Certified Advanced 208 Compliant Investigation / Vehicle to Object
Dynamic Science, Inc. / Case Number: DS03020
2003 GMC Yukon K1500
Texas
April, 2003

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

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16. Abstract

This on-site investigation focused on the Certified Advanced 208-Compliant (CAC) air bag system in a 2003 GMC Yukon K1500 4x2 sport utility vehicle. 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 GMC Yukon was being driven by a 45-year-old male. This single vehicle crash occurred in April, 2003 at 1505 hours in the state of Texas. The crash occurred on an interstate highway. The driver of the GMC Yukon attempted to avoid a non-contact vehicle. The driver lost control and struck a metal guardrail. The vehicle penetrated the guardrail and struck a concrete bridge support with its right side. There were no air bag deployments. The police indicated that the restrained driver sustained “C” type injuries. He refused medical treatment at the scene.

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Dynamic Science, Inc.
Crash Investigation
Case Number: DS03020

TABLE OF CONTENTS

BACKGROUND:

Figure 1. Front damage (Impact 1)

This on-site investigation focused on the Certified Advanced 208-Compliant (CAC) air bag system in a 2003 GMC Yukon K1500 sport utility vehicle. 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 GMC Yukon was being driven by a 45-year-old male. The crash occurred on an interstate highway. The driver of the GMC Yukon attempted to avoid a non-contact vehicle. The driver lost control and struck a metal guardrail. The vehicle penetrated the guardrail and struck a concrete bridge support with its right side. There were no air bag deployments. The police indicated that the restrained driver sustained "C" type injuries. He refused medical treatment at the scene.

This Certified Advanced 208-Complaint case was initially identified by a NHTSA review of GES police reports. The police report was faxed to DSI on May 19, 2003 with instructions to locate the case vehicle for an on-site investigation. Permission was obtained from the insurance company to inspect the case vehicle. The case was assigned a number on June 3, 2003. An on-site investigation was conducted and the data from the Sensing Diagnostic Module (SDM) was downloaded from the case vehicle. All field work was completed on June 3, 2003.

SUMMARY

Crash Site

Figure 2. Approach to impact 1 (south-west)

This single vehicle crash occurred in April, 2003 at 1505 hours. At the time of the crash, it was daylight and the weather was not a factor. The crash occurred of the left side (south-west) of an interstate junction road as it connects the southbound interstate with the westbound interstate in a city setting. The junction road is a single lane, concrete surfaced road that curves to the right (west) as it approaches the area of the crash. The road is bordered on both sides by asphalt surfaced shoulders and 0.6 meter (2.0 ft) high metal and wood guardrails. Near the departure area, the cross-slope of the left shoulder (west) is a positive 4.8 percent as the shoulder ramps up. Beyond the left (west) guardrail is an open field–grass and dirt surface. The elevation of the open field drops approximately 0.3 meters (1.0 ft) relative to the junction road. There is a

concrete bridge support pillar just adjacent to the guardrail that was impacted by the case vehicle. There were no traffic controls present and the speed limit is 97 km/h (60 mph).

Pre-Crash

The case vehicle is a 2003 GMC Yukon K1500 four door 4x2 rear wheel drive sport utility vehicle. The case vehicle was driven by a restrained 45-year-old male. Inspection of the driver's continuous loop 3-point seat integrated lap and shoulder safety seat belt indicated historical usage, and evidence of loading. The data from the downloaded SDM indicated that the driver's belt switch circuit status was BUCKLED. The driver was seated in a leather covered bucket seat that was adjusted to between the middle and rear most seat track position. The seat back was reclined rearward (24 degrees) aft of vertical.

The case vehicle initially traveling southbound on an interstate then transitioned onto the westbound junction road to head westbound on another interstate. The downloaded SDM non-deployment data indicates that five seconds prior to algorithm enable (AE), the case vehicle was traveling at 105 km/h (65 mph) and the brake switch circuit status was in the ON position. The driver indicated to the police that another vehicle ahead of him slowed. The driver of the case vehicle braked and swerved to the left in an effort to avoid colliding into the vehicle ahead of him.

Crash

The case vehicle crashed into the metal/wood guardrail (approximately 15.0 meters [50.0 ft] of the guardrail was newly replaced) on the left shoulder area with its lower front end and undercarriage areas (12FDLW1). The total velocity change for the case vehicle as calculated by the Barrier algorithm of the WinSmash collision model was 13.0 km/h (8.1 mph)[1]. The longitudinal and lateral delta V components were -13.0 km/h (-8.1 mph) and 0 km/h (0 mph), respectively. This is a borderline reconstruction given the yielding object–guardrail.

