

**TRANSPORTATION SCIENCES
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Veridian Engineering
Buffalo, NY 14225

**VERIDIAN ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION
SYSTEM CRASH INVESTIGATION
SCI TECHNICAL SUMMARY REPORT**

VERIDIAN CASE NO. CA02-024

VEHICLE - 2001 VOLVO V70 T5

LOCATION - STATE OF NORTH CAROLINA

CRASH DATE - MAY 2002

Contract No. DTNH22-01-C-17002

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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. <i>Abstract</i> This on-site investigation focused on a three-vehicle crash that involved a 2001 Volvo V70 that was equipped with a side impact occupant protection system (SIPS) that deployed as a result of a side impact intersection collision with a 1999 Ford Mustang. The Volvo was occupied by a 45-year-old female driver who was restrained by the manual 3-point lap and shoulder belt. At the initial left side impact, the driver's side air bag (SIPS II) and the left side inflatable curtain (IC) deployed. The driver initiated a lateral trajectory in response to the left side impact force and loaded the lap and shoulder belt and the deployed driver SIPS II air bag and IC. She sustained a minor abrasion on her left torso area from possible clothing friction as a result of the side air bag deployment. The Volvo was redirected in a counterclockwise (CCW) rotation across the intersection and struck the rear of a parked 1996 Nissan Sentra with the rear aspect. The Volvo came to rest on the roadway and the driver exited the vehicle under her own power. She did not receive medical treatment at the scene and was not transported. She did not seek follow-up medical treatment.			
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VERIDIAN CASE NO. CA02-024
SUBJECT VEHICLE - 2001 VOLVO V70 T5
LOCATION - STATE OF NORTH CAROLINA
CRASH DATE - MAY 2002**

BACKGROUND

This on-site investigation focused on a three-vehicle crash that involved a 2001 Volvo V70 (**Figure 1**) that was equipped with a side impact occupant protection system (SIPS) that deployed as a result of a side impact intersection collision with a 1999 Ford Mustang. The Volvo was occupied by a 45-year-old female driver who was restrained by the manual 3-point lap and shoulder belt. At the initial left side impact, the driver's side air bag (SIPS II) and the left side inflatable curtain (IC) deployed. The driver initiated a lateral trajectory in response to the left side impact force and loaded the lap and shoulder belt and the deployed driver SIPS II air bag and IC. She sustained a minor abrasion on her left torso area from possible clothing friction as a result of the side air bag deployment. The Volvo was redirected in a counterclockwise (CCW) rotation across the intersection and struck the rear of a parked 1996 Nissan Sentra with the rear aspect. The Volvo came to rest on the roadway and the driver exited the vehicle under her own power. She did not receive medical treatment at the scene and was not transported. She did not seek follow-up medical treatment.



Figure 1. Damaged 2001 Volvo V70

This crash was identified by the National Automotive Sampling System (NASS) PSU 43 during the weekly sampling of Police Accident Reports (PARs). This crash was not selected as a CDS case, however, the PAR was forwarded to the Veridian SCI team. The PAR was forwarded to NHTSA, and an on-site investigation was initiated due to the presence of the side impact inflatable occupant protection system deployment in the 2001 Volvo V70. The 1999 Ford Mustang could not be located for inspection.

SUMMARY

Crash Site

This three-vehicle crash occurred at a four-leg intersection of two urban roadways during daylight hours. At the time of the crash, the weather was clear and the asphalt roadway surface was dry. The one-way northbound roadway consisted of three travel lanes and was bordered by concrete curbs. The outboard travel lane on the east side was widened to accommodate curbside parking. The north roadway was

straight and had a downhill grade at the crash site. A hillcrest was located south of the intersection. The undivided east/west roadway consisted of two travel lanes in each direction and was bordered by concrete curbs. The east/west roadway had a hillcrest at the intersection. Traffic through the intersection was governed by stop signs for east/west traffic approaching the intersection. The stop sign on the southwest corner of the intersection for eastbound traffic was occluded by branches from an adjacent tree. The posted speed limit for the north roadway was 48 km/h (30 mph) and the posted speed limit for the east/west roadway was 56 km/h (35 mph). The scene schematic is included as **Figure 13** of this report.

