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CALSPAN ON-SITE ADVANCED OCCUPANT PROTECTION SYSTEM CRASH INVESTIGATION

SCI CASE NO: CA04-014

VEHICLE: 2004 SATURN ION
LOCATION: PENNSYLVANIA
CRASH DATE: FEBRUARY, 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.

TECHNICAL REPORT STANDARD TITLE PAGE

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16. Abstract

This on-site investigative effort focused on the performance of the Advanced Occupant Protection System (AOPS) in a 2004 Saturn Ion. The Saturn was involved in a fixed object frontal impact with a tree. The Saturn was equipped with an AOPS that consisted of dual-stage frontal air bags and retractor pretensioners for the front safety belts. The AOPS was not commanded to deploy in the moderate severity frontal crash. Additionally, the vehicle was equipped with an Event Data Recorder (EDR) that had the capabilities to record both pre-crash vehicle system and crash related data. That data was downloaded during the inspection as a supplement to the investigation. The 23 year old male driver and 25 year old male front right passenger were unrestrained at the time of the crash and were not injured. Neither occupant requested medical attention nor were they transported.

This crash was identified from a list of claims provided by an insurance company to the National Highway Traffic Safety Administration (NHTSA) that identified vehicles of high interest to the agency that had been involved in crashes. The Crash Investigations Division of the NHTSA assigned an on-site investigation of this crash to the Calspan Special Crash Investigations (SCI) team on March 15, 2004. The Saturn was located in a salvage yard pending auction and cooperation was established with the management facility to inspect the vehicle. The vehicle inspection took place the week of March 22, 2004.

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BACKGROUND

This on-site investigative effort focused on the performance of the Advanced Occupant Protection System (AOPS) in a 2004 Saturn Ion, **Figure 1.** The Saturn was involved in a fixed object frontal impact with a tree. The Saturn was equipped with an AOPS that consisted of dual-stage frontal air bags and retractor pretensioners for the front safety belts. The AOPS was not commanded to deploy in the moderate severity frontal crash. Additionally, the vehicle was equipped with an Event Data Recorder (EDR) that had the capabilities to record both pre-crash vehicle systems and crash related data. That data was downloaded during the inspection as a supplement to the investigation. The 23 year old male driver and 25 year old male front right passenger were unrestrained at the time of the crash and were not injured. Neither occupant requested medical attention nor were they transported.

Figure 1: 2004 Saturn Ion.

This crash was identified from a list of claims provided by an insurance company to the National Highway Traffic Safety Administration (NHTSA) that identified vehicles of high interest to the agency that had been involved in crashes. The Crash Investigations Division of the NHTSA assigned an on-site investigation of this crash to the Calspan Special Crash Investigations (SCI) team on March 15, 2004. The Saturn was located in a salvage yard pending auction and cooperation was established with the management facility to inspect the vehicle. The vehicle inspection took place the week of March 22, 2004.

SUMMARY

VEHICLE DATA

2004 Saturn Ion

The 2004 Saturn Ion was identified by the Vehicle Identification Number (VIN): 1G8AG525F64 (production sequence deleted). The four-door sedan was equipped with base model equipment to include: manual driver and front passenger seats, manual windows and power door locks. The power train consisted of a 2.2 liter/I4 engine linked to a four-speed automatic transmission. The service brakes were four-wheel disc without ABS. The vehicle was equipped with manual 3-point safety belts in all five seat positions. The safety belts for the driver and front right passenger were equipped with retractor pretensioners. The Advanced

Occupant Protection System (AOPS) consisted of dual-stage frontal air bags. The vehicle was manufactured in August 2003 and the odometer read 3,280 km (2,080 miles) at the time of the inspection. The Saturn was equipped with Firestone FR690 P185/70R14 tires in all four positions. The recommended tire pressure for both the front and rear positions was 210 kPa (30 PSI). The specific measured tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	162 kPa (23 PSI)	7 mm (9/32)	No	None
LR	179 kPa (26 PSI)	8 mm (10/32)	No	None
RF	162 kPa (23 PSI)	7 mm (9/32)	No	None
RR	0 kPa (0 PSI)	7 mm (9/32)	No	Tire flat, no visible damage

