

**TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION**

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**CALSPAN ON-SITE ADAPTIVE CONTROL INVESTIGATION
CALSPAN CASE NO. CA98-04
VEHICLE: 1995 FORD E-150
LOCATION: NEW YORK
CRASH DATE: JANUARY 1998**

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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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CALSPAN ON-SITE ADAPTIVE CONTROL INVESTIGATION
CALSPAN CASE NO. CA98-04
LOCATION: NEW YORK
CRASH DATE: JANUARY, 1998

BACKGROUND

This on-site crash investigation focused on a 1995 Ford E150 conversion van that was equipped with adaptive controls to meet the requirements of the 54 year old male driver. He was a double amputee of the lower extremities with limited motion of the upper extremities due to chronic rotator cuff injuries. The driver was involved in a single vehicle run-off-road crash with a tree (**Figure 1**) during evening hours in January, 1998. The vehicle sustained moderately severe front right damage which resulted in a velocity change of 29.8 km/h (18.5 mph). The driver was operating the vehicle from his motorized wheelchair which was restrained by an EZ Lock restraint device. He was restrained by the manual 3-point lap and shoulder belt system with additional restraint provided by the deployment of the front driver air bag system. The combination of restraint systems protected the driver from potentially serious injuries. He did sustain multiple soft tissue injuries from loading the manual belt webbing.



Figure 1. Front right three-quarter view of the Ford E150 van.

The driver of the Ford E150 van notified NHTSA of the crash on January 22, and the investigation was assigned to Calspan's Special Crash Investigation Team on that afternoon. An on-site investigation was conducted on January 26-27, 1998. The investigation focused on numerous issues which included the crashworthiness of the vehicle, the type and performance of the adaptive controls, the interaction between the driver and the deployed frontal air bag, and the type and performance of restraints for the wheelchair positioned driver.

SUMMARY

Crash Site

The crash occurred on a two-lane rural roadway in a residential area during nighttime hours (**Figure 2**). In the vicinity of the crash site, the road was straight and level with a posted speed limit of 56 km/h (35 mph). A left curve (relative to the vehicle's direction of travel) terminated at a point that was 131 m (430') north of the impending crash site. The asphalt travel lanes were bordered by 0.9 m (2.9') paved shoulders with low profile snow banks bordering the shoulders. There was no physical evidence at the crash scene due to precipitation of rain and snow which had fallen since the crash.



Figure 2. Overall view of the crash site and the pre-crash trajectory of the Ford E150 van.

Pre-Crash

The driver of the Ford E150 van was traveling in a southeasterly direction on the dry asphalt road surface at a driver estimated travel speed of 56 km/h (35 mph). He had successfully negotiated a moderate right curve and was traveling on a straight segment of roadway (**Figure 2**). The vehicle drifted outboard of the white painted edge line onto the 0.9 m (2.9') paved shoulder and the snow covered lawn area adjacent to the shoulder. The driver applied a counterclockwise steering input which redirected the vehicle across the travel lanes and onto a snow covered lawn area.

Crash

The center and left aspects of the vehicle's windshield impacted two overhanging branches of the tree immediately prior to frontal engagement with the trunk of the tree. The front right area of the Ford E150 van impacted a 45.7 cm (18.0") diameter spruce tree that was located 6.9 m (22.8') outboard of the left edge line. The impact speed for the vehicle was computed at 30.3 km/h (18.8 mph) based on the damage and trajectory algorithm of the SMASH program. The damage profile yielded a velocity change of 29.8 km/h (18.5 mph). The energy dissipated by the crash was 182,533 joules. The tree impact deployed the frontal (driver only) air bag system. As the vehicle crushed to maximum engagement, the van rotated in a clockwise (CW) direction due to the front right corner impact and came to rest engaged against the tree.

Post-Crash

Immediately following the crash, the driver manually opened the left front door to vent the vehicle of the deployment gases from the air bag. He then remotely opened the right rear side doors (dual hinged doors) and deployed the wheelchair platform lift. He was unable to remotely disengage the EZ Lock restraint system for the wheelchair, therefore he remained in his chair and waited for rescue personnel to arrive on-scene. The driver attempted to call 911 on his cellular telephone, however, the crash occurred in an area with no cellular phone coverage.

The local volunteer fire department responded to the crash scene within 10 minutes of the crash. In addition, local residents and several passing motorists stopped at the crash scene to assist the driver. As the firemen arrived on-scene, they initially checked the vitals of the driver prior to initiating removal procedures. The driver then instructed the firemen to manually disengage the EZ Lock restraint device. Following this procedure, the driver attempted to operate the Quickie P200 motorized wheelchair, however, the joystick did not activate the drive mechanism. The firemen subsequently released the free-wheel locking mechanism on the chair and pushed the chair onto the deployed wheelchair platform lift. The driver was lifted from the chair at the floor height of the vehicle onto a stretcher and placed in an ambulance for warmth. He noted that he was susceptible to *thermo-regular dysfunction* which affects amputees and victims of paralysis due to rapid change of ambient temperature. The driver was subsequently transported to the local fire department where he waited for private transportation to his residence. He refused medical treatment and/or transport to a medical facility. While at the fire department, he checked the condition of his chair and noted that an electrical connection had separated during the crash which rendered the chair inoperative. A fireman re-plugged the connector which provided power to the wheelchair.

