

CRASH DATA RESEARCH CENTER

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**CALSPAN ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION
CRASH INVESTIGATION**

SCI CASE NO. – CA08012

VEHICLE – 2007 HYUNDAI SONATA

LOCATION – STATE OF VIRGINIA

CRASH DATE – FEBRUARY 2008

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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TABLE OF CONTENTS

SUMMARY	1
CRASH SITE	1
VEHICLE DATA	2
2007 HYUNDAI SONATA	2
2005 FORD EXPLORER	2
2004 FORD FOCUS	2
CRASH SEQUENCE	3
PRE-CRASH	3
CRASH	3
POST-CRASH	4
VEHICLE DAMAGE	4
EXTERIOR DAMAGE – 2007 HYUNDAI SONATA	4
INTERIOR	5
EXTERIOR DAMAGE	6
2004 FORD FOCUS	6
MANUAL SAFETY BELT SYSTEMS	6
2007 HYUNDAI SONATA	6
FRONTAL AIR BAG SYSTEM	7
2007 HYUNDAI SONATA	7
SIDE IMPACT AIR BAG SYSTEM	7
2007 HYUNDAI SONATA	7
EVENT DATA RECORDER	8
OCCUPANT DEMOGRAPHICS/DATA	8
DRIVER INJURIES	9
DRIVER KINEMATICS	9

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BACKGROUND

This on-site investigative effort focused on the side impact inflatable occupant protection system in a 2007 Hyundai Sonata (**Figure 1**) and the injury sources of the restrained 31-year-old female driver. The Hyundai was equipped with seat back mounted side impact air bags for the front seat positions and curtain air bags for the four outboard positions. In addition to the side impact air bags, the Hyundai was equipped with a Certified Advanced 208-Compliant frontal air bag system. The Hyundai was involved in an intersection crash with a 2005



Figure 1. 2007 Hyundai Sonata.

Ford Explorer that resulted in left side damage to the Sonata. A 2004 Ford Focus subsequently struck the Explorer as the vehicle came to rest. As a result of the crash, the Hyundai's left seat back mounted side impact air bag and the left side curtain air bag deployed. The driver of the Hyundai sustained minor injuries during crash and was transported to a hospital where she was treated and released.

This crash was identified by the Calspan General Estimate System (GES) through the review of Police Accident Reports (PAR). The Calspan Special Crash Investigations (SCI) team forwarded the PAR to the Crash Investigation Division (CID) of the National Highway Traffic Safety Administration (NHTSA) due to the deployed side impact protection system. The Hyundai was located at a salvage facility and cooperation was established to inspect the vehicle. The Explorer was sold from a salvage facility prior to the case assignment. Due to privacy issues, the buyer information could not be obtained from the salvage facility; therefore, an inspection of the Explorer was not conducted. The Focus was repaired prior to the case assignment; however, a partial inspection of the repaired vehicle was obtained. This investigation was assigned to the Calspan SCI team on March 10, 2008. The on-site investigation was conducted on March 18, 2008.

SUMMARY

Crash Site

This crash occurred during the evening hours of February 2008 at a T-intersection. The north/southbound leg of the intersection consisted of two-travel lanes that were separated by double yellow center lines. The north/south leg was 7.9 meters (22.6 feet) in width and contained a left curve for the northbound travel lane which ended at the intersection. The east/westbound legs of the intersection were configured with one through traffic lane in each direction. The east leg measured 18.5 meters (60.6 feet) in width and contained a

center left turn lane. The travel lanes on the east leg were separated by double yellow center lines. The west leg of the intersection measured 20.6 meters (67.6 feet) in width and contained a right turn only lane. There was a positive grade in the eastbound and northbound directions. The traffic lanes on the west leg were separated by a painted flush median. The intersection was controlled by stop signs for the northbound traffic. The posted speed limit for the north/south roadway was 56 km/h (35 mph) and 89 km/h (55 mph) for the east/west roadway. The scene schematic is included as **Figure 14** of this report.

