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ON-SITE ADVANCED OCCUPANT PROTECTION SYSTEM INVESTIGATION

CASE NUMBER - IN-02-006
LOCATION - TEXAS
VEHICLE - 2003 TOYOTA COROLLA LE
CRASH DATE - August 2002

Submitted:

March 23, 2004

Contract Number: DTNH22-01-C-07002

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
National Center for Statistics and Analysis
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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.

Technical Report Documentation Page

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16. *Abstract*

This report covers an on-site investigation of an air bag deployment crash that involved a 2003 Toyota Corolla LE and a fixed object (i.e., a traffic light pole). This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System features as well as an **E**vent **D**ata **R**ecorder (EDR) and the case vehicle's driver (37-year-old male) did not sustain any reported injuries as a result of the crash. The case vehicle was passing through a four-leg intersection, traveling west in the inside lane of a five-lane, divided, city trafficway (i.e., on the west leg of the intersection, both the east and westbound roadways had two through lanes while the eastbound roadway had a left-hand turn lane). A noncontact vehicle, which had been traveling south, made a right-hand turn at the intersecting roadway and was merging into the inside westbound lane, inhibiting the case vehicle's westward travel. The case vehicle's driver veered leftward into the median's curb. The crash occurred in the median of the trafficway. The left front wheel of the case vehicle impacted the median curb, depositing a scrape along the curb's concrete. The case vehicle continued westward and impacted the light pole in the median of the trafficway. The front left corner of the case vehicle collided with the light post, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle re-entered the westbound roadway and came to rest in the inside lane heading in a westerly direction. The case vehicle's driver was seated with his seat track located in between its middle and rearmost positions, and the tilt steering wheel was located in its upmost position. He was restrained by his available, active, three-point, lap-and-shoulder, safety belt system and did not sustain any injuries as a result of this crash.

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BACKGROUND IN-02-006

This on-site investigation was brought to NHTSA's attention on September 27, 2002 by NASS GES sampling activities. This crash involved a 2003 Toyota Corolla LE (case vehicle). The crash occurred in August 2002, at 2:30 p.m., in Texas and was investigated by the applicable city police department. This crash is of special interest because the case vehicle was equipped with multiple **A**dvanced **O**ccupant **P**rotection **S**ystem (AOPS) features as well as an **E**vent **D**ata **R**ecorder (EDR) and the case vehicle's driver (37-year-old, Asian or Pacific Islander, male) did not sustain any reported injuries as a result of the crash. This contractor inspected the scene and vehicle on October 7, 2002, and a permission form to harvest the **E**lectronic **C**ontrol **U**nit, which houses the EDR technology, was signed by the insurance adjuster on the same day. This contractor interviewed the driver for the case vehicle on October 16, 2002. This report is based on the Police Crash Report, an interview with the case vehicle's driver, scene and vehicle inspections, occupant kinematic principles, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was passing through a four-leg intersection, traveling west in the inside lane of a five-lane, divided, city trafficway, and intended to continue traveling straight ahead (i.e., on the west leg of the intersection, both the east and westbound roadways had two through lanes while the eastbound roadway had a left-hand turn lane). According to the case vehicle's driver, a noncontact vehicle, which had been traveling south, made a right-hand turn at the intersecting roadway and was merging into the inside westbound lane, inhibiting the case vehicle's westward travel. The case vehicle's driver avoided the noncontact vehicle by braking and steering to the left, but as a result, the case vehicle veered leftward into the median's curb. The crash occurred in the median of the trafficway; see **CRASH DIAGRAM** at end.

The left front tire and wheel of the case vehicle impacted the median curb approximately 7 meters (23.0 feet) east of the light pole, depositing an approximate 1 meter (3.3 foot) scrape along the curb's concrete. The case vehicle continued westward and impacted the light pole in the median of the trafficway. Although the front bumper fascia was not present with the case vehicle at the time of this contractor's inspection, the damage to the case vehicle indicates that front left corner of the case vehicle collided with the light post, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. According to the case vehicle's driver, the case vehicle re-entered the westbound roadway and came to rest in the inside lane heading in a westerly direction.