VEHICLE DAMAGE

Exterior

The front right area of the Ford E150 van impacted the tree. The initial contact involved the chromed steel front bumper area that was located outboard of the right frame rail. The lower grille, right headlight, and fiberglass hood subsequently impacted the tree. The direct contact damage began 47.0 cm (18.5") left of center and extended 41.9 cm (16.5") to the right front corner (**Figure 3**). The tree impact deformed the full width of the frontal structure which resulted in a combined direct and induced damage length of 170.2 cm (67.0"). Maximum crush was 59.1 cm (23.25") located at the lower radiator support level 74.9 cm (29.5") right of center. Two crush profiles were documented at the lower and upper levels of the radiator support due to separation of the front right bumper corner. The crush profile (**Figure 4**) at the lower radiator support was the best representation of crush profile and was documented as follows: C1=0 cm, C2=1.3 cm (0.5"), C3=3.6 cm (1.4"), C4=15.5 cm (6.1"), C5=38.7 cm (15.25"), and C6=56.9 cm (22.4"). The Collision Deformation Classification (CDC) was 12-FREW-4.



Figure 3. Overall view of the frontal damage.



Figure 4. Close -up view of the crush profile.

Windshield damage resulted from engagement against overhanging tree branches. The center impact area produced a star-like crack to the glazing that extended into the header area. The second impact point was located 17.8-45.7 cm (7.0-18.0") left of center, directly forward of the driver's position. This contact cracked the laminated glazing in a rectangular pattern and separated the outer layer of glass. There was no penetration of the plastic laminate or separation of the perimeter bond adhesive.

The frontal crush resulted in contact between the outboard aspect of the right front I-beam axle and the inner aspect of the right front wheel against the trunk of the tree. This contact deformed the alloy wheel (**Figure 5**) and rotated the steering system in a clockwise direction. As the right front wheel rotated to the lock position, the force load against the wheel and suspension components stripped the threads of the spindle nut and sheared the cotter key which resulted in separation of the outer bearing, washer, adjustment spindle nut, and the grease cap. The tow operator noted these components and the wheel hub cover lying adjacent to the right front wheel at the final rest position of the vehicle. (The driver/owner stated the front wheel bearings were re-packed with grease and the front-end was aligned on December 31, 1997. He further stated that he did not experience vibration or instability in the vehicle prior to the crash, therefore, this repair work was not a factor in the loss of control or the spindle nut separation).



Figure 5. Close-up view of the impact damage to the right front wheel.

Interior

The interior of the Ford E150 van sustained moderate damage that was associated with the exterior deformation which resulted in intrusion of frontal components. Intrusion of the passenger compartment to the Ford E150 van was limited to the front right occupant space (unoccupied). Maximum intrusion involved approximately 12.7 cm (5.0") of rearward displacement of the right toe pan and the lower A-pillar. The compression of the A-pillar bowed the right front door outward as the door remained closed during the crash. Intrusion of the upper right A-pillar was 7.6 cm (3.0") which resulted in cracking of the laminated windshield. In addition to the A-pillar displacement, the right mid instrument panel was displaced 7.6 cm (3.0") rearward. There was no forward displacement of the front right captain's chair.

The restrained driver loaded the deployed frontal air bag which prevented him from direct contact with the steering assembly. His loading force was absorbed by the belt system and the air bag as no damage resulted to the steering wheel. Furthermore, there was no compression of the energy absorbing steering column.

VEHICLE DATA/HISTORY

The involved 1995 Ford E150 van was manufactured on 3/95 as an incomplete vehicle and was modified as a conversion van by Tradewinds Conversions of Elkhart, IN. The vehicle was identified by vehicle identification number (VIN) 1FDEE14H6SH (production number omitted). The conversion process involved the installation of a high rise fiberglass top that extended the full width and length of the roof area, captains chairs for the front and second row of seating, a three passenger third seat with adjustable head restraints, large side windows between the left B- and C-, C- and D-pillars, and at the right C- and D-pillars. The interior of the conversion van was trimmed with fabric and wood accents. A color television with a VCR was mounted into the high rise roof area above the front seated positions, immediately forward of the B-pillars. The exterior of the van was finished with a series of horizontal stripes and aftermarket alloy wheels were mounted with P235/75R15XL all-season tires.

