

**TRANSPORTATION SCIENCES  
CRASH RESEARCH SECTION**

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**VERIDIAN ON-SITE DRIVER/SEAT BELT FATALITY INVESTIGATION  
VERIDIAN CASE NO. CA99-002  
VEHICLE: 1993 SUBARU LEGACY  
LOCATION: VIRGINIA  
CRASH DATE: FEBRUARY 1999**

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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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<i>16. Abstract</i> <p>This on-site investigation focused on a two-vehicle intersection crash that involved a 1993 Subaru Legacy (subject vehicle) and a 1999 Pontiac Grand AM. The Subaru was equipped with a frontal driver air bag that deployed as a result of an offset frontal impact with the left front side area of the Pontiac. The 77 year old female driver of the Subaru was restrained by the automatic motorized shoulder belt system, however, she did not wear the manual lap belt. At impact, the driver initiated a forward trajectory into the path of the deploying driver air bag. The expanding air bag contacted the face of the driver which resulted in multiple abrasions of the cheeks, nose, lips, and chin. She loaded the automatic shoulder belt webbing which resulted in multiple bilateral rib fractures, a ruptured spleen, ruptured heart, ruptured liver, a left pulmonary contusion, and a band-like contusion across the anterior chest. Although the driver was within the deployment path of the air bag, the bag was not a mechanism for the internal injuries. She was removed from the vehicle and transported to a local hospital where she expired within 30 minutes of the crash.</p>			
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**VEHICLE: 1993 SUBARU LEGACY**  
**LOCATION: VIRGINIA**  
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***BACKGROUND***

This on-site investigation focused on a two-vehicle intersection crash that involved a 1993 Subaru Legacy (subject vehicle) and a 1999 Pontiac Grand AM. The Subaru was equipped with a frontal driver air bag that deployed as a result of an offset frontal impact (**Figure 1**) with the left front side area of the Pontiac. The 77 year old female driver of the Subaru was restrained by the automatic motorized shoulder belt system, however, she did not wear the manual lap belt. At impact, the driver initiated a forward trajectory into the path of the deploying driver air bag. The expanding air bag contacted the face of the driver which resulted in multiple abrasions of the cheeks, nose, lips, and chin. She loaded the automatic shoulder belt webbing which resulted in multiple bilateral rib fractures, a ruptured spleen, ruptured heart, ruptured liver, a left pulmonary contusion, and a band-like contusion across the anterior chest. Although the driver was within the deployment path of the air bag, the bag was not a mechanism for the internal injuries. She was removed from the vehicle and transported to a local hospital where she expired within 30 minutes of the crash.



**Figure 1. Front right 3/4 view of the Subaru Legacy.**

The crash occurred during early morning nighttime hours in February 1999. The investigating officer notified NHTSA's Special Crash Investigation Team of the crash on March 8, 1999. The crash was subsequently assigned to the Veridian/Calspan SCI team on the morning of the 8<sup>th</sup> as an on-site investigation. An on-site investigation was subsequently scheduled for Friday, March 12, with the investigation piggy-backed onto another on-site effort (Case No. CA99-03).

***SUMMARY***

***Crash Site***

The crash occurred during nighttime hours at a signalized four-leg intersection in an urban/commercial area. The intersection consisted of a state route and a local collector roadway. Both roadways were divided by grass medians and comprised of eight (8) travel lanes, inclusive of left and right turn lanes. Traffic flow was regulated by an on-colors, pre-timed overhead signal system. The traffic ways were straight and level. The investigating officer noted in his report that the weather was clear and dry with an ambient temperature of 0.6 degrees C (31.0 degrees F). A heavy frost covered unprotected vehicles and grassy surfaces. The posted speed limit for the Subaru was 72 km/h (45 mph) while the speed limit for the Pontiac was 56 km/h (35 mph).

