

**TRANSPORTATION SCIENCES**  
**Crash Research Section**

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**VERIDIAN ON-SITE REDESIGNED AIR BAG INVESTIGATION**  
**VERIDIAN CASE NO. CA98-43**  
**VEHICLE: 1998 CHEVROLET MALIBU LS**  
**LOCATION: PENNSYLVANIA**  
**CRASH DATE: JULY 1998**

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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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<p>16. <i>Abstract</i> This on-site investigation focused on a severe off-set frontal impact sequence with a tree that involved a 1998 Chevrolet Malibu. The Malibu was equipped with redesigned frontal air bags that deployed as a result of the crash. The vehicle was occupied by a 47 year old male driver and his 10 year old son who was seated in the front right passenger position. The driver was not restrained by the manual belt system, however, the child passenger was properly restrained. Both occupants initiated forward trajectories and loaded the deployed air bags which offered exceptional crash protection to the high severity impact. The driver sustained incapacitating blunt force injuries of the chest and abdominal areas while the child passenger sustained soft tissue injuries of the upper extremities. Both occupants were transported by ambulance to a local hospital for treatment. The driver was admitted for treatment while the child passenger was treated and released. Due to allegations that this crash was an intentional act, the family refused to cooperate with the SCI program.</p>			
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## CALSPAN ON-SITE REDESIGNED AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA98-43

VEHICLE: 1998 CHEVROLET MALIBU LS

LOCATION: PENNSYLVANIA

CRASH DATE: JULY, 1998

### **BACKGROUND**

This on-site investigation focused on a severe off-set frontal impact sequence with a tree that involved a 1998 Chevrolet Malibu (**Figure 1**). The Malibu was equipped with redesigned frontal air bags that deployed as a result of the crash. The vehicle was occupied by a 47 year old male driver and his 10 year old son who was seated in the front right passenger position. The driver was not restrained by the manual belt system, however, the child passenger was properly restrained. Both occupants initiated forward trajectories and loaded the deployed air bags which offered exceptional crash protection to the high severity impact. The driver sustained incapacitating blunt force injuries of the chest and abdominal areas while the child passenger sustained soft tissue injuries of the upper extremities. Both occupants were transported by ambulance to a local hospital for treatment. The driver was admitted for treatment while the child passenger was treated and released. Due to allegations that this crash was an intentional act, the family refused to cooperate with the SCI program.



**Figure 1. Severe front right damage to the Chevrolet.**

The crash occurred in July 1998, and was identified during another on-site SCI investigation in the Pennsylvania area. The redesigned frontal air bag system was confirmed through the NHTSA Crash Investigation Division and the case was assigned for investigation on August 4, 1998.



**Figure 2. Overall view of the crash site in the southbound direction.**

### **SUMMARY**

#### ***Crash Site***

The crash occurred on a residential road during daylight hours in a mid block area. The roadway consisted of two travel lanes that were straight with a 1.5 percent negative grade to the south (**Figure 2**). The travel lanes were bordered by 0.8 m (2.5') wide natural dirt shoulders with large diameter trees bordering both road edges. The involved tree consisted of a cluster of two closely spaced trunks with diameters of 22.8 and 35.6 cm (9.0 and 14.0"). The mid point of the cluster was located 1.6 m (5'3") outboard of the right road edge. The dry asphalt road surface was 5.9 cm (19'7") in width and was posted with a 40 km/h (25 mph) speed limit.

## ***SUMMARY (continued)***

### ***Vehicle Data***

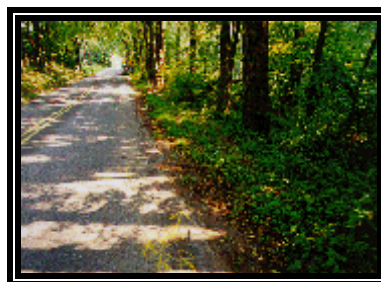
The involved vehicle was a 1998 Chevrolet Malibu LS, 4-door sedan. The Malibu was powered by a 3.1 liter V-6, transverse mounted engine linked to a 4-speed automatic overdrive transmission. In addition to the drive train, the Malibu was equipped with front disc/rear drum brakes with anti-lock (ABS) and P215/60R15 all-season tires mounted on OEM alloy wheels. The Malibu was manufactured on 05/98 and was identified by vehicle identification number 1G1NE52M9W6 (production number deleted). The driver borrowed the vehicle from a family member at the on-set of this trip. The Malibu was a new vehicle with an unknown odometer reading due to the lack of power to the instrument cluster.

