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CALSPAN ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION

CASE NO: CA09008

VEHICLE: 1994 SUBARU LEGACY L

LOCATION: PENNSYLVANIA

CRASH DATE: FEBRUARY 2009

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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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BACKGROUND

This on-site investigation focused on a Child Safety Seat (CSS) and the injury sources for a restrained 4-year-old male passenger that was positioned in a backless booster seat in the right rear seating position of a 1994 Subaru Legacy station wagon **(Figure 1)**. The Subaru was involved in a run-off-road crash with a tree and was driven by a restrained 22-year-old female. The vehicle was equipped with a driver's frontal air bag and motorized two-point automatic shoulder belts with manual lap belts for the front positions and manual three-point lap and shoulder belt for the rear outboard seats. The second row center seat was equipped with a manual lap belt. As a result of the crash, the 4-year-old male sustained fatal head injuries. He was transported to a trauma center where he was pronounced deceased. The driver sustained fractures of the right patella and femur and was transported to a trauma center for treatment.

Figure 1. 1994 Subaru Legacy.

This crash was identified by the Crash Investigation Division (CID) of the National Highway Traffic Safety Administration (NHTSA) through an internet news article. Due to the presence of the CSS, the article was forwarded to the Calspan Special Crash Investigations (SCI) team for follow-up on February 18, 2009. The vehicle and CSS were located and cooperation was established with the police agency to conduct the inspections. An on-site investigation was assigned to the Calspan SCI team on February 19, 2009. The vehicle, CSS, and the crash site inspections were conducted on February 24, 2009.

SUMMARY

Crash Site

The crash occurred during the daytime hours in February 2009. At the time of the crash, it was snowing and the asphalt roadway was ice and snow covered. The crash occurred on the south roadside of a two-lane east/west roadway in a rural setting. The travel lanes were 3.6 m (11.8 ft) wide and were bordered by narrow asphalt shoulders. The north and south shoulders measured 1.8 m (5.9 ft) and 1.4 m (4.6 ft), respectively. The travel lanes were separated by a solid yellow centerline for westbound traffic which represented a no passing zone and a broken yellow centerline for eastbound traffic. The roadside environment consisted of a tree line and natural growth. The roadway was straight and

contained a positive 1.2 percent grade for westbound traffic. A 47 cm (18.5") diameter tree located 5.2 m (17 ft) from the south shoulder was the point of impact. The speed limit in the area of the crash was 89 km/h (55 mph). The Crash Schematic is included as **Figure 15** at the end of this narrative report.

Crash Sequence

Pre-Crash

The 22-year-old female driver of the Subaru was operating the vehicle westbound on the snow/ice covered roadway **(Figure 2)**. A non-contact vehicle was traveling ahead of the Subaru. As the vehicles began to ascend the grade, the driver of the Subaru initiated a passing maneuver around the non-contact vehicle. After passing this vehicle, the driver applied a right steering input in order to reenter the westbound lane. During the reentry, the rear of the vehicle lost traction resulting in a loss of directional control. The driver counter steered to the left and the Subaru departed the left side of the road and traveled approximately 10 meters (33 feet) in a straight line path. The trajectory of the vehicle was supported by the track marks observed in the on-scene police images **(Figure 3)**. The crash site had experienced additional snow fall from the time of the crash to the time of the SCI inspection; therefore, these tire marks were not present at the time of the SCI scene inspection.

Figure 2. Westbound travel path of the Subaru.

Figure 3. Off-road tire marks from the Subaru.

Crash

The front of the Subaru impacted a 47 cm (18.5") diameter tree that was located 5.2 meters (17 feet) south of the road edge **(Figure 4)**. The impact location of the vehicle was slightly off-set to the left inducing a counterclockwise rotation. The Subaru rotated approximately 30 degrees and came to rest against the tree. The direction of force for this impact was 12 o'clock. The damage algorithm of the WinSmash program was used to calculate a delta-V for this impact. The total calculated delta-V was 49 km/h (30 mph) with longitudinal and lateral components of -49 km/h (30 mph) and 0 km/h, respectively. As a result of the crash, the driver's frontal air bag deployed.

