TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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VERIDIAN ON-SITE SIDE IMPACT AIR BAG INVESTIGATION

VERIDIAN CASE NO. CA99-21

VEHICLE - 1997 CADILLAC DEVILLE

LOCATION - STATE OF NEW YORK

CRASH DATE - JUNE, 1999

Contract No. DTNH22-94-D-07058

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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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On-site investigation of an acute angle collision that involved a 1997 Cadillac Deville 4-door sedan equipped with front and side impact air bags.

16. *Abstract*
This on-site investigation focused on the injury mechanisms of an 83 year old male driver of a 1997 Cadillac Deville 4-door sedan. The vehicle was equipped with frontal air bags for the driver and right passenger positions which deployed as a result of an acute angle collision with a 1997 Plymouth Grand Voyager SE. The Cadillac was also equipped with side impact air bags for the driver and right front passenger positions which did not deploy during the crash. The investigation allowed a closer evaluation of the vehicle damage/resultant principal direction of force (PDOF) and its association with the non-deployment of the side impact air bag system.

The Cadillac was westbound and attempted to turn left (south) at a 3-leg intersection when it crossed into the path of the northbound Plymouth. As the Cadillac crossed the northbound lanes the front left area of the Plymouth impacted the left passenger area of the Cadillac. The impact resulted in moderate damage to both vehicles. The 83 year old male driver of the 1997 Cadillac Deville was improperly restrained by the available 3-point manual lap and shoulder belt system with the shoulder belt placed under the arm. At impact, he initiated a forward/lateral trajectory in response to the 10 o'clock impact force and loaded the manual restraint and deployed driver air bag. Although no injuries were reported as a result of contact to the driver air bag, loading of the manual restraint resulted in multiple contusions to the left upper chest. He also sustained a fractured left scapula, contusions to the left ribs (with a collapsed left lung) and a left pneumothorax from loading to the door panel. Contact to the door armrest resulted in contusions of the left pelvis and thigh. The driver of the Cadillac Deville was transported to a local trauma center for treatment and admitted for 8 days. The driver and rear seated child occupants of the Plymouth Grand Voyager sustained multiple soft tissue injuries and sought treatment later at a medical facility.

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BACKGROUND

This on-site investigation focused on the injury mechanisms of an 83 year old male driver of a 1997 Cadillac Deville 4-door sedan. The vehicle was equipped with frontal air bags for the driver and right passenger positions which deployed as a result of an acute angle collision with a 1997 Plymouth Grand Voyager SE. The Cadillac was also equipped with side impact air bags for the driver and right front passenger positions which did not deploy during the crash. The investigation allowed a closer evaluation of the vehicle damage/resultant principal direction of force (PDOF) and its association with the non-deployment of the side impact air bag system.

The Cadillac was westbound and attempted to turn left (south) at a 3-leg intersection when it crossed into the path of the northbound Plymouth. As the Cadillac crossed the northbound lanes the front left area of the Plymouth impacted the left passenger area of the Cadillac. The impact resulted in moderate damage to both vehicles. The 83 year old male driver of the 1997 Cadillac Deville was improperly restrained by the available 3-point manual lap and shoulder belt system with the shoulder belt placed under the arm. At impact, he initiated a forward/lateral trajectory in response to the 10 o'clock impact force and loaded the manual restraint and deployed driver air bag. Although no injuries were reported as a result of contact to the driver air bag, loading of the manual restraint resulted in multiple contusions to the left upper chest. He also sustained a fractured left scapula, contusions to the left ribs (with a collapsed left lung) and a left pneumothorax from loading to the door panel. Contact to the door armrest resulted in contusions of the left pelvis and thigh. The driver of the Cadillac Deville was transported to a local trauma center for treatment and admitted for 8 days. The driver and rear seated child occupants of the Plymouth Grand Voyager sustained multiple soft tissue injuries and sought treatment later at a medical facility.