Vehicle Data

2007 Hyundai Sonata

The 2007 Hyundai Sonata was a four-door sedan that was identified by Vehicle Identification Number (VIN) 5NPEU46F27H (production number deleted). The Sonata was a uni-body design and was powered by a 3.3 liter transverse mounted six-cylinder engine linked to a five-speed automatic transmission with front wheel drive. The braking system consisted of power assisted front and rear disc brakes with an Antilock Braking System (ABS) feature. Additionally, the Hyundai was equipped with Electronic Stability Control and traction control. The tires on the Sonata were Michelin Pilot HX MXMA, size P215/60R16 mounted on five-spoke OEM alloy wheels. The vehicle manufacturer recommended cold tire pressure was 207 kPa (30 PSI) for the front and rear. The specific tire data at the time of the SCI inspection of the Sonata was as follows:

Position	Measured Tire Pressure	Measured Tread Depth	Tire/Wheel Damage
Left Front	283 kPa (41 PSI)	5 mm (6/32")	None
Left Rear	221 kPa (32 PSI)	6 mm (8/32")	None
Right Front	221 kPa (32 PSI)	6 mm (8/32")	None
Right Rear	214 kPa (31 PSI)	6 mm (8/32")	None

The interior of the Sonata was configured with leather surfaced five-passenger seating. The front bucket seats were separated by a center console and equipped with adjustable head restraints. Both front head restraints were adjusted 2 cm (0.8") above the full down positions. The rear seating consisted of a bench seat with a forward folding back. Eighty percent of the seat back folded forward with the outboard aspects remaining stationary. The outboard positions of the rear seat were equipped with adjustable head restraints, both adjusted to the full-down positions.

2005 Ford Explorer

The 2005 Ford Explorer was sold from a salvage facility prior to the initiation of the case. The location of the Ford could not be determined; therefore, this vehicle was not inspected for this investigation. The PAR identified the VIN as 1FMDU74K75U (production number deleted).

2004 Ford Focus

The 2004 Ford Focus was identified by the following VIN: 1FAFP33P04W (production number omitted). A partial inspection of this vehicle was obtained during this on-site

investigation consisting of exterior images of the repaired Ford Focus. The front wheel drive Focus was powered by a 2.0-liter transverse mounted four-cylinder engine linked to a four-speed automatic transmission.

Crash Sequence

Pre-Crash

The restrained 31-year-old female driver of the Hyundai Sonata was traveling north approaching the intersection where her intention was to turn left (**Figure 2**). She was decelerating for a regulatory stop sign and stopped at the three-leg intersection.

A 72-year-old male was operating the 2005 Ford Explorer eastbound approaching the intersection. The 2004 Ford Focus was operated by 50-year-old female eastbound behind the Explorer. **Figure 3** is a view of the eastbound travel path for the Explorer and Focus.

During the SCI interview with the driver's spouse, he stated that the driver of the Hyundai was stopped at the intersection and that she observed a non-contact vehicle traveling eastbound approaching the intersection. As the non-contact vehicle neared the intersection, the driver activated the right turn signal. At this point, the driver of the Hyundai proceeded to enter the intersection to turn left.



Figure 2. Hyundai's approach to the intersection.



Figure 3. Ford Explorer and Ford Focus eastbound travel paths.

Crash

The frontal area of the Explorer impacted the left passenger side area of the Hyundai. The driver of the Focus observed the collision and applied a right steering input as she neared the impact. As the Ford and Hyundai traveled to final rest, the left side mirror of the Focus impacted the right rear corner of the Explorer. The Ford Focus did not come in contact with the Hyundai.