Pre-Crash

The 45-year-old female driver of the 2001 Volvo V70 was operating the vehicle northbound on the middle lane of the northbound one-way roadway on approach to the four-leg intersection (**Figure 2**). She estimated the speed of her vehicle at 56 km/h (35 mph). The 17-year-old male driver of the 1999 Ford Mustang was operating the vehicle eastbound on approach to the four-leg intersection (**Figure 3**). For unknown reasons, the driver of the Ford Mustang disregarded the stop sign and entered the intersection as the Volvo was traveling through the intersection. The driver of the Volvo braced her arms against the steering wheel and applied the brakes when she realized the imminent collision. It was not known if the driver of the Mustang attempted any avoidance maneuvers.

Crash

The front aspect of the Ford Mustang impacted the left side aspect of the Volvo. Impact resulted in moderate damage to the Volvo, and police-reported moderate damage to the Mustang. The damage algorithm (missing vehicle routine) of the WinSMASH program computed a total delta-V of 12.0 km/h (7.5 mph) based on the crush profile of the Volvo. The longitudinal component was -7.7 km/h (-4.8 mph) and the lateral component was -9.2 km/h (-5.2 mph). Based on the elongated damage pattern on the Volvo, it appears the Mustang sustained contact with the Volvo as the Volvo continued in a northbound direction across the front of the Mustang. The Volvo was redirected in a CCW rotation through the intersection and traveled toward the outboard curb of the northbound roadway. The Volvo rotated approximately 160 degrees and the rear aspect of the Volvo struck the rear aspect of a parked 1996 Nissan Sentra that was parked along the outboard curb. The damage algorithm of the WinSMASH program computed a total delta-V for the Volvo of 14.0 km/h (8.7 mph) and a total delta-V of 22.0 km/h (13.7 mph) for the Nissan Sentra. The secondary impact displaced the Sentra forward and the rear aspect was deflected CCW onto



Figure 2. Northbound approach for the Volvo V70



Figure 3. Eastbound approach for the Ford Mustang

the east roadside. The right rear side aspect of the Sentra struck the inboard post of a speed limit sign and came to rest. The Volvo came to rest facing south on the outboard northbound lane.

Post-Crash

The driver of the Volvo V70 stated that she called a family member on a cellular telephone before she exited the vehicle. She stated that someone attempted to open the left front door from the outside but the door would not open. She opened the door from the inside of the vehicle and exited the vehicle under her own power. She sustained a minor torso abrasion and did not receive medical treatment. It was not known how the driver of the Mustang exited the vehicle. He sustained police-reported possible injuries, but was not transported to a medical facility.

VEHICLE DATA - 2001 Volvo V70

The 2001 Volvo V70 was identified by the Vehicle Identification Number (VIN): YV1SW53D812 (production sequence omitted). The Volvo V70 was leased through a local auto dealer. The electronic odometer reading was not available, but the driver estimated the odometer reading to be approximately 22,520 km (14,000 miles). The vehicle was a four-door station wagon configured with a rear lift gate hinged at the top aspect. The vehicle was equipped with a 2.3 liter, 5-cylinder engine, a 5-speed "Geartronic" microprocessor-controlled automatic transmission with "Auto-Stick" function, power four-wheel disc brakes with anti-lock, traction control, stability control, aluminum/alloy wheels, power steering, a tilt and telescoping steering column, steering wheel mounted audio and cruise controls, power door locks, power windows, and automatic climate control. The Volvo V70 was equipped with Pirelli P6 Four Seasons P235/45R17 tires. The specific tire data is as follows:

Tire	Tread	Pressure
LF	5.6 mm (7/32")	262.0 kpa (38.0 psi)
LR	5.6 mm (7/32")	255.1 kpa (37.0 psi)
RF	4.8 mm (6/32")	241.3 kpa (35.0 psi)
RR	4.8 mm (6/32")	248.2 kpa (36.0 psi)

The front seating positions in the Volvo V70 were configured with bucket seats with fixed head restraints and the Whiplash Protection Seating System (WHIPS). The WHIPS system activated during the secondary rear impact with the Nissan Sentra. The following description of WHIPS was obtained from the Volvo website:

WHIPS is a mechanical system which is built into the front seats. It consists of a spring-suspended wire frame in the backrest and a special mechanism which holds the backrest and seat together.

If the car is struck from behind, the system is activated in two phases. During the first phase, the wire frame, and its limited-travel springs, helps prevent the occupant of the seat from being pressed too deeply into the backrest. It also provides support for the spine and prevents it from excessive bending. At the same time, the WHIPS mechanism enables the whole of the backrest to move backwards, preventing the passenger from being thrown forwards. The upper part of the backrest moves upwards and forwards to enable the head restraint to better support the neck and head. In the second phase, the WHIPS mechanism allows the backrest to tip backwards, absorb the force generated by the collision, and reduce the dangerous catapult effect.