NHTSA was notified of the crash on Thursday, July 8, 1999 and assigned the case to the Veridian Special Crash Investigation Team on Friday, July 9, 1999 for an on-site investigative effort. The on-site team departed the morning of Monday, July 12, 1999 to conduct the local investigation.

SUMMARY

Crash Site

This two vehicle crash occurred during the afternoon hours of June, 1999. At the time of the crash, it was daylight with no adverse conditions as the roads were dry. The crash occurred on a state route that consisted of four travel lanes **(see Figure 8 - page 8)** that curved to the left for northbound traffic. The northbound travel lanes were divided by a painted median while the southbound lanes included a designated left turn lane. The intersecting road consisted of three lanes with a positive grade to the west which curved left for westbound traffic. Traffic control at the rural 3-leg intersection included a stop sign for westbound traffic (with an overhead red flashing signal) with a posted speed limit of 72 km/h (45 mph).

Pre-Crash

The 83 year old male driver of the 1997 Cadillac Deville was operating the vehicle westbound **(Figure 1)** on the 3-lane intersecting roadway. He stopped for the stop sign and failed to detect the Plymouth as he turned left to proceed south. The 39 year old female driver of the 1997 Plymouth Grand Voyager SE was operating the vehicle northbound at a (driver) reported speed of 72 km/h (45 mph) and negotiating a left curve **(Figure 2)** when she observed the Cadillac turn left across her path of travel. Upon recognition of the impending harmful event, the driver braked in avoidance (ABS equipped).

Figure 1. Westbound approach for the 1997 Cadillac Deville.

Figure 2. Northbound approach for the 1997 Plymouth Grand Voyager SE.

Crash

As the Cadillac crossed the northbound lanes of the 5 lane roadway, the front left area of the Plymouth struck the left passenger area of the Cadillac. Impact resulted in moderate damage to both vehicles. The impact induced deceleration was sufficient to deploy the Cadillac's frontal air bag system. The WinSMASH damage algorithm computed velocity changes of 26.8 km/h (16.7 mph) for the subject vehicle and 27.5 km/h (17.1 mph) for the striking Plymouth. Respective longitudinal components were -17.2 km/h (-10.7 mph) and -25.8 km/h (-16.0 mph). Respective lateral components were 20.5 km/h (12.7 mph) and -9.4 km/h (-5.8 mph). *This report will be updated with the Cadillac's Sensing and Diagnostic Module (SDM) data when received from General Motors.* The Collision Deformation Classification (CDC) for this impact to the Cadillac Deville was 10-LYEW-2 with a resultant direction of force of (-)50 degrees. The CDC for this impact to the Plymouth Grand Voyager was 01-FDEW-2 with a resultant direction of force of (+)20 degrees. Both vehicles came to rest in the southbound lanes with the Cadillac facing southwest and the Plymouth facing northwest.

Post-Crash

The driver of the Cadillac exited the vehicle through the right front door with some assistance. The driver of the Plymouth exited the vehicle under her own power as the child occupants exited with some assistance. Treatment was rendered at the scene by fire department personnel and emergency medical technicians (EMT). The driver of the Cadillac was transported to a local trauma center for treatment and admitted for 8 days. The driver of the Plymouth did not seek treatment but transported her children later to a private physician for evaluation. Both vehicles were towed from the scene.

VEHICLE DATA

The 1997 Cadillac Deville was identified by the vehicle identification number (VIN): 1G6KD54Y8VU (production number deleted). The police report listed the driver as the owner of the vehicle (purchased August 1997). The vehicle was a 4-door sedan equipped with front wheel drive and a 4.6 liter, V-8 Northstar engine. The vehicle's odometer reading was 11,675 km (7,255 miles) at the time of the crash. The seating was configured with a front split bench (with separate backs) and a rear bench. The driver reported no previous crashes or maintenance on the Cadillac's air bag system (original equipment). No cell phone was present or in use at the time of the collision.

EXTERIOR VEHICLE DAMAGE

Exterior - 1997 Cadillac Deville

Figure 3. Left side damage to the 1997 Cadillac Deville.

