CRASH DATA RESEARCH CENTER

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CALSPAN REMOTE REAR OCCUPANT PROTECTION PROGRAM CRASH INVESTIGATION

NASS/SCI COMBO CASE NO.: 2007-08-118B

VEHICLE: 2003 SUBARU LEGACY

LOCATION: PENNSYLVANIA

CRASH DATE: JULY 2007

Contract No. DTNH22-07-C-00043

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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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16. Abstract This remote investigation focused on the severity of the crash and the usage of the 3-point lap and shoulder belt system for the rear right passenger of a 2003 Subaru Legacy. The Subaru was involved in severe head-on crash with a 2000 Chrysler Voyager. The crash resulted in the death of a restrained 86-year old male rear right passenger of the Subaru. In addition to the rear right passenger, the Subaru was driven by a restrained 76-year old female with a restrained 74-year old female in the front right seat position. The Subaru was equipped with dual-stage frontal air bags for the driver and front right passenger positions that deployed as a result of the crash. The vehicle was also equipped with retractor mounted pretensioners for the two frontal outboard seating positions, which actuated during the crash. Responding to the force of the impact, the driver loaded the 3-point manual lap and shoulder restraint and sustained multiple soft tissue injuries. She sustained a right clavicle fracture, a transverse process fracture of L3, and a burst fracture of L4. The front right passenger loaded the lap and shoulder restraint and sustained a sternum fracture and multiple soft tissue injuries. She also sustained fractures of the second and fourth right side ribs, a right clavicle fracture, and a transverse process fracture of L3 due to kinematical movement involved with the severe impact forces. The rear right passenger loaded the lap and shoulder restraint and sustained a myocardium laceration, a coronary artery laceration, an aorta laceration, a pericardium laceration, a spleen laceration, bilateral rib fractures (2–5), a sternum fracture, and multiple soft tissue injuries. As a result of the high impact forces, he also sustained an intraventricular cerebrum hemorrhage, a subarachnoid hemorrhage, a basilar skull fracture, and a left clavicle fracture. All three occupants in the Subaru were transported to a regional trauma center. The driver and front right passenger were admitted and the rear right passenger was pronounced deceased prior to admission. The two occupants of the Chrysler were also transported to a regional trauma center and admitted with moderate injuries. Both vehicles were towed from the scene due to severe damage.			
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BACKGROUND

This remote investigation focused on the severity of the crash and the usage of the 3-point lap and shoulder belt system for the rear right passenger of a 2003 Subaru Legacy **(Figure 1)**. The Subaru was involved in severe head-on crash with a 2000 Chrysler Voyager. The crash resulted in the death of a restrained 86-year old male rear right passenger of the Subaru. In addition to the rear right passenger, the Subaru was driven by a restrained 76-year old female with a restrained 74-year old female in the front right seat position. The Subaru was equipped with dual-stage frontal air bags for the driver and front right passenger positions that deployed as a result of the crash. The vehicle was also equipped with retractor mounted pretensioners for the two frontal outboard seating positions, which actuated during the crash. Responding to the force of the impact, the driver loaded the 3-point manual lap and shoulder restraint and sustained multiple soft tissue injuries. She sustained a right clavicle fracture, a transverse process fracture of L3, and a burst fracture of L4. The front right passenger loaded the lap and shoulder restraint and sustained a sternum fracture and multiple soft tissue injuries. She also sustained fractures of the second and fourth right side ribs, a right clavicle fracture, and a transverse process fracture of L3 due to kinematical movement involved with the severe impact forces. The rear right passenger loaded the lap and shoulder restraint and sustained a myocardium laceration, a coronary artery laceration, an aorta laceration, a pericardium laceration, a spleen laceration, bilateral rib fractures (2–5), a sternum fracture, and multiple soft tissue injuries. As a result of the high impact forces, he also sustained an intraventricular cerebrum hemorrhage, a subarachnoid hemorrhage, a basilar skull fracture, and a left clavicle fracture. All three occupants in the Subaru were transported to a regional trauma center. The driver and front right passenger were admitted and the rear right passenger was pronounced deceased prior to admission. The two occupants of the Chrysler were also transported to a regional trauma center and admitted with moderate injuries. Both vehicles were towed from the scene due to severe damage.

