TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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VERIDIAN ON-SITE AIR BAG/INFANT FATALITY INVESTIGATION
VERIDIAN CASE NO. CA99-07
VEHICLE: 1995 SATURN SC2
LOCATION: ALABAMA
CRASH DATE: APRIL 1999

Contract No. DTNH22094-D-07058

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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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This on-site investigation focused on the injury mechanisms and cause of death of a 6 week old infant female positioned in the front right of a 1995 Saturn SC2. The vehicle was equipped with frontal air bags for the driver and right passenger positions which deployed during the crash. The infant was positioned in a rear-facing child safety seat (RFCSS) that was improperly secured by the manual 3-point lap and shoulder belt system. The frontal area of the Saturn impacted and underrode the rear of a stopped (disabled) 1988 Pontiac Grand Prix. The impact deployed the Saturn's frontal air bag system. The 23 year old female driver of the Saturn was unrestrained. She sustained multiple soft tissue injuries from contact with the knee bolster and the front left air bag. The infant sustained severe closed head injuries from the expansion of the front right passenger air bag and module cover flap against the shell of the child safety seat. She was transported to a local hospital and transferred to a children's medical center by ambulance where she expired en route.</td></tr>
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BACKGROUND

This on-site investigation focused on the injury mechanisms and cause of death of a 6 week old infant female positioned in the front right of a 1995 Saturn SC2. The vehicle was equipped with frontal air bags for the driver and right passenger positions which deployed during the crash. The infant was positioned in a rear-facing child safety seat (RFCSS) that was improperly secured by the manual 3-point lap and shoulder belt system **(Figure 1)**. The frontal area of the Saturn impacted and underrode the rear of a stopped (disabled) 1988 Pontiac Grand Prix. The impact deployed the Saturn's frontal air bag system. The 23 year old female driver of the Saturn was unrestrained. She sustained multiple soft tissue injuries from contact with the knee bolster and the front left air bag. The infant sustained severe closed head injuries from the expansion of the front right passenger air bag and module cover flap against the shell of the child safety seat. She was transported to a local hospital and transferred to a children's medical center by ambulance where she expired en route.

Figure 1. On-scene image of the deployed front right air bag and the child restraint following the removal of the infant.

Notification was initially provided to NHTSA by the regional NASS PSU team leader in the Tuscaloosa, AL area. The COTR confirmed the low-to-moderate crash severity with the investigating officer and assigned the case to the Veridian SCI team on April 22, at 0941 hours. Due to the fatal outcome of the infant and air bag involvement, an on-site investigation was conducted on April 27-28. In addition to the SCI investigation, General Motors provided a technical representative to download the Sensing and Diagnostic Module (SDM) data from the Saturn.

SUMMARY

Crash Site

The crash occurred in a mid block area of a divided minor arterial roadway in an urban/commercial area **(Figure 2)**. The eastbound travel lanes consisted of three through lanes with a designated left turn lane. The asphalt road surface was level with a slight curve to the left for eastbound traffic flow. The outboard edge of the roadway was bordered by a 0.4 m (1.3') paved shoulder and a 12.7 cm (5.0") barrier curb. Driveways for an automobile dealership intersected the outboard curbline. At the time of the daylight crash, the conditions were clear and dry. Traffic flow was moderate-to-heavy due to the rush hour time frame. The posted speed limit was 72 km/h (45 mph). The schematic is included as **Figure 12** (Page 14).

Figure 2. Approach view of the crash site.

Vehicle Data/History

The subject vehicle was a 1995 Saturn SC2, 2-door coupe. The vehicle was manufactured on 9/94 and was identified by vehicle identification number 1G8ZG1274SZ (production number deleted). The driver and her husband purchased the Saturn as a used vehicle in July 1997 from a local Saturn dealership. At the time of purchase the vehicle's odometer reading was approximately 77,000 km (48,000 miles). At the time of the crash, the vehicle's odometer reading was 108,414 km (67,367 miles). The couple stated that during their ownership of the Saturn, the vehicle was not involved in any previous crashes and that maintenance was limited to routine items (oil changes, etc).

The Saturn was powered by a transverse mounted 4-cylinder engine linked to a 5-speed manual transmission. The vehicle was equipped with frontal air bags for the driver and right passenger positions. In addition to the frontal air bag system, the Saturn was equipped with manual 3-point lap and shoulder belt systems for the four outboard seated positions. The Saturn was also equipped with a tilt steering column mechanism and manually operated door windows and seat track mechanisms.