The resultant directions of force for the impact between the Explorer and the Hyundai were 1 o'clock for the Explorer and within the 10 o'clock sector for the struck Sonata. The missing vehicle algorithm of the WinSMASH program was used to compute delta V's. The total velocity change for the Hyundai was 39 km/h (24.2 mph), with a longitudinal component of -20 km/h (-12.4 mph) and a lateral component of 34 km/h (21.1 mph). The total delta V for the Explorer was 33 km/h (20.5 mph). The

longitudinal and lateral components for the Explorer were -31 km/h (-19.3 mph) and -11 km/h (-6.8 mph), respectively.

Post-Crash

There was no physical evidence or police documentation to support the exact final rest positions of the vehicles. Based on the configuration and the directions of force, the Hyundai was displaced laterally to its right and came to rest facing a northwest direction. The Explorer traveled forward and left due to the lateral force from the Hyundai, facing northeast at rest. The Focus came to rest in close proximity to the rear of the Explorer facing a southeast direction. The Hyundai and the Ford Explorer sustained disabling damage and were towed from the crash site. The Ford Focus sustained minor damage and was driven from the crash site. The restrained 31-year-old female driver of the Hyundai sustained soft tissue injuries during crash and was transported to a hospital where she was treated and released.

Vehicle Damage

Exterior Damage – 2007 Hyundai Sonata

The exterior of the Hyundai Sonata sustained moderate severity damage as a result of the intersection crash (**Figures 4 and 5**). The Hyundai was subsequently deemed a total loss by the insurance carrier and was transferred to a salvage facility where it was inspected. The residual damage was measured along the lower door elevation. The maximum crush measured 50 cm (19.7”) and was located on the aft aspect of the front left door, 163 cm (64.2”) forward of the left rear axle. The direct contact damage measured 179 cm (70.5”) and began 59 cm (23.2”) forward of the left rear axle. The height of the maximum crush measured 53 cm (20.9”). A crush profile was documented at the lower door level and was as follows: C1 = 4 cm (1.6”), C2 = 32 cm (12.6”), C3 = 41 cm (16.1”), C4 = 39 cm (15.4”), C5 = 16 cm (6.3”), C6 = 1 cm (0.4”). In addition to the crush profile, a single measurement documenting the distance between the sill and the door was obtained. This measurement is identified as the Door Sill Differential (DSD) and was 29 cm (11.4”). The Collision Deformation Classification (CDC) assigned for this damage was 10-LYEW-3.



Figure 4. Residual damage to the left side of the Hyundai Sonata.



Figure 5. Oblique view of the left side crush.

Interior

The 2007 Hyundai Sonata sustained moderate severity interior damage that was attributed to occupant contact points and passenger compartment intrusion. Two possible occupant contact points were noted to the interior (**Figure 6**). These contacts were located on the Rear Upper Quadrant (RUQ) and Rear Lower Quadrant (RLQ) of the left front door. The occupant contact to the RUQ consisted of a black scuff mark while the contact to the RLQ was evidenced by a fracture of the plastic door panel. These occupant contact points were considered as possible due to the proximity of the seat back air bag. In the deployed state, the seat back air bag membrane was positioned over the location of the contacts. Therefore, the fracture possibly occurred as the door panel intruded and deformed around the driver's left hip. The resultant intrusions are listed within the table below with **Figures 7 and 8** depicting the passenger compartment intrusions:



Figure 6. Possible occupant contact points.

Location	Component	Magnitude	Direction
Left Front	Door panel	37 cm (14.6")	Lateral
Left Front	Roof side rail	1 cm (0.4")	Lateral
Left Front	Instrument panel	4 cm (1.6")	Lateral
Left Front	Seat back	25 cm (9.8")	Lateral
Left Front	Seat cushion	34 cm (13.4")	Lateral
Left Front	Sill	3 cm (1.2")	Lateral
Left Front	Knee bolster	Approx. 8 cm (3.0")	Vertical
Left Front	Side panel forward of A-pillar	1 cm (0.4")	Lateral
Left Front	B-pillar	32 cm (12.6")	Lateral
Left Front	Center console	5 cm (2.0")	Lateral
Left Rear	Roof side rail	1 cm (0.4")	Lateral
Left Rear	Door panel	29 cm (11.4")	Lateral
Left Rear	Sill	16 cm (6.3")	Lateral
Left Rear	Seat back	Approx. 2 cm (0.8")	Lateral
Left Rear	Seat cushion	Approx. 2 cm (0.8")	Lateral



Figure 7. Lateral intrusion into the driver's position.