The Cadillac Deville sustained moderate left side damage as a result of the impact with the Plymouth Grand Voyager **(Figure 3)**. The direct contact damage began 23.0 cm (9.1 in) aft of the left front axle and extended rearward 181.0 cm (71.3 in) to the left rear door. The combined direct and induced damage length (Field L) was 241.0 cm (94.9 in). Six crush measurements were documented at the level of the mid-door: C1= 0 cm, C2= 20.0 cm (7.9 in), C3= 31.0 cm (12.2 in), C4= 30.0 cm (11.8 in), C5= 18.0 cm (7.1 in), C6= 0 cm. The Plymouth's front left headlight assembly was embedded between the left front fender and the leading edge of the front door. The crush pattern shattered the left front side glazing and produced induced buckling to the roof area at the left A and B-pillar. Induced damage was also noted to the left side window frames and rear door panel which bowed outward from the impact force. Reduction in the left side wheelbase measured 5.0 cm (2.0 in). The windshield fractured at the left upper/lower A-pillar from exterior impact forces as the right lower windshield fractured from the (interior) front right passenger air bag.

Exterior - 1997 Plymouth Grand Voyager SE

Figure 4. Frontal damage to the 1997 Plymouth Grand Voyager SE.

The Plymouth Grand Voyager SE sustained moderate frontal damage as a result of the impact with the Cadillac Deville **(Figure 4)**. Although the initial direct contact damage began at the front left bumper corner and extended 49.0 cm (19.3 in) inboard, subsequent wrap damage to the remainder of the front end occurred during sustained contact between the vehicles prior to separation. This resulted in a direct damage length which extended 154.0 cm (60.6 in) inboard along the *bumper fascia*. The impact deformed the full frontal width resulting in a combined direct and induced damage length (Field L) of 131.0 cm (51.6 in). Six crush measurements were documented at the level of the reinforcement bar (bumper cover separation): C1= 33.0 cm (13.0 in), C2= 31.0 cm (12.2 in), C3= 24.0 cm (9.4 in), C4= 19.0 cm (7.5 in), C5= 14.0 cm (5.5 in), C6= 6.0 cm (2.4 in). The front left headlight assembly separated and was found in the forward

door seam of the Cadillac. Induced damage was noted to the left fender which was displaced slightly rearward (left front wheel not restricted/deflated). Reduction in the left side wheelbase measured 4.0 cm (1.6 in). The windshield was undamaged with all side glazing intact. The end structure was displaced 5.0 cm (2.0 in) to the left [>10.2 cm (4.0 in) of end shifting required to increment the principal direction of force].

INTERIOR VEHICLE DAMAGE

Interior - 1997 Cadillac Deville

Interior damage to the Cadillac Deville identified through the vehicle inspection was moderate and was attributed to intrusions and occupant contact **(Figure 5)**. Superficial routine wear marks were documented to the latchplate of the front left 3-point manual lap and shoulder restraint along with (impact related) fabric transfers/blood spattering to the upper and lower sections of the webbing. The lower retractor assembly was restricted by the B-pillar intrusion with the belt in the extended (used) position. Blood transfers were noted to the lower portion of the driver air bag along with white vinyl transfers from expansion within the module. An indentation was identified on the left front armrest, door panel and knee bolster (padded type) along with scuff marks to the left instrument panel. The door panel hardware was scratched and out of place. A small scratch mark and blood transfer were documented on the left A-pillar. No loading to the steering wheel rim was found (tilt column between the full up and center positions). Blood spattering was noted on the face of the passenger air bag attributed to the driver's forearm injury as he exited the vehicle post-crash. The right windshield was fractured from deployment of the passenger air bag. Lateral intrusions into the driver space included 16.0 cm (2.3 in) of B-pillar intrusion, 11.0 cm (23.4 in) of door panel intrusion and 8.0 cm (12.2 in) of sill intrusion. Additional intrusions were documented to the rear left space which included 25.0 cm (12.3 in) of door panel intrusion and 19.0 cm (12.2 in) of sill intrusion.

