

CRASH DATA RESEARCH CENTER

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**CALSPAN REMOTE CERTIFIED ADVANCED 208-COMPLIANT
VEHICLE CRASH INVESTIGATION**

CASE NO: 2004-02-041A

VEHICLE: 2004 GMC YUKON XL

LOCATION: NEW YORK

CRASH DATE: MARCH 2004

Contract No. DTNH22-01-C-17002

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 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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<p>16. Abstract This remote investigation focused on the performance of the Certified Advanced 208-Compliant (CAC) safety system in a 2004 GMC Yukon XL. The manufacturer of this vehicle has certified that this 2004 GMC Yukon XL meets the advanced air bag requirements of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The 2004 GMC was involved in a severe head-on impact with a 1999 International 4700 single-unit straight flatbed truck that resulted in the death of a 42-year old male driver and a 14-year old rear right passenger. Both the driver and rear right passenger were unrestrained. In addition to the driver and rear right passenger, the vehicle was occupied by a 43-year old female seated in the front right position and a 7-year old male seated in the rear left position. The 7-year old child was the only restrained occupant in the vehicle. The Yukon was equipped with advanced dual-stage frontal air bags for the driver and front right passenger positions that deployed as a result of the crash. At impact, the driver initiated a forward and upward trajectory. The striking truck reinforced the intruded components as it partially overrode the Yukon. As the heavy truck overrode the Yukon, its front end partially intruded into the front left seating area through the windshield. The driver loaded the air bag, steering assembly, roof, and front left instrument panel before rebounding rearward into the center console and the seat back. The driver sustained multiple traumatic blunt force injuries, including multiple rib fractures, a major spleen laceration, bilateral lung contusions, and other lacerations to the internal organs, along with multiple bone fractures and soft-tissue injuries, which are described in detail later in this report. The driver expired at the scene. The unrestrained front right passenger loaded the right instrument panel and sustained a right distal radial fracture, a closed head injury as well as multiple soft-tissue injuries. The rear left occupant, who was reportedly restrained by a manual three-point lap and shoulder belt, sustained a fractured right clavicle. The unrestrained rear right occupant loaded the front right seat back, roof, and a roof-mounted DVD monitor. He sustained multiple traumatic blunt force injuries, including severe fractures along the frontal and basilar skull, a partial avulsion of brain tissue along the left and right frontal lobes, lacerations of the liver, spleen and right kidney, as well as multiple extremity fractures and soft-tissue injuries, which are discussed in greater detail later in this report. This passenger expired at the scene.</p>			
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**CALSPAN REMOTE CERTIFIED ADVANCED 208-COMPLIANT VEHICLE
CRASH INVESTIGATION
SCI TECHNICAL SUMMARY REPORT
NASS/SCI COMBO CASE NO: 04-02-041A
SUBJECT VEHICLE – 2004 GMC YUKON XL
LOCATION - NEW YORK
CRASH DATE – MARCH 2004**

BACKGROUND

This remote investigation focused on the performance of the Certified Advanced 208-Compliant (CAC) safety system in a 2004 GMC Yukon XL (**Figure 1**). The manufacturer of this vehicle has certified that this 2004 GMC Yukon XL meets the advanced air bag requirements of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The vehicle was equipped with an Event Data Recorder (EDR) that was downloaded during the NASS-CDS vehicle inspection. The EDR printout is included as

Attachment A of this report. The 2004 GMC was involved in a severe head-on impact with a 1999 International 4700 single-unit straight

flatbed truck that resulted in the death of a 42-year old male driver and a 14-year old rear right passenger. Both the driver and rear right passenger were unrestrained. In addition to the driver and rear right passenger, the vehicle was occupied by a 43-year old female seated in the front right position and a 7-year old male seated in the rear left position. The 7-year old child was the only restrained occupant in the vehicle. The Yukon was equipped with advanced dual-stage frontal air bags for the driver and front right passenger positions that deployed as a result of the crash. At impact, the driver initiated a forward and upward trajectory. The striking truck reinforced the intruded components as it partially overrode the Yukon. As the heavy truck overrode the Yukon, the front end partially intruded into the front left seating area of the Yukon through the windshield. The driver loaded the air bag, steering assembly, roof, and front left instrument panel before rebounding rearward into the center console and the seat back. The driver sustained multiple traumatic blunt force injuries, including multiple rib fractures, a major spleen laceration, bilateral lung contusions, and other lacerations to the internal organs, along with multiple bone fractures and soft-tissue injuries, which are described in detail later in this report. The driver expired at the scene. The unrestrained front right passenger loaded the right instrument panel and sustained a right distal radial fracture, a closed head injury as well as multiple soft-tissue injuries. The rear left occupant, who was reportedly restrained by a manual three-point lap and shoulder belt, sustained a fractured right clavicle. The unrestrained rear right occupant loaded the front right seat back, roof, and a roof-mounted DVD monitor. He sustained multiple traumatic blunt force injuries, including severe fractures along the frontal and basilar skull, a partial



Figure 1 - Subject vehicle 2004 GMC Yukon XL.

avulsion of brain tissue along the left and right frontal lobes, lacerations of the liver, spleen and right kidney, as well as multiple extremity fractures and soft-tissue injuries, which are discussed in greater detail later in this report. This passenger expired at the scene.

The crash was identified by PSU 02 of the National Automotive Sampling System (NASS) during its weekly sampling of police reported crashes. The case was subsequently selected for inclusion in the 2004 NASS CDS data file and assigned case number 2004-02-041A. The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) assigned a remote combined investigation of this crash to the Special Crash Investigations team at Calspan Corporation as part of the CAC-208 safety systems study.

SUMMARY

Crash Site

The crash occurred on a two-lane, east/west roadway (**Figure 2**) in a sparsely populated residential area during daylight hours. The roadway was surfaced with asphalt and was delineated with a broken yellow centerline and white edge lines. The travel lanes were 3.5 m (11.5') in width and were bordered by paved shoulders of which the north shoulder was 2.0 m (6.6') in width and south shoulder was 2.4 m (7.9'). The environment alongside the roadway consisted of natural growth and sporadic dwellings protected by one guardrail on the south roadside approximately 1 m (3.3') outboard the roadway. At the time of the crash, the road



Figure 2 - Overall view of the east/west roadway.

surface was dry and there were no adverse atmospheric conditions present. The Yukon was traveling in a westerly direction on a straight and level roadway and the straight truck was traveling eastbound on the same roadway. An uninvolved vehicle was traveling westbound in front of the Yukon prior to the crash. The speed limit was posted at 89 km/h (55 mph). The Crash Site Schematic is included as **Figure 14** at the end of this narrative report.

