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ON-SITE ADAPTIVE CONTROL-EQUIPPED VEHICLE INVESTIGATION

CASE NUMBER - IN00-018
LOCATION - INDIANA
VEHICLE - 1997 DODGE RAM 2500
CRASH DATE - October, 2000

Submitted:

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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 be 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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15. <i>Supplementary Notes</i> On-site adaptive control-equipped vehicle investigation involving a 1997 Dodge Ram 2500 van, with manual safety belts, pretensioners, a driver's air bag, and adaptive controls, <u>and</u> a tree					
16. <i>Abstract</i> This report covers an on-site investigation of an adaptive control-equipped vehicle crash that involved a 1997 Dodge Ram 2500 van (case vehicle) and a tree. This crash is of special interest because the case vehicle was equipped with adaptive control equipment, and the case vehicle's unrestrained, paraplegic driver (27-year-old male) did not sustained any injuries as a result of the crash. The case vehicle was traveling south in southbound lane of a two-lane, undivided, city street (i.e., there was one lane in both the north and southbound directions). The case vehicle's driver unexplainably departed the right side of the roadway and, as a result, traveled along the west shoulder and roadside. The driver steered to the left and over-corrected, enabling the case vehicle to re-enter the roadway. The case vehicle traveled transversely across both lanes and off the east edge of the roadway, while rotating slightly counterclockwise. The case vehicle continued eastward on the roadside through a residential lawn. The crash occurred approximately 15 meters (49.2 feet) from the east edge of the roadway in the front yard of a house. Initially the front left bumper corner of the case vehicle impacted (i.e., a very narrow frontal impact) a large tree. Shortly thereafter, the left front wheel snagged on the tree, causing the case vehicle's driver supplemental restraint (air bag) to deploy. After impacting the tree the case vehicle rotated approximately 80 degrees counterclockwise prior to coming to rest, heading north-northwest. The case vehicle's driver was seated upright with the seat track of his six-way power seat located in its forward-most position, and the tilt steering wheel was located in its middle position. He was not using his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a pretensioner which had fired properly by pulling the slack out of the webbing making it taut. The driver, according to his interview, did not sustain any injuries as a result of this crash.					
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TABLE OF CONTENTS

IN00-018

Page No.

BACKGROUND 1

SUMMARY 1

CRASH CIRCUMSTANCES 3

CASE VEHICLE: 1997 DODGE RAM INCOMPLETE CONVERSION VAN 5

 CASE VEHICLE DAMAGE 6

 AUTOMATIC RESTRAINT SYSTEM 6

 ADAPTIVE CONTROLS 7

 CASE VEHICLE DRIVER KINEMATICS 8

 CASE VEHICLE DRIVER INJURIES 10

CRASH DIAGRAM 11

SELECTED PHOTOGRAPHS 12

 Figure 1: Case vehicle’s right roadway departure onto west shoulder 3

 Figure 2: Case vehicle’s transverse path across road from west shoulder
 area onto residential lawn and into tree 4

 Figure 3: Case vehicle’s damaged front left corner viewed from left of front 4

 Figure 4: Close-up of direct contact to case vehicle’s front left bumper 4

 Figure 5: Residential tree struck by case vehicle’s front left 5

 Figure 6: Close-up of case vehicle’s narrow front left corner engagement
 With tree 5

 Figure 7: Case vehicle’s front seating area showing no contact evidence 6

 Figure 8: Case vehicle’s deployed driver air bag 6

 Figure 9: Case vehicle’s driver foot well area viewed from left showing
 adaptive controls for parking brake and brake and throttle controls 7

 Figure 10: Close-up from left of center of case vehicle’s adaptive controls
 for parking brake and brake and throttle controls 7

 Figure 11: Close-up from right of center of case vehicle’s adaptive controls
 for parking brake and brake and throttle controls 7

 Figure 12: Case vehicle’s driver seat showing seat’s six-way power hand
 controls 7

	<u>Page No.</u>
SELECTED PHOTOGRAPHS (Continued)	
Figure 13: Close-up from floor level of case vehicle's driver seat showing six-way power control unit	8
Figure 14: Close-up of case vehicle's driver seat and safety belt with pretensioner engaged	8
Figure 15: Case vehicle's interior showing powered wheel chair lift and right side doors	9
Figure 16: Case vehicle's floor mounted, wheelchair lock-down system	12
Figure 17: Close-up of case vehicle's powered wheel chair lift	12

