TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Advanced Information Engineering Services
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GENERAL DYNAMICS CERTIFIED ADVANCED 208-COMPLIANT VEHICLE INVESTIGATION

CASE NO: CA03-048

VEHICLE: 2003 CHEVROLET SILVERADO

LOCATION: STATE OF FLORIDA

CRASH DATE: MAY 2003

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

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CRASH DATE – MAY 2003

BACKGROUND

This on-site investigative effort focused on the crash severity, the performance of the Certified Advanced 208-Compliant (CAC) Safety System, and the resulting injury mechanisms for a 30-year-old female driver of a 2003 Chevrolet Silverado pickup truck **(Figure 1)**. A CAC vehicle is certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC safety system consisted of dual-stage frontal air bags, an occupant sensing system for the front right seating position, and an Event Data Recorder (EDR). The Silverado was involved in a run-off-road crash with a tree that resulted in moderate damage to the vehicle, and a subsequent minor right side sideswipe impact with a guardrail. The unrestrained driver relinquished control of the vehicle and the Silverado departed the left road edge and impacted an overhanging tree and tree limb located on the curbed median of a divided roadway. The fractured tree limb penetrated the windshield and became lodged in the passenger compartment. The impact was sufficient to deploy the first stage of the dual-stage driver's air bag. Since the front right seat was not occupied, the front right passenger's air bag did not deploy. The Silverado was redirected to the opposite side of the roadway and sideswiped a guardrail before coming to rest. The driver sustained a nosebleed and was transported by ambulance to a regional trauma center for treatment and released.

Figure 1. Damaged 2003 Chevrolet Silverado

The Police Accident Report (PAR) for this crash was forwarded to the NASS Zone Center following routine sampling activities by NASS PSU 41 in August, 2003. The PAR was forwarded to the General Dynamics SCI team for review and the data was e-mailed to NHTSA as a potential Certified Advanced Compliant crash investigation. The SCI team secured cooperation from the insurance company and gained access to the vehicle and approval to download the EDR. NHTSA approved the case for on-site investigation on September 2, 2003.

VEHICLE DATA – 2003 Chevrolet Silverado

The 2003 Chevrolet Silverado was identified by the Vehicle Identification Number (VIN): 1GCEC19VX3Z (production sequence omitted). The odometer reading could not be obtained due to the damage to the electrical system as a result of the crash. The vehicle was a four-door, extended-cab, full-size, 4 x 2, pickup truck. The pickup truck was equipped with a 4.8 liter V-8 engine, power brakes with four-wheel ABS, an automatic four-speed transmission, power

steering, and a tilt steering wheel. The Silverado was equipped with Goodyear Wrangler P235/75R16 tires. The manufacturer's recommended tire pressure for the tires was 240 kpa (35 psi). The specific tire data is as follows:

Tire	Measured Pressure	Maximum Pressure	Tread Depth	Restricted	Damage
LF	206.8 kpa (30.0 psi)	303.4 kpa (44.0 psi)	7 mm (9/32")	No	None
LR	206.8 kpa (30.0 psi)	303.4 kpa (44.0 psi)	6 mm (8/32")	No	None
RF	213.7 kpa (31.0 psi)	303.4 kpa (44.0 psi)	6 mm (8/32")	No	None
RR	210.3 kpa (30.5 psi)	303.4 kpa (44.0 psi)	6 mm (8/32")	No	None

The Silverado was configured with a 40/20/40 split bench seat with folding backs and adjustable outboard head restraints for the front seating positions. The center position was configured with a fold-down center armrest. The driver's seat was positioned 12.7 cm (5.0") rear of full-forward and 10.2 cm (4.0") forward of the full-rear track position. The front right seat was positioned in the full-rear position. The rear seating positions were configured with a folding bench seat with adjustable head restraints for the outboard positions.

CRASH SITE

This single-vehicle crash occurred during the nighttime hours of May 2003 in the state of Florida. At the time of the crash, the weather was clear and the asphalt roadway surface was dry. The crash occurred on the eastbound lanes of a four-lane divided roadway. The east/west roadway was configured with two travel lanes in each direction that were separated by a curbed median and bordered by asphalt shoulders. Grassy areas bordered each shoulder and the eastbound shoulder was bordered by a W-beam guardrail. The curbed median consisted of grass and several trees, and was configured with left turn channels. Some of the tree branches partially extended horizontally over the inboard travel lanes. The roadside environment consisted of trees, grass, and wooded areas. The posted speed limit was 64 km/h (40 mph). The scene schematic is included as **Figure 11** of this narrative report.