Vehicle Data – 2004 GMC Yukon XL

The subject vehicle in this two-vehicle crash was a 2004 GMC Yukon XL, 4-door sport utility vehicle. The Yukon was manufactured in 12/03 and was identified by Vehicle Identification Number (VIN) 1GKFK66U54J (production number omitted). The vehicle was a body-on-frame design powered by a conventionally mounted 6.0-liter gasoline engine linked to a four-speed automatic transmission with a console-mounted shifter. The Yukon was equipped with four-wheel drive, four-wheel disc brakes with anti-lock (ABS), power assisted steering, a direct tire pressure monitoring system (TPMS) and an Electronic Stability Control (ESC) system. The ESC feature detects and helps correct lateral traction loss while cornering by automatically reducing the throttle and applying

the brakes in response to traction loss. The vehicle was also equipped with OEM 6-spoke alloy wheels with Goodyear HP P265/70R17 tires with a manufacturer specified pressure of 221 kPa (32 PSI). The specific tire data at the time of the SCI vehicle inspection is identified in the following table:

Position	Measured Tire Pressure	Measured Tread Depth	Damage
Left Front	Unknown	Unknown	Wheel Missing
Right Front	0 kPa	9 mm (11/32")	None
Left Rear	255 kPa (37.0 PSI)	9 mm (11/32")	None
Right Rear	255 kPa (37.0 PSI)	9 mm (11/32")	None

The interior of the Yukon was configured with front bucket seats with reclining seat backs and adjustable head restraints, which were in the full down position. The front right seat back was loaded by the rear right passenger and deformed forward and to the right side of the vehicle. A full-length center console was present with a center armrest and rear storage compartment.

The second and third rows were equipped with three asymmetrical split bench seats with folding backs and adjustable head restraints in all three seating positions. The head restraints were in the full down position at the time of the inspection. The second and third rows were equipped with folding seats to allow more cargo storage room.

The seating interior surfaces were leather. The driver and passenger's seat was an electrically adjustable seat with height, lumbar, and tilt adjustment. The Yukon was equipped with power windows, power locks, and power adjusted exterior rear view mirrors. The interior rear view mirror was mounted to the windshield. The vehicle was also equipped with an aftermarket audio and video system. The viewing screen for the system was mounted to the roof above the driver's head, which was configured to allow the driver to view the screen along with other passengers. The system's DVD player was mounted on the roof's midline between the first and second seat rows and protruded vertically approximately 15 cm (6") into the passenger compartment.

Vehicle Data - 1999 International 4700 Single-Unit Straight Truck

The International 4700 series, Class VI, 4 x 2 flatbed truck was identified by the VIN on the police report: 1HTSCAAM4XH (production sequence omitted). The vehicle was not inspected, but the team did acquire images from the police jurisdiction (**Figure 3**). The truck was configured with a conventional cab, high entry, and was designed with the cab behind the engine. The vehicle was used as a flatbed tow truck, but was not transporting any vehicles at the time of the crash.



Figure 3 - 1999 International 4700 series truck.

The truck sustained severe front-end damage as a result of the impact with the Yukon and was towed from the scene. The majority of the cab components were fractured and placed on the flatbed prior to removing the vehicle from the scene.

Crash Sequence

Pre-Crash

The 42-year old driver of the GMC Yukon was traveling in a westerly direction on the two-lane roadway (**Figure 4**) behind another unrelated vehicle. The 4700 Series truck was traveling in an easterly direction on the same roadway. The Yukon was equipped with an Event Data Recorder (EDR) that was downloaded during the NASS-CDS investigation. The EDR recorded five seconds of pre-crash data. Based on the output, the vehicle's speed was recorded at 95 km/h (58 mph) at the five-second interval prior to the crash with five percent throttle application and no braking. The vehicle maintained a 5 percent throttle application as he was passing the unrelated vehicle and then steered left onto the southbound shoulder to avoid the oncoming truck. The scene inspection revealed no physical evidence of pre-crash braking by either vehicle.



Figure 4 - Yukon's westbound trajectory.

The Yukon attempted to pass the unrelated vehicle, and upon realization that the straight truck occupied the oncoming eastbound lane, the driver steered left onto the southbound shoulder in an attempt to avoid the impact. In an attempt to avoid striking the Yukon, the driver of the truck steered right onto the southbound shoulder. The EDR recorded a decrease in the Yukon's speed from the 95 km/h (58 mph) speed at the five-second interval to 86 km/h (55 mph) at the one-second pre-crash interval. The driver did not apply the brakes and the vehicle maintained a five percent throttle throughout the five-second interval prior to the crash.

Crash

The entire front end of the Yukon impacted the front and undercarriage of the straight truck on the southbound shoulder of the roadway (**Figure 5**). The direction of force was 1 o'clock for the Yukon and 12 o'clock for the truck. The impact to the Yukon encompassed the entire front end. The area of maximum crush at the bumper level was at the front left corner with a depth of 133.0 cm (52.4"). During the impact, the truck overrode the Yukon's front end and contacted the Yukon's windshield, header, and left A-pillar partially intruding into the passenger compartment prior to disengaging. The barrier-only algorithm of the



Figure 5 - Point of impact.

WinSMASH program computed a total longitudinal velocity change of -63.0 km/h (-39.1 mph). The EDR recorded a maximum longitudinal velocity change of -73 km/h (-45.6 mph). The EDR recorded a second deployment level event as a result of the override of the heavy truck. The deployment level event occurred 0.2 seconds after the first event and recorded a longitudinal velocity change of -19 km/h (-12.0 mph). The crash deployed the frontal air bags for the driver and front right passenger positions.

Following the impact, the Yukon was pushed backward several feet and came to final rest over the centerline facing in a southwesterly direction. The truck departed the right roadside and came to rest approximately 6.1 m (20.0') from the south road edge in a grassy area and was facing in a southeasterly direction.

Post-Crash

Immediately following the crash, witnesses called 911 for assistance. Due to the severe damage to the Yukon, rescue crews extricated all four occupants from the vehicle by removing the left side doors, and prying the front right door and tailgate open. The driver and rear right passenger were unresponsive. The rescue crew pried the front right door open allowing the passenger to exit. The occupant was reportedly incoherent; she exited the vehicle and ran from the crash site before being recovered by emergency personnel. The rear left passenger was removed through the rear left door. The family dog was seated in the third row prior to the crash. At impact, it apparently was displaced into the front right seating area and was removed from the vehicle along with the other occupants. The police did not determine the belt use status for any of the occupants.

The driver and the 14-year old seated in the rear right seat expired at the scene. The 43-year old female seated in the front right position was transported to a local hospital following the crash and was then transferred to a trauma center and admitted for one day for a closed head injury and fractured right wrist. The 7-year old male seated in the rear left position was transported to a trauma center and admitted for one day with a right clavicle fracture. A local veterinarian treated the family dog.

Vehicle Damage – 2004 GMC Yukon XL

Exterior

The 2004 GMC Yukon XL sustained severe damage as a result of the impact with the 1999 International 4700 Series flatbed truck (**Figure 6**). The NASS-CDS investigation reported the maximum crush at the bumper level to be 133 cm (52.3”), located at the front left corner. The direct contact damage was reported to extend from the left bumper corner to the right bumper corner, which measured 170 cm. (66.9”). The Field L measurement was also 170 cm (66.9”). The crush profile measured at the level of the bumper beam was as follows: C1 = 133 cm (52.3”), C2 = 89 cm (35.0”), C3 = 78 cm (30.7”), C4 = 74 cm (29.1”),



Figure 6 - Frontal damage to the 2004 GMC Yukon XL.

C5 = 69 cm (27.2”), C6 = 81 cm (31.9”). The Collision Deformation Classification (CDC) for this impact was incremented to include the lateral left end shift and was an SCI revised 81-FDEW-5.

After the initial impact, the straight truck partially overrode the front end of the Yukon and the truck’s front bumper contacted the windshield, the header, and the front left A-pillar before intruding into the passenger compartment. The roof was crushed vertically along the windshield header roughly 30 cm (11.8”). The vertical roof crush resulted from interaction between it and the undercarriage of the striking truck before they disengaged.