### ***Vehicle Data***

The 1993 Subaru Legacy was a four-door sedan that was equipped with a frontal air bag system for the driver's position. The air bag deployed as a result of the impact sequence with the Pontiac Grand Am. In addition to the air bag, the Subaru was equipped with automatic motorized shoulder restraints and manual lap belts for the front outboard seated positions, manual 3-point lap and shoulder belts for the outboard rear positions, and a center rear lap belt. The front bucket seats were covered with fabric with homemade terry cloth seat covers. Both bucket seats had adjustable head restraints and seat back supports.

The Subaru was powered by a transverse mounted 2.2 liter, four cylinder engine that was coupled to a 5-speed manual transmission with a floor mounted shifter. The vehicle was manufactured on 8/92 and was identified by vehicle identification number 4S3BC6335P1 (production number deleted). At the time of the crash, the odometer had recorded 152,397 km (94,698 miles). The Subaru appeared to be in very good condition for the model year and recorded mileage.

### ***Pre-Crash***

The 77 year old female driver had exited her residence and partially scrapped a heavy frost from the windshield and side windows of the Subaru. She entered the vehicle and was en route to work as a waitress. The driver was traveling in a northerly direction in the center through lane of the state route at a police estimated speed of 72 km/h (45 mph). Witness statements indicated that as the driver approached the intersection, the overhead signal system changed from a green to red phase for north/southbound traffic flow. The driver of the Subaru either failed to detect the signal change or attempted to proceed through the intersection due to the light traffic density at the intersection.

The 1999 Pontiac was driven by a 22 year old male who was traveling in a westerly direction on the intersecting local road. On his approach to the intersection, the overhead signal system was in a red phase for east/westbound traffic flow. The driver stopped at the mouth of the intersection and waited for the signal phase to change. As the light turned green for westbound traffic, the Pontiac driver accelerated into the intersection from the outboard travel lane. His estimated travel speed into the intersection was 16-24 km/h (10-15 mph).

Witnesses at the intersection noted that the driver of the Subaru did not initiate avoidance actions (i.e., braking and/or steering inputs) as she entered the intersection against the red signal phase. The investigating officer noted in his supplemental report that there were no tire marks at the scene to support braking by either vehicle.

### ***Crash***

The front center and right area of the Subaru Legacy impacted the left front fender area of the Pontiac in a L-configuration crash sequence. The impact resulted in crash forces of 1 o'clock for the Subaru and 10 o'clock for the struck Pontiac Grand Am. The damage algorithm of the WinSMASH program computed velocity changes of 22.2 km/h (13.8 mph) for the subject vehicle and 19.8 km/h (12.3 mph) for the struck Pontiac. The specific longitudinal and lateral components were -20.9 km/h (-13.0 mph) and -7.6 km/h

(-4.7 mph) for the Subaru. The impact induced deceleration was sufficient to deploy the Subaru's supplemental front driver air bag. In addition, the Pontiac was equipped with redesigned frontal air bags for the driver and passenger positions which deployed during this crash.

The initial impact rotated the Subaru in a counterclockwise (CCW) direction while the Pontiac rotated in a clockwise direction. The left rear quarter panel area of the Pontiac subsequently sideslapped the right rear side area of the Subaru. The secondary sideslap resulted in lateral force directions of 3 o'clock for the Subaru and 9 o'clock for the Pontiac.

Following the secondary engagement, the vehicles separated. The Subaru was redirected in a northwesterly direction where it traversed the grass median and the southbound travel lanes. The vehicle came to rest diagonal to the southbound lanes at police reported distance of 45 m (148') from the initial point of impact (POI). The Pontiac was redirected in a northerly direction and traveled a longitudinal distance of 47 m (155') before coming to rest adjacent to the outboard edge line of the northbound travel lanes.

### ***Post-Crash***

The investigating officer arrived on-scene within 3 minutes of the crash. He immediately proceeded to the Subaru and noted the driver seated in the left front position with her upper body slumped onto the right front seat cushion. The front driver air bag was deployed and the automatic shoulder belt system was buckled to the track mounted buckle assembly. Fire and rescue personnel arrived within minutes of the officer and checked the pulse rate of the driver. Her pulse rate was recorded at 5, therefore immediate CPR procedures were initiated. The Subaru driver was transported by ambulance to a local hospital where she expired within 30 minutes of the crash.