All of the seating positions in the Volvo were also equipped with anti-submarining guards. The contoured shape of the seat frame with a high front edge is designed to prevent occupants from sliding under and out of the manual restraint systems in a crash. The front left seat was removed at the base post-crash and the seat track position could not be determined.

The rear seating positions were configured with a 60/40 bench seat with folding backs. The seat cushions were designed to fold forward against the front seat backs and the rear seat backs folded downward behind the forward-folding cushions (**Figure 4**). At the time of the vehicle inspection, the rear left seat cushion was removed and the rear seats were folded forward. Both the seat cushions and seat backs were equipped with locking mechanisms in the upright and full-down positions. The rear seat was configured with fixed-height head restraints that pivoted fore and aft for the outboard positions. The center position was configured with an adjustable head restraint in the full-down position and a fold down center arm rest. A retractable 60/40 split cargo net was present in the rear seat backs that extended vertically to the roof. The cargo net was fully retracted at the time of the vehicle inspection, however, the driver stated that at the time of the crash the cargo net was extended to the roof.



Figure 4. View of folded rear seats

The vehicle's battery was located in the rear cargo area on the left aspect. The fuse panel was also located in the rear cargo area on the rear aspect of the left interior panel. The battery and fuse panel were exposed at the time of the vehicle inspection (**Figure 5**).



Figure 5. View of battery and fuse panel

VEHICLE DAMAGE

Exterior Damage - 2001 Volvo V70

The 2001 Volvo V70 sustained moderate left side damage as a result of the impact with the Ford Mustang (**Figure 6**). The direct contact damage began at the leading edge of the left front door and extended 224.8 cm (88.5") rearward across the left side doors and onto the left rear quarter panel. Direct contact was evidenced by longitudinal abrasions and scuff marks were present above and below the side rub strip on the left side doors. Both doors sustained lateral crush above the sill as a result of the initial impact with the Mustang. The sill trim on the front left aspect was partially separated. A sheet metal tear that measured 6.4 cm (2.5") in width and 1.3 cm (0.5") in height was located below the mid-door rub strip on the lower aspect of the left rear door. The combined direct and induced damage began 44.5 cm (17.5") forward of the leading edge of the left front door and extended 289.6 cm (114.0") rearward across the left side doors and left rear quarter panel. The rear aspect of the left front fender was deformed inward and the forward aspect of the left rear quarter panel was deformed inward as a result of induced damage. The forward deflection point on the left side was located 2.5 cm (1.0") aft of the front axle and the rear deflection point was located 19.1 cm (7.5") aft of the rear axle. The left rear wheel was abraded and scuffed from direct contact with the Mustang as the vehicles disengaged. The top trim which extended longitudinally from the left A-pillar to the left D-pillar along the roof side rail was separated. The Collision Deformation Classification (CDC) for the impact with the Mustang was 10-LZEW-2. Six crush measurements were documented along the bottom aspect of the mid-door rub strip and were as follows: C1 = 0.0 cm, C2 = 5.7 cm (2.3"), C3 = 14.0 cm (5.5"), C4 = 7.6 cm (3.0"), C5 = 8.9 cm (3.5"), C6 = 0.0 cm.

The Volvo V70 sustained moderate rear aspect damage as a result of the secondary impact with the parked Nissan Sentra (**Figures 7 and 8**). The direct contact damage began 11.4 cm (4.5") left of center on the lift gate and extended laterally 68.6 cm (27.0") to the rear left corner. Paint transfers from the Sentra were present on the lift gate. The lift gate was fractured as a result of direct contact 39.4 cm (15.5") left of center. The fracture extended diagonally to the bottom left aspect and upward to the base of the glazing. The rear bumper fascia was separated from the vehicle and not available at the time of the vehicle inspection. The plastic honeycomb filler sustained minor crush and deformation on the rear left corner aspect. The combined direct and induced damaged involved the entire width of the rear plane. Six crush



Figure 6. View of left side damage to the VolvoV70



Figure 7. View of rear left damage to the Volvo V70



Figure 8. View of tailgate and rear damage to the Volvo V70

measurements were documented along the rear bumper and were as follows: C1 = 2.5 cm (1.0"), C2 = 2.5 cm (1.0"), C3 = 0.0 cm, C4 = 0.0 cm, C5 = 0.0 cm, C6 = 0.0 cm. The CDC for the secondary impact with the Nissan Sentra was 06-BYEW-1.