CRASH SEQUENCE

Pre-Crash

Although not reported by police, rescue personnel reported that the 30-year-old female driver exhibited a strong odor of alcohol. She was operating the vehicle eastbound on the inboard lane of the four-lane divided roadway. The output from the EDR indicated that the vehicle speed five seconds prior to the impact was 126 km/h (78 mph). The driver relinquished control of the vehicle and the Silverado veered slightly to the left against the inboard curb in a tracking mode. The Silverado overrode the curb edge and continued eastbound toward a tree on the median **(Figure 2)**.

Figure 2. Eastbound approach showing struck tree

The tree trunk was leaning toward the eastbound lanes of the roadway and also had limbs overhanging the median curb edge **(Figure 3)**. A V-shaped limb that encompassed two smaller limbs which measured 12.7 cm (5.0”) and 10.2 cm (4.0”) in diameter, radiated off the top of the trunk and was directly in the path of the Silverado. The driver applied the brakes, evidenced by the brake switch circuit status shown as “on” on the EDR output, and the vehicle speed one second prior to Algorithm Enable (AE) was 84 km/h (52 mph).

Figure 3. Close-up of the tree

Crash

The Silverado impacted the tree trunk with the front left aspect. Due to the angled nature of the tree, the direct contact to the vehicle was located above the bumper. The impact with the tree trunk was sufficient to deploy the first stage of the driver’s air bag, as indicated on the EDR output. The maximum SDM-recorded velocity change was -12.2 km/h (-7.6 mph) for the initial impact with the tree trunk. The time from algorithm enable to the maximum SDM-recorded velocity change was 182.5 milliseconds. The tree trunk impact caused a slight counterclockwise (CCW) rotation of the Silverado and the windshield and windshield header struck the V-shaped overhanging tree limb with the front center aspect. The secondary impact severed the tree limb completely from the tree, which resulted in the V-shaped limb becoming wedged against the center of the windshield header. The bottom aspect penetrated the windshield into the passenger compartment and the top aspect overrode the roof of the Silverado.

The Silverado continued in a forward direction and re-entered the roadway in a tracking mode. The vehicle crossed both travel lanes and departed the right roadside. The right side aspect of the Silverado sideswiped a W-beam guardrail as it came to rest facing east on the roadside.

Post-Crash

It was not known how the driver exited the vehicle, although rescue personnel reported that she was found seated in the rear seat of the Silverado upon their arrival. She was transported by ambulance to a regional trauma center where she was treated and released.

VEHICLE DAMAGE

Exterior Damage – 2003 Chevrolet Silverado

The 2003 Chevrolet Silverado sustained moderate frontal damage **(Figure 4)** as a result of the tree impact. The direct damage on the hood began 26.7 cm (10.5”) left of the centerline and extended laterally to the right 35.6 cm (14.0”). The direct contact with the tree produced abrasions and concave deformation to the leading edge of the hood. The corresponding direct damage on the frontal plane began at the front left corner above the bumper and extended laterally 71.1 cm (28.0”) to the centerline of the upper radiator

Figure 4. Frontal damage to the Silverado

support. The left side of the radiator and upper radiator support were abraded and crushed rearward. The left headlamp and grille were separated. The left front fender was crushed rearward to the left front axle. The combined direct and induced damage measured 137.2 cm (54.0") across the upper radiator support **(Figure 5)**. The entire radiator was displaced rearward, and the upper and lower radiator supports were deformed. The hood was buckled rearward the rear aspect of the left front fender was deformed as a result of induced buckling. Six crush measurements were documented along the upper radiator support and were as follows: C1 = 48.9 cm (19.3"), C2 = 40.0 cm (15.8"), C3 = 35.6 cm (14.0"), C4 = 21.0 cm (8.3"), C5 = 5.7 cm (2.3"), C6 = 0.0 cm. The Collision Deformation Classification (CDC) for the initial tree impact was 12-FYMW-2.

