On-scene Investigation / Vehicle to Vehicle
Dynamic Science, Inc. / Case Number: DS02022
2001 Saturn SL2 four door sedan
California
October, 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 crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract

This three vehicle broadside type collision occurred at a four leg intersection. The collision occurred in California in October, 2002 at 1303 hours. The case vehicle is a 2001 Saturn SL2 four-door sedan that was being driven by a restrained 18-year-old male. There was a restrained 22-year-old male occupant in the front right seat of the case vehicle. The case vehicle was equipped with a driver's air bag, a front right passenger air bag, a driver's head curtain side air bag, and a front right passenger head curtain side air bag. The head curtain side air bags were located in the roof rails above the doors and deploy downward.

The other vehicle is a 2002 Toyota Sienna van that was driven by a restrained 41-year-old male. The second other vehicle is a 1994 Ford Ranger Pickup that was being driven by a restrained 55-year-old male. There was a restrained 39-year-old female occupant in the front right seat.

The case vehicle was stopped for a red traffic light at a freeway off-ramp heading west. The Ford was also stopped for the red traffic light of the freeway off-ramp, to the left of the case vehicle and heading west. The Toyota was northbound approaching the intersection. When the traffic light turned green for the case vehicle and the Ford, both vehicles entered the intersection. The driver of the case vehicle accelerated to a speed of 24 km/h (15 mph). At a point between 4 and 3 seconds before impact, the driver of the case vehicle began braking. The speed of the case vehicle just prior to impact was 11 km/h (7 mph). The driver of the Toyota saw the vehicles enter the intersection and began braking and steering to the left. However, the Toyota failed to stop for the red traffic light and struck the left side of the Ford. The Ford rotated in a clockwise direction and there was a second impact between these two vehicles. The Toyota continued forward and struck the left side of the case vehicle. At impact, the driver's head curtain side air bag deployed in the case vehicle. The driver and front right passenger air bags did not deploy.

17. Key Words	18. Distribution Statement
Air bag, deployment, head curtain side air bag, side air bag, crash, redesigned	

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Dynamic Science, Inc.
Accident Investigation
Case Number: DS02022

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BACKGROUND:

Description:	This head curtain side air bag case was identified by DSI through insurance contacts. The case was reported to the NHTSA on October 29, 2002. DSI was assigned the case on October 30, 2002. All field work was completed on November 4, 2002.
Investigation Type:	On-scene
Crash Location:	California
Crash Date:	October, 2002
Notification Date:	October 30, 2002
Field Work Completed:	November 4, 2002

SUMMARY:

This three vehicle broadside type collision occurred at a four leg intersection. The collision occurred in California in October, 2002 at 1303 hours. The case vehicle is a 2001 Saturn SL2 four-door sedan that was being driven by a restrained 18-year-old male (178 cm/70 in, 73 kg/160 lbs)[1]. There was a restrained 22-year-old male occupant (185 cm/73 in, 77 kg/170 lbs) in the front right seat of the case vehicle. The case vehicle was equipped with a driver's air bag, a front right passenger air bag, a driver's head curtain side air bag, and a front right passenger head curtain side air bag. The head curtain side air bags were located in the roof rails above the doors and deploy downward.

The other vehicle is a 2002 Toyota Sienna van that was driven by a restrained 41-year-old male. The second other vehicle is a 1994 Ford Ranger Pickup that was being driven by a restrained 55-year-old male. There was a restrained 39-year-old female occupant in the front right seat.

Figure 1. Toyota Sienna approach (North)

Figure 2. Case vehicle and Ford Ranger approach (West)

[1]Restraint use based on vehicle inspection. The SDM indicated that the driver's seat belt was buckled.