Figure 5. Occupant contact damage to the vehicle interior.

Interior - 1997 Plymouth Grand Voyager SE

Interior damage to the Plymouth Grand Voyager identified through the vehicle inspection was minor and was attributed to occupant contact. Superficial routine wear marks were documented to the latchplate of the front left 3-point manual lap and shoulder restraint along with (impact related) fabric transfers to the shoulder portion of the webbing. A black mascara transfer was identified on the left upper quadrant of the driver air bag. Although no deformation was noted to the steering wheel rim or steering column (tilt column set to the full up position), the left instrument panel was fractured with scuff marks to the surrounding area. Superficial routine wear marks were also documented to the latchplates of the rear left and right 3-point manual lap and shoulder belts along with (impact related) loading marks to the shoulder webbings.

MANUAL RESTRAINT SYSTEMS

The interior of the Cadillac Deville consisted of a six passenger seating configuration with a split front bench (with separate backs) and a rear bench which accommodates three individual seating positions. The outboard seating positions were equipped with 3-point manual lap and shoulder belt systems (no pretensioners present) with continuous loop webbing and a sliding latchplate. Superficial wear marks were identified on the front left, right and rear left latchplates which supported routine usage. The front left lower retractor assembly was restricted by the lateral
B-pillar intrusion with the belt in the extended (used) position. Blood and fabric transfers were documented to the upper and lower portions of the webbing which were consistent with usage at the time of the crash. The front and rear center positions were equipped with a 2-point manual lap belt system.

AUTOMATIC RESTRAINT SYSTEMS

Figure 6. 1997 Cadillac Deville driver air bag.

The Cadillac was equipped with front air bags for the driver and right passenger positions. The frontal air bags deployed as a result of the crash. The driver air bag module was identified by the General Motors part number: *16758060* with a bar coded lot number of *10472A3*. The driver air bag was housed in the center of the steering wheel with a vertically oriented flap tear seam (I-configuration) which followed the contour of the Cadillac emblem on the center of the hub. The flaps were symmetrical in shape and measured 7.0 cm (9.3 in) in width and 10.5 cm (4.1 in) in height. No contact evidence was identified on the exterior surface of the module cover flaps, but light blood spattering was noted to the lower section of the air bag attributed to the driver's forearm injury. White vinyl transfers were also noted to the face of the bag from expansion within the module. The diameter of the driver air bag measured 63.5 cm (25.0 in) in its deflated state **(Figure 6)**. No internal tether straps were present. The bag was vented by two ports located at the 3 o'clock and 9 o'clock (centered) sectors on the rear aspect of the air bag.

The front right passenger air bag deployed from the right mid-instrument panel area with a module design recessed into the instrument panel. The passenger air bag module was identified by the General Motors part number: *Cadillac E/K* *16759479-17* with a bar coded lot number of: *TRAE70206330*. Although no contacts were identified to the exterior surface of the module cover flap, blood spattering was noted to the face of the air bag which was attributed to the driver's forearm injury as he exited the vehicle post-crash. The passenger air bag measured 44.0 cm (17.3 in) in width and 60.0 cm (23.6 in) in height in its deflated state. The bag was tethered by two internal straps and vented by two ports located at the 10 o'clock and 2 o'clock sectors on the side aspect of the air bag. Black vinyl transfers were found to the right (front/back) aspect of the air bag from expansion within the module. The right mid-windshield area was fractured from the normal deployment of the air bag.

The 1997 Cadillac Deville was also equipped with door-mounted side impact air bags for the front left and right seating positions. The air bags did not deploy as a result of the crash. The left side air bag was housed in the door panel above the armrest [36.0 cm (14.2 in) above floor level] with a horizontally

oriented flap tear seam (H-configuration). The air bag module was identified by the General Motors bar coded number: *AQ8076Q5R5HKJ2*. The sensor was identified by the bar coded number: *AT9116K271313V2J* with the lot number: 16209116. The flaps were rectangular in shape as the upper flap measured 28.5 cm (11.2 in) in width and 9.1 cm (3.6 in) in height while the lower flap measured 28.5 cm (11.2 in) in width and 8.4 cm (3.3 in) in height.