This on-site investigation was brought to NHTSA's attention on October 31, 2000 by NASS CDS sampling activities. This crash involved a 1997 Dodge Ram 2500 van (case vehicle) and a tree. The crash occurred in October, 2000, at 1:40 a.m., in Indiana and was investigated by the applicable city police department. This crash is of special interest because the case vehicle was equipped with adaptive control equipment and the case vehicle's unrestrained, paraplegic driver [27-year-old, White (Hispanic) male] did not sustained any injuries as a result of the crash. This contractor inspected the scene and vehicle on 2-3 November, 2000. This contractor interviewed the driver for the case vehicle on November 8, 2000. This report is based on the Police Crash Report, interviews with the case vehicle's driver, the investigating police officer, and a witness; scene and vehicle inspections; occupant kinematic principles; and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling south in southbound lane of a two-lane, undivided, city street and the driver intended to continue southbound towards his residence (i.e., there was one lane in both the north and southbound directions). The case vehicle's driver unexplainably departed the right side of the roadway and, as a result, traveled along the west shoulder and roadside. The driver steered to the left and over-corrected, enabling the case vehicle to re-enter the roadway. The case vehicle traveled transversely across both lanes and off the east edge of the roadway, while rotating slightly counterclockwise. The case vehicle continued eastward on the roadside through a residential lawn. Just prior to the crash, the case vehicle's driver made no avoidance maneuvers. The crash occurred approximately 15 meters (49.2 feet) from the east edge of the roadway in the front yard of a house owned by the witness to the crash; see **CRASH DIAGRAM** below.

Initially the front left bumper corner of the case vehicle impacted (i.e., a very narrow frontal impact) a large tree. Shortly thereafter, the left front wheel snagged on the tree, causing the case vehicle's driver supplemental restraint (air bag) to deploy. After impacting the tree the case vehicle rotated approximately 80 degrees counterclockwise prior to coming to rest, heading north-northwest.

The 1997 Dodge Ram 2500 was a rear wheel drive incomplete conversion van (VIN: 2B6HB21X5VK-----). The case vehicle was equipped with four-wheel, anti-lock brakes. Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FLAE-6 (10)**. No reconstruction program was used on this crash because it was out-of-scope (i.e., sideswipe type damage); however, this contractor's visually estimated Delta V is low [between 14-23 km.p.h. (9-14 m.p.h.)]. The case vehicle was towed due to damage.

The case vehicle's contact with the tree involved its front left (very narrow frontal) corner. Direct damage began 9 centimeters (3.5 inches) inward from the front left bumper corner. Because of the struck tree's angled growth, the direct damage above the bumper was greater than along the bumper and extended from the left fender inwards, a measured distance of 16 centimeters (6.3 inches). There was direct damage contact to the left "A"-pillar and windshield.

The direct damage extended along the left side, a measured distance of 79 centimeters (31.1 inches), and continued to the outside rearview mirror. The wheelbase on the case vehicle's left side was shortened 8 centimeters (3.1 inches) while the right side was extended 2 centimeters (0.8 inches). The case vehicle's front bumper, bumper fascia, grille, hood, front left headlight and turn signal assemblies, and left fender were directly damaged and crushed rearward. In addition, the left corner of the windshield was cracked and the left "A"-pillar and outside rearview mirror sustained tree contact. Furthermore, the case vehicle's left front wheel assembly was torn loose from the vehicle and the driver's door and was deformed rearward causing it to be jammed closed.

Because the driver was a paraplegic, the case vehicle was equipped with several adaptive controls designed specifically for drivers with disabilities. A **Mobility Products & Design** 3500 series single handle controller was used for both the brake and throttle controls and, in addition, a **Mobility Products & Design** raised parking brake handle was added. Also installed was a **Ricon** six-way, power seat base. This contractor's inspection of these adaptive controls showed no evidence of malfunction. The driver's interview confirmed this contractor's assessment of these items. The case vehicle was also equipped with a wheelchair lock-down, a **Ricon** internal power swing-door operator, and a **Ricon Personal Use** wheelchair lift.

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and air bag fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with four tethers, each 7.6 centimeters (3.0 inches) wide, sewn interiorly at the 1, 5, 7, and 11 o'clock positions. The driver's air bag had two vent ports, approximately 3.2 centimeters (1.25 inches) in diameter, located at the 11:30 and 12:30 o'clock positions. The deployed driver's air bag was round with a diameter of 65 centimeters (25.6 inches). There was no contact evidence readily apparent on the driver's air bag. There was no other visible evidence of occupant contact on the interior surfaces of the case vehicle.