The case vehicle was stopped for a red traffic light at a freeway off-ramp heading west. The Ford was also stopped for the red traffic light of the freeway off-ramp, to the left of the case vehicle and heading west. The Toyota was northbound approaching the intersection at a minimum pre-braking travel speed of 66 km/h (41 mph). When the traffic light turned green for the case vehicle and the Ford, both vehicles entered the intersection. The driver of the case vehicle accelerated to a speed of 24 km/h (15 mph)[2]. At a point between 4 and 3 seconds before impact, the driver of the case vehicle began braking. The speed of the case vehicle just prior to impact was 11 km/h (7 mph). The driver of the Toyota saw the vehicles enter the intersection and began braking and steering to the left. However, the Toyota failed to stop for the red traffic light and struck the left side of the Ford. The Ford rotated in a clockwise direction and there was a second impact between these two vehicles. The Toyota continued forward and struck the left side of the case vehicle. The total velocity change for the case vehicle as calculated by the Missing Vehicle algorithm of the WinSmash collision model was 22 km/h (14 mph). The longitudinal and lateral delta V components were -4 km/h (-2 mph) and 22 km/h (14 mph), respectively. The impact was sufficient to generate a Near Deployment Event. A Near Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the front air bags. The Sensing Diagnostic Module (SDM) recorded a forward velocity change of -3.5 km/h (-2.2 mph) at the 120 ms mark with a maximum velocity change of -4.2 km/h (-2.6 mph) at the 100 ms mark. At impact, the driver's head curtain side air bag deployed in the case vehicle. The driver and front right passenger air bags did not deploy.

Figure 3. Case vehicle, left side

Figure 4. Case vehicle, close up of damage

[2]Speed as recorded by electronic module. Acceleration calculations indicated a speed of 23 km/h (14 mph), see Attachment 1 (Calculations).

The driver of the case vehicle complained of pain to his left shoulder and left arm. He was transported by ground ambulance to a local hospital for treatment. He sustained minor lacerations to his left hand from flying glass and a contusion to the left flank from the side door. He was treated and released. The front right occupant complained of pain to his stomach and knees. He was also transported by ground ambulance to a local hospital for treatment. He sustained an abrasion to the left side of his abdomen from the lap portion of the seat belt. He was treated and released.

Figure 5. Driver's head curtain side air bag

The driver of the Toyota Sienna complained of pain to both arms, but indicated that he would seek his aid on his own.

The driver of the Ford Ranger complained of pain to his neck, left leg, and left arm. He also sustained a 0.6 cm (0.25 in) laceration near his right eye. He was transported by ground ambulance to a local hospital. The front right occupant of the Ford complained of pain to her left thigh, left elbow, and neck. She was transported by ground ambulance to a local hospital for treatment.

All three vehicles were towed from the scene due to damage. The case vehicle was declared a total loss by the insurance company.

