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ON-SITE INTEGRATED SEAT BELT INVESTIGATION

VERIDIAN CASE NO: CA01-043

VEHICLE: 2001 CHEVROLET K1500 PICK-UP TRUCK

LOCATION: COLORADO

CRASH DATE: JULY 2001

Contract No. DTNH22-94-07058

Prepared for:

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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 be 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 of the involved vehicle(s) or their safety systems.

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17. *Abstract*

This on-site investigation focused on the performance of the driver's seat-integrated restraint system in a 2001 Chevrolet K1500 extended cab pick-up truck and the injury mechanism of the restrained 20 year old male driver. The Chevrolet was involved in a roadside departure/rollover crash. The vehicle was equipped with a frontal air bag system, an event data recorder (EDR) and integrated seat belts for the front seat positions. The driver failed to negotiate a left curve and allowed the vehicle to depart the right side of the road at high speed. The vehicle traveled along the road shoulder, across an intersecting road into an open field, and subsequently rolled over. The frontal air bags in the vehicle did not deploy. The restrained driver sustained a non-fatal cervical fracture (not further specified) and was transported to a local hospital. The front right and right rear passengers were restrained and sustained police reported minor injuries.

This crash was reported to the Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) by the Colorado State Police in August, 2001. NHTSA subsequently assigned an on-site investigation of the crash to the Special Crash Investigations team at Veridian Engineering. The purpose of the investigation was to evaluate the performance of the integrated restraint system, and the possibility of a relationship between the restraint system performance and the driver's injury. The investigation determined the cause of the driver's cervical fracture was related to roof deformation and not the performance of the integrated restraint. The data stored on-board the vehicle's EDR was extracted as a supplement to the investigation. The vehicle was impounded by the State Police pending the SCI investigation.

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BACKGROUND

This on-site investigation focused on the performance of the driver's seat-integrated restraint system in a 2001 Chevrolet K1500 extended cab pick-up truck and the injury mechanism of the restrained 20 year old male driver. The Chevrolet was involved in a roadside departure/rollover crash. The vehicle was equipped with a frontal air bag system, an event data recorder (EDR) and integrated seat belts for the front seat positions. The driver failed to negotiate a left curve and allowed the vehicle to depart the right side of the road at high speed. The vehicle traveled along the road shoulder, across an intersecting road into an open field, and subsequently rolled over. The frontal air bags in the vehicle did not deploy. The restrained driver sustained a non-fatal cervical fracture (not further specified) and was transported to a local hospital. The front right and right rear passengers were restrained and sustained police reported minor injuries.

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SUMMARY

Crash-Site

This single-vehicle crash occurred during the morning hours in July, 2001. At the time of the crash, it was daylight and the weather was not a factor. The road surface was dry. The crash occurred off the right (north) side of a two-lane east/west state route, located in a rural setting. There was a left curve for westbound traffic. **Figure 1** is a westbound trajectory view of the crash scene.

Figure 1: Westbound trajectory view at the roadside departure.

A north/south two lane road intersected the primary roadway, forming a three-leg intersection approximately 107 m (350 ft) west of the roadside departure. At the departure, the cross-slope of the north shoulder was a negative 11 percent. The shoulder transitioned into a level open field on the north side of the road. In the westbound direction, the shoulder ramped up slightly to meet the intersecting road. The mouth of the intersection was approximately 12 m (40 ft) wide. West of the intersection, the elevation of the open field dropped approximately 1 m (3 ft) relative to the road. The speed limit in the area of the crash was 105 km/h (65 mph).

Pre-crash

The 2001 Chevrolet pick-up was westbound driven by a restrained 20 year old male. The vehicle was also occupied by a restrained 17 year old male front right passenger and a restrained 17 year old rear right seat passenger. The crash occurred when the driver of the Chevrolet failed to negotiate the left curve and departed the right side of the road. The driver steered to the left on the earthen road shoulder in an attempt to regain the roadway causing the vehicle to yaw counterclockwise. The vehicle traveled approximately 46 m (150 ft) along the shoulder striking a delineator post with the right side of the vehicle and then continued 53 m (175 ft) where the vehicle encountered the embankment bordering the intersecting north/south road. The Chevrolet had yawed approximately 30 degrees counterclockwise upon reaching the embankment. **Figures 2 and 3** are views along the Chevrolet's yawing trajectory. The police speed reconstruction indicated the Chevrolet was traveling in access of 145 km/h (90 mph) when it departed the road.

