

Advanced 208 Compliant Investigation / Vehicle to Vehicle  
Dynamic Science, Inc. / Case Number: 2003-79-039J  
2003 GMC Yukon  
California  
February, 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 crash-worthiness performance of the involved vehicle(s) or their safety systems.*

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16. Abstract  This was a single vehicle rollover collision. The collision occurred in February, 2003 at 0905 hours in the state of California. The crash occurred on a six-lane divided interstate highway. The speed limit is 105 km/h (65 mph). The case vehicle is a 2003 GMC Yukon Denali SLT 4x2 sport utility vehicle driven by an unrestrained 23-year-old female. The rear left seat was occupied by a 2-year-old female who was seated in a Graco forward facing convertible child safety seat. The rear middle seat was occupied by a 5-month-old male who was seated in a rear facing infant seat. The case vehicle was traveling southbound at a police estimated speed of 97-105 km/h (60-65 mph) in the first lane from the right. In the adjacent lane was a second sport utility vehicle. Witnesses indicate that both vehicles attempted lane changes towards one another. It appears both drivers saw the respective other vehicle and steered away. The driver to the left was able to maintain control of the vehicle. The driver of the case vehicle initially steered right and traveled onto the right hand shoulder. The driver over-steered to the left, and then back again to the right as she lost control of the vehicle. The case vehicle struck a curb (event 1)—causing an air bag non-deployment event. The vehicle departed the roadway on the right side and traveled down an embankment onto a two lane truck bypass where it overturned (event 2). It crossed the roadway and then contacted its roof against a concrete wall (event 3). The vehicle went down another embankment and continued overturning until coming to rest on its left side in a concrete culvert. The driver was ejected and seriously injured.				
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**Dynamic Science, Inc.**  
**Crash Investigation**  
**Case Number: 2003-79-039J**

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## BACKGROUND:

**Description:** This Advanced 208-Compliant Vehicle Investigation was identified by the local National Automobile Sampling System Primary Sampling Unit (PSU). This vehicle was certified by the manufacturer to meet the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The case was reported to DSI on March 20, 2003. This was an SCI/PSU combination case. The case vehicle was inspected and the System Diagnostic Module (SDM) downloaded on March 27, 2003. A DSI SCI investigator was present during the inspection.

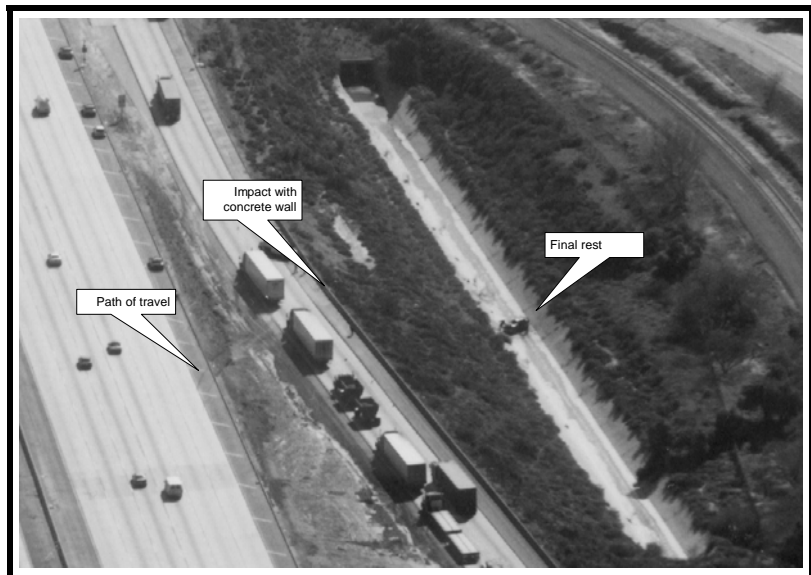
**Investigation Type:** Advanced 208 Compliant  
**Crash Location:** California  
**Crash Date:** February, 2003  
**Notification Date:** March 20, 2003  
**Field Work Completed:** NA

## SUMMARY

### Crash Site

This was a single vehicle rollover collision. The collision occurred in February, 2003 at 0905 hours in the state of California.

The crash occurred on a six-lane divided interstate highway. To the west of this roadway is a 12 m (40 ft) dirt embankment with a negative grade. Immediately to the west of the embankment is a two-lane, one way truck by-pass roadway that is bordered to the west by a 0.9 m (3 ft) high concrete wall. To the west of the wall is a 27 m (90 ft) wide descending dirt and foliage embankment. To the west of this embankment is a 12 m (40 ft) wide water drainage culvert. The speed limit is 105 km/h (65 mph).



**Figure 1.** Overview of crash scene

## Pre-Crash

The case vehicle is a 2003 GMC Yukon Denali SLT 4x2 sport utility vehicle (VIN: 1GKEC13TX3Rxxxxxx) driven by an unrestrained<sup>1</sup> 23-year-old female (170 cm/67 in, 69 kg/153 lbs). The rear left seat was occupied by a 2-year-old female (66 cm/26 in, 13 kg/28 lbs) who was seated in a Graco forward facing convertible child safety seat. The rear middle seat was occupied by a 5-month-old male (62 cm/24 in, 8kg/18 lbs) who was seated in a rear facing infant seat (Graco). This occupant was asleep prior to the crash.

