentum of the Ranger deflected the Voyager in a lateral and slightly CW direction, and the vehicles remained engaged and came to rest on the roadside concrete drainage ditch. The Cadillac came to rest in an angled orientation across both westbound lanes facing southwest. During the crash sequence, the driver of the Cadillac DeVille was ejected from the vehicle through the backlight. The final rest position of the Cadillac's driver was not known.

Post-Crash

Due to the engagement of the Ford Ranger against the right front door area of the Voyager, the Ranger was moved rearward post-crash to allow patient access for rescue personnel. The occupants of the Plymouth Voyager were removed from the vehicle by rescue personnel. Rescue personnel removed the left front door and right side sliding door with hydraulic tools. The right B-pillar was cut on the top and bottom portions to facilitate extrication of the occupants. The driver sustained fatal injuries and expired at the scene. The front right passenger and 3-year-old child passenger sustained police-reported serious injuries and were transported by ambulance to a local hospital. The driver of the Cadillac sustained police-reported serious injuries and was transported by ambulance to a local hospital. The occupants of the Ford Ranger did not sustain injury and did not receive medical treatment. A representative from the company that owned the pickup truck stated that the CNG's storage cylinder valve was closed by an occupant of the Ranger shortly after the crash.

VEHICLE DAMAGE

Exterior Damage – 1994 Plymouth Voyager

The 1994 Plymouth Voyager sustained severe damage as a result of the multiple impacts. The direct contact damage from the initial impact with the Cadillac began on the front left corner of the bumper fascia and extended laterally 92.7 cm (36.5") across the frontal plane (**Figure 4**). The direct contact extended vertically from the bumper fascia to the hood, and direct contact abrasions extended 31.8 cm (12.5") rearward from the



Figure 2. Frontal view of the damaged Voyager

front left corner of the hood. Due to the rotation of the DeVille, the direct damage continued onto the left side plane, which resulted in two planes of engagement from the initial impact. The bumper fascia, headlights, and grille were separated. The upper and lower radiator supports were crushed rearward, the maximum crush measuring 71.1 cm (28.0") at the front left corner. The left front fender was crushed rearward and inward from direct contact. The combined direct and induced damage involved the entire frontal width of the Voyager and measured 96.5 cm (38.0") across the upper radiator support. The windshield was fractured and out of place. The right front fender was displaced outward. The left A-pillar sustained considerable rearward displacement. The A-pillar displacement resulted in significant vertical buckling of the left roof side rail and outward buckling of the left front door. The frontal crush displaced the left front axle rearward, which resulted in the reduction of the left wheelbase by 54.0 cm (21.3"). The left front wheel sustained two opposing dents on the outboard aspect as a result of the rearward compression against the left sill. Six crush measurements were documented along the upper radiator support and were as follows: C1 = 71.1 cm (28.0"), C2 = 65.7 cm (25.9"), C3 = 51.4 cm (20.3"), C4 = 12.9 cm (5.1") C5 = 13.3 cm (5.3"), C6 = 5.7 cm (2.3"). The Collision Deformation Classification for the initial impact with the Cadillac DeVille was 12-FYEW-4.

The Voyager sustained moderate left side damage as a result of the secondary sideslap with the Cadillac DeVille. The direct and induced damage on the left side began 37.0 cm (14.6") forward of the left front axle, extended 334.0 cm (131.5") rearward, and terminated at the left rear bumper corner. The maximum crush measured 34.9 cm (13.8), located 37.0 cm (14.6") forward of the left front axle. Numerous abrasions and paint transfers from the Cadillac were present along the entire left side of the Voyager from direct contact. Red paint transfers from the Cadillac's right side pinstripe were also present. The left trim was separated and lateral crush was present on the entire left side plane. A scuff mark was present on the left rear aspect of the rear bumper fascia from contact with the Cadillac, and left aspect of the fascia was partially separated. All left side glazing as well as the backlight disintegrated. Six crush measurements were documented along the left side of the Voyager and were as follows: C1 = 1.9 cm (0.8"), C2 = 3.8 cm (1.5"), C3 = 14.0 cm (5.5"), C4 = 12.7 cm (5.0"), C5 = 20.3 cm (8.0"), C6 = 34.9 cm (13.8). The CDC for the secondary sideslap with the Cadillac DeVille was 09-LDEW-3.