Figure 2: Westbound view of the Chevrolet's yawing trajectory.

Figure 3: Trajectory view approaching the intersection.

Figure 4 is a look back view from the intersection of the yawing trajectory. As the Chevrolet climbed the embankment bordering the intersecting road, the positive slope of the terrain in the Chevrolet's direction of travel caused the vehicle to vault. The slope of the embankment measured approximately +7 percent

in the westward direction. Inspection of the shoulder revealed the tire marks abruptly stopped and did not continue onto the asphalt pavement. The absence of the tire marks on the pavement indicated the vehicle had vaulted the roadway.

Figure 4: Look back view at the intersection.

Crash

The Chevrolet vaulted approximately 29 m (96 ft) across the intersecting road and impacted the ground with its left front tire and suspension. The initial ground contact resulted in a gouge that measured approximately 3 m (10 ft) in length and 12 cm (6 in) in depth. The ground impact, **Figure 5**, fractured the left front shock absorber and separated the left front tire, wheel and brake assembly from the vehicle. The police investigator reported that the shock absorber was embedded in the ground. The impact did not command the deployment of the frontal air bag system. Air bag deployment was not warranted because the longitudinal component of the impact force was reduced by the combination of the vehicle's rotation (yaw) and the vertical nature of the impact. The vehicle's Event Data Recorder (EDR) did record a near deployment event. The complete EDR is attached to the end of this report.

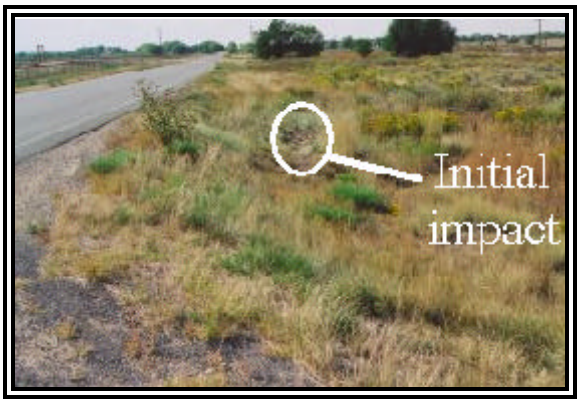

Figure 5: View west of the intersection where the vehicle impacted and rolled.

After the initial ground impact, the vehicle initiated a right side leading tripped rollover. The vehicle rolled 8 quarter turns (2 revolutions) over a distance of 57 m (189 ft). The Chevrolet came to rest on its wheels facing southward. A schematic of the crash is attached to the end of this report, **Figure 14**, page 10. During the second quarter turn, the vehicle impacted the ground with its roof and left side pillars (A/B/C). The left aspect of the roof crushed down and to the right. The driver's head impacted the roof during this sequence and he sustained an unspecified cervical fracture.

Post-crash

The police and ambulance personnel responded to the crash scene. The three occupants of the Chevrolet were intoxicated and had no recollection of the crash events. The driver was removed from the vehicle and transported by ambulance to a local hospital for treatment. The front right and rear right passengers sustained police reported minor injuries and were also transported. It should be noted, the rear right passenger was out of the vehicle and was ambulatory upon the arrival of the police. The police report indicated he was ejected from the vehicle. The SCI investigation determined this passenger was restrained by the manual belt system and exited the vehicle under his own power. The probability of ejection was not consistent with his restraint use, his lack of injury, and nature of the rollover.

2001 CHEVROLET K1500 PICK-UP TRUCK

The 2001 Chevrolet K1500 pick-up truck was identified by the Vehicle Identification Number (VIN): 2GCEK19T311 (production sequence deleted). The 4-wheel drive, ½ ton pick-up truck was an extended cab/short box model with a 364.5 cm (143.5 in) wheelbase. The power train consisted of a 4.8 liter/V-8 engine linked to a 4-speed automatic transmission. The vehicle was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front right passenger air bags. The 3-point manual restraint systems were integrated into the driver and front passenger seats. The restraint system for the rear bench seat consisted of 3-point lap and shoulder belts for the outboard positions and a center lap belt. The service brakes were a 4-wheel disc, anti-lock system. The electronic odometer could not be read at the time of the inspection due to collision damage to the electrical system. The date of vehicle manufacture was August 2000.