The driver/owner of the Ford E150 van originally purchased the vehicle as a complete conversion van from a Schenectady, NY Ford dealership on July 3, 1995. The original sticker price of the van was \$38,117.65, however, the purchase price was negotiated to \$33,000. The driver required specialized adaptive equipment for the vehicle to meet his driving requirements. This prescription was prepared by the Veteran's Administration (VA) Hospital in Albany, NY. The VA selected a local facility in the Albany area to install the adaptive equipment and perform the vehicle modifications. These included zero effort power steering and braking systems, a 15.2 cm(6.0") drop floor configuration, an EZ Lock wheelchair restraining device, a spinner knob on the steering wheel, an EMC Incorporated EGB II Silver Edition left hand operated acceleration/braking mechanism mounted to the left mid instrument panel, touch pads for the various functions of the van, a right side mounted wheelchair platform lift with remotely operated right side doors, and a remote camera backing system with a display monitor mounted to the center windshield header area. The modifications and installation of the adaptive equipment was performed by the Albany facility with components provided by a subcontractor and the drop floor system installed by a second subcontractor. Following the completion of these tasks, the driver received the van on October 19, 1995.

During the following months of usage, the driver experience numerous problems and noted safety violations with the van that he documented and provided in letter format to the Department of Veteran Affairs, dated July 18, 1997. (A copy of this letter was forwarded to NHTSA prior to this crash.) He subsequently fought through arbitration to gain the right to have the vehicle rebuilt which required the complete removal and replacement of the drop floor and removal and reinstallation of all adaptive equipment with proper rewiring of the components. This rebuilding process was completed by a specialty facility in New Hampshire (Ride-A-Way) over an extended time period of nearly one year which involved a delayed start time due to the arbitration. The vehicle was redelivered to the driver on June 27, 1997.

The driver returned the vehicle to the speciality facility in New Hampshire in September, 1997, for a follow-up inspection of the vehicle. While returning to his residence in New York State, the driver was involved in a minor front-to-rear impact sequence with another vehicle. He was subsequently reevaluated for range-of-motion in the upper extremities in October, 1997, as he was experiencing difficulty in rotating the OEM steering wheel although it was equipped with a spinner knob positioned on the inside of the steering wheel rim at the 2 o'clock sector. The reevaluation identified a deficiency in arm movement due to shoulder injuries (rotator cuffs), therefore it was recommended that a remote steering system should be installed in the vehicle.

In October, 1997, an estimate was generated in the amount of \$26,000 for the installation of a DS 2000 Digital Steering System by EMC. The van was transported to the New Hampshire speciality facility for the installation of this steering system and an auxiliary battery system. It should be noted that a tri-pin steering assist device was mounted on the DS 2000 system. This upgrade required extensive modifications to the steering column which defeated the OEM tilt mechanism. Due to the placement of a servo-system within the column, a locking pawl was removed from the column and a segment of the tilt joint was machined out. The OEM steering wheel was subsequently positioned in the full-up (tilt) position at the reinstallation of the column. The vehicle was available to the driver on January 6, 1998.

The driver returned to the New Hampshire facility on January 6th where he spent three days learning to operate the E150 with the DS 2000 remote steering system. He noted that he wanted to ensure that he was fully capable of operating the vehicle prior to departing New Hampshire. This crash subsequently occurred on the evening of January 21, as the driver was returning from a visit with his relatives.

ADAPTIVE CONTROLS/MODIFICATIONS

The Ford E150 van was extensively equipped with adaptive equipment that was required to meet the needs of the driver. An overall view of the interior and the adaptive equipment is provided in **Figure 6**. As previously noted, he was a double amputee of the lower extremities and had sustained multiple injuries of the shoulders (rotator cuffs) which restricted the motion and strength of his upper extremities. The driver's mobility was limited to the use of a motorized wheelchair, therefore he required a vehicle that could accommodate the wheelchair for both access to the van and as a position to drive the vehicle. The adaptive equipment and vehicle modifications included the following:



Figure 6. Overall view of the interior adaptive controls.

