

On-Site Advanced Occupant Protection Systems Investigation
Dynamic Science, Inc. / Case Number: DS02-027
2002 GMC Envoy 4x2 Four-door Sport Utility Vehicle
California
July, 2002

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crash-worthiness performance of the involved vehicle(s) or their safety systems.

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15. Supplemental Notes The case vehicle was declared a total loss by the insurance company. It was then sold as salvage to a private company in Mexico. The vehicle was repaired and then resold to a private party in California, but the front air bag modules in the vehicle were not replaced.					
16. Abstract This two vehicle collision occurred in the northbound travel lanes of an interstate in southern California in July, 2002 at 0715 hours. The case vehicle is a 2002 GMC Envoy SUV that was driven by a restrained 35-year-old male. The case vehicle was traveling northbound on the interstate in the second lane from the left at a driver reported 89 km/h (55 mph). The other vehicle was a 1991 Ford F150 pickup that was driven by a 55-year-old male. The other vehicle was towing a 1992 Pacific utility trailer. The front right seat of the other vehicle was occupied by a 46-year-old female. The other vehicle was also traveling northbound in the third lane from the left and to the right of the case vehicle at a driver reported 89 km/h (55 mph). The driver of the other vehicle veered to the left to avoid an object on the roadway and in doing so entered the lane the case vehicle was traveling in. The driver of the case vehicle attempted to change lanes to the left, but was unable to do so because there was another vehicle there. The other vehicle sideswiped the right rear (04RZEW1) of the case vehicle with its left front fender. This caused the driver of the case vehicle to lose control of the vehicle veer to the left. The case vehicle crossed the innermost traffic lane and with its front struck (01FDEW2) the concrete divider wall. The total velocity change calculated by the Barrier algorithm of the WINSMASH collision model was 19.0 km/h (11.8 mph). The longitudinal and lateral delta V components were -17.9 km/h (-11.1 mph) and -6.5 km/h (-4.0 mph), respectively. The SDM recorded a maximum velocity change of 31.53 km/h (-19.59 mph). On impact with the concrete divider wall, both front air bags in the case vehicle deployed. The case vehicle bounced off the concrete divider wall with the rear left bumper corner (12LBES1) of the case vehicle and struck the wall again. The case vehicle rotated clockwise 180 degrees to final rest facing in a southerly directions on all four wheels within the first and second lanes from the left. The driver of the case vehicle was able to exit the vehicle under his own power. He complained of pain to his lower back, neck, right foot and left shoulder. He was transported to a trauma center and was treated by the ER staff and then admitted to the hospital. Emergency medical records indicated that he sustained an abrasion to his right dorsal foot and an abrasion to his right knee. He was released from the hospital one day post crash. Neither occupant in the other vehicle reported injuries to the police at the crash scene. The police report did not indicate any treatment at the scene or at a later time. The case vehicle was towed from the scene due to damage and subsequently declared a total loss by the insurance company. The other vehicle sustained minor damage to the front left side and was driven from the scene.					
17. Key Words AOPS, air bag, deployment, injury, SDM			18. Distribution Statement		
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Dynamic Science, Inc.
Crash Investigation
Case Number: DS02-027

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BACKGROUND:

Description: This Advanced Occupant Protection Systems (AOPS) case was identified by DSI through insurance contacts. The case was reported to the NHTSA on November 14, 2002. DSI was assigned the case on November 19, 2002. An on-scene investigation was conducted and the case vehicle was inspected on November 22, 2002. Present at the inspection was a representative of the insurance company who did not allow downloading of the data in the Sensing and Diagnostic Module (SDM). Permission to download the data was obtained the following day from the insurance company, but the case vehicle had been sold at the salvage auction and towed to Mexico. The vehicle was tracked after it was repaired and sold back to a buyer in the U.S. The data from the SDM was downloaded on April 2, 2003, after the vehicle had been repaired.

Investigation Type:	On-Site Advanced Occupant Protection Systems
Crash Location:	California
Crash Date:	July, 2002
Notification Date:	November 19, 2002
Field Work Completed:	April 2, 2003

SUMMARY

Crash Site

This two vehicle collision occurred in the northbound travel lanes of an interstate in southern California in July, 2002 at 0715 hours. At the time of the crash there were no adverse weather conditions and the concrete surface was dry. The northbound interstate was configured with five travel lanes that were separated by raised ceramic reflectors. To the east, the interstate was bordered by an asphalt shoulder. To the west, the interstate was bordered by an asphalt shoulder and beyond the shoulder by a raised concrete divider wall that separated the northbound lanes from HOV lanes. The northbound interstate roadway was straight and level. The speed limit was 105 km/h (65 mph) for automobiles and 89 km/h (55 mph) for vehicles towing trailers.