Exterior Damage

Figures 6 through 8 are views of the damaged Chevrolet. The vehicle sustained direct damage to the undercarriage, roof and side planes consistent with an impact with a delineator post and an 8 quarter turn rollover. The right rear quarter-panel exhibited direct damage from contact with the delineator post. This contact pattern began 25 cm (10 in) forward of the right rear axle and extended rearward 113.0 cm (44.5 in). The lateral deformation was an estimated 3.8 cm (1.5 in) throughout the contact and measured 6.4 cm (2.5 in) in height. There was a white paint transfer noted within the contact pattern. The Collision Deformation Classification (CDC) of this damage was 12-RBMS-1.

The front undercarriage and the front cross-member in particular exhibited evidence of direct ground contact as a result of the vault. Dirt, grass and debris were embedded throughout the area. The left front wheel and suspension was dislodged from the vehicle during the initial ground contact. The front axle sheared at the transfer case, the lower control arm fractured at the frame and the upper control arm fractured at the ball joint. The direction of force to cause this damage was primarily in the 2 o'clock planar direction and had a vertical component. This force direction was consistent with the vehicle's counterclockwise rotation and trajectory. The CDC of the ground impact was 00-UFDW-1.

The overall longitudinal dimensions of the vehicle were unchanged indicating the roll was primarily lateral. The left front fender damage measured 64 cm (25 in) in length and was crushed laterally 26.7 cm (10.5 in). The left side doors were jammed during the rollover by deformation. The left front door was opened at the scene during driver extrication. The left rear door was forced open during the inspection. The right side doors were jammed shut and could not be opened. The windshield was fractured and all the side glazings and the backlight shattered during the rollover. The right side wheelbase dimension was unchanged. The CDC of the rollover damage was 00-TYDO-4.

Figure 6: Front view of the Chevrolet.

Figure 7: Left front view of the damaged Chevrolet.

Figure 8: Left side view of the Chevrolet.

Figure 9: Rear view of the damaged roof.

Interior Damage

The interior damage to the Chevrolet consisted primarily of vertical intrusion of the roof and lateral intrusion of the left roof side rail. The roof crushed down 41.9 cm (16.5 in) above the driver's seat and the left roof side rail deformed 24.1 cm (9.5 in) right as a result of the rollover. The left roof side rail impacted and compressed the driver's head restraint. The residual deformation of the seat back and head restraint measured approximately 15 cm (6 in). **Figures 10 and 11** are views of the driver's seat back deformation.

Figure 10: Left view of the driver's interior.

Figure 11: Right view of the driver's seat deformation.

The intrusion of the roof is described in the table below:

Component	***Direction***	***Left***	***Center***	***Right***
Header	Vertical	15.2 cm (6.0 in)	11.4 cm (4.5 in)	0
Backlight	Vertical	39.4 cm (15.5 in)	37.3 cm (14.7 in)	31.8 cm (12.5 in)
Center left aspect of roof above driver seat	Vertical	41.9 cm (16.5 in)		
		at A pillar	***at B pillar***	***at C pillar***
Left roof side rail	Vertical	22.9 cm (9.0 in)	25.4 cm (10 in)	22.9 cm (9.0 in)
Left roof side rail	Lateral		24.1 cm (9.5 in)	

The driver's seat was adjusted to a rear track position. The seat back was reclined 26 degrees aft of vertical. The horizontal distance from the center hub of the steering wheel to the seat back measured 61.7 cm (24.3 in). The front right seat was adjusted to a rear track position. The seat back was reclined 34 degrees aft of vertical.

The vehicle's interior was mud soiled as a result of the rollover, hampering the identification of occupant contacts. Inspection of the interior forward of the driver's position revealed no obvious evidence of occupant contact. There was no displacement of the steering column's shear capsule. There were no right front interior occupant contacts. The occupant space above and surrounding the rear right passenger was free of obvious contacts. The lack of occupant contacts supported the use and effectiveness of the manual restraint systems in the vehicle.

Manual Restraint System

The manual restraint system for the front seat positions in the 2001 Chevrolet K1500 consisted of seat-integrated 3-point lap and shoulder belts with continuous loop webbing and sliding latch plates. The rear seat manual restraints consisted of 3-point lap and shoulder belts with fixed D-rings for the outboard positions and a center lap belt.