Figure 1 - An overall post-crash view of the 2003 Subaru Legacy.

The crash was initially selected for investigation by one of the NASS teams during their sampling process. The Special Crash Investigation (SCI) team was notified of the crash during the NASS quality control procedures who then notified the Crash Investigations Division (CID) of the National Highway Traffic Safety Administration (NHTSA). Due to the fatal injuries sustained by the rear right passenger of the Subaru, the crash was

assigned by NHTSA as a remote level investigation on October 17, 2007 for the rear occupant protection program. The remote investigation involved a comprehensive review of the NASS case file and this narrative report, which outlines the specifics about the crash. This report has been linked to the NASS Electronic Data System (EDS).

SUMMARY

Crash Site

The crash occurred on a two-lane north/south roadway in the state of Pennsylvania in July 2007. At the time of the crash, the asphalt roadway was dry and there were no adverse weather conditions. The roadway was straight and level and was configured with one lane in each direction that was separated by a painted double-yellow centerline. The lanes were 3.5 m (11.5 ft) in width and were bordered by painted white fog lines and asphalt shoulders. The crash occurred within the business district of a small rural town. The posted speed limit for the roadway was 56 km/h (35 mph). The Crash Schematic is included as **Figure 9** at the end of the narrative.

Vehicle Data

2003 Subaru Legacy

The 2003 Subaru Legacy was designed as a four door sedan and was identified by the Vehicle Identification Number (VIN): 4S3BE635037 (sequence number omitted). The vehicle's odometer reading was estimated by the driver to be 48,280 km (30,000 miles) during the NASS interview. The vehicle's GVWR was 1,996 kg (1,240 lb) with 1,007 kg (626 lb) distributed to the front axle and 989 kg (615 lb) to the rear axle. The all-wheel drive vehicle was equipped with a 4-cylinder, 2.5-liter engine linked to a 4-speed automatic transmission. The braking system consisted of 4-wheel disc brakes with an anti-lock braking system (ABS). The vehicle was equipped with 41 cm (16") steel wheels and P205/55R16 tires. The vehicle manufacturer's recommended cold tire pressure was 221 kPa (32 PSI) for the front tires and 207 kPa (30 PSI) for the rear tires. The tire table below contains revised SCI data for make, model, and damage:

Position	Tire Make/Model	Tire Pressure	Tread Depth	Damage
LF	Continental Ultrex	255 kPa (37 PSI)	9 mm (11/32")	None
LR	Continental Ultrex	255 kPa (37 PSI)	9mm (11/32")	None
RR	Winston Classic	221 kPa (32 PSI)	9 mm (11/32")	None
RF	Continental Ultrex	Tire Flat	9 mm (11/32")	Tire cut/torn

The 2003 Subaru Legacy was configured with front bucket seats with adjustable head restraints. The driver and front right passenger's seat track was adjusted to the rear most track positions. The second row consisted of a fixed bench seat with a fold-down center armrest allowing access to the trunk. All three second row seating positions were configured with integral head restraints.

Vehicle Data – 2000 Chrysler Voyager

The 2000 Chrysler Voyager was designed as a minivan with two front doors and two rear sliding doors. The vehicle was identified by the VIN: 2C4GJ25G7YR (production number omitted). The vehicle's odometer reading was estimated by the driver to be

120,700 km (75,000 miles) during the NASS interview. The vehicle's GVWR was 2,313 kg (1,437 lb) with 1,202 kg (747 lb) distributed to the front axle and 1,179 kg (733 lb) to the rear axle. The front-wheel drive vehicle was powered by a 6-cylinder, 3.3-liter engine linked to a 4-speed automatic transmission. The braking system was configured with ventilated disc brakes for the front wheels and drum brakes for the rear wheels. The vehicle was equipped with 36 cm (14") steel wheels and Republic Enterprise P205/75R14 tires. The specific tire information at the time of the NASS inspection was as follows:

Position	Tire Make/Model	Tire Pressure	Tread Depth	Damage
LF	Republic Enterprise	207 kPa (37 PSI)	5 mm (6/32")	None
LR	Republic Enterprise	221 kPa (37 PSI)	8 mm (10/32")	None
RR	Republic Enterprise	Unknown	7 mm (9/32")	None
RF	Republic Enterprise	Tire Flat	6 mm (8/32")	Tire de-beaded

Crash Sequence

Pre-Crash

The 76-year old female driver of the Subaru was traveling northbound on the two-lane roadway while the 79-year old male driver of the Chrysler was traveling southbound on the same roadway **(Figures 2** and **3)**. Both vehicles were traveling within the business district of a small rural town and intended to continue straight. The Subaru crossed the roadway's centerline and entered the southbound lane. There was no evidence of pre-crash braking by the Subaru. During the NASS interview, the 79-year-old driver of the Chrysler reported that he had no time to initiate any avoidance actions prior to the crash.

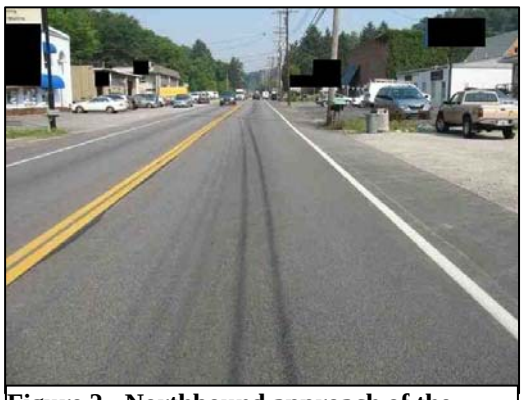

Figure 2 - Northbound approach of the Subaru Legacy.

Figure 3 - Southbound approach of the Chrysler Voyager.

Crash

The front of the Subaru impacted the front of the Chrysler in the southbound lane. The directions of force for the Subaru and the Chrysler were both in the 12 o'clock sector. The impact resulted in severe damage that was sufficient to deploy the frontal air bags in both vehicles. The damage algorithm of the WinSMASH program computed a total

delta-V of 53 km/h (33 mph) for the Subaru. The total delta-V for the Chrysler was 48 km/h (29.8 mph). The specific longitudinal and lateral velocity changes were -53 km/h (-33 mph) and 0 km/h for the Subaru. The Chryslers longitudinal and lateral velocity changes were -48 km/h (-30 mph) and 0 km/h. The Subaru was displaced slightly rearward and came to rest facing in northbound direction. The Chrysler rotated approximately 20 degrees clockwise and came to rest facing in a slight southwest direction. Both vehicles remained on the southbound lane post-crash **(Figure 4)**.

Figure 4 - Post-crash positions of both vehicles.

Post-Crash

The three occupants in the Subaru and two in the Chrysler were injured and unable to exit their vehicles under their own power. Emergency personnel arrived on scene and removed all five passengers from their vehicles due to serious injuries. They were all transported to regional trauma center and the two front seat occupants of the Subaru and both occupants from the Chrysler admitted for their injuries. The rear right passenger of the Subaru expired prior to admission. Both vehicles were towed from the scene due to severe damage.

Vehicle Damage

Exterior Damage – 2003 Subaru Legacy

The 2003 Subaru Legacy **(Figure 5)** sustained severe frontal damage as result of a head-on impact with the 2000 Chrysler Voyager. The direct contact damage encompassed the full frontal plane and measured 140 cm (55”) in length. The maximum crush was located at the front right bumper corner and measured 68 cm (26.8”) in depth. The impact caused the frontal bumper cover and energy absorption material to separate from the vehicle. Therefore, the NASS investigator

Figure 5 - Frontal damage to the Subaru Legacy.

measured the crush profile to the bumper beam and later made adjustments to the profile. The crush profile consisted of six equidistant measurements taken along the bumper beam and were as follows: C1 = 22 cm (8.7”), C2 = 39 cm (15.4”), C3 = 57 cm (22.4”), C4 = 63 cm (24.8”), C5 = 67 cm (26.4”), C6 = 68 cm (26.8”). The Collision Deformation Classification (CDC) was 12-FDEW-3.

