TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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VERIDIAN ON-SITE
SIDE IMPACT CURTAIN DEPLOYMENT FATALITY / EVENT DATA RECORDER EQUIPPED VEHICLE INVESTIGATION

VERIDIAN CASE NO. CA01-044

VEHICLE - 2001 SATURN SL1

LOCATION - STATE OF MICHIGAN

CRASH DATE - JULY, 2001

Contract No. DTNH22-94-D-07058

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.

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15. *Supplementary Notes* On-site investigation of a oblique angle collision that involved a 2001 Saturn SL1 4-door sedan equipped with a side impact curtain.			
16. *Abstract* This on-site investigation focused on the injury mechanisms that caused the death of a 57 year old female front right passenger of a 2001 Saturn SL1 4-door sedan. The Saturn SL1 was equipped with redesigned frontal air bags and side impact curtains. The right side impact curtain deployed as a result of an oblique angle collision with a 2001 GMC Yukon SLT 4x4 sport utility vehicle. The driver of the 2001 Saturn SL1 was operating the vehicle northbound on approach to a 3-leg intersection. The Saturn driver slowed the vehicle due to traffic congestion ahead as the rear right area was impacted by the front left area of a 2001 Ford Explorer Sport-Trac 4x4 sport utility also traveling northbound behind the Saturn. This initial impact re-directed the Saturn counterclockwise into the opposing travel lanes, and across the path of the southbound 2001 GMC Yukon. As the Saturn crossed the southbound lanes, the right passenger area was impacted by the frontal area of the GMC. Impact resulted in severe damage to the Saturn and minor damage to the GMC. This secondary impact deployed the Saturn's right side impact curtain. The unrestrained 22 year old female driver of the 2001 Saturn SL1 was displaced rearward (out-of-position) in a reclined position due to the initial rear-end impact. She initiated a lateral/slightly rearward trajectory in response to the secondary 4 o'clock impact force and loaded the front right seat back/passenger resulting in unspecified non-incapacitating injuries. The Saturn driver was subsequently transported to the emergency room of a local hospital for treatment and released. The unrestrained 57 year old female front right passenger of the 2001 Saturn SL1 was also displaced rearward (out-of-position) in a semi-reclined position due to the initial rear-end impact. Hyper extension of the neck over the seat back/head restraint resulted in a fracture and dislocation of the atlanto-occipital joint along with an underlying brain stem laceration. At impact with the GMC, she initiated a lateral/slightly rearward trajectory in response to the 4 o'clock impact force. The Saturn driver entered the front right space and compressed the passenger against the right side interior surface resulting in a multitude of soft tissue injuries, bilateral rib fractures, and abdominal trauma. Although death was probably immediate, the Saturn passenger was transported to a local trauma center and pronounced deceased shortly after arrival.			
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BACKGROUND

This on-site investigation focused on the injury mechanisms that caused the death of a 57 year old female front right passenger of a 2001 Saturn SL1 4-door sedan. The Saturn SL1 was equipped with redesigned frontal air bags and side impact curtains. The right side impact curtain deployed as a result of an oblique angle collision with a 2001 GMC Yukon SLT 4x4 sport utility vehicle. The driver of the 2001 Saturn SL1 was operating the vehicle northbound on approach to a 3-leg intersection. The Saturn driver slowed the vehicle due to traffic congestion ahead as the rear right area was impacted by the front left area of a 2001 Ford Explorer Sport-Trac 4x4 sport utility also traveling northbound behind the Saturn. This initial impact re-directed the Saturn counterclockwise into the opposing travel lanes, and across the path of the southbound 2001 GMC Yukon. As the Saturn crossed the southbound lanes, the right passenger area was impacted by the frontal area of the GMC. Impact resulted in severe damage to the Saturn and minor damage to the GMC. This secondary impact deployed the Saturn's right side impact curtain. The unrestrained 22 year old female driver of the 2001 Saturn SL1 was displaced rearward (out-of-position) in a reclined position due to the initial rear-end impact. She initiated a lateral/slightly rearward trajectory in response to the secondary 4 o'clock impact force and loaded the front right seat back/passenger resulting in unspecified non-incapacitating injuries. The Saturn driver was subsequently transported to the emergency room of a local hospital for treatment and released. The unrestrained 57 year old female front right passenger of the 2001 Saturn SL1 was also displaced rearward (out-of-position) in a semi-reclined position due to the initial rear-end impact. Hyper extension of the neck over the seat back/head restraint resulted in a fracture and dislocation of the atlanto-occipital joint along with an underlying brain stem laceration. At impact with the GMC, she initiated a lateral/slightly rearward trajectory in response to the 4 o'clock impact force. The Saturn driver entered the front right space and compressed the passenger against the right side interior surface resulting in a multitude of soft tissue injuries, bilateral rib fractures, and abdominal trauma. Although death was probably immediate, the Saturn passenger was transported to a local trauma center and pronounced deceased shortly after arrival.

The crash notification was provided to NHTSA by the local investigating police agency on Thursday, August 16, 2001 and immediately assigned to the Veridian SCI team as an on-site investigative effort. The on-site investigator arrived on August 21st and completed field activities on Thursday, August 23, 2001.

SUMMARY

Crash Site

This four vehicle crash occurred during the afternoon hours of July, 2001. At the time of the crash, it was daylight with no adverse conditions as the roads were dry. The crash occurred at a (straight/level) 3-leg intersection between a local artery and an elementary school driveway **(see Figure 19 - page**

16). The northbound lanes consisted of one (inboard) through lane, and one right turn lane which provided access to the adjacent elementary school. The southbound lanes consisted of one (inboard) through/right turn lane and one (outboard) deliniated "flair" passing lane which merged approximately 57.0 meters (187.0 feet) south of the intersection. The asphalt surfaced roadway was bordered by barrier curbs to the east and a narrow paved shoulder (and grass field) to the west. Traffic control consisted of an overhanging signal system in a steady green phase for north/southbound traffic. Intersecting traffic was required to trip the signal by an in-road detection system. The posted speed limit at the crash site was 80.0 km/h (50.0 mph).

Pre-Crash

The restrained 28 year old female driver of the 2001 Ford Explorer Sport-Trac (V1) was operating the vehicle northbound **(Figure 1)** on approach to the 3-leg intersection *(at a police reported unknown speed)* when she became distracted by a conversation with the front right passenger and failed to observe traffic congestion ahead. Upon recognition of the impending harmful event, she braked in avoidance and remained in the northbound lane prior to the collision. The front right and rear right seating positions were occupied by a restrained 37 year old female and 37 year old male, respectively.

The unrestrained 22 year old female driver of the 2001 Saturn SL1 (V2) was operating the vehicle northbound on approach to the 3-leg intersection when she observed traffic congestion ahead. She slowed the vehicle from a (EDR recorded) speed of 27.4 km/h (17.0 mph) at the pre-crash five second interval to 12.9 km/h (8.0 mph) at the three second interval, *which was one second prior to the initial impact with the Ford.*

The unrestrained 28 year old female driver of the 2001 GMC Yukon SLT 4x4 sport utility vehicle (V3) was operating the vehicle southbound **(Figure 2)** on the inboard lane at a (driver reported/EDR recorded) speed of 67.6 km/h (42.0 mph) when she observed the northbound Saturn cross her path of travel. Upon recognition of the impending harmful event, she steered right/braked in avoidance, and entered the outboard (southbound) lane prior to the collision. This trajectory was evidenced by 8.4 meters (27.6 feet) of ABS brake marks identified at the scene. The vehicle slowed to a (EDR recorded) speed of 19.3 km/h (12.0 mph) at the one second pre-crash interval. The GMC's EDR logged active braking three seconds prior to impact **(as a near deployment event; see Figure 21 - page 18)**. The front right seating position was occupied by a restrained 9 year old male child. The rear left/right seating positions were occupied by an unrestrained and restrained 13 year old male, respectively. The rear center position was occupied by a 3 month old infant male who was restrained within a rearward facing child safety seat.

