TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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REMOTE ADVANCED 208-COMPLIANT VEHICLE CRASH INVESTIGATION VERIDIAN SCI TECHNICAL SUMMARY REPORT

NASS/SCI COMBO CASE NO. 2002-09-239J

VEHICLE – 2003 GMC YUKON

LOCATION - MARYLAND

CRASH DATE – DECEMBER 2002

Contract No. DTNH22-01-C-17002

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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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.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. 2002-09-239J	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle Remote Advanced 208-Compliant Vehicle Crash Investigation Vehicle: 2003 GMC Yukon Location: Maryland		*5. Report Date*: August 2003 *6. Performing Organization Code*	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Transportation Sciences Crash Data Research Center Veridian Engineering P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* C00410.0000.0097 *11. Contract or Grant No.* DTNH22-01-C-17002	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: December 2002 *14. Sponsoring Agency Code*	
15. Supplementary Note Remote investigation of a frontal crash of a 2003 GMC Yukon equipped with an advanced frontal air bag system that was compliant with the revised FMVSS 208.			
16. Abstract This investigation focused on the performance of the Advanced 208-Compliant occupant protection system in a 2003 GMC Yukon. The GMC was involved in a front-to rear crash with a 2002 Ford Focus that resulted in deployment of the Yukon's advanced driver air bag system. The 66-year old restrained male driver of the GMC sustained a (self-reported) cervical strain as a result of the crash. The crash was selected for investigation by PSU 09 of the National Automotive Sampling System as Case No: 2002-09-239J. The Crash Investigation Division of the National Highway Traffic Safety Administration subsequently assigned a joint investigation of the crash to the Veridian SCI team due to the agency's interest in assessing the performance of the Advanced 208-Compliant vehicles. This remote effort involved a review and analysis of the NASS EDCS data, download of the GMC's on-board Event Data Recorder (EDR) and completion of a narrative summary report.			
17. Key Words 208 Compliant Advanced frontal air bag Seat weight sensor Driver air bag deployment Minor injury		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 14	*22. Price*

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BACKGROUND

This investigation focused on the performance of the Advanced 208-Compliant occupant protection system in a 2003 GMC Yukon. The GMC was involved in a front-to rear crash with a 2002 Ford Focus that resulted in deployment of the Yukon's advanced driver air bag system. The 66-year old restrained male driver of the GMC sustained a (self-reported) cervical strain as a result of the crash.

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SUMMARY

Crash Site

This three-vehicle crash occurred during the afternoon hours in December 2002. At the time of the crash, it was dark with street lights illuminating the area and it was raining. The road surface was wet. The crash occurred on a four-lane north/south state highway in a suburban setting. The speed limit in the area of the crash was 56 km/h (35 mph). **Figure 1** is a southbound approach view of the 2003 GMC Yukon.

Figure 1: Southbound trajectory view of the GMC.

Pre-Crash

The 2003 GMC Yukon was southbound in the outboard lane driven by a 66-year old restrained male. The driver had a reported height and weight of 173 cm (68 in) and 88 kg (195 lb). He was the vehicle's sole occupant and reported that his speed was approximately 40 km/h (25 mph).

South of GMC's location, a southbound 2002 Ford Focus was driven by a 64-year old female in the inboard lane of the road and a northbound 1991 Ford Escort was driven by a 36-year old

male. Reportedly the driver of the Ford Escort fell asleep and the Ford Escort drifted into the southbound lane directly in the path of the Ford Focus.

Crash

The front left corner area of the Focus struck the front left corner area of the Escort in an off-set head-on impact configuration. The Focus separated from this impact with a counterclockwise rotation and rightward displacement. The Focus entered the outboard southbound lane directly in the path of the GMC.

The front plane of the GMC impacted the back left aspect of the Ford Focus in a 12/7 o'clock impact configuration. The southbound momentum of the GMC displaced the Focus southward and amplified its counterclockwise rotation. The Focus reportedly came to rest facing eastward straddling the divider separating the southbound lanes. The GMC came to rest in the outboard southbound lane several meters north of the Focus. The Ford Escort came to rest (from the initial impact) in the center turn lane. The final rest locations of the vehicles were not documented by the police investigation and could not be determined during the NASS scene inspection. A generalized crash schematic developed by the NASS team is attached to the end of this report as **Figure 9**.