Figure 8. View of intrusions from the second row.

Exterior Damage 2004 Ford Focus

The 2004 Ford Focus sustained minor damage as result of the impact with the Ford Explorer. The damage was confined to the left side mirror which was replaced. Thus, damage data was not obtained for this vehicle. A partial CDC assigned to this vehicle of 12-LPGS-1. **Figure 9** is of the repaired Ford Focus.



Figure 9. Repaired Ford Focus.

Manual Safety Belt Systems 2007 Hyundai Sonata

The Hyundai was equipped with manual 3-point lap and shoulder belts for the five designated seat positions. All belt systems utilized continuous loop webbings with sliding latch plates. The driver's belt retracted onto an Emergency Locking Retractor (ELR) and was equipped with a retractor pretensioner. The upper D-ring was adjustable and was set to the full-up position. The driver used the safety belt at the time of the crash, which was supported by the actuated retractor pretensioner that locked the safety belt in its extended position. The safety belt webbing contained a light colored transfer on the outboard aspect below the stop button. The source of this transfer could not be identified. **Figure 10** shows the driver's safety belt and the transfer.



Figure 10. Driver's safety belt

The front right and three rear belt systems utilized switchable ELR and Automatic Locking Retractor (ALR). Additionally, the front right safety belt contained a retractor pretensioner that did not actuated. These positions were unoccupied at the time of the crash.

Frontal Air Bag System
2007 Hyundai Sonata

The Hyundai was equipped with a Certified Advanced 208-Complaint (CAC) frontal air bag system that consisted of dual stage driver and passenger air bags, seat track positioning sensors, a front right occupant presence sensor, retractor pretensioners, and safety belt buckle switches. A CAC vehicle is certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

The driver's frontal air bag was conventionally mounted within the center of the four-spoke steering wheel rim. The front right air bag was mounted in the mid instrument panel. The lateral impact did not warrant deployment of the driver's frontal air bag.

Side Impact Air Bag System
2007 Hyundai Sonata

The Sonata was equipped with front seat back mounted side impact air bags and roof side rail mounted curtain air bags. The left side impact deployed the driver's seat back air bag and the left curtain air bag.

The left seat back mounted air bag was concealed within the outboard aspect of the seat back. The air bag deployed through a tear seam at the forward aspect of the seat back (**Figure 11**). The D-shaped air bag membrane measured 30 cm (11.8") in height and 30 cm (11.8") in width and consisted of two panels sewn together at the forward edge. A single vent port was present on the top outboard aspect and measured 5 cm (2.0") height and 3 cm (1.2") in width. The inboard aspect of the membrane was unremarkable. A black scuff mark was present on the outboard panel that measured approximately 5 cm (2.0") in height and 5 cm (2.0") in width. It's unknown what produced this scuff mark; however, it appeared to line-up with the scuff mark on the door panel.

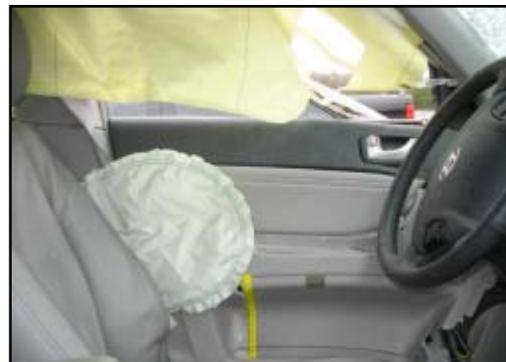


Figure 11. Deployed left seatback mounted side impact air bag.