Figure 1. Direction of travel both vehicles (north)

CRASH SEQUENCE

Pre-Crash

The case vehicle is a 2002 GMC Envoy SUV that was driven by a restrained 35-year-old male (183 cm/72 in, 113 kg/250 lb). The case vehicle was traveling northbound on the interstate in the second lane from the left at a driver reported 89 km/h (55 mph)¹.

The other vehicle was a 1991 Ford F150 pickup that was driven by 55-year-old male. This vehicle was towing a 1992 Pacific utility trailer. The front right seat of the Ford was occupied by a 46-year-old female. The Ford was also traveling northbound in the third lane from the left and to the right of the case vehicle at a driver reported speed of 89 km/h (55 mph).

Crash

The driver of the other vehicle veered to the left to avoid an object on the roadway and in doing so entered the case vehicle's lane of travel. The driver of the case vehicle attempted to change lanes to the left, but was unable to do so because there was another vehicle already there. The other vehicle sideswiped the right rear (04RZEW1) of the case vehicle with its left front fender. This caused the driver of the case vehicle to lose control of the vehicle and it veered to the left. The case vehicle crossed the northbound traffic lane striking (01FDEW2) the concrete divider wall with its left front. Data downloaded from the SDM indicates that the brake switch circuit status was in the "OFF" position through the entire pre-crash sequence. The total velocity change calculated by the Barrier algorithm of the WINSMASH collision model was 23.0 km/h (14.3 mph). The longitudinal and lateral delta V components were -21.6 km/h (-13.4 mph) and -7.9 km/h (-4.9 mph), respectively. The SDM recorded a maximum velocity change of 31.53 km/h (-19.59 mph). On impact with the concrete divider wall, both front air bags in the case vehicle deployed.



Figure 2. Damage right side case vehicle (impact 1)

The case vehicle bounced off the concrete divider wall causing the left bumper corner (12LBES1) of the case vehicle struck the wall. The case vehicle rotated clockwise 180 degrees and came to final rest facing in a southerly directions on all four wheels within the first and second lanes from the left.

Post-Crash

The driver of the case vehicle was able to exit the vehicle under his own power. He complained of pain to his lower back, neck, right foot and left shoulder. He was transported to a trauma center and was treated by the ER staff and then admitted to the hospital. The driver's cervical and lumbar spine, chest, pelvis, left scapula were x-rayed for possible injuries. His cervical spine was also CT-scanned. No codeable injuries were reported as a result of the x-rays and CT-scan. Emergency medical records indicated that he sustained an abrasion to his right dorsal foot from possible contact with the accelerator pedal, and an abrasion to his right knee from possible

¹ Data downloaded from the SDM indicates that the case vehicle's speed five seconds before algorithm enable was 111 km/h (69 mph).

contact with the lower instrument panel. He was released from the hospital one day post crash.

Neither occupant in the other vehicle reported injuries to the police at the crash scene. The police report did not indicate any treatment at the scene or at a later time.

The case vehicle was towed from the scene due to damage and subsequently declared a total loss by the insurance company. The other vehicle sustained minor damage to the front left side and was driven from the scene.

VEHICLE DATA - 2002 GMC Envoy 4x2 Four-door Sport Utility Vehicle

The case vehicle was equipped with a four speed automatic transmission, power four-wheel anti-lock disc brakes, alloy wheels, power steering , a tilt steering wheel, power door locks, power windows, and the OnStar system.