The interior of the vehicle was configured with leather front bucket seats with adjustable head restraints and a rear bench seat with forward folding back rests. The Malibu was equipped with a tilt steering wheel and power accessories which included windows, door locks, outside mirrors, and a 6-way front left seat. In addition to the redesigned frontal air bag system, the Malibu was equipped with 3-point lap and shoulder belts in the four outboard seated positions and a center rear lap belt.

### ***Crash Sequence***

#### ***Pre-Crash***

The driver and his son were attending a conference at a local college and borrowed the 1998 Chevrolet Malibu to drive to purchase soft drinks. The driver traveled on several local streets in the area and turned onto the tree-lined street, traveling in a southerly direction. The 10 year old male front right passenger relayed to the investigating officer that the driver accelerated the vehicle to a speed which exceeded the 40 km/h (25 mph) speed limit. The child passenger reminded the driver of the speed limit, however, he continued to accelerate while negotiating a series of elevation changes in the road. On the descent of a hillcrest, the driver allowed the vehicle to drift onto the earth shoulder (**Figure 3**). A rotating tire print from the right



**Figure 3. Point of departure for the Chevrolet Malibu.**

side tires marked on the earth surface for a distance of 14.1 m (46'3") as the vehicle continued in a tracking orientation toward a tree cluster that was located 1.6 m (5'3") outboard of the right road edge. The child passenger alleged his father intentionally accelerated and directed the vehicle into the tree. There was no evidence of braking on the asphalt road surface or the earth shoulder. The crash schematic is attached as **Figure 14**, Page 11.

#### ***Crash***

The front right area of the Malibu impacted the tree cluster (**Figure 4**) at a WinSMASH computed speed of 98.0 km/h (60.9 mph). The vehicle crushed to a maximum depth of 124.5 cm (**Figure 5**) which resulted in a WinSMASH computed velocity change of 83.1 km/h (51.6 mph) with a longitudinal component of -83.1 mph (-51.6 mph). As a result of the high velocity change, the frontal air bag system deployed. The impact force was within the 12 o'clock sector, however, due to the offset (right) impact, the vehicle rotated in a CW direction as it separated from the struck tree. The Malibu rotated approximately 84 degrees in a CW direction into the travel lanes. It should be noted that the original length of the bumper reinforcement beam was used as the damage length in the reconstruction program. This best represented the damage profile and yielded reasonable results for this severe crash.

## ***Crash Sequence***

### ***Crash (continued)***



**Figure 4. Struck tree.**



**Figure 5. Impact damage to the front right of the Chevrolet Malibu.**

Representatives from ESIS, an insurance provider to GM, downloaded the hexi-decimal codes from the sensing and diagnostic module (SDM). The codes were interpreted by GM and the data was forwarded to the Veridian SCI team. The SDM recorded a deployment event with a velocity change of 74.0 km/h (46.0 mph) and a time frame from algorithm wake-up to deployment of 10 ms. The air bag indicator lamp had been off for 125 ignition cycles prior to deployment.

### **Post-Crash**

The Chevrolet Malibu came to rest nearly perpendicular to the travel lanes with its center of gravity positioned near the mid point of the southbound travel lane. At rest, the vehicle was facing in a westerly direction.

As the vehicle came to rest, the 10 year old child front right passenger unbuckled his manual restraint system and exited the vehicle. The driver remained in the vehicle and was removed by emergency medical technicians (EMTs). A passing motorist stopped at the crash scene and found the child passenger in a highly agitated stated. The child entered his vehicle and refused to ride in the ambulance with the driver (father). The child alleged the driver deliberately accelerated the vehicle to an unsafe speed and steered into the tree. At the scene, the driver was uncooperative with the fire and EMT personnel. Both occupants were subsequently transported to a local hospital. The child was treated and released while the driver was admitted for treatment.