- A drop floor configuration was required to allow for the height of a wheelchair ramp/lift and to facilitate mobility of the driver within the vehicle. This was achieved by removing the majority of the original floor and installing a drop floor which provided an additional 15.2 cm (6.0") of overall interior height to the vehicle. The drop floor extended laterally between the sills of the van and longitudinally from the left toe pan area around the internal engine cover and base of the right front seat to the position of the third bench seat. The actual height gain was measured at 14.0 cm (5.5") on the inside of the vehicle. The drop floor was formed from 10 gauge sheet metal with 8 gauge sidewalls. Alloy body mount spacers that were 5.7 cm (2.25") in height were placed between the OEM rubber body mounts and the sheet metal body of the vehicle. It should be noted that the drop floor remained intact from the crash with no separation or buckling noted. All body mounts remained intact with the exception of the right front mount at the leading edge of the frame rail. The sheet metal was displaced due to the frontal crush which resulted in the separation of the upper mount from the body.
- The driver noted that following the initial modification of the van by the Albany contractor, at approximately 48,000 km (30,000 miles) of usage, he replaced the tires and was informed by the service facility that the right front shock mount was fractured. At this time, he authorized the replacement of the front shocks and the installation of rear air shocks with the addition of a helper spring added to the rear leaf springs. The original gross vehicle weight rating (GVWR) was 3,175 kg (7,000 lbs.). Although the weight of the vehicle following all modifications was unknown, it was doubtful that the vehicle exceeded the original GVWR.
- Due to the drop floor configuration, modification of the OEM fuel system was required. The OEM fuel tank was mounted forward of the rear axle between the frame rails with the fuel filler door mounted on the left side between the B-and C-pillars. A modified fuel system was installed in the vehicle with a 98 liter (26 gallon) steel fuel tank mounted between the frame rails, aft of the rear axle. The tank was manufactured by Transfer Flow and was identified by Serial No. 7D1717270 with a date of manufacture of 4/97. Due to the rearward placement of the tank, the fuel filler door was relocated aft of the rear axle on the left rear quarter panel. The OEM filler door remained in place, however, a plastic shield was fastened to the inner aspect of the unit which closed off the opening to the removed OEM filler tube. There was no damage to the aftermarket tank, retrofitted fuel lines, or leakage of fuel.
- Access to the vehicle was provided by a remote entry system which electrically opened the right side (dual hinged) doors. A backup system with a manually operated toggle switch was mounted inside the rear doors of the vehicle in the event of remote failure. An electro-hydraulic wheelchair platform lift (**Figure 7**) was mounted to the drop floor directly inboard of the



Figure 7. Platform lift.

right side doors. The platform lift was manufactured by Crow River Industries, Inc. and was identified by Serial No. 9509007 and Model No. 7684KAFF. The lift consisted of a fixed platform that rotated vertically within the vehicle for storage. When deployed, the driver would position the motorized chair on the lift at ground or van floor level, and activate the lift in a vertical motion to enter or exit the vehicle. The power unit of the lift was mounted at the OEM floor height of the vehicle adjacent to the right C-pillar. The overall dimensions of the lift platform were 68.6 cm (27.0") in width and 134.6 cm (53.0") in depth. There was no damage to the platform lift unit from the crash sequence.

- The steering and braking systems had been adapted to reduced effort systems. A second power steering pump was added to the vehicle by the initial transformation to an adaptive control vehicle. The representative from Ride-A-Way who installed the remote steering system noted that the remote system did not require a secondary pump, however, this system was left in place. In addition to the reduced effort steering system, a backup power steering system was installed. A red button was mounted on the top surface of the left front door panel at the forward third aspect of the panel. This button was labeled PSBUS which activated the power steering backup system when depressed.

- The acceleration and braking functions of the vehicle were controlled by a left hand operated EGB II, Silver Edition Series adapted control that was manufactured by EMC Inc. The unit was mounted to a bracket attached to the left mid instrument panel adjacent to the left door and protruded 38.1 cm (15.0") rearward of the instrument panel (**Figure 8**). The mounting bracket of the unit was equipped with a hinge point at the forward end which allowed the unit to rotate forward and upward to gain access to the driver's position from the left front door. A locking pin secured the unit in a horizontal position which was required to correctly operate these functions. Acceleration was achieved by sliding a T-handle in a forward direction while braking was controlled by pulling the T-handle in a rearward direction. There was no damage to the EGB II unit. In addition to the EGB II, a form fitted rigid foam pad was mounted on the rear third of the top of the left front door panel. This form fitted pad held the left forearm in position for the driver to comfortably operated the acceleration and braking functions. The overall dimensions of the pad were 12.7 x 29.2 cm (5.0") x (11.5").



Figure 8. EGB II hand control for throttle and brake functions.

- As previously noted in the Vehicle History section, the steering system had been equipped with a remote adaptive control unit (DS 2000 remote steering system) mounted to the mid center instrument panel. The OEM steering wheel remained in place for an able-bodied driver and to



Figure 9. Engagement of the upper module cover flap against the spinner knob.

support the driver's frontal air bag system. Prior to the installation of the DS 2000 remote steering system, an MPD spinner knob was mounted to the inner aspect of the steering wheel rim at the 2 o'clock position, immediately above the right upper spoke. Mounting was achieved by two band clamps affixed to the circumference of the wheel. The spinner knob was 4.8 cm (1.875") in diameter and protruded 5.1 cm (2.0") above the profile of the steering wheel rim. The knob was not damaged and rotated freely on its shaft mount. It should be noted that the asymmetrical upper cover flap for the driver's side air bag system contacted the spinner knob during the deployment sequence (**Figure 9**), however, no damage resulted from the contact. At the time of our inspection of the vehicle, the upper flap was engaged with the mounting bracket of the spinner knob. An aftermarket rubberized steering wheel cover was positioned over the OEM wheel.