Figure 5. Frontal view of the damaged Silverado

The secondary impact with the tree limb resulted in moderate damage to the windshield and windshield header of the Silverado **(Figure 6)**. The direct damage on the windshield header began 36.8 cm (14.5") inboard of the top of the left A-pillar and extended 34.3 cm (13.5") laterally to the right. The windshield header sustained longitudinal and vertical crush as a result of the limb impact. The combined direct and induced damage involved the entire width of the windshield and windshield header and measured 124.5 cm (49.0"). The maximum crush was located at the center of the windshield header and measured 11.4 cm (4.5"). The windshield was holed as a result of the tree limb penetration and the windshield header was buckled laterally and rearward at the center aspect. The CDC for the secondary impact with the tree limb was 12-FYGN-7.

Figure 6. View of windshield header damage and tree limb

The Silverado sustained minor right side damage as a result of the guardrail sideswipe. The direct contact damage began on the right front corner of the front bumper, continued 485.0 cm (190.9") rearward along the lower door area, and terminated 25 cm (9.8") aft of the right rear axle **(Figure 7)**. The direct contact resulted in abrasions that measured 12.7 cm (5.0") in height and were located on the lower aspect of the side trim. The CDC for the sideswipe event was 12-FRLS-9.

Figure 7. Damage to the right side of the Silverado

Interior Damage – 2003 Chevrolet Silverado

The Silverado sustained severe interior damage as a result of passenger compartment intrusion **(Figures 8 and 9)**. The instrument panel was displaced and intruded into the passenger compartment. The knee bolster was partially separated and the right instrument panel was displaced against the front right seat cushion. The plastic dome/map light console was separated from the headliner and the rear view mirror was separated from direct contact with the intruding tree limb. The tree limb intruded 116.8 cm (46.0”) into the front right position from the base of the windshield. Minor body fluid (blood) transfers were present on the left aspect of the headliner and on the inboard aspect of the driver’s sun visor. Scuff marks that measured 7.6 cm (3.0”) in length were present on the center of the windshield header and headliner from direct contact with the tree limb. They began 14.0 cm (5.5”) left of the centerline and extended 17.8 cm (7.0”) to the right. The headliner was separated 7.6 cm (3.0”) vertically from the windshield header at the centerline.

Figure 8. Interior view from left side

Figure 9. Interior view from right side

Multiple intrusions were documented as follows:

Position	Intruded Component	Magnitude of Intrusion	Direction
FL	Windshield header	9.5 cm (3.8”)	Longitudinal
FL	Windshield header	4.4 cm (1.8”)	Vertical
FL	Left instrument panel	19.7 cm (7.8”)	Longitudinal
FC	Windshield header	11.4 cm (4.5”)	Longitudinal
FC	Windshield header	11.4 cm (4.5”)	Vertical
FC	Instrument panel	31.8 cm (12.5”)	Longitudinal
FC	Tree limb, 12.7 cm (5.0”) in diameter	116.8 cm (46.0”)	Longitudinal
FR	Windshield header	2.5 cm (1.0”)	Longitudinal
FR	Right instrument panel	43.8 cm (17.3”)	Longitudinal
FR	Right instrument panel	45.7 cm (18.0”)	Vertical
FR	Tree limb, 12.7 cm (5.0”) in diameter	116.8 cm (46.0”)	Longitudinal

MANUAL RESTRAINT SYSTEMS – 2003 Chevrolet Silverado

The Silverado was equipped with integrated manual 3-point lap and shoulder belts for the driver and front right passenger seating positions. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR). The front right passenger's safety belt was configured with a sliding latch plate and a switchable ELR/Automatic Locking Retractor (ALR). The front center position was equipped with a 2-point lap belt with a locking latch plate. The rear outboard seating positions were equipped with manual 3-point lap and shoulder belts with sliding latch plates and switchable ELR/ALR's. The rear center position was equipped with a 2-point lap belt with a locking latch plate.

Figure 9. View of driver's safety belt highlighting webbing crease and scuff mark

The driver was not utilizing the manual restraint in this crash. Belt non-use was supported by a pronounced crease in the webbing at the plastic retractor cover (in the stowed position) and lack of loading evidence on the safety belt webbing. In addition, a scuff mark was present on the outboard aspect of the driver's seat back from engagement of the safety belt stop button against the seat back fabric while in the stowed position **(Figure 9)**. The EDR summary indicated that the driver's belt switch circuit status was "unbuckled."