Scene Diagram

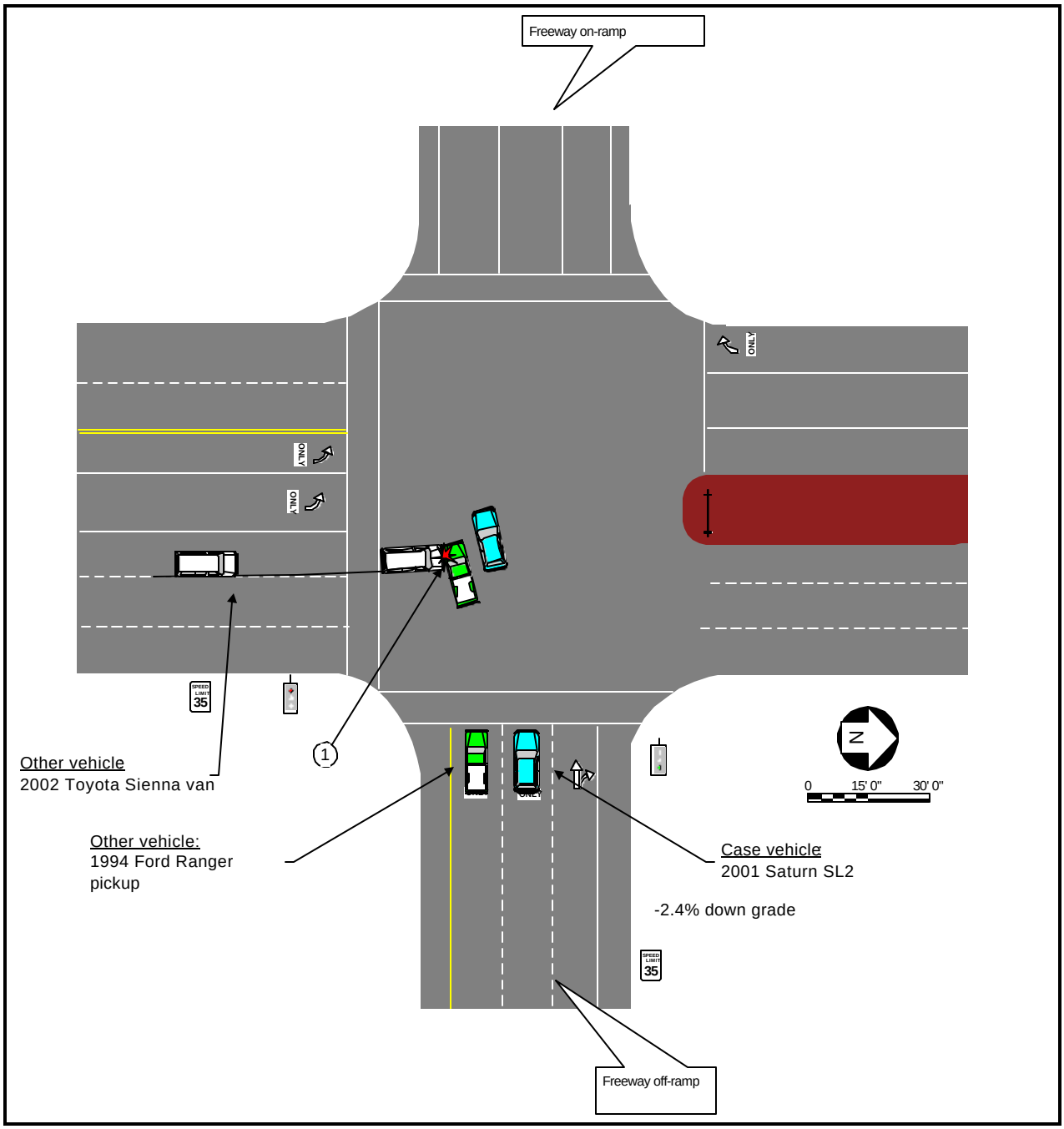


Figure 6. Scene diagram–impact 1

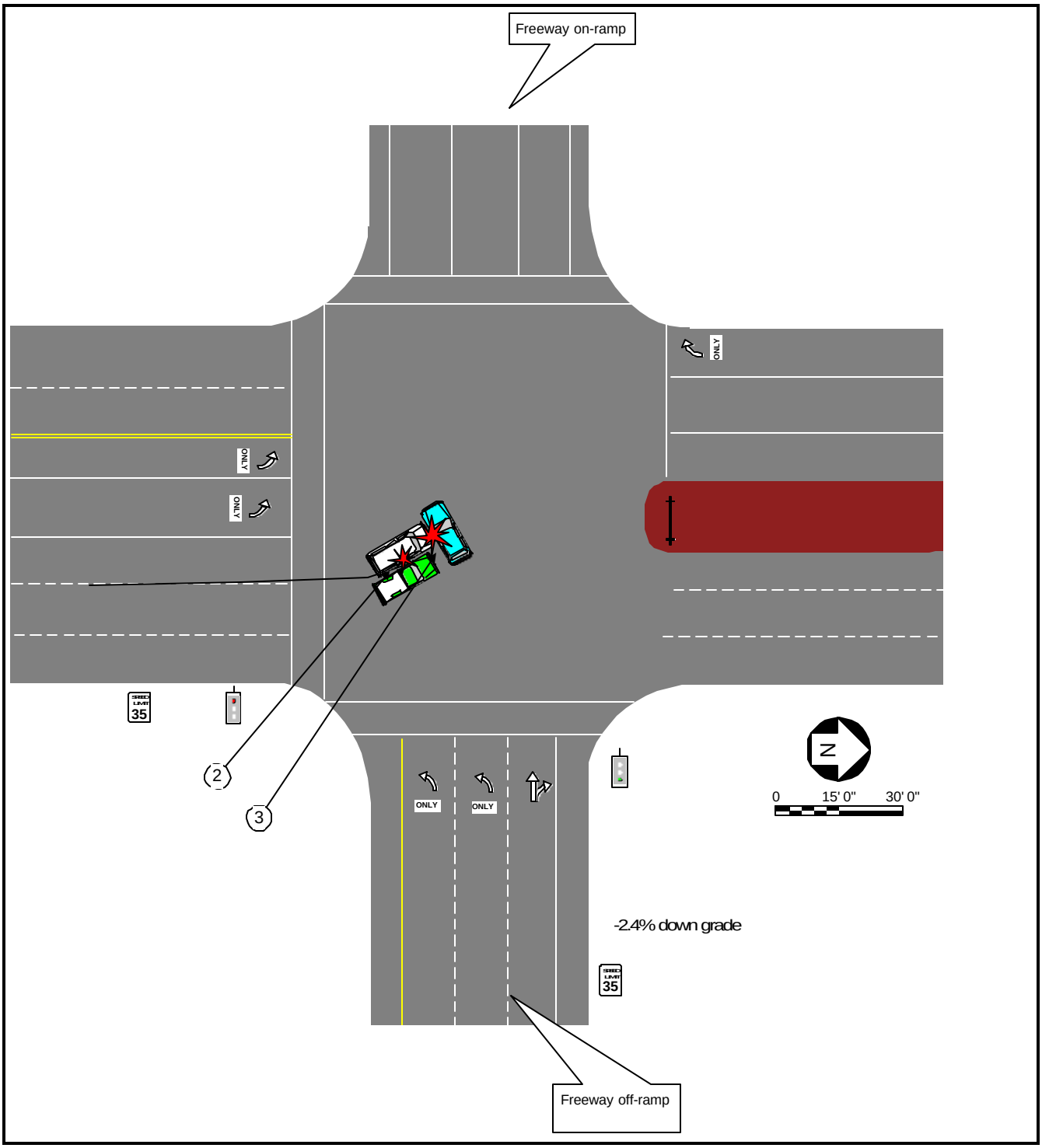


Figure 7. Scene diagram–impacts 2 and 3

DETAILED INFORMATION

Vehicles

Case vehicle

Description:	2001 Saturn SL2 four door sedan	
VIN:	1G8ZK547X1Z3xxxxxx	
Odometer:	30,997 km (19,261 miles)	
Engine:	1.9 L, 4 cylinder	
Reported Defects:	None	
Cargo:	None	
Damage Description:	Lateral crush to left side, left door. Side glass disintegrated. Vehicle towed from scene.	
CDC:	09LYEW3	
Delta V:	Total	22 km/h (14 mph)
	Longitudinal	-4 km/h (2 mph)
	Latitudinal	22 km/h (14 mph)
	Energy	28,005 joules (20,655 ft-lbs)

Figure 8. Case vehicle, left side

The case vehicle sustained 184 cm (72 in) of direct contact to the left side of the vehicle. The damage began 35 cm (14 in) forward of the rear axle and extended into the driver's door. The residual crush measured along the sill was as follows: C1=0 cm (0 in), C2=5 cm (2 in), C3=18 cm (7 in), C4=22 cm (9 in), C5=22 cm (9 in), C6=0.5 cm (0.2 in). The maximum crush was between C4 and C5. The principle direction of force was within the 9 o'clock sector and was an estimated 280 degrees. The left front door intruded 30 cm (12 in) into the passenger compartment. The left front window disintegrated upon impact. Both left side doors were jammed shut.

Safety features discussion

