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CALSPAN ON-SITE AIR BAG SUCCESS INVESTIGATION
CALSPAN CASE NO. CA98-18
VEHICLE: 1998 FORD ESCORT ZX2
LOCATION: NEW YORK
CRASH DATE: JANUARY 1998

Contract No.
DTNH22-94-D-07058

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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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.

TECHNICAL REPORT STANDARD TITLE PAGE

1. *Report No.* CA98-18	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* Calspan On-Site Air Bag Success Investigation Vehicle: 1998 Ford Escort ZX2 Location: New York		5. *Report Date*: August, 1999 6. *Performing Organization Code*	
7. *Author(s)* Crash Research Section		8. *Performing Organization Report No.*	
9. *Performing Organization Name and Address* Transportation Sciences Crash Research Section Calspan Operations P.O. Box 400 Buffalo, New York 14225		10. *Work Unit No.* CO1115.0000.(8420-8429) 11. *Contract or Grant No.* DTNH22-94-D-07058	
12. *Sponsoring Agency Name and Address* U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		13. *Type of Report and Period Covered* Technical Report Crash Date: January, 1998 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* On-site investigation of a severe frontal crash that deployed the frontal air bags in a 1998 Ford Escort ZX2. The belted 20 year old female driver sustained moderate severity injuries from the 68 km/h (42 mph) delta V crash.			
16. *Abstract* This on-site investigation focused on a single vehicle run-off-road crash that involved a 1998 Ford Escort ZX2. The 20 year old female driver failed to negotiate a right curve at a police reported imprudent speed. The vehicle departed the left road edge and struck a tree with the front left area of the vehicle resulting in a 68 km/h (42 mph) speed change. The severe impact deployed the Escort's driver and right front passenger air bag system. The belted driver sustained a comminuted fracture/dislocation of the right ankle (AIS-2), fractures of all three malleoli (AIS-2), a concussion with brief loss of consciousness (AIS-2), and three lacerations of the right lower extremity (AIS-1).			
17. *Key Words* Severe frontal impact Energy management loop Ridedown of the crash forces		18. *Distribution Statement* General Public	
19. *Security Classif. (of this report)* Unclassified	20. *Security Classif. (of this page)* Unclassified	21. *No. of Pages* 10	22. *Price*

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BACKGROUND

This on-site investigation focused on a single vehicle run-off-road crash that involved a 1998 Ford Escort ZX2. The 20 year old female driver failed to negotiate a right curve at a police reported imprudent speed. The vehicle departed the left road edge and struck a tree with the front left area of the vehicle resulting in a 68 km/h (42 mph) speed change **(Figure 1)**. The severe impact deployed the Escort's frontal (driver and passenger) air bag system. The belted driver sustained a comminuted fracture/dislocation of the right ankle (AIS-2), multiple fractures of the malleolus (AIS-2), a concussion with brief loss of consciousness (AIS-2), and three lacerations of the right lower extremity (AIS-1).

Figure 1. Frontal damage to the Ford Escort.

This crash was initially identified during a review of the 1998 vehicle model year Police Crash Reports (PCR) at the local county Sheriff's Department on March 20, 1998. The PCR documented a severe crush profile to the involved 1998 Ford Escort which was initially identified as a vehicle with a redesigned frontal air bag system. The crash was assigned as an on-site redesigned investigation on March 20. Although the Escort was a total loss, the vehicle was located at a local Buffalo area salvage yard and documented for the SCI investigation. The vehicle identification number and the date of manufacturer listed the Escort as equipped with first generation, non-redesigned air bags. However, due to the severity of the crash and the performance of the restraint systems (manual belt and air bag), the NHTSA COTR reclassified the investigation as a "saved by the bag" investigation.

SUMMARY

Crash Site

The crash occurred on a two lane state route in a rural area during the early morning hours of January, 1998. The asphalt road surface was dry, level, and curved to the right with respect to the vehicle's northbound path of travel. The posted speed limit was 56 km/h (35 mph).

Pre-Crash

The 20 year old female driver of the Ford Escort had completed a 14 hour work shift at a local ski resort and was returning to her residence. She was traveling in a northerly direction on the two-lane state route at a driver estimated speed of 64 km/h (40 mph). The reconstruction of the crash indicated that her initial travel speed was probably in the 80-89 km/h (50-55 mph) range. On the approach to the crash site, the state route consisted on a series of moderate S-curves which the driver successfully negotiated. As she entered the right curve, the driver continued on a straight line trajectory and crossed the centerline into the southbound travel lane **(Figure 2)**.