The 2003 Toyota Corolla LE was a front wheel drive, four-door sedan (VIN: 1NXBR32E23Z------). The case vehicle was not equipped with anti-lock brakes. The case vehicle was equipped with multi stage frontal air bags and seat belt pretensioners with force limiters. Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **12-FLEE-4** (**0 degrees**)–for the light pole impact (2nd event), and **12-FLWN-3** (**0 degrees**)–for the curb impact (1st event). The WinSMASH reconstruction program, damage only algorithm was used on the case vehicle's highest severity impact with the light pole. The preliminary Total, Longitudinal, and Lateral Delta Vs are, respectively: 13.0 km.p.h. (8.1 m.p.h.), -13.0 km.p.h. (-8.1 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). It should be noted that the light pole impacted by the case vehicle

was sheared off by the case vehicle's left front wheel assembly. For this reason, the WinSMASH barrier results should be considered borderline and represent the uppermost limit of a delta V for this crash. However, based on this contractor's experience, the results appear reasonable.

The case vehicle's contact with the light post involved a small portion of the front left bumper corner as well as a large amount of the left front fender and wheel assembly. Direct damage began at the front left bumper corner and extended a short, but unknown distance toward the vehicle's center. Residual maximum crush was measured as 6 centimeters (2.4 inches) at C_1. More heavily damaged was the left fender, where most of the direct contact took place. The case vehicle's left front wheel was also sheared from the vehicle and this contributed to the wheelbase on the case vehicle's left side being shortened approximately 27 centimeters (10.6 inches) while the right side was extended approximately 1 centimeter (0.4 inches). The case vehicle's left fender was sheared from the vehicle, as were the front bumper fascia, grille, and left and right headlight and turn signal assemblies; although, it should be noted that these items may have been manually removed from the vehicle post crash. The case vehicle's right front and rear tires were not damaged, deflated, or physically restricted. Induced damage was also noted to the left front door. No obvious induced damage or remote buckling was noted to the remainder of the case vehicle's exterior.

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 the air bag's fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the cover flaps. Because the air bag's fabric was cut away from the module/wheel hub, the existence, number, and size of tethers or vent ports could not be assessed nor could the shape or size of the driver's air bag be described. The Police Crash Report made no mention of any evidence of contact or damage to the air bag's fabric.

The front right passenger's air bag was located in the top of the instrument panel. An inspection of the front right air bag module's cover flaps and the air bag's 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 front right passenger's air bag was designed without any tethers. The front right air bag had two vent ports, approximately 5.5 centimeters (2.2 inches) in diameter, located at the 10:30 and 2:30 o'clock positions. The deployed front right air bag was rectangular with a height of approximately 45 centimeters (17.7 inches) and a width of approximately 42 centimeters (16.5 inches). An inspection of the front right air bag's fabric revealed no contact evidence readily apparent on the air bag's fabric. Furthermore, there was no right front occupant, and there is no indication or evidence that driver contacted the front right air bag.

The Electronic Control Unit (**ECU**) for this vehicle was located underneath the center dash. The **ECU** was removed by this contractor and submitted to the agency. The **ECU** was sent to the manufacturer for data interpretation and no response has been received at the time of report submission.

Inspection of the case vehicle's interior revealed that there was no other evidence of occupant contact on the interior surfaces of the case vehicle. However, the right windshield's glazing was cracked but this was attributed to contact by the deploying front right passenger air bag's fabric. Furthermore, there was no evidence of intrusion to the case vehicle's interior, no evidence of compression to the energy absorbing sheer capsules in the steering column, and no deformation to the steering wheel rim.

Immediately prior to the crash, the case vehicle's driver [170 centimeters and 68 kilograms (67 inches, 150 pounds)] was seated in a slightly reclined posture with his back against the seat back, his left foot on the floor, his right foot on the brake, and both hands on the steering wheel rim. His seat track was located in between its middle and rearmost positions, and the tilt steering wheel was located in its upmost position.

The case vehicle's driver was restrained by his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a retractor-mounted pretensioner. Furthermore, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate revealed that the pretensioner had actuated, and the webbing was not retractable into the "B"-pillar, indicating it was in use at the time of the crash. In addition, there was trace evidence of loading on webbing near the "D"-ring.