The driver's manual restraint system consisted of a continuous loop 3-point lap and shoulder belt with a sliding latch plate. The emergency locking retractor was located in the B-pillar. The front right seat and all rear outboard seat positions were equipped with lap and shoulder belts using switchable automatic/emergency locking retractors. The middle rear seat was equipped with a lap belt. The vehicle was not equipped with seat belt pretensioners.

Figure 9. Exterior view, head curtain side air bag

Figure 10. Interior view, head curtain side air bag

The case vehicle was equipped with redesigned (reduced force) driver and front right passenger air bags, a driver's roof rail mounted head impact air bag, and a front right passenger roof rail mounted head curtain side air bag. The driver's air bag was mounted in the steering wheel hub. The front right passenger air bag was a mid instrument panel mount. The front air bags did not deploy. The side air bags were an option for the S model for 2001. The head curtain side air bag modules were located in the roof rails above the front doors. They were designed to deploy downwards. The inflation cylinders were located in the instrument panel inboard of the A-pillars. The side impact sensors were located in the lower B pillars for sedans. The driver's side head curtain side air bag did deploy during the crash. This air bag was 81 cm (32 in) long and was secured by tethers at either end. The single module cover flap opened at the designed tear point and there was no damage to the cover. There were no indications of any contact or damage to the air bag itself.