The Voyager sustained moderate right side damage as a result of the impact with the Ford Ranger. The direct damage began 3.0 cm (1.2") forward of the right front axle and extended 133.0 cm (52.4")



Figure 5. Left side sideslap damage



Figure 6. Right side damage showing sill deformation

rearward along the right side (**Figure 6**). White paint transfers from the Ranger were present on the right front fender, the right front door, and the right front sill. The right side door trim was separated. The rear aspect of the right front fender was crushed rearward and inward, and the forward aspect of the right sill sustained lateral crush. The combined direct and induced damage began 16.0 cm (6.3") forward of the front right axle and extended 155.0 cm (61.0") rearward to the rear aspect of the right front door. The right front door was buckled rearward slightly. All of the right side glazing was disintegrated. Six crush measurements were documented along the right side and were as follows: C1 = 14.6 cm (5.8"), C2 = 24.8 cm (9.8"), C3 = 14.0 cm (5.5"), C4 = 11.4 cm (4.5"), C5 = 15.9 cm (6.3"), C6 = 12.7 cm (5.0"). The CDC for the right side impact with the Ford Ranger was 02-RYEW-3.

Interior Damage -1994 Plymouth Voyager

The Plymouth Voyager sustained severe interior damage as a result of passenger compartment intrusion and occupant contact. The driver's space was reduced as a result of intrusion (**Figure 7**). The left, right, and bottom aspects of the steering wheel rim were deflected forward from driver loading. The maximum deflection measured 15.2 cm (4.0") at the 6 o'clock position. An abrasion was present on the bottom aspect of the steering wheel rim that began at the spoke located at the 8 o'clock position and extended CCW 15.9 cm (6.3"). The top of the steering wheel rim was engaged against the top aspect of the left instrument panel. The intrusion of the left instrument panel combined with the driver's forward loading resulted in steering column compression and upward deflection. The outboard corner of the knee bolster sustained an area of longitudinal scuff marks from engagement against the displaced left front door. The scuff marks measured 3.4 cm (2.5") in width and 21.6 cm (8.5") in height. A scuff mark was centered on the top aspect of the knee bolster from the driver's knee that measured 14.0 cm (5.5") in width and 16.5 cm (6.5") in height. The driver's seat track was jammed as a result of the crash, and the seat cushion was buckled longitudinally and rotated inboard 10 degrees.



Figure 7. Interior view showing intrusions and contacts in the driver's position

The front right position also sustained interior damage (**Figure 8**). A heavy abrasion was present on the right aspect of the upper center instrument panel from expansion of the air bag as it was compressed against the instrument panel by the front right occupant. The abrasion measured 2.5 cm (1.0") in width and 14.0 cm (5.5") in height. Two air bag-related scuff marks were located on the outboard aspect of the lower center instrument panel, immediately inboard of the glove box door. The upper scuff mark measured 5.1 cm (2.0") in width and 12.7 cm (5.0") in height. The lower scuff



Figure 8. Interior view of front right passenger's position

mark measured 8.9 cm (3.5”) in width and 5.1 cm (2.0”) in height. The headliner and sun visor were abraded over and area that measured 50.8 cm (20.0”) in width from the right roof side rail and 30.5 cm (12.0”) in length from the windshield header. The cargo drawer under the front right seat opened during the crash. The second row bench seat back was bowed 12.7 cm (5.0”) forward 15.2 cm (6.0”) left of the seat back centerline due to contact with the loose vehicle battery. The third row bench seat was displaced forward and CCW as a result of contact with the loose vehicle tire and wheel. The right side aspect was disengaged from the floor anchors. The right aspect of the bench seat was deflected forward 17.8 cm (7.0”). The entire rear aspect of the seat back exhibited scuff marks, and the maximum seat back deflection measured 10.2 cm (4.0”) and was located 17.8 cm (7.0”) right of the seat back centerline.