CRASH SITE

This single vehicle run-off-road/fixed object crash occurred during the daylight hours in February 2004. At the time of the crash, weather was snow/sleet and rain. The asphalt road pavement was police reported as icy. The crash occurred on a two-lane east/west rural road at the exit of a small radius left curve for eastbound traffic. The radius of the curve measured 85 m (280 ft). A stand of small diameter trees located 3 m (10 ft) from the edge of the travel lane bordered the road. A 36 cm (14 in) diameter tree located at the end of the tree stand was the point of impact. At the beginning of the curve, the road had a negative grade (estimated greater than 2 percent) in the eastbound direction. The grade transitioned to level in the area of the impact. A north/south two lane road located 23 m (75 ft) east of the point of impact intersected the primary road from the south forming a three leg intersection. The speed limit in the area of the crash was 56 km/h (35 mph). **Figure 2** is an eastbound trajectory view approaching the crash site. **Figure 3** is a view of the point of impact.

Figure 3: Eastbound trajectory view 55 m (180 ft) from impact.

Figure 2: View of the point of impact.

CRASH SEQUENCE

Pre-Crash

The 23-year-old male driver was operating the Saturn eastbound attempting to negotiate the left curve. The road conditions were reported as icy; the weather was snow and sleet. A 25 year old male was seated in the vehicle's front right position. Neither occupant of the Saturn was restrained by the vehicle's manual safety belt system. As the Saturn approached the exit of the curve, the driver lost directional control and the vehicle departed the right side of the road. A probable tire mark located 16 m (52 ft) west of the point of impact defined the location of the vehicle's roadside departure. A schematic of the crash is attached to the end of this report as **Figure 7**.

Crash

The crash occurred when the center aspect of the vehicle's front plane impacted the 36 cm (14 in) diameter tree. The eastward momentum of the Saturn was stopped by the tree and resulted in 58 cm (23 in) of longitudinal crush at the center line. The vehicle rotated approximately 20 degrees clockwise and came to rest facing southeast in close proximity to the tree. The delta V of the crash calculated by the Barrier Algorithm of the WINSMASH model was 35 km/h (21.7 mph).

Post-Crash

The police responded to the crash scene. Both occupants had exited the Saturn under their own power and refused medical treatment. The vehicle was towed due to the disabling damage and was considered a total loss by the insurance carrier.

2004 SATURN ION

Exterior Damage

Figures 3 and 4 are the front and overhead views of the Saturn. The frontal plane of the vehicle sustained 28 cm (11.0 in) of direct contact damage as a result of the tree impact. The direct damage started 14 cm (5.5 in) left of center and ended 14 cm (5.5 in) right of center. The combined width of the direct and induced frontal damage extended across the entire 145 cm (57 in) frontal width of the vehicle. The components damaged in the impact included the front bumper fascia and reinforcement bar, center grille, hood, radiator, air conditioner condenser, upper radiator support and headlamp assemblies. The right forward uni-body frame end deformed 15 cm (6 in) inboard during the impact phase, as the bumper reinforcement bar crushed into a U-pattern. The residual crush profile measured along the reinforcement bar was as follows: C1 = 1 cm (2.5 in), C2 = 21 cm (8.3 in), C3 = 49 cm (19.3 in), C4 = 58 cm (22.8 in), C5 = 50 cm (19.7 in), C6 = 1 cm (2.5 in). The right wheelbase reduction measured 6 cm (2.5 in). The left wheelbase was unchanged. All four doors remained closed during the impact and were operational at the time of the SCI inspection. The Collision Deformation Classification (CDC) was 12-FCEN-3. The delta V of the crash calculated by the Barrier Algorithm of the WINSMASH model was 35 km/h (21.7 mph). The longitudinal and lateral components were -35 km/h (-21.7 mph) and 0, respectively.