Immediately prior to the crash the case vehicle's driver [180 centimeters and 84 kilograms (71 inches, 185 pounds)] was seated in an upright posture with his back against the seat back, both feet on the floor, his left hand on the hand controller, and his right hand on the steering wheel. His seat track was located in its forward-most position, the seat back was upright, and the tilt steering wheel was located in its middle position.

The case vehicle's driver was not using his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a pretensioner. There was no mention by the driver of belt pattern bruising and/or abrasions to his body. In addition, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate revealed that the pretensioner had fired, and the webbing was taut between the "D"-ring and the floor mounted housing indicating it was not in use at the time of the crash. Furthermore, there was no evidence of loading on any of these belt system components. Photographs taken by this contractor showed the pretensioner mechanism had worked properly by pulling the slack out of the webbing making it taut.

The case vehicle's departure off the west edge of the roadway and down a short incline had no effect on the unrestrained driver's torso. When the driver steered sharply to the left, attempting to get his vehicle back onto the roadway, his over-corrective steering maneuver combined with the nonuse of his available safety belts, resulted in the driver moving to his right while the case vehicle traveled transversely across the roadway. There was extra weight on the case vehicle's right side from the vehicle's wheelchair lift and power swing doors. This extra weight may have caused the vehicle to tip further to its right, relative to the vertical axis, contributing to the vehicle's counterclockwise yaw. As the case vehicle finished traversing the roadway and started crossing over the east shoulder and the residential lawn, the driver moved back to his left as the vehicle continued to accelerate. The case vehicle's impact with the tree enabled the driver to continue forward and slightly upward toward the 10 degree Direction of Principal Force as the case vehicle decelerated. The initial narrow end engagement and subsequent wheel interaction (i.e., similar to a sideswiping impact that starts on the side but results in pocketing) resulted in the air bag deploying late during the sequence of the impact. This delayed deployment occurred due to the prolonged change in time (Delta T) relative to the change in speed (magnitude of Delta V-i.e., ramp versus spike). It wasn't until the case vehicle's left front tire snagged on the tree that the driver's air bag deployed. According to the case vehicle's driver, the deploying air bag skirted his head and contacted his right shoulder, knocking him backwards into his seat back. When maximum engagement with the tree occurred, the case vehicle rotated rapidly counterclockwise. As a result of the counterclockwise rotation, the driver to move to his left, with respect to the vehicle, loading the left front door's interior surface, as the vehicle rotated underneath him. Given the driver's description of the air bag skirted his head and striking him on the right shoulder, it is most likely that the vehicle was beginning to move counterclockwise when the air bag deployed. As the vehicle continued to rotate counterclockwise and decelerated to rest, the driver rebounded off the door's surface and moved back towards his right. According to the driver, at final rest, he remained in his seat, but his exact posture is unknown.

The driver was transported by ambulance to the hospital for precautionary measures. According to his interview, he did not sustain any injuries as a result of this crash and was examined and released.

CRASH CIRCUMSTANCES

The case vehicle was traveling south in southbound lane of a two-lane, undivided, city street and the driver intended to continue southbound towards his residence (i.e., there was