Post-Crash

Following the crash, two passers-by, the driver of the non-contact vehicle and a nurse, stopped to render aid to the driver and the child passenger. Both parties stated to the investigating police officer that they observed the child in the rear right seating position restrained by the vehicle's lap and shoulder belt. However, the exact positioning of the safety belt is unknown. The passers-by removed the child from the vehicle. The nurse began resuscitative efforts on the child as they waited for emergency medical personnel to arrive. The nurse stated to the police investigator that she heard the child making gurgling sounds, indicative of fluid in the lungs. The child was transported to a hospital where he was pronounced deceased upon arrival. The driver of the Subaru was extricated from the vehicle. The fire department facilitated the extrication by cutting the roof structure from the vehicle. During this process, the rear safety belts were cut. The driver was transported to a trauma center where she was treated for a fractured right patella and femur. The Subaru sustained disabling damage and was towed from the crash site to a police impound yard.

Figure 4. Area of impact with the 47 cm (18.5") diameter tree.

Vehicle Data – 1994 Subaru Legacy L

The 1994 Subaru Legacy was a four-door station wagon that was identified by the Vehicle Identification Number (VIN): 4S3BJ6335R7 (production number omitted). The vehicle information placard which contained the manufacture date, Gross Vehicle Weight Rating (GVWR), and tire data information was not affixed to the vehicle. The all-wheel drive vehicle was equipped with a 4-cylinder, 2.2-liter engine that was linked to a four-speed automatic transmission. The service brakes consisted of front disc and rear drum with an Anti-lock Braking System (ABS). The odometer reading at the time of the SCI inspection was 210,889 kilometers (131,040 miles). The Subaru was equipped with steel wheels and Goodyear Assurance P185/70R14 tires. The recommended front and rear tire pressure was 207 kPa (30 PSI) and 200 kPa (29 PSI), respectively. The recommended tire data was obtained from a reference manual. The specific tire data at the time of the SCI inspection was as follows:

Position	**Measured Pressure**	**Measured Tread Depth**	**Damage**
Left Front	221 kPa (32 PSI)	7 mm (9/32")	None
Left Rear	117 kPa (17 PSI)	8 mm (10/32")	None
Right Front	221 kPa (32 PSI)	7 mm (9/32")	None
Right Rear	207 kPa (30 PSI)	7 mm (9/32")	None

The 1994 Subaru was equipped with front bucket seats with height adjustable head restraints. Both front head restraints were in the full-down position. The driver's seat was adjusted to the mid-to-forward track position. The second row was configured with a right-side-wide 60/40 split bench seat. The second row was not equipped with head restraints.

Vehicle Damage

Exterior Damage

The 1994 Subaru Legacy **(Figure 5 and 6)** sustained severe frontal damage as a result of the impact with the tree. The direct contact damage was confined to the center front aspect of the vehicle and measured 47 cm (18.5"). The direct damage began 24 cm (9.4") right of the centerline and extended to 23 cm (9.1") left of the centerline. The maximum crush measured 69 cm (27.2") and was located 9 cm (3.5") left of the centerline. Six equidistant crush measurements were documented along the bumper beam of the vehicle and were as follows: C1 = 31 cm (12.2"), C2 = 41 cm (16.1"), C3 = 69 cm (27.2"), C4 = 65 cm (25.6"), C5 = 38 cm (15.0"), C6 = 12 cm (4.7"). The Collision Deformation Classification (CDC) for this impact was 12-FCEW-3.