The 33 year old male driver of the 2000 Chevrolet K-1500 Silverado 4x4 pickup truck (V4) was operating the vehicle northbound (ahead of the Saturn and Ford) and entered the 3-leg intersection at a (driver reported) speed of 8.0 - 16.0 km/h (5.0 - 10.0 mph) when he slowed for traffic congestion ahead to a (EDR recorded) speed of 10.0 km/h (6.0 mph) at the pre-crash five second interval. During the following four seconds of the pre-crash interval, the vehicle's speed fluctuated to a speed of 12.9 km/h (8.0 mph), as the Chevrolet's EDR logged repeated on/off active braking **(as a near deployment event; see Figure 22 - page 19)**. This was indicative of two foot *("feathered")* driving as both feet are used to operate the automatic transmission accelerator and brake pedals.

Figure 1. Northbound approach view.

Figure 2. Southbound approach view.

Crash - Impact #1

As the Ford Explorer (V1) approached the 3-leg intersection, the front left area impacted the rear right area of the Saturn SL1 (V2) which resulted in moderate damage to the Ford and severe damage to the Saturn **(Figure 3)**. Pre-impact braking by the Ford Explorer was confirmed by the variance in bumper heights between the two vehicles, and lack of associated override/underride damage sustained. The point of impact was confirmed by tire marks and gouge marks documented at the crash site. Although the involved drivers could not recall the specific phase of the overhead traffic control, physical evidence and vehicle recorded speeds suggested that the light was in a steady green phase as *northbound* congestion slowed traffic to a sluggish pace. The Saturn's EDR logged a vehicle speed of 12.9 km/h (8.0 mph) one second prior to the crash which, when compared to the following interval, equaled an acceleration rate of 30.6 km/h (19.0 mph).

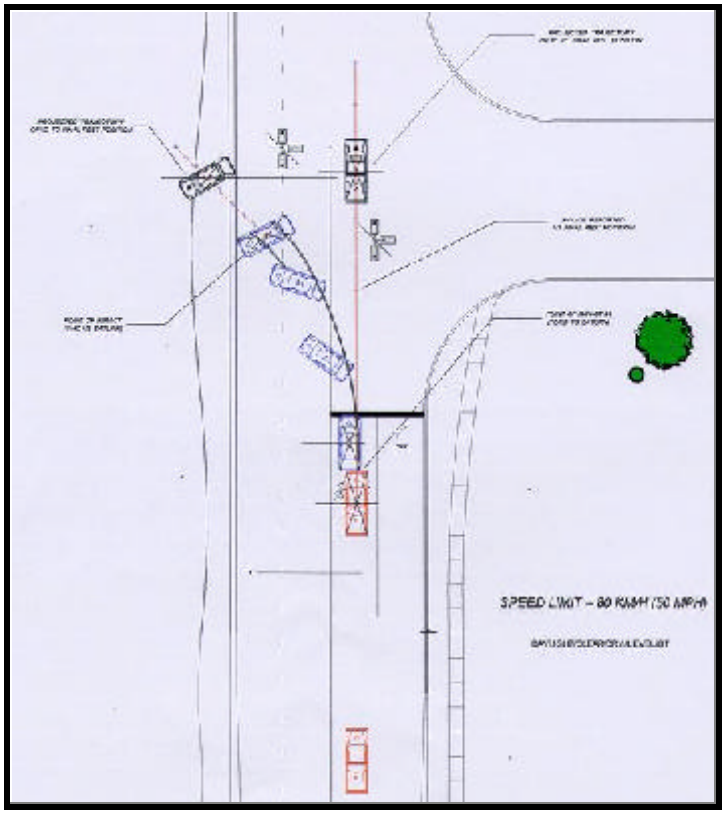

Figure 3. Impact #1 schematic - (V1) Ford vs. (V2) Saturn.

Vehicle velocity changes and impact speeds were calculated utilizing the damage and trajectory algorithms of the WinSMASH reconstruction program. Although multiple impact scenarios invalidate the use of the trajectory algorithm for the determination of impact speeds, the inclusion of vehicle EDR data and the presence of physical evidence allowed for certain parameters to be established within a reasonable and conservative amount of accuracy. Therefore, the projected post-impact trajectories yield results that can be included in the final case report. Although SAE standards do not specifically address the use of these methods, given reasonable practice encourages the utilization of all data for the purposes of safety research. The WinSMASH trajectory algorithm computed speeds *at impact* of 13.0 km/h (8.1 mph) for the Saturn (V2) and 80.5 km/h (50.0 mph) for the striking Ford (V1). Computed velocity changes were 36.6 km/h (22.7 mph) for the Saturn and 20.5 km/h (12.7 mph) for the Ford with matching respective positive and negative longitudinal values. Impact resulted in deployment of the Ford's redesigned frontal air bag system.

Impact #2

At this point, the Saturn (V2) rotated 115 degrees counterclockwise and traveled 18.6 meters (61.0 feet) along its post-impact trajectory into the southbound lanes **(Figure 4)**, and across the path of the southbound 2001 GMC Yukon (V3). The Saturn's pre-impact trajectory was evidenced by 20.7 meters (67.9 feet) of yaw marks identified at the scene. As the Saturn crossed the outboard (southbound) lane, the right passenger area was impacted by the frontal area of the GMC resulting in severe damage to the Saturn

Figure 4. Northwest post-impact trajectory for the 2001 Saturn SL1 (V2).

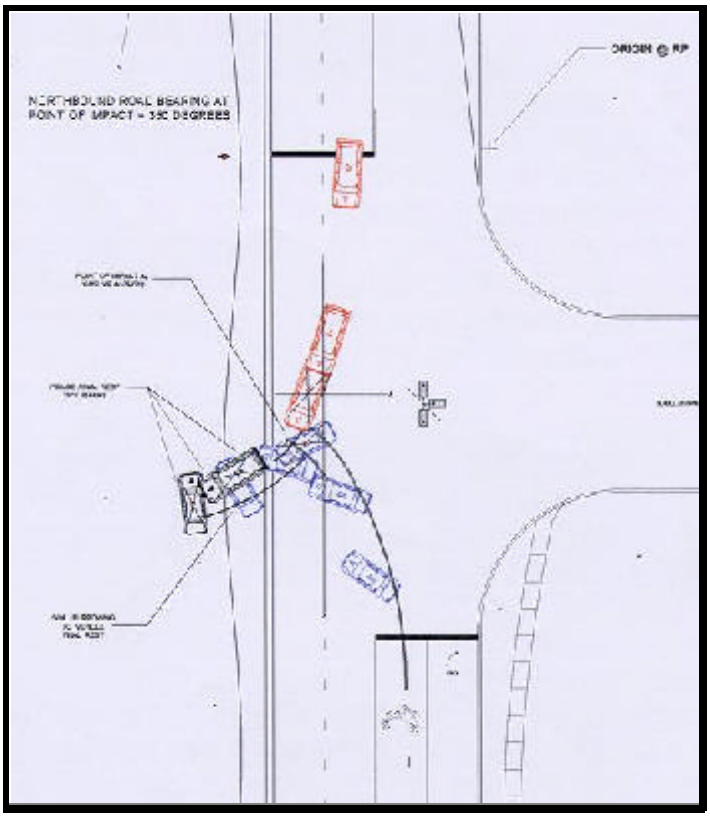

Figure 5. Impact #2 schematic - (V3) GMC vs. (V2) Saturn.