Multiple passenger compartment intrusions were documented in the Voyager and were as follows:

Position	Component	Magnitude of Intrusion	Direction
FL	Toe pan	45.7 cm (18.0”)	Longitudinal
FL	Left A-pillar (at base)	30.5 cm (12.0”)	Longitudinal
FL	Left A-pillar (at beltline)	15.2 cm (6.0”)	Longitudinal
FL	Left instrument panel	19.1 cm (7.5”)	Longitudinal
FL	Left A-pillar	12.7 cm (5.0”)	Lateral
FL	Left B-pillar	8.9 cm (3.5”)	Lateral
FL	Windshield header	15.2 cm (6.0”)	Longitudinal
FC	Center instrument panel	19.1 cm (7.5”)	Longitudinal
FC	Toe pan	49.5 cm (19.5”)	Longitudinal
FR	Right instrument panel	3.8 cm (1.0”)	Longitudinal
FR	Right toe pan	21.6 cm (8.5”)	Longitudinal

Exterior Damage – 1994 Cadillac DeVille

The Cadillac DeVille sustained moderate right side damage as a result of the multiple impacts (**Figure 9**). The right side damage was separated into two impacts at the right B-pillar. This was based on the assumption that the initial impact with the Voyager terminated in the vicinity of the right B-pillar, given the Voyager's damage pattern and damage length. The direct damage from the initial impact with the Plymouth Voyager began 81.3 cm (32.0") aft of the right front axle and extended 154.9 cm (61.0") forward along the right side plane to the right front bumper corner. The front aspect of the right sill was crushed laterally, and the right front door had been removed from the vehicle. The maximum crush on the right front aspect measured 42.2 cm (16.6") at the right A-pillar. The right front fender was crushed laterally and the right front axle was displaced forward from snagging against the Voyager. The forward displacement of the right front wheel resulted in the elongation of the right wheelbase by 20.6 cm (8.1"). The right side of the hood was displaced upward. The combined direct and induced damage for the impact with the Voyager began at the right B-pillar and extended 256.5 cm (101.0") forward to the right front bumper corner. Six crush measurements were documented along the mid-door level (projected for the missing door) and were as follows: C1 = 18.5 cm (7.3"), C2 = 23.6 cm (9.3"), C3 = 42.2 cm (16.6"), C4 = 29.5 cm (11.6"), C6 = 2.5 cm (1.0"). The CDC for the initial impact with the Voyager was 04-RYEW-3.



Figure 9. View of right side damage to the DeVille

The secondary sideslap impact with the Voyager resulted in moderate right rear damage to the Cadillac (**Figure 10**). The combined direct and induced damage began at the right B-pillar and extended rearward 238.8 cm (94.0") to the right rear bumper corner. The right rear door panel and rear quarter panel sustained minor lateral crush and abrasions. A silver paint transfer was present on the right C-pillar of the DeVille from direct contact with the Voyager during the sideslap. The CDC for the sideslap event was 03-RDEW-1. Damage to the right rear quarter panel was also present from the third impact with the Ford Ranger. White paint transfers were present on the right rear corner and extended around the tail light onto the face of the trunk.



Figure 10. View of right rear damage to the DeVille

A red paint transfer from the Cadillac's pinstripe was located on the left front fender of the Ranger, which supported the right side plane damage (Figure 11). The right rear quarter panel was fractured and deformed around the taillight. The CDC for the impact with the Ford Ranger was 05-RBES-1. Although the third impact with the Ford Ranger resulted in overlapping damage to the right rear quarter panel, six crush measurements were documented along the right side of the DeVille, resulting in a single crush profile for both events. Six crush measurements were documented along the right rear aspect of the Cadillac and were as follows: C1 = 0.0 cm, C2 = 0.0 cm, C3 = 0.0 cm, C4 = 7.0 cm (2.8"), C5 = 14.0 cm (5.5"), C6 = 8.1 cm (3.2").



Figure 11. Close-up of the right rear damage from the Ranger

Exterior Damage – 1994 Ford Ranger Pickup Truck

The Ford Ranger pickup truck (Figure 12) sustained moderate left side damage as a result of the initial sideswipe impact with the Cadillac DeVille. The direct contact damage began at the left front bumper corner and extended rearward 278.0 cm (109.4") along the left side. A red paint transfer from the pinstripe on the right rear quarter panel of the Cadillac was present on the rear aspect of the left front fender. The left front fender and left door sustained abrasions and lateral deformation. The combined direct and induced damage began at the left front bumper corner and extended rearward 305.0 cm (120.1"). Minor inward deflection was noted on the left rear quarter panel forward of the left rear axle. The CDC for the initial sideswipe impact with the DeVille was 11-LDES-1. Six crush measurements were documented along the left side aspect and were as follows: C1 = 0.0 cm, C2 = 1.9 cm (0.8"), C3 = 6.1 cm (2.4"), C4 = 7.4 cm (2.9"), C5 = 10.2 cm (4.0"), C6 = 27.9 cm (11.0").