The Subaru's wheelbases were compressed as the vehicle deformed. The left and right wheelbases were compressed 9 cm (3.5") and 2 cm (0.8"), respectively. Although the roof was cut off the vehicle, the four doors were closed and operational at the time of the SCI inspection. The alignment of the right front door was altered by body deformation could no longer close properly. The windshield was cut from the vehicle and it is unknown if it was damaged during the crash. The side and rear glazing was not damaged.

Figure 5. Overall view of the Subaru.

Figure 6. Overhead view of the crush profile.

Interior Damage

The interior damage to the Subaru consisted of moderate severity intrusion to the front left and right toe pans, instrument panel, and occupant loading of the steering assembly, knee bolsters, instrument panel, and air bag. The complete profile of intruded components identified during the SCI vehicle inspection are listed in the following table:

Position	Component	Magnitude	Direction
Front Left	Toe pan	12 cm (4.7”)	Longitudinal
Front Left	Instrument panel	3 cm (1.2”)	Longitudinal
Front Center	Instrument panel	3 cm (1.2”)	Longitudinal
Front Right	Toe pan	1 cm (0.4”)	Longitudinal
Front Right	Instrument panel	3 cm (1.2”)	Longitudinal

Several discernable occupant contact points were identified during the SCI vehicle inspection. The restrained female driver of the Subaru was displaced forward during the impact. She loaded the steering assembly and the knee bolster in two locations. The driver’s knees struck the knee bolster which resulted in fracturing of the rigid plastic knee bolster cover and pocketing of the steel backer panel. The pocketing occurred to the left and right aspects of the backer panel. The center instrument panel exhibited damage; however, this appeared to be induced damage from the exterior crash force rather than occupant contact. The driver also contacted and loaded the steering wheel rim and column. The top section of steering wheel rim was deformed forward 11 cm (4.3”). The steering column loading resulted in compression of the shear capsules. The left shear was compressed 0.5 cm (0.2”) and the right was compressed 1 cm (0.4”). **Figure 7** is an overall view of the driver’s area.

Figure 7. Overall view of the driver's area and contact points.

The child was displaced forward during the crash which resulted in his head contacting the right B-pillar **(Figure 8)**. This contact was located 5 cm (2”) above the belt line and was evidenced by hair, body fluid, and skin. No additional contact points were noted for this passenger. Belt loading evidence was observed during the inspection. This loading is described in the ***Safety Belt*** section of this report.

Figure 8. Rear right passengers B-pillar contact point.

The glove box door was fractured during the crash. This damage was attributed to a bag full of items which weighed approximately 2.2-4.5 kg (5-10 lbs) that was placed on the front right seat. The bag was displaced forward during the crash contacting the glove box door resulting in the noted damage. The cargo area of the Subaru contained a stroller and a large box among other items. The box was not present at the time of the SCI inspection; however, it was observed in the police on-scene images. The box was

estimated at 61 x 76 x 51 cm (24 x 30 x 20”) width x depth x height and was filled with unknown items. This cargo was displaced forward during the crash resulting in deformation of the second row seat back. The deformation occurred to the center aspect. The deformation included the inboard aspects of the left and right side of seat back. The maximum forward displacement occurred at the center aspect and was approximately 19 cm (7.5”).

Frontal Air Bag System

The 1994 Subaru Legacy was equipped with a frontal air bag for the driver’s position only. As a result of the tree impact, the driver’s frontal air bag deployed. The driver’s air bag was housed within the steering wheel and was concealed by two cover flaps. The top and lower flaps measured 17 cm (6.7”) in width. In height, the top and lower flaps measured 8 cm (3.1”) and 5 cm (2”), respectively. The air bag was 58 cm (22.8”) in diameter in its deflated state and had a maximum excursion of 26 cm (10.2”). The air bag was vented by two ports at the 11 and 1 o’clock positions on the rear panel and was tethered by two internal tethers.