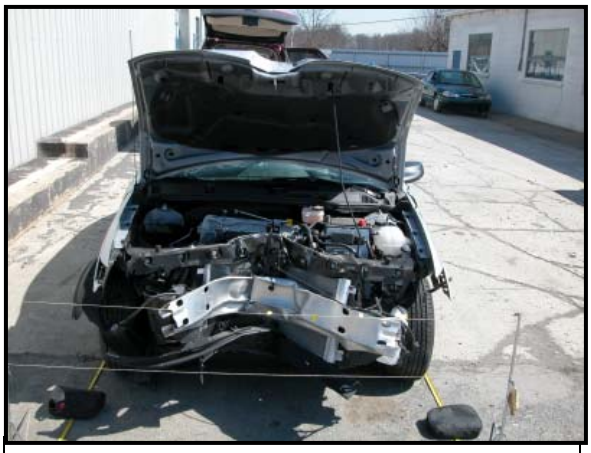


Figure 4: Front view of the Saturn.

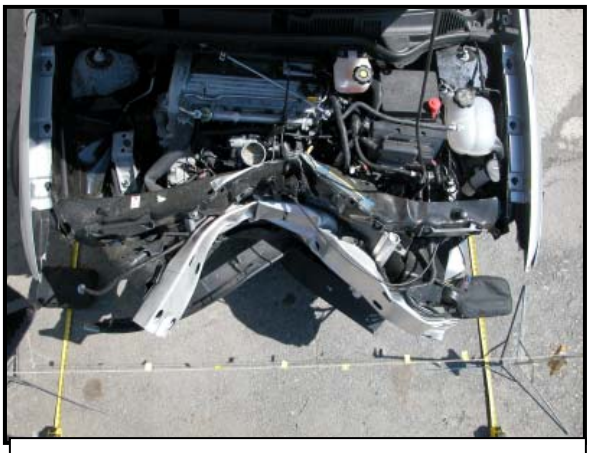


Figure 5: Overhead view of the frontal damage.

Interior Damage

Figure 6 is an interior view of the Saturn. The vehicle's interior damage consisted of the identified (unrestrained) occupant interior contacts. There was no intrusion or damage related to the exterior force of the impact. There was no deployment of the vehicle's frontal air bags.

Figure 6: Interior view.

The driver seat was adjusted to a full rear track position. The total seat track travel measured 25 cm (10 in). The seat back was reclined 30 degrees aft of vertical, measured 36 cm (14 in) above the seat bight. The horizontal distance from the seat back to the steering wheel hub measured 76 cm (30 in). The tilt steering wheel was in the full up position. There was no evidence of loading or deformation to the steering wheel rim. There was no displacement of the steering column's shear capsules. The control stalk for the turn signals was fractured from a probable left hand contact.

The windshield was fractured forward of the driver's position from the driver's head contact. The fracture site was located 41 cm (16 in) right of the left A-pillar and 10 cm (3.8 in) below the windshield header. The center mirror was fractured and rotated from probable contact with the driver's right hand. The driver's knee bolster exhibited a scuff from the driver's right lower extremity. The scuff measured 5 cm x 6 cm (1.8 in x 2.5 in); it was located 16 cm (6.3 in) right of the steering column centerline and 46 cm (18 in) above the floor.

The front right passenger seat was located in a rear position 5 cm (2 in) forward of full rear. The total seat track travel measured 25 cm (10 in). The seat back angle measured 20 degrees. This angle was measured 36 cm (14 in) above the seat bight. The horizontal distance from the seat back to the instrument panel measured 78 cm (30.5 in). The horizontal distance from the head restraint to the windshield measured 116 cm (45.8 in). The rake angle of the windshield measured 27 degrees.

The windshield forward of the front right position was fractured. Two fracture sites were identified from contact by the passenger head and right hand, respectively. The fracture site from the head strike was located 34 cm (13.5 in) left of the right A-pillar and 50 cm (19.5 in) below the header. Several hair strands were embedded in the fracture. The fracture associated with the passenger's right hand was located 20 cm (7.8 in) left of the right A-pillar and 28 cm (11 in) below the header. Two scuffs were identified on the lower instrument panel resultant to contact from the passenger's lower extremities. A 5 cm x 5 cm (2 in x 2in) scuff attributed to the right lower extremity was located 46 cm (18 in) above the floor on the left upper corner of the glove box door. A 6 cm x 4 cm (2.5 in x 1.5 in) left lower extremity scuff was located 46 cm (18 in) above the floor and 18 cm (7 in) inboard of the right outer edge of the instrument panel.