CERTIFIED ADVANCED COMPLIANT SAFETY SYSTEM

Frontal Air Bag System

The 2003 Chevrolet Silverado was equipped with a Certified Advanced Complaint Safety System that included dual-stage frontal air bags, an occupant sensing system for the front right seating position, and an EDR. The initial tree impact was sufficient to warrant a first stage deployment of the driver's air bag. The driver's air bag **(Figure 10)** deployed from the steering wheel hub through symmetrical I-configuration cover flaps. Each cover flap measured 7.0 cm (2.8") in width and 11.7 cm (4.6") in height. The deployed air bag measured 66.0 cm (26.0") in diameter. The air bag was vented by two circular ports located at the 11 and 1 o'clock positions on the rear aspect of the air bag. The vent ports measured 2.5 cm (1.0") in diameter and were located 8.9 cm (3.5") inboard of the peripheral seam. The air bag was tethered by two internal straps located at the 3 and 9 o'clock positions that measured 12.7 cm (5.0") in width. An area of faint body fluid transfer (blood) was present on the upper left quadrant of the face of the air bag. The faint transfer extended to the rear aspect of the air bag, from probable post-crash handling by the driver. An area of abrasion was located on the bottom left quadrant of the air bag and measured

Figure 10. Deployed driver's air bag

8.3 cm (3.3”) in width and 10.2 cm (4.0”) in height from contact with the fractured windshield. Dark vinyl transfers were present on the bottom aspect adjacent to the peripheral seam from engagement against the cover flaps during the expansion of the air bag.

Occupant Sensing System

The CAC safety system was configured with a weight sensor in the front right seat cushion designed to detect occupant presence and automatically suppress the front right passenger’s air bag if it detected a weight consistent with a child seat, a booster seat, or a child sitting in the front seat, or if it determined that the front seat was empty. The air bag on/off status could be confirmed by a light on the rearview mirror. Since the front right seat was not occupied, the CAC system suppressed the front right passenger’s air bag. Both front seat positions were also equipped with seat track position sensors which adjusted the air bag deployment level if the seat was in a forward track position.

Event Data Recorder (EDR*)*

The Silverado’s EDR was downloaded by the SCI investigator and the EDR summary report is attached as **Attachment A** at the end of this narrative report. The system recorded a Deployment Event as a result of the tree impact. The system also recorded a previous Non-Deployment Event that was unrelated to this crash and was recorded 113 ignition cycles before this crash. The non-deployment event showed the ignition was on to arm the system, but the engine speed was zero which suggested the engine was not running at the time of the event. In addition the recorded delta-V as 0 km/h, the pre-crash vehicle speed was zero, the throttle percentage was zero, and the brake circuit status was listed as “off.”

OCCUPANT DEMOGRAPHICS – 2003 Chevrolet Silverado

Driver

Age/Sex:	30-year-old female driver
Height:	Unknown
Weight:	64 kg (140 lb)
Seat Track Position:	12.7 cm (5.0”) rear of full-forward and 10.2 cm (4.0”) forward of full-rear
Manual Restraint Use:	Unrestrained
Usage Source:	Vehicle inspection, EDR
Eyewear:	Unknown
Type of Medical Treatment:	Transported by ambulance to a regional trauma center for treatment and released

Driver Injuries

Injury	***Injury Severity (AIS 90/Update 98)***	***Injury Source***
Epitaxis (nosebleed)	Minor (251090.1,4)	Driver’s air bag

Injury source: Hospital records

Driver Kinematics

The 30-year-old female driver was operating the vehicle under the influence of alcohol. She was not restrained by the available manual 3-point lap and shoulder belt. At impact with the tree, the driver's air bag deployed and the driver initiated a forward trajectory. She contacted the expanding air bag with her face which resulted in a nosebleed. The tree limbs intruded into the passenger compartment to the right of the driver and she rebounded rearward. She regained partial control of the Silverado and steered the vehicle to the outboard shoulder. She was probably displaced slightly as the Silverado struck the guardrail, and she brought the vehicle to a controlled stop against the guardrail. It was not known how the driver exited the vehicle, and rescue personnel reported that she was found seated in the rear seat of the Silverado upon their arrival. She was transported by ambulance to a regional trauma center for treatment and released. The driver had additional complaints of shoulder pain, neck pain, and back pain, although there were no related injuries diagnosed by the trauma center.