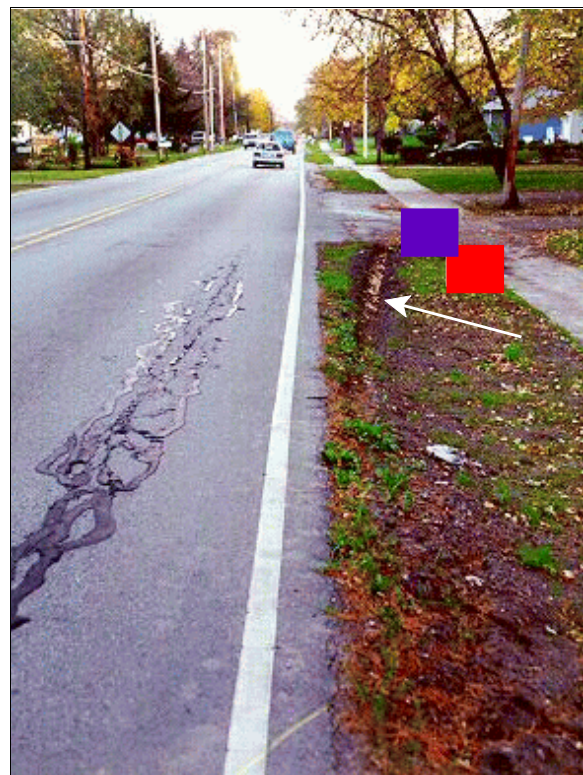


Figure 1: Case vehicle's right roadway departure which precipitated driver's overcorrection during re-entry onto roadway; Note: tire mark on unimproved shoulder (case photo #02)

one lane in both the north and southbound directions). The case vehicle's driver unexplainably departed the right side of the roadway and, as a result, traveled along the west shoulder and roadside (**Figure 1** above). The driver steered to the left and over-corrected, enabling the case vehicle to re-enter the roadway. The case vehicle traveled transversely across both lanes and off the east edge of the roadway, while rotating slightly counterclockwise. The case vehicle continued eastward on the roadside through a residential lawn (**Figure 2**). Just prior to the crash, the case vehicle's driver made no avoidance maneuvers. The crash occurred approximately 15 meters (49.2 feet) from the east edge of the roadway in the front yard of a house owned by the witness to the crash; see **CRASH DIAGRAM** below.



Figure 2: Case vehicle's transverse travel path across road from west shoulder area onto residential lawn and into tree; Note: arrows highlight tire scuffs (case photo #05)

The city roadway was straight and level at the area of impact. The pavement was bituminous, but traveled, and the width of both the travel lanes was 3.8 meters (12.5 feet). The shoulders were essentially not improved, with a narrow (unknown) paved (i.e., bituminous) shoulder adjacent to the grassy area on the both the east and west sides of the roadway. No curbs were present. Pavement markings consisted of a double solid yellow centerline for both north and southbound traffic. In addition, solid white edge lines were present. The estimated coefficient of friction was 0.65. There was a regulatory **STOP** sign (Manual on Uniform Traffic Control Devices, R1-1) approximately 40 meters (131 feet) north of the crash scene. The legal speed limit was 48 km.p.h. (30 m.p.h.). No regulatory speed limit sign was posted near the crash site. At the time of the crash the light condition was dark, but illuminated by overhead street lamps at the area of impact, the atmospheric condition was foggy, and the road pavement was dry. Traffic density was light, and the site of the crash was primarily urban residential.



Figure 3: Case vehicle's damaged front left corner viewed from left of front showing narrow corner damage extending down left side; Note: direct contact to left windshield, "A"-pillar, and outside mirror (case photo #26)



Figure 4: Close-up of direct contact (i.e., yellow tape outwards) to case vehicle's front left bumper corner from tree engagement (case photo #23)

Initially the front left bumper corner (**Figures 3 and 4**) of the case vehicle impacted (i.e., a very narrow frontal impact) a large tree (**Figure 5** below). Shortly thereafter, the left front

wheel snagged on the tree, causing the case vehicle's driver supplemental restraint (air bag) to deploy. After impacting the tree the case vehicle rotated approximately 80 degrees counterclockwise prior to coming to rest, heading north-northwest.

CASE VEHICLE

The 1997 Dodge Ram 2500 was a rear wheel drive, two-passenger, four-door, incomplete conversion van (VIN: 2B6HB21X5VK-----) equipped with a 3.9L, V-6 engine and a three-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum, four-wheel, anti-lock system. The case vehicle's wheelbase was 278 centimeters (109.6 inches), and the odometer reading at inspection was 98,099 kilometers (60,956 miles).



Figure 5: Residential tree struck by case vehicle's front left; Note: left front tire mark highlighted on wood timber (case photo #10)



Figure 6: Close-up of case vehicle's narrow front left corner engagement with tree; Note: missing left front wheel and width (i.e., yellow tape) of direct damage (case photo #27)

Inspection of the vehicle's interior revealed an adjustable (i.e., a six-way, power seat base) front bucket seat with integral head restraints for the driver; an adjustable front bucket seat with integral head restraints for the front right passenger; no other seats; and continuous loop, three-point, lap-and-shoulder, safety belt systems at the front outboard positions. The driver's seat (only) had a pretensioner in the retractor. The front seat belt systems were not equipped with manually operated height adjusters for the "D"-rings. The vehicle was equipped with a knee bolster for the driver's seating position, and it was not deformed. Automatic restraint was

provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver's seat position only. The driver's air bag deployed as a result of the case vehicle's very narrow frontal impact with the tree. In addition, the vehicle was equipped with adaptive controls; see **ADAPTIVE CONTROLS** below.