The driver of the Pontiac complained of knee pain and was transported to a local hospital where he was treated and released. Both vehicles sustained disabling damage and were towed from the crash scene.

## **VEHICLE DAMAGE**

### ***Subaru - Exterior***

The Subaru sustained moderate frontal damage (**Figure 2**) from the initial impact sequence with the Pontiac Grand Am. The direct contact damage began 22.9 cm (9.0") left of center and extended 94.6 cm (37.25") to the right corner of the front bumper. Maximum crush was documented at 34.9 cm (13.75") which was located at the right bumper corner (**Figure 3**). The combined induced and direct contact damage was 139.7 cm (55.0") which involved the full frontal width of the vehicle. The crash profile at bumper level was as follows: C1 = 2.5 cm (1.0"), C2 = 4.4 cm (1.75"), C3 = 10.4 cm (4.1"), C4 = 15.7 cm (6.2"), C5 = 20.3 cm (8.0"), C6 = 34.9 cm (13.75"). The Collision Deformation Classification (CDC) for this impact was 01-FZEW-2 with an improved



**Figure 2. Frontal damage to the Subaru Legacy.**

principal direction of force (PDOF of 20 degrees. Damaged components included the front bumper system, grille, hood, radiator and radiator support, and both front fenders. There was no glass damage and all four doors remained closed and operational.



**Figure 3. Profile view documenting the extent of frontal crush.**



**Figure 4. Sideslap damage to the right rear side area of the Subaru.**

The secondary sideslap (**Figure 4**) resulted in a damage profile that began 59.9 cm (23.6") forward of the right rear axle and extended 139.1 cm (54.75") to the trailing edge of the right quarter panel. Maximum crush was 10.4 cm (4.1") located on the quarter panel 22.9 cm (9.0") rearward of the axle position. The crush profile for this sideslap was as follows: C1 = 0 cm , C2 = 7.6 cm (3.0"), C3 = 8.9 cm (3.5"), C4 = 2.5 cm (1.0"), C5 = 0 cm, C6 = 0 cm. The CDC for this damage pattern was 03-RZEW-2.

#### ***Subaru - Interior***

Interior damage to the Subaru was isolated to the deployment of the frontal driver air bag system and driver contact with the interior components. There was no intrusion of the passenger compartment. The driver was seated in a presumed mid-to-forward seat track position which positioned her within range of the deploying driver air bag system. The expanding front driver air bag initially contacted the driver's face which resulted in abrasions of both cheeks, nose, and lips. Autopsy photographs noted a displacement of the driver's nose to her left, however, preliminary medical information did not note the nasal fracture. Facial contact on the air bag was evidenced by make-up and lipstick transfers. Two separate transfer patterns were noted to the horizontal midline of the bag on each side of the tether reinforcement. These patterns actually formed one contact point when the bag was refolded with the sides folded toward the center. The tether area subsequently impacted the face of the driver as the bag continued to expand. Again, make-up and lipstick transfers evidenced the contact to the tether area.

The driver loaded the automatic shoulder belt webbing as she began to submerge the belt system due to the lack of use of the manual belt system. A zipper-type abrasion pattern was evident to the inside surface (aspect exposed to the chest of the driver) of the webbing at the level of the mid chest. This abrasion was 10.2 cm (4.0") in length and extended the full width of the belt.

The driver's knees contacted and fractured the knee bolster on each side of the steering column (**Figure 5**). The combination of air bag expansion against the driver and driver loading of the expanding air bag



resulted in minimal compression of the energy absorbing steering column. The left shear capsule (**Figure 6**) was compressed 4.8 mm (3/16") while the right capsule was compressed 7.9 mm (5/16"). There was no bending of the steering wheel rim and/or spokes.



**Figure 5. Driver knee contact damage to the bolster cover.**



**Figure 6. Left shear capsule displacement.**

### ***Pontiac - Exterior***

The Pontiac Grand Am was assessed as a total loss by the insurance carrier and was sold at public auction prior to the assignment of this investigation. Photographs of the vehicle were obtained from the investigating police agency, therefore the following damage estimates were generated for input into the WinSMASH program.