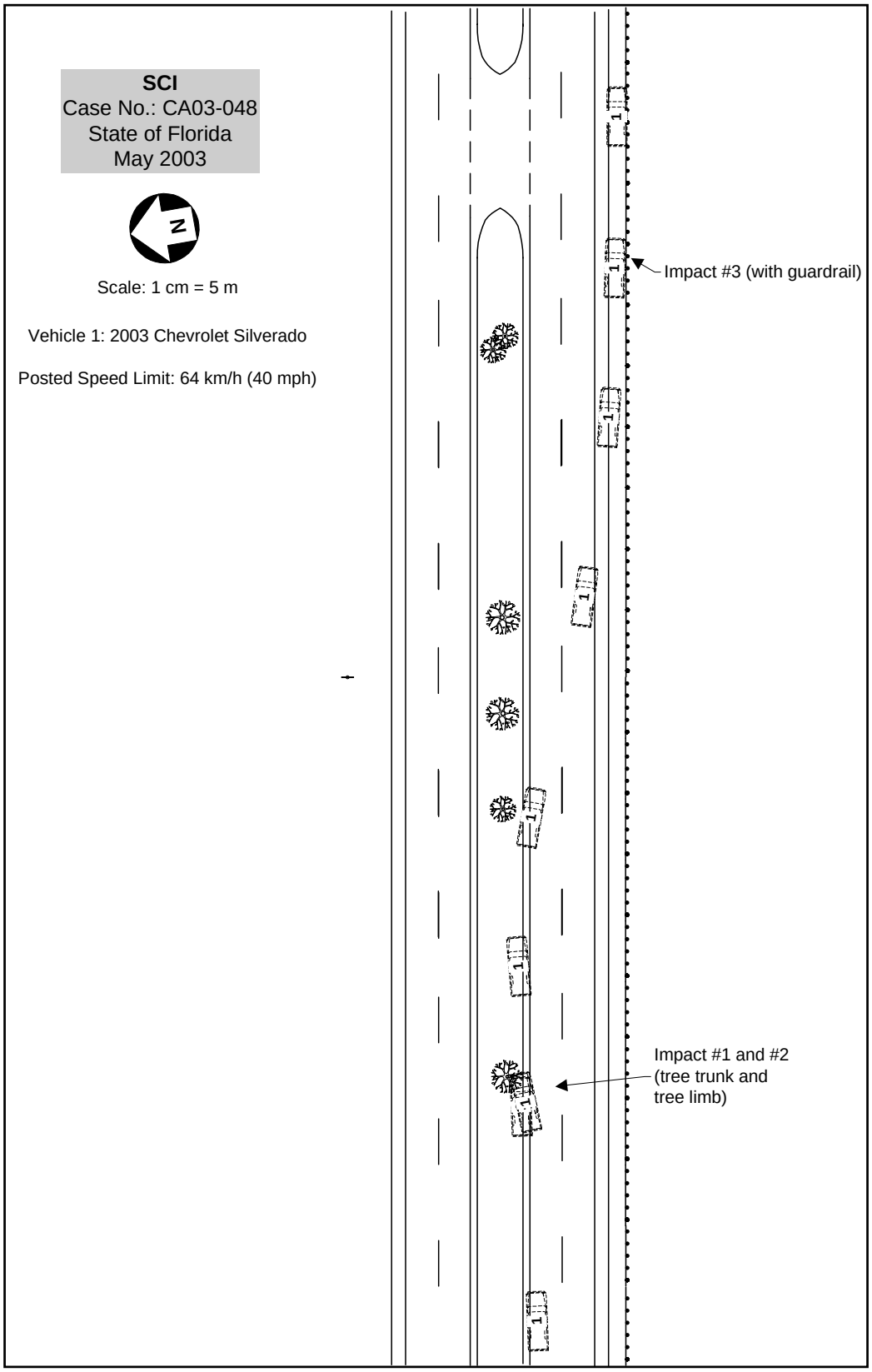


Figure 11. Scene schematic

ATTACHMENT A: EDR REPORT

CDR File Information

Vehicle Identification Number	1GCEC19VX3Zxxxxxx
Investigator	[redacted]
Case Number	
Investigation Date	8/27/03
Crash Date	
Filename	CA03-048 NO SEQUENCE.CDR
Saved on	8/27/2003 9:42:26 AM
Data check information	6141ADCF
Collected with CDR version	Crash Data Retrieval Tool 2.00
Collecting program verification number	A31D1C76
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: 35 Date: 01-02-03 Checksum: 6200
Event(s) recovered	Deployment Non-Deployment

