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CRASH DATA RESEARCH CENTER

Advanced Information Engineering Services
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ON-SITE AIR BAG NON-DEPLOYMENT/ DRIVER FATALITY INVESTIGATION

CASE NO: CA03-046

VEHICLE: 2001 HYUNDAI ELANTRA

LOCATION: NEW YORK

CRASH DATE: AUGUST, 2003

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. Abstract This on-site investigation focused on the issues surrounding the driver air bag non-deployment, and the fatal injury mechanisms of a male driver of a 2001 Hyundai Elantra**.** The Hyundai was involved in a severe frontal impact with a 1995 Chevrolet G20 cargo van. The Hyundai Elantra was equipped with an Advanced Occupant Protection System (AOPS) that consisted of front safety belt pretensioners, redesigned frontal air bags and front right occupant detection. The Hyundai's safety belt pretensioners and frontal air bags failed to deploy as a result of the impact. The Hyundai was occupied by a 27 year old restrained male driver and was the vehicle's sole occupant. Reportedly, the Hyundai drifted left of center precipitating the crash. The Chevrolet van was equipped with a Supplemental Restraint System that consisted of a driver (only) air bag that deployed during the crash. The estimated travel speed of the Hyundai was 89 km/h (55 mph). The Coroner's report listed the Hyundai driver's immediate cause of death as a lacerated aorta and a cervical spine fracture.			
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TABLE OF CONTENTS

SCI1 ON-SITE AIR BAG NON-DEPLOYMENT/
DRIVER FATALITY INVESTIGATION
CASE NO: CA03-046
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BACKGROUND

This investigation focused on the issues surrounding the driver air bag non-deployment, and the fatal injury mechanisms of a male driver of a 2001 Hyundai Elantra, **Figure 1.** The Hyundai was involved in a severe frontal impact with a 1995 Chevrolet G20 cargo van. The Hyundai Elantra was equipped with an Advanced Occupant Protection System (AOPS) that consisted of front safety belt pretensioners, redesigned frontal air bags and front right occupant detection. The Hyundai's safety belt pretensioners and frontal air bags failed to deploy as a result of the impact. The Hyundai was occupied by a 27 year old restrained male driver and was the vehicle's sole occupant. Reportedly, the Hyundai drifted left of center precipitating the crash. The Chevrolet van was equipped with a Supplemental Restraint System that consisted of a driver (only) air bag that deployed during the crash. The estimated travel speed of the Hyundai was 89 km/h (55 mph). The Coroner's report listed the Hyundai driver's immediate cause of death as a lacerated aorta and a cervical spine fracture.

Figure 1: Left front view of the Hyundai.

The Crash Investigation Division of the National Highway Traffic Safety Administration received notification of this crash through the Office of Defects Investigation (ODI). The father-in-law of the Hyundai driver reported the potential defect through the DOT Auto Safety Hotline. ODI requested the assignment of an on-site crash investigation and the Special Crash Investigations team at General Dynamics was instructed to proceed with the investigation. Cooperation with the New York State Police investigators and the insurance carrier for the respective vehicles was established. Both vehicles were available for inspection.

VEHICLE DATA

2001 Hyundai Elantra GLS

The 2001 Hyundai Elantra GLS was identified by the Vehicle Identification Number (VIN): KMHDN54D91U (production sequence deleted). The digital odometer could not be read at the time of the inspection. The vehicle's date of manufacture was April 18, 2001. The four-door sedan was equipped with a 2.0 liter/I4 engine, 4-speed automatic transmission, power assist front disc/rear drum brakes, power steering and OEM steel wheels. The Hyundai Elantra was equipped with an Advanced Occupant Protection System (AOPS) that consisted of 3-point lap

and shoulder belts with retractor pretensioners and belt force limiters for the front occupants, redesigned frontal air bags and front right occupant presence detection. The vehicle was also equipped with seat-mounted side impact air bags for the driver and front right passenger. The three rear seat positions were equipped with 3-point lap and shoulder belts. The subject vehicle was equipped with Michelin Energy MXV4 tires (size P195/60R15). The manufacturer's recommended tire pressure was 207 kPa (30 PSI). The specific measured tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	Tire Flat	4 mm (5/32)	Yes	Debeaded
LR	214 kPa (31 PSI)	2 mm (2/32)	No	None
RF	207 kPa (30 PSI)	5 mm (6/32)	No	None
RR	193 kPa (28 PSI)	2 mm (2/32)	No	None