VIN: 1GKDS13S622XXXXXX
 Odometer: Unknown digital display-no power available
 Engine: 4.2L, V6
 Reported Defects: None
 Cargo: None

The case vehicle was equipped with P245/65R17 Michelin Cross Terrain brand tires. The front left tire was de-beaded at the time of the vehicle inspection. The specific tire data is as follows:

Tire	Measured Tread Depth	Measured Pressure	Recommended Pressure	Restricted	Damage
LF	9 mm (11/32 in)	Flat	241 kPa (35 psi)	Yes	None
LR	10 mm (13/32 in)	228 kPa (33 psi)	241 kPa (35 psi)	No	None
RR	9 mm (11/32 in)	221 kPa (32 psi)	241 kPa (35 psi)	No	None
RF	9 mm (11/32 in)	145 kPa (21 psi)	241 kPa (35 psi)	No	None

The front seating positions in the 2002 GMC Envoy were configured with bucket seats with adjustable head restraints. Both head restraints were slightly above the full down positions at the time of the vehicle inspection. Both front bucket seats were equipped with power seat adjustments and the vehicle had no power. Both the driver's and front right seats were adjusted to between the middle and rear most seat positions (the driver's 39.5 cm/15.5 in from the lower A pillar). The seat backs were slightly reclined. The rear seating positions were configured with a 60/40-split bench with folding backs. The bench seats were configured with head restraints on the outboard positions that folded rearward when the seat backs were folded forward.

VEHICLE DAMAGE

EXTERIOR DAMAGE - 2002 GMC Envoy

Damage Description:	Impact 1 (versus other vehicle) Minor damage to the right rear which included the rear fender, and right rear door.	
	Impact 2 (versus concrete divider wall) Moderate damage to the front bumper, grille, hood, left front fender. Minor damage to left rear fender, lights and bumper.	
CDC:	Impact 1- 04RZEW1 Impact 2- 01FDEW2 Impact 3- 12LBES1	
Delta V ² (Impact 2):	Total	23.0 km/h (14.3 mph)
	Longitudinal	-21.6 km/h (-13.4 mph)
	Latitudinal	- 7.9 km/h (-4.9 mph)
	Energy	51914 Joules (38290 ft/lbs)

The sideswipe impact (1) with the other vehicle resulted in minor right rear damage to the case vehicle. The direct/induced damage began at the rear right bumper corner and extended forward 199.0 cm (78.3 in). A crush deformation code of 04RZEW1 was assigned to the damage.

The impact (2) with the concrete divider wall resulted in moderate damage to the front of the case vehicle. The direct damage began at the front right bumper corner and extended across the entire front end. Six crush measurements were taken along the metal bumper backing bar and were as follows: C1=28.0 cm (11.0 in), C2=24.0 cm (9.5 in), C3=16.0 cm (6.3 in), C4=9.0 cm (3.5 in), C5=3.0 cm (1.2 in), C6=5.0 cm (2.0 in). Maximum crush was located at C1. A crush deformation code of 01FDEW2 was assigned to the damage. The principal direction of force was within the 01 o'clock sector and was an estimated 20 degrees. The impact energy was managed by the forward structures of the vehicle.



Figure 3. Front left damage case vehicle (impact 2).

² Calculated using Barrier algorithm of WinSmash and stiffness coefficient calculated using NCAP Test 4416.

The damaged components included the upper and lower radiator supports and the metal bumper backing that was crushed rearward. The front bumper fascia was partially broken away. The left front wheel was displaced rearward and the left wheelbase was shortened by 7.8 cm (3.1 in). The front left tire was de-beaded from the rim.

INTERIOR DAMAGE - 2002 GMC Envoy

Interior damage to the case vehicle was minor and attributed to the deployment of both frontal air bags. There were no visible evidence of driver contacts. Both front air bags, the entire dashboard area, and the entire rear bench seat were splattered with coffee. All doors remained operational.

MANUAL RESTRAINT SYSTEMS - 2002 GMC Envoy

The case vehicle was configured with integrated manual 3-point continuous loop lap and shoulder safety belts with sliding latch plates for the front seat positions. The driver's safety belt was configured with a belt-sensitive emergency locking retractor (ELR) and the front right passenger's safety belt was configured with a belt-sensitive switchable/automatic locking retractor (ALR). The driver's latch plate had abrasions that were consistent with historical usage. The plastic part of the latch plate, where the safety seat belt webbing looped through, also exhibited abrading which is consistent with usage of the safety belt at the time of the crash. Data downloaded from the SDM also indicated that the driver's belt switch circuit status was "buckled" at deployment. The front right occupant's latch plate also had abrasions that were consistent with historical usage.



Figure 4. Driver's integrated lap and shoulder belt.

The three rear seating positions were configured with manual 3-point continuous loop lap and shoulder safety seat belts with sliding latch plates and switchable (ELR/ALR) retractors. The rear outboard safety belts were configured with D-rings and the center position was integrated into the seat back. The rear outboard seats were equipped with Lower Anchors and Tethers For Children (LATCH) anchors.