CASE VEHICLE DAMAGE

The case vehicle's contact with the tree involved its front left (very narrow frontal) corner. Direct damage began 9 centimeters (3.5 inches) inward from the front left bumper corner (**Figures 3 and 4** above). Because of the struck tree's angled growth (**Figure 5** above), the direct damage above the bumper was greater than along the bumper and extended from the left fender inwards, a measured distance of 16 centimeters (6.3 inches). There was direct damage contact to the left "A"-pillar and windshield. The direct damage extended along the left side, a measured distance of 79 centimeters (31.1 inches), and continued to the outside rearview mirror. The wheelbase on the case vehicle's left side was shortened 8 centimeters (3.1 inches) while the right side was extended 2 centimeters (0.8 inches). The case vehicle's front bumper, bumper fascia, grille, hood, front left headlight and turn signal assemblies, and left fender were directly damaged and crushed rearward. In addition, the left corner of the windshield was cracked and the left "A"-pillar and outside rearview mirror sustained tree contact. Furthermore, the case vehicle's left front wheel assembly was torn loose from the vehicle and the driver's door and was deformed rearward causing it to be jammed closed (**Figure 3** above and **Figure 6** above).

Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FLAE-6 (10)**. No reconstruction program was used on this crash because it was out-of-scope (i.e., sideswipe type damage); however, this contractor's visually estimated Delta V is low [between 14-23 km.p.h. (9-14 m.p.h.)]. The case vehicle was towed due to damage.

An examination of the case vehicle's interior revealed that there was no visible evidence of occupant contact on the interior surfaces of the case vehicle (**Figure 7**).

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that



Figure 7: Case vehicle's front seating area, greenhouse, interior surface of driver's door, and deployed driver's air bag showing no obvious evidence of occupant contact (case photo #43)



Figure 8: Case vehicle's deployed driver air bag; Note: no evidence of driver contact is visible (case photo #56)

contained a frontal air bags at the driver seating position. The driver’s air bag deployed as a result of the very narrow frontal impact with the tree. The case vehicle’s driver air bag was located in the steering wheel hub. The module cover consisted of asymmetrical “H”-configuration cover flaps made of thick vinyl with overall dimensions of 18 centimeters (7.1 inches) at the horizontal seam and 6.1 centimeters (2.4 inches) vertically for the upper flap and 6.7 centimeters (2.6 inches) vertically for the lower flap. An inspection of the air bag module’s cover flaps and air bag fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver’s air bag was designed with four tethers, each 7.6 centimeters (3.0 inches) wide, sewn interiorly at the 1, 5, 7, and 11 o’clock positions. The driver’s air bag had two vent ports, approximately 3.2 centimeters (1.25 inches) in diameter, located at the 11:30 and 12:30 o’clock positions. The deployed driver’s air bag was round with a diameter of 65 centimeters (25.6 inches). There was no contact evidence readily apparent on the driver’s air bag (**Figure 8** above).

ADAPTIVE CONTROLS



Figure 9: Case vehicle’s driver seating area viewed from driver’s door sill area showing vehicle’s adaptive equipped hand controls for parking brake and brake and throttle controls (case photo #39)



Figure 10: Close-up from left of center of case vehicle’s adaptive equipped control linkages for parking brake and brake and throttle controls (case photo #41)



Figure 11: Close-up from right of center of case vehicle’s adaptive equipped hand control linkages for parking brake and brake and throttle controls (case photo #42)



Figure 12: Case vehicle’s driver seat showing seat’s six-way powered hand controls (highlighted) along right side of seat; Note: deployed driver’s air bag and three-point safety belt system (case photo #47)

Because the driver was paraplegic, the case vehicle was equipped with several adaptive controls designed specifically for drivers with disabilities. A **Mobility Products & Design** 3500 series hand control was used for both the brake and throttle controls and, in addition, a **Mobility Products & Design** raised parking brake handle was added (**Figures 9** through **11** above). Also installed was a **Ricon** six-way, power seat base (**Figure 12** above and **Figure 13**). This contractor's inspection of these adaptive controls showed no evidence of malfunction. The driver's interview confirmed this contractor's assessment of these items. The case vehicle was also equipped with a wheelchair lock-down (see **SELECTED PHOTOGRAPHS, Figure 16** below), a **Ricon** internal power swing-door operator, and a **Ricon Personal Use** wheelchair lift (see **SELECTED PHOTOGRAPHS, Figure 17** below). According to the interview with the case vehicle's driver, the adaptive controls did not affect the vehicle's control loss.