The front left, front right, and rear left doors jammed shut as a result of the crash. The rear right door and tailgate remained closed and operational. The jammed doors were opened with extrication equipment by the rescue teams. The windshield was 100 percent fractured by deformation patterns and direct contact with the striking truck. There was minor bond separation along the base of the windshield near the left A-pillar. Integrity loss occurred through the front left, rear left, and third row left side glazing.

Interior

The interior of the subject Yukon sustained severe damage that was associated with exterior deformation, passenger compartment intrusion, and occupant contact. The area of greatest intrusion occurred in the driver’s seating position (**Figure 7**); the steering assembly intruded 60 cm (23.6”) laterally, 45 cm (17.7”) vertically, and 15 – 30 cm (6 – 12”) longitudinally. The steering assembly rotated upward and to the right as the cowl of the vehicle intruded rearward. The driver loaded the steering assembly and the deploying air bag during the impact and traveled upward into the roof as the crush intruded into the Yukon. The steering assembly was found in the second seat at the time of the NASS inspection. The rescue personnel likely separated it from the column. The driver rebounded into the left seat and deformed the seat back and center console. The SCI revised intrusions initially identified during the NASS-CDS inspection are listed by their magnitude in the following table:

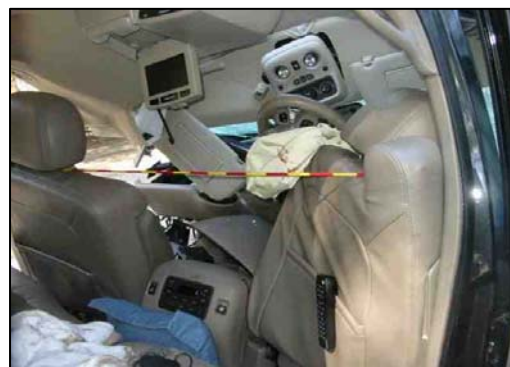


Figure 7 - Frontal view of interior - intrusion and front right seat back.

Position	Component	Magnitude	Direction
Front Left	Steering assembly	60 cm (23.6”)	Lateral
Front Left	Windshield	54 cm (21.3”)	Vertical
Front Left	Steering assembly	45 cm (17.7”)	Vertical
Front Left	Windshield Header	34 cm (13.4”)	Longitudinal
Front Left	Instrument panel left	32 cm (12.6”)	Longitudinal
Front Left	Roof	30 cm (11.8”)	Vertical
Front Left	Steering Assembly	15 – 30 cm (6 - 12”)	Longitudinal
Front Left	Toe pan	18 cm (7.1”)	Longitudinal

Position	Component	Magnitude	Direction
Front Left	Exterior of striking vehicle	8 – 15 cm (3 - 6")	Longitudinal
Front Left	Door panel	3 – 8 cm (1 - 3")	Lateral
Front Left	Kick panel	3 – 8 cm (1 - 3")	Lateral
Front Center	Windshield	49 cm (19.3")	Vertical
Front Center	Windshield header	30 cm (11.8")	Vertical
Front Right	Front seat back	35 cm (13.8")	Lateral
Front Right	Roof	8 – 15 cm (3 - 6")	Vertical
Front Right	Windshield header	8 – 15 cm (3 – 6")	Vertical
Third Row Center	Seat back	9 cm (3.5")	Longitudinal
Third Row Center	Seat back	7 cm (2.8")	Longitudinal

The NASS-CDS vehicle inspection reported occupant contact of the unrestrained driver into the roof, left instrument panel, sun visor, and driver’s air bag during the initial crash sequence, and contact to the seat back and center console as the driver rebounded rearward. Evidence supporting the NASS-CDS contact points included strands of hair embedded into the roof liner and on the seat back after rebounding as well as accompanying scuffmarks and fractures of the contacted panels. Based on general kinematics, it is possible that the driver also contacted the windshield, the header, and an undetermined area of the striking truck prior to rebounding into the left front seat.

The NASS team reported that the unrestrained front right passenger appeared to have initiated a forward and slight trajectory to the right as she loaded the knee bolster, right door panel, and air bag, evidenced by scuffmarks on each component. During the impact, the rear right passenger contacted and loaded and severely deformed the front right seat back, which facilitated the front right passenger in her forward-right trajectory. The front right seat was laterally compressed 17 cm (6.7") to 43 cm (16.9") in width from its original condition of approximately 60 cm (23.6"). The head restraint in this seating position was pushed into the right B-pillar during the crash. It is likely that the front right passenger’s head struck the B-pillar during the rebound following maximum engagement.

The rear-left passenger was restrained by the 3-point lap and shoulder belt. The inspection revealed deep scuffmarks on the lower aspect of the driver’s seat back, indicative of some level of occupant contact. The NASS team reported scuffing on the interior of the manual lap belt, which was attributed to interaction between the rear left occupant’s abdominal region and the lap belt.



Figure 8 - DVD player protruding from the roof.

The unrestrained rear right occupant was straddling the rear center and rear right seating positions. At impact, this occupant initiated a forward and upward trajectory and loaded the front right seat back and the CD player

protruding from the roof (**Figure 8**). The front right seat back was deformed forward and to the right approximately 15 – 20 cm (6 - 8”). Direct contact to the seat back was limited to the left half evidenced by deep gouging and scuff patterns. After disengaging from the seat back, the rear right occupant rebounded into the middle-left of the second row evidenced by heavy blood and tissue transfers near the seat bight at that location. The kinematics surrounding all four occupants is discussed in greater detail in the Occupant Kinematics section of this report.

The third row consisted of a split bench seat with folding backs. The seat was deformed by an undetermined type of cargo that was stowed in the area behind the seat. The cargo loaded the lower middle portion of the third row seating area and deformed the seat to a gradual “U” shape. The family dog was in the third row of the vehicle. At impact, the dog was displaced forward and over the second row seats and, according to police, into the front right seating area where it was recovered.

Manual Safety Belt Systems

The GMC Yukon XL was equipped with 3-point continuous loop safety belt systems for the front-seated positions. Both belt systems were equipped with sliding latch plates and were retracted into the outboard top aspects of the seat backs. The driver’s side was equipped with an Emergency Locking Retractor (ELR) while the front right position was equipped with a switchable ELR/Automatic Locking Retractor (ALR). Both retractors incorporated the belt sensitive feature, which locked the retractor during rapid spool-out of the webbing.

Neither front row occupant was believed to have used their safety belt. Neither belt displayed the wear patterns commonly associated with an impact of this severity. The front row latch plates did not yield evidence of loading and the plastic pivot point at the top aspect of the seat back failed to show frictional abrasions consistent with belt usage. Both belts were spooled completely into their housing and no rippling of the webbing was present.

The rear outboard seating positions were equipped with continuous loop 3-point lap and shoulder belt systems affixed to the respective C-pillars. The buckle assemblies were anchored to the seat cushions. Both outboard rear seat belt systems were equipped with sliding latch plates, fixed D-rings, and switchable ELR/ALR retractors. The center rear position was equipped with an integrated belt system built into the left seat back of the 60/40 split bench seat.



Figure 9 - Scuffmark on rear left safety belt.

The rear left passenger was reportedly restrained by the 3-point lap and shoulder belt system. Belt usage was supported by a scuff pattern on the lap belt webbing (**Figure 9**). The rear right occupant did not wear the safety belt system at the time of the crash. The lack of belt usage was supported by his trajectory

and subsequent contact points to the front right seat back and roof-mounted aftermarket DVD player. The safety belt did not yield evidence of loading. The rear center seat was not occupied at the time of the crash.