## **VEHICLE DAMAGE**

### ***Exterior***

The Chevrolet Malibu sustained severe frontal damage as a result of its impact sequence with the tree cluster. Maximum crush was 124.5 cm (49.0") located on the bumper reinforcement bar, 52.1 cm (20.5") right of center. The direct contact damage began 21.6 cm (8.5") right of center of the bumper fascia and extended 50.8 cm (20.0") to the front right corner. The impact deformed the entire frontal width of the vehicle which resulted in a combined direct and induced damage length (Field L) of 59.7 cm (23.5"). The front right structure was crushed straight back which displaced the left side structure laterally to the right. The lateral shift of the leading edge of the right front fender was approximately 55.9 cm (22.0") while the bumper reinforcement bar was displaced 88.9 cm (35.0") to the right. The impact separated the bumper fascia and the styrofoam backer material, therefore the crush profile was documented at the level of the reinforcement bar (**Figure 6**). This frontal crush profile was as follows: C1 = 9.8 cm (3.9"), C2 = 29.8 cm (11.75"), C3 = 51.1 cm (20.1"), C4 = 79.4 cm (31.25"), C5 = 124.5 cm (49.0"), C6 = 123.8 cm (48.75"). The Collision Deformation Classification (CDC) for this impact was 12-FZEW-5



**Figure 6. Profile view of the frontal damage pattern.**

The severe off-set front right impact reduced the length of the right wheelbase by 60.4 cm (23.75") and elongated the left side by 1.2 cm (0.5"). Damaged components included the entire frontal structure, the right A-pillar, roof and right roof side rail, and both right side doors.

The right front door was jammed closed due to frontal deformation. The left front, left rear, and right rear doors remained closed during the crash and were operational post-crash. The windshield was cracked full width and height by the deformation and the right front door glazing was shattered by the damage. All remaining tempered glazing remained intact.

### ***Interior***

The interior of the Chevrolet Malibu sustained severe damage that was associated with exterior deformation, occupant contact, and deployment of the frontal air bag system. The frontal air bag system deployed as designed with the driver and right bags deploying from their respective module assemblies. The front right air bag module cover flap opened in an upward direction and contacted the intruding laminated windshield. The glazing was fractured due to the rearward displacement of the right A-pillar and cowl.

The front passenger compartment was significantly reduced in size by intrusion of numerous components. Maximum intrusion involved 50.2 cm (19.75") of rearward displacement of the right mid A-pillar with displacement of the right instrument panel and toe pan. The following table (**Table 1**) identifies the additional intruding components, the magnitude of the intrusion, and the direction of displacement.



**Table 1.  
Intruding Components**

<b>Component</b>	<b>Magnitude</b>	<b>Direction</b>
Left toe pan	10.2 cm (4.0")	Longitudinal
Steering column (A dimension)	20.3 cm (8.0")	Longitudinal
<b>Component</b>	<b>Magnitude</b>	<b>Direction</b>
Left corner of mid instrument panel	2.8 cm (1.1")	Longitudinal
Center mid instrument panel	39.4 cm (15.5")	Longitudinal
Right mid A-pillar at beltline	50.2 cm (19.75")	Longitudinal
Right toe pan	44.4 cm (17.5")	Longitudinal
Right corner of mid instrument panel	48.3 cm (19.0")	Longitudinal
Right lower A-pillar	30.2 cm (11.9")	Longitudinal
Right upper A-pillar at side rail juncture	3.8 cm (1.5")	Longitudinal

The driver's right knee impacted the left side of the of the mid instrument panel 12.7-17.8 cm (5.0-7.0") right of center and 27.9-36.8 cm (11.0-14.5") below the top instrument panel. The contact scuffed and fractured the plastic panel. His left knee contacted the rigid bolster panel, however, no contact evidence was visible on the plastic panel.

The driver loaded the deployed redesigned front left air bag and compressed the bag against the steering assembly, deforming the steering wheel rim and compressing the energy absorbing steering column. The upper rim of the 4-spoke steering wheel rim was deformed approximately 3.2 cm (1.25") forward while the lower rim was displaced 1.3 cm (0.5") forward. The shear brackets of the energy absorbing column were completely separated and displaced 2.8 cm (1.1") forward.

The front right child passenger was restrained by the manual belt system. His loading of the belt separated the energy management loop and produced a transfer of the D-ring on the belt webbing. The child additionally loaded the deployed front right air bag, however, there was no contact evidence on the bag membrane.

His left knee loaded the glove box door which that was evidenced by a tissue transfer located 9.5-13.3 cm (3.75-5.25) inboard of the left edge of the door and 14.0-19.7 cm (5.5-7.75") below the top of the glove

box door. The child passenger's right knee impacted the glove box 1.9-3.6 cm (0.75-1.4") inboard of the right edge of the door and 17.8-19.7 cm (7.0-7.75") below the top edge. A tissue transfer evidenced this contact point.