The initial impact damage was located on the left front fender area of the Grand Am (**Figure 7**). An exemplar vehicle was examined for comparison measurements. The overall length of the damage profile was approximately 130 cm (51") which extended from the front bumper corner to the left A-pillar. Maximum crush was approximately 30 cm (12") located at the leading edge of the left front fender. The crush profile at mid fender height was estimated as follows: C1 = 2 cm (1"), C2 = 10 cm (4"), C3 = 15 cm (6"), C4 = 20 cm (8"), C5 = 30 cm (12"), C6 = 25 cm (10"). Damaged components included the left front fender, the bumper fascia and reinforcement bar, left front shock tower and inner fender structures, the radiator support panel, left headlight and turn signal assembly, and the hood. There was no glazing damage noted in the photographs. The CDC for this impact event was 10-LYEW-4.



**Figure 7. Left front damage to the Pontiac Grand Am.**

The secondary sideslap damage was located at the left rear quarter panel between the axle position and the bumper corner. The length of the damage profile was approximately 89 cm (35"). Maximum crush was estimated at 5-8 cm (2-3") located at the trailing edge of the left rear quarter panel. The CDC for this damage pattern was 09-RBEW-1.

### ***Pontiac - Interior***

The interior damage to the Pontiac appeared to be limited to the deployment of the redesigned frontal air bag system for the driver and passenger positions. The top mounted passenger air bag module cover flap did not impact the windshield. The driver complained of a knee injury, however, bolster contact/damage was not visible in the police photographs.

### ***Subaru Frontal Air Bag System***

The 1993 Subaru Legacy was equipped with a frontal driver air bag which deployed during the initial crash sequence with the left side area of the Pontiac Grand Am. The system consisted of two front mounted air bag crash sensors, a front center console mounted air bag control module, the steering wheel mounted air bag inflator and bag module, a clockspring assembly, and the instrument panel mounted air bag indicator lamp. The system was not equipped with an electronic data recorder. At the time of the vehicle inspection, there was no power available to the vehicle, therefore the status of the indicator lamp could not be tested.

The front driver air bag deployed as designed from the module contained within the four-spoke steering wheel rim. The module cover was configured with nearly symmetrical vinyl flaps that opened in an H-configuration. The horizontal tear seam was 16.5 cm (6.5") in length with vertical flap measurements of 8.3 cm (3.25") for the upper and 5.7 cm (2.25") for the lower flap. There was no damage or contact evidence to the cover flaps. The SRS logo and the word AIRBAG were molded into the upper cover lap, adjacent to the horizontal tear seam.

The air bag membrane was constructed of two panels that were sewn with an internal peripheral seam. The overall bag diameter, in its deflated state, was 67.3 cm (26.5"). The bag was vented by two 3.8 cm (1.5") diameter vent ports that were located on the back side of the air bag at the 10 and 2 o'clock sectors. The ports were located 18.4 cm (7.25") forward of the peripheral seam. The bag was tethered by four internal tethers that were sewn to the face of the bag with a 17.8 cm (7.0") reinforcement. The tethers were 6.0 cm (2.375") in width and were located at the 12/6 and 3/9 o'clock positions. The air bag membrane was stamped with the following alpha-numeric identification:

FG2009629  
S  
98211AA000040  
BBS1001  
4SS924449  
160492

The driver's face was positioned within the deployment path of the frontal air bag system. This was evidenced by numerous make-up and lipstick transfers on the face of the bag. A make-up and partial lipstick transfer was documented to the left side of the bag, 15.9-23.5 cm (6.25-9.25") left of center which extended 6.4 cm (2.5") to 3.8 cm (1.5")



**Figure 8. Make-up transfer to folded sides of bag face.**

below the vertical centerline of the bag. A similar contact pattern was located on the right side of the air bag 12.7-21.6 cm (5.0-8.5") right of the centerline which extended 5.1 cm (2.0") above to 3.8 cm (1.5") below the horizontal centerline. These transfers originated as a single contact point as the bag deployed from the module assembly. As the sides of the bag were folded inward, the make-up and lipstick transfers matched (**Figure 8**) which identified the driver's forward position at the time of deployment.