- The remote steering system was identified as a DS 2000, Digital Steering System by EMC, Inc **Figure 10**. The unit was mounted horizontally to the center mid instrument panel above the removable engine cover. The overall dimensions of the DS 2000 unit were 19.1 cm (7.5") in length and 11.4 cm (4.5") in width. A 15.2 cm (6.0") diameter 3-spoke horizontally mounted wheel was affixed to a steering shaft that extended from the center of the unit 5.7 cm (2.25") forward of the rear edge of the unit. The driver



Figure 10. DS 2000 remote steering system.

operated the DS 2000 with his right hand that was positioned in a tri-pin adapted control mounted to the right spoke area of the three-spoke wheel of the DS 2000. The tri-pin base was 8.9 cm (3.5") in width at the bottom of the control with an overall length of 13.3 cm (5.25"). The wrist pins of the tri-pin device were positioned on 7.6 cm (3.0") centers with the hand grip pin positioned 10.8 cm (4.25") forward of the wrist pins. The tri-pins were 2.2 cm (0.875") in diameter and 8.6 cm (3.375") in height. During the crash, the driver's right hand probably loaded the tri-pin adapted control which slightly deformed the pivot shaft of the device. His hand subsequently separated from the tri-pin and impacted the mid instrument panel. There was no damage to the DS 2000 unit.

Although the steering was remote through the DS 2000, the unit was configured with a 2:1 ratio due to the small diameter of the wheel. The OEM steering wheel remained engaged with the steering system and the OEM wheel tracked the motion of the DS 2000. The adaptive steering system was also speed-sensitive at speeds in excess of 56 km/h (35 mph).

- Two touch pads were mounted in the E150 van which provided the driver with cluster controls to activate all functions for the vehicle. A rectangular 10.2-15.2 cm (4.0 x 6.0") Digipad II Silver Edition by EMC was mounted with four velcro tabs to the inboard aspect of the EGB II throttle and brake adaptive control bracket. This pad contained eight (two horizontal rows of four) touch pads which activated the exterior lights, wipers and washers, interior fan, cruise control system, and the dome light. There was no

damage to the touch pad and the unit was in position at the time of our inspection. The driver, however, noted that touch pad probably disengaged from the velcro mount during the crash sequence.

The second touch pad was mounted directly forward of the DS 2000 remote steering system. The pad was positioned at a angle of approximately 30 degrees which provided the driver with both visual and hand contact. This Digipad II Silver Edition Series by EMC, contained the same configuration of touch pads. The functions provided for right hand operation included ignition and start engine pads, parking brake, EZ Lock tie down release, left front and right front power window controls, auxiliary battery switch, and shifting of the automatic transmission. Lights for the various modes of the transmission functions (park, reverse, neutral, and drive) were positioned vertically at the right edge of the touch pad. There was no apparent damage to the touch pad.

- The right side doors and the platform lift were remotely operated by toggle switches mounted to the lower instrument panel right of the OEM steering column. The toggle switches were 3.2 cm (1.25") in length and were mounted horizontally. The left toggle switch operated the dual doors while the center switch folded and unfolded the wheelchair platform lift. The right switch operated the platform in both the up and down position. There was no damage to these switches, however, the placement of the switches could have been detrimental to an able bodied driver or a disabled driver with lower extremities (i.e., knee contact).
- The E150 van was equipped with a remote backing system that included a wide angle lens camera that was mounted to the back of the high-rise roof over the backlight header, a monitor mounted to the center windshield area of the passenger compartment, and an audible alarm. The outboard mounted camera was manufactured by Audiovox with an identifier of AOS-10. The camera was square in design and was protected by an exterior weather resistant case. The monitor was a 12.7 cm (5.0") diagonal screen incorporated into a black plastic case. The unit was also manufactured by Audiovox with the AOS-10 designation. There was no damage to the monitor or the mounting bracket.
- The driver's manual restraint system had been altered from the OEM restraint. The driver's side restraint system (**Figure 11**) consisted of a 3-point belt continuous loop belt with an inertia activated locking retractor mounted to the lower aspect of the left B-pillar. The upper anchorage was tethered to the left roof side rail rearward of the B-pillar. The lower anchorage was mounted to the sill directly forward of the retractor. The buckle for the left front belt was mounted to a rigid steel strap that extended the buckle vertically from the floor (**Figure 12**). The strap was 3.8 cm (1.5") wide and 55.9 cm (22.0") in length and was formed with a 90 degree angle at the floor for the anchorage point. The strap was bolted to the drop floor with a single Grade 8, 11 mm (7/16") diameter bolt.



Figure 11. Configuration of the left front manual belt system.