The left curtain air bag deployed from the roof side rail (**Figure 12**). The air bag membrane measured 167 cm (65.7") in length. At the front left seating position, the membrane measured 35 cm (13.8") in height extending 1 cm (0.4") below the top of the door panel. The height of the curtain air bag membrane at the left rear position was 34 cm (13.4") and extended 2 cm (0.9") below the top of the door panel. The height of the curtain air bag membrane provided head protection from the roof side rail to belt line of the vehicle.

The air bag was equipped with a single tether at the A-pillar, which measured 17 cm (6.7") in length. Longitudinally, the coverage area of the curtain air bag covered the left side glazing. At the forward aspect there was a non-inflatable triangular shaped section

that began at the A-pillar and extended 29 cm (11.4”) rearward. Within this section were three cut outs in the membrane (**Figure 13**). These cut outs began approximately 10 cm (4.0”) below the roof rail and 12 cm (4.7”) rear of the A-pillar. The top two cuts outs were rectangular in shape measuring 5 cm (2.0”) in height and 15 cm in width (5.9”). The bottom cut out was triangularly shaped with dimensions of 5 cm (2.0”) and 15 cm (5.9”), height by width.

At the C-pillar a 3 cm (1.2”) gap was present, which began at the seat back and extended to the C-pillar.

The curtain air bag was free of damage and occupant contact points.

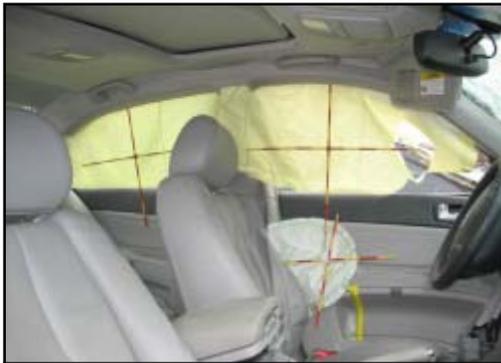


Figure 12. Deployed left side curtain air bag.



Figure 13. Cut outs on forward aspect of the curtain air bag.

Event Data Recorder

The 2007 Hyundai Sonata was not equipped with a downloadable Event Data Recorder (EDR).

Occupant Demographics/Data

Driver Age/Sex:	31-year old/Female
Height:	168 cm (66.0”)
Weight:	57 kg (125 lbs)
Eyewear:	Prescription eyeglasses
Seat Track Position:	Full-rear track
Manual Safety Belt Use:	Manual 3-point lap and should belt
Usage Source:	Vehicle inspection
Egress from Vehicle:	Exited under her own power through the right front door
Mode of Transport	
From Scene:	Ambulance
Type of Medical Treatment:	Treated and released at a local hospital

Driver Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Contusion to the left hip	Minor (890402.1,2)	Rear lower quadrant of the left front door panel
Left knee contusion	Minor (890402.1,2)	Forward lower quadrant of the left front door panel
Right knee contusion	Minor (890402.1,1)	Instrument panel

Source = Interview with driver's husband

Driver Kinematics

The 31-year-old female driver was seated in a rear-track position and was restrained by the manual 3-point lap and shoulder belt system. At impact with the Ford, the left seat back mounted air bag and left side curtain air bag deployed. The driver's door intruded laterally right as she initiated a left trajectory in response to the 10 o'clock impact force. Her left hip contacted the deployed seat back mounted side impact air bag reinforced by the door panel. The door panel intruded laterally and contacted the driver's left hip. Her left knee contacted the forward lower quadrant of the door panel. These contacts resulted in the left hip and left knee contusions. Her right knee contacted the deforming instrument panel which resulted in the contusion to this body region. There were no identified occupant contact points to the deployed curtain air bag.

The driver exited the vehicle unassisted and was transported to a hospital where she was treated and released.