The principal other vehicle (POV) in this crash was a 1988 Pontiac Grand Prix, 2-door sedan. The Pontiac was disabled in the curb lane of the minor arterial roadway with the hood raised and the emergency flashers activated. The Pontiac was occupied by two adult female occupants positioned in the front outboard seated positions. These seat positions were equipped with automatic door mounted, 3-point lap and shoulder belt systems. The Grand Prix was manufactured on 10/88 and was identified by vehicle identification number 1G2WJ14W4JF (production number deleted). The vehicle's odometer reading was 303,320 km (188,480 miles).

Pre-Crash

The driver of the Saturn was en route to an appointment and was traveling in an easterly direction on the minor arterial roadway. She stated that while en route to her destination, her infant daughter became irritable while positioned in the right rear of the Saturn. The driver stopped the vehicle and repositioned the infant and the child safety seat in the front right of the Saturn. In this position, the driver thought she could watch the infant more closely.

While proceeding in an easterly direction on the minor arterial roadway at an estimated speed of 56-64 km/h (35-40 mph), the driver noted a moderate-to-heavy volume of traffic in the center and inboard travel lanes. She initiated a lane change maneuver to the outboard travel lane. During this maneuver, the driver checked for approaching traffic by looking to her right and over her right shoulder, momentarily diverting her attention away from the forward direction.

The 1988 Pontiac Grand Prix was disabled in the outboard eastbound travel lane with the hood raised and the emergency flashers activated. The Pontiac was occupied by two adult females seated in the driver and front right positions of the vehicle. The occupants were waiting in the vehicle for assistance and were unrestrained.

As the driver of the Saturn entered the outboard travel lane, she failed to detect the disabled vehicle in time to successfully avoid the impending crash. The driver braked with sufficient force to lock the front wheels

of the Saturn. Locked wheel skid marks were visible in the on-scene police photographs, however, these marks were not documented by the investigating police department. It should be noted that the tire marks had eroded from the heavily traveled road surface prior to this on-site investigation. The front right tire skid mark was approximately 4.5-6.0 m (15.0-20.0') in length while the left skid mark was approximately 3.6-4.5 m (12.0-15.0') in length. The Saturn skidded to impact with the rear of the Pontiac Grand Am. Based on an average skid distance of 5.3 m (17.5') and an estimated coefficient of friction of .65, the Saturn underwent an equivalent velocity loss due to braking of 29.6 km (18.4 mph).

Crash

The full frontal area **(Figure 3)** of the Saturn impacted the rear of the disabled Pontiac Grand Prix in a 12 o'clock/6 o'clock impact configuration. Initial contact involved the face of the Saturn's front bumper against the lower face of the rear bumper of the Pontiac. The impact speed for the Saturn was computed at 28.8 km/h (17.9 mph) by the damage and trajectory algorithm of the WinSMASH program. As a result of the pre-crash braking which compressed the front suspension, and the wedge profile of the Saturn, the frontal area of the Saturn subsequently underrode the rear of the Pontiac. Consequently, the Saturn penetrated under the Pontiac which elevated the rear tires of the Pontiac off the asphalt road surface while displacing the vehicle in a forward direction. The damage algorithm of the WinSMASH program computed velocity changes of 14.8 km/h (9.2 mph) for the Saturn and 11.1 km/h (6.9 mph) for the struck Pontiac. (The SDM recorded a velocity change of 32 km/h [20 mph]. This data analysis was provided by General Motors.) The impact induced loading and clockwise deflection was visible in the skid marks which terminated within a meter east of the point of impact. This indicated the driver released brake pedal pressure as the vehicle traveled to final rest.

Figure 3. Frontal damage to the Saturn SC2.

Final Rest

The vehicles came to rest fully engaged **(Figure 4)** approximately 2.4-3.0 m (8.0-10.0') east of the point of impact. The impact rotated the Pontiac Grand Prix approximately 9 degrees in a counterclockwise direction while the Saturn rotated approximately 8 degrees clockwise from its initial pre-crash position. At rest, the rear of the Pontiac was elevated with the rear tires completely off the pavement surface. The rear area of the Grand Prix was resting on top of the front fenders of the Saturn with the rear bumper at the level of the Saturn's front axle.

Figure 4. Final rest positions of the vehicles.

Post-Crash Activities

Immediately following the crash, the driver of the Saturn noted that the child safety seat was displaced slightly rearward from its pre-crash position. She further noted that the infant appeared to be unconscious. The driver immediately unbuckled the harness of the rear-facing child restraint and removed the infant from the restraint.