and minor damage to the GMC **(Figure 5)**. The WinSMASH trajectory algorithm computed speeds *at impact* of 68.9 km/h (42.8 mph) for the Saturn and 16.0 km/h (9.9 mph) for the striking GMC. Computed velocity changes were 33.9 km/h (21.1 mph) for the Saturn and 16.5 km/h (10.3 mph) for the striking GMC. The Saturn's latitudinal component was 16.9 km/h (10.5 mph) as the GMC's longitudinal component was -16.2 km/h (-10.1 mph). Impact induced deceleration was not sufficient to deploy the GMC's redesigned frontal air bag system, however, the Saturn's right side impact curtain did deploy. The Saturn's EDR recorded a near deployment event **(see Figure 20 - page 17)**. Although the obtuse nature of the impact configuration resulted in initial engagement along the front left and center sections of the GMC, subsequent spin out contact (or clockwise rotation of the Saturn) engaged the remainder of the end structure during post-impact travel. The vehicles sustained contact 9.7 meters (31.8 feet) in a southwesterly direction to final rest off the west shoulder with the Saturn facing northwest and the GMC facing southwest **(Figure 6)**. This post-impact trajectory was evidenced by 8.6 meters (28.2 feet) of scuff marks and soil furrowing identified at the crash site.

Figure 6. Police photo northeast of the 2001 Saturn (V2) and 2001 GMC (V3) final rest position.

Impact #3

Following the impact with the Saturn (V2), the Ford Explorer Sport-Trac (V1) continued northbound

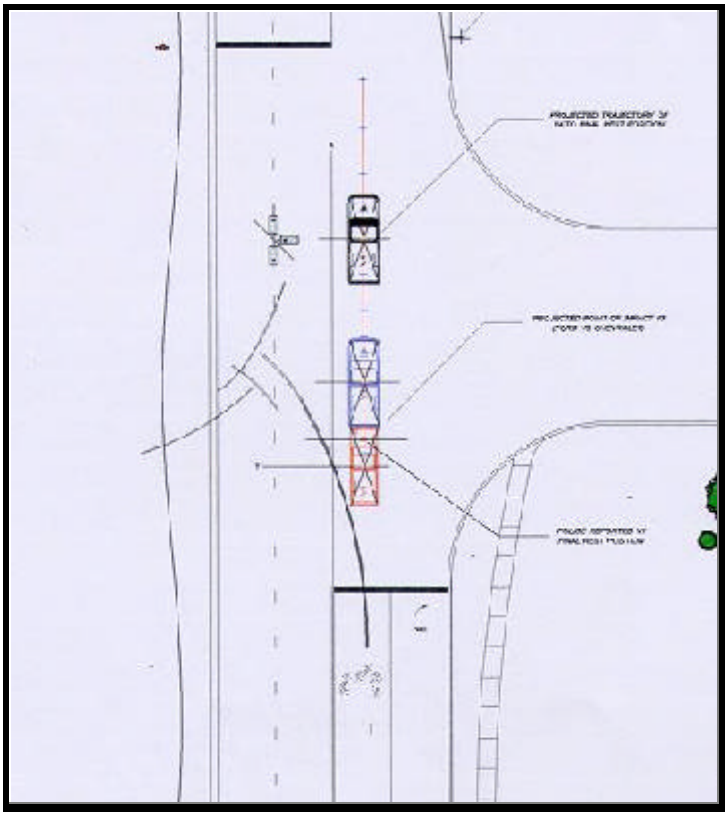

Figure 7. Impact #3 schematic - (V1) Ford vs. (V4) Chevrolet.

15.8 meters (51.8 feet) as the frontal area struck the rear area of the 2000 Chevrolet K-1500 Silverado pickup truck (V4) which resulted in minor damage to both vehicles **(Figure 7)**. The WinSMASH trajectory algorithm computed speeds *at impact* of 36.0 km/h (22.4 mph) for the Ford and 11.4 km/h (7.1 mph) for the struck Chevrolet, with respective matching negative and positive longitudinal values. The Ford traveled 1.8 meters (5.9 feet) to final rest in the northbound lane **(Figure 8)** as the Chevrolet was driven approximately 28.4 meters (93.2 feet) to final rest off the east shoulder in the northeast sector of the intersection **(Figure 9)**.

Figure 8. Police photo north of the 2001 Ford Sport-Trac (V1) final rest position.

Figure 9. Police photo north of the 2000 Chevrolet pickup (V4) final rest position.

Post-Crash

Following the crash, the occupants of the Ford (V1), GMC (V3), and Chevrolet (V4) exited their respective vehicles under their own power. Treatment was rendered at the crash site by fire department personnel and emergency medical technicians (EMTs). The front seated occupants of the Ford Explorer (V1) refused treatment/transport for minor soft tissue extremity injuries. The rear right occupant was transported by ambulance to the emergency room of a local hospital with complaints of neck pain and was subsequently treated and released.

Although initially delayed by lower extremity restriction, the Saturn driver (V2) exited the vehicle under her own power through the left front door. She was transported by ambulance to the emergency room of a local hospital for treatment of (police reported unspecified) non-incapacitating injuries and released. The front right passenger was removed from the vehicle through the left front door by rescue personnel in an unconscious state, and transported by ambulance to a nearby trauma center where she was pronounced deceased shortly after arrival.

The driver of the GMC Yukon (V3) complained of unspecified neck/left knee pain and refused treatment or transport to a local medical facility. The front right child passenger sustained an abrasion to the right shin and received no treatment. The rear left child passenger sustained an upper tooth fracture and was transported by ambulance to the emergency room of a local hospital for treatment and released within two hours. The remaining rear seated child passengers were reported by the driver as uninjured in the crash.

The driver of the Chevrolet pickup truck (V4) complained of unspecified neck/back pain, but sought no treatment for his injuries. The Ford Explorer, Saturn SL1, and GMC Yukon were towed due to disabling vehicle damage as the Chevrolet pickup truck was impounded by police with non-disabling vehicle damage.

VEHICLE DATA

(V2) 2001 Saturn SL1 4-door sedan

The 2001 Saturn SL1 was manufactured in April, 2001 and identified by the vehicle identification number (VIN): 1G8ZH54821Z (production number deleted). The parent of the driver was listed by police as the lessee of the vehicle. The vehicle was a 4-door sedan equipped with front-wheel drive, power windows and a 1.9 liter, 4-cylinder engine. At the time of the crash, the odometer had recorded 11,054 km (6,869 miles). The seating was configured with front bucket and a rear bench seat (with folding backs). The driver reported to police no previous crashes or maintenance on the Saturn's redesigned frontal air bag or side impact curtain system.