The damage was more prominent on the right aspect of the bumper beam; as a result, the right side wheelbase was compressed 20 cm (7.9”) and the left side wheelbase was elongated 4 cm (1.6”). The right fender deformed rearward and the right front tire was aired-out and restricted by the deformed frontal components.

Interior Damage – 2003 Subaru Legacy

The interior of the Subaru sustained minor damage as a result of passenger compartment intrusion and occupant contact. Three minor intrusions were identified during the NASS investigation within the front row. The left and right frontal floor pans were intruded laterally in the range of 5 cm (2”). The right toe pan intruded longitudinally in the range of 5 cm (2”) into the driver’s space.

The NASS investigation revealed occupant contact locations in the form of scuffing to the left lower knee bolster in two locations, which were attributed to the driver’s knees. The NASS investigator identified two additional contact points to the windshield header which were attributed to the driver. However, it is improbable that the driver, who was belted and relatively small in stature, would have contacted the header. The glove compartment door on the front right instrument panel was contacted and scuffed by the front right passenger’s knees in two locations. The front right passenger also loaded her belt evidenced by loading marks on the shoulder belt webbing. The rear right occupant was displaced forward during the impact and loaded the lap and shoulder belt. The sudden displacement and loading of the belt resulted in a frictional abrasion to the rear right seat cushion from the rear right passenger. The NASS investigation detailed a possible occupant contact point located on the right side C-pillar; however, after a review of the evidence in the case, it was determined that it was doubtful that the C-pillar was the source of the right rear passenger’s head injuries. No further evidence of occupant contact was found during the NASS investigation.

Exterior Damage – 2000 Chrysler Voyager

The 2000 Chrysler Voyager sustained **(Figure 6)** severe damage as a result of the impact with the 2003 Subaru Legacy. The direct contact damage encompassed the full frontal width and measured 124 cm (49”) in length. The maximum crush was located 5 cm (2”) right of the vehicle’s centerline and measured 53 cm (20.8”) in depth. The impact caused the frontal bumper cover and energy absorption material to separate from the vehicle. The NASS investigator measured the crush profile to the

Figure 6 - Damaged frontal plane of the Chrysler Voyager.

bumper beam and later made the proper adjustments to the profile. The crush profile consisted of six equidistant measurements to the bumper beam and was as follows: C1 = 38 cm (15”), C2 = 42 cm (16.5”), C3 = 51 cm (20”), C4 = 48 cm (18.9”), C5 = 43 cm (17”), C6 = 42 cm (16.5”). The CDC for the impact with the Subaru was 12-FDEW-3.

Manual Restraints – 2003 Subaru Legacy

The 2003 Subaru Legacy was equipped with 3-point lap and shoulder restraints for all five seating positions. Both front belts were configured with sliding latch plates and retractor pretensioners, which actuated during the crash. The driver’s belt utilized an Emergency Locking Retractor (ELR), while the front right belt utilized a switchable ELR/Automatic Locking Retractor (ALR). The NASS investigation revealed a frictional abrasion on the driver’s shoulder belt webbing near the D-ring, consistent with usage during the crash. The front right passenger’s belt exhibited a 13 cm (5”) loading mark pattern indicative of belt usage. The exact location of the loading evidence was not reported for either belt within the NASS case.

