

**TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER**

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SIDE IMPACT OCCUPANT PROTECTION NON-DEPLOYMENT INVESTIGATION

VERIDIAN CASE NO: CA02-060

VEHICLE: 2002 HYUNDAI SONATA

LOCATION: MASSACHUSETTS

CRASH DATE: DECEMBER 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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<p>16. Abstract</p> <p>This on-site investigation focused on the issues surrounding the non-deployment of a side impact air bag installed in a 2002 Hyundai Sonata that was involved in a left side impact crash. The Hyundai was equipped with a Supplemental Restraint System that consisted of dual frontal air bags and seat mounted side impact air bags for the driver and front right passenger. None of the air bags deployed as a result of the crash. The Hyundai was struck in an intersection-type collision by a 1999 Toyota Tacoma pick-up truck resulting in moderate disabling damage to the Hyundai. The Hyundai was occupied by an unrestrained 59 year old male driver and an unrestrained 56 year old female front right passenger. The driver sustained fatal injuries consisting of a posterior head laceration and multiple blunt force internal injuries. The Hyundai's front right passenger sustained police reported minor severity lacerations. The 30 year old unrestrained male driver of the Toyota was not injured.</p> <p>This crash was reported to NHTSA's Office of Defects Investigation (ODI) by the investigating police department. ODI requested an on-site investigation of the crash from NHTSA's Crash Investigation Division (CID) due to the non-deployment of the left side impact air bag. CID subsequently assigned an on-site investigative effort to the Veridian Special Crash Investigations team on December 18, 2002. Coordination with the investigating police department was initiated and the on-site inspection took place on January 6, 2003. The vehicles were impounded pending the SCI inspection.</p>			
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BACKGROUND

This on-site investigation focused on the issues surrounding the non-deployment of a side impact air bag installed in a 2002 Hyundai Sonata that was involved in a left side impact crash. The Hyundai was equipped with a Supplemental Restraint System that consisted of dual frontal air bags and seat mounted side impact air bags for the driver and front right passenger. None of the air bags deployed as a result of the crash. The Hyundai was struck in an intersection-type collision by a 1999 Toyota Tacoma pick-up truck resulting in moderate disabling damage to the Hyundai. The Hyundai was occupied by an unrestrained 59 year old male driver and an unrestrained 56 year old female front right passenger. The driver sustained fatal injuries consisting of a posterior head laceration and multiple blunt force internal injuries. The Hyundai's front right passenger sustained police reported minor severity lacerations. The 30 year old unrestrained male driver of the Toyota was not injured.

This crash was reported to NHTSA's Office of Defects Investigation (ODI) by the investigating police department. ODI requested an on-site investigation of the crash from NHTSA's Crash Investigation Division (CID) due to the non-deployment of the left side impact air bag. CID subsequently assigned an on-site investigative effort to the Veridian Special Crash Investigations team on December 18, 2002. Coordination with the investigating police department was initiated and the on-site inspection took place on January 6, 2003. The vehicles were impounded pending the SCI inspection.

SUMMARY

Crash Site

This two-vehicle crash occurred during the evening hours in December, 2002. At the time of the crash, it was dark and the weather was cloudy. The road surface was damp. Reportedly, it began to rain heavily after the crash, hampering the post-crash investigation by the police.

The crash occurred on an east/west, two-lane divided state highway. There was a left curve for eastbound traffic. At the scene, a one-way road intersects the state highway from the southwest at an acute angle forming a Y-type intersection. The intersecting traffic could merge and continue eastbound or turn sharply left into a cross-over for westbound travel. The intersection was controlled by a stop sign for the intersecting traffic. There were no obstructions in the intersection that would have impaired either driver's visibility. The speed limit in the area of the crash was 56 km/h (35 mph). **Figure 1** is an eastbound trajectory view approaching the intersection. A schematic of the crash sequence and the configuration of the intersection is depicted on **Figure 16** attached to the end of this report.



Figure 1: Eastbound trajectory view approaching the intersection.