Interior Damage - 2001 Volvo V70

Interior damage to the Volvo V70 was moderate and attributed to compartment intrusion. The left rear door was jammed shut, and the tailgate was separated from the vehicle. There was no damage to the windshield or side glazing, however, the backlight was disintegrated as a result of the rear impact. Compartment intrusion included the following:

Position	Component	Intrusion	Direction
LF	Left front door	3.2 cm (1.3")	Lateral
LF	Left B-pillar	1.6 cm (0.6")	Lateral
LF	Left roof side rail	1.3 cm (0.5")	Lateral
LR	Left rear door	3.2 cm (1.3")	Lateral

The raised aspect of the left sill forward of the left B-pillar for the SIPS was deformed by the intrusion of the left front door. There was no evidence of occupant contact within the vehicle interior.

Exterior Damage - 1999 Ford Mustang

The 1999 Ford Mustang could not be located for inspection. The PAR reported a damage severity of FD-6 on the TAD scale.

Exterior Damage - 1996 Nissan Sentra

The 1996 Nissan Sentra sustained moderate rear aspect damage as a result of the impact with the Volvo V70 (**Figure 9**). The bumper fascia was separated from the vehicle. The direct contact damage on the bumper fascia began 15.9 cm (6.3") left of center and extended laterally 48.3 cm (19.0") to the rear left corner. The left rear quarter panel and trunk lid were abraded crushed forward from direct contact. The combined direct and induced damage involved the entire width of the Sentra and measured 123.2 cm (48.5"). The entire bumper beam was displaced as a result of the crush on the rear left corner. The backlight was disintegrated as a result of induced damage. The CDC for the impact with the Volvo was 07-BYEW-4. Six crush measurements were documented along the rear bumper beam and were as follows: C1 = 40.6 cm (16.0"), C2 = 31.1 cm (12.3"), C3 = 23.2 cm (9.1"), C4 = 14.0 cm (5.5"), C5 = 4.4 cm (1.8"), C6 = 0.0 cm.



Figure 9. Rear damage to the 1996 Nissan Sentra

MANUAL RESTRAINT SYSTEMS - 2001 Volvo V70

The 2001 Volvo V70 was equipped with manual 3-point lap and shoulder belts for each seating position. The driver's manual restraint was configured with continuous loop webbing, a sliding latch plate, an automatic height adjuster, and a load-limiting emergency locking retractor (ELR) with a retractor pretensioner. The driver's seat belt exhibited minor stretch marks located 58.4 cm (23.0") above the lower anchor that extended 45.7 cm (18.0") up the shoulder belt portion of the webbing. There were no abrasions found on the upper anchorage or latch plate housing. The front right passenger's manual restraint was configured with continuous loop webbing, a sliding latch plate, and a load limiting switchable/automatic locking retractor (ALR) with a retractor pretensioner.

The rear seat manual restraints were configured with sliding latch plates and switchable/ALR's with retractor pretensioners. The retractors for the rear seat belts were mounted in the seat backs.

FRONTAL AIR BAG SYSTEM - 2001 Volvo V70

The 2001 Volvo V70 was equipped with dual-stage frontal air bags for the driver and front right passenger positions. Sensors in the seat belt buckles determined the threshold for frontal air bag deployment. The system continuously monitored the buckle status and adjusted the frontal air bag deployment (no deployment, first stage only, or dual stage deployment) based on crash severity and seat belt usage. The frontal air bag system did not deploy in this crash.

SIDE IMPACT AIR BAG SYSTEM - 2001 Volvo V70

The side impact inflatable occupant protection system in the 2001 Volvo V70 consisted of side impact air bags (SIPS II) that were mounted in the front seat backs and inflatable curtains (IC) which were located in the roof side rails between A- and C-pillars. The left side SIPS II and IC deployed as a result of the left side impact with the Ford Mustang. The sensors for the side impact occupant protection system were located in the lower B-pillars and behind the rear door openings. If only the rear sensor was activated in a crash, the IC would deploy but not the front SIPS II's.