Figure 2. Pre-crash trajectory of the Ford Escort.

The Escort crossed the southbound travel lane and departed the left (west) road edge in a presumed tracking attitude. The investigating officer stated that there was no evidence of attempted avoidance maneuvers at the scene of the crash.

Crash

The front left area of the Ford Escort impacted a 35.6 cm (14.0") diameter tree that was located 3.6 m (12.0') outboard of the west edge line **(Figure 3)**. The impact speed was computed at 77.0 km/h (47.8 mph) by the damage and trajectory algorithm of the WinSMASH program. The 12 o'clock direction of force impact crushed the frontal structure to a maximum depth of 114.3 cm (45.0"), located 25 cm (10") left of the vehicle's centerline, directly outboard of the driver's position **(Figure 4)**. The speed change was computed at 68.0 km/h (42.3 mph) by the WinSMASH program. Due to the 12 o'clock impact force, the longitudinal component equaled the total speed change of 68.0 km/h. As a result of the severe frontal impact, the vehicle's frontal driver and passenger air bags deployed.

Figure 3. Struck tree and final rest position of the Escort.

Figure 4. Frontal damage to the Ford Escort.

The Ford crushed to maximum engagement and initiated a counterclockwise (CCW) rotation as the vehicle traveled to rest. The Escort rotated approximately 36 degrees CCW before coming to rest engaged against the struck tree. Although the damage to the vehicle was rated as severe, the tree sustained minimal bark damage.

Post-Crash

A local resident heard the crash and immediately called 911 for police assistance. The driver attempted to exit the vehicle from the right side door, however, she was unable to open the door. She further reported that her right foot was trapped between the foot controls and the (intruding) floor pan of the vehicle. The local volunteer fire department was dispatched to the scene. Fire department personnel opened the right door to treat and remove the driver from the vehicle. She was subsequently transported by ambulance to a local hospital where she was admitted for treatment. The Escort was towed from the scene.

VEHICLE DATA

The 1998 Ford Escort ZX2, 2 door sedan, was identified by vehicle identification number (VIN) 3FALP1135W (production number deleted) and was manufactured on 4/97. The 4th VIN character in the Ford line identified the type of air bags for the 1998 model year vehicles. The Escort line requires a "K" in the 4th position for redesigned air bags. This vehicle was produced early in model year 1998, therefore it was not equipped with redesigned air bags. The introduction of redesigned air bags was a change during the model year production. In addition to the VIN identifier, all redesigned air bag equipped Ford products should have a front door window sticker that notes "Second Generation Air Bag". The left front door glazing was shattered for this crash involved vehicle and the right door glazing was void of the window sticker.

The Ford Escort was leased by the parents of the driver on July 1, 1997, for primary use by the driver. She was a full-time college student with seasonal part-time employment at the local ski resort. The vehicle had recorded 12,903 km (8,018 miles) throughout the 7 months of usage. Following the crash, the Escort was towed from the scene to a local tow yard where the insurance company classified the vehicle as a total loss. The Escort was transferred to a local insurance storage lot where it was auctioned to the highest bidder. A local salvage yard purchased the vehicle at a bid price of $350 on March 4, and transported the vehicle to their yard for dismantling and the sale of used parts. The vehicle was, however, intact at the time of the SCI inspection.

The Escort was equipped with a 2.0 liter I-4 cylinder transverse mounted engine linked to a 4-speed automatic overdrive transmission. The transmission selector lever was floor-mounted within the center console. The vehicle was also equipped with power-assisted rack-and-pinion steering and power-assisted front disc/rear drum brakes. Due to the severity of the exterior and interior damage, it was unknown if the vehicle was equipped with an anti-lock (ABS) braking system.

The passenger compartment consisted of front bucket seats for the outboard positions and a split-back/folding rear bench, 2 passenger rear seat. The front seat backs were equipped with adjustable head restraints. The driver's side head restraint was in the full-down position while the passenger side head restraint was adjusted 3.2 cm (1.25") above the seat back support. Additional interior features included power operated side windows, and power door locks.