Other vehicle

Description:	2002 Toyota Sienna van	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Moderate damage to right front and right side, per police report. Vehicle towed from scene.	
CDC:	Unknown	
Delta V:	Total	14 km/h (9 mph)
	Longitudinal	-13 km/h (-8 mph)
	Latitudinal	-5 km/h (-3 mph)
	Energy	10,362 joules (7,643 ft lbs)

Other vehicle

Description:	1994 Ford Ranger pickup	
VIN:	Unknown	
Odometer:	Unknown	
Engine:	Unknown	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Moderate damage to left side, per police report. Vehicle towed from the scene.	
CDC:	Unknown	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

Occupants

Case vehicle (Saturn)	Occupant 1	Occupant 2
Age/Sex:	18/Male	22/Male
Seated Position:	Front left	Front right
Seat Type:	Fabric covered bucket seat. Seat adjusted to rear most track position. Seat back slightly reclined.	Fabric covered bucket seat. Seat adjusted to rear most track position. Seat back slightly reclined.
Height:	178 cm (70 in)	185 cm (73 in)
Weight:	73 kg (160 lbs)	77 kg (170 lbs)
Occupation:	Full time college student.	Full time college student.
Pre-existing Medical Condition:	None noted	None noted
Alcohol/Drug Involvement:	None	None
Driving Experience:	1 year	NA
Body Posture:	Normal, upright	Normal, upright
Hand Position:	Both hands on steering wheel, left higher than right	NA
Foot Position:	Left on floor board, right on brake	Presumed to be on floor.
Restraint Usage:	3-point continuous loop lap and shoulder belt, used	3-point continuous loop lap and shoulder belt, used
Air bag:	Steering wheel mounted front air bag, did not deploy. Roof rail mounted head curtain side air bag, deployed.	Mid instrument panel mounted front air bag, did not deploy. Roof rail mounted head curtain side air bag, did not deploy.

Other vehicle (Toyota)	Occupant 1
Age/Sex:	41/Male
Seated Position:	Front left
Seat Type:	Bucket seat
Height:	175 cm (69 in)
Weight:	59 kg (130 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Unknown
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Right foot presumed to be on brake.
Restraint Usage:	Lap and shoulder belt used, per police report

Other vehicle (Ford)	Occupant 1	Occupant 2
Age/Sex:	55/Male	39/Female
Seated Position:	Front left	Front right
Seat Type:	Unknown	Unknown
Height:	170 cm (67 in)	Unknown
Weight:	73 kg (160 lbs)	Unknown
Occupation:	Unknown	Unknown
Pre-existing Medical Condition:	None noted	None noted
Alcohol/Drug Involvement:	None	NA
Driving Experience:		NA
Body Posture:	Unknown	Unknown
Hand Position:	Unknown	Unknown
Foot Position:	Unknown	Unknown
Restraint Usage:	Lap and shoulder belt used, per police report	Lap and shoulder belt used, per police report

Injuries and Injury Mechanisms

Case vehicle (Saturn)

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Lacerations, left hand	790600.1,2	882.0	Flying glass
	Contusion, left flank	590402.1,2	922.2	Door side panel
RF Occupant:	Abrasion, abdomen	590202.1,2	911.0	Lap portion of seat belt

Other vehicle (Toyota)

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	Complained of pain to both arms	Not codeable		

Other vehicle (Ford)

	INJURY	OIC CODE	ICD-9	SOURCE
Driver:	0.64 cm (0.25 in) laceration right eye	290600.1,1	870.0	Unknown
RF Occupant:	Complained of pain			

Occupant Kinematics

The 18-year old driver of the case vehicle was seated in the fabric covered bucket seat in a normal, upright fashion. The seat was adjusted to the rear most track position. The seat back was slightly reclined. The seat back was covered by flower print seat cover. He was wearing the available lap and shoulder belt. The shoulder belt upper anchorage was in the mid position. Both of his hands were on steering wheel, with the left slightly higher than right. He was wearing all plastic sunglasses and a short sleeve shirt. At impact, the head curtain side air bag deployed. The driver responded to the 280 degree direction of force by moving to his left and slightly forward. His head likely engaged the air bag, but there were no resultant visible contacts to the air bag and the driver stated that he did not have any facial or head injuries. The side glass did disintegrate–most likely due to distortion from the intruding vehicle. The driver did sustain several minor lacerations from the flying glass. His left flank engaged the intruding door panel–causing a contusion.