Figure 3. Impact 1 with guardrail

The case vehicle vaulted over the guardrail and continued airborne for approximately 2.0 meters (7.0 ft) while rotating counterclockwise and subsequently collided with a concrete bridge support pillar with the vehicle's right side (02RZAW2). There was what appeared to be black tire transfer on the concrete bridge support pillar that began 100.0 cm (39.0 in) from the ground. The total velocity change for the case vehicle as calculated by the Barrier algorithm of the WinSmash collision model was 14.0 km/h (8.7 mph). The longitudinal and lateral delta V components were -4.8 km/h (-3.0 mph) and -13.2 km/h (-8.2 mph), respectively. The result fit the collision model and appear reasonable.

[1]Calculated using stiffness values derived from NCAP test 4549

The case vehicle then rotated clockwise off the concrete bridge support pillar and impacted the ground, leading with its front left tire (09LFWN1). The ground impact separated the front left tire, wheel and brake assembly from the vehicle. The case vehicle came to rest upright and heading in a westerly direction.

Post-Crash

The police report indicates that the driver of the case vehicle sustained “C” type injuries. He refused to have an ambulance called out to the scene of the crash for medical treatment. It is not known at this time if he sought medical treatment for his injuries at a later time. The case vehicle was towed from the scene due to damage and later declared a total loss by the insurance company.

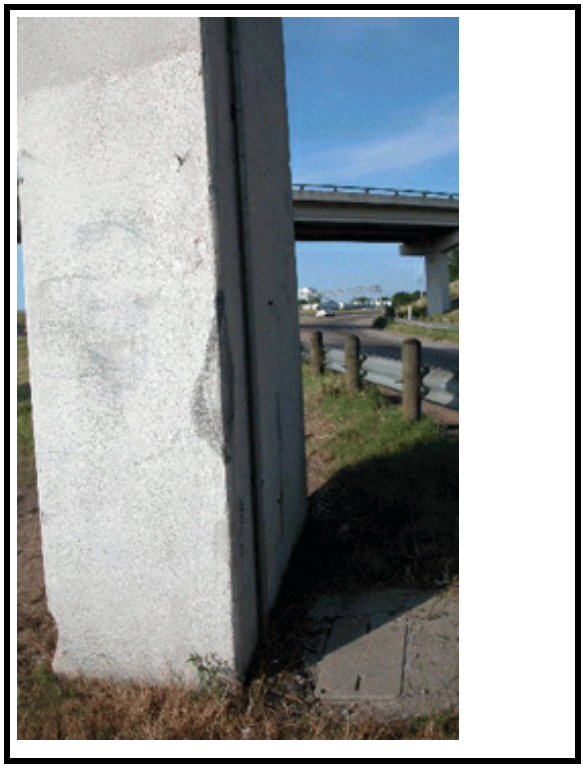


Figure 4. Impact 2 with concrete bridge support pillar

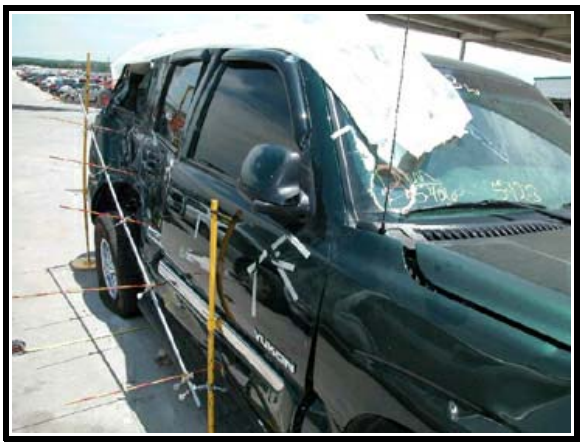


Figure 5. Exterior right side damage (Impact 2)