Figure 12. Rigid steel strap for vertical positioning of the belt buckle.

The driver was properly belted at the time of the crash. The continuous loop belt webbing was extended over the left arm of the Quickie P200 wheelchair and under the right arm of the chair, buckled into the elevated buckle assembly. This belt path provided the driver with the “best fit” of the restraint system. The lap belt segment of the webbing was engaged against a vertical tube of the chair. This tube was covered with a black vinyl wrap which transferred onto the lower segment of the webbing. The diagonally oriented black transfer was located on the interior aspect of the webbing 33.0-45.7 cm (13.0-18.0”) above the lap belt sill anchorage. An abrasion/gouge mark was located on the webbing immediately below the transfer on the forward aspect of the webbing. There was no other damage or contact evidence on the belt system. The modified buckle strap remained intact with no separation or bending of the lower attachment point.

In addition to the left front belt system, the driver’s prescription for the adaptive controls required a second restraint system for a wheelchair. This was required in the event the driver opted to transport an additional wheelchair passenger. The restraint was manufactured by Q’Straint and consisted of a long length of light blue belt webbing that was attached at the roof side rail and four brackets that were flush mounted in the drop floor. The belt webbing was 190.5 cm (75.0”) in length with a latchplate sewn to the end of the webbing. The floor anchorages were mounted in pairs with the forward pair positioned 26.7 cm (10.5”) rearward of the B-pillar and the rear pair positioned 134.6 cm (53.0”) rearward of the frontal brackets. The lateral spacing for the brackets were on 64.8 cm (25.5”) centers.

- The driver’s wheelchair was restrained by a electrically operated EZ Lock locking system (**Figure 13**) that was bolted to the drop floor of the vehicle. The system consisted of the mechanical locking unit and a front locator (inverted J-type hook). The EZ Lock base unit



Figure 13. EZ Lock wheelchair restraint system.

was identified by Model No. 6290 and had overall dimensions of 16.2 cm (6.375") laterally and 27.7 cm (10.125") fore and aft. A 2.5 cm (1.0") emergency release level extended from the forward right side of the unit. The device was bolted to the floor with four bolts located at the corners of the unit. The forward edge of the unit was mounted longitudinally at the forward aspect of the left B-pillar. The remote release was located on the touch pad that was positioned forward of the DS 2000 remote steering system. The front locator was bolted to the floor with four bolts and was located 19.1 cm (7.5") forward of the leading edge of the EZ Lock base unit. The front locator had an overall height of 10.2 cm (4.0") which provided lateral stability to the wheelchair.

A 2.5 cm (1.0") diameter bolt was threaded into the base of the Quickie P200 motorized wheelchair. As the driver positioned the chair in the driver's position of the vehicle, the forward aspect of the chair engaged with the front locator as the protruding bolt engaged into the tapered slot and locking pawl for the EZ Lock restraint. There was no evidence of loading or damage on the EZ Lock system, or deflection of the wheelchair bolt.

The right push handle on the back of the driver's chair was deflected in a rearward direction from probable rebound of the driver. There was no other damage visible on the chair or reported by the driver.

AUTOMATIC RESTRAINT SYSTEM

The 1995 Ford E150 van was equipped with a Supplemental Restraint System (SRS) that consisted of a frontal air bag system for the driver's position. The SRS deployed as a result of the frontal impact sequence with the struck tree. The driver air bag module was incorporated within the four spoke steering wheel rim. The OEM cruise controls were mounted on the wheel adjacent to the module cover between the spokes of the wheel. The air bag module cover was an H-configuration with asymmetrical cover flaps. The upper flap was 20.3 cm (8.0") in width with a height of 12.7 cm (5.0"). The lower cover flap was 20.3 cm (8.0") in width with a height of 3.8 cm (1.5"). Both cover flaps were molded of a rigid vinyl material and were approximately 4.8 mm (3/16") in thickness. The upper flap contacted the adaptive spinner knob that was mounted to the inner aspect of the steering wheel rim at the 2 o'clock position. The contact did not displace the knob or damage the cover flap. The flap was engaged (pinched) against the base of the spinner knob in the full open position at the time of vehicle inspection. There was no air bag contact evidence on the knob from the deploying air bag or suspected impedance of the bag's deployment path.

The air bag membrane was approximately 60.1 cm (24.0") in diameter and was tethered by four internal tethers. The tether panel was sewn to the face of the bag in a circular pattern that was 17.8 cm (7.0") in diameter. Maximum excursion of the bag in its deflated state was 27.9 cm (11.0") from the face of the module cover. The air bag was vented by two ports that were located at the 11 and 1 o'clock sectors. The ports were 3.8 cm (1.5") in diameter.