Figure 12. Left side damage to the Ranger

The Ford Ranger (Figure 13) also sustained moderate front right damage as a result of the secondary impact with the Voyager. The direct contact damage began at the right front bumper corner and extended 50.0 cm (19.7") laterally to the left. Silver paint transfers and abrasions were present on the bumper and on the forward left aspect of the hood. The front right corner of the bumper was crushed rearward, as well as the right front fender. The combined direct and induced damage involved the entire frontal width of



Figure 13. Front right damage to the Ranger

the Ranger and measured 137.0 cm (53.9") across the bumper. The right aspect of the hood was buckled rearward and upward and the right front fender was displaced rearward against the leading edge of the right door. The CDC for the frontal impact with the Voyager was 12-FREW-2. Six crush measurements were documented along the front bumper and were as follows: C1 = 2.3 cm (0.9"), C2 = 1.9 cm (0.8"), C3 = 6.1 cm (2.4"), C4 = 7.4 cm (2.9"), C5 = 10.2 cm (4.0"), C6 = 27.9 cm (11.0").

ALTERNATIVE FUEL SYSTEM – 1994 FORD RANGER

The 1994 Ford Ranger pickup truck was equipped with a commercial aftermarket conversion CNG fuel system (**Figure 14**), which augmented the vehicle's OEM unleaded fuel system. The Ranger was purchased in December 1994 as a new vehicle for business use. The CNG fuel system was installed by NGV Southeast Technology Center shortly after the vehicle was purchased. A company representative stated that the Ranger had a range of approximately 209 km (130 miles) per tank of CNG, and was refueled with CNG daily. The company was equipped with a CNG compressor, which was installed onto a quick disconnect fitting in the vehicle's grille for refueling, once the tank valve was opened. The company representative stated that there was no routine maintenance performed on the CNG system other than periodic adjustments of the timing system, and that the CNG storage tank had not been pressure tested.



Figure 14. CNG cylinder in the bed of the Ford Ranger

The CNG system consisted of a pressurized fiberglass-wrapped, aluminum, cylinder that was rated to 3,000 PSI. A valve was present on the left aspect of the cylinder (relative to the vehicle) with a pressure gauge fixed to the valve assembly that was rated to 700,000 kPa (10,000 PSI). A section of 0.6 cm (1/4") diameter aluminum tubing delivered the CNG to the engine compartment through the pickup truck bed, forward along outboard aspect of the left frame rail, and to a pressure regulator in the engine compartment. A ball-valve (**Figure 15**) was present on the aluminum delivery tubing and was located 149.9 cm (59.0") forward of the left rear axle and was vertically centered on the outboard left frame rail. The CNG flowed through a regulator, through a filter, into a Combined Computer and Metering Valve (Compuvalve), and into a multi-point injection system.



Figure 15. View looking rearward of aluminum tubing and ball valve on the left frame rail

The pressurized cylinder measured 38.1 cm (15.0”) in diameter, 127.0 cm (50.0”) in length, and was mounted laterally in the forward aspect of the bed of the Ranger. The model number on the cylinder was YY3156 2YY. The aluminum cylinder was wrapped with fiberglass, however, the ends of the cylinder were exposed. The cylinder was secured by two 6.4 cm (2.5”) wide, 0.6 cm (1/4”) thick steel brackets that were mounted to the bed floor and the top of the forward wall of the bed. A steel diamond-plate cover that measured 3.2 mm (1/8”) in thickness was secured over the CNG cylinder.

The Ranger was running on CNG at the time of the crash. At the time of the vehicle inspection, the cylinder valve was closed. Upon opening the valve, a slight leak was detected by the SCI Investigator at the outbound fitting off of the valve assembly. The pressure gauge did not move from the zero position upon the opening of the regulator.