VEHICLE DATA - 2003 GMC Yukon

The 2003 GMC Yukon K1500 4x2 sport utility was identified by the Vehicle Identification Number (VIN): 1GKEC13Z03RXXXXXX. At the time of the vehicle inspect, the GMC had 8,700 km (5,406 miles) on the odometer. The GMC Yukon is a sport utility vehicle that was equipped with a 5.3 liter, eight cylinder engine, a four-speed automatic transmission, rear wheel drive, cruise control, 4-wheel disc anti-lock brakes, and a tilt steering wheel. The 2003 GMC Yukon was equipped with Firestone Wilderness P265/70R16 tires. The manufacturer recommended cold tire pressure is 241 kPa (35 psi). The specific tire data is as follows:

Tire	Tread	Pressure	Recommended pressure
LF	9 mm (11/32 in)	Flat	303 kPa (44 psi)
LR	8 mm (10/32 in)	269 kPa (39 psi)	303 kPa (44 psi)
RF	9 mm (11/32 in)	152 kPa (22 psi)	303 kPa (44 psi)
RR	8 mm (10/32 in)	Flat	303 kPa (44 psi)

The interior of the 2003 GMC Yukon consisted of a eight passenger seating configuration. The front row was comprised of two leather covered reclining bucket seats. A 2nd row was comprised of a leather covered 60/40 split-folding bench seat (seats three). A 3rd row was comprised of a leather covered split-folding bench seat (seats three). The driver was seated in a leather covered bucket seat that was adjusted to between the middle and rear most seat track position. The seat back was reclined rearward (24 degrees) aft of vertical.

VEHICLE DAMAGE

Exterior Damage - 2003 GMC Yukon

The 2003 GMC Yukon sustained moderate front damage as a result of the impact with the guardrail. The case vehicle sustained direct damage across the entire front bumper that began at the front right bumper corner. Maximum crush was 16.8 cm (6.6 in) located at C5. For the second impact versus the concrete bridge support pillar, the case vehicle sustained direct damage of 269.0 cm (105.9 in) that began at the right rear bumper corner and extended forward to the front right passenger's door area. Maximum crush was 18.0 cm (7.1 in) located at C1. For the third impact versus the ground, the ground impact separated the front left tire, wheel and brake assembly from the vehicle.

CDC (Impact 1):	12FDLW1	
Delta V:	Total	13.0 km/h (8.1 mph)
	Longitudinal	-13.0 km/h (-8.1 mph)
	Latitudinal	0 km/h (0 mph)
	Energy	15,991 joules (11,794 ft lbs)
CDC (Impact 2):	02RZAW2	
Delta V:	Total	14.0 km/h (8.7 mph)
	Longitudinal	-4.8 km/h (-3.0 mph)
	Latitudinal	-13.2 km/h (-8.2 mph)
	Energy	29590 joules (21,824 ft lbs)
CDC (Impact 3):	09LFWN1	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

Interior Damage - 2003 GMC Yukon

The 2003 GMC Yukon sustained minor interior damage as a result of passenger compartment intrusion. The right door panel, right side panel, and right C pillar sustained lateral intrusion. The two right doors were jammed shut. The third row side glass was disintegrated as a result of the pillar impact.

The specific passenger compartment intrusion were documented as follows:

Position	Intruded Component	Magnitude of Intrusion	Direction
RR (row 2)	Door panel	4.0 cm (1.6 in)	Lateral
RR (row 3)	Side panel	5.0 cm (1.9 in)	Lateral
RR (row 3)	C pillar	6.0 cm (2.4 in)	Lateral

MANUAL RESTRAINT SYSTEMS - 2003 GMC Yukon

The driver's manual restraint system consisted of a seat integrated continuous loop 3-point manual lap and shoulder safety belt with a sliding latch plate. The emergency locking retractor was located in the seat back. The non-deployment event recorded by SDM reports that the driver's belt switch circuit status was "BUCKLED".

The front right bucket seat, the three seat positions of the 2nd row split-folding bench seats, and the two outboard seat positions of the 3rd row split-folding bench seats were equipped with continuous loop 3-point manual lap and shoulder safety belts with sliding latch plates. All but the 2nd row right seat and the 3rd row middle seat positions were equipped with switchable emergency/automatic locking retractors. The retractor type for the 2nd row middle seat position could not be determined because the retractor was found locked by the intruding right side of the vehicle. The 3nd row middle seat position was equipped with a manual lap belt with a locking latch plate. The 2nd row middle and right seat positions were equipped with Lower Anchors and Top tethers for Children (LATCH).