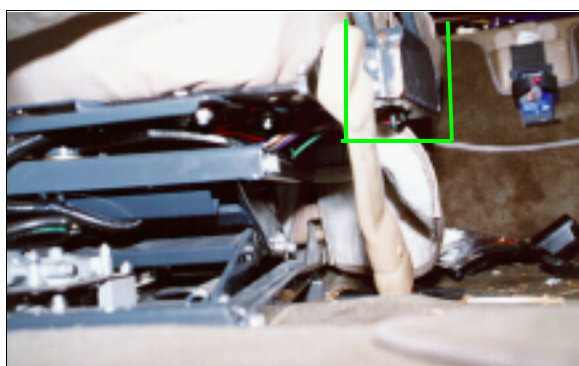


Figure 13: Close-up from floor level of case vehicle's driver seat showing (highlighted) six-way power control unit and seat belt post (case photo #49)

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash the case vehicle's driver [180 centimeters and 84 kilograms (71 inches, 185 pounds)] was seated in an upright posture with his back against the seat back, both feet on the floor, his left hand on the hand controller, and his right hand on the steering wheel. His seat track was located in its forward-most position, the seat back was upright, and the tilt steering wheel was located in its middle position.

The case vehicle's driver was not using his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a pretensioner. There was no mention by the driver of belt pattern bruising and/or abrasions to



Figure 14: Close-up of case vehicle's driver seat and safety belt system showing pretensioner engaged (case photo #44)

his body. In addition, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate revealed that the pretensioner had fired, and the webbing was taut between the "D"-ring and the floor mounted housing indicating it was not in use at the time of the crash. Furthermore, there was no evidence of loading on any of these belt system components. Photographs taken by this contractor (**Figure 14** above) showed the pretensioner mechanism had worked properly by pulling the slack out of the webbing making it taut.

The case vehicle's departure off the west edge of the roadway and down a short incline had no effect on the unrestrained driver's torso. When the driver steered sharply to the left, attempting to get his vehicle back onto the roadway, his over-corrective steering maneuver combined with the nonuse of his available safety belts, resulted in the driver moving to his right while the case vehicle traveled transversely across the roadway. There was extra weight on the case vehicle's right side from the vehicle's wheelchair lift and power swing doors (**Figure 15** and see **SELECTED PHOTOGRAPHS, Figure 17** below). This extra weight may have caused the vehicle to tip further



Figure 15: Case vehicle's interior "cargo area" viewed from back showing wheelchair lift and powered right side doors (case photo #59)

to its right, relative to the vertical axis, contributing to the vehicle's counterclockwise yaw. As the case vehicle finished traversing the roadway and started crossing over the east shoulder and the residential lawn, the driver moved back to his left as the vehicle continued to accelerate. The case vehicle's impact with the tree enabled the driver to continue forward and slightly upward toward the 10 degree Direction of Principal Force as the case vehicle decelerated. The initial narrow end engagement and subsequent wheel interaction (i.e., similar to a sideswiping impact that starts on the side but results in pocketing) resulted in the air bag deploying late during the sequence of the impact. This delayed deployment occurred due to the prolonged change in time (ΔT) relative to the change in speed (magnitude of ΔV —i.e., ramp versus spike). It wasn't until the case vehicle's left front tire snagged on the tree that the driver's air bag deployed. According to the case vehicle's driver, the deploying air bag skirted his head and contacted his right shoulder, knocking him backwards into his seat back. When maximum engagement with the tree occurred, the case vehicle rotated rapidly counterclockwise. As a result of the counterclockwise rotation, the driver to move to his left, with respect to the vehicle, loading the left front door's interior surface, as the vehicle rotated underneath him. Given the driver's description of the air bag skirting his head and striking him on the right shoulder, it is most likely that the vehicle was beginning to move counterclockwise when the air bag deployed. As the vehicle continued to rotate counterclockwise and decelerated to rest, the driver rebounded off the door's surface and moved back towards his right. According to the driver, at final rest, he remained in his seat, but his exact posture is unknown.