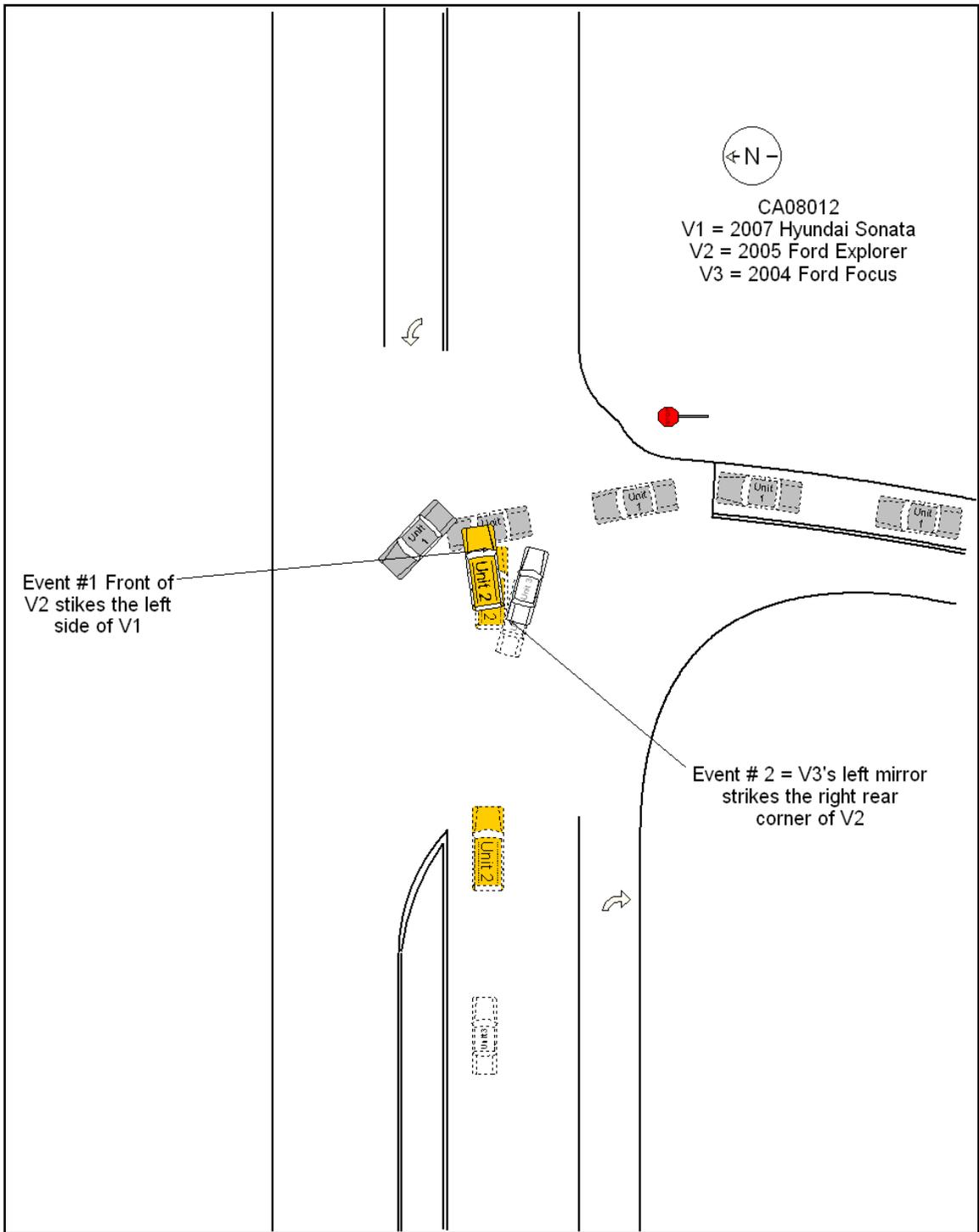


Figure 14: Scene Schematic