The third row outboard seating positions were equipped with continuous loop 3-point lap and shoulder belt systems affixed to the respective D-pillars. The buckle assemblies were anchored to the seat cushions. Both outboard third row seat belt systems were equipped with sliding latch plates, fixed D-rings, and switchable ELR/ALR retractors. The third row center position was equipped with an integrated belt system built into the left seat back of the 60/40 split bench seat.

Certified Advanced 208-Compliant Safety System

The 2004 GMC Yukon XL was equipped with a Certified Advanced 208-Compliant safety system. The manufacturer of this vehicle has certified that this 2004 GMC Yukon XL meets the advanced air bag requirements of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The safety system contains dual-stage frontal air bags for the driver and front right positions, occupant sensing for the front right position, and safety belt buckle switch sensors. A Stage-2 deployment occurred as both air bags inflated as a result of the frontal impact with the straight truck.



Figure 10 - Driver's frontal air bag.

The driver's air bag deployed through symmetrical I-configuration module cover flaps. Each flap was 7 cm (2.8") in width and 12 cm (4.7") in length. The cover flaps opened at the designated tear points. The driver's air bag measured 60 cm (23.6") in diameter in its deflated state (**Figure 10**) and contained two internal tether straps. Two ports located at the 11 and 1 o'clock sectors vented the bag. The steering assembly was found in the second seat at the time of the NASS inspection. The rescue personnel likely separated it from the column.

A faint blood transfer was present on the backside of the bag and measured approximately 1 cm (0.4") and was located 5 cm (2.0") inboard of the bag's peripheral seam. The backside of the bag also had several small tears as a result of contact with the windshield.

The front right air bag deployed from a mid-mount module cover flap that measured 38 cm (15.0") in width and 15 cm (5.9") in length. The cover flap was a single ply molded vinyl flap that was hinged at the top surface, which allowed the flap to open in an upward direction.



Figure 11 - Right front passenger air bag.

The deployed front right air bag (**Figure 11**) measured 54 cm (21.3”) in width and 50 cm (20.0”) in length. The bag was vented by two ports located at the lateral aspects of the bag in the 3 and 9 o’clock positions. The bag was not tethered. The front right seat was occupied; as such, the sensor in the seat reported this condition to the EDR and the EDR properly deployed the air bag at a stage 2 level. Both front row seats were equipped with side air bags located in their respective seat back. The side air bags did not deploy during the crash sequence.

Event Data Recorder

The Yukon’s EDR was downloaded during the NASS inspection of the vehicle. The EDR was downloaded using the Vetronix Crash Data Retrieval Tool with software version 2.24 and was reported using software version 2.70. The download was accomplished by connecting the CDR tool directly to the Sensing and Diagnostic Module (SDM) located under the front left seat. The SDM recorded both a Deployment and Deployment Level event 0.2 seconds apart.

The EDR System Status at Deployment provided the following:

The driver and passenger’s Safety Belt Switch Circuit Status was listed as Unbuckled. The maximum SDM recorded velocity change was –73 km/h (-45.61 mph) at 110 msec of Algorithm Enable (AE). The driver and passenger frontal air bags met First and Second Stage deployment commands at 10 msec of AE.

The EDR System Status at Deployment Level provided the following:

The driver and passenger’s Safety Belt Switch Circuit Status was listed as Unbuckled. The maximum SDM recorded velocity change was 19 km/h (12.99 mph) at 107.5 msec of AE. The driver and passenger frontal air bags met First and Second stage deployment commands at 17.5 msec of AE.

The EDR output is included as **Attachment A** of this narrative report.

Occupant Demographics

Driver

Age/Sex: 42-year old/Male
Height: 178 cm (70.1”)
Weight: 100 kg (220 lbs)
Seat Track Position: Full rear
Safety Belt Usage: None used
Usage Source: NASS vehicle inspection/EDR output
Egress from Vehicle: Removed by rescue personnel
Mode of Transport: Expired at scene – transported to hospital morgue
Type of Treatment: None

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Major spleen laceration	Severe (544226.4,1)	Steering assembly
Rib cage fractures – bilateral (3 ribs on each side)	Severe (450232.4,3)	Steering assembly
Bilateral lung contusions	Severe (441410.4,3)	Steering assembly
Left femur fracture	Serious (851800.3,1)	Knee bolster – Not direct
Sternum fracture	Moderate (450804.2,4)	Steering assembly
Multiple liver lacerations extending down right lobe (NFS)	Moderate (541820.2,2)	Steering assembly
Cervical spine fracture (C3)	Moderate (650216.2,6)	Roof
Thoracic spine fracture NFS	Moderate (650416.2,7)	Steering assembly
Left wrist fracture NFS	Moderate (751800.2,1)	Left instrument panel
Left upper arm fracture	Moderate (751800.2,1)	Left instrument panel
Right adrenal gland laceration (NFS)	Minor (540220.1,2)	Steering assembly
Forehead abrasion	Minor (290202.1,7)	Roof
Right eyebrow laceration	Minor (290602.1,7)	Roof
Right eyelid abrasion	Minor (297202.1,2)	Sun visor
Right nostril abrasion	Minor (290202.1,4)	Air bag
Left lower cheek abrasions	Minor (290202.1,1)	Air bag
Right upper lip contusion	Minor (290402.1,8)	Steering assembly
Chin laceration (3 cm)	Minor (290602.1,8)	Steering assembly
Scalp abrasion	Minor (190202.1,9)	Roof
Scalp contusion	Minor (190402.1,9)	Roof
Left chest abrasion	Minor (490202.1,1)	Steering Assembly
Abdomen abrasion	Minor (590202.1,2)	Steering assembly
Abrasions to left upper arm	Minor (790202.1,1)	Left instrument panel
Left antecubital laceration (4 cm in depth)	Minor (790602.1,1)	Left instrument panel
Right upper arm contusion	Minor (790402.1,2)	Center console
Right forearm abrasion	Minor (790202.1,2)	Center console
Left knee abrasion	Minor (890202.1,1)	Knee bolster

Source: Autopsy

Driver Kinematics

The 42-year-old male driver of the 2004 GMC Yukon XL was seated in a full rear track position and was unrestrained. At impact, the frontal air bag system deployed. The driver responded to the 1 o'clock direction of force by initiating a forward and slightly right trajectory. The unrestrained driver loaded through the air bag and into the steering wheel rim, hub and spokes; as he was engaging these components, the steering



Figure 12 - Steering wheel hub and spoke.

assembly intruded vertically and laterally due to severe rearward displacement of the engine components through the cow. The driver's loading deformed the wheel rim and spokes in all quadrants (**Figure 12**). Due to the contact with the steering assembly, the driver sustained a major spleen laceration, six fractured ribs (bilateral fractures of three unspecified ribs on each side of the cage), bilateral lung contusions, a sternum fracture, multiple liver lacerations extending down the right lobe, a thoracic spine fracture, a right adrenal gland laceration, and multiple soft-tissue injuries to the face and chest.

The upward movement of the steering column allowed the driver to be displaced vertically into the roof. This was evidenced by severe component deformation and accompanying scuffmarks. The resultant contact with the roof caused multiple scalp and forehead abrasions and a laceration to the right eyebrow. His head pocketed into the roof and as his body continued forward and upward, his neck hyper-extend resulting in a C3 fracture of the cervical spine.