The case vehicle was traveling southbound at a police estimated speed of 97-105 km/h (60-65 mph)<sup>2</sup> in the first lane from the right. In the adjacent lane was a second sport utility vehicle. Witnesses indicate that both vehicles attempted lane changes towards one another. It appears both drivers saw the respective other vehicle and steered away. The driver to the left was able to maintain control of the vehicle. The driver of the case vehicle initially steered right and traveled onto the right hand shoulder. The driver over-steered to the left, and then back again to the right as she lost control of the vehicle.

## Crash

The case vehicle struck a curb (event 1)—causing an air bag non-deployment event. The vehicle departed the roadway on the right side and traveled down an embankment onto a two lane truck bypass where it overturned (event 2). It crossed the roadway and then contacted its roof against a concrete wall (event 3). The vehicle went down another embankment and continued overturning until coming to rest on its left side in a concrete culvert.



Figure 2. Left rear, case vehicle



Figure 3. Front left, case vehicle

<sup>1</sup>No sign of loading, SDM indicated NOT buckled, driver ejection

<sup>2</sup>Vetronix data indicate a travel speed of 121 km/h (75 mph)

## Post-Crash

The driver of the case vehicle was ejected through the left front window near the area of final rest. The driver reported that she sustained numerous serious injuries, including: head injury with unconsciousness (AIS = 4), heart contusion (AIS=1), cerebrum hemorrhage (AIS=3), neck fracture, splenic laceration (AIS=2), bilateral pelvic fractures, rib fractures, left scapular fracture, and a left femur fracture. She was transported to a local trauma center by air. She arrived with a Glasgow Coma Scale (GCS) of 8. She was hospitalized for 2-1/2 weeks. She was off from work 1-1/2 months.



Figure 4. Top, left side

The 2-year-old left rear occupant was transported from the scene by air ambulance for observation. She arrived with a GCS of 15. She sustained contusions to the left and posterior scalp.

The 5-month-old male rear middle seat occupant was transported from the scene by air ambulance. He arrived with the GCS of 15. He sustained small abrasions to the scalp and lower leg and a contusion right side of his head.



Figure 5. Right rear

The case vehicle sustained major damage and was towed from the scene. It was later declared a total loss by the insurance company.