Several areas of dirt and expansion marks were present across the air bag fabric. Additionally, a contact area was noted to the face of the air bag. This contact consisted of a purple-colored make-up transfer that began at the centerline and extended downward 25 cm (9.8”) and extended 4-6 cm (1.6-2.4”) left of the centerline.

Safety Belt Systems

The 1994 Subaru Legacy was equipped with a manual lap belt and a motorized shoulder belt in each front seat position. The lap belt consisted of a retractable webbing, Emergency Locking Retractor (ELR), a buckle mounted to the inboard aspect of the seat, and a sewn-on latch plate. The lap belt retractor was located on the left side of the seat cushion. The motorized shoulder belt consisted of a retractable webbing, an ELR mounted on the inboard side of the seat and a sewn-on latch plate. A motorized mouse was attached to a track located within the roof side rail above the door. The mouse ran forward to the A-pillar when the front door was opened and returned to a rearward position adjacent the B-pillar with the door closed. The shoulder belt latch plate attached to the mouse and was designed to remain latched. The forward and aft movement of the mouse allowed for the ingress/egress of the occupants and positioned the belt for use.

Figure 9: Driver's shoulder belt webbing.

At the time of the SCI inspection, the driver's lap belt webbing was stowed in the ELR retractor and encased in ice and snow. The roof was cut from the vehicle by the first responders, thus exposing the retractor to the elements. The lap belt could not be inspected. The driver's shoulder belt was stowed in the inboard retractor at initial inspection. Inspection of the webbing revealed a 43 cm (16.9") section that appeared loaded and stressed **(Figure 9)**. The loading was attributed to the driver's torso during the frontal impact. With the shoulder belt spooled out, the loaded section was located 46 cm (18.1") to 89 cm (35") above the retractor. The mouse was located in the retracted position adjacent to the cut pillar.

Figure 10: Rear right safety belt webbing.

The rear seat positions of the Subaru were equipped with three-point lap and shoulder belts in the outboard positions and a center rear lap belt. The outboard restraints consisted of continuous loop webbing, sliding latch plates, ELR, and fixed D-rings. The center rear restraint consisted of an adjustable length webbing and a locking latch plate. The center position was not occupied. The rear left position was used to restrain an unoccupied CSS.

The SCI inspection of the rear right restraint revealed signs of obvious use **(Figure 10)**. The webbing was cut by the rescue personnel as they cut the roof from the vehicle. The safety belt was cut 16 cm (6.3") above the latch plate. The exposed webbing section measured 110 cm (43.3") in length from the outboard anchor to the cut end. The balance of the webbing had spooled back into the retractor and could not be inspected. The rear right webbing was gathered and jammed in the latch plate. The latch plate was located 94 cm (37") above the anchor. Examination of the webbing adjacent to the jammed latch plate revealed 9 cm (3.5") of heavily abraded webbing. The hardware on the latch plate exhibited corresponding abrasions. Refer to **(Figure 11)**. As the child occupant loaded the lap belt, the belt folded over onto itself. The folded webbing section measured 22 cm (8.7"). Examination of the D-ring revealed minor frictional abrasions associated with use.

Figure 11. Frictional abrasions of the rear right latch plate.

Figure 12. Loose fit of the lap belt webbing.

Given the disparity in the nature (strength) of the abrasions between the D-ring and latch plate, it is probable that the child's loading force translated primarily to the lap belt. Inspection of the rear right restraint determined that excess slack developed in the lap belt due to the combined kinematic loading of the child, and the physical seat back loading produced by unsecured objects in the trunk. **Figure 12** is an overhead view of the booster seat and the lap belt slack. The longitudinal distance between the seat bight and the webbing measured 39 cm (15.3").