FRONTAL AIR BAG SYSTEM - 2003 GMC Yukon

The case vehicle was equipped with advanced dual stage frontal air bags. The driver's air bag module was located in the center hub of the steering wheel rim and did not deploy during the crash because the forces generated during the crash events were below the air bag deployment threshold of the restrained driver. The front right passenger air bag was a mid-mount design located in the right aspect of the instrument panel. The front right passenger air bag did not deploy due to case vehicle being equipped with a Passenger Sensing System, and the absence of a front right occupant. The Passenger Sensing System is designed to automatically switch the air bag on or off based on a passenger's weight. The system also uses a sensor in the passenger-side seat belt to measure how much tension is exerted by the seat belt when it is being cinched down, another means of determining what may be on the seat. There is an indicator on the rear-view mirror that alerts vehicle occupants to the status of the system at all times. If the light reads "Passenger Air Bag ON," the air bag is programmed to deploy in a frontal crash of sufficient severity. If it reads "Passenger Air Bag OFF," the system has turned off the air bag because it determined either that there is no occupant on the front passenger seat, or that a rear-facing infant seat, a forward-facing child restraint, a booster seat or a smaller person, such as a child who has outgrown child restraints, is present.

Figure 6. Non-deployment of driver's air bag

Figure 7. Front right Passenger Sensing System, monitored on rear view mirror

The SDM recorded a non-deployment event with a maximum recorded velocity change of -11.65 km/h (-7.24 mph) at the 300 millisecond mark (long pulse). The SDM also recorded that multiple events were associated with this record and that one or more associated events were not recorded.

Advanced Occupant Protection System Discussion

This vehicle was equipped with an advanced occupant protection system. The system consists of the SDM, dual-level (dual stage) driver and front right passenger air bags, a front right passenger sensing system, seat mounted side air bags at both front seat positions, and a driver's seat belt latch usage detector. The system is controlled by the SDM. The primary function of the SDM is to control the deployment of the occupant protection systems. The system records the vehicle's forward velocity change. The SDM will record 100 milliseconds of data after the deployment criteria is met and up to 50 milliseconds of data before deployment criteria is met. The SDM will also record 150 milliseconds of data after non-deployment criteria is met.

One event was recorded by the SDM, a Non-Deployment event at 944 ignition cycles.

The Vetronix system status at Non-Deployment report indicates that:

1. SIR warning lamp status was OFF.
2. The driver's belt switch status was BUCKLED.
3. Ignition cycles at non-deployment 944.
4. Ignition cycles at investigation 947.
5. Maximum SDM recorded velocity change -11.65 km/h (-7.24 mph).
6. Algorithm enable (AE) to maximum SDM recorded velocity change was 300 milliseconds.
7. Event recording complete YES.
8. Multiple events associated with this record YES.
9. One or more associated events not recorded YES.
10. The vehicle speed was 105 km/h (65 mph) 5 seconds before AE, decelerated to 101 km/h (63 mph) 4 seconds before AE, to 95 km/h (59 mph) 3 seconds before AE, to 85 km/h (53 mph) 2 seconds before AE, to 64 km/h (40 mph) 1 seconds before AE.
11. The brake switch status was ON from 5 through 1 seconds before AE.

OCCUPANT DEMOGRAPHICS - 2003 GMC Yukon

	Driver
Age/Sex:	45/Male
Seated Position:	Front left
Seat Type:	Leather covered bucket seat
Height:	Unknown
Weight:	Unknown
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Presumed to be greater than 10 years
Body Posture:	Presumed to be upright.
Hand Position:	Unknown
Foot Position:	Right foot presumed to be on the brake
Restraint Usage:	Lap and shoulder belt available, used
Air bag:	Steering wheel mounted driver's air bag. Non deployed.