An occupant of the struck Pontiac proceeded to the Saturn and opened the driver's door to check on the

condition of the driver. The Saturn driver immediately exited the vehicle and proceeded to the rear of the vehicle, holding the infant in her arms. A salesperson from the automobile dealership adjacent to the crash site heard the crash and proceeded to the vehicles. As she walked to the Saturn, she heard someone yell that a baby was involved. This person opened the right door and noted that the occupants had exited the vehicle, however, she observed the child safety seat in the front right position of the vehicle.

At this point, the witness proceeded to the driver of the Saturn and asked "if the baby was okay". The driver handed her the baby and this witness proceeded to the grass area adjacent to the roadway. She had received Red Cross training and used her skills to evaluate the condition of the infant. She determined that the infant was not breathing. A fellow salesperson offered to administer rescue breathing on the infant. As this occurred, the driver of the Saturn returned to the vehicle to call her husband on her cellular telephone.

Police and paramedics arrived within minutes of the crash. The infant was transported by ambulance to a local hospital where she was evaluated and identified as critical due to closed head injuries. The medical staff decided to transfer the infant to a major children's medical center located approximately 80 km (50 miles) away. The local medical helicopter was out-of-service due to mechanical problems, therefore transferral was arranged by ambulance. The infant expired en route to the medical facility. The time of death was approximately 2.5 hours following the crash.

VEHICLE DAMAGE

Saturn

Exterior - The full frontal area of the Saturn engaged the rear plane of the disabled Pontiac Grand Prix. The front bumper initially impacted then underrode the rear bumper of the Grand Prix **(Figure 5)**. The direct contact damage extended full width which resulted in a combined induced and direct damage length of 121.3 cm (47.75"). There was no residual crush at the level of the bumper reinforcement bar.

Figure 5. Profile view documenting the minimal crush profile.

Figure 6. Underride damage to the hood face and upper radiator support panel.

Due to the front suspension compression and wedge profile of the Saturn's frontal plane, the vehicle's

bumper underrode the rear of the struck Pontiac. As a result of the elongated engagement, the direct contact damage extended onto the top surface of the Saturn's bumper fascia and subsequently involved the hood face of the Saturn. The hood latch released which allowed the aluminum hood to buckle at the designated fold point and deflect rearward as the Saturn penetrated under the Pontiac. Residual structural crush occurred at the upper radiator support panel **(Figure 6)**. The crush profile was documented as follows: C1-0.6 cm (0.25"), C2-1.3 cm (0.5"), C3-1.9 cm (0.75"), C4-1.9 cm (0.75"), C5-2.9 cm (1.1"), C6-2.9 cm (1.1"). Maximum crush occurred at the C5-C6 locations. The Collision Deformation Classification (CDC) for this damage pattern was 12-FDEW-1.

Interior - There was no damage to the interior of the Saturn other that deployment of the frontal air bag system. A white vinyl/plastic transfer was noted to the inside surface of the front right door glazing. This transfer resulted from contact with the RFCSS during the expansion of the front right air bag membrane.

Pontiac

Exterior - The rear of the Pontiac Grand Prix sustained minor damage **(Figure 7)** from its impact sequence with the Saturn SC2. The initial contact deformed the rear bumper fascia in a forward direction, however, as the Saturn continued forward, the frontal area of the wedge profile underrode the rear plane of the Pontiac. There was longitudinal crush to the rear bumper system of the Pontiac. The honeycomb structure of the rear bumper system was displaced vertically. The tailpipe and spare tire well of the Grand Prix were deformed forward and vertically, respectively. Isolated buckling of the right rear quarter panel was noted forward of the wheel opening. The CDC for this damage was 06-BDLW-1.

Figure 7. Rear damage to the Pontiac Grand Prix.

Interior - The interior damage to the Pontiac was minor and was associated with occupant loading. Both front seat back supports were deflected rearward as the occupants responded to the 06 o'clock direction of force. The front left seat back was displaced to an angle of 40 degrees while the right seat back angle measured 25 degrees.

AUTOMATIC RESTRAINT SYSTEM (Saturn)

The 1995 Saturn was equipped with a Supplemental Inflatable Restraint (SIR) system that consisted of frontal air bags for the driver and right passenger positions. The system deployed as a result of the frontal impact sequence with the rear of the disabled 1988 Pontiac Grand Prix. The SIR was configured with a single point Sensing and Diagnostic Module (SDM), the steering wheel mounted driver air bag module, and the mid right instrument panel mounted front passenger air bag module assembly. Both units deployed as designed during the crash sequence **(Figure 8)**.

Figure 8. Deployed frontal air bag system.