The case vehicle's driver braked and steered to the left attempting to avoid the noncontact vehicle. As a result of these attempted avoidance maneuvers and the use of his available safety belts, he most likely moved slightly forward and to his right just prior to the curb impact. The case vehicle's impact with the curb had little or no effect upon the driver's posture as the case vehicle continued westward. The impact (i.e., deployment) with the light post caused the case vehicle's driver to continue forward and slightly leftward toward the case vehicle's **0** degree Direction of Principal Force as the case vehicle decelerated. As a result, he loaded his safety belts. 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 bags 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). The deploying driver air bag contacted the driver, most likely in his face and chest. As a result, he was propelled backwards into his seat back as the case vehicle continued forward. According to the case vehicle's driver, at final rest he was seated near his original pre-crash position, and he exited the vehicle with the assistance of the emergency medical personnel.

The driver was examined by the emergency medical personnel at the scene but was not transported by ambulance to the hospital. Although the case vehicle's driver indicated that he was "shaken up," he did not sustain any injuries as a result of this crash.

CRASH CIRCUMSTANCES

The case vehicle was passing through a four-leg intersection, traveling west in the inside lane of a five-lane, divided, city trafficway (**Figure 1** below), and intended to continue traveling straight ahead (i.e., on the west leg of the intersection, both the east and westbound roadways had

two through lanes while the eastbound roadway had a left-hand turn lane). According to the case vehicle's driver, a noncontact vehicle, which had been traveling south, made a right-hand turn at the intersecting roadway and was merging into the inside westbound lane, inhibiting the case vehicle's westward travel. The case vehicle's driver avoided the noncontact vehicle by braking and steering to the left, but as a result, the case vehicle veered leftward into the median's curb. The crash occurred in the median of the trafficway; see **CRASH DIAGRAM** at end.

Figure 1: Case vehicle's westward travel path in inside westbound lane showing impact location (i.e., arrow) with light pole, mounted in median (case photo #04)

Figure 2: Northeastward close-up view of impact to median curb from case vehicle's left front wheel (case photo #07)

Figure 3: Base of light pole, located in median, that was sheared by contact with case vehicle's left front wheel assembly (case photo #09a)

The city roadway was straight and level (i.e., actual slope was 1.9% negative to the west) at the area of impact. The pavement was concrete, and the width of the travel lanes for both vehicles was 3.8 meters (12.5 feet). The westbound roadway was bordered by barrier curbs, and a curb was associated with the 1.1 meter (3.6 feet) wide unprotected, raised, grassy median (**Figure 2**). Pavement markings consisted of a faint, dashed, white lane line that separated the inside and outside westbound lanes. Furthermore, no centerline or yellow "no passing" line (e.g., painted curb line) was present. In addition, no edge lines were present. The estimated coefficient of friction was 0.75. Traffic controls consisted of two ***SCHOOL ADVANCE*** warning signs (Manual on Uniform Traffic Control Devices, S1-1), located further west of the point of the crash site (**Figure 3**). The statutory speed limit was 64 km.p.h. (40 m.p.h.), but no regulatory speed limit sign was posted near the crash site. At the time of the crash the light condition was daylight, the atmospheric condition was clear and/or cloudy, and the road pavement was dry. Traffic density was light, and the site of the crash was primarily an urban residential and school area. In addition, there was a driveway within a short distance of the crash site (**Figures 1** and **3**).

The left front tire and wheel of the case vehicle impacted the median curb (**Figure 2**) approximately 7 meters (23.0 feet) east of the light

pole, depositing an approximate 1 meter (3.3 foot) scrape along the curb's concrete. The case vehicle continued westward and impacted the light pole in the median of the trafficway (**Figure 3** above). Although the front bumper fascia was not present with the case vehicle at the time of this contractor's inspection, the damage to the case vehicle indicates that front left corner (**Figure 4**) of the case vehicle collided with the light post, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. According to the case vehicle's driver, the case vehicle re-entered the westbound roadway and came to rest in the inside lane heading in a westerly direction (**Figure 5**).