Post-Crash

The police and two ambulance crews responded to the scene. The driver of the Ford Escort was restrained by the two-point lap belt and a two-point motorized shoulder belt at the time of the crash. The motorized mouse of the shoulder belt disengaged from the track due to an overload causing the driver to become restrained only by the lap belt. He sustained a cerebral concussion and multiple forehead lacerations as a result of windshield contact. The ambulance personnel rendered aid and transported the driver to a regional trauma center. The restrained driver of the Ford Focus exited the vehicle under her own power and was not treated at a medical facility. The restrained driver of the GMC sustained (self reported) cervical strain and declined medical treatment.

1991 FORD ESCORT

The 1991 Ford Escort was identified by the Vehicle Identification Number (VIN): 1FAFP1286MW (production sequence deleted). The front-wheel drive, two-door hatchback was equipped with a transverse mounted 1.8 liter/I4 engine linked to a 4-speed automatic transmission. The frontal safety restraint systems consisted of a lap belt with a two-point motorized shoulder belt for the front occupants. The vehicle was manufactured in September 1990 and was not equipped with a Supplemental Restraint System. The odometer had recorded 134,392 km (83,507 miles) at the time of the inspection.

Figure 2 is a view of the frontal impact damage to the Escort. The vehicle sustained 40 cm (16 in) of direct contact damage that began 29 cm (11 in) left of center and extended to the left corner of the front bumper. The combined width of the direct and induced damage extended across the 138.0 cm (54.3 in) entire frontal end width of the vehicle. The damaged components included the front bumper, center grille, left headlamp assembly, hood, left front fender and components of the left front suspension. The left wheelbase was shortened 16.0 cm (6.3 in).

The crush profile measured along the front bumper was as follows: C1=48 cm (19 in), C2=25 cm (10 in), C3=14 cm (6 in), C4=9 cm (4 in), C5=5 cm (2 in), C6=2 cm (1 in). The delta V calculated by the Damage Algorithm of the WINSMASH model was 22 km/h (14 mph). The longitudinal and lateral components of the delta V were -22 km/h (-14 mph) and 0, respectively. The Collision Deformation Classification (CDC) was 12-FLEE-3.

Figure 2: Front view of the 1991 Ford Escort.

2002 FORD FOCUS

The 2002 Ford Focus was identified by the Vehicle Identification Number (VIN): 3FAHP31342R (production sequence deleted). The front-wheel drive, two-door hatchback was equipped with a transverse mounted 2.0 liter/I4 engine linked to a 5-speed automatic transmission. The manual restraint system consisted of 3-point lap and shoulder belts in all five seat positions. The front restraints were equipped with pretensioners. The Supplemental Restraint System consisted of redesigned driver and front right passenger air bags. The air bags had deployed as a result of the impact. The vehicle was manufactured in February 2002 and had registered 17,703 km (11,000 miles).

Figure 3 is a view of the frontal damage to the Focus. The vehicle sustained 34 cm (13.4 in) of direct contact damage that began 29 cm (11.4 in) left of center and extended to the left corner of the front bumper. The combined width of the direct and induced damage extended across the entire 126 cm (49.6 in) frontal end width of the vehicle. The outboard left aspect of the bumper fascia was fractured and the left end of the bumper reinforcement was deflected rearward. The primary zone of engagement appeared to have occurred immediately outboard of the left end of the reinforcement bar. The frontal contact pattern transitioned to longitudinal direct damage

Figure 3: Front view of the 2002 Ford Focus.

to the left front fender and left front suspension components. The reported frontal crush profile was as follows: C1=4 cm (2 in), C2=4 cm (2 in), C3=3 cm (1 in), C4=2 cm (1 in), C5=0 cm, C6=0 cm. The reported crush profile appeared to have underestimated the severity of the damage based on an analysis of the photographs. The reported delta V calculated by the Damage Algorithm of the WINSMASH model was 20 km/h (12 mph). The longitudinal and lateral components of the delta V were -20 km/h (-12 mph) and 3 km/h (2 mph), respectively. The Collision Deformation Classification (CDC) was 12-FLEE-3.