A schematic of a CNG conversion system was obtained from the Alternative Fuels Data Center’s website, maintained by the United States Department of Energy. This schematic is a sample, and not an exact depiction of the system present in the Ranger. The schematic is included as Appendix A of this report. The web link is as follows:

<http://www.afdc.doe.gov/pdfs/schemats.pdf>

MANUAL RESTRAINT SYSTEMS – 1994 PLYMOUTH VOYAGER

The front seating positions in the Plymouth Voyager were configured with manual 3-point lap and shoulder belts. Both front seat safety belts were cut by rescue personnel to facilitate the extrication of the occupants, and both safety belts were used to secure the front doors post-crash. The driver’s safety belt was configured with a sliding latch plate, adjustable D-ring, and an emergency locking retractor (ELR). The retractor was jammed in the used position, and rescue personnel cut the driver’s safety belt webbing 116.8 cm (46.0”) above the lower anchorage. The point at which the webbing was cut was also located 63.5 cm (25.0”) inboard of the driver’s D-ring which was located in the full-up position. The driver’s safety belt webbing exhibited stretch marks from occupant loading and the plastic-coated D-ring exhibited abrasions. The latch plate was removed from the driver’s safety belt and was not with the vehicle.

The front right passenger’s safety belt was configured with a cinching latch plate and an ELR. The D-ring was separated from the B-pillar as a result of the rescue operations, but sustained abrasions from the safety belt loading. The front right passenger’s safety belt webbing was cut from the lower anchor and from the retractor, and used to secure the right front door. The retractor was exposed and was jammed.

The second row two-person bench seat was configured with manual 3-point lap and shoulder belts for each seating position. Both had fixed D-ring anchors, ELR’s, and cinching latch plates. The right side safety belt was configured with a steel spring clasp on the lower anchor of the lap belt portion. A plastic sleeve that measured 25.4 cm (10.0”) in length and 5.1 cm (2.0”) in width was located adjacent to the clasp on the webbing. The clasp engaged with one of two steel rings labeled “A” and “B”. The “A” ring was located on the floor on the rear right corner aspect of the

second row bench seat. The “B” ring was located on the forward aspect of the interior lower C-pillar. The safety belt was anchored at the “A” ring at the time of the vehicle inspection. The owner’s manual stated the following information regarding the anchor placement:

“If the vehicle has a two passenger seat in the second row, the anchor must be installed in the floor mounting position marked with an “A”, next to the seat. If the vehicle has a three-passenger seat or bucket seat in the second row, the seat belt must be installed in the side mounting position. This position is on the lower part of the trim panel, marked with a “B”, just rearward of the side door opening.”

The third row was configured with manual 3-point lap and shoulder belts with fixed D-rings, cinching latch plates, and ELR’s for the outboard positions and the center position was configured with a lap belt with a locking latch plate.

CHILD SAFETY SEAT – INTEGRATED FORWARD-FACING CSS

The 1994 Plymouth Voyager was equipped with integrated forward-facing CSS’s in both positions of the second row bench seat. The CSS seat cushions folded forward from the bench seat back and the CSS head restraints rotated upward from the seat back. The CSS head restraints measured 20.3 cm (8.0”) in height, 29.8 cm (11.8”) in width, and 5.7 cm (2.3”) in thickness in the stowed position. In the used position, the CSS head restraint measured 15.2 cm (6.0”) in height. A 7.6 cm (3.0”) long nylon loop was present on the outboard aspect of each CSS that protruded from under the head restraints in the stowed position, which released the CSS seat cushions and head restraints from the seat back. The CSS head restraint locked into position when fully extended, and could be released to re-stow by pulling on the spring-loaded nylon loop. The CSS seat cushions measured 27.9 cm (11.0”) in width, 33.0 cm (13.0”) in length, and 7.6 cm (3.0”) in height. The CSS cushions extended 21.6 cm (8.5”) forward from the seat back. A horseshoe-shaped removable fabric pad was affixed to each seat cushion with Velcro fasteners, which measured 1.9 cm (0.8”) thick and were open at the forward/center aspects for access to the harness system buckles. The CSS’s were configured with 5-point harnesses with harness adjustment tabs on the forward aspects of each CSS cushion. The harness retainer clips were two-piece plastic clips that locked together when engaged.

Due to the integrated nature of the CSS, a model number and date of manufacture were not available. The warning labels on the CSS cushions were worn and difficult to distinguish.