OCCUPANT INJURIES -2003 GMC Yukon

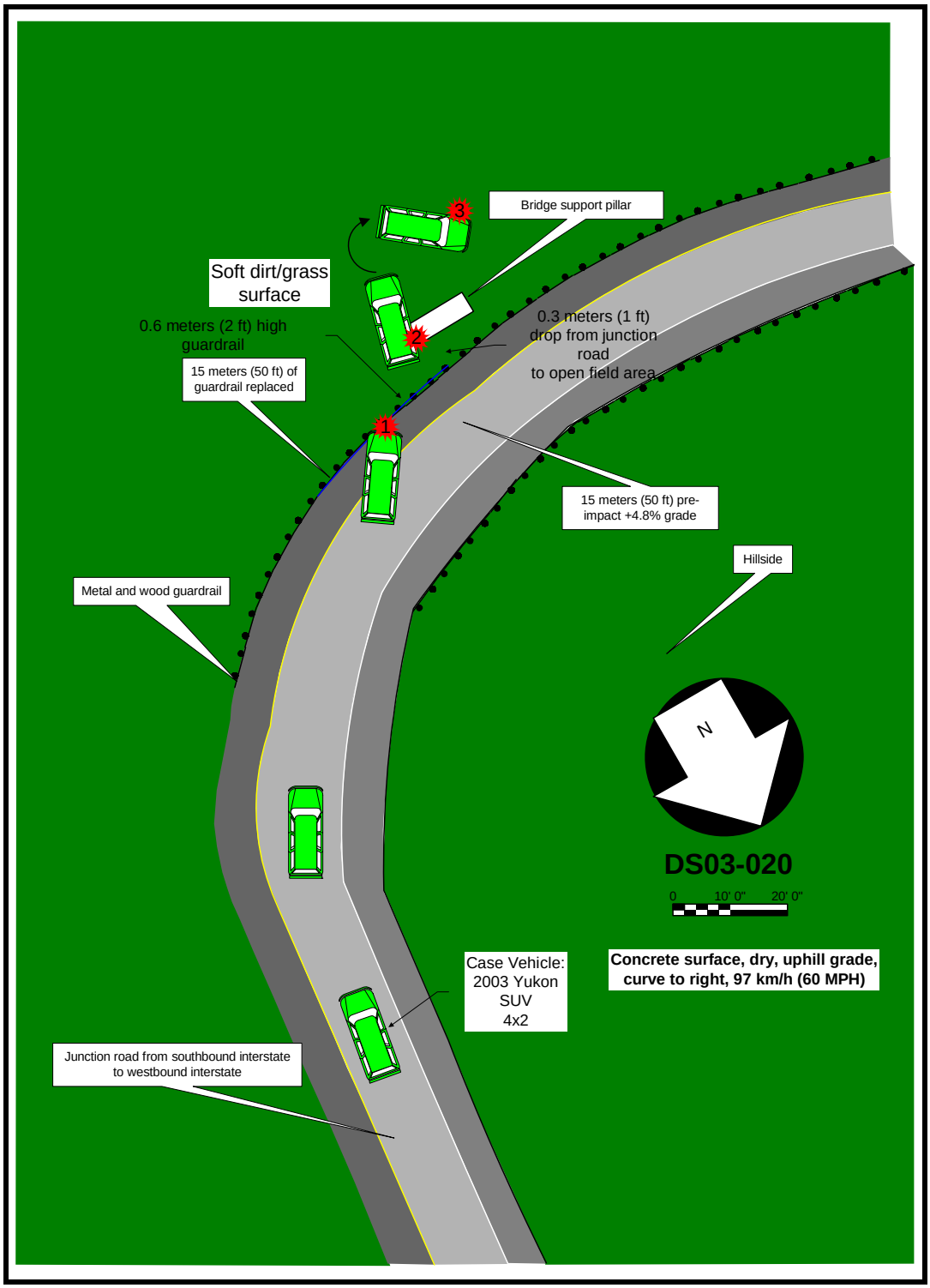
No reported injuries.

OCCUPANT KINEMATICS - 2003 GMC Yukon

Figure 8. Adjustable pedals–location

The 45-year-old male driver was seated in an upright posture and restrained by the integral 3-point lap and shoulder belt. The safety seat belt indicated historical usage, and evidence of loading. The data from the downloaded SDM indicated that the driver's belt switch circuit status was BUCKLED. The driver was seated in the leather covered bucket seat that was adjusted to between the middle and rear most seat track position. The seat back was reclined rearward (24 degrees) aft of vertical. His hands were likely on the steering wheel. His right foot was on the brake. The GMC Yukon was equipped with adjustable pedals that were adjusted to approximately 4.0 cm (1.6 in) rearward of most forward position. At impact, the driver initiated a forward trajectory and began loading the lap and shoulder belt. There were no indications that the driver engaged any interior structures. As the Yukon penetrated the guardrail it began a slight counterclockwise yaw. The right rear of the Yukon struck a concrete bridge support. The driver pitched forward and to the right in response to the 2 o'clock direction of force. Again, there were interior structures contacted. The Yukon rotated about the structure and contacted the ground with its left front tire. The driver did not report any injuries and was able to exit the vehicle under his own power.