Figure 4 is a view of the Focus's back plane damage sustained as a result of the impact from the GMC. The 87 cm (34.3 in) of direct contact damage began 19 cm (7.5 in) right of center and extended to the left corner of the rear bumper. The direct damage wrapped around the left rear corner and extended onto the left rear quarterpanel panel. The direct damage pattern was indicative of the 7 o'clock direction of the impact force. The reported residual crush profile along the rear bumper was as follows: C1=15 cm (5.9 in), C2=9 cm (3.5 in), C3=2 cm (0.8 in), C4=0 cm, C5=0 cm, C6=0 cm. The reported delta V calculated by the Damage Algorithm of the WINSMASH model was 22 km/h (14 mph). The longitudinal and lateral components of the delta V were 21 km/h (13 mph) and 8 km/h (5 mph), respectively. The Collision Deformation Classification (CDC) was 07-BYAW-2.

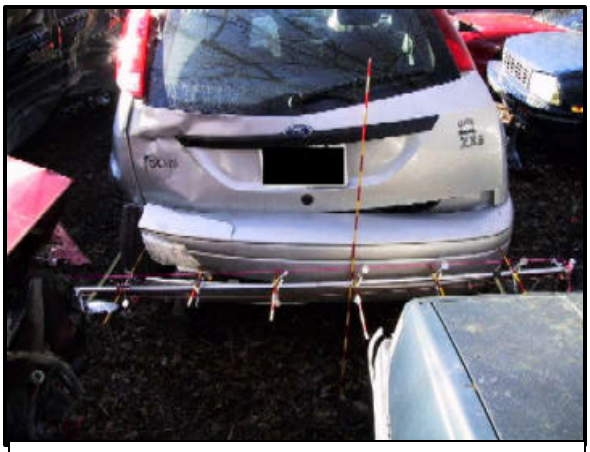


Figure 4: Damage to the back plane of the Focus.

ADVANCED 208-COMPLIANT VEHICLE
2003 GMC YUKON

The 2003 GMC Yukon, **Figure 5**, was identified by the Vehicle Identification Number (VIN): 1GKEK13Z43J (production sequence deleted). The four wheel drive, ½ ton, sport utility vehicle was equipped with a 5.3 liter/V8 engine linked to a 4-speed automatic transmission with overdrive. The vehicle's Gross Vehicle Weight Rating (GVWR) was 3,130 kg (6,900 lb). The service brakes were hydraulic, self adjusting, power assisted front and rear disc brakes with anti-lock (ABS). The GMC was equipped for eight passenger seating (2-3-3). The manual restraint system consisted of 3-point lap and shoulder belts in Rows 1 and 2, and in the outboard positions of Row 3. The center position of Row 3 was lap belt

Figure 5: Left front view of the Yukon.

equipped. The Supplemental Restraint System (SRS) consisted of Advanced 208-Compliant frontal air bags for the driver and front right passenger. The odometer had recorded 3,434 km (2,134 miles) at the time of the crash. The vehicle's date of manufacture was September 2002.

Exterior Damage

The front plane of the GMC sustained 173 cm (68 in) of direct and induced damage that extended across the entire frontal end width of the vehicle. The direct damage width measured 112 cm and began at the left front corner. The damaged components included the front bumper, center grille, left headlamp assembly, and hood. There was no change in the wheelbase dimensions. The reported residual crush profile along the front bumper was as follows: C1=0 cm, C2=0 cm, C3=18 cm (7 in), C4=14 cm (6 in), C5=1 cm (0.5in), C6=0 cm. The maximum crush was located along the vehicle's center line and measured 27 cm (10 in). The reported crush profile appeared to underestimate the overall damage sustained by the vehicle. The forward aspect of the hood sustained an estimated 30 cm (12 in) of direct contact damage during its deformation indicative of above-bumper damage not quantified in the crush profile. The Collision Deformation Classification (CDC) was 12-FZEW-1. The reported total delta V calculated by the Damage Algorithm of the WINSMASH model was 8 km/h (5 mph) and underestimated the severity of the crash. The longitudinal and lateral components of the delta V were -8 km/h (-5 mph) and +1 km/h (+0.6 mph), respectively. The estimated total delta V based on SCI experience and analysis of the photographs was approximately 16 km/h (10 mph). This estimated delta V was more consistent with the 14.9 km/h (9.3 mph) maximum delta V reported by the vehicle's EDR.