VEHICLE DAMAGE

Exterior

The Ford Escort sustained severe frontal damage as a result of the tree impact sequence **(Figure 5)**. Maximum crush was 114.3 cm (45.0") located on the front bumper fascia, 25 cm (10") left of center. The crush profile was located directly outboard of the driver's compartment. The direct contact damage began at the vehicle's centerline (on the hood face) and extended 33.0 cm (13.0") to the left. The narrow impact deformed the frontal structure in a U-configuration which resulted in a combined induced and direct contact damage length (Field L) of 68.6 cm (27.0"). This measurement extended from corner-to-corner across the bumper reinforcement bar, parallel to the reference line which reflected the original length of the vehicle. The left bumper corner was displaced rearward while the right corner was displaced both rearward [99.1 cm (39")] and laterally [61 cm (24")]. The impact separated the bumper fascia from the reinforcement bar, therefore the crush profile was documented at the reinforcement bar **(Figure 6)**. The crush profile was as follows: C1 = 99.1 cm (39.0"), C2 = 114.3 cm (45.0), C3 = 69.9 cm (27.5"), C4 = 48.3 cm (19.0"), C5 = 20.2 cm (8.0"), C6 = 18.7 cm (7.4").

Figure 5. Left side view of the crush profile.

The 12 o'clock direction of force impact displaced the frontal structure rearward resulting in a Collision Deformation Classification (CDC) extent zone of 6, which extended rearward of the original base of the windshield. The overall CDC for this impact sequence was 12-FYEN-6. The frontal deformation reduced the left wheelbase by 70.4 cm (27.7") and the right wheelbase by 5.1 cm (2.0").

Figure 6. Close-up view of the severe frontal crush.

The left front door was displaced against the left B-pillar. Although the door remained closed during the crash and post-crash activities, the door was opened during the SCI inspection process by lifting up on the exterior door release lever. The right door was not physically damaged by the crash forces. This door remained closed during the crash and was opened post-crash by rescue personnel to remove the driver from the vehicle.

Glazing damage occurred to the laminated windshield and the left side tempered door and quarter window glass. The laminated windshield was extensively cracked across the full width and height due to the rearward displacement of the left A-pillar and contact from the hood. The plastic lamination at the left upper area of the windshield was torn, however, it was unknown it this occurred as a result of the hood contact against the windshield or resulted from sagging of the glazing over the two months since the crash occurred. The adhesive bond at the lower right A-pillar and base of the windshield was partially separated due to the lateral displacement of the frontal structure. The tempered left side door glazing was shattered as a result of reward displacement of the left A-pillar and buckling of the door. The adjacent left (fixed) quarter window was shattered by the impact forces and deformation to the side structure. The backlight and right side glazing remained intact.

VEHICLE DAMAGE (continued)

Interior

The interior of the Ford Escort sustained extensive damage that was associated with exterior deformation which resulted in severe intrusion of interior components into the driver's compartment. Additional minor severity damage resulted from driver loading of the knee bolster, steering wheel rim, manual belt system, and the left door panel. Maximum intrusion involved 60.3 cm (23.75") of rearward displacement of the brake pedal. The intruding components, location, magnitude, and direction are documented in the following **Table 1**:

Table 1. Intrusion Values

Intruding Component	*Vehicle Position*	*Magnitude*	*Direction*
Toe pan	Front left	52.1 cm (20.5")	Longitudinal (rearward)
Brake pedal	Front left	60.3 cm (23.75")	Longitudinal (rearward)
Steering wheel/column	Front left	20.3 cm (8.0")	Longitudinal (rearward)
Upper instrument panel	Front left	25.4 cm (10.0")	Longitudinal (rearward)
Mid instrument panel	Front left	24.8 cm (9.75")	Longitudinal (rearward)
Lower A-pillar	Front left	17.8 cm (7.0")	Longitudinal (rearward)
Center instrument panel	N/A	21.0 cm (8.25")	Longitudinal (rearward)

The steering column was rotated vertically to an angle of 45 degrees by the intrusion of the instrument panel and the toe pan. The driver loaded the wheel and column through the deployed air bag which resulted in 3.8 cm (1.5") of deformation to the upper half of the wheel rim. The energy absorbing steering column was fully compressed by the intrusion of the toe pan, however, the shear capsules were not compressed. Occupant loading of the wheel assembly was reduced by the use of the manual belt system and deployment of the air bag.