As the vehicle continued to crush, the left instrument panel and knee bolster subsequently intruded into the passenger compartment. The driver's left arm contacted the intruded instrument panel causing the left wrist fracture, an upper left arm fracture, a four-inch laceration to the left antecubital, and several abrasions to the upper left arm. The driver's left knee loaded the bolster resulting in a left knee skin abrasion. The loading force transmitted into the upper leg resulting in a fracture of the femur.

After striking the roof, the driver rebounded into the center console and sustained a right upper arm contusion and a right forearm abrasion. The center console was displaced to the right and, according to the NASS investigation, contained scuffmarks consistent with occupant contact.

The driver was removed from the vehicle by rescue personnel and was pronounced dead at the scene. His body was transported to the regional morgue for autopsy.

Front Right Passenger

Age/Sex: 43-year old/Female
Height: 157 cm (61.8")
Weight: 72 kg (159 lbs)
Seat Track Position: Full rear
Safety Belt Usage: None used
Usage Source: NASS vehicle inspection / EDR output
Egress from Vehicle: Removed by rescue personnel
Mode of Transport: Helicopter to a regional trauma center
Type of Treatment: Admitted for injuries for one day

Front Right Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Right radius fracture	Moderate (752802.2,2)	Right door panel
Closed head injury, LOC NFS	Moderate (160406.2,0)	B-pillar
Bilateral contusions on clavicles	Minor (790202.1,3)	Air bag
Right wrist contusion	Minor (790402.1,2)	Right door panel
Left elbow contusion	Minor (790402.1,1)	Seat back
Bilateral knee abrasions	Minor (890202.1,3)	Knee bolster
Anterior neck contusion*	Minor (390402.1,5)	Air bag
Bilateral knee contusions*	Minor (890402.1,3)	Knee bolster
Right knee abrasion*	Minor (890202.1,2)	Right door panel

*Source: Medical records and interview. * Denotes interview as source*

Front Right Passenger Kinematics

The 43-year-old female was seated in the front right position of the 2004 GMC Yukon XL and was unrestrained. At impact, the CAC frontal air bag system deployed. The front right passenger initiated a forward and slightly right trajectory responding to the 1 o'clock direction of force. She loaded the deployed front right air bag resulting in bilateral contusions to the clavicle and a contusion of the neck. The front right air bag protected the passenger from contact against the front right instrument panel.

The front right passenger also engaged the right door panel and knee bolster, evidenced by scuffmarks on these components. She sustained a right radius fracture, a right wrist contusion, and an abrasion to the right knee as a result of contacting the door panel. Contact to the knee bolster resulted in bilateral knee abrasions and contusions. She lost consciousness during the crash, most likely after striking the B-pillar with her head after rebounding from her forward trajectory.

Rescue personnel removed the front right passenger from the vehicle. She immediately ran down the roadway incoherently before being recovered by the first responders. She was initially transported to a local hospital by ambulance. After being triaged, she was transferred to a trauma center by helicopter due to her head injury. She was admitted to the trauma center for one day and then released.

Rear Left Passenger

Age/Sex: 7-year old/Male
Height: 122 cm (48.0")
Weight: 24 kg (53 lbs)
Seat Track Position: Non adjustable seat track
Safety Belt Usage: Lap and shoulder belt
Usage Source: NASS vehicle inspection
Egress from Vehicle: Removed by rescue personnel
Mode of Transport: Helicopter to a regional trauma center
Type of Treatment: Admitted for injuries for one day

Rear Left Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Right clavicle fracture	Moderate (752200.2,2)	Rear right occupant on rebound
Right upper arm contusions	Minor (790402.1,2)	Rear right occupant on rebound

Injury source: Medical records.

Rear Left Passenger Kinematics

The 7-year-old rear left male passenger of the 2004 GMC Yukon XL was seated in a presumed upright posture. He was restrained by the manual 3-point lap and shoulder belt system, which was evidenced by minor loading on the lap portion of the safety belt webbing. The hospital also noted that this occupant had a lap belt signature mark across his abdomen; however, the facility did not designate any specific injury to the abdomen.

At impact, the rear left passenger initiated a forward and slightly right trajectory as a result of the 1 o'clock direction of force. He loaded the manual safety belt system, which restricted his movement and prevented him from contact with the front right seat back. His feet struck the back of the front seat backs, evidenced by two noticeable scuffmarks present on the lower aspect of the seat back. No lower extremity injury was reported for this event. This passenger sustained a right clavicle fracture and multiple upper arm contusions. The SCI revised injury source to this passenger was the unbelted rear right occupant rebounding from the original crash forces into the rear left seating position.

This passenger was removed from the vehicle and transported to a regional trauma center via helicopter. He was admitted for one day and then released.

Rear Right Passenger

Age/Sex: 14-year old/Male
Height: 160 cm (63.0")
Weight: 45 kg (99 lbs)
Seat Track Position: Non-adjustable seat track
Safety Belt Usage: None used
Usage Source: NASS vehicle inspection/injury pattern

Egress from Vehicle: Removed by rescue personnel
 Mode of Transport: Expired at scene, transported to hospital morgue
 Type of Treatment: None

Rear Right Passenger Kinematics

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Heart (myocardium) laceration perforation	Severe (441012.5,4)	Right front seat back
Liver laceration complex (OIS Grade V)	Severe (541828.5,1)	Right front seat back
Interior basilar skull fracture, NFS	Severe (150206.4,8)	Roof mounted DVD player
Vault skull fracture	Severe (150406.4,5)	Roof mounted DVD player
Left and right cerebrum lacerations with partial brain tissue avulsion	Severe (140690.5,3)	Roof mounted DVD player
Bilateral lung contusions	Severe (441410.4,3)	Right front seat back
Left cerebrum subarachnoid hemorrhage	Serious (140684.3,1)	Roof mounted DVD player
Right cerebrum subarachnoid hemorrhage	Serious (140684.3,2)	Roof mounted DVD player
Pituitary gland laceration	Serious (140799.3,8)	Roof mounted DVD player
Rib fracture left side	Serious (450214.3,1)	Right front seat back
Left orbit fracture, NFS	Moderate (251200.2,1)	Roof mounted DVD player
Right orbit fracture, NFS	Moderate (251200.2,2)	Roof mounted DVD player
Nose fracture, open	Moderate (251004.2,4)	Roof mounted DVD player
Maxilla fracture, NFS	Moderate (250802.2,9)	Roof mounted DVD player
Mandible fracture, NFS	Moderate (250600.1,9)	Roof mounted DVD player
Spleen laceration minor	Moderate (544222.2,1)	Right front seat back
Kidney laceration, NFS	Moderate (541620.2,2)	Right front seat back
Chest abrasion	Minor (490202.1,4)	Right front seat back
Heart (myocardium) contusion	Minor (441002.1,4)	Right front seat back
Abrasion to left side of back	Minor (690202.1,2)	Rear left occupant on rebound
Right upper arm abrasion	Minor (790202.1,2)	Right front seat back
Right forearm and hand contusion	Minor (790402.1,2)	Right front seat back
Left knee contusion	Minor (890402.1,1)	Center console
Abrasion to lower left leg	Minor (890202.1,1)	Center console

Injury source: Medical records.

Rear Right Passenger Kinematics

The 14-year-old rear right passenger of the 2004 GMC Yukon XL was unrestrained and was straddling the rear center and rear left seating positions. At impact, the rear right passenger initiated a forward and slightly right trajectory as a result of the 1 o'clock direction of force. This passenger loaded the front right seat back with his torso and struck his head on the roof-mounted aftermarket DVD player that protruded vertically approximately 15 cm (6") into the passenger compartment.