Attachment 1. Scene Diagram



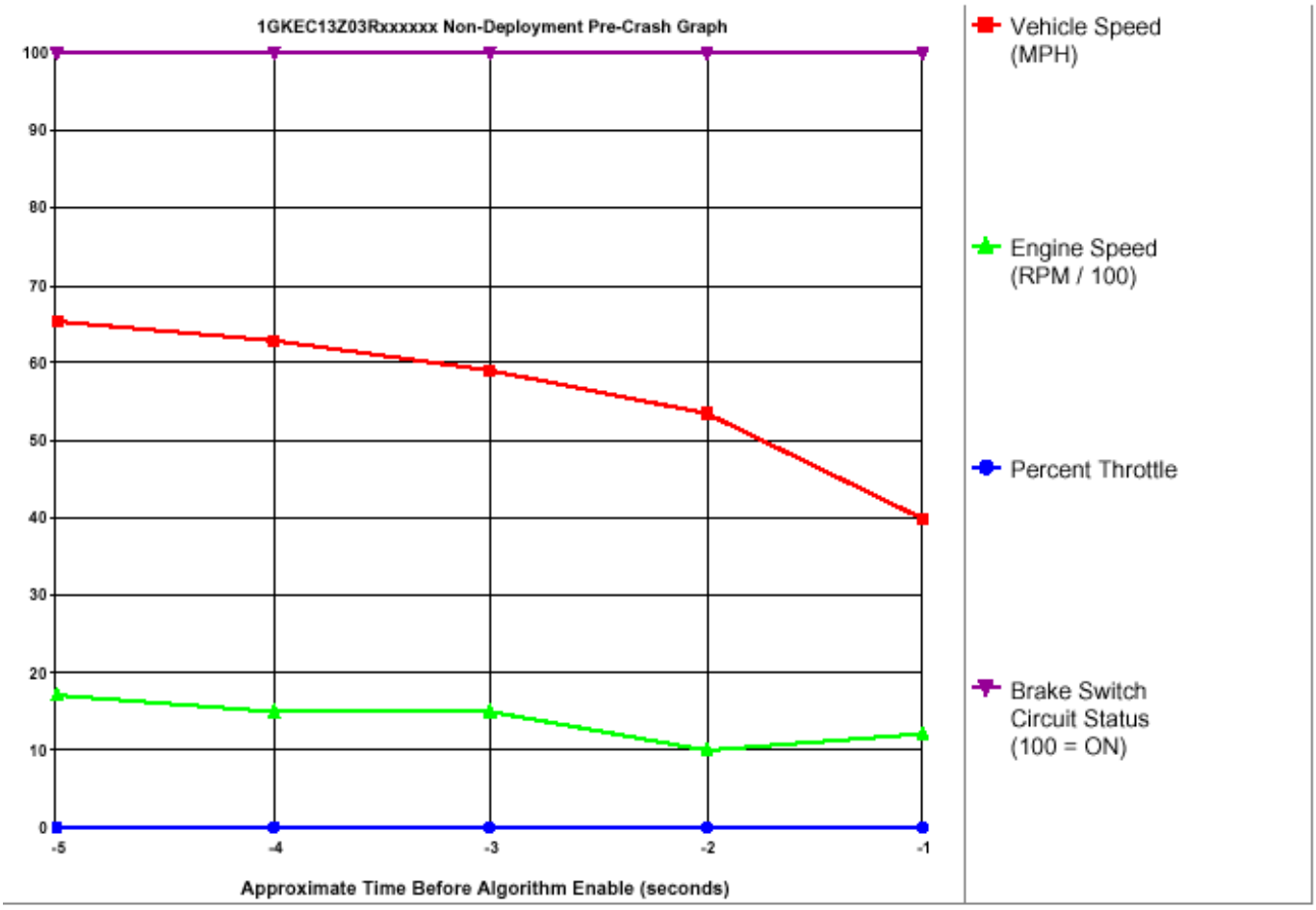
Attachment 2. Vetronix Report

Vetronix

CDR CRASH DATA RETRIEVAL SYSTEM

System Status At Non-Deployment

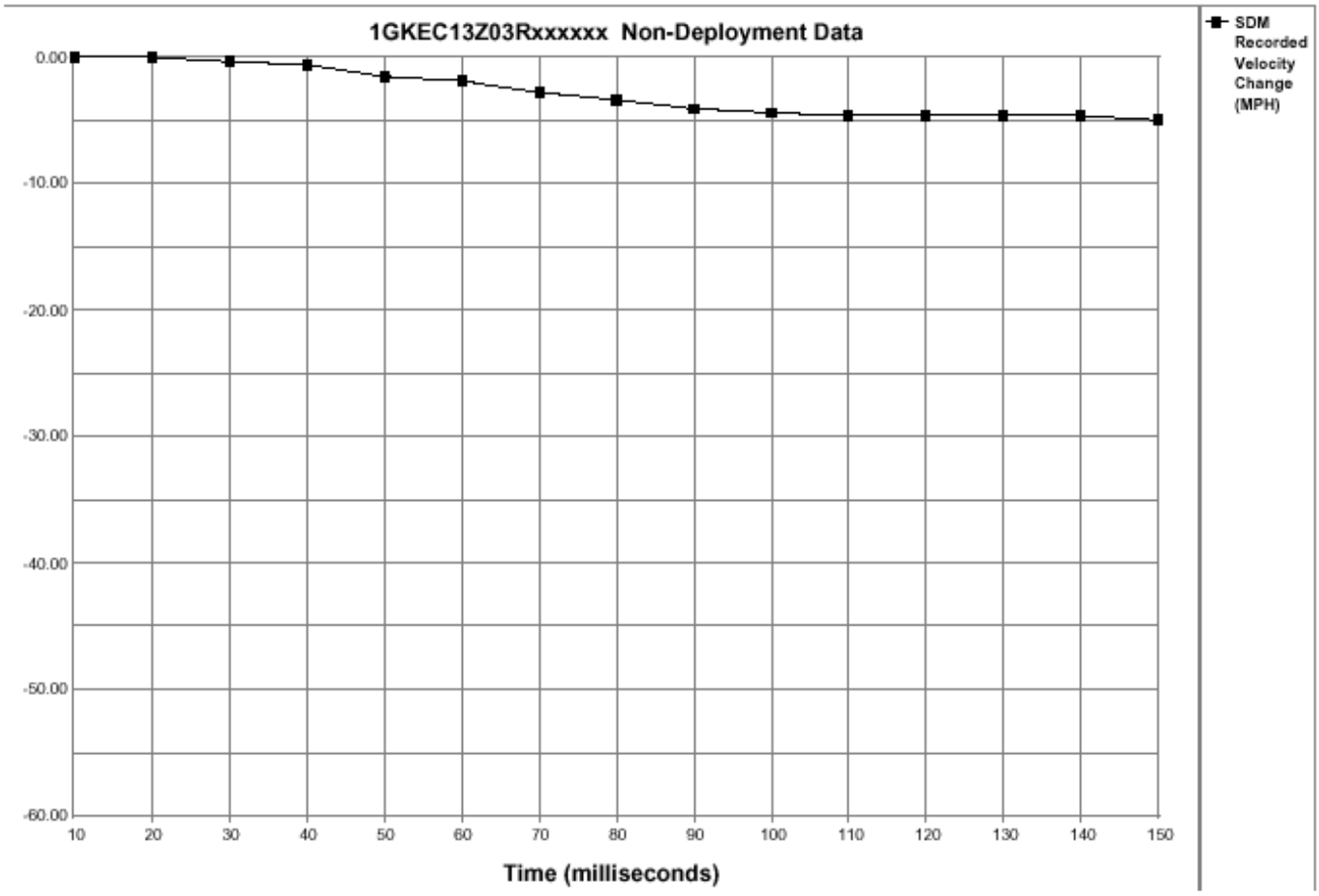
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Non-Deployment	944
Ignition Cycles At Investigation	947
Maximum SDM Recorded Velocity Change (MPH)	-7.24
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	300
Event Recording Complete	Yes
Multiple Events Associated With This Record	Yes
One Or More Associated Events Not Recorded	Yes



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	65	1728	0	ON
-4	63	1472	0	ON
-3	59	1472	0	ON
-2	53	1024	0	ON
-1	40	1216	0	ON

Vetronix

CDR CRASH DATA RETRIEVAL SYSTEM



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	0.00	0.00	-0.31	-0.62	-1.55	-1.86	-2.79	-3.41	-4.03	-4.34	-4.65	-4.65	-4.65	-4.65	-4.96