CRASH SEQUENCE

Pre-Crash

The 1999 Toyota Tacoma was eastbound on the inboard lane driven by an unrestrained 30 year old male. The driver reported his speed was approximately 56 to 64 km/h (35 to 40 mph). The 2002 Hyundai was initially stopped facing east-northeast on the intersecting secondary road. The Hyundai was driven by a 59 year old male and was occupied by a 56 year old female front right passenger. The occupants of the Hyundai were unrestrained. It was the Hyundai driver's intention to cross the primary road's eastbound lanes and enter the median cross-over in order to travel westbound. The front right passenger indicated that she was talking to the driver regarding which way to travel. The conversation in the vehicle may have been a distraction to his driving task.

Crash

The crash occurred when the Hyundai accelerated forward in a northeastward direction directly into the path of the Toyota. The right frontal area of the Toyota struck the left side of the Hyundai in a 12/7 o'clock impact configuration. The Hyundai's seat-mounted left side impact air bag did not deploy. The total delta V of the Hyundai calculated by the WINSMASH model was 24.0 km/h (14.9 mph). The longitudinal and lateral delta V components were +18.4 km/h (+11.4 mph) and +15.4 km/h (+9.6 mph), respectively.

The lateral momentum of the Hyundai, coupled with probable left steering by the Toyota, re-directed both vehicles into the center median. The Toyota came to rest facing northward approximately 12 m (40 ft) northeast of the impact. The Hyundai was accelerated forward by the impact and remained engaged with the Toyota as the vehicles entered the median. As the vehicle approached the same eastbound velocity, the Hyundai then rotated counterclockwise across the front of the Toyota, and through the median evidenced by tire marks documented during the police investigation. The Sonata then entered the westbound lanes facing northwestward, rolled across the westbound lanes and came to rest against a road sign on the north shoulder. **Figure 2** is a view looking northward at the Toyota's final rest location and depicting the Hyundai's tire marks through the median. **Figure 3** is a view of the final rest location of the Hyundai.

The impact's Principle Direction of Force (PDOF) was an estimated 220 directions with respect to the Hyundai. The PDOF was confirmed by a match-up of the vehicles during the SCI investigation, **Figure 4**. The right frame rail of the Toyota's front bumper system penetrated the left front door of the Hyundai. This damage pattern was used to align the vehicles during the match-up. The reconstructed impact configuration was consistent with the intersection configuration and the crash dynamics. In this contractor's opinion, the shallow PDOF relative to the vehicle's longitudinal axis resulted in an impact that was below the lateral threshold required to deploy the left side impact air bag.



Figure 2: Toyota FRP and Hyundai's tire marks through the median



Figure 3: Hyundai FRP.



Figure 4: Overhead view of the reconstructed crash configuration.

Post-Crash

The police, fire and ambulance personnel responded to the scene. The fire department extricated the driver from the Hyundai by opening the left front door. He was bleeding profusely about the head upon their arrival and was emergently transported by ambulance to a local hospital located within 16 km (10 miles) of the crash site. Medical intervention proved unsuccessful and he was pronounced deceased prior to admission. The front right passenger exited the vehicle under her own power. The police reported she sustained minor facial lacerations. She was transported to a local hospital, treated, and released the same evening. The driver of the Toyota was not injured and was ambulatory at the scene.

2002 HYUNDAI SONATA

The 2002 Hyundai Sonata GLS was identified by the Vehicle Identification Number (VIN): KMHWF35H72A (production sequence deleted). The Hyundai's power train consisted of a 2.7 liter, V-6 engine linked to a 4-speed automatic transmission. The manual restraint system consisted of 3-point lap and shoulder belts in the five seat positions. The front restraints were equipped with retractor pretensioners and belt force limiters. The Supplemental Restraint System consisted of frontal air bags and seat mounted side impact air bags for the driver and front right passenger. The vehicle was manufactured in August, 2001 and was purchased new by the driver in November 2002. The service history supplied by the Hyundai dealership indicated the vehicle had no prior crash history. The odometer had registered 20,428 km (12,694 miles) at the time of the crash.