DRIVER DEMOGRAPHICS

Age/Sex:	83 year old male
Height:	180 cm (71 in)
Weight:	82 kg (180 lb)
Seat Track Position:	17.5 cm (6.9 in) aft of the forward most position
Manual Restraint Use:	3-point lap and shoulder belt system (improper usage)
Usage Source:	Vehicle inspection, driver interview, medical report
Eyeware:	Prescription glasses
Type of Medical Treatment:	Transported to a local hospital and admitted (8 days)

Driver Injuries

Injury	*Severity (AIS 90)*	*Injury Mechanism*
Left pneumothorax (with pleural effusion)	Serious (442202.3,2)	Left door panel
Fracture left scapula (subglenoid/blade: non-displaced)	Moderate (753000.2,2)	Left door panel
Contusion left ribs (with collapsed lung-left lower lobe)	Minor (450202.1,2)	Left door panel
Contusion left lateral chest (proximal to armpit)	Minor (490402.1,2)	Shoulder belt webbing
Contusion left medial chest	Minor (490402.1,2)	Shoulder belt webbing
Laceration left posterior hand	Minor (790602.1,2)	Left door panel hardware
Abrasion left posterior forearm (proximal to wrist- shape of half dollar)	Minor (790202.1,2)	Wristwatch (indirect contact injury from door hardware)
Avulsion left posterior forearm	Minor (790802.1,2)	Left door panel hardware
Laceration left elbow	Minor (790602.1,2)	Left door panel hardware
Contusion left hip	Minor (890402.1,2)	Left door panel armrest
Contusion left lateral thigh	Minor (890402.1,2)	Left door panel armrest
Laceration right knee	Minor (890602.1,1)	Steering column

Driver Kinematics

The 83 year old male driver of the 1997 Cadillac Deville was seated in an upright position with the seat back slightly reclined and the seat track adjusted 17.5 cm (6.9 in) aft of the forward most position. His left hand was placed on the door armrest with his right hand at the 3 o'clock sector on the steering wheel rim. He was improperly restrained by the available 3-point lap and shoulder belt system with the shoulder harness placed under the arm. This was evidenced by the SCI investigator's visual observation of the injury specifics in conjunction with the driver's demonstration of routine harness placement during the initial interview.

At impact, the driver initiated a forward/lateral trajectory in response to the 10 o'clock impact force and loaded the manual restraint and deployed driver air bag. Belt usage was confirmed by fabric transfers and the pattern of blood spattering to the upper and lower portions of the webbing **(Figure 7)** which were consistent with usage at the time of the crash, further evidenced by the restricted retractor assembly with the belt in the extended (used) position. Improper belt usage resulted in multiple contusions to the left upper chest area. No injuries were reported as a result of loading the deployed driver air bag. Loading of the left door panel resulted in a fractured left scapula, contusions of the left ribs (with a collapsed left lung) and a left pneumothorax, evidenced by the indentations and scuff marks documented to this component. He also sustained contusions of the left pelvis and thigh from contact to the door armrest as evidenced by the indentation and scuff marks documented to this component. As the driver continued the forward/lateral trajectory, his left elbow and (posterior) forearm struck the door hardware resulting in a laceration and avulsion of the soft tissue as evidenced by the displaced hardware and blood transfers to the surrounding area. This mechanism forced the wristwatch into the forearm resulting in a laceration and abrasion, evidenced by the size/shape of the injury relative to the kinematic response pattern.

Figure 7. Blood and fabric transfers to the shoulder restraint.

Following the collision, the driver observed "smoke" (venting air bag gases) in the vehicle and yelled for help while attempting to exit the vehicle. He exited the vehicle through the right front door with assistance from a witness and subsequently sat on a nearby ditchbank until the ambulance arrived. The driver was transported via ambulance to a local trauma center for treatment and admitted for 8 days.