A large make-up transfer was noted to the center tether reinforcement of the bag. The transfer extended horizontally 8.3 cm (3.25") left of center to 3.8 cm (1.5") right of center and vertically from the centerline to 6.1 cm (2.4") below the reference line. A continuation of this transfer was located at the lower sector of the reinforcement. The make-up transfer extended 1.9 cm (0.75") right of center to 12.7 cm (5.0") left and 2.5-12.7 cm (1.0-5.0") below the horizontal centerline. A lipstick transfer was centered within the above make-up transfer. This was located 2.5-7.6 cm (1.-3.0") left of center and 7.6-10.8 cm (3.0-4.25") below the horizontal reference line. These transfers that were located on and around the tether reinforcement occurred as the bag continued to inflate following the initial split transfer to both sides of the reinforcement.

Based on the facial contact patterns to the air bag, it appeared that the fold pattern permitted the upper and lower quadrants of the bag to expand first, followed by the sides with the subsequent expansion of the center of the bag. There was no damage to the air bag membrane.

#### ***Subaru Automatic Seat Belt System***

The 1993 Subaru was equipped with automatic motorized shoulder belt systems for the front seated positions. The belt webbings extended from center mounted inertia activated locking retractors and buckled into the motorized buckle assembly. At the time of the SCI inspection, both automatic belt systems were in the forward track positions that was consistent opening the doors post-crash during the treatment and removal of the driver from the vehicle. The left side belt system was buckled to the motorized mouse unit while the right side was unfastened and retracted into the center retractor mechanism.

The automatic motorized belt system was in use by the driver at the time of the crash. This was confirmed by the initial observations of the first arriving officer at the scene of the crash and by a load induced abrasion to the belt webbing. The driver loaded the belt webbing during the initial impact with the Pontiac which produced a zipper-like abrasion (**Figure 9**) pattern to the inner surface of the webbing (side of webbing exposed to the body of the driver). This abrasive type pattern was located 48-58 cm (19-23") below the track mounted buckle assembly and extended across the full width of the webbing. The location of this abrasion was consistent with proper usage of the automatic system. There was no further damage or loading evidence to the shoulder belt webbing and/or hardware.



**Figure 9. Zipper-like abrasion pattern top the belt webbing.**

### ***Subaru Manual Belt Systems***

In addition to the automatic shoulder belt systems, the Subaru Legacy was equipped with manual lap belts for the front seat positions. The lap belts extended from an outboard mounted inertia activated locking retractor and buckled into center mounted buckle assemblies. A single loop energy management loop was stitched into the lap belt webbing of the driver's side belt system immediately below the fixed latchplate. The loop when deployed, would provide an additional 8.3 cm (3.25") of lap webbing for the ridedown mode. This loop was not deployed in this vehicle.

The latchplate did not yield signs of routine usage (i.e., wear marks) for the high mileage that was recorded on the vehicle's odometer. The lack of these wear marks suggested that the driver or driver's of this vehicle were not frequent users of the lap belt system. The driver was observed by the first arriving officer at the scene as restrained by the automatic shoulder belt system, however, the lap belt was not in use. This resulted in improper usage of the vehicle's belt systems.

### ***Subaru Driver Demographics***

Age/Sex: 77 year old female  
Race/Ethnic Origin: Unknown  
Height: 162.6 cm (64.0")  
Weight: 53.1 kg (117.0 lb)  
Restraint Usage: Automatic motorized shoulder belt system, no lap belt usage  
Usage Source: Vehicle inspection, observations of the first arriving officer  
Trip Plan: En route to work  
Vehicle Familiarity: Unknown  
Route Familiarity: Daily, long term resident of area  
Mode of Transport  
From Scene: Ambulance  
Type of Medical  
Treatment: Transported to a local hospital where she expired within 30 minutes of the crash