Exterior Damage

Figures 5 and 6 are views of the Hyundai's left side damage. The left side of the Hyundai sustained moderate damage as a result of the impact. The combined width of the direct contact and induced damage measured 232.4 cm (91.5 in). The pattern and flow of the damage was indicative of the 7 o'clock direction of the impact. The damage began 6.3 cm (2.5 in) forward of the left rear axle and extended forward onto the left front fender. The residual crush profile at the mid-door elevation was as follows: C1=0, C2=14.0 cm (5.5 in), C3=37.6 cm (14.8 in), C4=35.8 cm (14.1 in), C5=12.7 cm (5.0 in), C6=2.0 cm (0.8 in). The left doors were jammed shut due to deformation and the side glazing disintegrated. The left front door was opened by extrication. The right frame horn of the Toyota Tacoma contacted and penetrated left front door 24.1 cm (9.5 in) forward of its trailing edge during the impact. The roof buckled due to the lateral deformation. The left aspect of the windshield was fractured. The left wheelbase was reduced 6.6 cm (2.6 in) due to bending of the vehicle's unibody. The right wheelbase lengthened 1.0 cm (0.4 in). The Collision Deformation Classification was 07-LPAW-3. The total delta V calculated by the Damage Algorithm of the WINSMASH model was 24.0 km/h (14.9 mph). The longitudinal and lateral delta V components were +18.4 km/h (+11.4 mph) and +15.4 km/h (+9.6 mph), respectively.

The front plane of the Hyundai contacted and deformed a road sign support post as it rolled to its final rest location (refer to Figure 3 above). There was no residual frontal crush as a result of this event. The sign contact was located 30 cm (12 in) right of vehicle center and the CDC was 12-FCLN-1.



Figure 6: Left side view of the Hyundai.



Figure 5: Left rear view of the damage along the PDOF.

1999 TOYOTA TACOMA

The 1999 Toyota Tacoma pick-up truck was identified by the Vehicle Identification Number (VIN): 4TAPM62N9X2 (production sequence deleted). The two wheel drive pick-up truck was a regular cab model manufactured with a 262 cm (103 in) wheelbase. The vehicle was equipped with a 2.4 liter, I-4 engine linked to a 4-speed automatic transmission. The manual restraint system consisted of 3-point lap and shoulder belts in the outboard positions and a center lap belt. The Supplemental Restraint System consisted of driver and front passenger air bags with a cut-off switch. There was no deployment of the frontal air bags. Analysis of the crash determined that the severity of the crash was below the deployment threshold. The Toyota was manufactured in June 1999 and the odometer reading was 51,958 km (32,286 miles).

Exterior Damage

The front plane of the Toyota sustained direct contact damage that extended across the vehicle's entire 147 cm (58 in) end width, **Figure 7**. The damage pattern was biased to the vehicle's right side indicative of the angular impact configuration. The maximum crush was located at the right front bumper corner. The residual crush profile along the front bumper was as follows: C1=1.3 cm (0.5 in), C2=3.3 cm (1.3 in), C3=9.4 cm (3.7 in), C4=13.2 cm (5.2 in), C5=15.2 cm (6.0 in), C6=26.2 cm (10.3 in). The crush of the bumper exposed the end of the right frame rail. This component contacted and penetrated the exterior panel of the Hyundai's left front door. The deformation of the right front fender and wheelhouse contacted and restricted the right front tire. The right wheelbase was shortened 5.8 cm (2.3 in). The left wheelbase was unchanged. There was no cab to bed contact. The Collision Deformation Classification was 12-FDEW-2. The total delta V calculated by the Damage Algorithm of the WINSMASH model was 32.0 km/h (19.9 mph). The longitudinal and



Figure 7: Front view of the Toyota.

lateral components were -32.0 km/h (-19.9 mph) and 0, respectively. The WINSMASH calculation overestimated the Toyota's delta V based on SCI field experience. An estimated 24 km/h (15 mph) delta V was more consistent with the magnitude of the Toyota's damage and the crash dynamics.

2002 HYUNDAI SONATA

Interior Damage

The front left and rear left occupant spaces sustained moderate intrusion as a result of the exterior crash forces. **Figure 8** is a view of the driver's interior. **Figures 9 and 10** are front and rear views into the occupant compartment depicting the extent of the intrusion. The lateral intrusion of the left front door measured at the center aspect of the arm rest was 16.5 cm (6.5 in). The lateral intrusion of the left rear door measured at its center aspect was 22.9 cm (9.0 in). The intrusion of the left B-pillar measured at the D-ring was 36.8 cm (14.5 in). The left B-pillar was in contact with the driver's seat back and had compressed the seat back approximately 15 cm (6 in) laterally. The center console was deformed to the right due to contact from the driver's right hip.