Figure 6: Frontal view of the damaged GMC.

Interior Damage

Figure 7 is an overall interior view of the front compartment in the GMC. The vehicle's interior damage consisted of minor occupant scuffing contacts attributed to the hands of the driver.

These contacts were minor in nature and did not produce any injuries. There was no intrusion into the occupant compartment attributed to the exterior crash forces.

The driver seat was located in a mid-track position. The four-spoke steering wheel rim was not deformed and there was no shear capsule displacement. The steering wheel was rotated 90 degrees counterclockwise at the time of the inspection. There was no contact evidence on the driver's knee bolster.

The driver's manual 3-point lap and shoulder belt was integrated into the design of the seat back. The seat belt was stowed within the retractor and the retractor was operational. Examination of the latch plate revealed minor evidence of historical use, however, this was consistent with the age of the vehicle. Inspection of the restraint's webbing and hardware surfaces did not reveal any crash related evidence.

Figure 7: Front interior view of the GMC.

Supplemental Restraint System (SRS)

The Supplemental Restraint System in the 2003 GMC Yukon consisted of advanced dual stage driver and front right passenger air bags. The vehicle's frontal air bags were certified by the manufacturer to be in compliance with the requirements of the advanced air bag Federal Motor Vehicle Safety Standard (FMVSS) 208. The front right passenger seat was equipped with a weight sensor to detect occupant presence. Both front seats were equipped with seat track position sensors. The SRS was monitored and controlled by a Sensing and Diagnostic Control Module (SDM) located under the driver seat. The SDM was removed from the vehicle by the NASS researcher and forwarded to the SCI team where it was downloaded. In summary, the EDR indicated the vehicle was traveling at 56 km/h (35 mph), approximately five seconds prior to the crash and decelerated to 51 km/h (32 mph), approximately one second prior to impact. The driver seat belt was buckled and the SRS warning lamp was off. The deployment criteria for both the Stage 1 and Stage 2 driver air bag deployment was met 25 milliseconds after algorithm

enable (AE). The maximum-recorded delta V was -14.9 km/h (-9.3 mph) at 130 milliseconds after (AE). The complete EDR report is attached to the end of this report.

Figure 8: Driver air bag.

The driver air bag module was designed in the typical manner and located in the center hub of the steering wheel rim. The I-configuration module cover flaps were not damaged. The flaps were symmetrical and measured 7 cm (2.8 in) by 12 cm (4.7 in), width by height. The driver air bag measured 70 cm (27.6 in) in diameter in its deflated state. Two internal straps sewn to the face of the bag tethered the air bag. It was vented by two ports located in the 11/1 o'clock sectors on the backside of the bag. **Figure 8** is a view of the driver air bag. The 12 o'clock sector of the bag is at the left side of the photograph; the steering wheel was turned 90 degrees counterclockwise at the time of the inspection. There was no direct evidence of occupant contact to the face of the bag. The EDR reported that a Stage 2 deployment occurred.

The front right passenger air bag module was a mid-mount design located in the right aspect of the instrument panel. The front right air bag was not deployed. The GMC driver was the vehicle's sole occupant, as such, the weight sensor in the front right passenger seat reported this condition to the SDM and the SDM suppressed the deployment of the module.

DRIVER DEMOGRAPHICS

2003 GMC Yukon

Age/Sex:	66 year old /Male
Height:	173 cm (68 in)
Weight:	88 kg (194 lb)
Restraint Use:	3-point lap and shoulder belt
Usage Source:	Vehicle inspection, PAR, EDR output
Medical Treatment:	Not injured, declined medical transport

DRIVER INJURY

Injury	*Injury Severity (Update AIS 98)*	*Injury Mechanism*
Cervical spine strain	Minor (640278.1,6)	Inertial flexion over the seat belt

Note: the above referenced injury was reported via interview with the driver. No medical records were available.