SCENE DIAGRAM

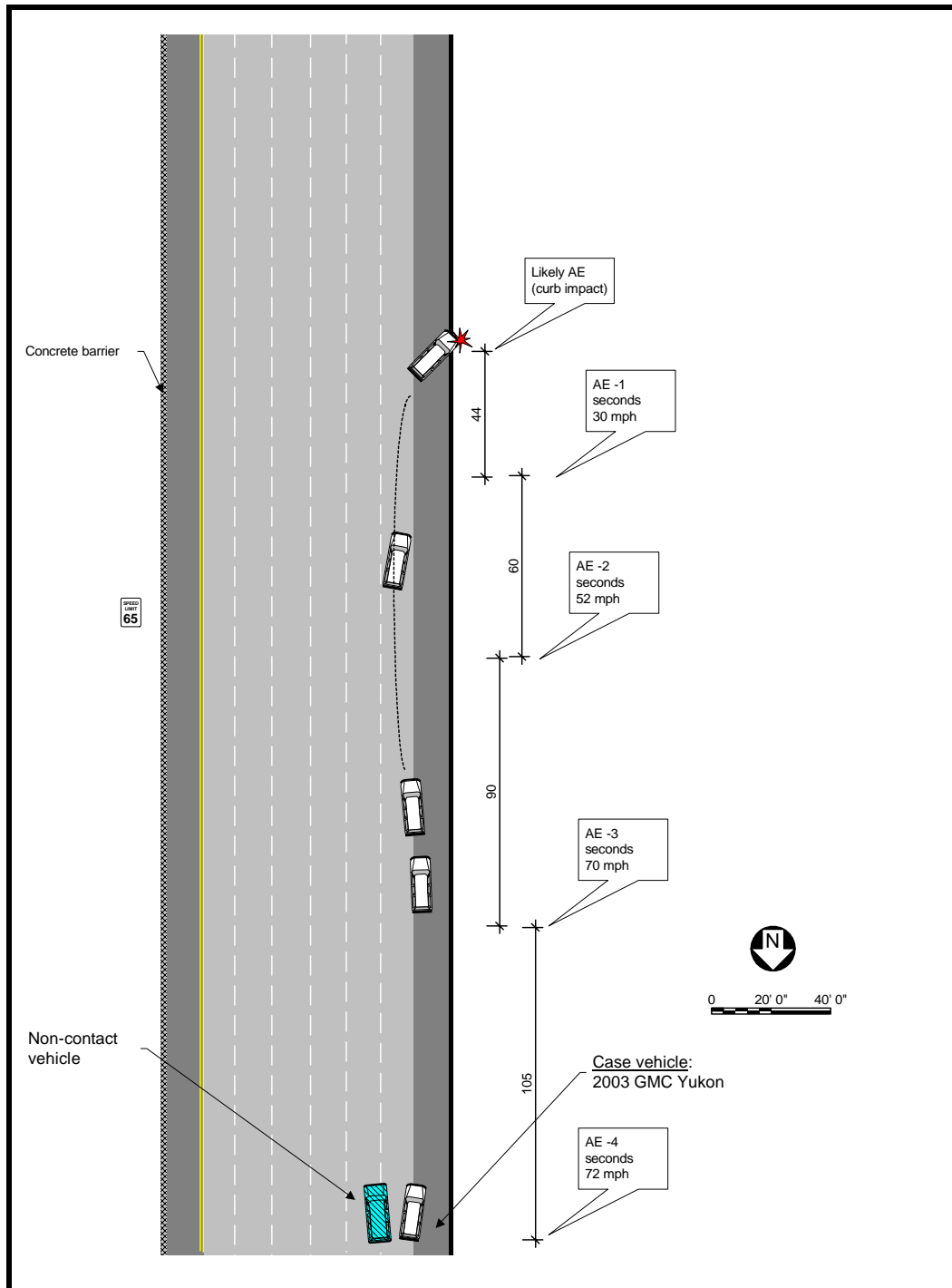


Figure 6. Initial evasive maneuver and contact with curb



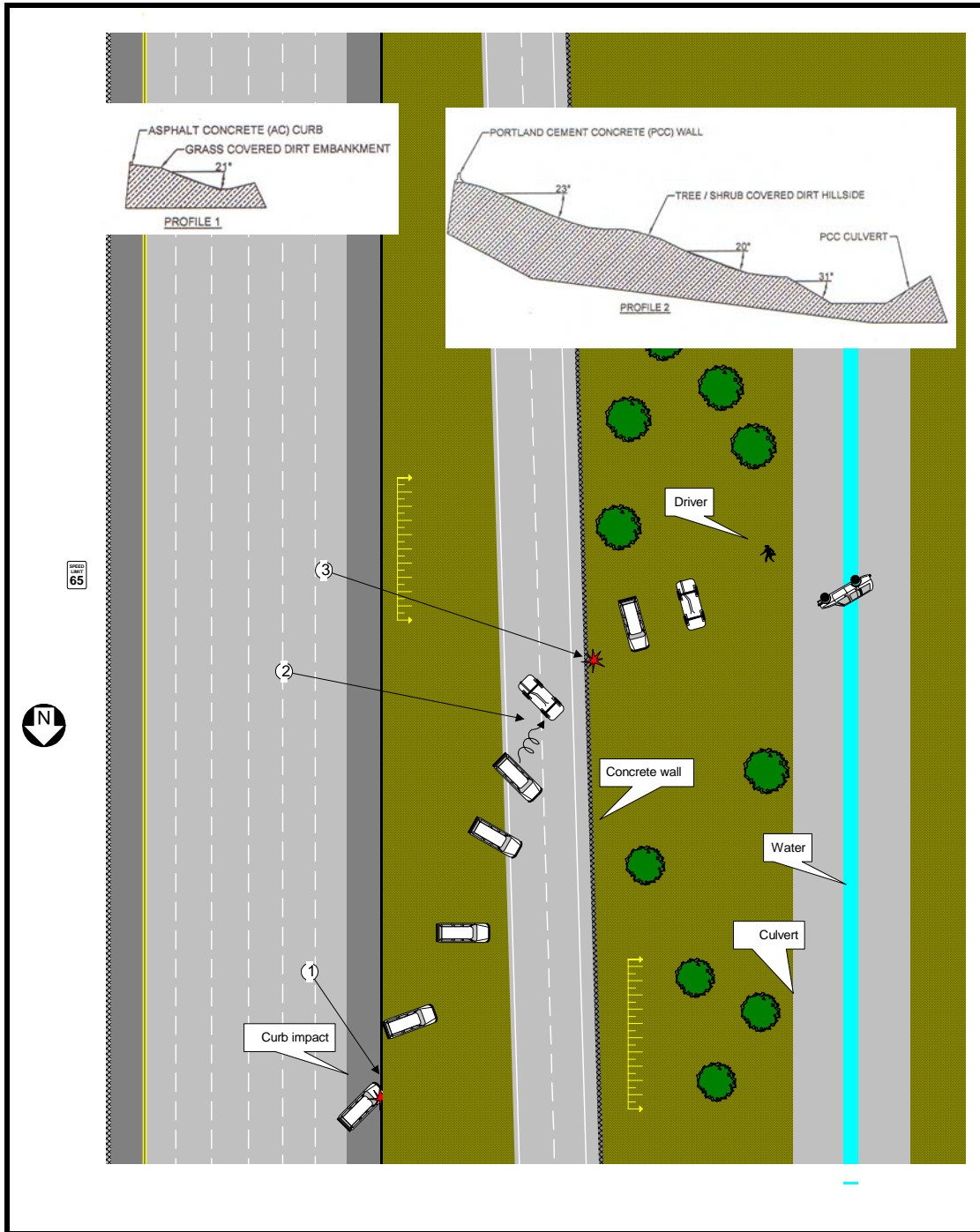


Figure 7.. Travel path after initial contact with curb

**VEHICLE DATA - 2003 GMC Yukon Denali SLT 4x2 sport utility vehicle**

VIN: 1GKEC13TX3Rxxxxxx  
 Odometer: 17,861 km (11,099 miles)  
 Engine: 5.3 L, 8 cylinder  
 Reported Defects: None  
 Cargo: Child seats, 9 kg (20 lbs)

The 2003 GMC Yukon was equipped with Firestone Wilderness LE P265/70R16 tires with aluminum alloy rims. The specific tire data is as follows:

<b>Tire</b>	<b>Tread</b>	<b>Pressure</b>	<b>Recommended pressure</b>
LF	8 mm (0.3 in)	Tire flat	303 kPa (44 psi)
LR	8 mm (0.3 in)	Tire flat	303 kPa (44 psi)
RF	8 mm (0.3 in)	Tire flat	303 kPa (44 psi)
RR	8 mm (0.3 in)	Tire flat	303 kPa (44 psi)

The vehicle was equipped with leather-covered bucket seats with integral lap and shoulder belts in the front seat positions. The driver's position was equipped with adjustable foot controls. The second row was a split-bench, three passenger seat equipped with lap and shoulder belts at each position. The middle and right side seats were equipped with LATCH attachments. The third row was a 50/50 split-bench, three passenger seat equipped with integral lap and shoulder belts at the outboard positions. The middle seat was equipped with a lap belt. The seat backs recline and the entire seat assembly can be removed from the vehicle.

## VEHICLE DAMAGE

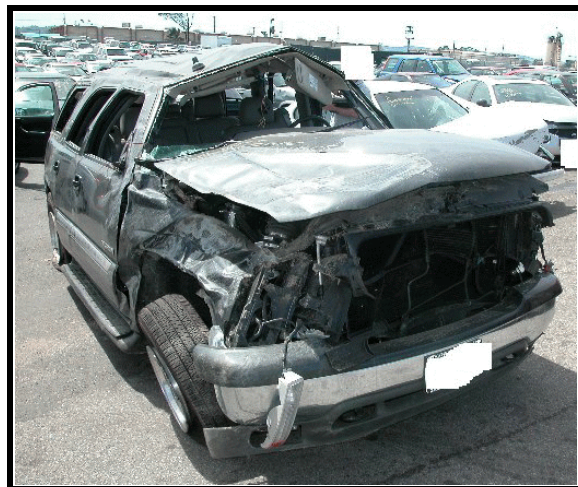
### Exterior Damage - 2003 GMC Yukon

**Damage Description:** The left front door, left rear door, and the tailgate were all jammed shut. There was integrity loss for the windshield, both the left and right side windows, and the backlight. There was lateral and vertical intrusions, primarily to the right side. There was damage to all four rims. With the exception of the left rear, the damage appears to be rollover related. The rear left might also be from the rollover, but there is a longitudinal component that could be related to the initial curb impact.

**CDC:**  
 Impact 1 (curb): 09LFWN1  
 Impact 2 (rollover): 00TDD03  
 Impact 3 (wall impact): 00TFZW2

**Delta V:**

Total	Unknown
Longitudinal	Unknown
Latitudinal	Unknown
Energy	Unknown



**Figure 8.** Front right, case vehicle

### Interior Damage - 2003 GMC Yukon

The GMC Yukon sustained interior damage from intrusion and occupant contacts. There was vertical intrusion along the entire right side roof rail, the right side A/B/C pillars, and through the right side door rail. The most significant intrusion occurred at the front left seat area roof side rail and measured 14.0 cm (5.5 in) along the vertical axis. There were skin scuffs and transfers found on the front header and left side roof rail from the driver as she was ejected from the vehicle. The roof mounted climate control/lighting pod was dislodged from the vehicle and came to rest within the vehicle. The turn signal was broken off at the base. The windshield was holed from impact forces. The left, right, and rear glazing was disintegrated from impact forces. The left front door, left rear door, and rear hatch were all jammed shut. The right side doors remained closed and operational.



**Figure 9.** Front view of case vehicle showing windshield and roof rail intrusions



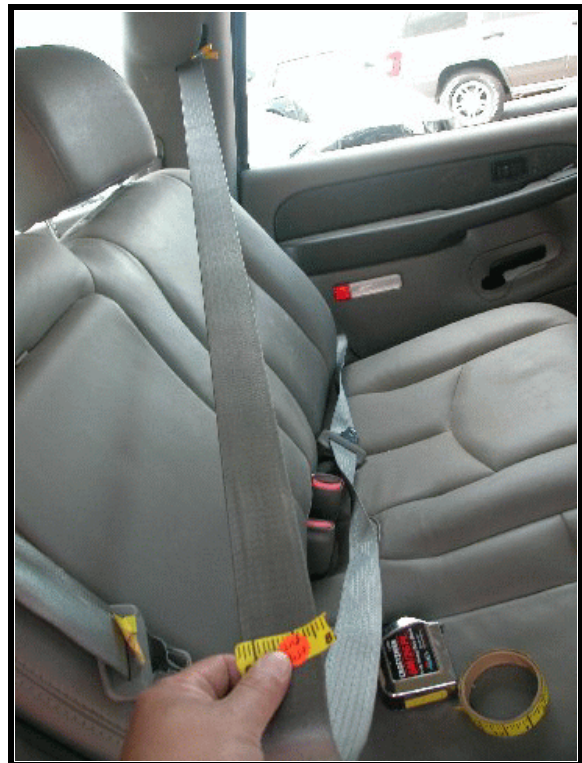
**Figure 10.** Driver contacts to roof, roof rail, and header

**MANUAL RESTRAINT SYSTEMS - 2003 GMC Yukon**

The GMC Yukon was equipped with integral 3-point lap and shoulder belts with sliding latch plates for the front outboard seat positions. The driver's seat was equipped with an emergency locking retractor (ELR), the front right seat belt was equipped with a switchable retractor that was in ELR mode. The second row was equipped with lap and shoulder belts at the outboard seat positions and an integral lap and shoulder belt at the middle seat position. There were sliding latch plates for each belt. There were switchable retractors in ELR mode for the middle and left seat positions. There were LATCH connections at the middle and right side seat locations. The third row was a 50/50 split-bench, three passenger seat equipped with integral lap and shoulder belts at the outboard seat positions and a lap belt for the middle seat position.