Child Safety Seat

The 4-year-old male was positioned in a Cosco Highrise backless booster child safety seat and was restrained by the vehicle's manual three-point lap and shoulder belt in the rear right seating area **(Figure 13)**. The safety seat was manufactured by Dorel Juvenile Group and contained model number 22-297-DSW. The manufacture date of the safety seat was 12-19-2007 and had a "do not use beyond date of December 2013." This safety seat was designed to be used with children that are over 1-year in age, weighing 13.6-45.4 kg (30-100 lbs), and whose height is 85-145 cm (34-57"). The labeling indicates that the child should be restrained with a lap and shoulder belt system when using the safety seat. The safety seat was constructed of a plastic shell and contained a padded seating surface, built-in cup holder on the left side, and fixed height arm rests.

Figure 13. Overall view of the child safety seat.

The inspection of the safety belt system indicated that slack was present in the webbing. Although the shoulder belt portion was cut, the 110 cm (43.3") section of webbing that remained contained evidence of loading and creasing which indicated usage. The positioning of the lap belt was supported by the gathered section of webbing in the latch plate. The gathered webbing prevented any movement of the webbing through the sliding latch plate. In the buckled position, the lap belt extended 39 cm (15.3") from the rear edge of safety seat to the forward edge **(Figure 14)** creating a large arc of webbing. During the crash, the child and the safety seat loaded the safety belt webbing resulting in frictional abrasions to the belt path. On the left side, these frictional abrasions were minor and measured 4 cm (1.6") in height and wrapped around the belt path 1 cm (0.4"). The

Figure 14. Overhead view of the booster seat.

abrasions on the right belt path were more extensive and measured 8 cm in height and also wrapped around the belt path 1 cm (0.4”). The safety seat was not damaged during the crash.

An unoccupied Cosco/Dorel Scenera CSS was stowed in the cargo area of the vehicle.

Occupant Demographics/Data

Driver

Age/Sex:	22-year-old/Female
Height:	Unknown
Weight:	100 kg (220 lbs)
Seat Track Position:	Mid-to-forward track position
Eyewear:	Unknown
Safety Belt Usage:	Motorized shoulder belt, manual lap belt not used
Usage Source:	Vehicle inspection
Egress from Vehicle:	Extricated from the vehicle by the fire department
Mode of Transport from Scene:	Ambulance
Type of Medical Treatment:	Transported to a hospital, treated and released

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Right mid shaft femur fracture (transverse, displaced)	Serious (851814.3,1)	Knee bolster (indirect)
Right patella fracture	Moderate (852400.2,1)	Knee bolster
Upper mid chest abrasion	Minor (490202.1,4)	Shoulder belt
Small lacerations to the right hand	Minor (790602.1,1)	Windshield
Abrasions to the top of the right hand	Minor (790202.1, 1)	Windshield
Right knee abrasions	Minor (890202.1,1)	Knee bolster

Source – Medical Records

Driver Kinematics

The female driver was seated in a mid-to-forward track position and was restrained by the motorized shoulder belt. The lap portion of the restraint was not in use. The driver lost directional control of the Subaru on a snowy/icy road during a passing maneuver. The vehicle departed the left side of the road and impacted a tree with its front plane.

At impact, the inertial locking retractor locked the shoulder belt and the driver air bag deployed. The deploying air bag displaced the driver’s right hand into the windshield resulting in the abrasions and lacerations to the right hand. The driver responded to the 12 o’clock direction of force with a forward trajectory. The driver’s torso loaded the shoulder belt resulting in the chest abrasion. Her upper body began to decelerate in

response to this loading. Due to the lap belt not being used, the forward inertia of her unrestrained lower body caused the driver to submarine (under) the shoulder belt. The driver translated forward and her knees contacted and deformed the knee bolster/lower instrument panel. This contact resulted in the right knee abrasions, and the right patella fracture. Additionally, this contact resulted in the indirect loading of her femur and its subsquent fracture. The driver's abdomen loaded and deformed the steering wheel rim. Compression of the steering column and shear capsules were noted from the driver's loading. Her face contacted the deployed driver air bag evidenced by a make-up transfer on the center of the membrane. As the vehicle rotated counterclockwise to rest, the driver rebounded back into the driver seat. The driver was transported to a hospital where she was treated for her injuries and released.