The driver air bag deployed from a conventionally mounted module assembly retained within the four-spoke steering wheel rim. The wheel was equipped with a tilt mechanism which was found adjusted to the most vertical position. The module cover flaps were in an I-configuration, hinged at the lateral aspects of the flaps. The symmetrically configured flaps were 13.3 cm (5.25") vertically, measured at the tear seam and 10.8 cm (4.25") horizontally. The outboard edges of the cover flaps were rounded to conform to the contour of the spoke cover. There was no damage or contact evidence to the cover flaps.

The deployed driver air bag measured approximately 53.3 cm (21.0") in diameter in its deflated state. The bag was vented by two 1.9 cm (0.75") diameter vent ports located at the 10 and 2 o'clock positions, centered 8.9 cm (3.5") forward of the peripheral seam. Internally, the bag was tethered by four tether straps located at the 12/6 and 3/9 o'clock positions. The tethers were sewn to the face of the bag with a 17.8 cm (7.0") diameter reinforcement. The identification numbers 864515 were printed on the forward panel of the driver bag at the 3 o'clock sector. There was no contact evidence or damage to the driver air bag.

The front right passenger air bag was mounted in a mid mount configuration in the right mid instrument panel. The passenger air bag module was recessed by a brow that protruded 3.8 cm (1.5") rearward over the top hinge point of the single cover flap. This brow was designed to direct the deployment path of the inflating air bag membrane. The single cover flap was 13.0 cm (5.1") in height and 30.2 cm (11.9") in horizontal length. AIRBAG was molded into the lower right quadrant of the bag.

The RFCSS was presumed to have been positioned within the deployment range of the mid mount flap. A faint "polishing" of the cover flap from probable contact against the shell of the RFCSS was noted to the leading edge of the vinyl flap. This scuff-type mark was located 7.6 cm (3.0") inboard of the left edge of the flap and extended 17.8 cm (7.0") to the right. The mark extended 1.3 cm (0.5") vertically onto the face of the flap.

A thin clear plastic liner was installed in the module assembly between the inside surface of the cover flap and the folded air bag membrane. During deployment, this plastic was torn from the module assembly. The separated plastic was 23.5 x 6.0 cm (9.25 x 2.375"). A fragment of the plastic became fused to the outboard aspect of the shell of the RFCSS. This was the only air bag related contact evidence on the RFCSS.

The front right passenger air bag was 78.7 cm (31.0") in width, 50.8 cm (20.0") in height, and approximately 35.6 cm (14.0) in depth in its deflated state. The bag was not vented directly into the passenger compartment, however, venting was probably achieved back through the manifold assembly. The bag was tethered internally with one wide band tether that was 16.5 cm (6.5") in width. At the location of the tether, bag excursion was limited to approximately 25.4 cm (10.0"). There was no contact evidence on the air bag membrane from involvement against the shell of the RFCSS. An air bag identification label had separated from the top aspect of the bag fabric. This label contained the following bar coded alpha-numeric sequence:

*T1CH257H10305
2000912E

Both sunvisors were equipped with 4.4 x 1.6 cm (1.75 x 0.625") warning labels affixed to the exposed surface of the visors when viewed in the stowed positions. These labels noted the following:

AIRBAG
SEE OTHER SIDE

The "Other Side" (top side) of the sunvisors contained a warning label that provided the following information: WARNING

- Death or Serious Injury Can Occur
- Children 12 and under can be killed by the air bag
- The back seat is the safest place for children
- Never put a rear facing child safety seat in the front
- Sit as far back as possible from the air bag
- Always use SEAT BELTS and CHILD RESTRAINTS

DRIVER AWARENESS OF SAFETY ISSUES

The driver stated during the SCI interview that she was aware of the presence of the frontal driver and passenger air bag systems, however, she was not aware of the associated deployment risks to children and rear-facing child safety seats. Furthermore, the driver was not familiar with the warnings listed on the labels affixed to the top surface of the sunvisors. Thirdly, the child safety seat had a warning label printed on the fabric adjacent to the right side of the child's head which warned of placement and death or serious injury consequences. When asked about the presence of this label, the driver "offered no comment".

MANUAL RESTRAINT SYSTEMS (Saturn)

The 1995 Saturn SC2 was configured as a four-passenger sport coupe with 3-point lap and shoulder belt systems available at the four outboard positions. The front belt systems consisted of separated lap and shoulder belt webbings affixed to a common (fixed) latchplate. Both webbing extended from emergency locking retractors (ELRs) and buckled into a center mounted buckle assembly. The upper anchorages for the front belt systems were adjustable with 8.9 cm (3.5") of vertical travel. Both D-rings were adjusted to the full down positions.