SDM Data Limitations

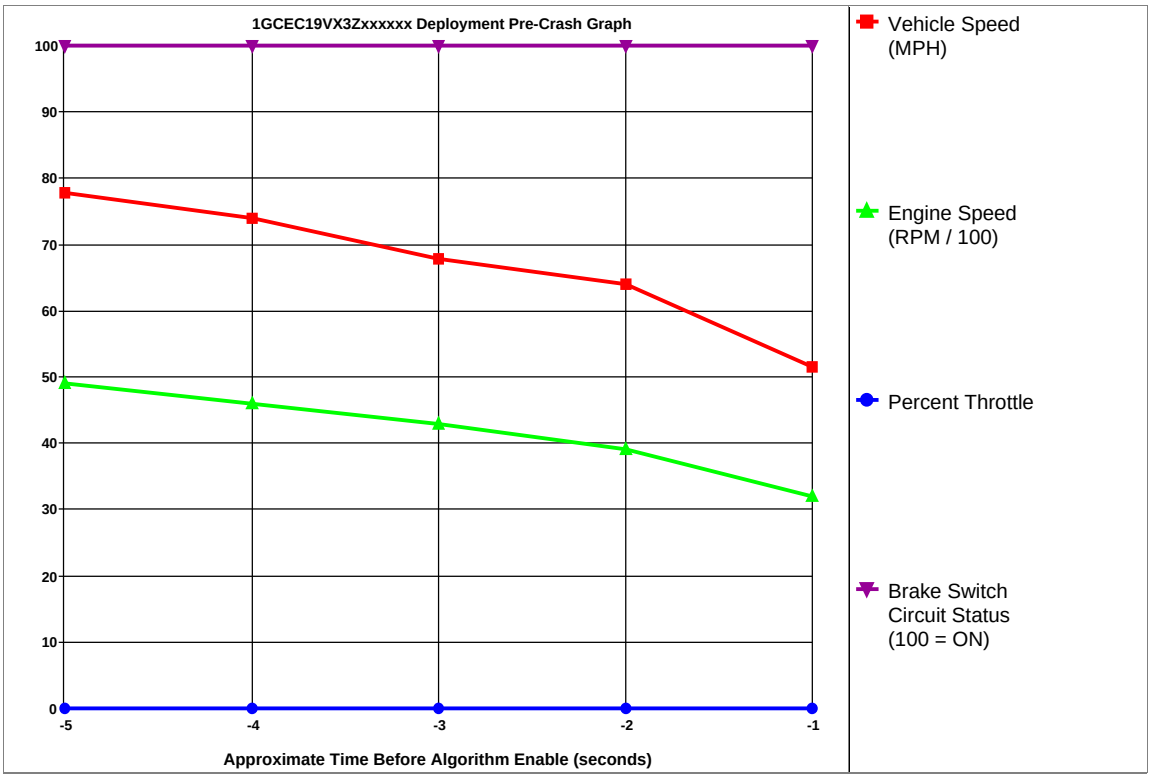
SDM Recorded Crash Events:
There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded 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. 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.