Manual Restraint System

The manual restraint system in the 2004 Saturn Ion consisted of 3-point lap and shoulder belts in all five seat positions. Each restraint was equipped with continuous loop webbing, sliding latch plate and inertial locking retractor. The driver and front right passenger retractors were equipped with pretensioners. The pretensioners did not fire in this crash.

The driver and front right passenger restraints were both stowed within their respective retractors at the time of the inspection and were operational. Both adjustable D-rings were in the lowest position. Examination of the latch plates revealed minor evidence of historical use consistent with the vehicle's mileage. Neither restraint exhibited any indicators of being in use during the crash. Based on the inspection of the safety belts and the vehicle's interior, it was determined that neither occupant was restrained at the time of the crash.

Advanced Occupant Protection System

The Advanced Occupant Protection System (AOPS) in the 2004 Saturn Ion consisted of dual-stage frontal air bags. The air bags were designed to deploy with different levels of force dependant on the severity of the crash. In this crash the frontal air bags were not commanded to deploy. The AOPS was controlled by a Sensing and Diagnostic Module (SDM) that had Event Data Recording (EDR) capabilities. The EDR was downloaded at the time of the inspection and

the data is attached to the end of this report. Given the severity of the impact damage, the computed WINSMASH delta V and the non-belted status of the occupants, the frontal air bag system probably should have deployed in this crash.

At inspection, the Saturn was powered up by turning the ignition key to the "ON" position. The vehicle's battery was still charged and the electrical system was intact. At power up, the air bag diagnostic indicator lamp (in the instrument cluster) flashed seven times during as the SDM went through its diagnostic sequence. The lamp then went out. The status of the air bag lamp indicated that the AOPS was functioning properly and that there were no faults in the system.

The Vetronix CDR hardware was connected to the J1962 port located under the left aspect of the instrument panel and the EDR was downloaded on ignition cycle 323. The data indicated a non-deployment event was stored on ignition cycle 321. Given that the key cycle of the event and the download were only separated by two cycles, it was possible that the stored data was related to the subject crash. However upon review of the EDR data, the stored data was deemed unreliable. The Pre-Crash vehicle speed and Engine RPM were recorded as Zero and the crash pulse data (Delta V) was also Zero. The maximum recorded SDM velocity change was -0.6 km (-0.40 mph) for this moderate severity crash.

The reason for the lack of reliable data related to the subject crash could not be determined to a reasonable degree of certainty. Generally, the lack of reliable EDR data is caused by an electrical (power) failure resultant of the impact which interrupts the recording process. Inspection of this vehicle found the electrical system and battery intact. However, the Saturn may have experienced an intermittent power failure resulting in a write failure. Another possible explanation could be that a non-deployment event was created during the process of towing the vehicle from the crash site and that event over-wrote the stored data related to the crash.

OCCUPANT DEMOGRAPHICS

	Driver	***Front Right Passenger***
Age/Sex:	23 year old/Male	25 year old/Male
Height:	Not reported	Not reported
Weight:	Not reported	Not reported
Seat Position:	Full rear track	Rear track, 5 cm forward of full rear
Restraint Use:	Unrestrained	Unrestrained
Usage Source:	SCI inspection, kinematics	SCI inspection, kinematics
Medical Treatment:	Not injured	Not injured

OCCUPANT INJURIES

Both occupants refused treatment and they were not transported.

DRIVER KINEMATICS

The 23 year old male driver was seated in a presumed upright posture with the driver's seat adjusted to a full rear track position. He was not utilizing the manual safety belt system and was

unrestrained at the time of the crash. Upon impact, the driver initiated a forward trajectory in response to the 12 o'clock direction of the impact. The driver translated forward and his knees/lower legs contacted the bolster. The driver's chest contacted the steering wheel and his head struck the windshield evidenced by the fracture. His left hand separated from the steering wheel fracturing the left control (turn signal) stalk. He was possibly reaching to brace with his right hand and contacted and fractured the center mirror. The driver then rebounded back into his seat where he came to rest.