The latchplate tab of the driver's belt system yielded faint wear marks that resulted from occasional usage. The wear marks did not appear to be consistent with frequent usage over the recorded odometer reading. The driver of the Saturn stated that she usually wears the manual belt system, however, on this particular trip, she could not recall if she was restrained.

There was no evidence on the driver's belt system (i.e., fabric/air bag transfers, stretching) to support usage during the crash. The air bag system's Sensing and Diagnostic Module (SDM) records driver belt usage at the time of the crash. The SDM data provided by General Motors for this vehicle indicated the driver belt system was not buckled at the time of air bag deployment.

The front right belt system was used improperly by the driver to restrain the rear-facing child safety seat. The lap belt webbing was routed through the molded slots in the shell of the restraint, however, the retractor was not sufficient to properly secure the restraint in this position.

There was no loading evidence on the lap belt aspect of the front right belt system. Usage was verified by the on-scene police photographs which captured the RFCSS in the vehicle with the lap belt extended through the proper loops in the restraint. This issue is further addressed in the Child Safety Seat Misuse section of this summary report.

CHILD SAFETY SEAT

The infant passenger of the 1995 Saturn SC2 was positioned in a rear-facing child safety seat (RFCSS) in the front right seat of the vehicle. The child safety seat was manufactured by Century Products on 04/21/98 and was identified as a *Smartfit* with a Model No. of 11611WVS. The RFCSS consisted of a molded plastic shell with a folding carrying handle, fabric covered padding, and an integral 3-point harness system. A detachable base was provided with the RFCSS, however, this base was not in use at the time of the crash. It should be noted that the base was found loose in the rear seat of the vehicle by the investigating officer at the scene of the crash. A locking clip was provided with the RFCSS and was found on the front right seat cushion at the scene of the crash. The locking clip was not used and was probably displaced from the shell of the RFCSS by the deploying air bag.

There was no residual damage to the RFCSS. The rear aspect of the shell did not yield evidence of contact (i.e., abrasions, fracture sites) although the RFCSS was positioned in the deployment path of the front right air bag and module cover flap. A small fragment of clear plastic was fused to the right outboard aspect of the of the molded reinforcement of the back of the restraint. This plastic was from the liner that was positioned between the air bag membrane and the inside surface of the module cover flap.

The child restraint was removed from the vehicle prior to the SCI inspection and forwarded to the parents (driver) of the infant passenger. At the request of the SCI investigator, the parents returned the RFCSS to the vehicle as they consented to an interview. The mother (driver) was asked to reinstall the RFCSS to the pre-crash position. This installation was as follows:

> The driver stated to the SCI investigator that she initially positioned the infant in the RFCSS in the right rear of the Saturn. However, en route to her destination, the infant became irritable and the driver stopped and repositioned the RFCSS to the front right position of the vehicle. In this position, the driver thought she could closely monitor the actions of the infant. It should be noted that the detachable base was not used in either position.
>
> The front right seat track was found adjusted to a forward track position. The seat track was set 3.8 cm (1.5") rearward of the full forward position and 13.7 cm (5.4") forward of the full rear position. The seat back support had been readjusted since the crash was positioned (per driver) to an angle of 20-25 degrees. The driver positioned the RFCSS in the front right and immediately noted that the seat track adjustment appeared to be too far forward. (The seat track position was verified from on-scene police photographs.) She adjusted the RFCSS to the proper angle as indicated by the level indicator located on the outboard aspect of the shell of the RFCSS. The driver then extended the manual lap and shoulder belt system and properly routed the lap belt webbing through the slots the were molded into the shell of the restraint. As a final adjustment, the driver pulled on the shoulder belt webbing in an effort to tighten the belt system. The pivoting

carrying handle was left in the vertical position and the fabric canopy was extended over the head of the infant. The driver stated that the child was restrained in the RFCSS by the integral 3-point harness with the chest clip in place over the chest area of the infant.

CHILD SAFETY SEAT MISUSE ISSUES

The driver's usage and installation of the RFCSS in the front right position of the Saturn resulted in several misuse issues. These issues are as follows:

- The RFCSS was positioned in the front right position of the Saturn which was equipped with a frontal air bag for the passenger position. This position was advised against on the warning label that was affixed to the top surface of both sunvisors and most notably on the label printed on the RFCSS fabric adjacent to the infant's head. This label read as follows:

  > DO NOT place rear-facing seat on front seat with air bag.
  > DEATH OR SERIOUS INJURY can occur. The back seat
  > is the safest place for children 12 and under.