Inspection of the driver's restraint revealed the webbing was extended and the seat back mounted retractor was locked. The length of the extended webbing measured 138.4 cm (54.5 in). The latch plate exhibited minor evidence of historical use consistent with the age of the vehicle. The faint frictional abrasions were identified on the latch plate's plastic surface caused by the driver's inertial loading at lock-up. The webbing was gathered in the plastic belt guide located on the upper outboard aspect of the seat back, **Figure 12**. Inspection of the driver's restraint system indicated the driver was restrained at the time of the crash. The data downloaded from the vehicle's EDR reported the driver belt was buckled as well.

Figure 12: Driver webbing captured at upper outboard guide.

The condition of the front right passenger restraint was found to be similar to the driver's belt upon inspection. The webbing was extended from the retractor 130.6 cm (51.4 in) and the retractor was locked. The webbing was gathered in the plastic guide on the upper outboard aspect of the seat back indicating the webbing had been loaded by the passenger during retractor lock-up. The inspection of the latch plate revealed faint historical usage marks consistent with the vehicle's age. Subtle frictional abrasions were noted on the plastic belt guide caused by the passenger's inertial loading, **Figure 13**.

Figure 13: Frictional abrasions on the front right latch plate.

The rear right restraint was stowed at the time of the inspection and the retractor was operational. Inspection of the latch plate revealed no evidence of routine use. Subtle friction abrasions were identified on the plastic belt guide of the latch plate and indicated the restraint was in use at the time of the crash. A 4.6 cm (1.8 in) diagonally oriented D-ring transfer was located on the webbing 102.6 (40.4 in) above the webbing's stop button. The inspection of the rear right restraint indicated the passenger was restrained at the time of the crash. Use of the restraint system would have prevented this occupant from ejection. It should be noted the police investigation reported this occupant was unrestrained and ejected.

Supplemental Restraint System

The Supplemental Restraint System (SRS) in the 2001 Chevrolet K1500 pick-up truck consisted of driver and front right passenger air bags. The frontal air bags did not deploy during the rollover crash sequence. The SRS was controlled by a single-point sensing and diagnostic module (SDM) located under the driver's seat. The SDM was capable of recording near-deployment and deployment events and 5 seconds of pre-crash data.

The EDR data was downloaded directly from the SDM during the SCI vehicle inspection. The EDR download results are included as an attachment at the end of this report, **Figures 15 and 16**. The data reported the driver's seat belt was buckled at the time of the crash. This buckled condition was confirmed by the SCI inspection. The pre-crash vehicle speed data was not useful for the purposes of crash reconstruction, due to the vehicle's yaw dynamics.

The redesigned driver air bag module was located in center hub of the steering wheel rim. The redesigned front right passenger air bag module was a mid-mount design located in the right aspect of the instrument panel. A cut-off switch was located in the center aspect of the instrument panel. The switch was turned to the air bag "ON" position. The frontal air bags did not deploy during the rollover crash sequence because the forces generated during the event were below the air bag deployment threshold. The threshold is calibrated along the vehicle's longitudinal axis.

OCCUPANT DEMOGRAPHICS

	Driver	**Front Right Passenger**	**Rear Right Passenger**
Age/Sex:	20 year old/Male	17 year old/Male	17 year old/Male
Height/Weight:	Unknown	Unknown	Unknown
Restraint Use:	Integrated 3-pt. lap and shoulder	Integrated 3-pt. lap and shoulder	3-pt. lap and shoulder
Usage Source:	SCI inspection	SCI inspection	SCI inspection
Medical Treatment:	Transported and admitted	Transported and released	Transported and released

DRIVER INJURY

Injury	**Injury Severity (AIS 98 Update)**	**Injury Mechanism**
Cervical spine fracture, NFS	Moderate (650216.2,6)	Contact to intruding roof structure

DRIVER KINEMATICS

Immediately prior to the crash, the driver was restrained and seated with a presumed normal posture in a rear track position. The police investigation determined the driver was intoxicated and was operating the vehicle in access of 145 km/h (90 mph). Upon entering the left curve, the driver steered late and failed to negotiate the curve. The vehicle departed the right side of the road. The driver steered to the left to correct his errant trajectory. However, due to the vehicle's excessive speed and the sloping relatively soft shoulder, the rear tires broke traction and the vehicle began to yaw counterclockwise. It was probable the driver fought for control of the vehicle and depressed the throttle. This action was documented in the EDR pre-crash data by the throttle position and engine RPM five seconds prior to Algorithm Enable (AE).