The second row belts were configured with sliding latch plates and switchable ELR/ALR retractors. The NASS case reported no loading evidence to the rear right belt; however, the investigation did conclude that the belt was utilized. During a review of the NASS case, it was evident that the belt was utilized as it was appreciably stretched and remained spooled out from its retractor. Additionally, a review of the images revealed a linear pattern of loading evidence along the shoulder aspect of the belt system. **Figures 7** and **8** illustrate the post-crash right rear belt system.

Figure 7 - Rear right lap and shoulder belt.

Figure 8 - Rear right lap and shoulder belt with potential loading evidence highlighted.

Frontal Air Bag System – 2003 Subaru Legacy

The 2003 Subaru Legacy was equipped with dual stage frontal air bags for the driver and front right passenger, both of which deployed during the crash. The driver’s air bag was concealed within the 4-spoke steering wheel hub and the front right air bag was concealed within the top instrument panel. The NASS case did not report any malfunction with the air bags or loading evidence from occupant contact.

Occupant Demographics

Driver

Age/Sex:	76-year old/Female
Height:	160 cm (63")
Weight:	48 kg (106 lb)
Seat Track Position:	Unknown
Manual Restraint Use:	3-point lap and shoulder belt
Usage Source:	Vehicle inspection
Eyewear:	Eyeglasses
Type of Medical Treatment:	Transported to regional trauma center and admitted for 39 days.

Driver Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Severity
Lumbar spine fracture (L3 – transverse process)	Moderate (650620.2,8)	Impact forces
Lumbar spine fracture (L4), NFS	Moderate (650630.2,8)	Impact forces
Right clavicle fracture	Moderate (752202.2,1)	Impact forces
Concussion	Moderate (160406.2,0)	Impact forces and possible air bag loading
Rib fracture (right side rib 2)	Minor (4502121,1)	Impact forces
Chest contusion	Minor (490402.1,0)	Shoulder belt webbing
Bilateral hip contusions	Minor (890202.1,3)	Lap belt webbing
Bilateral knee contusions*	Minor (890402.1,3)	Knee bolster
Upper extremity skin contusion, NFS	Minor (790402.1,9)	Unknown

Source: Trauma center medical records

**Interview*

Driver Kinematics

The restrained 76-year old female driver of the 2003 Subaru Legacy was seated in an upright posture. The NASS investigation reported that the driver's seat track was adjusted to the full rear position. However, based on the driver's physical dimensions, it is probable that the seat was moved rearward post-crash. At impact with the 2000 Chrysler Voyager, she initiated a forward trajectory responding to the 12 o'clock direction of force and loaded the 3-point lap and shoulder belt. This was evidenced by a transfer in the form of a D-ring frictional abrasion to the shoulder belt webbing and the actuated status of the retractor pretensioner. Correlating injuries as a result of belt loading included bilateral contusions to the driver's hips and a diagonal oriented contusion to her chest.

Due to the asymmetrical loading of the belt, the impact forces caused her upper torso to flex over the shoulder belt and she sustained an offside right clavicle fracture, fractures to the L3 and L4 aspects of her spine, and a fracture to her second right side rib. As she continued in a forward trajectory, her knees contacted the knee bolster resulting in bilateral contusions. She was also diagnosed with a concussion attributable to the impact forces involved with the sudden deceleration of the vehicle and the possible loading of the air bag. The driver was removed from the vehicle by emergency personnel and transported to a regional trauma center. She was admitted for 39 days and then released.

Front Right Passenger

Age/Sex:	74-year old/Female
Height:	163 cm (64")
Weight:	52 kg (115 lb)
Seat Track Position:	Full-rear seat track position
Manual Restraint Use:	3-point lap and shoulder belt
Usage Source:	Vehicle inspection
Eyewear:	Sunglasses
Type of Medical Treatment:	Transported to regional trauma center and admitted for 10 days.