The driver was transported by ambulance to the hospital for precautionary measures. According to his interview, he did not sustain any injuries as a result of this crash and was examined and released.

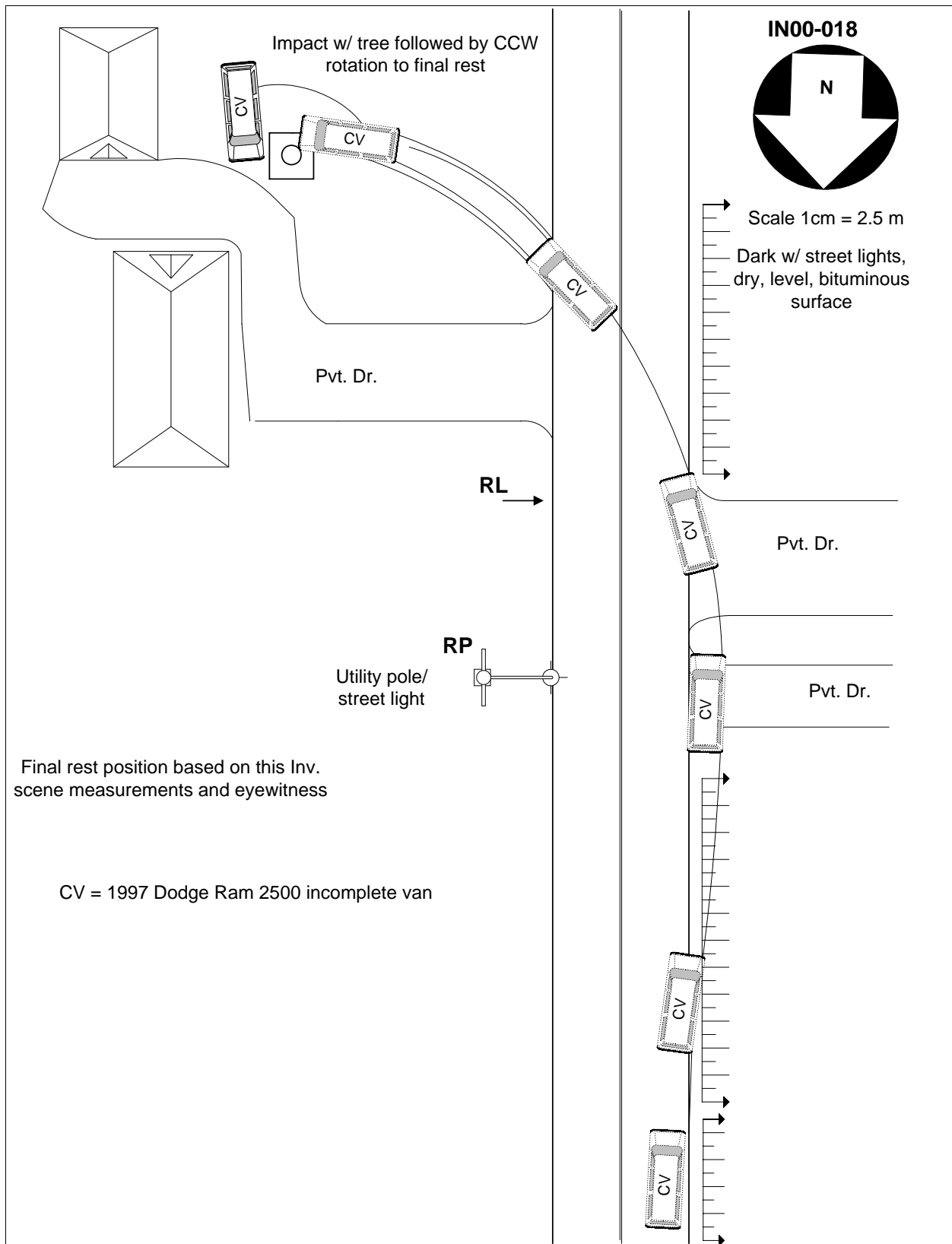




Figure 16: Case vehicle's floor mounted, wheelchair lock-down system located behind driver's seat and forward of left rear wheel well (case photo #60)



Figure 17: Close-up of case vehicle's powered wheelchair lift viewed from driver's seating area (case photo #62)