At the time of the SCI inspection the driver's wife reported that the air bag lamp in the instrument cluster had been illuminating periodically for one to two months prior to the crash. She was aware of the diagnostic procedure the air bag system conducted upon engine start-up. She was clear that the air bag system conducted this diagnostic procedure and that the light was illuminated at that time. She stated that the light would then "go out" and would then illuminate intermittently while driving. They had not taken the Hyundai in for service.

1995 Chevrolet G20 Cargo Van

The 1995 Chevrolet G20 cargo van was identified by the Vehicle Identification Number (VIN): 1GCEG25H5SF (production sequence deleted). The 680 kg (¾ ton) Chevrolet cargo van was configured with a 317.5 cm (125.0 in) wheelbase. The date of manufacture was April 1995. The odometer had registered 196,702 km (122,228 miles) at the time of the inspection. The power train consisted of a 5.0 liter/V8 engine linked to a 3-speed automatic transmission. The brakes were power assisted front disc/rear drum without ABS. The interior seating consisted of driver and front right passenger bucket seats with 3-point lap and shoulder belts. The Supplemental Restraint System consisted of a driver (only) air bag. The van was equipped with BF Goodrich Long Trail Radial T/A tires. The manufacturer's recommended tire pressure was 241 kPa (35 PSI). The specific measured tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	Tire Flat	10 mm (12/32)	Yes	Debeaded
LR	221 kPa (32 PSIi)	10 mm (12/32)	No	None
RF	221 kPa (32 PSI)	10 mm (13/32)	No	None
RR	214 kPa (31 PSI)	10 mm (13/32)	No	None

SUMMARY

CRASH SITE

The two-vehicle crash occurred during the nighttime hours in August 2003. At the time of the crash, it was dark without artificial lighting and the weather was not a factor. The road surface was dry. The crash occurred on a two-lane north/south state route in a rural setting. The combined width of the asphalt travel lanes measured 7 m (23 ft). The paved shoulders bordering the travel lanes measured 3 m (10 ft). There was a shallow right curve and a positive grade in the northbound direction. The road was marked with a passing zone in the southbound direction. The speed limit in the area of the crash was 89 km/h (55 mph). **Figure 2** is a northbound trajectory views at the crash site.

Figure 2: Northbound trajectory view.

CRASH SEQUENCE

Pre-crash

The 2001 Hyundai Elantra was northbound driven by a restrained 27 year old male, the vehicle's sole occupant. The driver was in the process of traveling to his home that was located within 16 km (10 miles) of the crash site. The 1995 Chevrolet G20 van was southbound driven by a restrained 54 year old male. The Chevrolet was occupied by a restrained 6 year old female front right passenger, and a 48 year old female seated in an unrestrained lawn chair reportedly placed between the front seats in the van's empty cargo area. The driver of the Chevrolet van reported he was traveling approximately 64 to 72 km/h (40 to 45 mph) and recalled the Hyundai gradually crossing the centerline into his lane. In an effort to avoid the crash, he steered to the right and began to brake. A witness, in transit behind the van, stated to the police investigator that the van was traveling approximately 64 to 72 km/h (40 to 45 mph) and he intended to pass the Chevrolet on the downgrade. However, he noted the northbound Hyundai and remained behind the van. The witness was able to avoid the crash by driving off the right side of the road and around the crash.

Crash

The crash occurred with the full frontal area of the Hyundai impacting the front left and central aspects of the Chevrolet in an offset head-on impact configuration. The directions of force were within the 12 o'clock sector for both vehicles. The impact occurred in the southbound travel lane bordering the fog line. The area of the impact was identified by an area of gouges marks attributed to the undercarriage of the Hyundai. The final rest positions of the vehicles were documented by the police investigation with road paint and were visible at the time of the SCI scene inspection.