Figure 8: Left front interior view.



Figure 9: Front view into the occupant compartment.



Figure 10: Rear view into the occupant compartment.

The unrestrained driver was seated in the full rear track position. The seat back was reclined 22 degrees aft of vertical. The horizontal distance from the seat back to the non-deployed driver air bag measured 74 cm (29 in). The front right passenger seat was also located in a full rear track position.

The driver's manual restraint was stowed in its retractor at the time of the inspection and the retractor was locked. The stowed webbing was captured between the left B-pillar and the outboard aspect of the driver's seat. The retracted and captured position of the restraint indicated the driver was unrestrained at the time of the crash. Inspection of the latch plate identified minimal historical usage evidence. The plastic trim covering the D-ring fastener was fractured by a contact from the driver's head during the crash sequence, **Figure 11**.



Figure 11: Driver's 3-point restraint.

The front right passenger's restraint was stowed in the retractor at the time of the inspection. The retractor was operational. Inspection of the restraint yielded no evidence of use during the crash. Examination of the latch plate revealed no evidence of historical use. The front right passenger was not restrained during the crash. Additionally, the front right passenger indicated in her police interview she was not restrained.

Supplemental Restraint System (SRS)

The SRS in the Hyundai Sonata consisted of frontal air bags and seat-mounted side impact air bags for the driver and front right passenger. The side impact air bags were designed to offer head and thorax protection. **Figure 12** is a depiction of the vehicle's deployed SRS taken from a 2002 Hyundai publication.



Figure 12: 2002 Hyundai Sonata SRS.

The driver air bag was located in the center hub of the steering wheel rim and the front right passenger air bag was a top mount design located in the right aspect of the instrument panel. The side impact air bag modules were housed in the outboard bolsters of the front seat backs. The SRS was monitored and controlled by a control module located within the center console. Satellite sensors controlling the deployment of the side impact air bags were located within the lower sill near the B-pillar junction. None of the air bags deployed in this crash. In this contractor's opinion, the severity of the crash appeared to be below threshold required for deployment, due in part to the 7 o'clock PDOF.

The Hyundai was mechanically and electrically intact. The engine was started and it operated properly. During the SCI inspection, the integrity of the SRS circuitry was examined to ensure the system was operational at the time of the crash. Upon initial key-up, the SRS warning lamp, located in the instrument cluster, illuminated and then flashes 6 times during its diagnostic sequence. The SRS warning lamp then went out. A warning chime also sounded 6 times and then stopped. The proper operation of the warning lamp and chime indicated the system went through its diagnostic sequence and the SRS was operating properly.

The 2002 Hyundai Sonata, manufactured between June 4, 2001 and February 7, 2002, was subject to NHTSA recall Campaign No: 02V145000. This recall involved the replacement of the vehicle's side impact air bag satellite sensors. Reportedly, the original sensors were overly sensitive and an inadvertent side impact air bag deployment could occur. The side impact sensors on the subject Hyundai had been replaced and the recall had been complied with on August 17, 2002. The records of that service supplied by the dealership indicated the vehicle's mileage was 14,968 km (9,301 miles) at that time.

The left side impact sensor was physically inspected; refer to **Figures 13 and 14**. The following manufacturer's nomenclature identified the sensor:

<i>Siemens: 95920-3D000</i>	<i>5WK43096</i>
<i>09D0008SAE</i>	<i>23020508</i>

A blue dot was located on the label and reportedly indicated that this sensor was a recall replacement. The wiring to the sensor was intact and it was not damaged. To ensure the side impact circuitry was operational, the electrical connector was removed from the sensor with the ignition key in the ON position. The SRS warning immediately illuminated indicating a fault in the circuit. The ignition key was then cycled OFF and back ON. The warning lamp flashed 6 times during the diagnostic sequence and then remained on, flagging the open side impact circuit.

As a final check of the system, the electrical connector was reattached to the left side impact sensor. With the connector reattached, the SRS warning lamp went out, after system ran its internal diagnostics, indicating the SRS was operating properly.