The left side integrated CSS was not used in this crash. A 3-year-old male child was restrained in the right side integrated CSS (**Figure 16**). At the time of the vehicle inspection, the right side CSS head restraint was found in the upright position. The harness system was adjusted such that the length of the harness webbing measured 53.3 cm (21.0”) between the harness slots and the lower anchors. The adjustment tab was adjusted to a residual



Figure 16. Second row right side integrated CSS

length of 22.9 cm (9.0"). The pre-crash position of the harness retainer clip was unknown. The harness retainer clip did not exhibit any abrasions or deformation. Minor stretch marks were present on the harness webbing. The loading to the right harness strap began 12.7 cm (5.0") below the harness slot and extended downward 33.0 cm (13.0"). The loading to the left harness strap began 6.4 cm (2.5") below the harness slot and extended downward 38.1 cm (15.0"). The plastic harness slots sustained only faint abrasions from the child loading against the harness straps.

The front right passenger stated that the driver secured the 3-year-old child in the integrated CSS. Due to his extremely limited vision and the fatality of the driver, he could not provide any information as to how the child was specifically restrained in the CSS.

SUPPLEMENTAL RESTRAINT SYSTEMS – 1994 PLYMOUTH VOYAGER

The 1994 Plymouth Voyager was equipped with frontal air bags for the driver and front right passenger positions that deployed as a result of the frontal impact. The driver's air bag (**Figure 17**) deployed from the center of the steering wheel hub from symmetrical H-configuration cover flaps. The cover flaps measured 5.7 cm (2.5") in height and 17.1 cm (6.8") in width. The driver's air bag measured 61.0 cm (24.0") in diameter. The driver's air bag was vented by two circular ports located at the 12 o'clock position on the rear of the air bag. The vent ports measured 2.5 cm (1.0") in diameter and were located 7.0 cm (2.8") from the circumferential seam and were spaced 5.1 cm (2.0") apart. The air bag was not tethered. The face of the air bag did not exhibit any contact evidence. The rear aspect of the air bag exhibited a moderate semi-circular scuff mark on the bottom left quadrant from compression against the steering wheel rim. The scuff mark measured 2.5 cm (1.0") in width and 22.9 cm (9.0") in length.



Figure 17. Deployed driver's air bag

The front right passenger's air bag (**Figure 18**) deployed from a top-mount module with a single cover flap design. The cover flap had been removed prior to the vehicle inspection and was not present in the vehicle. The front right passenger's air bag measured 66.0 cm (26.0") in height and 45.7 cm (18.0") in width. The air bag was vented through the porous bag membrane, as there were no vent ports located on the air bag. The air bag was tethered by two internal straps that measured 27.9 cm (11.0") in width and were located 12.7 cm (5.0") above and below the horizontal centerline of the air bag. The top panel and top and left side aspect of the face of the air bag exhibited blue discoloration. At the time of the vehicle inspection, the air bag and was found under the fractured



Figure 18. Deployed front right passenger's air bag

and out-of-place windshield. The discoloration was a result of moisture and sunlight, which transferred the blue tint at the top aspect of the windshield to the air bag fabric. A small area of orange fabric was present on the left seam on the air bag face. The fabric was located 5.1 cm (2.0”) above the horizontal centerline and measured 3.8 cm (1.5”) in height and 2.5 cm (1.0”) in width. What appeared to be two circular burn marks were present 5.7 cm (2.3”) left of the vertical centerline and 2.5 cm (1.0”) above and below the horizontal centerline, respectively. The upper burn mark measured 1.3 cm (0.5”) in diameter and the bottom burn mark measured 0.6 cm (0.3”) in diameter.

OCCUPANT DEMOGRAPHICS – 1994 PLYMOUTH VOYAGER

Driver

Age/Sex:	44-year-old/Female
Height:	Unknown
Weight:	Unknown
Seat Track Position:	15.9 cm (6.3”) rear of the full-forward track position and 4.4 cm (1.8”) forward of the full-rear track position
Manual Restraint Use:	Manual 3-point lap and shoulder belt
Usage Source:	Vehicle inspection
Eyewear:	Unknown
Type of Medical Treatment:	Fatally injured, expired at the scene