The southbound momentum of the Chevrolet stopped the northbound momentum Hyundai. The total delta V's of the Hyundai and Chevrolet calculated by the WINSMASH model were 82.9

km/h (51.5 mph) and 45.5 km/h (28.3 mph), respectively. The offset impact induced a counterclockwise rotation to the Hyundai and the vehicle came to rest at the point of impact. The Hyundai rotated approximately 65 degrees counterclockwise and came to rest facing westward, blocking the southbound lane. The Chevrolet separated from the impact with a southwest trajectory and came to rest facing south, straddling the fog line, approximately 2 m (7 ft) from the point of impact. The driver air bag in the Chevrolet deployed as a result of the crash. None of the safety systems (seat belt pretensioners and frontal air bags) in the Hyundai deployed. **Figure 16**, at the end of this report, is a schematic of the crash.

Post-crash

The police and ambulance personnel responded to the crash site. Upon their arrival, the driver of the Hyundai was unresponsive and was trapped within the vehicle. He had to be extricated. The driver was then transported to a local hospital located within 6 km (4 miles) of the crash scene. Medical intervention to stabilize and revive the driver proved unsuccessful due to the severity of his injuries. He was pronounced dead 58 minutes post-crash. The three occupants of the Chevrolet were transported via ambulance with non-life threatening injuries.

VEHICLE DAMAGE

2001 Hyundai Elantra - Exterior

The front plane of the Hyundai sustained 142.2 cm (56.0 in) of direct contact damage that extended across the entire end width of the vehicle, **Figure 3**. The frontal damage was biased to the left indicative of the angular offset impact configuration. The crush profile documented along the front bumper was as follows: C1 = 78 cm (30.7 in), C2 = 79.0 cm (31.1 in), C3 = 84.0 cm (33.1 in), C4 = 67.0 cm (26.4 in), C5 = 58.0 cm (22.8 in), C6 = 22.0 cm (8.7 in). Maximum crush was located at the left front corner (C1).

Figure 3: Front view of the Hyundai Elantra.

Figures 4 and 5 are the left side and left lateral views of the vehicle. The left front fender was completely crushed. The left front wheel assembly deformed rearward into the rear aspect of the wheel opening; the tire was restricted and aired out. The left wheelbase was reduced 29.3 cm (11.5 in). The windshield fractured in multiple locations from the exterior force of the crash. The left front door was jammed shut by the deformation and opened by extrication. The left rear door was jammed and could not be opened. The right doors remained operational. The center rear aspect of the roof was buckled. The Collision Deformation Classification (CDC) was 12-FDEW-3. The damage algorithm of the WINSMASH model computed a total velocity change of 82.9 km/h (51.5 mph) for the Hyundai. The longitudinal and lateral components were -81.7 km/h (-50.8 mph) and -14.4 km/h (-8.9mph), respectively. The calculated delta V was consistent with a reconstruction analysis using the conservation of momentum.

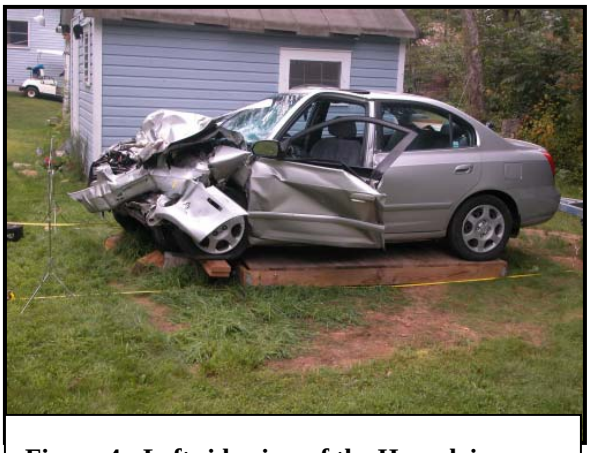

Figure 4: Left side view of the Hyundai.