FRONTAL AND SIDE AIR BAG SYSTEMS - 2002 GMC Envoy

The case vehicle was equipped with dual stage driver and front right passenger air bags. The driver's air bag module was located in the center hub of the steering wheel rim. The dual module cover flaps opened with a vertically oriented flap tear seam (I-configuration). The left and right flaps each measured 11.5 cm (4.5 in) high by 8.0 cm (3.1 in) wide. There were no indications of any damage to the module cover flaps. The diameter of the deflated circular air bag was 69.0 cm (27.2 in). It was equipped with two internal tether straps and two vent ports at the 11 and 01 o'clock positions. There were no indications of any damage or



Figure 5. Deployed front air bags.

occupant contact to driver's air bag. Primarily about the left half of the front of the air bag and the lower half of the back of the air bag coffee was splattered. There were eleven vertical folds and thirteen horizontal folds.

The front right passenger's air bag was a mid instrument panel mount with a single module cover flap. The module cover measured 13.0 cm (5.1 in) high by 33.0 cm (13.0 in) wide. The deflated air bag was vaguely rectangular in shape with a height of approximately 43.0 cm (16.9 in) and a width of approximately 49.0 cm (19.3 in). There was a single tether sewn across the entire top of the air bag. There were two vent ports at the 02 and 10 o'clock positions. There were no indications of any damage to the front right passenger air bag or module cover flap. On the front of the upper right quadrant was what appeared to be a lipstick transfer. There were also two red colored transfers to the mid-top and back right of the air bag. Both were similar in color and appearance to the lipstick transfer. The driver however indicated that there were no other occupants or cargo in the vehicle at the time of the crash. There were no indications of any damage to the module cover flaps, but the module cover was splattered with coffee and the air bag was soaked in coffee.



Figure 6. Front right passenger's air bag

The front seats were equipped with seat mounted side air bags. Neither side air bag deployed.

As noted earlier in this report, the data in the SDM was downloaded after the vehicle had been repaired and sold to a private party. The air bag module covers for both frontal air bags had been replaced, but the air bags had not been replaced. There was a digital message displayed after the vehicle's ignition was turned to the "ON" position that indicated that the air bags needed to be serviced. The private party was aware that the air bags had not been replaced and choose to buy the vehicle in this condition because it made the vehicle affordable.



Figure 7. Repaired driver's air bag

The air bag system is controlled by the SDM. The system consists of the SDM, dual stage driver and front right passenger air bags, seat mounted side air bags, and a driver's seat belt latch usage detector. The primary function of the SDM is to control the deployment of the occupant protection system. The system records the vehicle's forward velocity change. The SDM records 100 milliseconds of data after the deployment criteria is met and up to 50 milliseconds of data before deployment criteria is met.

The SDM data was downloaded using the Vetronix Crash Data Retrieval System. There was a dual stage deployment in this case. The recorded velocity change was higher than the calculated velocity change. This was possibly due to crush damage (shortening of the wheelbase) that is not accounted for in the crush profile. There were indications that the percent of throttle increased prior to impact. This appears to be some sort of anomaly since the engine RPM and vehicle speed were generally dropping throughout the event. The Vetronix report³ indicated that:

1. The SIR warning lamp status was OFF.
2. The driver's belt switch circuit status was BUCKLED.
3. Ignition cycles at deployment were 789.
4. Ignition cycles at investigation were 944⁴.
5. Maximum SDM recorded velocity change was -31.53 km/h (-19.59 mph).
6. The time from algorithm enable (AE) to maximum recorded velocity change was 117.5 milliseconds
7. Driver first stage time algorithm enabled to deployment command criteria met was 10 milliseconds.
8. Driver second stage time algorithm enabled to deployment command criteria met was 10 milliseconds.
9. Passenger first stage time algorithm enabled to deployment command criteria met was 10 milliseconds.
10. Passenger second stage time algorithm enabled to deployment command criteria met was 10 milliseconds.
11. Time between non-deployment and deployment events was N/A.
12. Frontal deployment level event counter was 1.
13. Event recording complete was YES.
14. Multiple events associated with this record was NO.
15. The vehicle speed was 111 km/h (69 mph) five through four seconds. The vehicle speed decelerated to 106 km/h (66 mph) three seconds before AE, to 101 km/h (63 mph) two seconds before AE, and 85 km/h (53 mph) to one second before AE.
16. The brake switch circuit status was OFF throughout the pre-crash sequence.