The driver's knees loaded and fractured the plastic knee bolster cover. An orange fabric transfer was noted to the left side of the bolster at the interior light dimmer switch location. This transfer was located 25.4 cm (10.0") left of the mid point of the steering column. In addition, her right knee/thigh contacted the keys and sheared the ignition key in the switch.

She loaded the manual belt system with sufficient force to deploy the energy management loop. Clothing and D-ring transfers were noted to the webbing. These are addressed in the manual restraint section of this summary report.

MANUAL RESTRAINT SYSTEM

The four outboard seated positions were equipped with 3-point manual lap and shoulder belt systems. The front belt systems consisted of a continuous loop webbing with a sliding latchplate that buckled into a center (inboard) mounted buckle assembly. An energy management loop was incorporated into the lower anchorage segment of the driver's lap belt webbing. The loop was concealed within a vinyl sleeve that was 24.1 cm (9.5") in length. The webbing was routed through a fixed D-ring and spooled onto a dual mode locking retractor that was located in the mid aspect of the B-pillar.

The driver was properly wearing the manual 3-point lap and shoulder belt system. Belt usage was supported by orange transfers embedded into the belt webbing from the driver's clothing, deployment of the energy management loop, and a D-ring transfer on the shoulder belt webbing. Furthermore, minimal loading of the displaced steering system resulted which supported belt use for this severe crash. The driver and her mother stated that she was a dedicated belt user and that the belt habit developed at a young age.

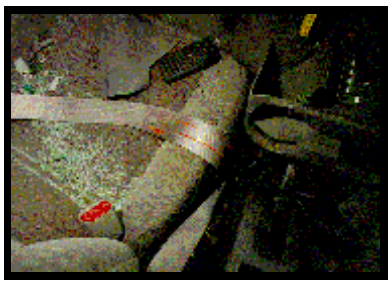

Figure 7. Orange fabric transfers embedded into the belt webbing.

The orange fabric (clothing) transfers were embedded into both sides of the belt webbing as the driver loaded the belt and compressed the webbing into her thoracic area. The lower aspect of the webbing at the left hip/abdominal regions probably folded over as the driver loaded the system which contributed to the transfers occurring on both sides of the webbing. The heaviest area of the fabric transfer occurred to the inner aspect of the webbing (side against driver) and extended 4.1 cm (1.6") below to 19.1 cm (7.5") above the latchplate stop button. The transfer consisted of three longitudinally oriented transfers that were parallel to the length of the webbing. The second area of orange fabric was on the forward aspect of the webbing located 8.6 cm (3.4") below the referenced stop button to 1.9 cm (0.75") above the button. The transfer extended longitudinally across the rear third aspect of the webbing.

The energy management loop was incorporated into the vinyl sleeve that extended over the lower anchorage and lower segment of the lap belt webbing. The overall length of the sleeve was 26.0 cm (10.25"). The management loop consisted of a single fold of webbing that was stitched together over a length of 10.2 cm (4.0"). The belt webbing was again folded over the stitched area to direct the belt in a vertical direction. A red "Replace Belt" label was sewn to the webbing at the second non-stitched fold point. The management loop and label were fully concealed within the vinyl sleeve pre-crash.

Figure 8. Deployed energy management loop.

Driver loading against the belt webbing fully deployed the management loop. This was accomplished by complete separation of the stitching which provided an additional 23.4 cm (9.25") of length to the lap belt webbing **(Figure 8)**. The elongation of the belt loop provided the driver with a greater ridedown of the belt system and contact with the fully deployed driver air bag which provided additional ridedown from the crash forces. In the fully deployed mode, the red Replace Belt label became visible as it extended 20.3 cm (8.0") above the floor mounted vinyl sleeve. This label provided a visual advisement to repair personnel to replace the belt system in a repairable crash.

MANUAL RESTRAINT SYSTEM (continued)

As the belt management loop deployed, orange fabric transfers extended further downward on the lap belt segment of the webbing. On the forward side of the webbing, the transfers continued diagonally 8.3-24.1 cm (3.25-9.5") below the stop button. A faint orange transfer extended on the inner aspect of the webbing 20.3-26.7 cm (8.0-10.5") below the stop button, ending at a point that was 1.2 cm (0.4") above the red "Replace Belt" label.

The driver's loading force against the belt system as the energy management loop deployed resulted in a black vinyl D-ring transfer on the shoulder belt webbing. The diagonally oriented D-ring transfer was located 139.1-142.2 cm (54.75-56.0") above the referenced latchplate stop button. This stop button was located on the webbing 30.4 cm (12.0") above the top of the management loop and 50.2 cm (19.75") above the center point of the lower sill anchorage bolt.