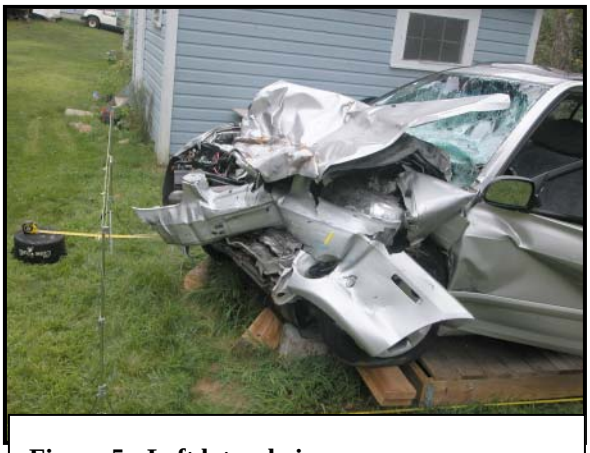

Figure 5: Left lateral view.

1995 Chevrolet G20 Cargo Van - Exterior

The front plane of the Chevrolet (**Figure 6**) sustained 162.6 cm (64.0 in) of combined direct and induced damage that extended across the vehicle's frontal end width. The direct damage measured 113.0 cm (44.5 in) and began 31.8 cm (12.5 in) left of center and extended to the left front corner. This frontal direct contact wrapped around the left front corner and extended 43.2 cm (17.0 in) onto the left side. The left front wheel assembly was displaced rearward into the aft aspect of the wheel opening. The left front tire debeaded and was restricted. The left wheelbase was reduced 53.1 cm (20.9 in). The left front door was jammed shut by deformation and opened by extrication. The residual crush profile measured along the front bumper was as follows: C1 = 93 cm (36.6 in), C2 = 80.0 cm (31.5 in), C3 = 65.0 cm (25.6 in), C4 = 55.0 cm (21.7 in), C5 = 12.0 cm (4.7 in), C6 = 0. The maximum crush was located at the left front corner (C1). The Collision Deformation Classification (CDC) was 12-FYEW-6. The total delta V calculated by the damage algorithm of the WinSmash model was 45.5 km/h (28.3 mph). The longitudinal and lateral delta V components were -45.5 km/h (-28.3 mph) and 0, respectively.

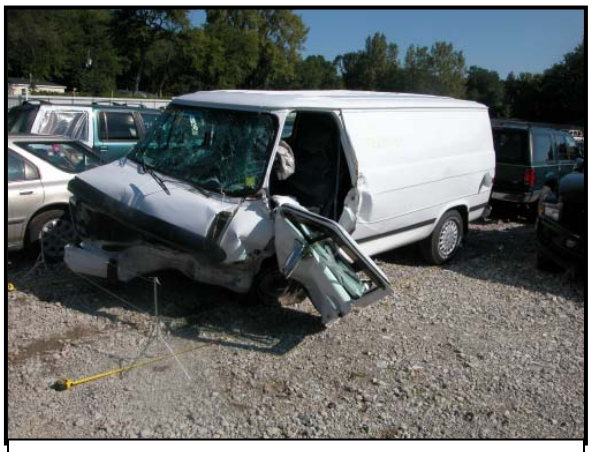

Figure 6: Left front view of the Chevrolet.

2001 Hyundai Elantra - Interior

The interior of the Hyundai sustained moderate damage and intrusion as a result of the exterior crash forces. **Figure 7** is a view of the driver's interior. The intrusion at the left corner of the instrument panel measured 33.0 cm (13.0 in). The center aspect of the instrument panel intruded 12.2 cm (4.8 in). The intrusion of the driver's foot well measured 18.8 cm (7.4 in).

Figure 7: Driver's interior view.

The driver's knee bolster exhibited two contacts from the driver's lower extremities. The right lower extremity contacted the bolster 22.9 cm (9.0 in) left of the steering wheel center line. The bolster's metal backer was deformed 5.1 cm (2.0 in) at this location. The right lower extremities contacted and penetrated the bolster 3.8 cm (1.5 in). This contact was located 17.8 cm (7.0 in) right of the steering wheel center line.