The bag was not damaged from its deployment sequence. Driver contact evidence was visible on the bag. Two faint red fabric transfers were noted to the left peripheral seam area of the bag at the 9 o'clock

sector. The 5.1 cm (2.0") diameter transfer resulted from interaction between the air bag and the red nylon jacket worn by the driver of the vehicle. A second faint red fabric transfer was noted to the 6 o'clock sector of the bag immediately above the peripheral seam on the face of the bag.

In addition to the red fabric transfers, several blood spatters were noted to the bag at the 3 and 6 o'clock positions. These blood spatters occurred post-crash from superficial abrasions to the right 5th finger and hand of the driver. The driver did not sustain injury from deployment of the driver air bag system. It should be noted that at the time of inspection, the steering wheel was rotated approximately 90 degrees in a counterclockwise (CCW) direction. This was the approximate orientation of the wheel at impact due to the CCW steering input initiated by the driver. This would have positioned the 9 o'clock sector of the bag in the path of the driver at deployment.

DRIVER DEMOGRAPHICS

Driver: 54 year old male
 Weight: 101.7 kg (226 lbs.)
 Manual Restraint
 Usage: 3-point lap and shoulder belt system
 Usage Source: Vehicle inspection, driver interview
 Eyewear: Prescription eyeglasses with metal frames; separated from face during crash but not damaged
 Vehicle Familiarity: Limited over 2.5 years of ownership due to installation of adaptive equipment and repairs to same, however, has amassed approximately 76,000 km (47,000 miles) of usage
 Route Familiarity: Travels frequently
 Trip Plan: Returning to residence
 Mode of Transport
 From Scene: Ambulance to local fire department where he waited for private transport to residence

DRIVER INJURIES

Injury	Injury Severity	Injury Mechanism
Contusion of the anterior left shoulder	Minor (790402.1,2)	Shoulder belt webbing
Abrasion of the anterior left shoulder	Minor (790202.1,2)	Shoulder belt webbing
Mid chest contusion	Minor (490402.1,4)	Shoulder belt webbing
Mid chest abrasion	Minor (490202.1,4)	Shoulder belt webbing
Right abdominal contusion	Minor (590402.1,1)	Shoulder belt webbing
Right abdominal abrasion	Minor (590202.1,1)	Shoulder belt webbing

Right anterior thigh contusion (over right stump)	Minor (890402.1,1)	Lap belt webbing
Right anterior thigh abrasion (over right stump)	Minor (890202.1,1)	Lap belt webbing
Two small abrasions of the right 5 th finger	Minor (790202.1,1)	Right touch pad/mid instrument panel

DRIVER KINEMATICS

The driver of the Ford E150 adaptive control van was a double amputee of the lower extremities at the level of the upper thighs with impairment of the upper extremities due to multiple injuries of the rotator cuffs. He was operating the vehicle from a Quickie P200 motorized wheelchair that was secured in the vehicle by an EZ Lock restraining device. The front aspect of the chair was positioned in the front locator which provided lateral restraint to the chair. The driver noted that his seated height was approximately 137.2 cm (54.0") and his weight was 102.5 kg (226.0 lbs.). He was wearing a long length red nylon wind breaker that was closed over his shirt and pants. In addition to his clothing, the driver was wearing prescription eyeglasses that consisted of metal frames.

The driver was operating the vehicle with a full compliment of adaptive equipment that included a DS 2000 remote steering system and an EGB II left hand control unit for the acceleration and braking functions. The OEM steering wheel was intact which contained the driver's side front air bag module. The tilt mechanism was defeated for the conversion of the remote steering system, however, the wheel was fixed in a full-up tilt position. During his operation of the vehicle, the driver's left hand was positioned on the EGB II with his forearm resting on a pad mounted to the top of the left front door panel. His right hand was positioned on the DS 2000 that was mounted to the mid instrument panel, immediately left of center. Both controls were positioned outboard of the OEM wheel.

On his approach to the impending crash scene, the driver applied a CCW counter steer maneuver through the DS 2000 as the vehicle initially departed the right road edge. The steering maneuver redirected the vehicle across the travel lanes and subsequently departed the left road edge. The driver could not recall applying the brakes through the EGB II adaptive control system. There was no evidence at the crash scene to support braking.

The driver was properly restrained the manual 3-point lap and shoulder belt system that was installed by the New Hampshire company responsible for the rebuild process of the vehicle. This belt system was similar to the OEM belt with a inertia activated locking retractor that was affixed to the sill at the B-pillar area adjacent to the lap belt anchorage. The upper anchorage (chrome plated D-ring) was tethered to the left roof side rail rearward of the B-pillar. The belt webbing was extended over the left arm of the wheelchair and across the torso of the driver. The latchplate was positioned under the right arm of the chair and buckled into the female buckle assembly that was mounted on a steel strap that extended 55.9 cm (22.0") vertically above the drop floor. This routing of the belt webbing properly positioned the shoulder belt webbing across the driver's torso with the lap belt aspect of the webbing positioned across his pelvic region.