**Figure 11.** Driver's seated position



**Figure 12.** Second row left seat belt

## CHILD SAFETY SEATS - 2003 GMC Yukon

The second row left seat was occupied by a 2-1/2 year old seated in a Graco Eddie Bauer forward facing convertible child seat with a tray shield. The model, model number, and date of manufacture are not known. This seat position was equipped with a LATCH connection but the LATCH was not used. According to the driver interview and seat belt evidence (see Figure 13), the child seat was tightly anchored to the vehicle using the 3-point lap and shoulder belt. The vehicle seat belt was routed through the back of the child seat. The harness straps were routed through the top slot of the seat back at the child's shoulder level. A harness clip was present and had been placed at armpit level on the child. The space between the harness and the child's chest was estimated to be the distance of one finger.



**Figure 13.** Load marks to left rear seat belt latch

The second row middle seat was occupied by a 5-month-old seated in a Graco rear facing infant seat. The model, model number, and date of manufacture are not known. The driver indicated that the seat was to be used for children weighing less than or equal to 11 kg (25 lbs). According to the driver interview and seat belt evidence (see Figure 14), the child seat was tightly anchored to the vehicle using the 3-point lap and shoulder belt. The vehicle seat belt was routed across the front of the child seat. The seat was equipped with a 3-point harness. The harness straps were routed through the top slot of the seat back at the child's shoulder level. A harness clip was present and had been placed at armpit level on the child. The space between the harness and the child's chest was estimated to be the distance of one finger. This seat position was equipped with a LATCH connection but the LATCH was not used.



**Figure 14.** Load marks to middle rear seat belt latch

Both child seats were purchased new at the time of the child's birth. Instruction manuals were available for both and the driver indicated that they had been read. Both child seats had been installed by the driver.

## AIR BAG SYSTEM - 2003 GMC Yukon

This vehicle was equipped with an advanced occupant protection system. The system recorded a non-deployment event. The system consists of the SDM, dual stage front air bags, a front right passenger sensing system, 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 150 milliseconds of data after the non-deployment criteria is met.

The downloaded data indicated that the case vehicle had a maximum recorded velocity change of 6.94 km/h (-4.31 mph) at the 150 ms mark.

The Vetronix report further indicates that:

1. The driver's belt switch status was unbuckled.
2. The time from algorithm enable (AE) to maximum recorded velocity change was 170 milliseconds
3. There were no air bag deployments.
4. The brake switch status was ON 5 seconds before algorithm enable (AE), was OFF for the next second, back ON for the next 2 seconds, and finally OFF in the last second.
5. There were 4 ignition cycles between the non-deployment event and the time of investigation.
5. The vehicle speed was 121 km/h (75 mph) five seconds before AE, decelerating to 48 km/h (30 mph) before AE.

It appears likely that the AE event was likely the vehicle's contact with the asphalt curb on the west side of the roadway.

	mph	fps	distance traveled
-5	75	109.95	
-4	72	105.55	107.75
-3	70	102.62	104.08
-2	52	76.23	89.42
-1	30	43.98	60.01
AE			<u>43.98</u>
		Total	405.24

The case vehicle was equipped with frontal air bags mounted in the steering wheel and top mounted in the instrument panel of the front right seat position. The front right passenger air bag includes a "Passenger Sensing System". The system is designed to automatically switch the air bag on or off based on a passenger's weight. There were also seat back mounted side air bags for the front outboard seat positions. There were no air bag deployments.

**Rollover related issues - 2003 GMC Yukon**

For the 2003 model year, the NHTSA Rollover Resistance rating for the Yukon was two stars (has a risk of rollover between 30% and 40%)<sup>3</sup>.

The case vehicle was equipped with GM's next-generation StabiliTrak stability enhancement system. StabiliTrak compares the driver's intended path with the vehicle's actual path, and selectively adjusts engine torque and any of the four brakes to help bring the vehicle back under control.

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<sup>3</sup>Per NHTSA: The Rollover Resistance Rating is an estimate of your risk of rolling over if you have a single vehicle crash. It does not predict the likelihood of that crash. The Rollover Resistance Rating essentially measures vehicle characteristics of center of gravity and track width to determine how "top-heavy" a vehicle is. The more "top-heavy" the vehicle, the more likely it is to roll over. The lowest rated vehicles (1-star) are at least four times more likely to roll over than the highest rated vehicles (5-stars).