(V1) 2001 Ford Explorer Sport-Trac 4x4 sport utility

The 2001 Ford Explorer Sport-Trac was manufactured in August, 2000 and identified by the vehicle identification number (VIN): 1FMZU77E81U (production number deleted). The driver was the lessee of the vehicle which was a 4-door sport utility equipped with four-wheel drive, rear ABS, power windows, door locks, front seats, and a 4.0 liter, V-6 engine. At the time of the crash, the odometer had recorded 10,079 km (6,263 miles). The seating was configured with front bucket and a rear split-bench seat (with folding backs). The driver reported no previous crashes or maintenance on the Ford's redesigned frontal air bag system.

(V3) 2001 GMC Yukon SLT 4x4 sport utility

The 2001 GMC Yukon SLT was manufactured in January, 2001 and identified by the vehicle identification number (VIN): 1GKEK13T11R (production number deleted). The driver's husband was the lessee of the vehicle which was a 4-door sport utility equipped with four-wheel drive, four-wheel ABS, power windows, door locks, front seats, and a 5.3 liter, V-8 engine. The GMC was also equipped with the OnStar system, however, the driver reported no active response after the collision. At the time of the crash, the odometer had recorded 3,471 km (2,157 miles). The seating was configured with front bucket and a rear split-bench seat (with folding backs). The driver reported no previous crashes or maintenance on the GMC's redesigned frontal or (seat mounted) side impact air bag system.

(V4) 2000 Chevrolet K-1500 Silverado 4x4 pickup truck

The 2000 Chevrolet K-1500 Silverado was manufactured in April, 2000 and identified by the vehicle identification number (VIN): 2GCEK19T8Y1 (production number deleted). The driver was the lessee of the vehicle which was a 4-door extended cab pickup truck equipped with four-wheel drive, four-wheel ABS, power windows, door locks, front seats, and a 5.3 liter, V-8 engine. At the time of the crash, the odometer had recorded 36,315 km (22,566 miles). The seating was configured with front bucket and a rear bench seat (with folding back). The driver reported no previous crashes or maintenance on the Chevrolet's redesigned frontal air bag system.

VEHICLE DAMAGE - Exterior

(V2) 2001 Saturn SL1 4-door sedan

The 2001 Saturn SL1 sustained severe damage as a result of the initial rear-end impact with the (V1) 2001 Ford Explorer Sport-Trac **(Figures 10 & 11)**. The direct contact damage began at the rear right bumper corner and extended 95.0 cm (37.4 in) inboard. The impact deformed the entire rear end width resulting in a combined direct and induced damage length (Field L) of 127.0 cm (50.0 in). Six crush measurements were documented at the level of the reinforcement bar *(bumper fascia separation)*: C1= 1.5 cm (0.6 in), C2= 14.5 cm (5.7 in), C3= 25.5 cm (10.0 in), C4= 39.5 cm (15.6 in), C5= 54.5 cm (21.5 in), C6= 56.5 cm (22.2 in). The Collision Deformation Classification (CDC) for this initial impact to the Saturn was 06-BZEW-6 with a principal direction of force of 180 degrees. Light colored paint transfers were documented along the direct contact damage. The backlight glazing was disintegrated as the trunk lid was displaced up and forward from the impact force. Induced contact damage produced extensive buckling along the rear header and right side pillars (roof glazing disintegrated). Both quarter panels were deformed forward which restricted the rear doors and the right rear wheel/tire (not deflated). Reduction in the right side wheelbase measured 17.0 cm (6.7 in) as elongation in the left side wheelbase measured 7.0 cm (2.8 in).

Figure 10. Rear right damage to the 2001 Saturn SL1 4-door sedan (V2).

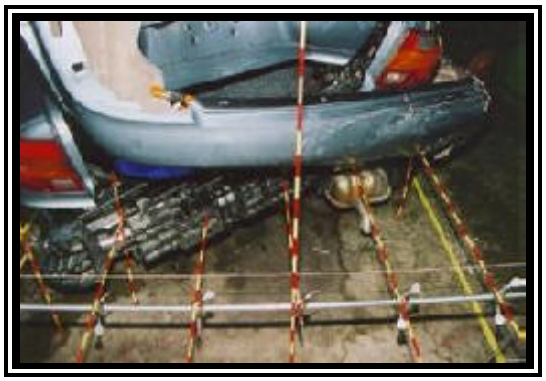

Figure 11. Contour gauge overview of the rear end structure (impact #1).

Direct contact damage was also identified to the right side surface attributed to the secondary impact with the (V3) 2001 GMC Yukon SLT **(Figure 12)**. The direct contact damage began 69.0 cm (27.2 in) aft of the right front axle and extended 148.0 cm (58.3 in) rearward. The combined direct and induced damage length (Field L) began 52.0 cm (20.5 in) aft of the right front axle and extended 205.0 cm (80.7 in) rearward. The stand offset method was utilized as six crush measurements were documented at the level of the mid-door: C1= 0 cm, C2= 10.0 cm (3.9 in), C3= 52.0 cm (20.5 in), C4= 50.0 cm (19.7 in), C5= 26.0 cm (10.2 in), C6= 0 cm. A maximum crush value of 61.0 cm (24.0 in) was documented 27.5 cm (10.8 in) forward of the C3 position. A secondary profile was obtained at the level of the sill to capture the B-pillar separation (door support failure) resulting in an *averaged profile* of: C1= 0 cm, C2= 10.0 cm (3.9 in), C3= 42.0 cm (16.5 in), C4= 38.0 cm (15.0 in), C5= 26.0 cm (10.2 in), C6= 0 cm. The CDC for this secondary impact to the Saturn was 04-RZAW-4 with a principal direction of

Figure 12. Impact #2 right side surface damage to the 2001 Saturn SL1 4-door sedan (V2) .

force of (+)120 degrees. The direct contact damage extended vertically above the beltline to the upper B-pillar area. Right B-pillar failure at the level of the lower sill allowed for extensive intrusion of interior components. The right side tempered glazings were disintegrated as the windshield fractured along the upper header and lower right A-pillar areas from exterior impact forces. Induced contact damage produced additional roof buckling along the right side pillars. Both left side tires were deflated (not restricted) with soil deposits noted in the wheels.

(V1) 2001 Ford Explorer Sport-Trac 4x4 sport utility

The 2001 Ford Explorer Sport-Trac 4x4 sustained moderate *(overlapping)* damage as a result of the impact with the 2001 Saturn SL1 (V2) and the 2000 Chevrolet Silverado (V4) pickup truck **(Figure 13)**. Pronounced and contrasting paint transfers allowed for the identification of separate direct damaged areas for accurate assignment of CDC's. The direct contact damage attributed to the initial impact with the Saturn began at the front left bumper corner and extended 84.0 cm (33.1 in) inboard. The CDC assigned to this impact was 12-FYEW-1 with a principal direction of force of 0 degrees.

Figure 13. Overlapping frontal damage to the 2001 Ford Explorer Sport-Trac 4x4 (V1).