Second Row Rear Right Child Passenger

Age/Sex:	4-year-old/Male
Height:	104 cm (40.9")
Weight:	23 kg (50 lbs)
Seat Track Position:	N/A, fixed
Eyewear:	Unknown
Child Restraint Use:	Positioned on a backless booster seat, restrained by the lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from Vehicle:	Removed by a passer-by
Mode of Transport from Scene:	Ambulance to hospital
Type of Medical Treatment:	Pronounced deceased shortly after arrival to the hospital

Second Row Rear Right Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Intraventricular hemorrhage	Severe (140678.4,9)	Right B-pillar
Subdural hemorrhage, NFS	Severe (140650.4,9)	Right B-pillar
Epidural hemorrhage, NFS	Severe (140630.4,9)	Right B-pillar
Right subarachnoid hemorrhage	Serious (140684.3,1)	Right B-pillar
Left subarachnoid hemorrhage	Serious (140684.3,2)	Right B-pillar
Cerebellum subarachnoid hemorrhage	Serious (140466.3,6)	Right B-pillar
Frontal bone fracture (horizontal fracture of adjacent front and left frontal bone 3.7 cm in length)	Moderate (150400.2,5)	Right B-pillar
Left tempo-parietal bone fracture (diagonal fracture 8.7 cm in length)	Moderate (150400.2,2)	Right B-pillar

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Left scalp laceration (large diagonal gaping laceration from the lateral aspect of left eyelid to the tempo-parietal area, 8.2 x 2.5 cm)	Minor (190602.1,2)	Right B-pillar
Left side scalp hematoma (left side anteriorly and into the tempo-parietal area)	Minor (190402.1,2)	Right B-pillar
Left cheek contusion (2.7 x 1.5cm)	Minor (290402.1,2)	Right B-pillar
Center abdomen contusion (at the gastroesophageal junction)	Minor (590402.1,4)	Lap belt
Bilateral hip contusions (left hip 4.5 x 4cm, and right hip 1.5 x 1.5 cm)	Minor (890402.1,3)	Lap belt

Source – Autopsy

Second Row Rear Right Child Passenger Kinematics

The 4-year-old male child was seated on a backless booster seat in the second row right position of the vehicle. The child was restrained by the vehicle's three-point lap and shoulder belt system. The observations of the SCI inspection indicated the lap portion of the safety belt was loosely adjusted about the booster seat and child. The position and adjustment of the shoulder belt could not be determined.

At impact, the ELR retractor locked the safety belt. The child and booster seat responded to the 12 o'clock direction of the impact force by initiating a forward trajectory. As the child and seat translated forward, the child began to load the lap portion of the belt with his abdomen. The loaded belt began to abrade the latch plate hardware and fold over onto its self. The continued loading of the lap belt caused the belt to gather and jam in the hardware of the latch plate as observed at the time of the SCI inspection. The loading of the lap belt resulted in the contusions to the child's hips and abdomen.

The slight off-set (left) impact location on the front of the vehicle induced a counterclockwise rotation. The lap belt loading caused the child to jackknife over the lap belt. The position of the shoulder belt most likely was below the level of the child's shoulder. In this position, the child would jackknife forward and rotate clockwise (when viewed from overhead). As the child translated forward and CW, the vehicle rotated CCW. The combination of the vehicle rotation and the child's forward kinematic pattern resulted in the left side of his head impacting the right B-pillar. The B-pillar contact was evidenced by body fluid, hair, and tissue resulting in the identified head, brain, and facial injuries. The child then rebounded back into the rear right position. During the rebound phase, the shoulder belt repositioned itself on the child's shoulder as observed by the passers-by responding to the crash.