Driver Kinematics

The 44-year-old female driver was presumed to have been seated in an upright posture. She was restrained by the manual 3-point lap and shoulder belt and had the seat track adjusted to 15.9 cm (6.3”) rear of the full-forward track position and 4.4 cm (1.8”) forward of the full-rear track position. At the initial impact with the Cadillac, the frontal air bag system deployed and the driver initiated a forward trajectory. She loaded the safety belt and contacted the deployed driver’s air bag. Her knees struck the knee bolster, evidenced by scuff marks. The combination of the longitudinal intrusion of the instrument panel and the forward loading of the driver compressed the air bag and the steering column, deflecting the column upward. She also loaded through the air bag and deformed the steering wheel rim in a forward direction 10 cm (4”). She was redirected to the left as the Cadillac struck the Voyager in the sideslap configuration. Her lateral trajectory continued to the left as the Voyager rotated CW and traveled onto the roadside. The driver was redirected to the right as the Ford Ranger struck the right side of the Voyager. She rebounded to the left and came to rest in the vehicle. She sustained fatal injuries and expired at the scene. Per an attorney representing the front right occupant, she did not receive medical treatment and no records were available. An autopsy was not performed.

Front Right Passenger

Age/Sex: 56-year-old/Male
Height: Unknown
Weight: Unknown
Seat Track Position: 5.1 cm (2.0”) rear of full-forward and 10.2 cm (4.0”) forward of full-rear
Manual Restraint Use: Manual 3-point lap and shoulder belt
Usage Source: Vehicle inspection
Eyewear: Unknown
Type of Medical Treatment: Transported by ambulance to a local hospital, admitted for five days, and released

Front Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Left comminuted intertrochanteric fracture with associated avulsion of greater tuberosity	Serious (851810.3,2)	Indirect – Glove box door
Left 10 th rib fracture	Minor (450212.1,2)	Shoulder belt webbing
Chest contusion	Minor (490402.1,4)	Shoulder belt webbing
Abdominal abrasion	Minor (590202.1,0)	Lap belt webbing
Abdominal contusion	Minor (590402.1,0)	Lap belt webbing
Left elbow abrasion	Minor (790202.1,2)	Center instrument panel
Left elbow laceration	Minor (790602.1,2)	Center instrument panel

Injury source: Emergency room records, Radiology report

Front Right Passenger Kinematics

The 56-year-old male front right passenger was seated in an upright posture and restrained by the manual 3-point lap and shoulder belt. He stated during a brief interview that his vision was extremely poor. The seat track was positioned 5.1 cm (2.0”) rear of the full-forward track position and 10.2 cm (4.0”) forward of the full-rear track position. At impact with the Cadillac, the frontal air bag system deployed and the driver initiated a forward trajectory. He loaded the safety belt and deployed front right passenger’s air bag. His forward loading compressed the air bag against the instrument panel, evidenced by air bag-related abrasions on the left aspect of the right instrument panel. Due to the severity of the crash, the loading to the safety belt resulted in a chest contusion, a left 10th rib fracture, an abdominal contusion, and an abdominal abrasion. The front right passenger also sustained a left comminuted intertrochanteric fracture with associated avulsion of greater tuberosity, which was an indirect result of left knee compression against the glove box door. He was redirected to the left in response to the secondary sideslap and subsequent CW rotation as the Voyager departed the roadside and sustained a left elbow abrasion

and contusion from probable contact with the center instrument panel. He was redirected to the right as a result of the right side impact with the Ford Ranger. He contacted the interior surface of the right front door and rebounded to the left as the Voyager came to final rest. He was removed from the vehicle by rescue personnel and transported by ambulance to a local hospital where he was admitted for five days and released.

Second Row Right Child Passenger

Age/Sex: 3-year-old/Male
 Height: Unknown
 Weight: Unknown
 Seat Track Position: Fixed
 Manual Restraint Use: Forward-facing integrated CSS with a 5-point harness
 Usage Source: Vehicle inspection, CSS inspection
 Eyewear: None
 Type of Medical Treatment: Transported by ambulance to a local hospital and admitted for treatment

Second Row Right Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Facial laceration, NFS	Minor (290600.1,9)	Flying glass

Injury source: Interview with front right passenger

Second Row Right Child Passenger Kinematics

The 3-year-old male child was seated in the integrated CSS on the right position of the second row bench seat. He was seated in an upright posture and was restrained by the integrated 5-point harness system. At the initial impact with the DeVille, he initiated a forward trajectory and loaded the harness system of the integrated CSS. The child was redirected laterally to the left as the sideslap occurred and continued his lateral motion as the Voyager rotated in a CW direction and traveled onto the roadside. He was redirected to the right as the Ranger struck the right side aspect of the Voyager. Throughout the crash sequence, his lateral motion was mitigated due to being restrained in the integrated CSS. The child sustained a facial laceration, which probably resulted from flying glass. The 3-year-old was removed from the CSS by rescue personnel and was transported by ambulance to a local hospital and admitted for treatment.