DRIVER KINEMATICS

Immediately prior to the crash, the restrained driver was seated in an upright posture with his seat adjusted to a mid-to rear track position consistent with his stature. The driver was aware of the crash that had occurred between the Ford Focus and the Ford Escort and was covering the brakes in preparation of an avoidance maneuver. The Ford Focus entered the outboard southbound lane subsequent to that crash directly in the path of the GMC and the impact occurred.

The force of the impact caused the emergency locking retractor of the driver's manual restraint to lock. The SDM controlling the air bag system sensed the crash and commanded a Stage 2 deployment of the driver's air bag. The driver responded to the 1 o'clock direction of the impact force and initiated a forward trajectory. The driver's torso and pelvic regions contacted the locking restraint system and rode down the forces of the crash. The inertia of the head caused the neck to flex forward as the driver's body loaded the manual restraint. This contact with the seat belt system was the probable cause of the reported cervical strain.

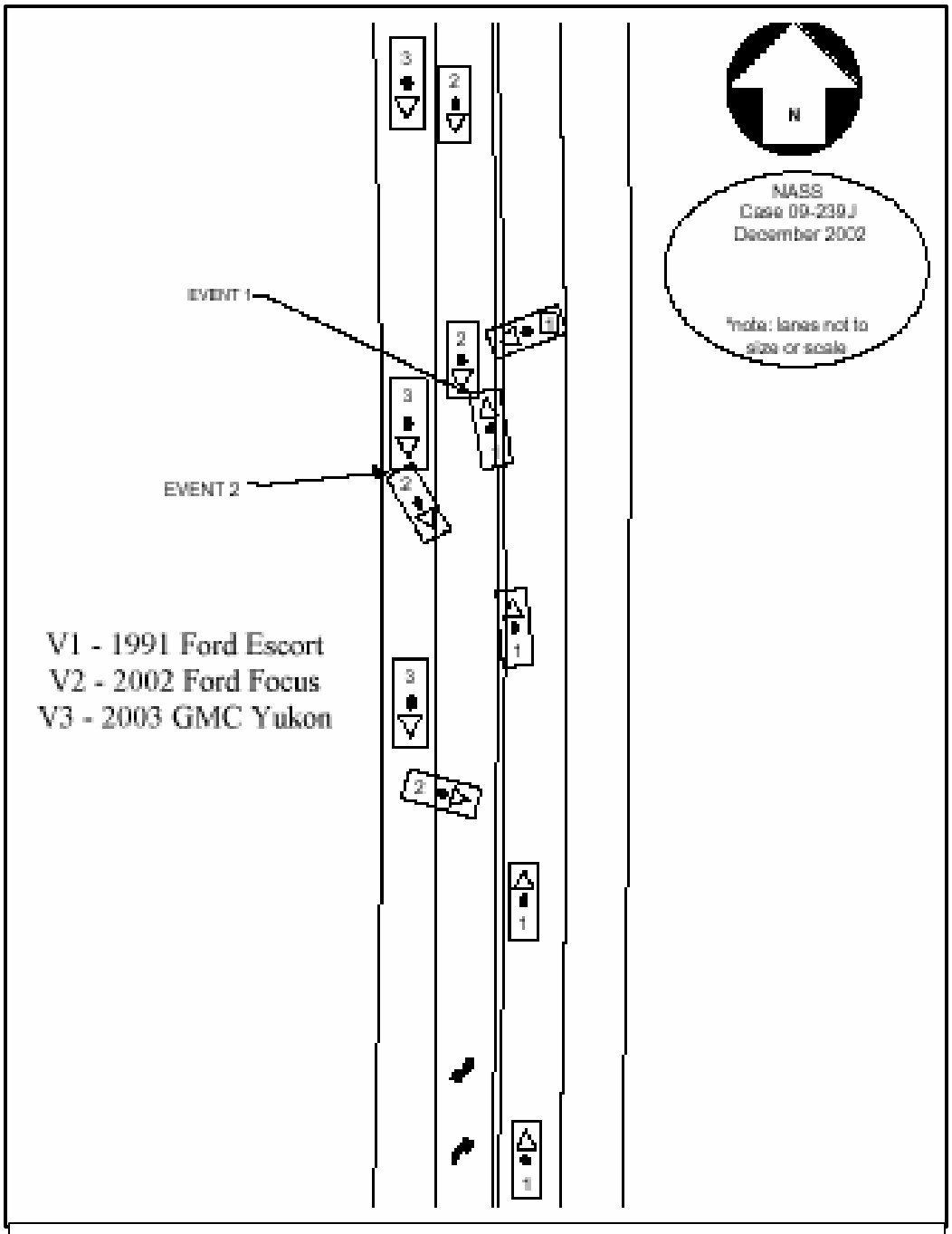


Figure 9: Crash Schematic

CDR File Information