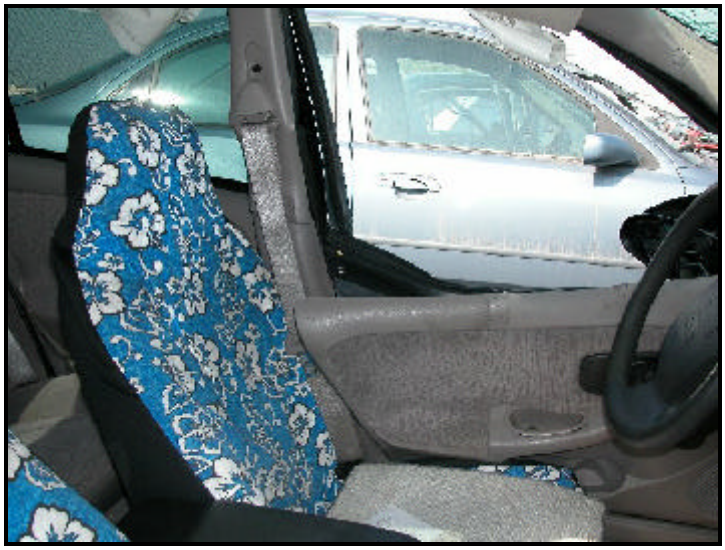


Figure 11. Left interior, door panel

The 22-year-old male front right passenger was seated in the fabric covered bucket seat in a normal, upright fashion. The seat was adjusted to the rear most track position. The seat back was slightly reclined. The seat back was covered by flower print seat cover. He was wearing the available lap and shoulder belt. The shoulder belt upper anchorage was in the mid position. At impact, he responded to the 280 degree direction of force by moving to his left and slightly forward. He loaded the seat belt causing an abrasion to the left side of his abdomen. He complained of pain to his knees (from coming together) but there was no visible injury.

Figure 12. Driver's seated position

Figure 13. Front right passenger seated position

Attachment 1. Calculations

CASE NUMBER: DS02022

Comments: Acceleration from stop for case vehicle

*** * END VEL W/ A RATE, I VEL, DISTANCE * ***

$Ve = \sqrt{Vi^2 + 2 \times a \times D}$

$Ve = \sqrt{0.00^2 + 2 \times 4.00 \times 53.00}$

$Ve = \sqrt{0.00 + 424.00}$

$Ve = \sqrt{424.00}$

$Ve = 20.59$

Ve = Ending Velocity in FPS.
Vi = Initial Velocity in FPS.
a = Acceleration in FPS².
D = The Distance in Feet.
2 = A Constant.

INPUTS:	
The Initial Vel in FPS is:	0.00
The Acceleration Rate is:	4.00
The Distance in Feet is:	53.00

RESULTS:	
The Ending Vel in FPS is:	20.59

CASE NUMBER: DS02022

Comments: Slide to stop speed for Sienna

*** * MINIMUM SPEED W/ KNOWN DRAG FACTOR * ***

$S = \sqrt{30 \times D \times f}$

$S = \sqrt{30 \times 76.10 \times 0.70}$

$S = \sqrt{1598.10}$

$S = 39.97$

S = The Speed in MPH.
30 = A Constant.
D = The Distance in Feet.
f = The Adjusted Accel/Drag Factor.

INPUTS:	
The Acceleration/Drag Factor is:	0.70
The Distance in Feet is:	76.10

RESULTS:	
The Speed in MPH is:	39.97
The Velocity in FPS is:	58.59

CASE NUMBER: DS02022

Comments: Minimum pre-braking travel speed for Sienna

*** * COMBINED MINIMUM SPEEDS W/ KNOWN SPEEDS * ***

$S = \sqrt{S^2(1) + S^2(2) + \ldots S^2(n)}$

$S = \sqrt{(39.97)^2 + (8.70)^2 + (0.00)^2 + (0.00)^2 + (0.00)^2 + (0.00)^2 + (0.00)^2 + (0.00)^2}$