The NASS team identified a contact point on the DVD player, supported by heavy tissue and blood transfer on the unit. As a result of this contact, the occupant sustained interior basilar skull fracture, a vault skull fracture, left and right cerebrum lacerations with partial tissue avulsions, left and right subarachnoid hemorrhage, a pituitary gland laceration, and fractures to the maxilla, mandible, nose, and left and right eye orbits. The front right seat (**Figure 13**) was compressed left to right



Figure 13 - Steering assembly and compressed front right seat.

laterally and also forward. Direct contact to the seat back was limited to the left half evidenced by deep gouging and scuff patterns. Resultant injuries from loading the seat back include a myocardium laceration perforation and contusion, a Grade V complex liver laceration, bilateral lung contusions, lacerations to the spleen and kidney, a rib fracture, and multiple soft-tissue injuries to the chest and right upper extremity. As this occupant was loading the seat back, his left leg contacted the center console and he sustained a left knee contusion and an abrasion to his lower left leg.

After disengaging from the seat back and DVD player, the rear left occupant rebounded into the middle and rear left of the second row. This was supported by heavy blood and tissue transfers near the seat bight at that location. As this occupant rebounded, he contacted the restrained rear left passenger, causing an abrasion to this occupant's back and multiple right arm injuries to the rear left passenger.

The rear right occupant expired at the crash site. Rescue personnel removed his body from the vehicle and transported it for autopsy.

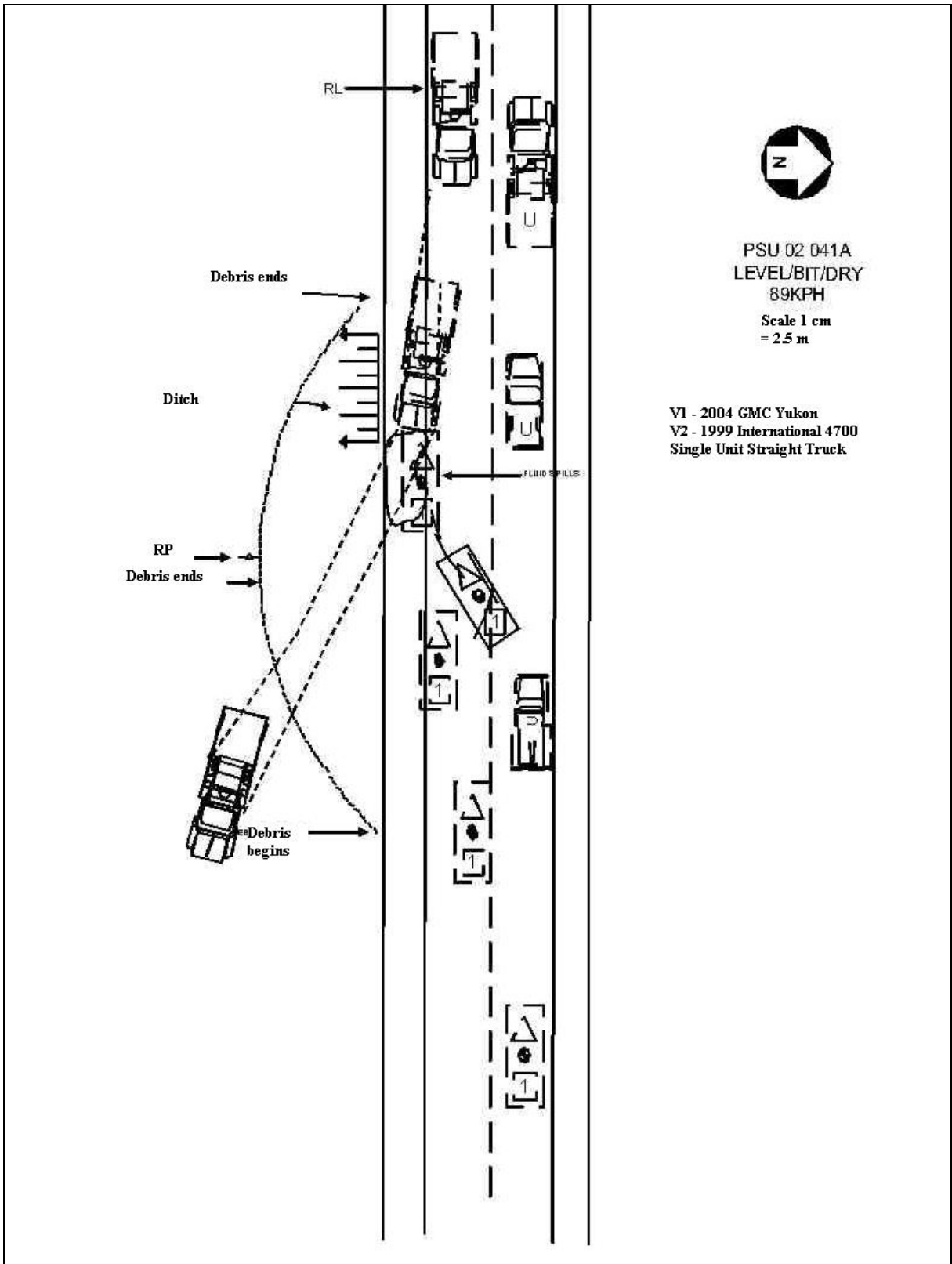


Figure 14 – NASS Scene Schematic

Attachment A: 2004 GMC Yukon XL EDR Printout

CDR File Information

Vehicle Identification Number	1GKFK66U54Jxxxxxx
Investigator	
Case Number	041A
Investigation Date	
Crash Date	
Filename	WITHOUTVIN.CDR
Saved on	Wednesday, April 7 2004 at 03:31:50 PM
Data check information	5B46C55A
Collected with CDR version	Crash Data Retrieval Tool 2.24
Collecting program verification number	70CD83DD
Reported with CDR version	Crash Data Retrieval Tool 2.70
Reporting program verification number	70812808
Interface used to collected data	Block number: 00 Interface version: 39 Date: 10-09-03 Checksum: 0300
Event(s) recovered	Deployment Deployment Level

SDM Data Limitations

SDM Recorded Crash Events:

There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded vehicle forward velocity change. This event will be cleared by the SDM after the ignition has been cycled 250 times. The second type of SDM recorded crash event is the Deployment Event. It also contains Pre-Crash and Crash data. The SDM can store up to two different Deployment Events, if they occur within five seconds of one another. Deployment events cannot be overwritten or cleared from the SDM. Once the SDM has deployed the air bag, the SDM must be replaced. The data in the non-deployment file will be locked after a deployment, if the non-deployment occurred within 5 seconds before the deployment or a deployment level event occurs within 5 seconds after the deployment.