**OCCUPANT DEMOGRAPHICS - 2003 GMC Yukon**

	Occupant 1	Occupant 2
Age/Sex:	23/Female	2/Female
Seated Position:	Front left	Second row left
Seat Type:	Leather covered bucket seat. Seat in between middle and rear most track positions.	Leather cover split bench seat with folding back.
Height:	170 cm (67 in)	66 cm (26 in)
Weight:	69 kg (152 lbs)	13 kg (29 lbs)
Occupation:	Unknown	NA
Pre-existing Medical Condition:	None noted	None noted
Alcohol/Drug Involvement:	None	NA
Driving Experience:	Unknown	NA
Body Posture:	Presumed to be normal, upright	Unknown
Hand Position:	Unknown	Unknown
Foot Position:	Unknown	Unknown
Restraint Usage:	Integral lap and shoulder belt available, not used	Lap and shoulder belt available, used with child safety seat.
Air bag:	Steering wheel mounted driver's air bag, seat back mounted side air bag. There were no air bag deployments.	NA

Age/Sex:	5 months/Male
Seated Position:	Second seat middle
Seat Type:	Split bench with folding back
Height:	61 cm (24 in)
Weight:	8 kg (18 lbs)
Occupation:	NA
Pre-existing Medical Condition:	None
Alcohol/Drug Involvement:	NA
Driving Experience:	NA
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt available, used with a child safety seat.

**OCCUPANT INJURIES -2003 GMC Yukon**

	<u>Injury</u>	<u>OIC Code</u>	<u>Source</u>	<u>Confidence Level</u>
Driver:	Concussive head injury	160820.4,0	Ground	Probable
	Subarachnoid hemorrhage	140684.3,9	Ground	Probable
	Heart contusion	441004.1,4	Ground	Probable
	Splenic laceration	544224.3,2	Ground	Probable
	Cervical spine fracture, facet	650222.3,6	Ground	Probable
	Pelvic fracture, closed	852602.2,6	Ground	Probable
	Pelvic fracture, displaced	852604.3,5	Ground	Probable
	Symphysis pubis separation	853000.3,5	Ground	Probable
	Rib fractures, right side	450222.3,1	Ground	Probable
	Femur fracture, left	851814.3,2	Ground	Probable
	Lumbar spinal fracture, transverse process	650620.2,2	Ground	Probable
	Finger dislocation	851010.1,2	Ground	Probable
	Scapula fracture	753000.2,2	Ground	Probable
	Scalp abrasion, left	190202.1,2	Ground	Probable
	Scalp contusion, left	190402.1,2	Ground	Probable
	Facial abrasion, right	290202.1,1	Ground	Probable
	Right hip/flank abrasion	890202.1,1	Ground	Probable
	Bilateral thigh abrasions	890402.1,3	Steering wheel rim	Probable
Left rear occupant:	Scalp contusion, posterior	190402.1,6	Child safety seat	Certain
	Scalp contusion, left	190402.1,2	Child safety seat	Certain
Rear middle occupant:	Scalp abrasion, right	190202.1,1	Child safety seat	Certain
	Scalp contusion, right	190402.1,1	Child safety seat	Certain

Lower extremity abrasion, right	890202.1,1	Belt restraint webbing / buckle	Certain
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## OCCUPANT KINEMATICS - 2003 GMC Yukon

The 23-year-old driver of the case vehicle was likely seated in a normal, upright fashion on the leather covered bucket seat. The seat had been adjusted to between the middle and rear most track positions. The seat back was essentially upright. The seat was equipped with a integral 3-point lap and shoulder belt that was not used during this crash. The driver's position was equipped with adjustable foot controls. The pedal was at the mid position. The driver was wearing glasses at the time of the crash. The case vehicle was traveling at approximately 121 km/h (75 mph). A non-contact vehicle moved into the lane occupied by the case vehicle. The driver of the case vehicle steered to the right and the case vehicle departed the roadway. The driver then steered back to the left and returned to the roadway. There was likely a small amount of side to side movement during these initial maneuvers. After returning to the roadway the driver again steered to the right and the vehicle began a clockwise rotation. This motion caused the driver to begin loading the left door. The vehicle departed the roadway on the right side and struck a small curb which likely caused a non-deployment event but did not radically affect the driver. The vehicle completely left the roadway and traveled down an



Figure 15. Driver ejection path



Figure 16. Contacts to the roof and header area

embankment while continuing the clockwise rotation until it was in excess of 100 degrees. As the vehicle reached the adjacent roadway it tripped and began overturning. The driver likely came out of her seat at this point, striking the bottom of the steering wheel with her thighs, and came into contact with the interior roof both on the left, middle, and right side. The vehicle continued overturning as it engaged a concrete wall that was parallel to the roadway. This was a minimal contact that did not alter the trajectory of the vehicle. The vehicle continued overturning. The driver was ejected from the vehicle through the driver's window and came to rest on the ground near a concrete culvert. Her injuries were attributed to contacts with the ground, but a number of the injuries could easily have come as a result of contacts within the vehicle during the rollover and her subsequent ejection.

The 2-year-old rear left seat occupant was seated in a Graco forward facing convertible child safety seat. According to the driver interview and seat belt evidence (load marks), the child seat was tightly anchored to the vehicle using the 3-point lap and shoulder belt. The vehicle seat belt was routed through the back of the child seat. The harness straps were routed through the top slot of the seat back at the child's shoulder level. A harness clip was present and had been placed at armpit level on the child. The space between the harness and the child's chest was estimated to be the distance of one finger. During the rollover event this occupant pitched from

side to side due to the centripetal forces. She sustained minor contusions to her scalp that were likely as a result of contact to the interior shell of the child seat. The child seat remained anchored to the vehicle throughout the rollover. Witnesses were able to removed the child and child seat from their anchored position shortly after the crash.