- The integral harness of the RFCSS was adjusted to the maximum adjustment points. The belt webbings were positioned through the top of two sets of slots in the backrest of the RFCSS shell **(Figure 9)**. In addition, the adjustment rod was routed through the top slots of the belt webbing which resulted in the maximum adjustment length of the harness. Although the harness adjustment could not be verified with the infant, the restraint was rated to a maximum weight of 9.1 kg (20 lb), therefore the belts should have been considerably loose on the 4.5 kg (10 lb) infant.

Figure 9. Adjustment slots in the harness system.

- The carrying handle was in the vertical position. This should always be in the forward and locked position, away from the infant occupant.

- Although the vehicle's manual belt system was properly routed through the belt path of the RFCSS, the system was used improperly based on the type of retractor mechanism. This belt system consisted of a separate lap and shoulder belt webbing affixed to a common latchplate. The lap belt extended from an emergency locking retractor (ELR). This configuration required the use a belt shortening clip on the outboard aspect of the lap belt webbing to securely restrain the RFCSS. The locking clip that was provided by the RFCSS manufacturer was found loose on the right front seat cushion and was not in use at the time of the crash.

DRIVER DEMOGRAPHICS (Saturn)

Age/Sex:	23 year old female
Height:	167.6 cm (66.0")
Weight:	61.2 kg (135.0 lb)

Race/Ethnic Background:	White, non-hispanic
Manual Restraint Usage:	None, 3-point lap and shoulder belt system was available
Usage Source:	SDM readout, vehicle inspection
Eyeware:	Contact lenses, remained in eyes
Medical Treatment:	None

DRIVER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanism
Superficial abrasion of the hands between the thumb and the index finger	Minor (790202.1,3)	Front left air bag
Small diameter contusion on the medial aspect of the left knee	Minor (890402.1,2)	Steering column cover
Several contusions on the right lower leg	Minor (890402.1,1)	Knee bolster
Soreness of the bottom of the right foot	N/A, not codeable	Brake pedal

DRIVER KINEMATICS

The driver of the Saturn was seated in a normal upright driving posture with the seat track adjusted to a mid track position. The seat track was positioned 8.9 cm (3.5") rearward of the full forward position and 6.4 cm (2.5") forward of the full rearward position **(Figure 10)**. It should be noted that the seat track did not slide freely to the full forward or full rearward positions. The seat back angle was measured at 20 degrees rearward of vertical. In this adjusted position, the horizontal distance between the seat back support and the front left air bag module cover was 55.9 cm (22.0"). The adjustable head restraint was in the full down position, however, due to the profile of the restraint, the bottom edge of the restraint was positioned 3.8 cm (1.5") above the top of the seat back support. The adjustable D-ring was set to the full-down position. Base on the lack of loading evidence on the belt system, and the SDM data, it was determined that the driver was not wearing the manual 3-point lap and shoulder belt system.

Figure 10. Adjusted seat track position, deployed air bag, and trajectory of the driver.

The driver was wearing a short-sleeved buttoned top, denim jeans, a watch on the left wrist, rings on the left ring finger, and contact lenses. She reported that there was no crash related damage to any of the clothing or jewelry items.

At impact, the driver was braking with her right foot and had both hands on the steering wheel in a probable bracing action with her hands positioned at the 3 and 9 o'clock positions. She further noted that she was looking at her infant daughter, therefore her head was turned to the right. As the Saturn impacted the rear of the Pontiac Grand Prix, the frontal air bag system deployed. The SDM recorded a time frame of 85 ms between the algorithm activation to system deployment.

The unrestrained driver probably initiated a forward trajectory in response to the frontal impact force immediately prior to air bag deployment. Her lower extremities contacted the rigid knee bolster which resulted in contusions of the right lower leg. The medial aspect of her left knee probably contacted the steering column cover which resulted in a small diameter contusion. There was no contact evidence to support these injury mechanisms. Her forward trajectory, in combination with her pre-crash braking actions, resulted in loading of her right foot against the brake pedal. This resulted in soreness to the bottom of the driver's right foot.

As the air bag deployed, the driver's face and chest loaded the air bag membrane which protected her from contact with the steering assembly. The driver stated that she sustained an abrasion of the hands between the thumb and the index finger bilaterally. This was attributed to the expanding air bag.

The driver subsequently rebounded into the seat back where she came to rest. She exited the vehicle unassisted and refused medical treatment, partially due to the critical status of her infant daughter.