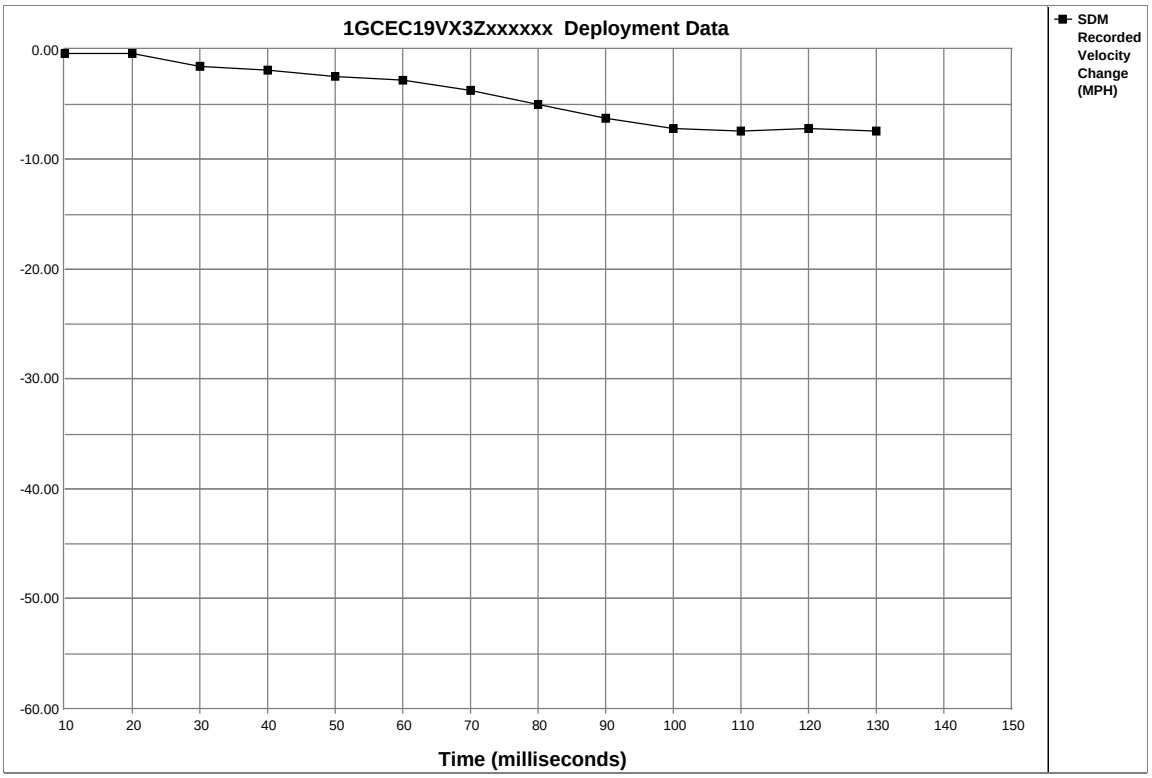
SDM Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the Class 2 data link, to the SDM.
-Brake Switch Circuit Status 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	1806
Ignition Cycles At Investigation	1807
Maximum SDM Recorded Velocity Change (MPH)	-7.60
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	182.5
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	30
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)	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



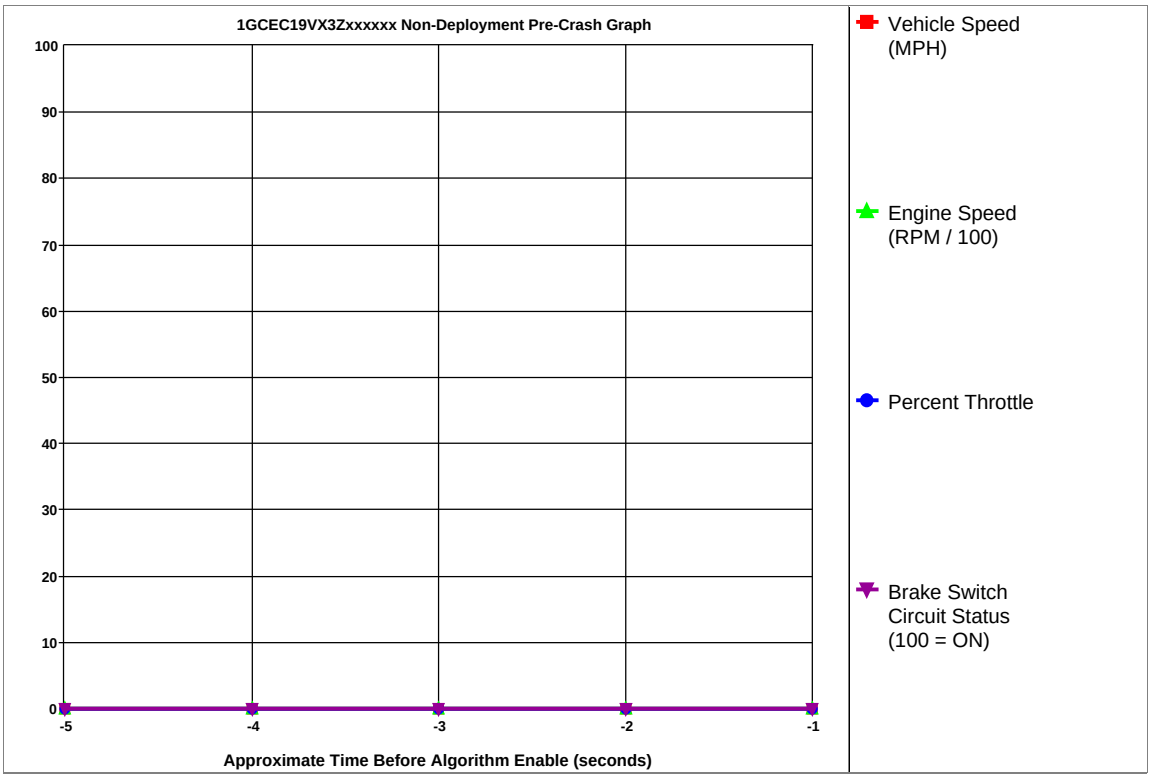
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	78	4864	0	ON
-4	74	4608	0	ON
-3	68	4288	0	ON
-2	64	3904	0	ON
-1	52	3200	0	ON