The 5-month-old rear middle seat occupant was seated in a rear facing Graco infant seat. This occupant was asleep prior to the crash. According to the driver interview and seat belt evidence (load marks), the child seat was tightly anchored to the vehicle using the 3-point lap and shoulder belt. The vehicle seat belt was routed across the front of the child seat. The seat was equipped with a 3-point harness. The harness straps were routed through the top slot of the seat back at the child's shoulder level. A harness clip was present and had been placed at armpit level on the child. The space between the harness and the child's chest was estimated to be the distance of one finger. During the rollover event this occupant pitched from side to side due to the centripetal forces. He sustained minor contusions to his scalp that were likely as a result of contact to the interior shell of the child seat. He also sustained abrasions to his right hip that were caused by the child seat harness. The child seat remained anchored to the vehicle throughout the rollover. Witnesses were able to removed the child and child seat from their anchored position shortly after the crash.

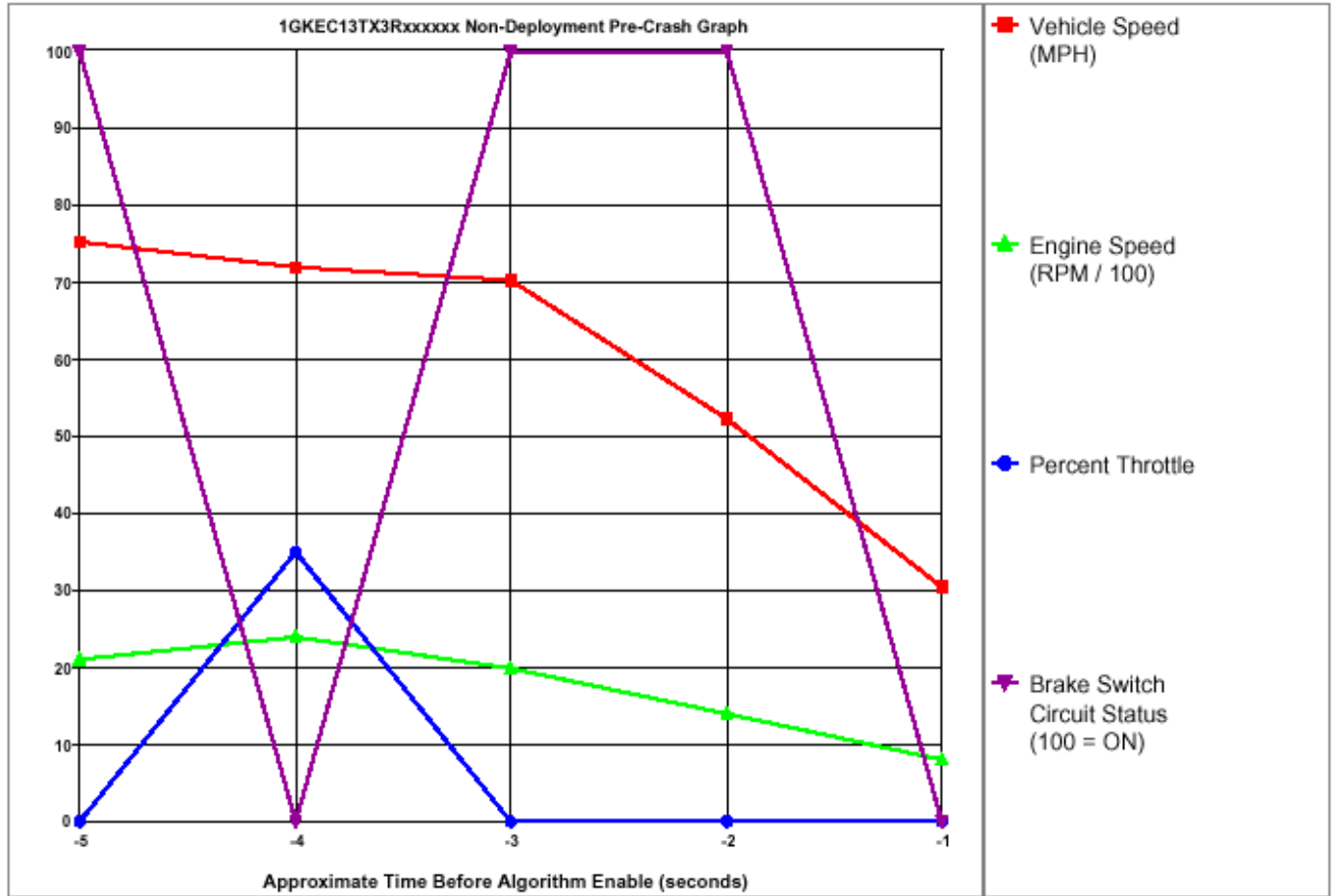
## Attachment A. Vetronix Report

**System Status At Non-Deployment**

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Ignition Cycles At Non-Deployment	941
Ignition Cycles At Investigation	945
Maximum SDM Recorded Velocity Change (MPH)	-4.31
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	170
Event Recording Complete	Yes
Multiple Events Associated With This Record	No
One Or More Associated Events Not Recorded	No