Vehicle Identification Number	1GKEK13Z43Jxxxxxx
Investigator	
Case Number	
Investigation Date	
Crash Date	
Filename	P09-239.CDR
Saved on	04/28/2003 3:03:59 PM
Data check information	EF5E833D
Collected with CDR version	Crash Data Retrieval Tool 2.00
Collecting program verification number	A31D1C76
Reported with CDR version	Crash Data Retrieval Tool 2.00
Reporting program verification number	A31D1C76
Event(s) recovered	Deployment

SDM Data Limitations

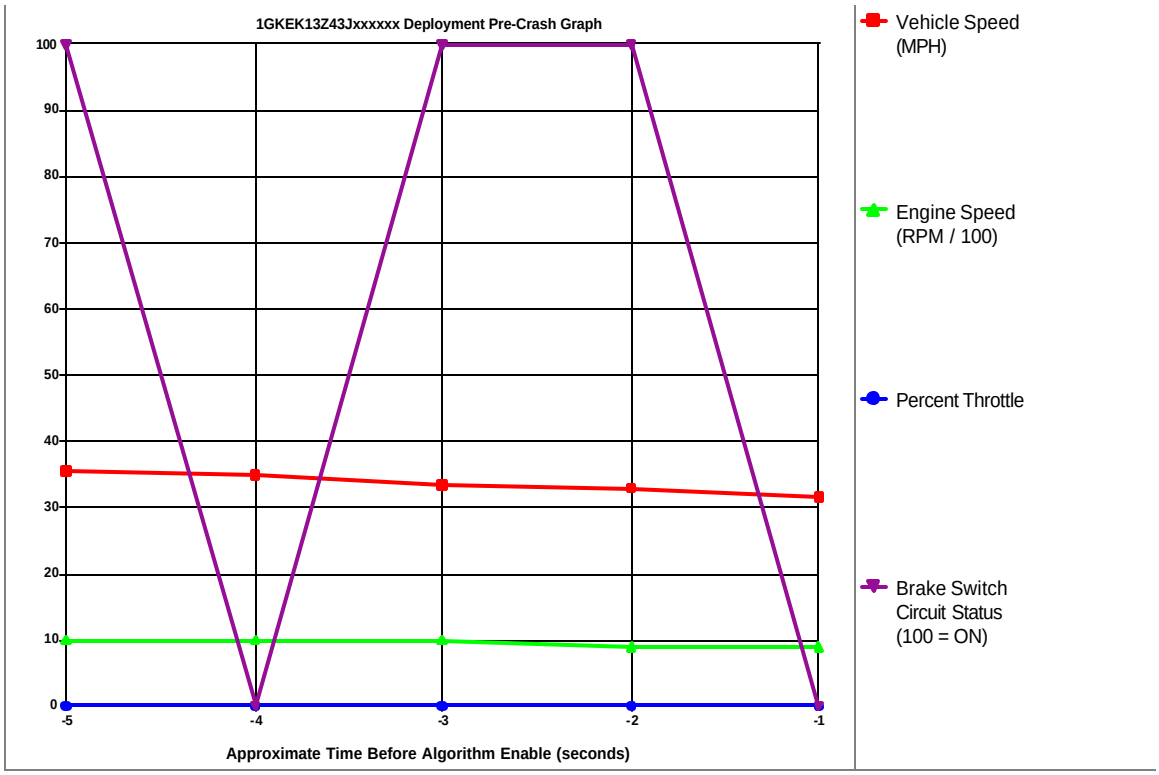
SDM Recorded Crash Events:
There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store 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 can not 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 is one of the measures used to make air bag deployment decisions. SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. 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. The SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. The SDM will also record 150 milliseconds of data after non-deployment criteria is met.
-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 for any of the four Pre-Crash data parameters (Vehicle Speed, Engine Speed, Percent Throttle, and Brake Switch Circuit Status).
-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.