Front Right Passenger Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Severity
Right rib fractures (ribs 2 and 4) with pnuemothorax	Serious (450222.3, 1)	Shoulder belt webbing
Right clavicle fracture	Moderate (752202.2,1)	Shoulder belt webbing
Lumbar spine fracture (L3 – transverse process)	Moderate (650620.2,8)	Impact forces
Sternum fracture	Moderate (450804.2,4)	Shoulder belt webbing
Chest abrasion	Minor (490202.1,0)	Shoulder belt webbing
Left hip contusion	Minor (850602.1,2)	Lap belt webbing
Left thigh contusion	Minor (890402.1,2)	Center console

Source: Trauma center medical records

Front Right Passenger Kinematics

The restrained 74-year old female front right passenger of the 2003 Subaru Legacy was seated in an upright posture. At impact with the 2000 Chrysler Voyager, she initiated a forward trajectory responding the 12 o'clock direction of force and loaded the 3-point lap and shoulder belt. This was evidenced by a transfer in the form of a 13 cm (5") loading mark pattern on the shoulder belt webbing and the actuated status of the retractor pretensioner. As she loaded the belt webbing, she sustained fractures to the sternum,

right clavicle, and second and fourth right side ribs. She also sustained a diagonally oriented contusion to the chest and a contusion to the left hip. The high velocity change of the vehicle at impact resulted in an L3 transverse process fracture of the spine. The front right passenger was removed from the vehicle by emergency personnel and transported to a regional trauma center. She was admitted for 10 days and then released.

Rear Right Passenger

Age/Sex:	86-year old/Male
Height:	183 cm (72")
Weight:	66 kg (146 lb)
Seat Track Position:	Non-adjustable seat track
Manual Restraint Use:	3-point lap and shoulder belt
Usage Source:	Vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Transported to regional trauma center and expired prior to admission.

Rear Right Passenger Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Severity
Multiple myocardium lacerations	Maximum (441016.6,4)	Shoulder belt webbing
Coronary artery laceration	Critical (420800.5,4)	Shoulder belt webbing
Bilateral rib fractures (right ribs 2-5 and left ribs 2 -5) with pneumothorax	Critical (450242.5,3)	Shoulder belt webbing
Cerebral intraventricular hemorrhage	Severe (140678.4,2)	Impact forces
Aortic laceration	Severe (420208.4,4)	Shoulder belt webbing
Right lung contusion with pneumothorax	Serious (441406.3,1)	Shoulder belt webbing
Basliar skull fracture	Serious (150200.3,8)	Impact forces
Subarachnoid hemorrhage	Serious (140663.3,6)	Impact forces
Sternum fracture	Moderate (450804.2,4)	Shoulder belt webbing
Left clavicle fracture	Moderate (752200.2,2)	Impact forces
Pericardium laceration	Moderate (441602.2,4)	Shoulder belt webbing
Spleen laceration	Moderate (544220.2,2)	Shoulder belt webbing

Injury	Injury Severity (AIS90/Update 98)	Injury Severity
Right shoulder contusion	Minor (790202.1,1)	Shoulder belt webbing
Chest contusion	Minor (490402.1,4)	Shoulder belt webbing
Chest abrasion	Minor (490202.1,4)	Shoulder belt webbing
Bilateral hip abrasions	Minor (890202.1,3)	Shoulder belt webbing
Abdomen contusion	Minor (590402.1,8)	Lap belt webbing
Left hip contusion	Minor (890402.1,2)	Lap belt webbing
Left leg abrasion	Minor (890202.1,2)	Front row seat back
Bilateral ankle contusions	Minor (890402.1,3)	Front row seat back
Right foot abrasion	Minor (890202.1,1)	Front row seat back
Right knee contusion	Minor (890402.1,1)	Front row seat back
Right elbow contusion	Minor (790402.1,1)	Right rear door panel