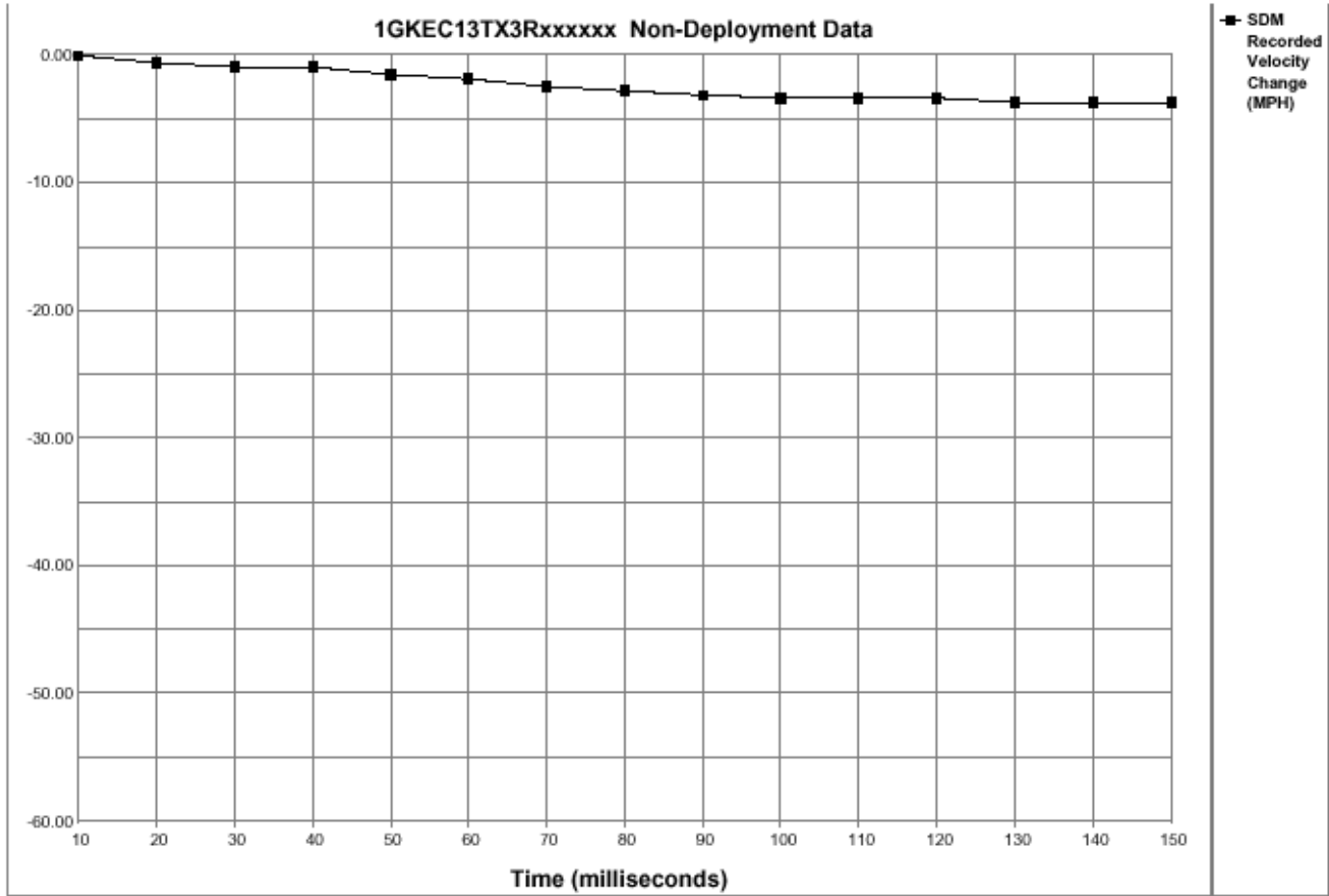
**CDR File Information**

Vehicle Identification Number	1GKEC13TX3Rxxxxxx
Investigator	
Case Number	
Investigation Date	
Crash Date	
Filename	2003-079-039J.CDR
Saved on	3/27/03 9:35:06 AM
Data check information	9CCCBAE8
Collected with CDR version	Crash Data Retrieval Tool 1.680
Collecting program verification number	337F4D2C
Reported with CDR version	Crash Data Retrieval Tool 2.10
Reporting program verification number	B6B4FDF8
Interface information	Block number: 00 Interface version: 34 Date: 09-30-02 Checksum: 6300
Event(s) recovered	Non-Deployment



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	75	2112	0	ON
-4	72	2432	35	OFF
-3	70	2048	0	ON
-2	52	1408	0	ON
-1	30	768	0	OFF





Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	0.00	-0.62	-0.93	-0.93	-1.55	-1.86	-2.48	-2.79	-3.10	-3.41	-3.41	-3.41	-3.72	-3.72	-3.72

**Attachment B. Calculations**

**CASE NUMBER: 2003-79-039J**

Comments: Calculation for first second. Calculations for additional seconds would be similar.

**\*\*DIST W/INIT & END VELOCITY & TIME \*\***

$$D = \frac{t \times (V_i + V_e)}{2}$$

$$D = \frac{1.0000 \times (109.9500 + 105.5500)}{2}$$

$$D = \frac{215.5000}{2}$$

$$D = 107.7500$$

D =The Distance in Feet.  
 V<sub>e</sub> =Ending Velocity in FPS.  
 V<sub>i</sub> =Initial Velocity in FPS.  
 2 =A Constant.  
 t=The Time in Seconds.

**INPUTS:**

The Ending Vel in FPS is:	105.5500
The Initial Vel in FPS is:	109.9500
The Time in Seconds is:	1.0000

**RESULTS:**

The Distance in Feet is:	107.7500
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