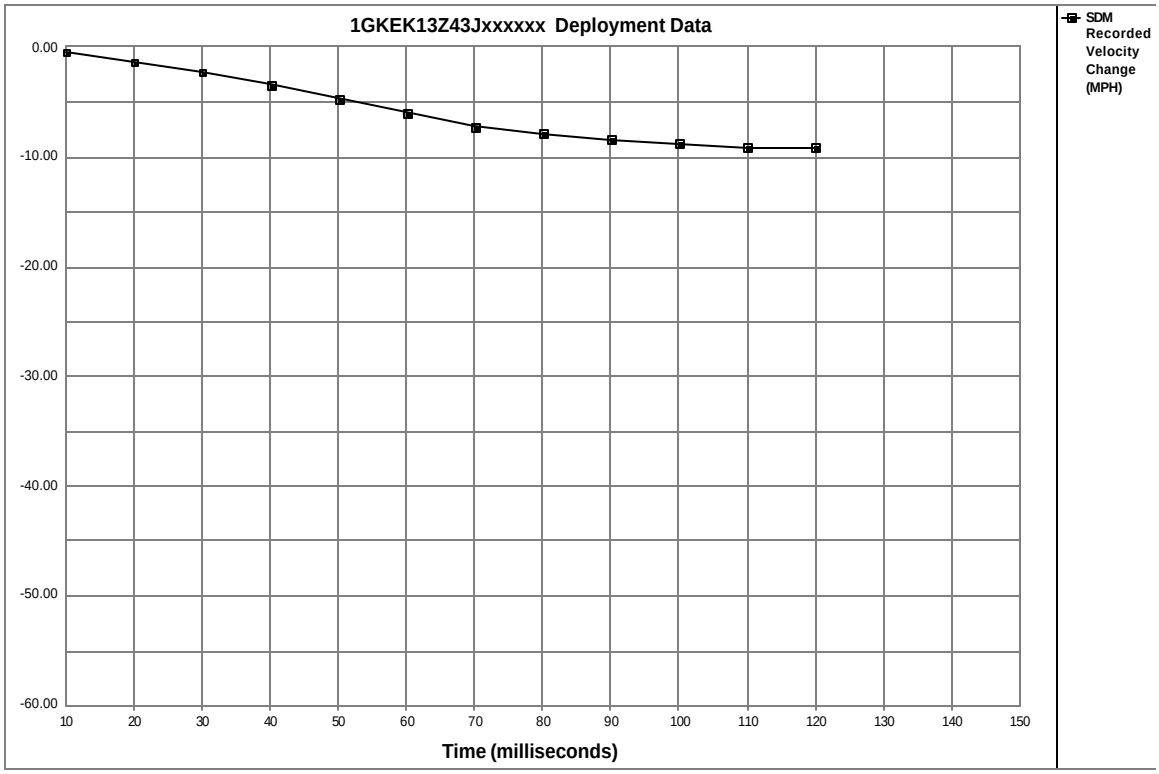
SDM Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the Class 2 data link, to the SDM.
-Brake Switch Circuit Status 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	BUCKLED
Ignition Cycles At Deployment	314
Ignition Cycles At Investigation	320
Maximum SDM Recorded Velocity Change (MPH)	-9.27
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	130
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	25
Driver Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	25
Passenger First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A
Passenger Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A
Time Between Non-Deployment And Deployment Events (sec)	N/A
Frontal Deployment Level Event Counter	1
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	35	1024	0	ON
-4	35	960	0	OFF
-3	34	960	0	ON
-2	33	896	0	ON
-1	32	896	0	OFF



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.31	-1.24	-2.17	-3.41	-4.65	-5.89	-7.13	-7.75	-8.37	-8.68	-8.99	-8.99	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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$04  4B 31 41 52 42 31
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