There were no performance failures identified with the manual belt system. Following the crash, the driver unbuckled the belt system as she attempted to exit the vehicle from the right front door. The belt partially retracted onto the B-pillar mounted retractor mechanism.

AUTOMATIC RESTRAINT SYSTEM

The 1998 Ford Escort ZX2 was equipped with frontal air bags for the driver and passenger positions. Although the vehicle was a 1998 model year, the air bags were not redesigned (second generation). The system did deploy as a result of a severe frontal impact sequence with a tree.

The air bag system consisted of a single point sensing and diagnostic module, the steering wheel mounted driver bag, the right instrument panel mounted passenger air bag, and the air bag indicator lamp. At the time of the inspection, the driver bag had been cut from the module assembly and removed from the vehicle. The remainder of the system was intact.

The driver air bag deployed from an H-configuration module cover assembly. The upper flap was 20.6 cm (8.1") in width at the horizontal tear seam and 5.7 cm (2.25") in height. The lower flap maintained the same width at the tear seam while tapering to 12.1 cm (4.75") at the hinge point. The vertical height of the lower flap was 8.9 cm (3.5"). The acronym SRS was molded into the lower right corner of the lower cover flap.

Although the driver air bag was cut from the vehicle, a large segment of the forward panel remained which contained the vent ports and tether straps. The bag was vented by two 2.5 cm (1.0") diameter ports located at the 10 and 2 o'clock sectors. Two 10.2 cm (4.0") wide band tether straps were positioned at the 12 and 6 o'clock sectors **(Figure 9)**. The identification number of 011792R was stamped onto the bag membrane at the 6 o'clock sector.

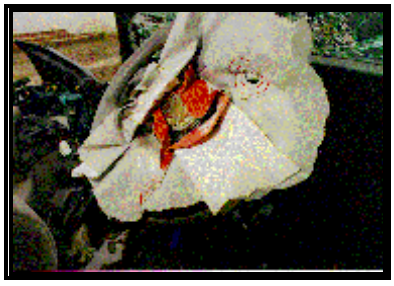

Figure 9. Vent ports and internal tethers of the driver air bag.

The front passenger air bag deployed from a module assembly that was mounted in the top and mid instrument panel of the vehicle. The single cover flap design was hinged at the top surface adjacent to the windshield. The cover flap was contoured to the profile of the instrument panel and was 33.0 cm (13.0) in width and 21.0 cm (8.25") in depth. SRS was molded into the lower right corner of the flap.

AUTOMATIC RESTRAINT SYSTEM (continued)

The air bag membrane was constructed of a typical nylon-type fabric and was 45.7 cm (18.0") in width and approximately 63.5 cm (25.0") in height on its deflated state **(Figure 10)**. The bag was vented by two 3.8 cm (1.5") diameter vent ports located at the 3 and 9 o'clock sectors of the side panels. The bag was not tethered and had a maximum rearward excursion of 66.0 cm (26.0") from the mid panel. This dimension was recorded at the mid point of the bag face in its deflated state. There was no damage or contact evidence to the front passenger bag.

The sunvisors contained warning labels on each side of the visor. The label exposed to the driver was 9.1 x 3.8 cm (3.6 x 1.5") and advised the following:

AIR BAG
WARNING
FLIP VISOR OVER

The label on the top side of the visor was 12.1 x 6.4 cm (4.75 x 2.5") and provided the following:

WARNING

- **DEATH or SERIOUS INJURY can occur.**
- Children 12 and under can be killed by the air bag.
- The BACK SEAT is the SAFEST place for children.
- NEVER put a rear-facing child seat in the front.
- Sit as far back as possible from the air bag.
- ALWAYS use SEAT BELTS and CHILD RESTRAINTS.