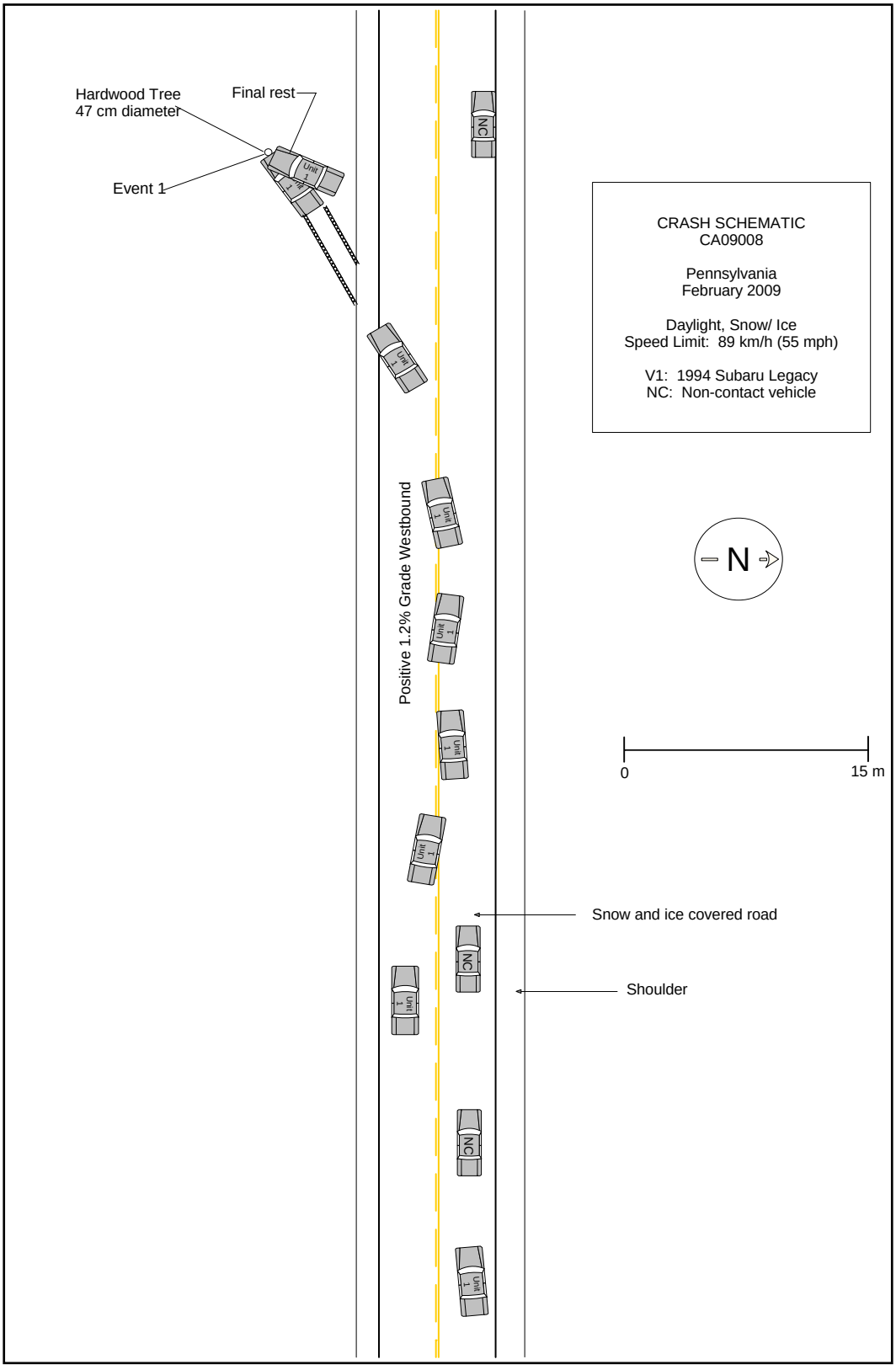

Figure 15: Crash Schematic