Figure 4: Case vehicle's very narrow front left corner impact viewed along left side (case photo #16)

Figure 5: Eastward view in inside westbound lane from case vehicle's approximate final rest position; Note: wheel contact along median curb (orange paint) base of light pole (arrow) in median (case photo #09b)

CASE VEHICLE

The 2003 Toyota Corolla LE was a front wheel drive, five-passenger, four-door sedan (VIN: 1NXBR32E23Z------) equipped with a 1.8L, I-4 engine and a four-speed automatic transmission. The case vehicle was equipped with dual stage, redesigned, driver and front right passenger air bag inflators and seat belt pretensioners with force limiters. Four wheel, anti-lock brakes and front seat back-mounted side impact air bags were optional for this model, but this vehicle was not so equipped. Braking was achieved by a power-assisted, front disc and rear drum system. The case vehicle's wheelbase was 260 centimeters (102.4 inches), and the odometer reading at inspection is unknown because the case vehicle was equipped with an electronic odometer.

Inspection of the vehicle's interior revealed adjustable front bucket seats with adjustable head restraints; a non-adjustable back bench seat with adjustable head restraints for the back outboard seating positions; and continuous loop, three-point, lap-and-shoulder, safety belt systems at the front and back seating positions. The exact position adjustment for any of the adjustable head restraints was not determined. The front seat belt systems were equipped with manually operated, upper anchorage adjusters for the "D"-rings. Both the driver and front right passenger had their upper anchorage adjusters located in the upmost positions. The vehicle was equipped with knee bolsters for both the driver and front right seating positions, neither of which showed evidence of contact or deformation. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of an advanced frontal air bag for the driver and front right passenger seating

positions. Both frontal air bags deployed as a result of the case vehicle's frontal impact with the light pole.

CASE VEHICLE DAMAGE

Figure 6: Elevated view of case vehicle's very narrow front left corner impact; Note: left fender and left front wheel were torn off during impact (case photo #17)

Figure 7: Case vehicle's very narrow front left corner impact viewed along front reference line (case photo #12)

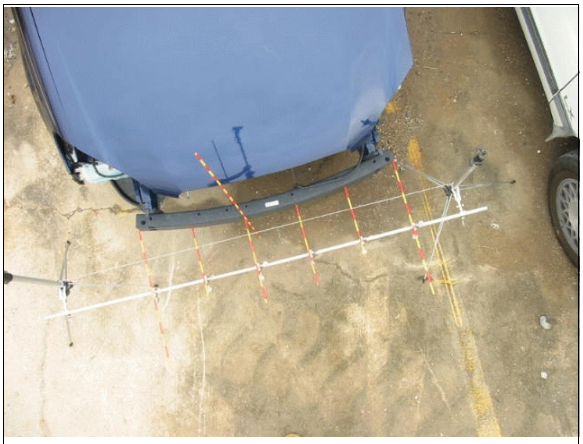


Figure 8: Overhead view of case vehicle crush profile with contour gauge present (case photo #13)

Figure 9: Case vehicle's left fender torn-off during impact with light pole; Note: slot for left headlight is towards left of photo (case photo #18)

The case vehicle's contact with the light post involved a small portion of the front left bumper corner as well as a large amount of the left front fender and wheel assembly (**Figure 6**). Direct damage began at the front left bumper corner and extended a short, but unknown distance toward the vehicle's center. Residual maximum crush was measured as 6 centimeters (2.4 inches) at C_1 (**Figures 7** and **8**). More heavily damaged was the left fender, where most of the direct contact took place. The case vehicle's left front wheel was also sheared from the vehicle and this contributed to the wheelbase on the case vehicle's left side being shortened approximately 27 centimeters (10.6 inches) while the right side was extended approximately 1 centimeter (0.4 inches). The case vehicle's left fender was sheared from the

vehicle (**Figure 9** above), as were the front bumper fascia, grille, and left and right headlight and turn signal assemblies (**Figures 4** and **6** above); although, it should be noted that these items may have been manually removed from the vehicle post crash. The case vehicle's right front and rear tires were not damaged, deflated, or physically restricted. Induced damage was also noted to the left front door. No obvious induced damage or remote buckling was noted to the remainder of the case vehicle's exterior.