INFANT PASSENGER DEMOGRAPHICS

Age/Sex:	6 weeks/female
Vehicle Position:	Front right
Length:	58.4 cm (23.0")
Weight:	4.5 kg (10.0 lb)
Restraint Type:	Rear-facing Century infant seat improperly restrained by the vehicle's manual 3-point belt system
Mode of Transport From Scene:	Ambulance to a local hospital
Type of Medical Treatment:	Evaluated and transferred by ambulance to a to a Children's hospital where she expired en route

INFANT PASSENGER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanism
Extensive skull fractures of the calvarium and posterior fossae, bilaterally	Moderate (150400.2,1 150400.2,2)	Front right passenger air bag module cover flap and expansion of air bag against the shell of the RFCSS

Injury	Injury Severity (AIS 90)	Injury Mechanism
Patchy subdural hemorrhage over the base of the brain	Severe (140650.4,9)	Front right passenger air bag module cover flap and expansion of air bag against the shell of the RFCSS
Cerebral edema	Severe (140668.3,9)	Front right passenger air bag module cover flap and expansion of air bag against the shell of the RFCSS
Diffuse subarachnoid hemorrhage	Serious (140484.3,9)	Front right passenger air bag module cover flap and expansion of air bag against the shell of the RFCSS
Intraventricular hemorrhage	Severe (140678.4,9)	Front right passenger air bag module cover flap and expansion of air bag against the shell of the RFCSS
Massive bilateral subscalp hemorrhage, anteriorly and posteriorly	Minor (190402.10)	Front right passenger air bag module cover flap and expansion of air bag against the shell of the RFCSS
Symmetrical dark red discoloration of the lower buttocks, medially, consistent with contusion	Minor (890402.1,3)	Loading against the shell of the child safety seat
Blue discoloration of the left lateral forehead and temporal scalp	Minor (190402.1,2)	Probable impact against the front seat back support

INFANT PASSENGER KINEMATICS

The 6 week old infant was positioned in a rear-facing Century *Smartfit* RFCSS in the front right position of the Saturn SC2. The driver stated that the infant was lying on her back and was awake at the time of the crash. She further stated that the infant was secured in the RFCSS by the integral harness system with the chest clip positioned over the chest of the child. Based on the adjustment of the harness system and the size of the infant, the harness was probably loose on the child, far exceeding the "one finger rule" of belt slack at the shoulder level of the infant.

The front right seat track was adjusted to a forward position, set 3.8 cm (1.5") rearward of the full forward and 13.7 cm (5.4") forward of the full rearward position. With the seat track adjusted to this position and the seat back reclined to a 20 degree angle, the horizontal distance between the seat back support and the mid mount module cover was 67.3 cm (26.5"). The leading edge of the seat cushion was 8.9 cm (3.5") rearward of the vertical profile of the cover flap. In this position, the forward edge of the shell of the RFCSS was positioned approximately 2.5 cm (1.0") rearward of the mid mount front right air bag module cover flap **(Figure 11)**. In addition, the shell of the RFCSS was positioned under the brow of the upper instrument panel.

Figure 11. Pre-crash position of the RFCSS.

At impact, the front right air bag deployed. The mid mount module cover flap opened against the leading edge of the shell of the RFCSS. Minimal scuffing was noted to the leading edge of the cover flap, however, no damage occurred to the shell of the RFCSS. The cover flap began to rotate the RFCSS in a rearward direction as the air bag membrane expanded against the shell of the RFCSS. A clear plastic film was positioned between the air bag fabric and the inside surface of the module cover. A fragment of this film was fused to the outboard aspect of the vertical reinforcement of the RFCSS. This contact was the only evidence on the RFCSS to support involvement with the deploying front right air bag.

As the front right air bag membrane continued to expand against the shell of the RFCSS, the RFCSS was displaced in a rearward direction, possibly against the seat back support. The vehicle's manual belt system was not effective in restraining the RFCSS in this rearward direction.

The infant's head was positioned in the area of the shell that was impacted by the module cover flap and the expanding air bag membrane. Although not directly contacted, the deploying front right air bag module cover against the shell of the RFCSS resulted in extensive skull fractures of the calvarium and posterior fossae bilaterally, subdural hemorrhage over the base of the brain, cerebral edema, diffuse subarachnoid hemorrhage, intraventricular hemorrhage, and massive subscalp hemorrhage.
The child's loading against the shell of the RFCSS during deployment and the subsequent rotation induced by the expansion resulted in contusion over the buttocks bilaterally. The infant's left forehead and temporal scalp probably impacted the front right seat back support during the rotational trajectory of the RFCSS. The integral harness of the RFCSS, although loosely fitted, restrained the infant in the RFCSS and prevented ejection from the RFCSS. The child and RFCSS subsequently rebounded back to the seat cushion where the RFCSS came to rest near its pre-crash position.