³ See Attachment 2

⁴ There are 155 ignitions cycles between deployment event and investigations because vehicle was repaired and sold to a private party prior to EDR download.

VEHICLE DATA - 1991 Ford F150

Description:	1991 Ford F150 pickup towing 1992 Pacific utility trailer, per police report	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None	
Cargo:	Unknown	
Damage Description:	Minor to the front right side per police report	
CDC:	Unknown, not available for inspection	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

OCCUPANT DEMOGRAPHICS - 2002 GMC Envoy

	Occupant 1
Age/Sex:	35/Male
Seated Position:	Front left
Seat Type:	Leather bucket seat, track adjusted between middle and rear most track positions. Adjustable head restraint not damaged. Seat back slightly reclined.
Height:	188 cm (74 in)
Weight:	82 kg (180 lb)
Occupation:	Unknown
Pre-existing Medical Condition:	Surgery to right great toe and shoulder for chronic dislocation
Alcohol/Drug Involvement:	None
Driving Experience:	Presumed >15 years
Body Posture:	Normal upright
Hand Position:	Both on steering wheel, unknown o'clock positions
Foot Position:	Right on accelerator pedal and left on floor
Restraint Usage:	Seat integrated lap and shoulder safety belt available and used
Air bag:	Steering wheel mounted front air bag available and deployed. Seat back mounted side air bag available and not deployed

OCCUPANT DEMOGRAPHICS - 1991 Ford F150

Age/Sex:	55/Male	46/Female
Seated Position:	Front left	Front right
Seat Type:	Unknown	Unknown
Height:	183 cm (72 in)	Unknown
Weight:	113 kg (250 lb)	Unknown
Occupation:	Unknown	Unknown
Pre-existing Medical Condition:	None reported	None reported
Alcohol/Drug Involvement:	None	NA
Driving Experience:	Presumed > 30 years	NA
Body Posture:	Unknown	Unknown
Hand Position:	Unknown	Unknown
Foot Position:	Unknown	Unknown
Restraint Usage:	Lap and shoulder safety belt available and used per police report	Lap and shoulder safety belt available and used per police report

OCCUPANT INJURIES - 2002 GMC Envoy

Driver injuries were obtained from medical records which included the Emergency Room medical records, Hospital Admission records, Radiology records (X-rays, CT), Lab records, and Discharge Summary records. The drivers cervical and lumbar spine, chest, pelvis, left scapula were x-rayed for possible injuries. His cervical spine was also CT scanned. No codeable injuries were reported.

	<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Driver:	Abrasion to right dorsal foot	890202.1, 1	Accelerator pedal	Possible
	Abrasion right knee	890202.1, 1	Lower left instrument panel	Possible
	Complained of pain to neck, lower back, left shoulder, and bilateral feet. Not codeable injuries.			