Figure 10: Vertical view of case vehicle's driver seating area showing residual of deployed driver air bag absence of obvious occupant contact evidence (case photo #33)

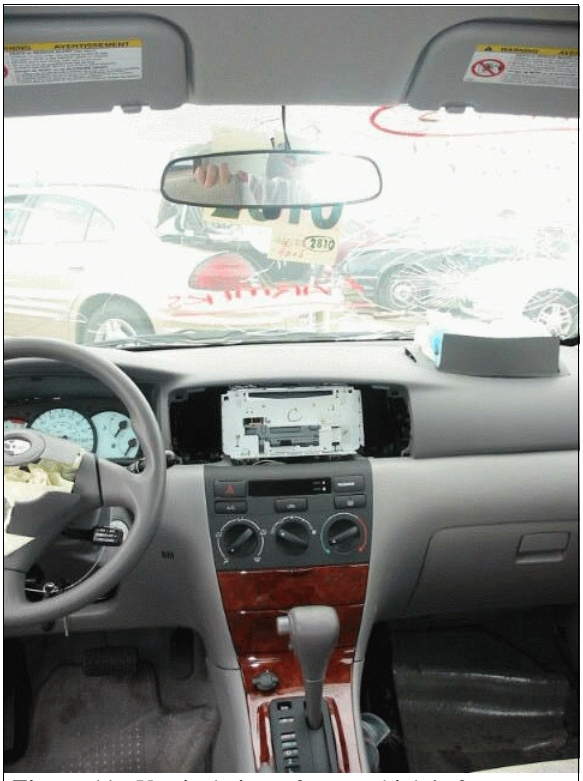


Figure 11: Vertical view of case vehicle's front seating and greenhouse areas showing absence of obvious occupant contact evidence and cracked right windshield's glazing–cracked from contact by front right air bag's fabric (case photo #34)

Inspection of the case vehicle's interior revealed that there was no other evidence of occupant contact on the interior surfaces of the case vehicle (**Figures 10** and **11**). However, the right windshield's glazing was cracked but this was attributed to contact by the deploying front right passenger air bag's fabric. Furthermore, there was no evidence of intrusion to the case vehicle's interior, no evidence of compression to the energy absorbing sheer capsules in the steering column, and no deformation to the steering wheel rim (**Figure 12**).

Figure 12: Case vehicle's undeformed steering wheel viewed from right and left "A"-pillar and side interior surfaces without occupant contact evidence (case photo #37)

Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **12-FLEE-4** (**0 degrees**)–for the light pole impact (2nd event), and **12-FLWN-3** (**0 degrees**)–for the curb impact (1st event). The WinSMASH reconstruction program, damage only algorithm was used on the case vehicle's highest severity impact with the light pole. The preliminary Total, Longitudinal, and Lateral Delta Vs are, respectively: 13.0 km.p.h. (8.1 m.p.h.), -13.0 km.p.h. (-8.1 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). It should be noted that the light pole impacted by the case vehicle was sheared off by the case vehicle's left front wheel assembly. For this reason, the WinSMASH barrier results should be considered borderline and represent the uppermost limit of a delta V for this crash. However, based on this contractor's experience, the results appear reasonable.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that contained advanced frontal air bags at the driver and front right passenger positions. Both frontal air bags deployed as a result of the frontal impact with the traffic light pole (2nd event). The case vehicle's driver air bag was located in the steering wheel hub. The module cover consisted of an inverted, triangular, curvilinear-shaped cover that contained three asymmetrical flaps made of thick vinyl. The top and largest flap was somewhat semicircular in design while the left and right lower flaps were obliquely oriented. The top cover flap had overall dimensions of 16 centimeters (6.3 inches) horizontally and 9 centimeters (3.5 inches) vertically at its widest point. The two bottom flaps were mirror imaged and each measured 8 centimeters (3.1 inches) horizontally to the hub and had an overall height of 8 centimeters (3.1 inches) vertically. An inspection of the air bag module's cover flaps and the air bag's fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the cover flaps (**Figure 13**). Because the air bag's fabric was cut away from the module/wheel hub (**Figure 14**), the existence, number, and size of tethers or vent ports could not be assessed nor could the shape or size of the driver's air bag be described. The Police Crash Report made no mention of any evidence of contact or damage to the air bag's fabric.