### ***Driver Injuries***

#### ***Autopsy Results***

<b><i>Injury</i></b>	<b><i>Injury Severity (AIS 90)</i></b>	<b><i>Injury Mechanisms</i></b>
Fractures of the left 2-4 ribs antero-laterally and right 3-5 ribs antero-laterally with left hemothorax (800 ml of clotted blood)	Serious (450220.3,3)	Automatic shoulder belt webbing

<i>Injury</i>	<i>Injury Severity (AIS 90)</i>	<i>Injury Mechanisms</i>
Left pulmonary contusion, extensive	Serious (441406.3,2)	Automatic shoulder belt webbing
Myocardium - full thickness traumatic rupture of the right ventricular apex (50 ml liquid blood in the pericardium)	Maximum (441014.6,4)	Automatic shoulder belt webbing
3 cm x 1 cm deep traumatic rupture of the spleen with 50 ml of clotted blood in the peritoneum	Moderate (544222.2,2)	Automatic shoulder belt webbing
4 x 3 x 2 cm deep extensive internal rupture of the right lobe of the liver	Moderate (541822.2,1)	Automatic shoulder belt webbing
Purple band-like diagonal contusion across the anterior chest	Minor (490402.1,4)	Automatic shoulder belt webbing
Multiple facial abrasions of the cheeks, nose, chin, and lips ranging in size of 1/4 x1/4" to 2 1/2x1"	Minor (290202.1,0)	Deploying driver air bag
Purple contusions over the right knee and lower anterior leg	Minor (890402.1,1)	Knee bolster

### ***Subaru Driver Kinematics***

The driver of the Subaru was a 77 year old female with a medical examiner reported height of 162.6 cm (64.0") and weight of 53.1 kg (117.0 lb). She was seated in a presumed mid-to-forward track position due to her stature. The seat track had been moved prior to SCI inspection. In the mid track position, the horizontal distance between the center of the driver air bag module and the seat back support was 53.1 cm (20.9") and 40.4 cm (15.9") in the full forward position. There was 20.9 cm (8.25") of total seat track movement. The seat back was found in a slightly reclined position that was consistent with normal usage.

At impact, the driver's head was in a forward and down position, exposing her face to the deploying front driver air bag. The air bag contacted her face which resulted in abrasions of both cheeks, nose, lips, and chin. The nose appeared to have been displaced to the left, however, there was no fracture documented in the autopsy report. The neck area was void of abrasion. Contact evidence on the air bag consisted of two distinct make-up and lipstick transfers that were located at each side of the center tether reinforcement panel. When the sides of the air bag membrane were folded inward,



**Figure 10. Overall view of the deployed front driver air bag .**

these transfers matched to a common contact pattern. This pattern suggested that the driver was positioned closed to the module as the tethered air bag membrane deployed.