The cloth covering and foam of the driver seat bolster was removed to assess and inspect the left side impact module. Examination found the module and wiring intact. There were no apparent faults with the module, **Figure 15**.

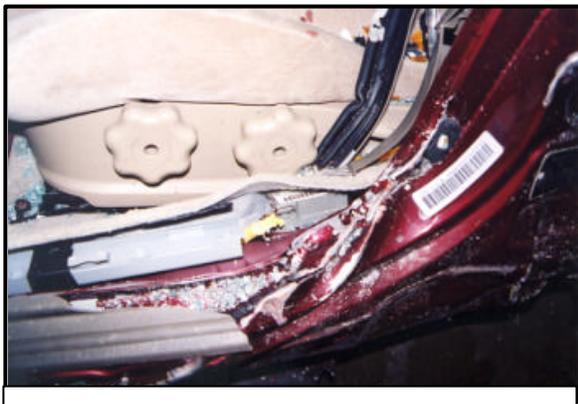


Figure 13: View of the left sill and side impact sensor location.



Figure 14: Left side impact sensor.



Figure 15: Non-deployed left side impact air bag.

OCCUPANT DEMOGRAPHICS

Hyundai Sonata

	<i>Driver</i>	<i>Front Right Passenger</i>
Age/Sex	59 year old/Male	59 year old/Female
Height:	183 cm (72 in)	175 cm (68 in) estimated
Weight:	145 kg (320 lb)	102 kg (225 lb) estimated
Restraint Use:	Unrestrained	Unrestrained
Usage Source	SCI inspection	SCI inspection
Medical Treatment	Fatal prior to admission	Treated and released

Toyota Tacoma

	<i>Driver</i>
Age/Sex	30 year old/Male
Height:	147 cm (58 in) estimated
Weight:	73 kg (160 lb) estimated
Restraint Use:	Unrestrained
Usage Source	SCI inspection
Medical Treatment	None

DRIVER INJURIES

Hyundai Sonata

<i>Injury</i>	<i>Injury Severity (AIS 98 Update)</i>	<i>Injury Mechanism</i>
Severe acute subarachnoid hemorrhage involving both cerebral hemispheres, cerebellum and brain stem.	Severe (140210.5,8) Serious (140684.3,1) (140684.3,2) (140466.3,6)	Impact to the left D-ring/B-pillar
Posterior fracture of the left ribs 2-6	Serious (450230.3,2)	Intruding left front door
Deep lung laceration to the posterior aspect of the left lower lobe measuring 5x3x3 cm with 300 ml hemo-thorax	Serious (441430.3,2)	Intruding left front door
Multiple contusions of the anterior aspect of the thigh, bilaterally	Minor (890402.1,3)	Steering wheel rim contact
6 cm (2.4 in) linear left occipital scalp laceration	Minor (190602.1,6)	Impact to the left D-ring/B-pillar

Note: the above referenced injuries were identified in the driver's Postmortem Examination Report.

DRIVER KINEMATICS

Immediately prior to the crash, the unrestrained driver was seated in a presumed normal posture. Reportedly, he was engaged in a conversation about which direction they were to travel in and may have been distracted. The driver accelerated the Hyundai forward directly into the path of the Toyota. Upon impact, the driver responded to the 7 o'clock direction of the impact by moving leftward and rearward. Coincident with this kinematic pattern the left side of the vehicle was intruding laterally.

The left posterior aspect of the driver's head impacted the D-ring and left B-pillar. This contact fractured the molded plastic trim covering the fastener and lacerated the driver's scalp. The force of this impact resulted in the identified severe acute subarachnoid brain hemorrhages. The lateral intrusion contacted the left flank of the driver resulting in multiple left rib fractures and the deep laceration of the lower lobe of the left lung. The force of the intrusion then displaced the driver to the right. The driver's right hip contacted and deformed the center console. The anterior aspect of the driver's thighs contacted the lower sector of the steering wheel rim and became contused. It was probable the driver contacted the front right passenger during the later stages of the crash sequence. He reportedly came to rest within his seat and had to be extricated from the vehicle.