Source: Autopsy

Rear Right Passenger Kinematics

The restrained 86-year old male rear right passenger of the 2003 Subaru Legacy was seated in an upright posture. At impact with the 2000 Chrysler Voyager, he initiated a forward trajectory responding the 12 o'clock direction of force and loaded the 3-point lap and shoulder belt. This was evidenced by severe stretching to the belt system and the webbing's inability to retract post-crash. As a result of the belt loading, the rear right passenger sustained lacerations to the myocardium, coronary artery, aorta and pericardium regions of the heart and a laceration of the spleen. The belt loading also resulted in a right lung contusion, multiple soft tissue injuries to his chest, right shoulder, and abdomen as well as a fracture to the sternum and symmetrical fractures of the second through fifth ribs bilaterally. As he continued in a forward trajectory, his lower extremities contacted the front right seat back resulting in bilateral ankle contusions and right foot and lower left leg abrasions. Due to the asymmetrical loading of the belt, the crash forces caused the rear right passenger's upper torso to flex over the shoulder belt and the rapid movement of his torso and head resulted in an offside fracture of the left clavicle, a basilar skull fracture, a posterior subarachnoid hemorrhage, and a cerebral intraventricular hemorrhage. The rear right passenger was removed from the vehicle by emergency personnel and transported to a regional trauma center. He was pronounced deceased prior to admission.

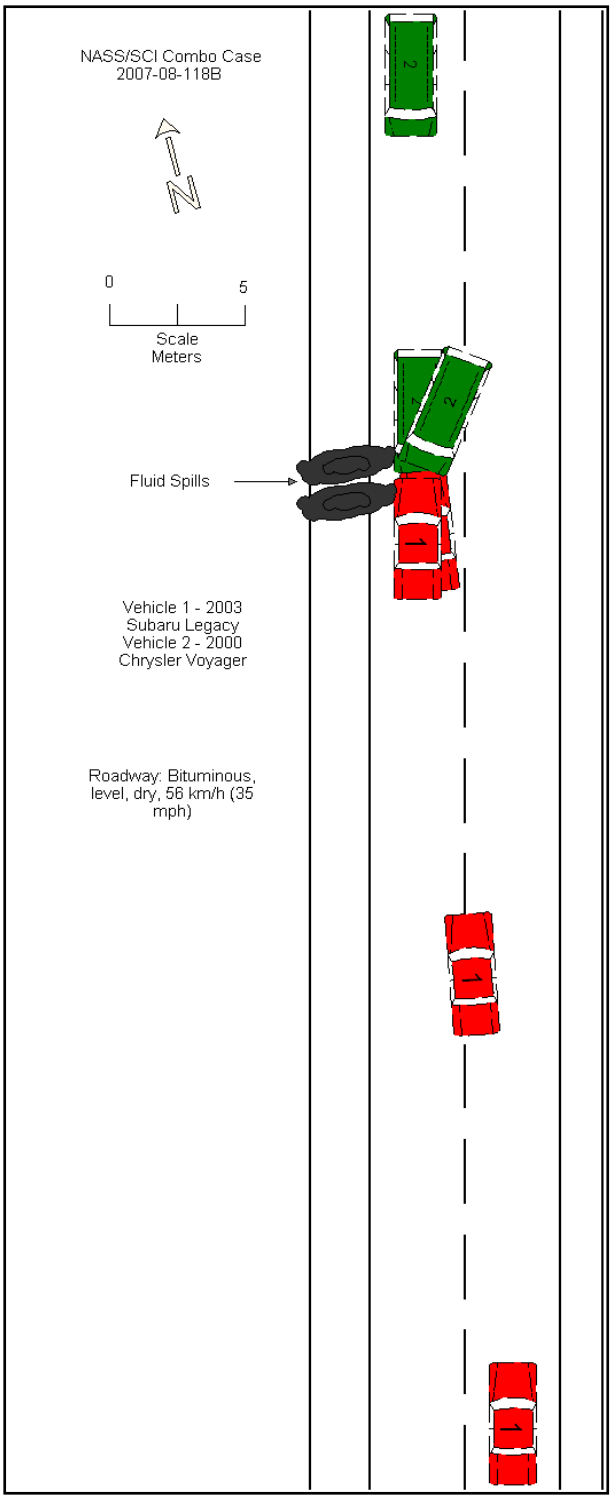

Figure 9 - Crash Schematic