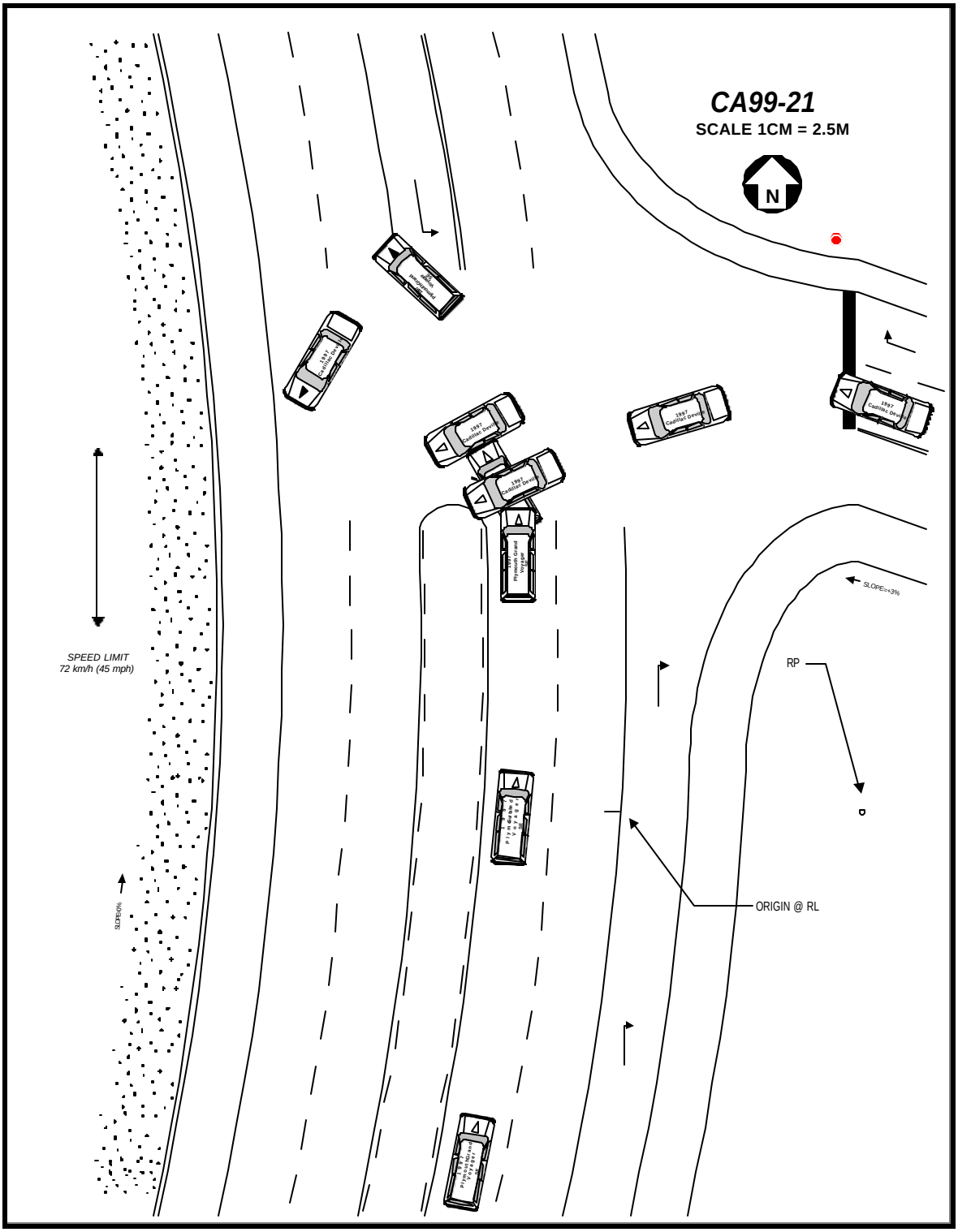

Figure 8. Scene Diagram