The direct contact damage attributed to the secondary impact with the Chevrolet began at the front left bumper corner and extended 111.0 cm (43.7 in) inboard. The CDC assigned to this secondary impact was 12-FDEW-1 with a principal direction of force of 0 degrees. The impacts deformed the entire front end width resulting in a combined direct and induced damage length (Field L) of 139.0 cm (54.7 in). Overlapping protocol was utilized as six crush measurements were documented at the level of the bumper: C1= 11.0 cm (4.3 in), C2= 3.0 cm (1.2 in), C3= 2.0 cm (0.8 in), C4= 1.0 cm (0.4 in), C5= 1.0 cm (0.4 in), C6= 0 cm. Black paint transfers were identified along the front left bumper area and attributed to the secondary impact with the Chevrolet. White/gray paint transfers were identified along the front left bumper/hood areas and attributed to the initial impact with the Saturn. The hood was deformed up and rearward from engagement against the rear end structures of the Saturn and Chevrolet. The grille assembly remained undamaged. The windshield was fractured at the lower left A-pillar and attributed to the initial impact with the Saturn. No wheelbase reduction, bed to cab contact, or roof buckle was identified.

(V3) 2001 GMC Yukon SLT 4x4 sport utility

The 2001 GMC Yukon SLT 4x4 sport utility vehicle sustained minor frontal damage as a result of the impact with the (V2) 2001 Saturn SL1 **(Figure 14)**. Although the obtuse angle impact configuration resulted in primary engagement along the front left and center sections of the end structure, subsequent (clockwise) wrap contact by the Saturn produced additional direct contact damage along the remainder of the front end width, resulting in a combined direct and induced damage length (Field L) of 168.0 cm (66.1 in). Six

Figure 14. Frontal damage to the 2001 GMC Yukon SLT 4x4 sport utility vehicle (V3).

crush measurements were documented at the level of the bumper: C1= 10.0 cm (3.9 in), C2= 3.0 cm (1.2 in), C3= 2.0 cm (0.8 in), C4= 2.0 cm (0.8 in), C5= 3.0 cm (1.2 in), C6= 4.0 cm (1.6 in). The CDC for this impact to the GMC was 12-FDEW-1 with a principal direction of force of (-)10 degrees. White/gray paint transfers were documented along the direct contact damage. The left headlight was fractured as the left tow hook was displaced rearward approximately 3.8 cm (1.5 in). Two pronounced indentations were noted to the leading edge of the hood and attributed to the right side B and C-pillars on the Saturn. Left side wheelbase reduction measured 2.0 cm (0.8 in). The windshield and all tempered glazings remained undamaged.

(V4) 2000 Chevrolet K-1500 4x4 pickup truck

The 2000 Chevrolet K-1500 Silverado 4x4 pickup truck sustained minor rear damage as a result of the impact with the (V1) 2001 Ford Explorer Sport-Trac **(Figure 15)**. The direct contact damage began 25.0 cm (9.8 in) inboard of the rear left bumper corner and extended right 114.0 cm (44.9 in). The impact deformed the entire rear end width resulting in a combined direct and induced damage length (Field L) of 173.0 cm (68.1 in). Six crush measurements were documented at the level of the bumper: C1= 17.0 cm (6.7 in), C2= 17.0 cm (6.7 in), C3= 16.0 cm (6.3 in), C4= 16.0 cm (6.3 in), C5= 15.0 cm (5.9 in), C6= 15.0 cm (5.9 in). The CDC for this impact to the Chevrolet was 06-BDEW-1 with a principal direction of force of 180 degrees. Blue/white paint transfers were documented along the direct contact damage and tailgate. Minor bed to cab contact was noted on both sides. No wheelbase reduction was identified.

Figure 15. Rear damage to the 2000 Chevrolet K-1500 4x4 pickup truck. (V4)

VEHICLE DAMAGE - Interior

(V2) 2001 Saturn SL1

Interior damage to the Saturn was severe and was attributed to component intrusions and occupant contact **(Figure 16)**. Extensive indentations were identified along the right lower interior surface. Scuff marks, small indentations, and skin tissue were documented on the right rear armrest with the door hardware displaced inward. Both front seat backs were deformed rearward by occupant loading, and attributed to the initial rear-end impact. The front seat backs were deformed beyond a rearward mid-range position and displaced against the rear seat cushion. The front left and right seat backs were respectively *unrestricted* and *restricted* in this deformed reclined position with prevalent displacement of the frame and failure of both seat back recline adjustment mechanisms noted. Intrusion of lateral components and driver loading during the secondary right side impact produced additional deformation to the lateral aspects of the front right seat back. Lateral displacement

Figure 16. Interior view of the 2001 Saturn SL1 (V2).

of the floor mounted transmission lever, console, and parking brake were identified. Lateral intrusions into the right occupant spaces involved 40.0 cm (15.7 in) of rear door/window frame, 40.0 cm (15.7 in) of B-pillar, 35.0 cm (13.8 in) of front door/window frame, 29.0 cm (11.4 in) of front/rear sill, 26.0 cm (10.2 in) of rear roof side rail, and 17.0 cm (6.7 in) of front roof side rail intrusion.

MANUAL RESTRAINT SYSTEMS - (V2) 2001 Saturn SL1

The interior of the Saturn consisted of a five passenger seating configuration with front bucket and a rear bench seat (with folding backs). The driver 3-point manual lap and shoulder belt system consisted of a continuous loop belt webbing with a sliding latchplate and a dual mode retractor (inertial lock/belt sensitive). The front right (and rear outboard) seating position was equipped with a 3-point manual lap and shoulder belt system which consisted of a continuous loop belt webbing with a sliding latchplate and a retractor equipped with an inertial and switchable lock mechanism. There was no loading evidence identified on the D-ring, latchplate, or webbing of the front restraints to suggest belt usage by either occupant. The passenger restraint was also restricted in the stowed position by extensive lateral B-pillar intrusion. The rear center seat was equipped with a 2-point manual lap belt and a locking latchplate.

SUPPLEMENTAL RESTRAINT SYSTEMS - (V2) 2001 Saturn SL1

The 2001 Saturn SL1 was equipped with redesigned frontal air bags for the driver and front right passenger positions which did not deploy as a result of the crash. The driver air bag was housed in the center of the steering wheel with a vertically oriented flap tear seam (I-configuration). The front right passenger air bag was housed in the right mid-instrument panel area with a single cover flap design hinged at the top aspect.

The Saturn was also equipped with side impact curtains for the outboard seating positions. The right side impact curtain deployed as a result of the impact with the (V3) 2001 GMC Yukon **(Figure 17)**. The side curtain air bag was housed between the interior roof headliner and structural roof side rail with a horizontal seam measuring 143.0 cm (56.3 in) in length (separation of the headliner versus an actual flap). Inflation was achieved by the use of a cold gas (stored) inflator located in the C-pillar. The air bag measured 84.0 cm (33.1 in) in width and 34.0 cm (13.4 in) in height in its deflated state. The air bag was tethered by 22.0 cm (8.7 in) external straps connected to the left A-pillar and left rear roof side rail. No vent ports were present. No contact evidence was identified to the air bag.

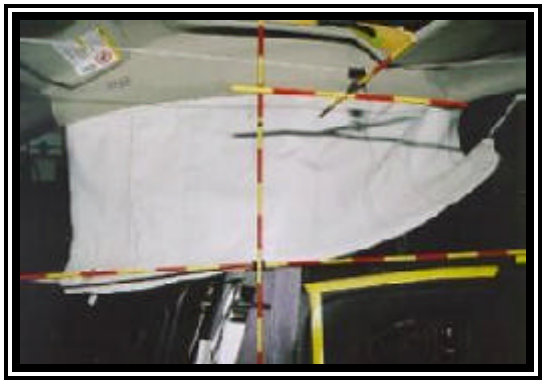

Figure 17. 2001 Saturn SL1 (V2) deployed right side impact curtain.