MEDICAL TREATMENT

The infant was immediately removed from the RFCSS by the driver (mother) of the Saturn. She was transported by ambulance to a local hospital where the infant was treated and evaluated. The medical staff determined the critical condition of the infant and recommended transferal to a major children's medical center located approximately 80 km (50 miles) from the crash area. Helicopter transport was scheduled, however, the helicopter was out-of-service due to mechanical problems. The infant was prepared for ambulance transport and expired within 1.6 km (1.0 mile) of the hospital destination. The time of death was recorded at approximately 2.5 hours following the crash.

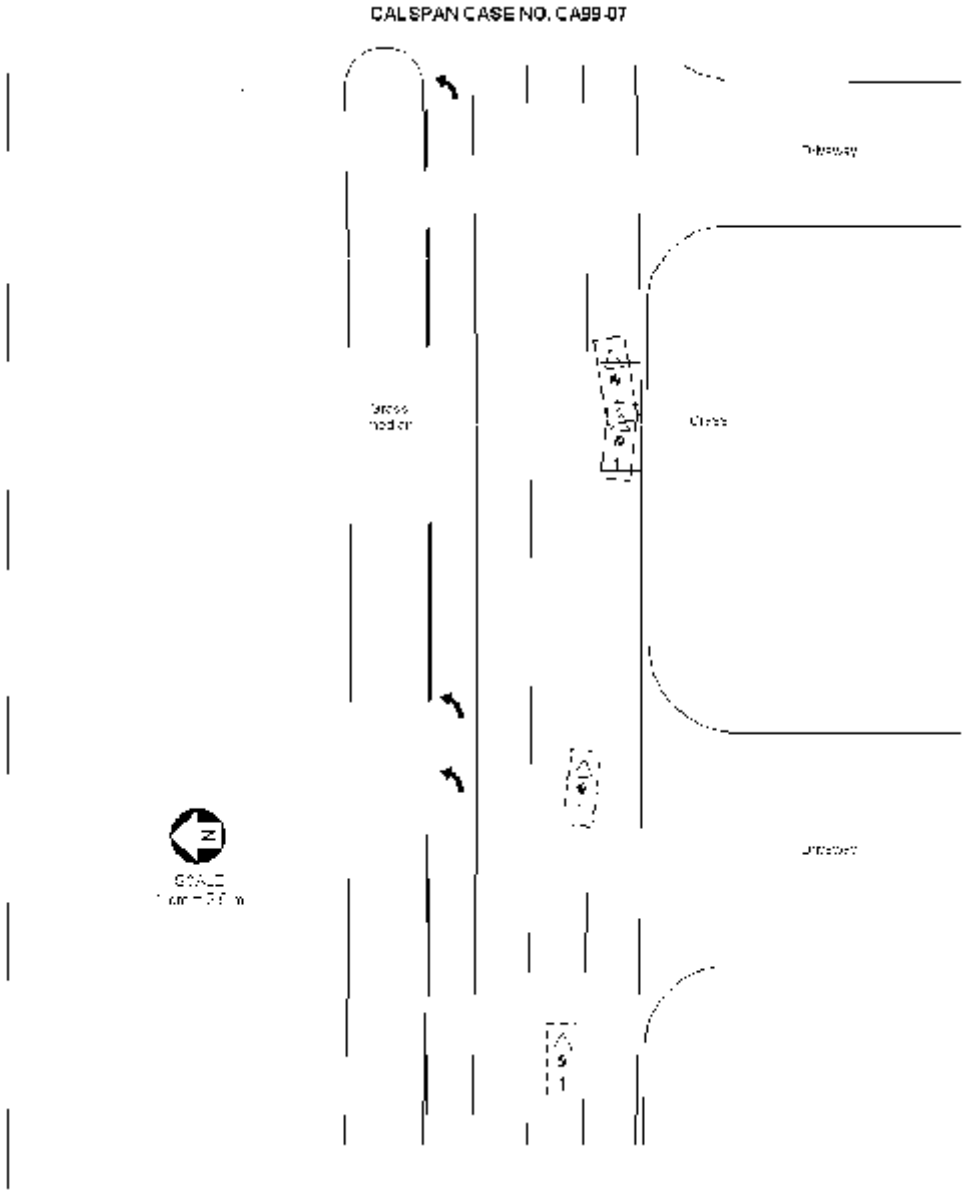

Figure 12. Crash schematic.