### ***MANUAL RESTRAINT SYSTEMS***

The Malibu was equipped with 3-point lap and shoulder belts for the four outboard seated positions and a center rear lap belt. The front belt systems consisted of a continuous loop webbing with a cinch-bar (locking) latchplate and adjustable D-rings. The belts retracted onto emergency locking retractors that were located in the lower aspect of the B-pillars. The lap belt aspect of the systems were anchored to the sills adjacent to the B-pillars. Additionally, the front belt webbings were sewn with an energy management loop that was incorporated into the lap belt webbing. The driver was not wearing the belt system, however, the child passenger was restrained, therefore the front right management loop deployed due to occupant loading (**Figure 7**). The single fold management loop provided an additional 4.4 cm (1.75") of ridedown of the belt system when deployed.



**Figure 7. Deployment of the front right energy management loop.**

The loading evidence of the front right belt system consisted of a subtle D-ring transfer on the shoulder belt webbing that was 6.4 cm (2.5") in length. There was no other damage to the front right belt system other than the occupant loading evidence.

### ***AUTOMATIC RESTRAINT SYSTEM***

The 1998 Chevrolet Malibu was equipped with a Supplemental Inflatable Restraint (SIR) system that consisted of redesigned air bags for the driver and right passenger positions (**Figure 8**). A single point sensing and diagnostic module (SDM) which detected, deployed, and recorded deployment data was positioned under the front right seat of the vehicle. The data from the module was downloaded by an independent ESIS representative and is provided on Page 6 of this section..



**Figure 8. Overall view of the deployed redesigned frontal air bags.**

The front left (driver) air bag module was housed in a typical configuration within the 4-spoke steering wheel rim with the spokes were located at the 3/9 and 5/7 o'clock sectors. The module cover was an I-configuration with symmetrical flaps measuring 13.7-7.4 cm (5.4x2.9"), height by width. The cover flaps opened the designated tear seams with the hinge points located at the outboard aspects of the flaps. The deployed front left air bag membrane was approximately 63.5 cm (25.0") in diameter in its deflated state and was tethered by two 12.7 cm (5.0") wide band tether straps located at the 12 and 6 o'clock sectors. The tethers were sewn to the face of the bag with a 16.5 cm (6.5") diameter

reinforcement. Two 1.9 cm (0.75") vent ports were located on the back side of the bag at the 11 and 1 o'clock sectors, centered 11.4 cm (4.5") inboard of the internally sewn peripheral seam.

There was no damage (e.g. tears) to the deployed front left air bag. A series of vertically oriented black vinyl transfers were noted to the face of the bag at the 6 o'clock sector. The transfers were located 18.4-20.9 cm (7.25-8.25") below the horizontal centerline of the bag and centered on the vertical centerline. These transfers were related to bag expansion within the module assembly.

The front right air bag deployed from a top mount module in the right upper instrument panel (**Figure 9**). The module was concealed within a single cover flap that was hinged at the forward aspect of the flap. The vinyl skin of the flap was bonded to an alloy inner liner that acted as a reinforcement and hinge mechanism. The overall dimensions of the flap were 32.4 cm (12.75") laterally and 14.6 cm (5.75") in depth. The rigid hinge mechanism resulted in a fixed position of the flap post-deployment. The cover flap rotated approximately 125 degrees to the upper instrument panel during deployment. A bar coded label on the inside surface of the cover flap identified the assembly as \*AL 8522 1 5 077 U 0384\*.



**Figure 9. Deployment of the front right air bag.**

The front right air bag membrane was rectangular in shaped with overall dimensions of 50.8 cm (20.0") horizontally and 68.6 cm (27.0") vertically. The bag was tethered internally by two 7.6 cm (3.0") wide straps sewn to the face of the bag. The horizontal line of stitching was located near the mid point of the bag face, 38.7 cm (15.25") below the top aspect of the bag. The tether stitching extended the full width of the bag. There was no contact evidence or damage to the front right passenger air bag.

### ***SDM Data***

The SDM data was downloaded in a hexi-decimal format by an independent investigator of the ESIS group and forwarded to GM for interpretation. The results of the download were provided to the Calspan SCI team for this investigation. The data from the 1998 Chevrolet Malibu yielded the following:

- The time duration from the system algorithm wake-up to deployment was 10 ms
- The air bag deployment event recorded a delta V of 74 km/h (46 mph)
- The SIR indicator lamp was off for 125 ignition cycles prior to deployment.