The vehicle vaulted across the intersection and impacted the ground with the left front suspension and undercarriage. The frontal air bag system did not deploy in the event due to the non-horizontal nature of the impact coupled with the vehicle's yaw. The vehicle rebounded from this impact, vaulted a short distance and then initiated a right side leading eight quarter turn rollover.

The retractors of the manual restraint systems in the Chevrolet locked response to the inertial change of the impact and roll. The driver contacted and loaded the locked restraint system evidenced by the frictional abrasions at the latch plate and the gathered webbing at the belt guide on the upper outboard aspect of the seat. The manual restraint system maintained the driver's position within the interior and minimized his contact with the forward interior.

The vehicle rolled inverted, during the second quarter turn, impacting down on the left roof side rail. The roof crushed down and the side rail was displaced to the right. The side rail impacted the driver's seat restraint and seat back. The driver's head impacted the deformed roof structures resulting in his cervical fracture. The vehicle then continued to roll six more quarter turns coming to rest on its wheels. The belt system remained locked through the rollover event. The driver came to rest within his occupant space and was removed by the emergency responders.

RIGHT FRONT AND RIGHT REAR OCCUPANTS

Prior to the crash, the right front and right rear occupants of the Chevrolet were restrained. The occupants were alcohol impaired and their pre-crash postures were no known. Upon impact and subsequent rollover, the manual restraint systems locked and the occupants loaded the belt system. The belt systems maintained the occupants within their respective spaces and minimized their contact to the vehicle's interior. The interior space above the right side occupants was maintained throughout the rollover and they were relatively uninjured. The left front passenger was reportedly assisted from the vehicle by the emergency responders. The right rear passenger unbuckled his seat belt and exited the vehicle under his own power. He was not ejected, as indicated in the police report.