At impact, the driver air bag deployed from the four-spoke steering wheel assembly. The driver responded to the 12 o'clock impact force by initiating a forward trajectory with respect to the decelerating vehicle. He initially loaded the manual belt webbing as the inertia activated retractor locked at impact. His loading force against the belt webbing resulted in a continuous diagonally oriented contusion with abrasion (AIS-1) that extended from the anterior left shoulder, across the mid chest area, onto the right lower quadrant of the abdomen. Although not witnessed, the driver noted that the contusion/abrasion extended onto the stump of his anterior right thigh.

His forward trajectory resulted in contact with the deployed driver's frontal air bag. Contact was determined by two faint red fabric transfers that were noted at the peripheral seam of the bag at the 9 o'clock and 6 o'clock position of the bag. This contact pattern suggests that the OEM steering wheel was rotated in a CCW direction as the driver contacted the air bag which was consistent with the pre-crash countersteer maneuver. The driver did not report injury from his involvement with the deployed air bag. There was no damage to the steering wheel rim as the lower rim area was exposed to the driver due to the upward position of the tilt mechanism.

The driver's right hand initially loaded the tri-pin steering assist that was mounted on the 15.2 cm (6.0") diameter wheel of the DS 2000 remote steering system. The suspected hand contact resulted in a slight deformation of the pivoting shaft for the tri-pin. His hand probably separated from the tri-pin steering assist and impacted the touch pad and/or mid instrument panel which resulted in two small abrasions of the right 5th finger. There was no contact evidence to support this contact sequence, however, the touch pad was dislodged from the velcro mount. The DS 2000 was not damaged from driver contact.

The driver's wire framed prescription eyeglasses separated from his face during the crash. He noted that the glasses came to rest on the drop floor of the vehicle and that the eyewear was not damaged. Therefore, due to the lack of damage to the eyeglasses and no facial abrasions were present, the eyeglasses probably separated from the impact force and not from air bag contact.

The driver rebounded into the low back rest of his wheelchair. His rebound trajectory was evidenced by a rearward deflection of the right vertical push handle on the chair. There was no other residual damage to the chair or complaint of injury by the driver.

POST-CRASH ACTIVITIES

Immediately following the crash, the driver detected a smoke-like substance within the vehicle that was associated with deployment of the air bag system. His initial concern was a vehicle or electrical fire. The driver manually opened the left front door to gain access to fresh air. He then deployed the right side doors by the toggle switch that was mounted to the lower instrument panel adjacent to the steering wheel. As the doors opened, he deployed the wheelchair ramp to its horizontal position. The driver reached for the right hand operated touch pad that was located directly forward of the DS 2000 remote steering system mounted to the center mid instrument panel. This touch pad was dislodged from the velcro mount and was supported by the wire harness. The driver retrieved the touch pad control unit to turn-off the vehicle's ignition system. He then attempted to remotely release the EZ Lock wheelchair restraint, however, the locking mechanism did not disengage.

The driver retrieved his cellular telephone and attempted to call for emergency response by dialing 911. Following numerous attempts, he was unable to connect with an operator. During this time frame, several passing motorists and residents who resided near the crash site, approached the van to check on the condition of the driver. Following his positive response, he was informed that his cellular phone would not operate since the crash occurred in an area with no cellular telephone coverage. One of the initial responders to the crash scene notified 911 via their residential phone.

The driver estimated that less than ten minutes had elapsed as the local volunteer fire department arrived on-scene. The first responders of the fire department initially assessed the condition of the driver and checked his vital signs prior to his removal from the vehicle. He instructed the fireman to manually release the EZ Lock with the emergency release lever attached to the forward aspect of the floor mounted unit. As the locking unit was released, the driver attempted to back his motorized wheelchair from the EZ Lock restraint device toward the deployed ramp. The chair did not respond to the joystick movements. The driver then instructed the firemen to release the free-wheel level located on the lower rear aspect of the Quickie P200 wheelchair. Following this procedure, the firemen manually wheeled the chair onto the deployed ramp.

The driver noted that he was beginning to feel the cold temperature due to his exposure to the winter air. He was concerned of developing *thermo-regular dysfunction* which affects amputees and victims of paralysis. The firemen lifted the driver from his chair that was positioned on the ramp of the van and placed him on a stretcher. The stretcher was loaded into the awaiting ambulance which had maintained a warm temperature. The driver refused transport to a medical facility, therefore he was transported to the local fire department.

Following his arrival to the fire department, the driver was kept in a warm environment and offered liquids for hydration. He asked one of the firemen to check the electrical connectors on his wheelchair. One of the connectors had separated which resulted in the loss of battery current to the electric motors. After the connector was reattached, the driver tested the chair and noted that it was fully operational. His daughter was subsequently called to the fire department for private transport to his residence.