The 4-spoke steering wheel rim was rotated approximately 90 degrees clockwise at inspection. The steering column was completed separated from the shear capsules and the column had dropped. The left and right shear separation measured 5.1 cm (2.0 in) and 4.6 cm (1.8 in), respectively. The steering wheel rim support casting (fastened to the steering column end) was fractured by inertial loading from the occupant. The steering wheel rim was cut in 1 and 9 o'clock sectors during the extrication process for unknown reasons. **Figure 8** is a view of the deformed steering wheel rim. **Figure 9** is a lateral view across the steering wheel viewed from the 1 o'clock sector to the 8 o'clock sector of the fractured casting.

Figure 8: View of the steering wheel rim.

Figure 9: Lateral view across the plane of the steering wheel from 1 to 8 o'clock.

The driver's seat was adjusted in a mid-to-rear track position. The seat was jammed by floor pan deformation and could not be moved. The seat back was reclined 12 degrees aft of vertical. Upon inspection, it was noted that the driver's seat cushion was rotated approximately 30 degrees counterclockwise (refer to Figure 8 above) with respect to the vehicle's longitudinal axis. Further inspection revealed the adjustable portion of the rear inboard seat track had separated from the fixed portion of the inboard seat track, **Figure 10**. The separation occurred as a result of the driver loading the lap portion of the locked safety belt. The inboard safety belt buckle was attached to the inboard seat track and was the load path between the driver and the fixed portion of the seat track.

Figure 10: View of the driver's separated inboard seat track.

MANUAL RESTRAINT SYSTEM

2001 Hyundai Elantra

The manual restraint system in the 2001 Hyundai Elantra consisted of 3-point lap and shoulder belts with continuous loop webbings and dual mode locking retractors for the five seat positions. The front restraints were equipped with retractor pretensioners. The D-rings for the front restraints were adjustable.

Inspection of the driver's safety belt indicated the first responders had cut the driver's safety belt during the extrication. A 140 cm (55 in) section of webbing was attached to the outboard anchor. This section of webbing had been used to tie the left front door closed during vehicle transport. The use of the belt in this manner hampered the identification of any crash related evidence on the webbing. The balance of the driver's webbing was spooled back into the retractor. The retractor was operational; the pretensioner had not fired. The webbing was extended from the retractor and an 8.9 cm (3.5 in) D-ring abrasion was identified, **Figure 11**. The abrasion began 15 cm (6 in) from the point where the webbing was cut. The driver's D-ring was adjusted in the full down position. Inspection of the friction surface of the D-ring identified a corresponding abrasion across the full width of the surface. Inspection of the latch plate revealed indications of historical use and crash related abrasions on its friction surface. The inspection of the driver's safety belt indicated that he was restrained at the time of the crash.

Figure 11: D-ring abrasion to the driver's restraint webbing.

ADVANCED OCUPANT PROTECTION SYSTEM

2001 Hyundai Elantra

The 2001 Hyundai Elantra was equipped with an Advanced Occupant Protection System (AOPS) that consisted of front safety belt pretensioners, redesigned frontal air bags and front right occupant detection. The subject vehicle was also equipped with front seat-mounted side impact air bags. The system was monitored and controlled by a Control Module located under the center console. None of the safety systems deployed in the crash. The driver's wife reported that the air bag light in the instrument cluster had been periodically illuminating, while the vehicle was being driven. She indicated the light had been on for a period of one to two months. The air bag light was an indicator the AOPS was in need of service.

The driver bag was a located in the center hub of the steering wheel. It was not deployed. **Figure 13** is a lateral view of the driver air bag module attached to the fractured casting. **Figure 14** is a close-up view of the back side of the module and the inflator. The inflator was manufactured by Autoliv Inc. and was identified by the following: *MAF M27 1M AOH.* Inspection of the inflator determined the electrical connector was still attached to the inflator; however, the connector was crushed. The connector had impacted the casting, when the casting was fractured by driver loading. **Figure 15** is a close-up view of the casting. Yellow transfers from the connector's housing were identified on the casting indicative of the contact. It should be noted that this contact sequence occurred late in the overall crash sequence and would not have compromised the proper deployment of the driver air bag.