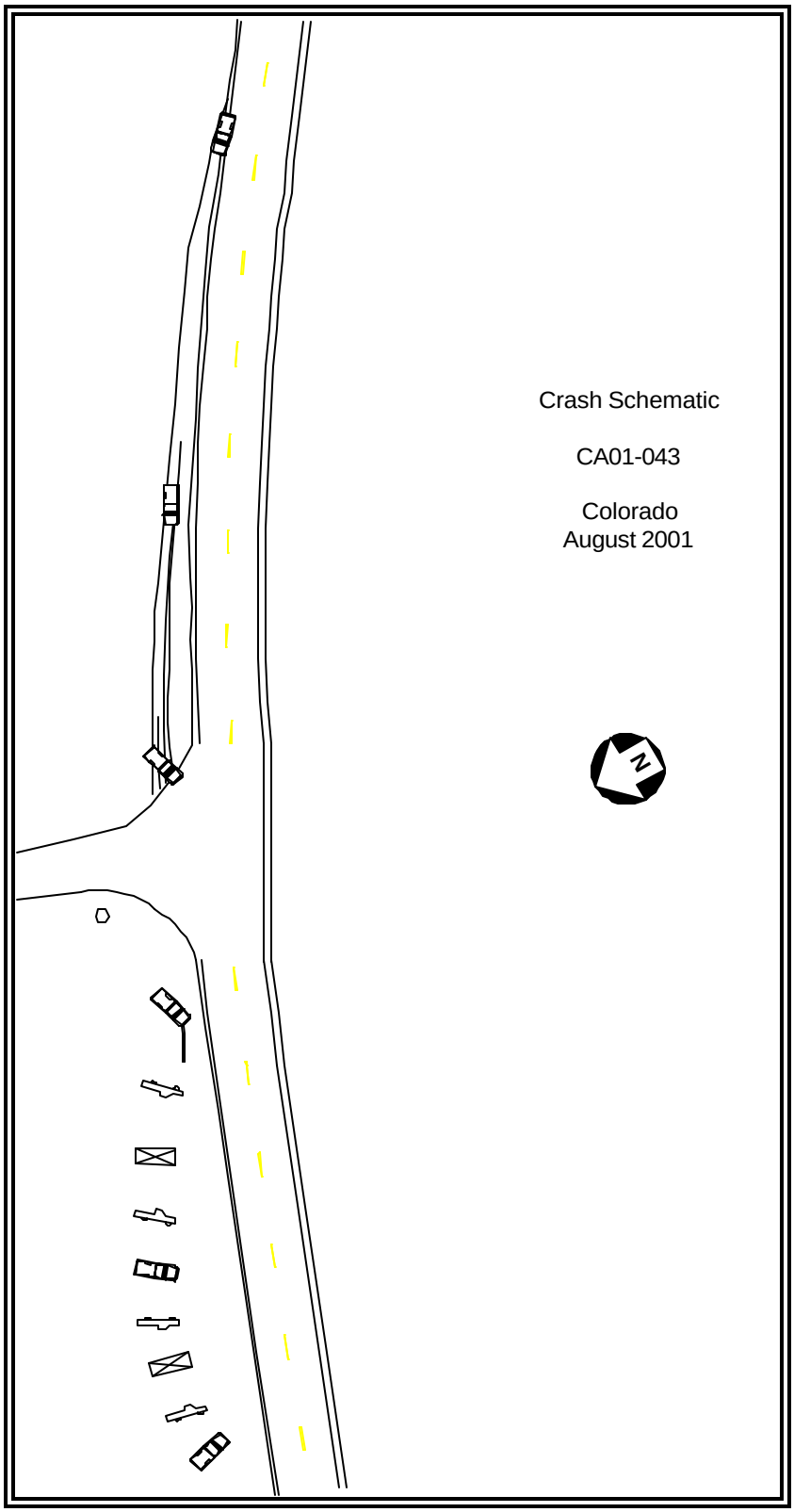

Figure 14: Crash schematic.