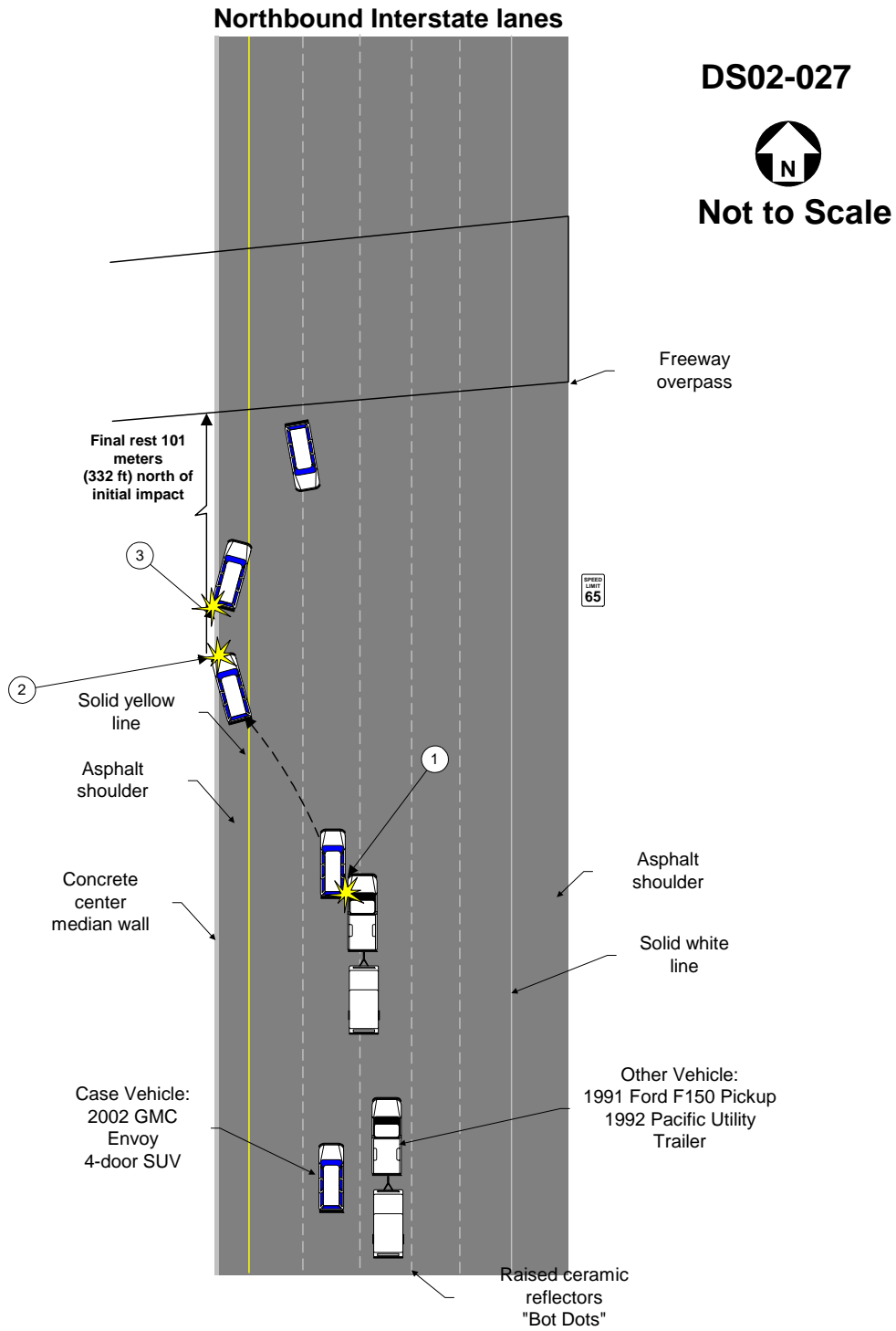
OCCUPANT INJURIES - 1991 Ford F150

	<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Driver:	No injuries reported			
Right Front Occupant:	No injuries reported			

OCCUPANT KINEMATICS - 2002 GMC Envoy

The 35-year-old male driver was wearing the available integrated 3-point continuous loop safety belt. The leather bucket seat was adjusted to between the middle and rear most seat track position. The seat back was slightly reclined. The head restraint was adjusted to slightly above the full down position. The side swipe impact (1) between the right rear side of the case vehicle and the front left side of the other vehicle did not have much affect on the driver of the case vehicle. He steered to the left in an effort to avoid the collision and lost control of the vehicle. On impact with the concrete divider wall, the driver's air bag deployed and driver initiated a forward and slightly lateral trajectory to the right. He loaded the safety belt, evidenced by abrading of the latch plate. His right knee possibly contacted the lower instrument panel even though there was no evidence of contact, and resulted in an abrasion. His right foot possibly contacted the accelerator pedal which resulted in an abrasion. The driver also loaded the deployed driver's air bag though there was no evidence of contact. He rebounded rearward into the seat back and was redirected to the left as the case vehicle rotated clockwise and struck the concrete divider wall with its left rear bumper corner. As the vehicle came to rest 180 degrees from its original travel direction, the driver came to rest in the left front seat upright. It is unknown if the case vehicle's OnStar System activated and dispatched emergency personnel. The driver exited the vehicle under his own power. He sustained police reported "complaint type injuries" and was transported by ambulance to a local trauma center. He was initially treated by ER personnel and admitted to the hospital and released the next day.