### ***DRIVER DEMOGRAPHICS***

Age/Sex:	47 year old male
Height/Weight:	Unknown
Manual Restraint	
System Usage:	None
Usage Source:	Vehicle inspection
Mode of Transport	
From Scene:	Ambulance
Medical Treatment:	Admitted to a local hospital for treatment of his injuries

***DRIVER INJURIES***

<b>Injury</b>	<b>Injury Severity (AIS 90)</b>	<b>Injury Mechanism</b>
Blunt chest injury (NFS)	Unknown (415099.7,0)	Steering assembly
Blunt abdominal injury	Unknown (515099.7,0)	Steering assembly

***DRIVER KINEMATICS***

The driver of the Chevrolet was seated in a presumed normal posture with the power seat track adjusted to a rear track position. The measured adjusted track position was 3.5 cm (1.375") forward of the full rear position, or 19.7 cm (7.75") rear of the full forward position. The post-crash seat back angle was deflected forward due to damage. The adjustable head restraint was set to the full down position. The driver was not wearing the manual 3-point lap and shoulder belt system. The lack of belt usage was determined by the lack of loading evidence on the belt webbing and the non-deployed status of the energy management loop.

At impact, the unrestrained driver initiated a forward trajectory in response to the frontal impact force and initially loaded the deployed front right air bag (**Figure 10**). Due to the high severity of the crash and the lack of manual restraint usage, the driver's loading force was transmitted through the air bag into the steering assembly. This was evidenced by 2.8 cm (1.1") of steering column shear bracket separation and 3.2 cm (1.25") of upper steering wheel rim deformation (**Figure 11**). As a result of this loading sequence, the driver sustained blunt chest and abdominal injuries. His right knee contacted the intruding mid instrument panel which scuffed and fractured the plastic components. There was no injury reported to the lower extremity.



**Figure 10. Overall view of the deployed front left redesigned air bag.**



**Figure 11. Steering wheel deflection from driver loading through the bag.**

The redesigned front left air bag provided the driver with automatic restraint which reduced his loading force against the steering assembly and distributed the forces over a wide body area. The driver remained in the vehicle post-crash and was removed by rescue personnel. He was transported by ambulance to a local hospital where he was admitted for treatment of the chest and abdominal injuries.

***FRONT RIGHT PASSENGER DEMOGRAPHICS***

Age/Sex: 10 year old male  
 Height/Weight: Unknown  
 Manual Restraint  
 System Usage: Proper use of the 3-point lap and shoulder belt  
 Usage Source: Vehicle inspection  
 Mode of Transport  
 From Scene: Ambulance  
 Medical Treatment: Treated at a local hospital and released

***FRONT RIGHT PASSENGER INJURIES***

Injury	Injury Severity (AIS 90)	Injury Severity
Soft tissue injuries of the upper extremities (NFS)	Minor (790099.1,3)	Unknown

***FRONT RIGHT PASSENGER KINEMATICS***

The front right child passenger was seated in an upright attitude with the seat track adjusted to a rear position and the seat back rest slightly reclined. The adjustable head restraint was set to the full down position. He was properly restrained by the manual 3-point lap and shoulder belt system. Belt usage was supported by loading evidence on the belt system which included a D-ring transfer on the shoulder belt webbing and complete separation of the energy management loop.

At impact, the frontal air bag system deployed early in the crash sequence. During this inflation process, the front right structure of the vehicle was displaced rearward into the passenger compartment resulting in severe intrusion into this passenger’s space. The child passenger began to move forward in response to the frontal impact force. He loaded the lap and shoulder belt webbing which restricted his forward trajectory. His loading force against the belt system produced a D-ring transfer to the shoulder belt webbing and full deployment of the energy management