SDM Data Limitations:

- SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. SDM Recorded Vehicle Forward Velocity Change is the change in velocity during the recording time and is not the speed the vehicle was traveling before the event, and is also not the Barrier Equivalent Velocity. This data should be examined in conjunction with other available physical evidence from the vehicle and scene when assessing occupant or vehicle forward velocity change. For deployments and deployment level events, the SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. For non-deployments, the SDM will record the first 150 milliseconds of data after algorithm enable.
- Event Recording Complete will indicate if data from the recorded event has been fully written to the SDM memory or if it has been interrupted and not fully written.
- SDM Recorded Vehicle Speed accuracy can be affected if the vehicle has had the tire size or the final drive axle ratio changed from the factory build specifications.
- Brake Switch Circuit Status indicates the status of the brake switch circuit.
- Pre-Crash Electronic Data Validity Check Status indicates "Data Invalid" if the SDM does not receive a valid message.
- Driver's Belt Switch Circuit Status indicates the status of the driver's seat belt switch circuit
- The Time Between Non-Deployment and Deployment Events is displayed in seconds. If the time between the two events is greater than 25.4 seconds, "N/A" is displayed in place of the time.
- If power to the SDM is lost during a crash event, all or part of the crash record may not be recorded.

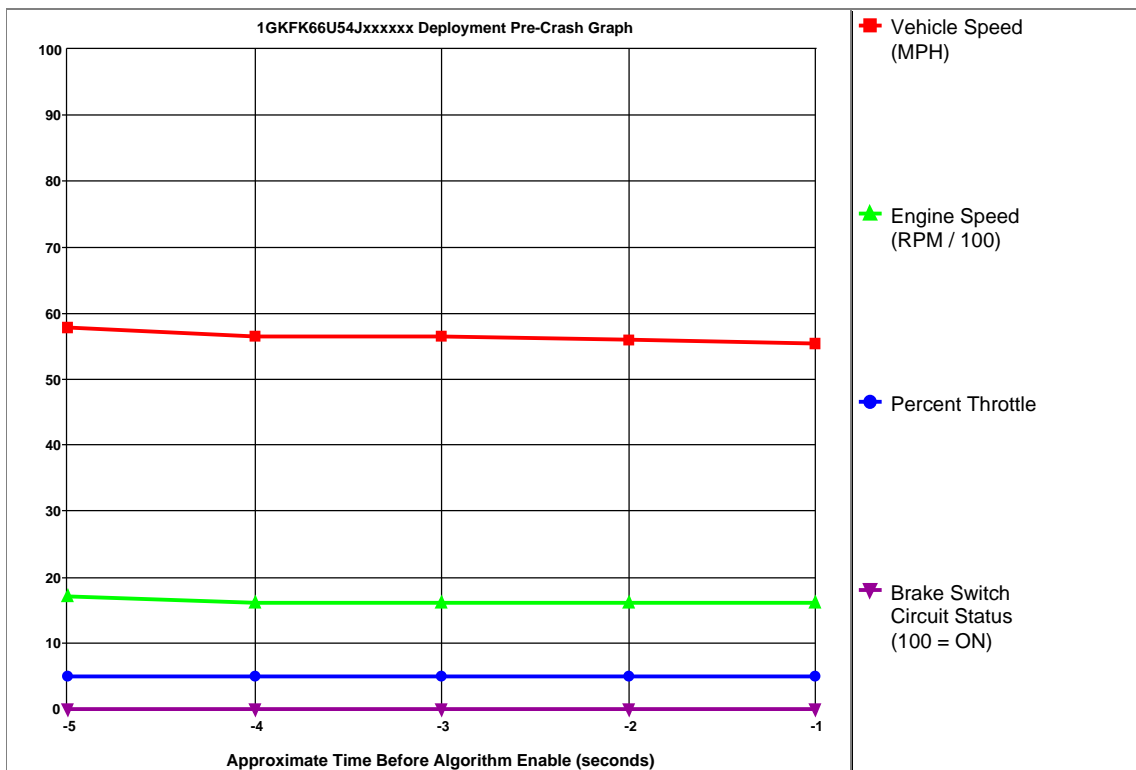
SDM Data Source:

All SDM recorded data is measured, calculated, and stored internally, except for the following:

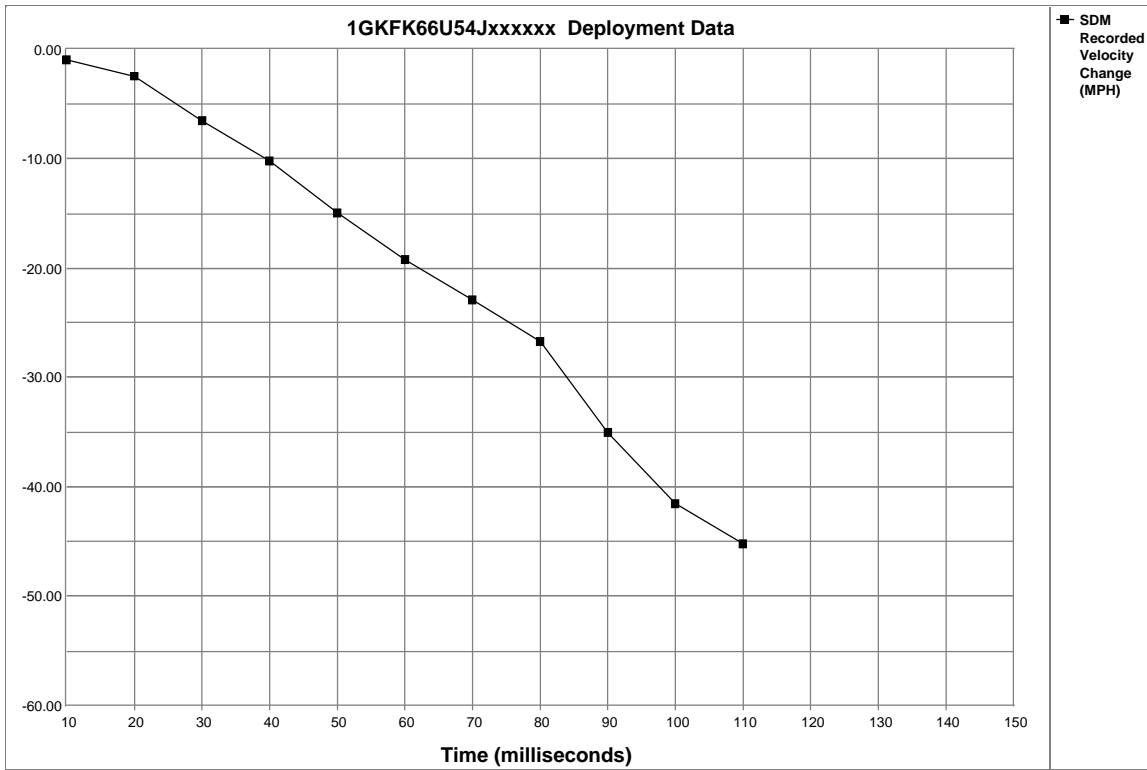
- Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the Class 2 data link, to the SDM.
- Brake Switch Circuit Status data is transmitted once a second by either the ABS module or the PCM, via the Class 2 data link, to the SDM.
- In most vehicles, the Driver's Belt Switch Circuit is wired directly to the SDM. In some vehicles, the Driver's Belt Switch Circuit Status data is transmitted from the Body Control Module (BCM), via the Class 2 data link, to the SDM.