Figure 13: Case vehicle's steering wheel showing deployed driver air bag module's cover flaps and residual of cutout air bag's fabric (case photo #39)

Figure 14: Interior of case vehicle's driver air bag module showing residual of cutout air bag (case photo #42)

The front right passenger's air bag was located in the top of the instrument panel. There were two, symmetrical, "H"-configuration, modular cover flaps. The cover flaps were made of

thick vinyl with overall dimensions of 20.5 centimeters (8.1 inches) at the horizontal seam and 6 centimeters (2.4 inches) vertically for both the upper and lower flaps. The profile of the case vehicle's instrument panel resulted in a 13 centimeter (5.1 inch) setback of the leading edge of the cover flap relative to the protruding right instrument panel. An inspection of the front right air bag module's cover flaps and the air bag's 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 front right passenger's air bag was designed with without any tethers. The front right air bag had two vent ports, approximately 5.5 centimeters (2.2 inches) in diameter, located at the 10:30 and 2:30 o'clock positions. The deployed front right air bag was rectangular with a height of approximately 45 centimeters (17.7 inches) and a width of approximately 42 centimeters (16.5 inches). An inspection of the front right air bag's fabric revealed no contact evidence readily apparent on the air bag's fabric (**Figure 15**). Furthermore, there was no right front occupant, and there is no indication or evidence that driver contacted the front right air bag.

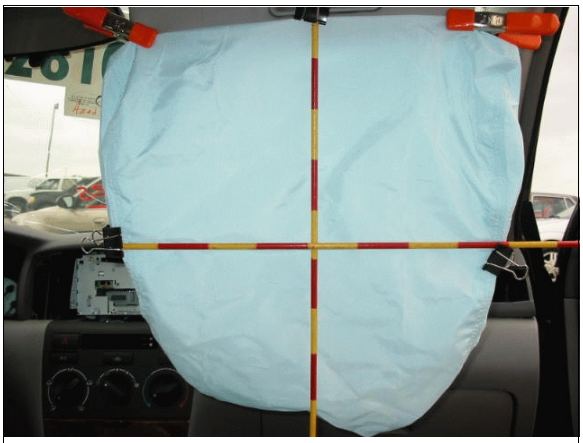


Figure 15: Case vehicle's deployed front right passenger air bag showing no occupant contact evidence (case photo #43)

EVENT DATA RECORDER

The **E**lectronic **C**ontrol **U**nit, which houses the EDR technology for this vehicle, was located underneath the center dash. The **ECU** was removed by this contractor and submitted to the agency. The **ECU** was sent to the manufacturer for data interpretation, and no response has been received at the time of report submission.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash, the case vehicle's driver [37-year-old, Asian or Pacific Islander, male; 170 centimeters and 68 kilograms (67 inches, 150 pounds)] was seated in a slightly reclined posture with his back against the seat back, his left foot on the floor, his right foot on the brake, and both hands on the steering wheel rim. His seat track was located in between its middle and rearmost positions, and the tilt steering wheel was located in its upmost position.