FRONT RIGHT OCCUPANT KINEMATICS

The 25 year old male front right passenger was seated in a rear track position with a presumed upright posture. He was not using the manual safety belt; he was unrestrained. Upon impact, the occupant initiated a forward trajectory in response to the 12 o'clock direction of the impact. The occupant translated forward and his knees/lower extremities contacted and scuffed the bolster/glove box door. His chest contacted the instrument panel and his head contacted and fractured the windshield. The occupant was probably attempting to brace with his right hand and contacted and fractured the windshield evidenced by the second fracture site. The occupant then rebounded back into his seat coming to rest.

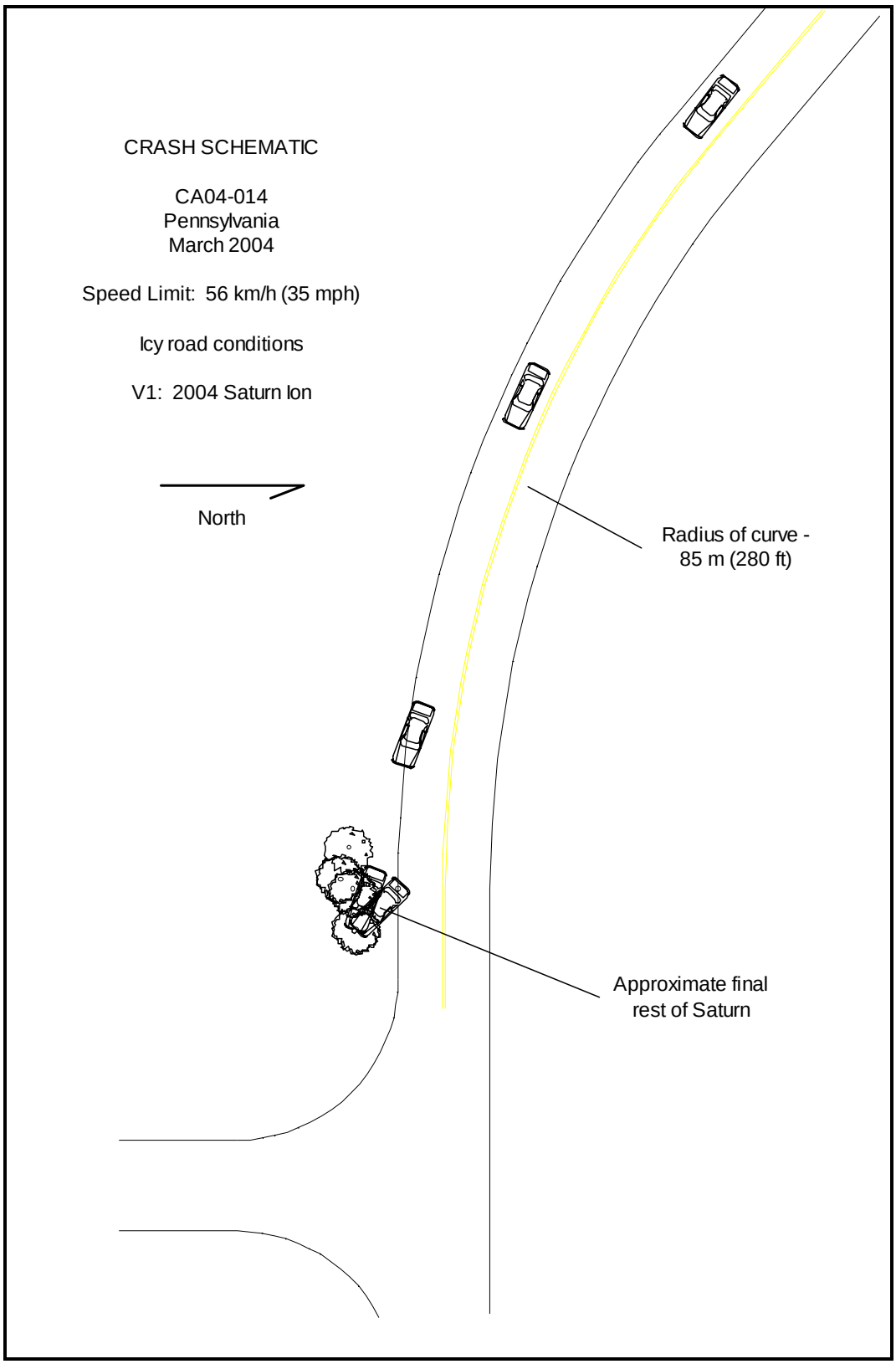


Figure 7: Crash Schematic.