ATTACHMENT A

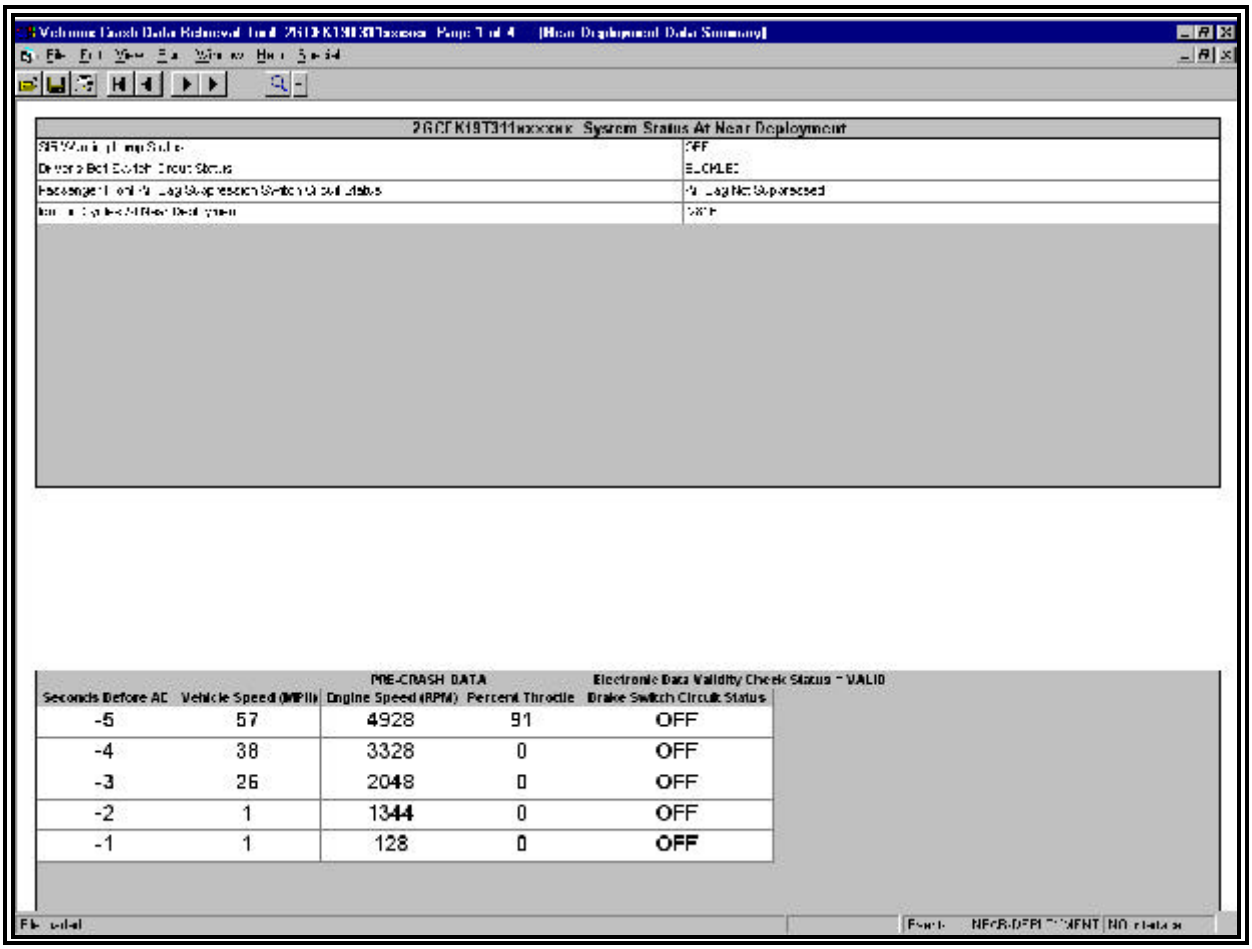

Figure 15: Near Deployment Data Summary

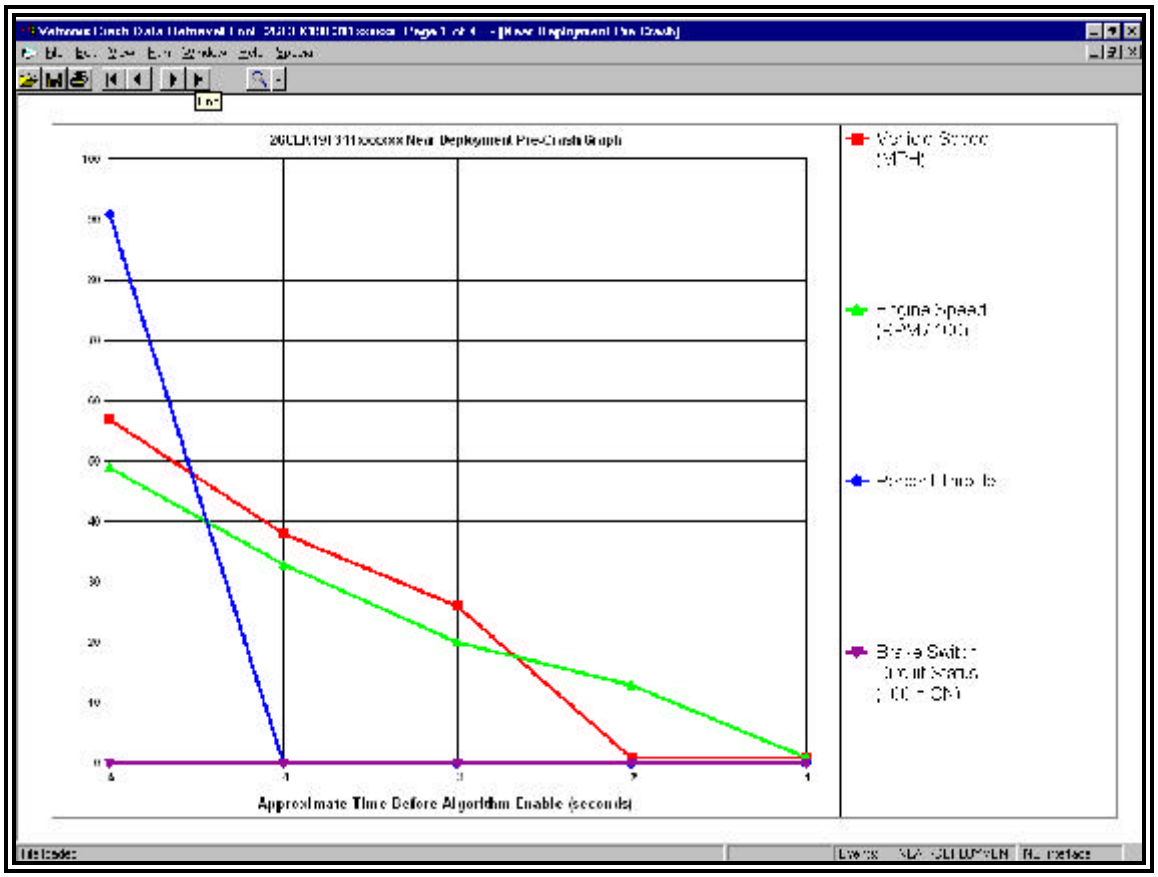

Figure 16: Near Deployment Pre-Crash Graph