$S = \sqrt{1597.60 + 75.69 + 0.00 + 0.00 + 0.00 + 0.00 + 0.00 + 0.00}$

$S = \sqrt{1673.29}$

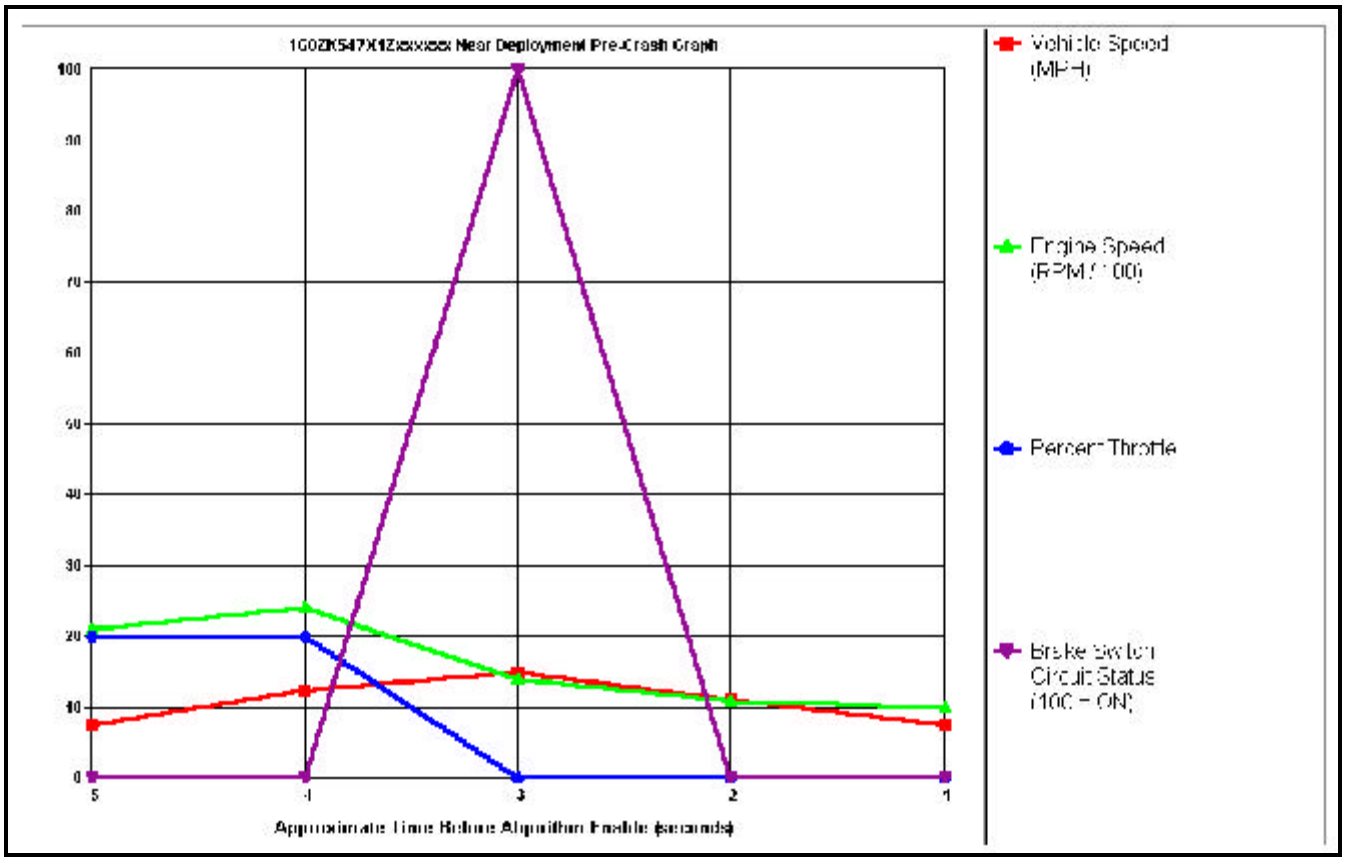
$S = 40.90$

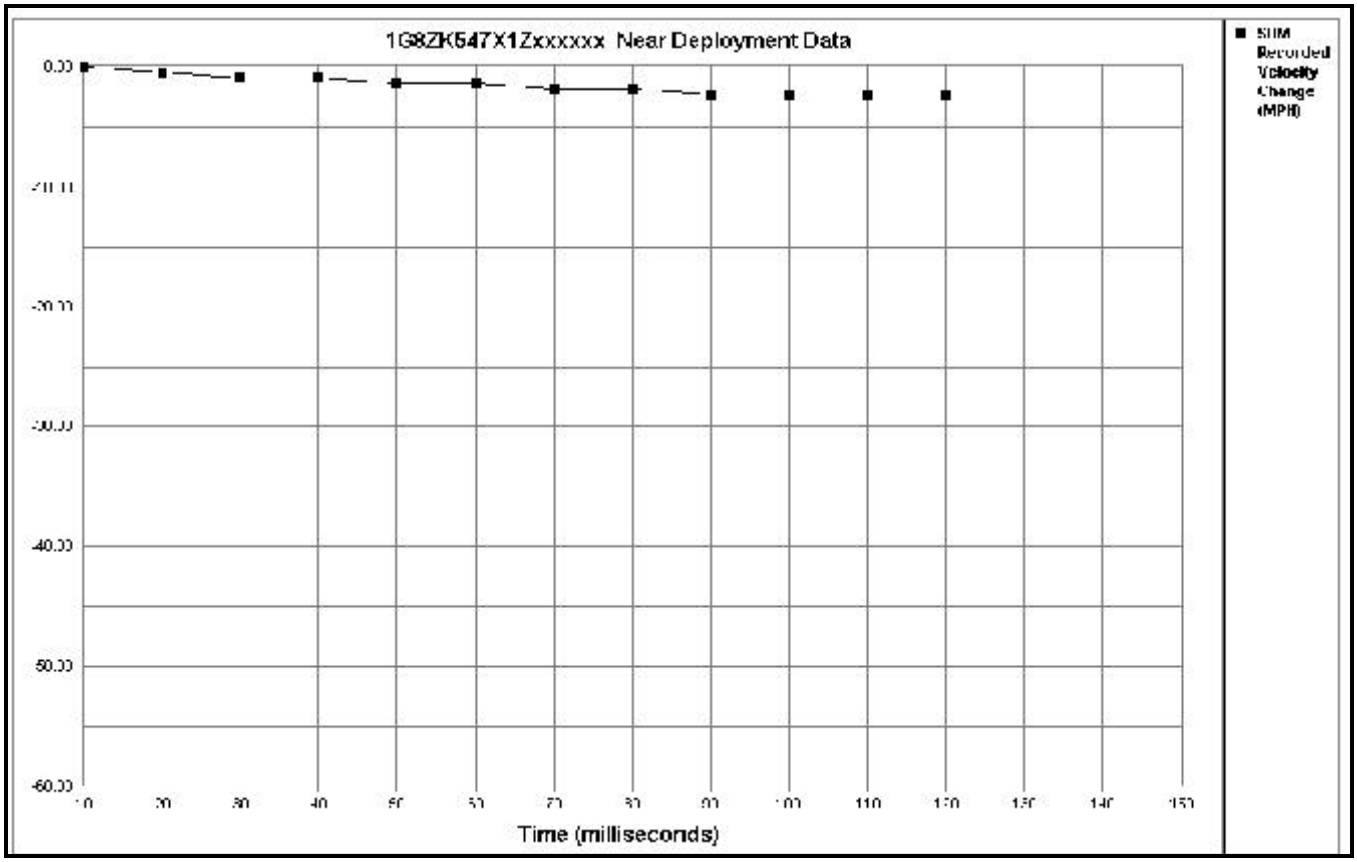
S = The Speed in MPH.
S^2 = The Individual Min. Speed.
(1), (2), (n) = The # of the individual speed.

INPUTS:	
Speed #1 in MPH is:	39.97
Speed #2 in MPH is:	8.70

RESULTS:	
The Speed in MPH is:	40.90
The Velocity in FPS is:	59.95

Attachment 2. Vetronix report for case vehicle (2001 Saturn SL2)




1G8ZK547X1Zxxxxxx Near Deployment Data
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
Time (milliseconds)
SDM Recorded Velocity Change (MPH)

1G8ZK547X1Zxxxxxx System Status At Near Deployment	
SR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Passenger Front Air Bag Suppression Switch Circuit Status	Air Bag Not Suppressed
Ignition Cycles At Near Deployment	3565
Ignition Cycles At Investigation	3573
Maximum SDM Recorded Velocity Change (MPH)	-2.99
Algorithm enable to Maximum SDM Recorded Velocity Change (msec)	100

Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
SDM Recorded Velocity Change	0.00	-0.41	-0.88	-0.88	-1.32	-1.32	-1.76	-1.76	-2.19	-2.19	-2.63	-2.19	N/A	N/A	N/A

PRE-CRASH DATA				
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	7	2112	20	OFF
-4	12	2432	20	OFF
-3	15	1408	0	ON
-2	11	1088	0	OFF
-1	7	960	0	OFF