ATTACHMENT A
EDR Data

CDR File Information

Vehicle Identification Number	1G8AG52F64Zxxxxxx
Investigator	
Case Number	
Investigation Date	
Crash Date	
Filename	
Saved on	
Data check information	8803731F
Collected with CDR version	Crash Data Retrieval Tool 2.24
Collecting program verification number	70CD83DD
Reported with CDR version	Crash Data Retrieval Tool 2.24
Reporting program verification number	70CD83DD
Interface used to collected data	Block number: 00 Interface version: 39 Date: 10-09-03 Checksum: 0300
Event(s) recovered	Non-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 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.

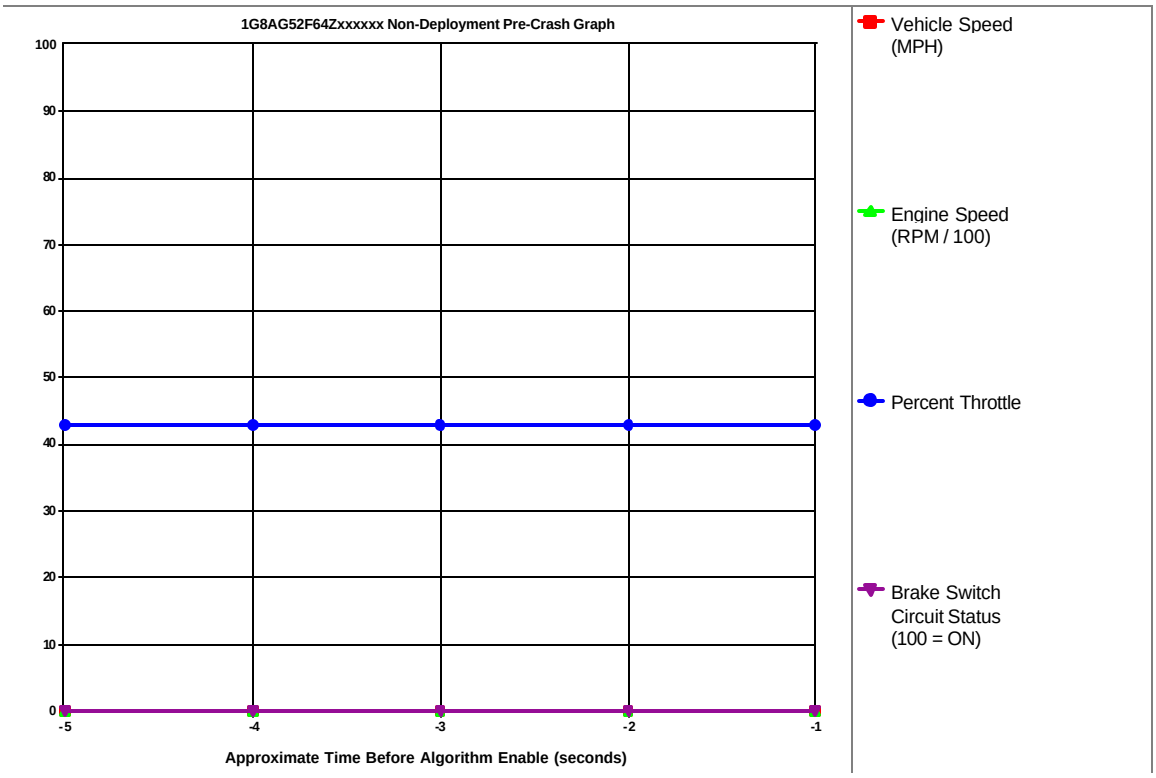
SDM Data Limitations:
-SDM Recorded Vehicle Forward Velocity Change is one of the measures used to make air bag deployment decisions. SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. SDM 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, 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 and deployment level events, 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 five 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. Depending on vehicle option content, the Brake Switch Circuit Status data may not be available.