EVENT DATA RECORDER (EDR)

(V2) 2001 Saturn SL1

The 2001 Saturn SL1 Sensing and Diagnostic Module (SDM) was located under the center console as the event data was retrieved via the J1962 connector found to the left of the steering column. The Event

Data Recorder (EDR) records deployment and near-deployment events for the frontal air bag system. In this crash, the EDR recorded a near deployment event at ignition cycle number 1028 *(ignition cycles at investigation were 1030)*. The system status at near deployment reflected the driver's belt switch circuit status as "unbuckled". As the vehicle and engine speed decreased during the first three seconds of the five second pre-crash interval, the brake switch circuit status went from "on" to "off" three seconds prior to algorithm activation. At the two second pre-crash interval, the vehicle's speed rapidly accelerated from 12.9 km/h (8.0 mph) to 43.5 km/h (27.0 mph), indicative of an impact induced velocity change. The vehicle's speed dropped to 33.8 km/h (21.0 mph) one second prior to algorithm activation.

(V3) 2001 GMC Yukon SLT 4x4

The 2001 GMC Yukon SLT SDM was located under the driver's seat as the event data was retrieved via the J1962 connector found to the left of the steering column. The EDR records deployment and near-deployment events for the frontal air bag system. In this crash, the EDR recorded a near deployment event at ignition cycle number 486. The system status at near deployment reflected the driver's belt switch circuit status as "unbuckled". As the vehicle and engine speed decreased from 67.6 km/h (42.0 mph) to 19.3 km/h (12.0 mph) during the five second pre-crash interval, the brake switch circuit status went from "off" to "on" three seconds prior to algorithm activation.

(V4) 2000 Chevrolet K-1500 Silverado

The 2000 Chevrolet K-1500 Silverado pickup truck SDM was located under the driver's seat as the data was retrieved via the J1962 connector found to the left of the steering column. The EDR records deployment and near-deployment events for the frontal air bag system. In this crash, the EDR recorded a near deployment event at ignition cycle number 1532. The system status at near deployment reflected the driver's belt switch circuit status as "unbuckled". As the vehicle and engine speed fluctuated from 8.0 km/h (5.0 mph) to 12.9 km/h (8.0 mph) during the five second pre-crash interval, the brake switch circuit status repeatedly went from "on" to "off", indicative of two foot *("feathered")* operation of the (automatic transmission) accelerator and brake pedals.

DRIVER DEMOGRAPHICS - (V2) 2001 Saturn SL1

Age/Sex:	22 year old female
Height:	170 cm (67 in)
Weight:	68 kg (150 lb)
Seat Track Position:	Middle position
Manual Restraint Use:	None
Usage Source:	Vehicle inspection
Eyeware:	Unknown
Type of Medical Treatment:	Transported to a local hospital and released

Driver Injuries

Injury	***Severity (AIS 90)***	***Injury Mechanism***
Unknown	Unknown	Unknown

Driver Kinematics

The unrestrained 22 year old female driver of the 2001 Saturn SL1 was presumed to be seated in an upright posture (3-point manual lap and shoulder belt system available) with the seat back slightly reclined and the seat track adjusted to a middle position. The lack of belt use was determined by the trajectory of the driver, contact points within the vehicle, and absence of loading evidence on the front left restraint system. Furthermore, the lack of belt use was confirmed by the vehicle's EDR summary.

At initial impact with the 2001 Ford Explorer Sport-Trac (V1), the driver initiated a rearward trajectory in response to the 6 o'clock impact force and loaded the seat back. Occupant loading deformed the seat back frame rearward as the recline adjustment mechanism failed which allowed the driver to continue the kinematic response into the rear seating area. She struck the rear seat back and probably remained in this abnormal posture as the vehicle rotated counterclockwise 115 degrees towards the secondary impact. The driver refused the SCI interview, therefore, injury information related to this impact is unknown.

At impact with the 2001 GMC Yukon SLT (V3), the driver was displaced rearward (out-of position) in a reclined posture against the rear seat back. She initiated a lateral and slightly rearward trajectory in response to the secondary 4 o'clock impact force. The driver struck the center console and continued into the passenger space where she loaded the front right seat back *and passenger*. This occupant kinematic trajectory was evidenced by the extensive lateral deformation documented to these components. Injury information related to this impact is also unknown.

During post-impact trajectory to final rest, the driver initiated a lateral response to the left and came to rest in the supine position with her head against the top of the rear left seat, her buttocks against the (reclined) front left seat back, and feet on the driver seat cushion. The passenger's head and upper torso were positioned on top of the driver's lower extremities, restricting her subsequent egress from the vehicle. She reported to police that she had to climb up and over the passenger to exit the vehicle through the left front door. The driver of the Saturn was transported by ambulance to the emergency room of a local hospital for treatment of unspecified non-incapacitating injuries and released. The use of the 3-point manual restraint would have mitigated the injuries sustained by the by the driver, and reduced loading potential onto the passenger by reducing excessive lateral occupant movement during the (secondary impact) kinematic response.

FRONT RIGHT PASSENGER DEMOGRAPHICS - (V2) 2001 Saturn SL1

Age/Sex:	57 year old female
Height:	170 cm (67 in)
Weight:	68 kg (149 lb)
Seat Track Position:	Mid-to-rear position
Manual Restraint Use:	None
Usage Source:	Vehicle inspection
Eyeware:	None
Type of Medical Treatment:	Transported to a local trauma center and pronounced deceased

Front Right Passenger Injuries

Injury	*Severity (AIS 90)*	*Injury Mechanism*
*Laceration brain stem	Maximum (140212.6,8)	Non-contact injury ^ (Hyper extension)
*Multiple bilateral lung lacerations (1000ml of blood in each pleural cavity)	Critical (441456.5,3)	Driver loading/right B-pillar +
*Multiple rib fractures (left 3rd - 7th anterior arch, right 1st - 10th posterior arch)	Severe (450240.4,3)	Driver loading/right B-pillar +
*Multiple bilateral lung contusions	Severe (441410.4,3)	Driver loading/right B-pillar +
*Cerebral subarachnoid hemorrhage	Serious (140684.3,9)	Right rear door hardware +
*Rupture inferior vena cava (3cm - above the diaphragm)	Serious (521204.3,7)	Driver loading/right B-pillar +
*Rupture left side of diaphragm with hemoperitoneum - 10 cm	Serious (440604.3,8)	Driver loading/right B-pillar +
*Fracture and dislocation atlanto-occipital joint	Moderate (650216.2,6)	Non-contact injury ^ (Hyper extension)
*Laceration spleen - not further specified	Moderate (544220.2,2)	Driver loading/right B-pillar +
*Laceration liver - not further specified	Moderate (541820.2,1)	Driver loading/right B-pillar +
*Multiple contusions to left face and ear	Minor (290402.1,2)	Driver loading +
*Multiple small abrasions to left face and ear	Minor (290202.1,2)	Driver loading +
*Large contusion left upper chest extending to the upper area of the left breast	Minor (490402.1,2)	Driver loading +
*Laceration left posterior upper extremity (8cm - proximal to elbow)	Minor (790602.1,2)	Driver loading (jewelry?) +
*Multiple small contusions right anterior upper extremity to include anterior forearm	Minor (790402.1,1)	Right rear door interior surface +
*Multiple small abrasions right anterior upper extremity to include anterior forearm	Minor (790202.1,1)	Right rear door interior surface +
*Contusion lower central abdomen - small	Minor (590402.1,4)	Right B-pillar +
*Abrasion anterior left thigh (proximal to pelvis)	Minor (890202.1,2)	Center console +
*Multiple small contusions right anterior foot	Minor (890402.1,1)	Right front door interior surface +
*Laceration right ankle (small - inside aspect)	Minor (890602.1,1)	Right front door interior surface +