**Figure 13. Intrusion of the right instrument panel into the front right passenger compartment.**

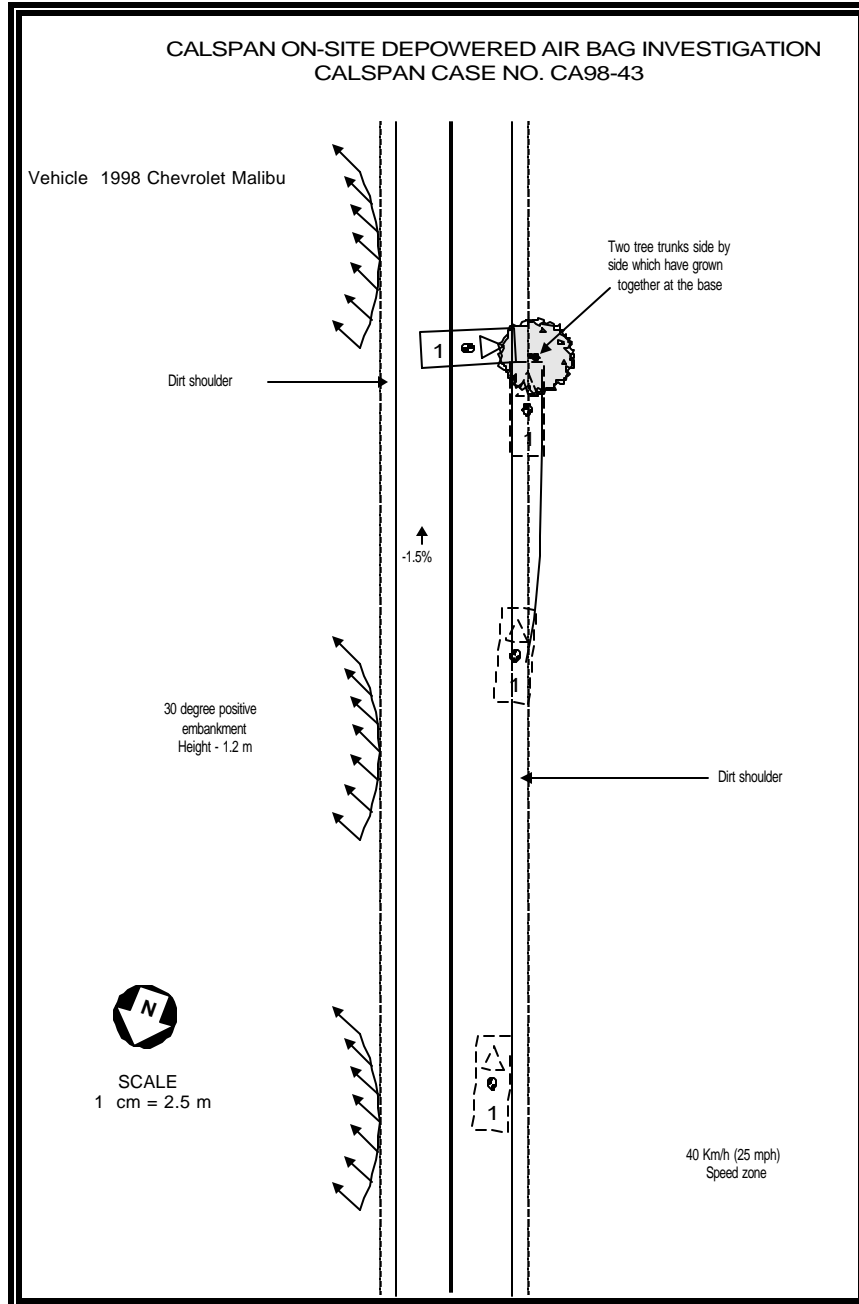


**Figure 12. Trajectory of the child passenger into the deployed front right air bag.**

loop that was incorporated into the lap belt aspect of the belt system. The belt system provided a ride-down to the passenger and held him in an upright attitude to load the deployed front right air bag with his entire upper body and head (**Figure 12**). It should be noted that the post-crash horizontal distance between the intruding right mid instrument panel and the front right seat back support (**Figure 13**) was 25.4 cm (10.0"). The combination of belt usage and automatic protection offered by the deployment of the redesigned front right air bag, afforded the child passenger with exceptional crash protection to the severe forces associated with this crash. The child passenger's knees contacted the intruding glove box door, however, no injury resulted from these contacts.

The child passenger sustained soft tissue injuries of the upper extremities from the crash sequence. There were no specific contact patterns that could be directly related to these injuries. Several blood transfers were noted to the right corner of the mid instrument panel.

Immediately following the crash, the child unbuckled the manual restraint system and exited the vehicle unassisted. He proceeded to a vehicle which stopped at the crash scene to offer assistance. He was extremely distraught at the scene of the crash with the fear that his father intentionally accelerated the vehicle to an unsafe speed and steered into the struck tree. The child was transported by ambulance to a local hospital for treatment of his injury.



**Figure 14. Crash Schematic**