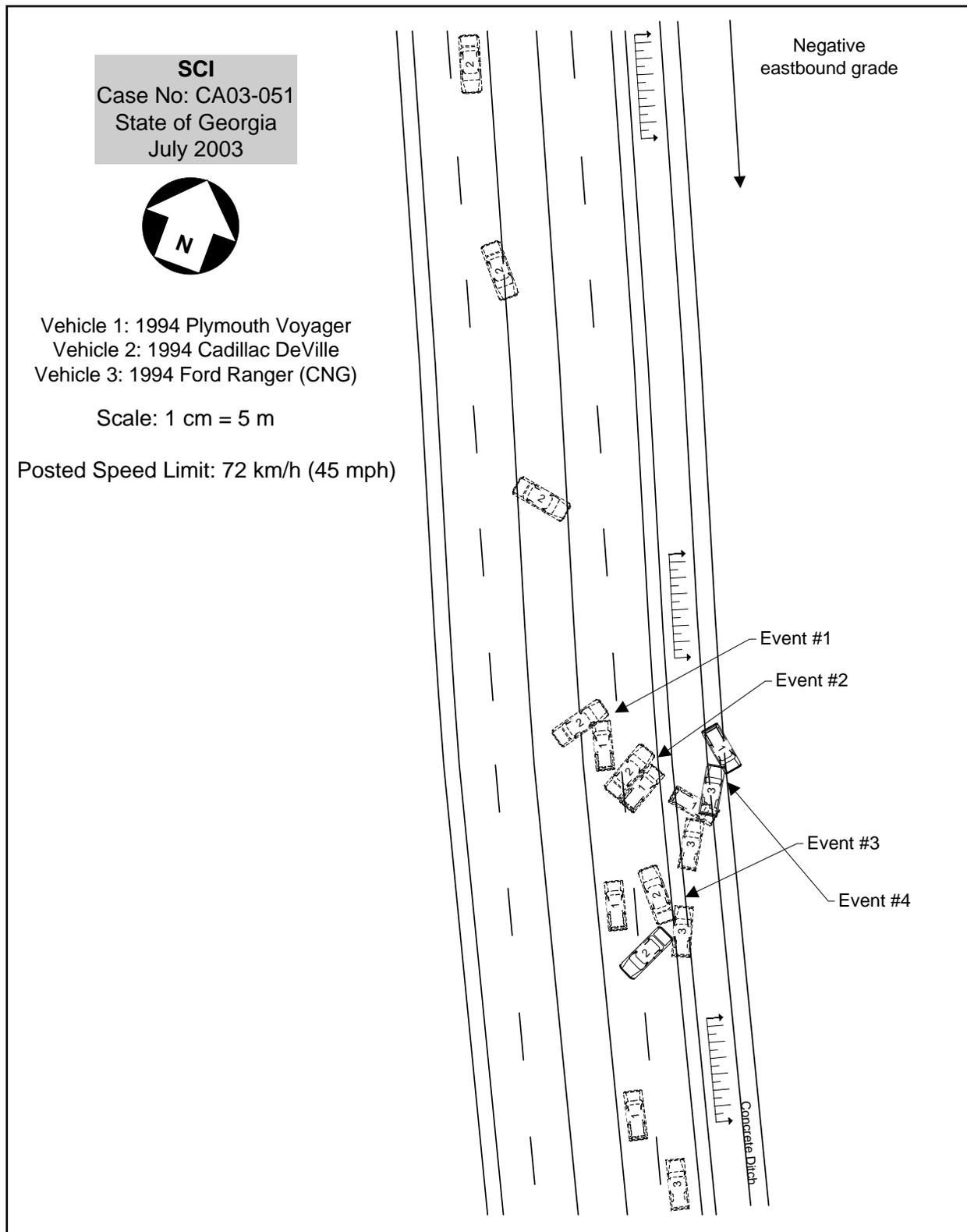


Figure 19. Scene schematic

Appendix A: Schematic of A Commercial Aftermarket CNG Conversion System