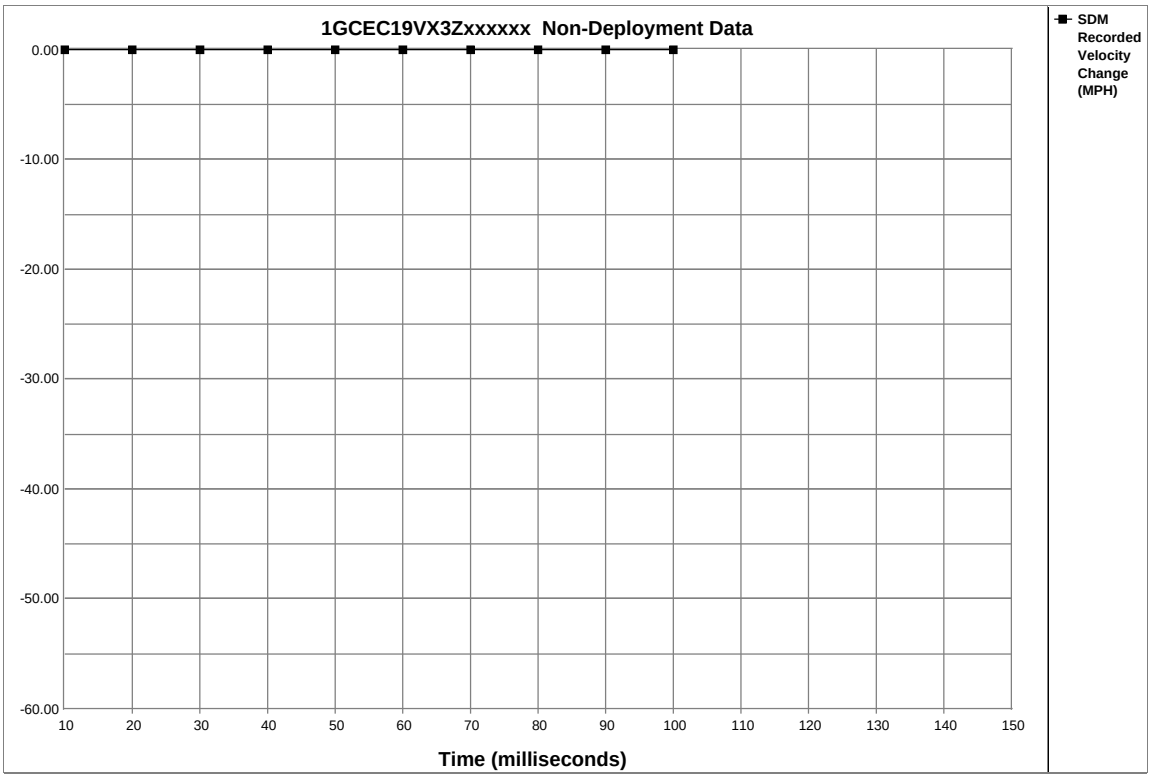
Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.31	-0.31	-1.55	-1.86	-2.48	-2.79	-3.72	-4.96	-6.20	-7.13	-7.44	-7.13	-7.44	N/A	N/A

System Status At Non-Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Ignition Cycles At Non-Deployment	1693
Ignition Cycles At Investigation	1807
Maximum SDM Recorded Velocity Change (MPH)	0.00
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	0
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	0	0	0	OFF
-4	0	0	0	OFF
-3	0	0	0	OFF
-2	0	0	0	OFF
-1	0	0	0	OFF



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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 33 55 53 39 31
$05  00 00 00 00 00 00
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