Figure 13: Left lateral view of the DAB.

Figure 14: View of the DAB inflator.

Figure 15: View of the fractured casting and yellow transfers.

DRIVER DEMOGRAPHICS

2001 Hyundai Elantra

Age/Sex:	27 year old/Male
Height:	173 cm (68 in)
Weight:	61 kg (135 lb)
Seat Position:	Mid-to-rear track
Restraint Use:	3-point lap and shoulder belt
Usage Source:	First responders, SCI inspection
Medical Treatment:	Transported and died prior to admission

DRIVER INJURY

2001 Hyundai Elantra

Injury	***Injury Severity (AIS update 98)***	***Injury Mechanism***
2 cm perforation of the right atrium	Critical (441012.5,4)	Steering wheel/column
2.5 cm transverse tear of the aorta at the junction of the heart and origin of the aorta and 3 cm transverse tear of the aorta at the junction of the descending and arch of the aorta	Critical (420212.5,4)	Steering wheel/column
Bilateral fractures of the first and tenth ribs along the anterior axillary lines with massive bilateral hemothorax	Serious (450222.3,3)	Steering wheel/column

Injury	*Injury Severity (AIS update 98)*	*Injury Mechanism*
Transverse fracture of the mid sternum	Moderate (450804.2,4)	Steering wheel/column
Fracture of the cervical vertebra with separation of C1 and C2	Moderate (650216.2,6)	Hyper-flexion of the neck compounded by mandible contact with the steering wheel rim
3 cm laceration of the lower lip with through and through tear	Minor (290602.1,8)	Steering wheel rim
Scattered small abrasions – mid anterior chest	Minor (490202.1,4)	Steering wheel/column
Small area of abrasion over the posterior left upper arm	Minor (790202.1,2)	Unknown
Abrasion on dorsum of right hand	Minor (790202.1,1)	Instrument panel
6 cm abrasion over right hip	Minor (890202.1,1)	Lap belt
Bilateral knee abrasions	Minor (890202.1,1) (890202.1,2)	Driver's knee bolster
Abrasion on dorsum of left foot	Minor (890202.1,2)	Foot controls
Abrasion on instep of right foot	Minor (890202.1,1)	Foot controls

DRIVER KINEMATICS

Immediately prior to the crash, the 27 year old male driver was operating the Hyundai northbound. He was seated in a mid-to-rear track position consistent with his stature and was restrained by the vehicle's 3-point lap and shoulder belt. For unknown reasons, the driver relinquished directional control of the Hyundai and it drifted left of center directly into the path of the Chevrolet.

At impact, the driver's Emergency Locking Retractor (ELR) locked. There was no deployment of the pretensioner or driver air bag. The driver initiated a forward trajectory in response to the 12 o'clock direction of the impact and loaded the locked safety belt system. His chest loaded the shoulder portion of the webbing evidenced by the D-ring abrasion and transfer to the shoulder webbing. The driver's pelvic region loaded the lap portion of the belt evidenced by the right hip abrasion. During this sequence, the driver's loading of the lap belt was transmitted through the inboard buckle stalk to the moving upper portion of the inboard seat track. This upper track experienced an overload condition and separated from the fixed portion of the track. This failure allowed the seat and the restrained driver to rotate forward.

Coincident to the belt loading the left instrument panel and toe pan were deforming rearward. The driver's chest impacted and loaded the steering wheel/column. This loading displaced the column from the shear capsules and fractured the driver air bag casting mount. The driver's

chest impact resulted in multiple rib fractures, the aortic tear and atrium injury. The sudden deceleration of his chest coupled with the inertia of his head resulted in the hyper-flexion of his neck. This kinematic pattern exceeded the anatomical limits of his cervical spine resulting in the C1/C2 fracture and separation. The driver then rebounded back into his seat where he was found.