*Source: autopsy report** *Impact source: impact #1=^ / impact #2=+*

Front Right Passenger Kinematics

The unrestrained 57 year old female front right passenger of the 2001 Saturn SL1 was presumed to be seated in an upright posture (3-point manual lap and shoulder belt system available) with the seat back slightly reclined and the seat track adjusted to a mid-to-rear position. The lack of belt use was determined by the trajectory of the passenger, contact points within the vehicle, and the front right restraint restricted in the stowed position by extensive lateral intrusions.

At initial impact with the 2001 Ford Explorer Sport-Trac (V1), the front right passenger initiated a rearward trajectory in response to the 6 o'clock impact force and loaded the seat back. Occupant loading deformed the seat back frame as the recline adjustment mechanism failed which allowed further rearward seat back movement. Hyper extension of the neck over the seat back and head restraint resulted in a fracture and dislocation of the atlanto-occipital joint. The resulting craniocervical instability placed the neck at further risk as she subsequently sustained an associated laceration of the brain stem. She remained in this abnormal posture against the deformed seat back as the vehicle rotated counterclockwise 115 degrees towards the secondary impact.

Figure 18. Passenger contact evidence to the right side interior surface.

At impact with the 2001 GMC Yukon SLT (V3), the passenger was displaced rearward (out-of-position) in a reclined posture. She initiated a lateral/slightly rearward trajectory in response to the 4 o'clock impact force and loaded the right side interior surface **(Figure 18)**. Head contact to the right rear door interior surface resulted in a subarachnoid hemorrhage as evidenced by the skin tissue and indentations documented on this component. Indentations along the lower doors and B-pillar clearly outlined lower extremity and pelvic regions. This distinct contact pattern further confirmed the passenger's abnormal posture as a result of the seat back recline adjustment mechanism failure. At this point, the driver entered the passenger space and compressed the passenger against the right B-pillar and door interior surface resulting in a multitude of soft tissue injury and internal trauma. This occupant-to-occupant contact resulted in multiple left side abrasions and contusions along with fractures of the left 3rd - 7th ribs. These injury mechanisms were evidenced by the extensive deformation identified on the center console and front right seat back from driver loading. Passenger compression against the right B-pillar and interior surface resulted in additional fractures of the right 1st - 10th posterior ribs and underlying critical bilateral lung contusions and lacerations. Additional internal trauma included unspecified lacerations of the liver/spleen along with ruptures of the diaphragm and *adjacent* inferior vena cava. During post-impact trajectory to final rest, the she initiated a lateral response to the left and came to rest in the prone position (on top of the driver's lower extremities) with her head/torso laterally across the center console and forward edge of the seat cushions. Although death was probably immediate, the passenger was removed by rescue personnel through the left front door in an unconscious state, and subsequently transported by ambulance to a local trauma center where she was pronounced deceased shortly after arrival. The failure of the seat back recline adjustment mechanism mitigated the effectiveness of the deployed right side impact curtain by allowing for an abnormal posture for the subsequent right side impact, and thus, provided no crash protection to the front right passenger.

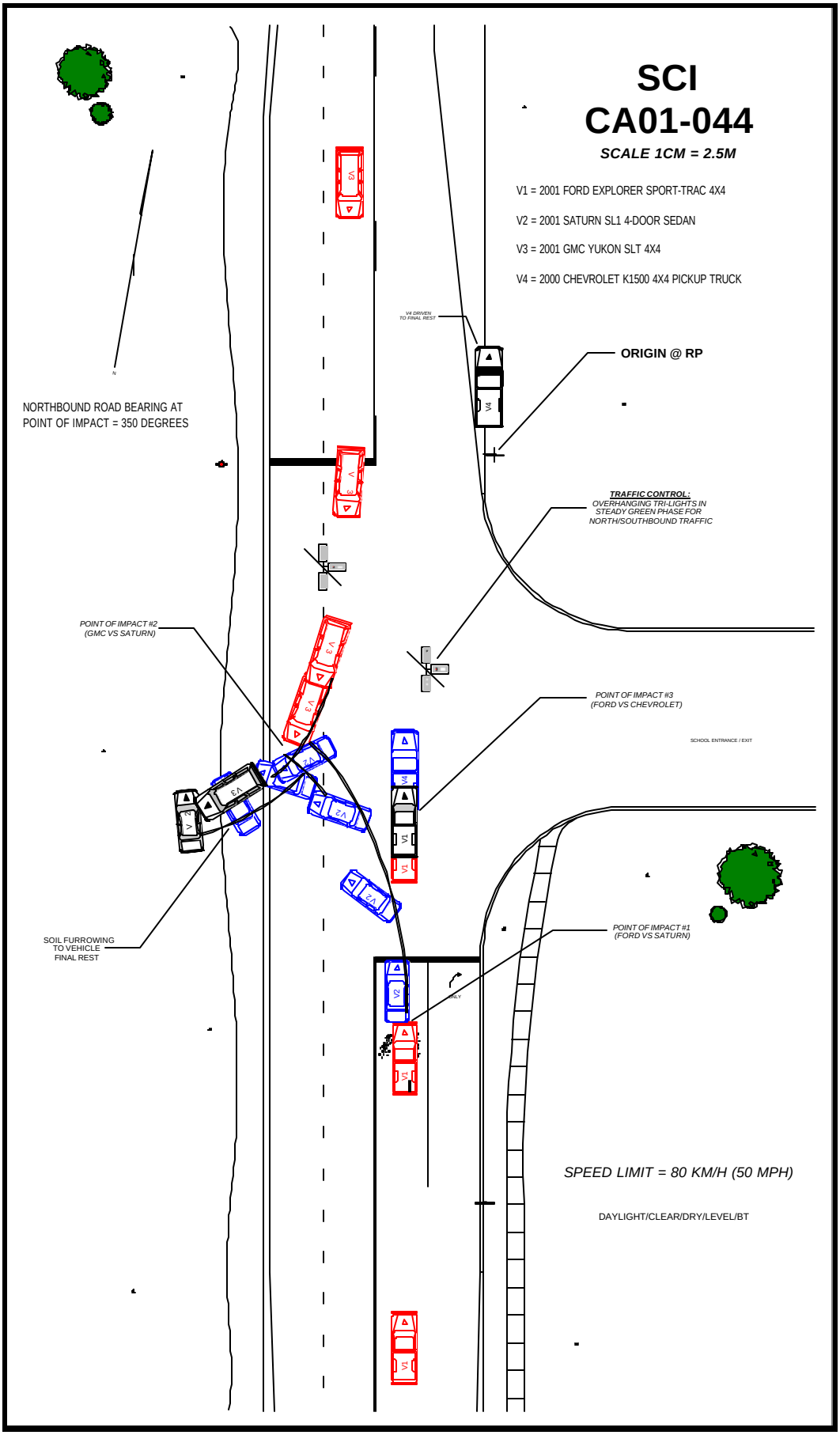

Figure 19. Scene Diagram (impacts #1-3).