DRIVER DEMOGRAPHICS

Age:	20 year old female
Height:	172.7 cm (68.0")
Weight:	68 kg (150 lb)
Race/Ethnic Origin:	White/non-hispanic
Manual Restraint Usage:	3-point lap and shoulder belt system
Usage Source:	Vehicle inspection, driver interview
Eyeware:	Contact lenses, one was displaced from eye (not recovered)
Vehicle Familiarity:	7 months, 13,000 km (8,000 miles)
Route Familiarity:	Traveled frequently
Trip Plan:	Returning to residence
Mode of Transport From Scene:	Ambulance to a local hospital
Type of Medical Treatment:	Admitted to the hospital for two days

DRIVER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanism
Comminuted fracture with dislocation of the right ankle	Moderate (850214.21)	Intruding toe pan
Fractures of the right lateral, medial, and posterior malleolus	Moderate (851612.2,1)	Intruding toe pan
Pillion type injury and crush component to the articular surface of the distal tibia	Moderate (853420.2,1)	Intruding toe pan
4 cm laceration of the posterior lateral mid right thigh	Minor (890602.1,1)	Fractured knee bolster panel
3 cm laceration over the right medial knee	Minor (890602.1,1)	Intruding knee bolster
1 cm laceration mid shaft, right lower leg	Minor (890602.1,1)	Intruding knee bolster
Closed head injury with concussion and brief loss of consciousness	Moderate (160414.2,0)	Impact force/ air bag loading/steering assembly
Right orbital contusion	Minor (297402.1,1)	Front right air bag/steering assembly
Contusions over both buttocks*	Minor (890402.1,1, 890402.1,2)	Seat cushion

**This injury was noted by the interviewees (driver and her mother) and was not documented in the hospital medical reports. All other injuries were documented in the emergency room and discharge summary records.*

DRIVER KINEMATICS

The driver of the 1998 Ford Escort ZX2 was seated in a presumed normal driving posture. Her manually operated bucket seat was adjusted to a rear track position with the seat back slightly reclined. The seat track was positioned 2.5 cm (1.0") forward of the full rear track position. The total length of seat track adjustment was 22.5 cm (8.75"). The adjustable head restraint was positioned on top of the seat back support, in the full down position. The driver was properly restrained by the manual 3-point lap and shoulder belt system. Belt usage was supported by clothing fabric transfers embedded into the belt webbing, a D-ring transfer, and full deployment of the system's energy management loop.

Figure 10. Driver loading of the air bag and steering assembly.

At impact, the supplemental frontal driver and passenger air bags deployed as the driver initiated a forward trajectory in response to the 12 o'clock impact force. She initially loaded the manual restraint system as evidenced by the fabric transfers and the deployment of the energy management loop. The belt system provided the driver with a ridedown effect as she loaded the air bag. Due to the high delta V crash, the driver compressed the bag against the steering wheel rim which resulted in 3.8 cm (1.5") of upper rim displacement. The bag provided the driver with an additional ridedown to the severe crash forces **(Figure 11)**. The driver sustained a right orbital contusion that resulted from bag loading and a concussion with brief loss of conscious from restraint (belt and bag) loading and the impact force.

Her forward motion and loading against the seat cushion resulted in contusions over the buttocks. As the driver responded in a forward direction, the left toe pan and brake pedal intruded into her space. As a result of loading the intruding floor components, she sustained a comminuted fracture with dislocation of the right ankle, fractures of the right lateral, medial, and posterior malleolus, and a pillion type injury and crush component to the articular surface of the distal tibia. The driver's knees contacted and fractured the intruding knee bolster resulting in lacerations of the lower extremities.

She probably rebounded from her forward motion into the seat back support before coming to rest in the driver's position. Following the crash, the driver attempted to exit the vehicle, however, her right leg was restricted by the intrusion of the toe pan and brake pedal.

MEDICAL TREATMENT

The driver was evaluated at the scene by volunteer paramedics and prepared for ambulance transport to a local hospital. On arrival to the hospital, the driver's blood pressure was recorded at 140/80 with a pulse rate of 115 and a respiration rate of 24. Her Glasgow Coma Score (GCS) was 15. She was initially evaluated in the trauma unit of the hospital and transferred to the operating room for an open reduction internal fixation on the right lower extremity fractures. She was subsequently discharge two days following the crash.

CONCLUSIONS

The driver received tremendous benefit from the manual belt system and the deployed driver air bag in this high severity frontal crash. The belt system energy management loop provided the driver with a ridedown effect to the severe crash forces. The deployed driver air bag enhanced the ridedown as she loaded both restraint systems which dissipated her energy from the crash. The energy was distributed over a wide body area and prevented the driver from substantially loading the intruding steering assembly, thus protecting her from severe wheel loading and the probability of severe or fatal injuries.