CRASH SCHEMATIC

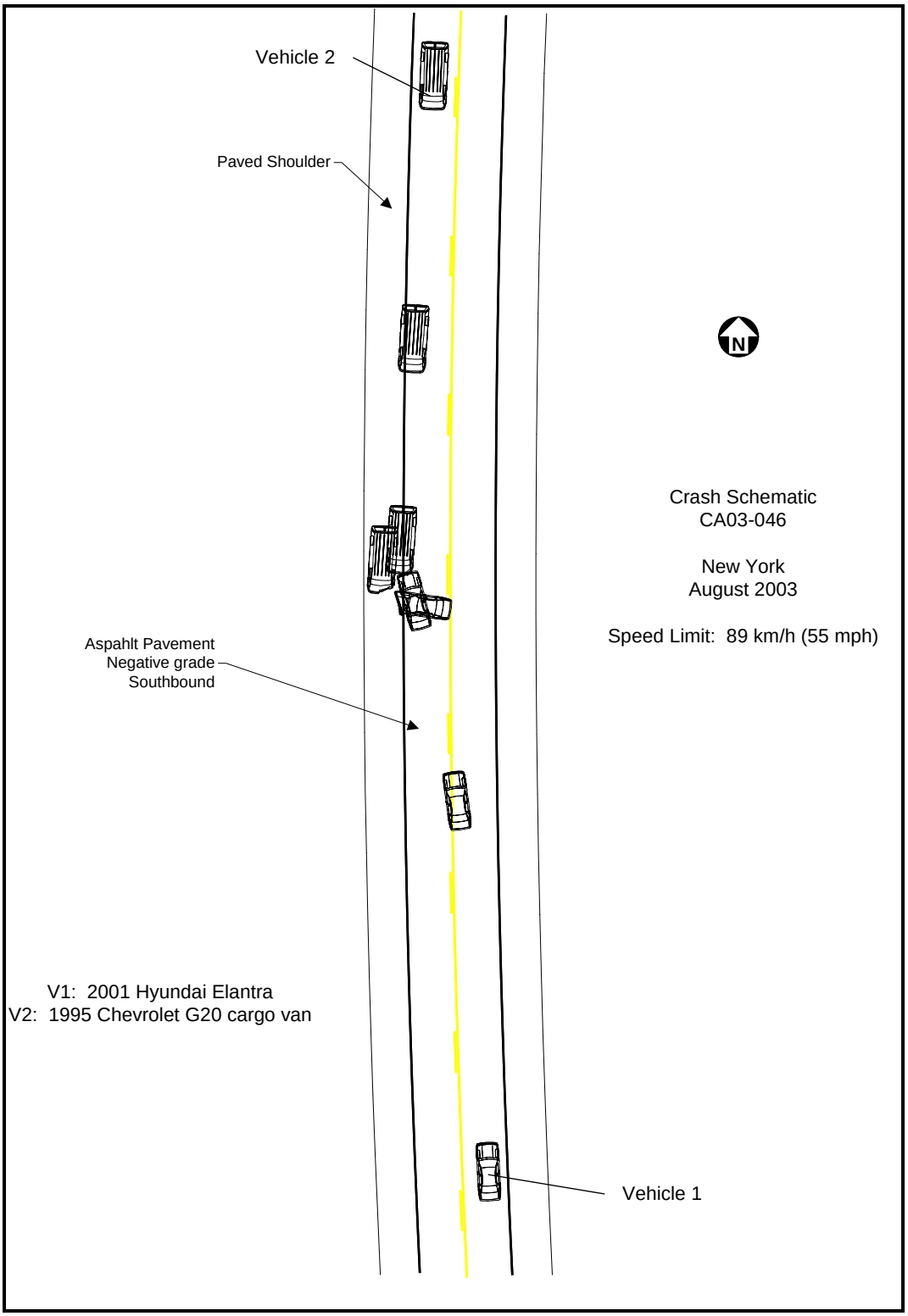

Figure 16: Crash Schematic.