System Status At Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Ignition Cycles At Deployment	592
Ignition Cycles At Investigation	593
Maximum SDM Recorded Velocity Change (MPH)	-45.61
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	107.5
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Driver Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Passenger First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Passenger Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Time Between Non-Deployment And Deployment Events (sec)	N/A
Frontal Deployment Level Event Counter	2
Event Recording Complete	Yes
Multiple Events Associated With This Record	No
One Or More Associated Events Not Recorded	No



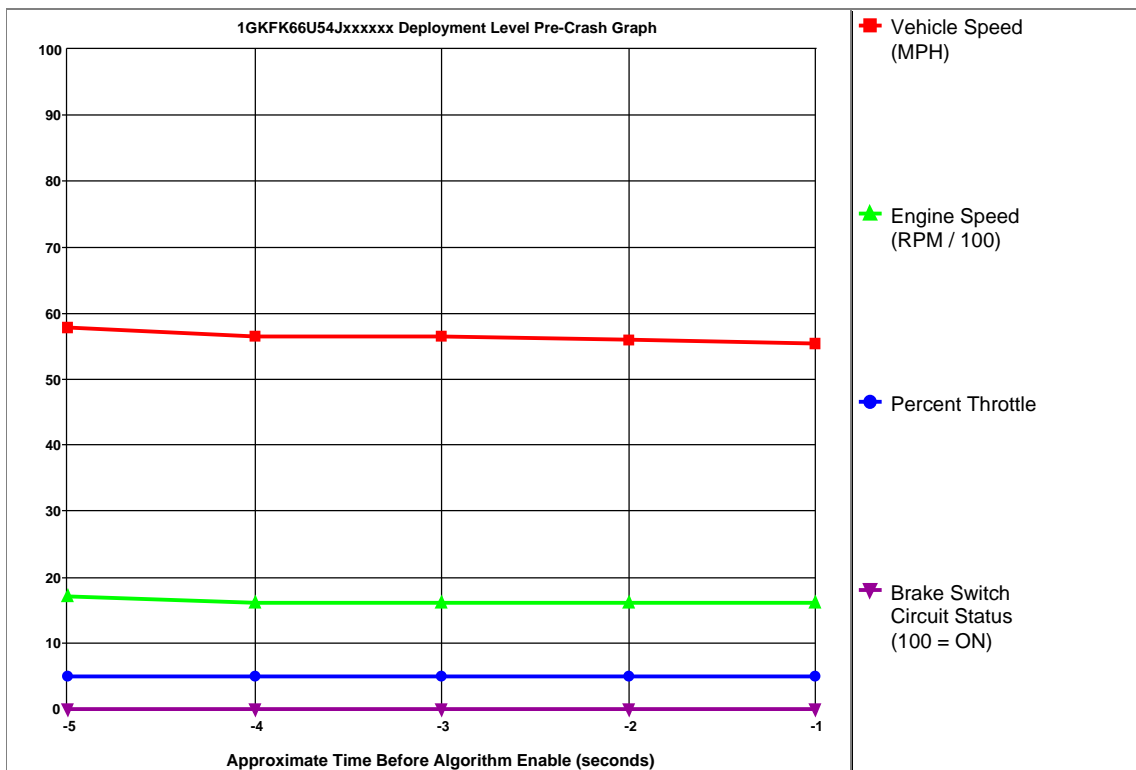
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	58	1664	5	OFF
-4	57	1600	5	OFF
-3	57	1600	5	OFF
-2	56	1600	5	OFF
-1	55	1600	5	OFF



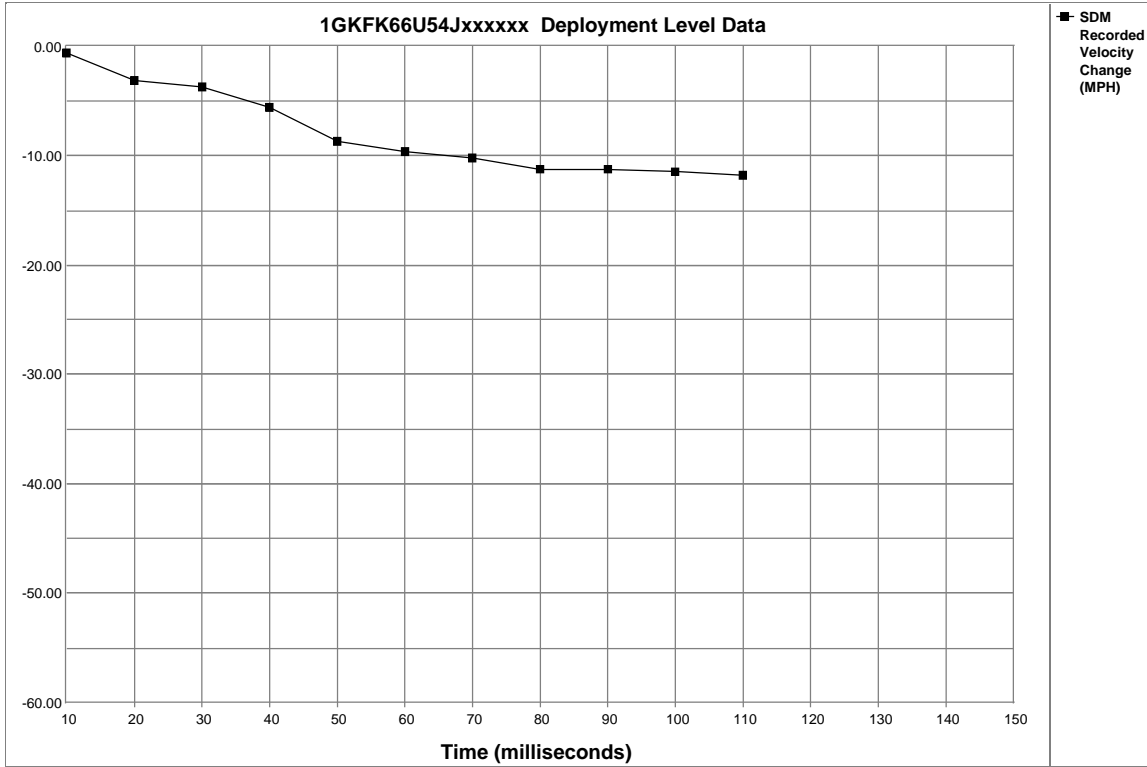
Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.93	-2.48	-6.51	-10.23	-14.88	-19.22	-22.94	-26.66	-35.03	-41.54	-45.26	N/A	N/A	N/A	N/A

System Status At Deployment Level

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Deployment Level	592
Ignition Cycles At Investigation	593
Maximum SDM Recorded Velocity Change (MPH)	-11.99
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	107.5
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	17.5
Driver Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A
Passenger First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	17.5
Passenger Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A
Frontal Deployment Level Event Counter	2
Time Between Deployment And Deployment Level Events (sec)	.2
Event Recording Complete	Yes
Multiple Events Associated With This Record	Yes
One Or More Associated Events Not Recorded	No



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	58	1664	5	OFF
-4	57	1600	5	OFF
-3	57	1600	5	OFF
-2	56	1600	5	OFF
-1	55	1600	5	OFF



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.62	-3.10	-3.72	-5.58	-8.68	-9.61	-10.23	-11.16	-11.16	-11.47	-11.78	N/A	N/A	N/A	N/A

Hexadecimal Data

This page displays all the data retrieved from the air bag module.
It contains data that is not converted by this program.

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$0B 00 00 00 00 00 00
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$11 83 81 83 7C 79 7D
$12 B3 9F 9E 22 22 11
$13 FF 02 00 00 00 00
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$15 FA FA FA FA FA FA
$16 FA FA FA FA FA FA
$17 FA FA 00 00 00 00
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$19 09 00 0A 00 00 64
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$41 00 00 0D 0D 0D 0D
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$45 00 00 0D 0D 0D 0D  
$46 0D 00 19 19 19 19  
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$4A FF FF FF FF FF FF  
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