The left SIPS II deployed from the front outboard aspect of the driver's seat back (**Figure 10**). The stitched tear seam along the forward edge of the seat back measured 54.6 cm (21.5") in height. An additional vertical tear in the outboard side aspect of the seat fabric was noted 3.8 cm (1.5") aft of the air bag tear seam and 22.9 cm (9.0") above the bottom aspect that measured 5.1 cm (2.0") long. The laceration was in proximity to the seat belt latch plate stop button in the seat belt's retracted mode. The source of the laceration was not known. In its deflated state, the forward excursion of the SIPS II measured 16.5 cm (6.5) at the center aspect and the air bag measured 40.6 cm (16.0") in height and 34.3 cm (13.5") in length. The SIPS II was vented by a single circular vent port that measured 2.5 cm (1.0") in diameter and was located 2.5 cm (1.0") below

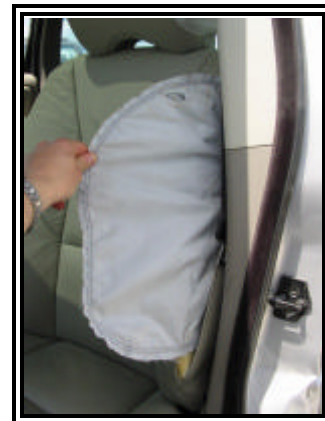


Figure 10. Deployed driver's SIPS II

the top aspect and 15.2 cm (6.0") rear of the forward aspect. The SIPS II air bag was not tethered. There was no contact evidence on the SIPS II at the time of the vehicle inspection.

The left IC deployed downward from the left roof side rail as a result of the left side impact with the Ford Mustang (**Figure 11**). The tear seam measured 144.8 cm (57.0") in length and extended from the left A-pillar to 8.9 cm (3.5") aft of the left C-pillar. In its deflated state, the IC measured 143.5 cm (56.5") in length, 30.5 cm (12.0") in height at the forward aspect and 33.0 cm (13.0") in height at the rear aspect. The IC was structured with various chambers with the chamber edges fused together. The configuration of the IC chambers was designed to concentrate the air channels to areas where it was likely for occupants to strike their heads. Volvo information stated that the IC inflates to full volume in approximately twenty-five thousandths of a second and remains inflated for approximately three seconds. The air bag was tethered at the forward aspect. The graduated tether measured 27.9 cm (11.0") in width at the aft aspect and 1.3 cm (0.5") in width at the forward aspect at the left A-pillar. The tether was anchored to the left A-pillar 45.7 cm (18.0") above the bottom aspect of the A-pillar and was cut post crash. There were no identifiable contacts present on the IC.



Figure 11. View of left side IC and SIPS II

The stored gas inflator for the IC was mounted longitudinally on the left roof side rail between the C- and D-pillars (**Figure 12**). According to Volvo, the gas in the IC was a mixture of argon and helium. The circular inflator canister was located 7.6 cm (3.0") aft of the left C-pillar and measured 30.5 cm (12.0") in length and 3.8 cm (1.5") in diameter. The inflator was manufactured by Autoliv. The inflation tube of the IC was configured in a circular pattern and overlapped the forward aspect of the inflator canister 7.6 cm (3.0") and was secured to the canister by a 1.0 cm (0.4") wide circular clamp.



Figure 12. View of stored gas inflator

OCCUPANT DEMOGRAPHICS - 2001 Volvo V70

Driver

Age/Sex: 45-year-old female
Height: 162.6 cm (64.0")
Weight: 65.8 kg (145.0 lb)
Seat Track Position: Mid-track
Manual Restraint Use: Manual 3-point lap and shoulder belt
Usage Source: Vehicle inspection, interview, police report
Eyewear: None
Type of Medical Treatment: Did not receive medical treatment

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Left torso abrasion	Minor (490202.1,2)	Side air bag - frictional interaction of clothing displaced by the side air bag

Injury source: Interview

Driver Kinematics

The 45-year-old female driver was seated in an upright posture with the seat adjusted to the mid-track position. She was restrained by the manual 3-point lap and shoulder belt. At impact with the Ford Mustang, the left SIPS II deployed forward from the driver's seat back and the left IC deployed downward from the left roof side rail. The SIPS II may have contacted the driver's clothing as it deployed forward which may have displaced the driver's clothing across the torso area which resulted in a minor left torso abrasion. The driver initiated a lateral trajectory toward the left side impact and loaded the manual restraint and the deployed SIPS II and IC. She was redirected slightly as the vehicle was deflected in a CCW rotation across the intersection. The driver stated that she moved very little during the crash sequence, which she attributed to the seat belt system. The Volvo traveled onto the outboard aspect of the roadway and struck the parked Nissan Sentra with the rear aspect. The driver initiated a rearward trajectory in response to the secondary rear impact and loaded the driver's seat back. The WHIPS mechanism in the driver's seat allowed the driver to "ride-down" the rear impact as she moved rearward. The driver rebounded forward as the Volvo came to rest. The driver used a cellular telephone to contact a family member and subsequently exited the vehicle under her own power. She refused medical treatment at the scene and was not transported to any medical facility.