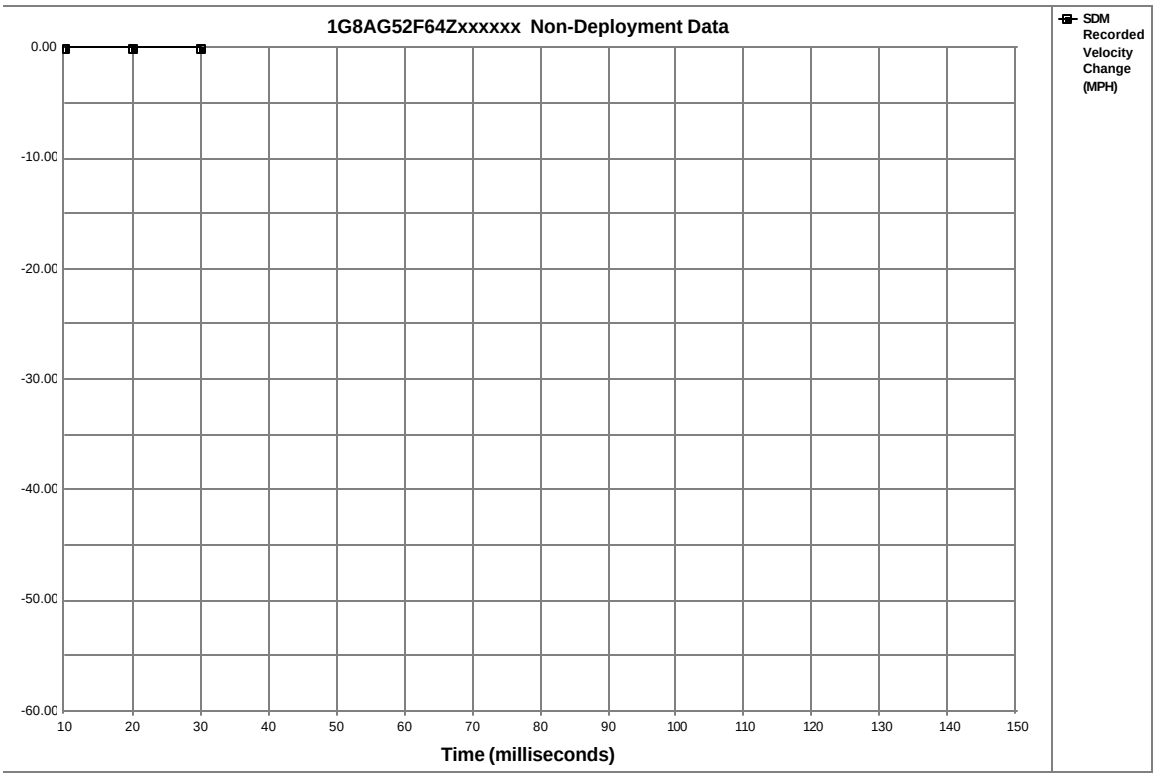
-In most vehicles, the Driver's Belt Switch Circuit is wired directly to the SDM. In some vehicles, the Driver's Belt Switch Circuit Status data is transmitted from the Body Control Module (BCM), via the Class 2 data link, to the SDM.

System Status At Non-Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Ignition Cycles At Non-Deployment	321
Ignition Cycles At Investigation	323
Maximum SDM Recorded Velocity Change (MPH)	-0.40
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	37.5
A Deployment was Commanded Prior to this Event	No



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	0	0	43	OFF
-4	0	0	43	OFF
-3	0	0	43	OFF
-2	0	0	43	OFF
-1	0	0	43	OFF



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
SDM Recorded Velocity Change	0.00	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	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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$04  4B 34 33 38 36 31
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$06  22 70 85 00 00 00
$10  FF D7 F8 00 00 00
$11  94 00 00 00 00 84
$12  00 00 00 00 00 00
$13  02 00 00 00 00 00
$14  F3 04 ED 00 50 00
$18  84 83 84 49 FF 00
$1C  38 32 41 FA FA FA
$1D  FA 38 32 41 FA FA
$1E  FA FA 00 00 00 00
$1F  00 01 00 00 00 00
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$2B  00 00 00 00 00 00
$2C  00 00 FF 00 00 1D
$2D  00 00 00 00 00 00
$2E  00 00 00 00 00 00
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