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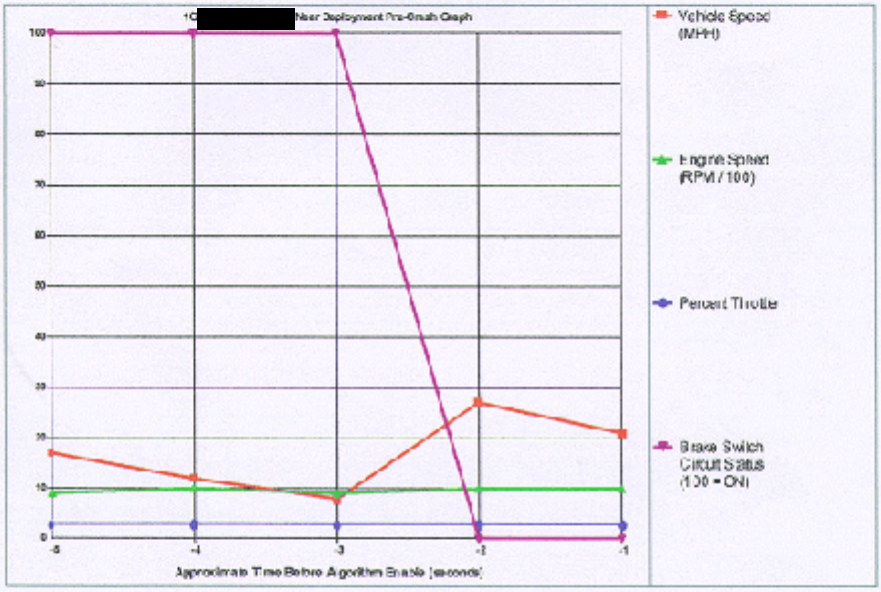
CDR CRASH DATA RETRIEVAL SYSTEM

System Status At Near Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Passenger Front Air Bag Suppression Switch Circuit Status	Air Bag Not Suppressed
Ignition Cycles At Near Deployment	1028
Ignition Cycles At Investigation	1030
Maximum SDM Recorded Velocity Change (MPH)	1090
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	75



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	17	896	3	ON
-4	12	960	3	ON
-3	8	896	3	ON
-2	27	960	3	OFF
-1	21	960	3	OFF

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Figure 20. (V2) 2001 Saturn SL1 EDR report.

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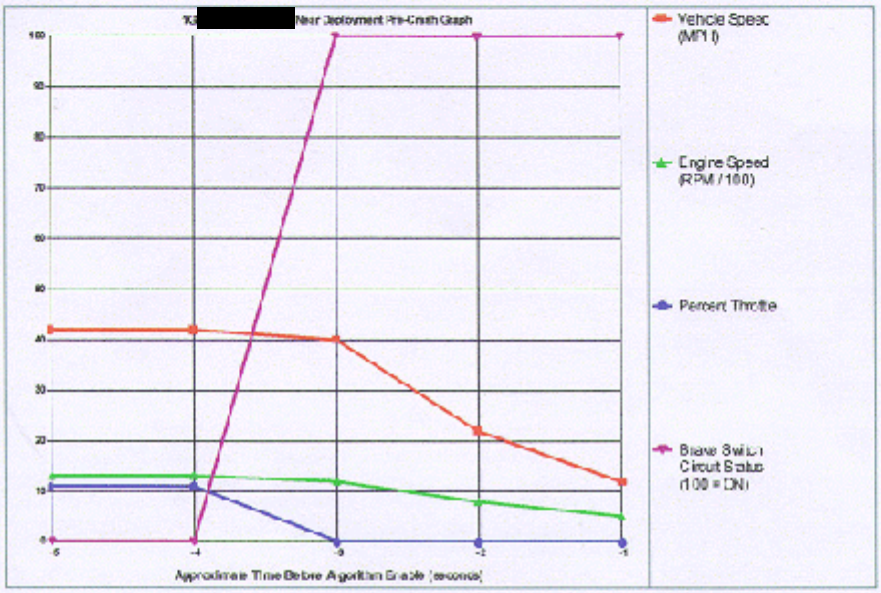
CDR CRASH DATA RETRIEVAL SYSTEM

System Status At Near Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Passenger Front Air Bag Suppression Switch Circuit Status	Air Bag Not Suppressed
Ignition Cycles At Near Deployment	466



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	42	1344	11	OFF
-4	42	1344	11	OFF
-3	40	1152	0	ON
-2	22	700	0	ON
-1	12	512	0	ON

[redacted]

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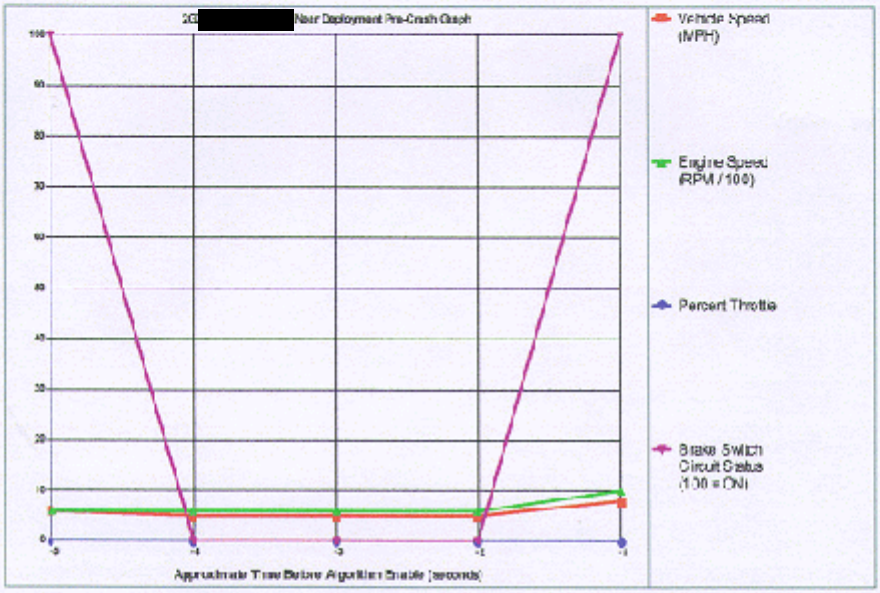
Figure 21. (V3) 2001 GMC Yukon SLT 4x4 EDR report.

Vetronix

CDR CRASH DATA RETRIEVAL SYSTEM

System Status At Near Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Passenger Front Air Bag Suppression Switch Circuit Status	Air Bag Suppressed
Ignition Cycles At Near Deployment	1532



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	6	640	0	ON
-4	5	640	0	OFF
-3	5	640	0	OFF
-2	5	640	0	OFF
-1	6	960	0	ON

[redacted]

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Figure 22. (V4) 2000 Chevrolet K-1500 4x4 pickup truck EDR report.