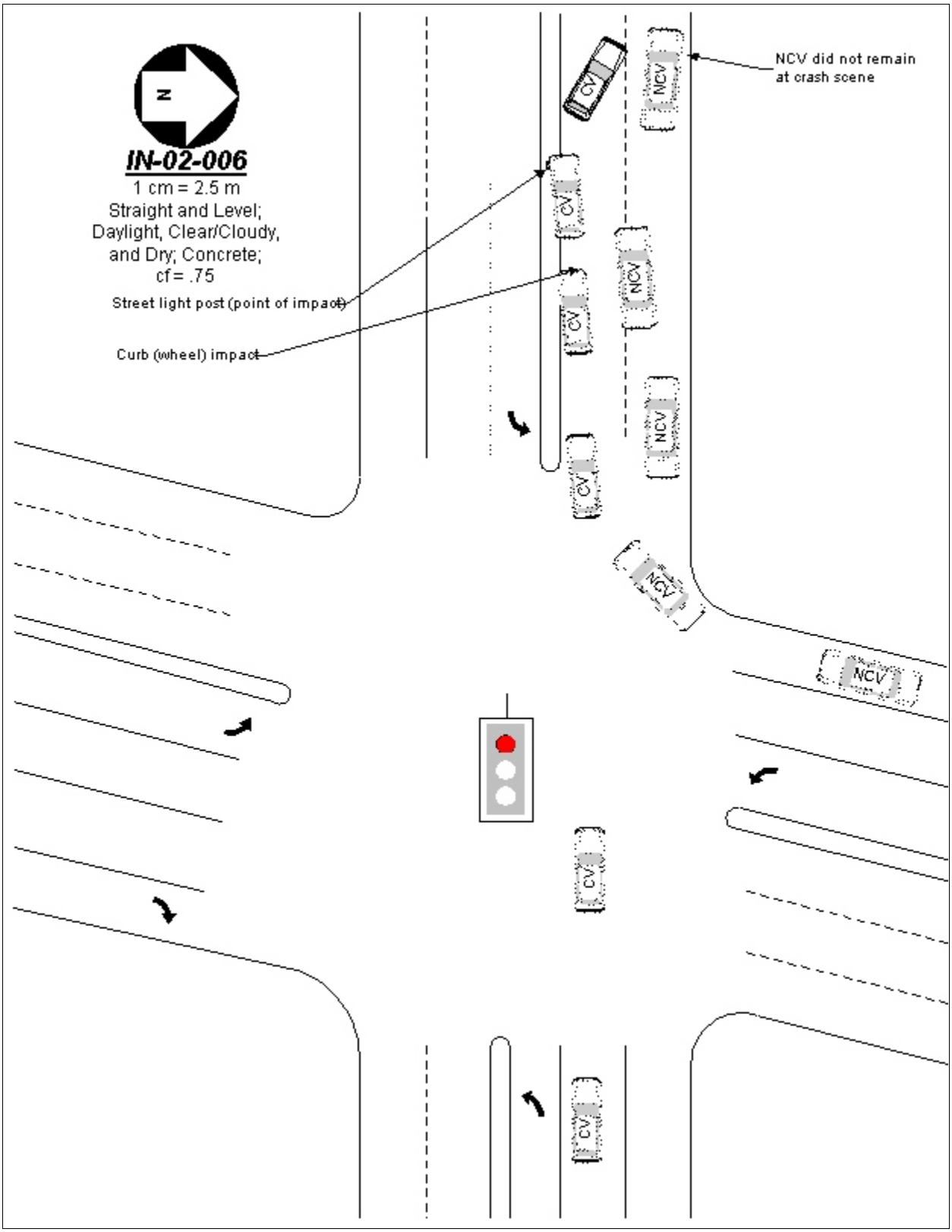
The case vehicle's driver was restrained by his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a retractor-mounted pretensioner. Furthermore, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate revealed that the pretensioner had actuated, and the webbing was not retractable into the "B"-pillar, indicating it was in use at the time of the crash. In addition, there was trace evidence of loading on webbing near the "D"-ring (**Figure 16** below).

Figure 16: Case vehicle's driver "D"-ring and webbing showing trace evidence of usage on webbing (case photo #29)

The case vehicle's driver braked and steered to the left attempting to avoid the noncontact vehicle. As a result of these attempted avoidance maneuvers and the use of his available safety belts, he most likely moved slightly forward and to his right just prior to the curb impact. The case vehicle's impact with the curb had little or no effect upon the driver's posture as the case vehicle continued westward. The impact (i.e., deployment) with the light post caused the case vehicle's driver to continue forward and slightly leftward toward the case vehicle's **0** degree Direction of Principal Force as the case vehicle decelerated. As a result, he loaded his safety belts. 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 bags 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). The deploying driver air bag contacted the driver, most likely in his face and chest. As a result, he was propelled backwards into his seat back as the case vehicle continued forward. According to the case vehicle's driver, at final rest he was seated near his original pre-crash position, and he exited the vehicle with the assistance of the emergency medical personnel.

CASE VEHICLE DRIVER INJURIES

The driver was examined by the emergency medical personnel at the scene but was not transported by ambulance to the hospital. Although the case vehicle's driver indicated that he was "shaken up", he did not sustain any injuries as a result of this crash.


N
IN-02-006
1 cm = 2.5 m
Straight and Level;
Daylight, Clear/Cloudy,
and Dry; Concrete;
cf = .75
Street light post (point of impact)
Curb (wheel) impact
NCV did not remain
at crash scene
CV
NCV