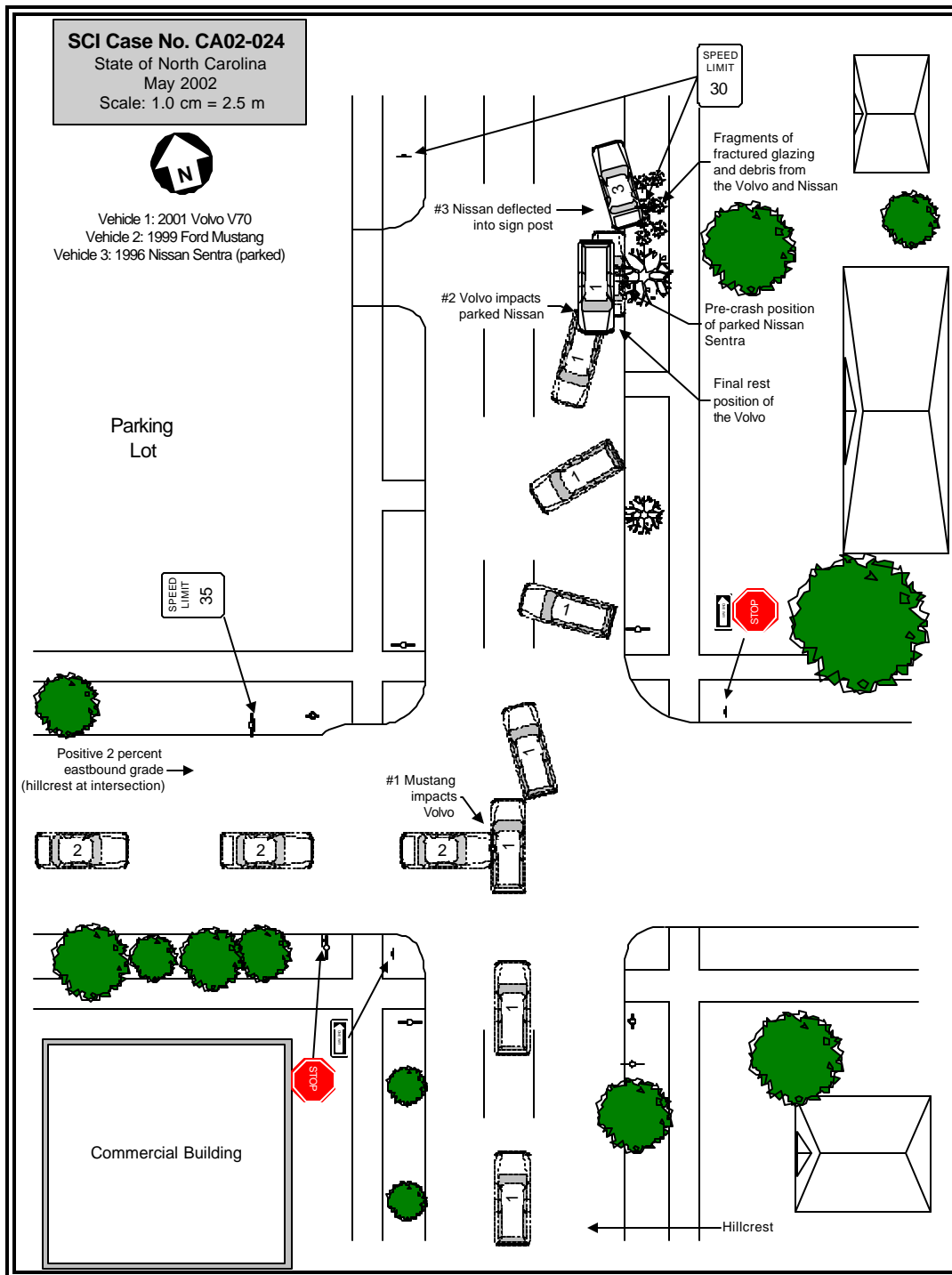


Figure 13. Scene schematic