Attachment 1. Scene Diagram

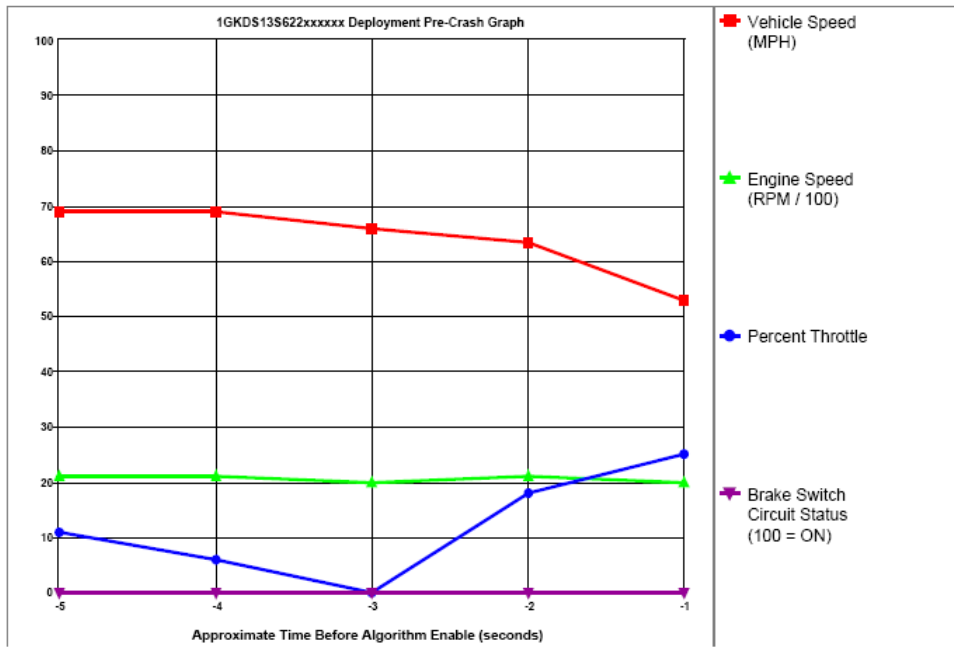


Attachment 2. Vetronix (SDM) Report

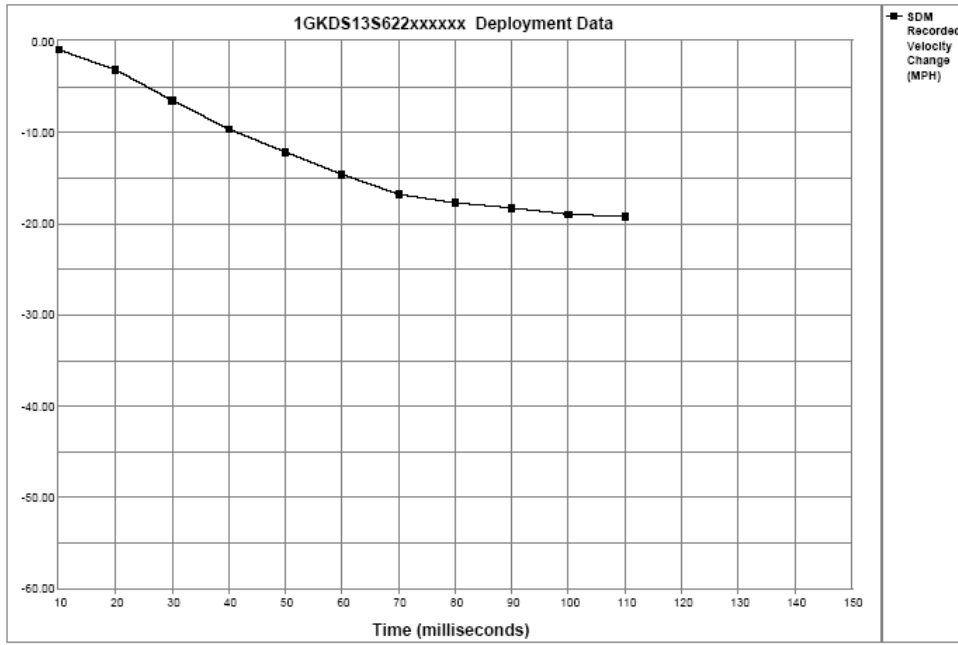


System Status At Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Deployment	789
Ignition Cycles At Investigation	944
Maximum SDM Recorded Velocity Change (MPH)	-19.59
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	117.5
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	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	69	2112	11	OFF
-4	69	2112	6	OFF
-3	66	1984	0	OFF
-2	63	2112	18	OFF
-1	53	1984	25	OFF



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.93	-3.10	-6.51	-9.81	-12.09	-14.57	-16.74	-17.67	-18.29	-18.91	-19.22	N/A	N/A	N/A	N/A