The driver was removed from the Hyundai through the left front door. He reportedly was bleeding profusely about the head and was unresponsive. He was transported via ambulance to a local hospital located with 6 km (10 miles) of the crash site. Resuscitative efforts proved unsuccessful and he was pronounced deceased prior to hospital admission.

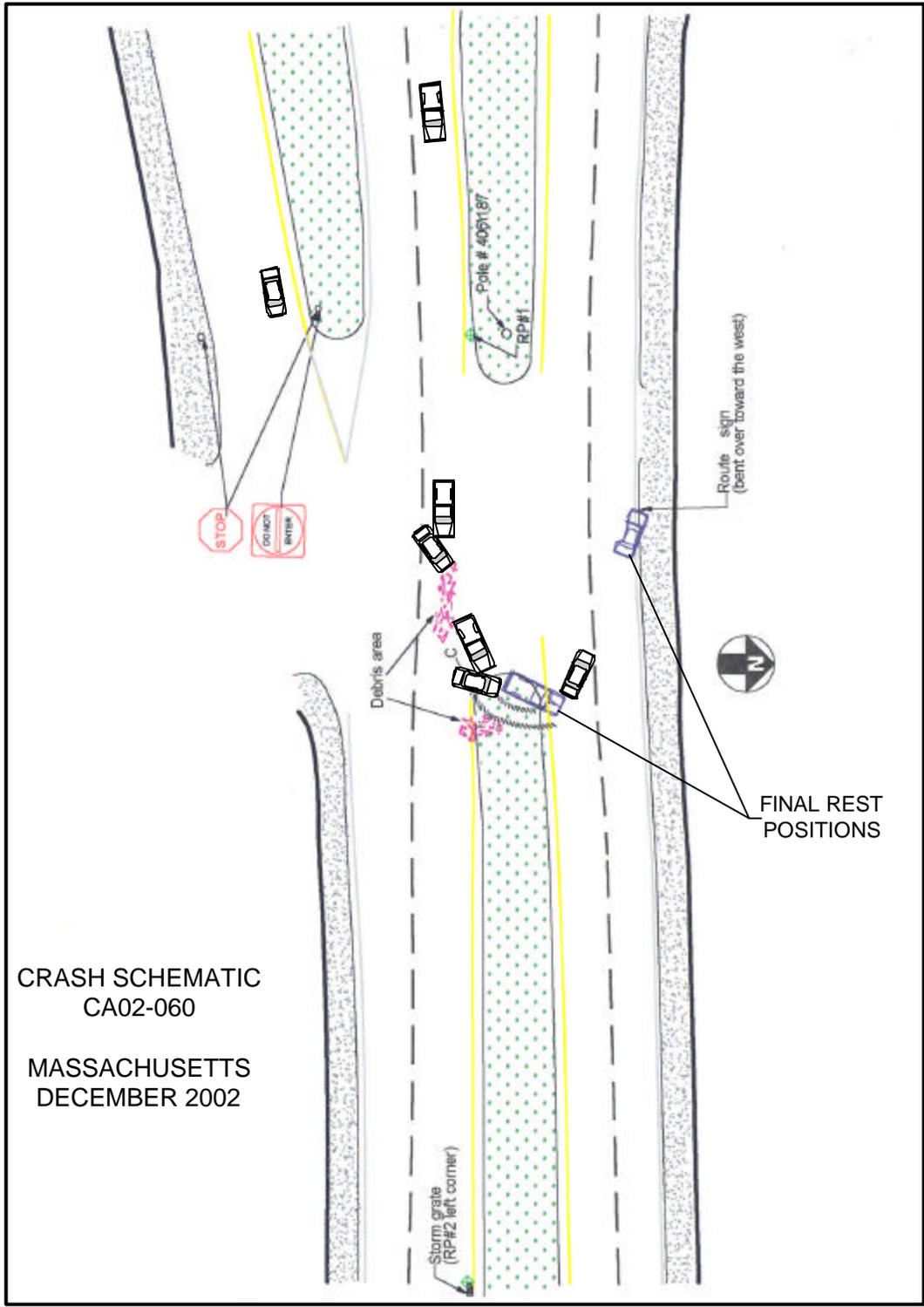


Figure 16: Crash schematic.