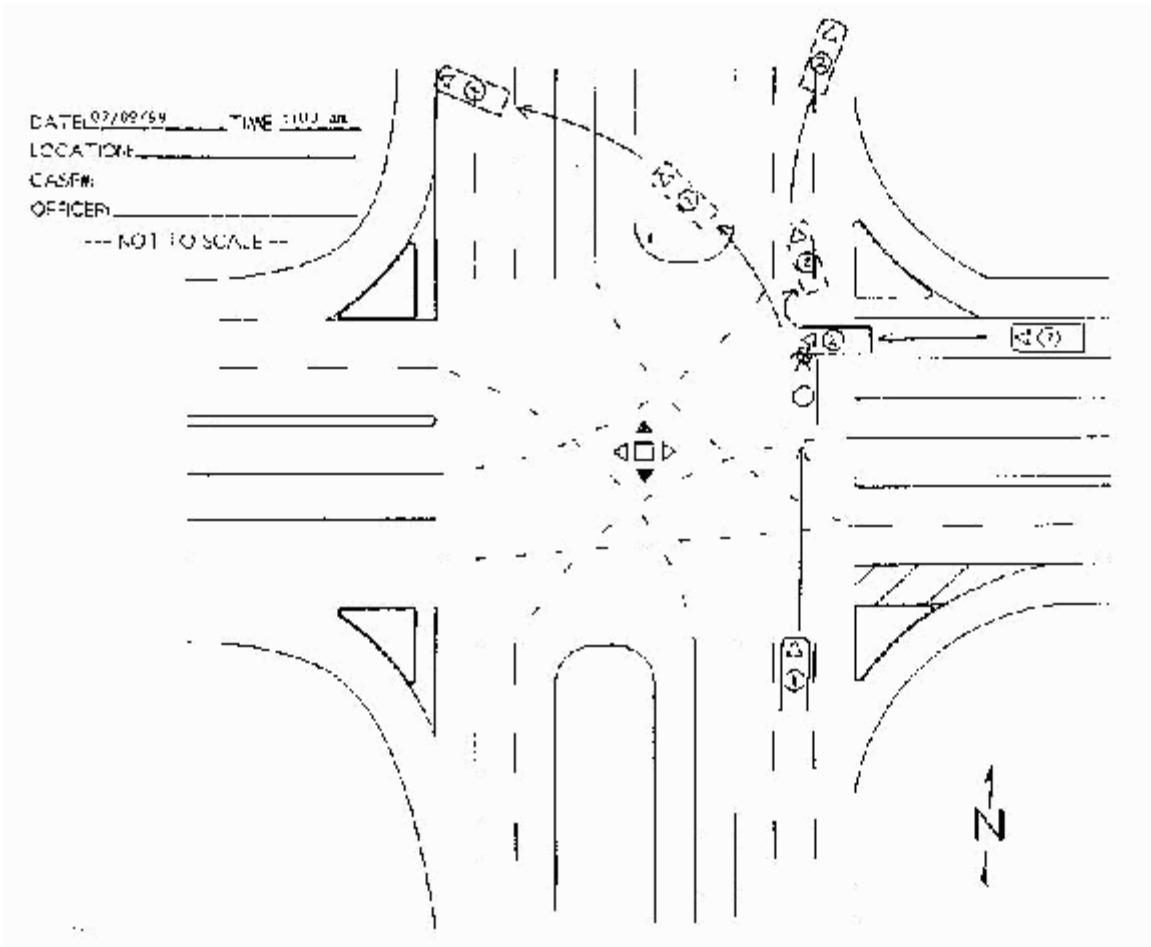
The continued expansion of the air bag resulted in the tether reinforcement contacting the face of the driver resulting in an additional, but separate make-up transfer pattern. The continued expansion of the bottom of the bag resulted in another transfer pattern of make-up and lipstick. This pattern was centered around the 6-8 o'clock sector of the tether reinforcement panel (**Figure 10**). There was no evidence of contact on the H-configuration module cover flaps.

As the driver initiated a forward trajectory in response to the frontal impact force, her torso loaded the automatic shoulder belt webbing which produced a zipper-type abrasion pattern to the webbing. As a result of belt loading, the driver sustained a diagonally oriented purple band-like contusion of the anterior chest, left antero-lateral fractures of ribs 2-4 and right 3-5 ribs, left hemothorax and a pulmonary contusion, a full thickness traumatic rupture of the right ventricular apex of the myocardium, a ruptured spleen, and a ruptured right lobe of the liver.

Due to the lack of lap belt usage, the driver partially submarined the shoulder belt webbing and loaded the knee bolster with both knees. The knee contacts fractured the bolster on each side of the steering column and displaced the plastic panel approximately 5.1 cm (2.0") forward. As a result of the knee contact, the driver sustained purple contusions over the right knee and the anterior lower right leg.

The energy absorbing steering column was partially compressed due to driver loading and/or air bag expansion against the driver. This was evidenced by partial compression of the shear capsule assemblies. The left shear bracket was displaced 4.8 mm (3/16") while the right shear was displaced 7.9 mm (5/16").

The driver rebounded and came to rest slumped across the right front seat cushion of the Subaru where she was found by the first arriving officer on-scene. The driver was removed from the vehicle and administered CPR. She was transported by ambulance to a local hospital where she expired within 30 minutes of the crash. An invasive autopsy was performed on the body approximately 29 hours following the crash.



**Figure 11. Scene Schematic**