

**TRANSPORTATION SCIENCES  
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**VERIDIAN ON-SITE SIDE AIR BAG RELATED CHILD  
SERIOUS INJURY INVESTIGATION**

**VERIDIAN CASE NO. CA01-049**

**VEHICLE - 1997 NISSAN QUEST XE**

**LOCATION - STATE OF NORTH CAROLINA**

**CRASH DATE - MAY, 2001**

Contract No. DTNH22-01-C-17002

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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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16. <i>Abstract</i> <p>This on-site investigation focused on the injury mechanisms of a 9 year old male front right child passenger of a 1997 Nissan Quest XE minivan. The Nissan Quest was equipped with frontal air bags for the driver and front right passenger positions which deployed as a result of a rear-end collision with a 1987 GMC Sonoma pickup truck. The driver of the Nissan was operating the vehicle westbound on the inboard lane of an urban four lane roadway when she failed to observe traffic slowing ahead. A rear-end collision resulted in moderate damage to both vehicles. The restrained 30 year old female driver of the 1997 Nissan Quest initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint and deployed driver air bag. She was uninjured in the collision. The unrestrained 9 year old male front right child passenger was displaced out-of-position forward due to the pre-crash braking actions of the driver. His right arm/hand was raised in front of his face in a shielding posture. At impact, he was forward within the path of the expanding air bag which struck his face and anterior right forearm resulting in multiple soft tissue trauma. Expansion of the air bag membrane against the right forearm resulted in extensive internal trauma to include crush injury to the right subclavian artery/vein, transection of the right axillary artery/brachial plexus, a right clavicle/humerus fracture, and an avulsion of the cervical nerve roots off the spinal cord. He also sustained a thermal burn to the right eye and forearm from venting air bag gases. The child passenger was propelled rearward into the front right seat back which resulted in additional soft tissue injury to the chest and fractures of the 1<sup>st</sup> and 2<sup>nd</sup> posterior right ribs. The front right child passenger was transported to a local hospital and subsequently transferred to a nearby trauma center for treatment and admitted for eight days. The second row left seating position of the Nissan was occupied by a 3 year old male restrained within a forward facing child safety seat. The second and third row right seating positions of the Nissan were occupied by a restrained 7 year old female and unrestrained 9 year old female, respectively.</p>			
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VERIDIAN CASE NO. CA01-049  
VEHICLE - 1997 NISSAN QUEST XE  
LOCATION - STATE OF NORTH CAROLINA  
CRASH DATE - MAY, 2001**

***BACKGROUND***

This on-site investigation focused on the injury mechanisms of a 9 year old male front right child passenger of a 1997 Nissan Quest XE minivan. The Nissan Quest was equipped with frontal air bags for the driver and front right passenger positions which deployed as a result of a rear-end collision with a 1987 GMC Sonoma pickup truck. The driver of the Nissan was operating the vehicle westbound on the inboard lane of an urban four lane roadway when she failed to observe traffic slowing ahead. A rear-end collision resulted in moderate damage to both vehicles. The restrained 30 year old female driver of the 1997 Nissan Quest initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint and deployed driver air bag. She was uninjured in the collision. The unrestrained 9 year old male front right child passenger was displaced out-of-position forward due to the pre-crash braking actions of the driver. His right arm/hand was raised in front of his face in a shielding posture. At impact, he was forward within the path of the expanding air bag which struck his face and anterior right forearm resulting in multiple soft tissue trauma. Expansion of the air bag membrane against the right forearm resulted in extensive internal trauma to include crush injury to the right subclavian artery/vein, transection of the right axillary artery/brachial plexus, a right clavicle/humerus fracture, and an avulsion of the cervical nerve roots off the spinal cord. He also sustained a thermal burn to the right eye and forearm from venting air bag gases. The child passenger was propelled rearward into the front right seat back which resulted in additional soft tissue injury to the chest and fractures of the 1<sup>st</sup> and 2<sup>nd</sup> posterior right ribs. The front right child passenger was transported to a local hospital and subsequently transferred to a nearby trauma center for treatment and admitted for eight days. The second row left seating position of the Nissan was occupied by a 3 year old male restrained within a forward facing child safety seat. The second and third row right seating positions of the Nissan were occupied by a restrained 7 year old female and unrestrained 9 year old female, respectively.

The crash notification was provided to NHTSA and immediately assigned to the Veridian SCI team as an on-site investigative effort on Tuesday, November 13, 2001. Although delays were incurred establishing cooperation with the family attorney, the on-site investigator departed on November 26<sup>th</sup> and completed field activities on Tuesday, November 27, 2001.

***SUMMARY***

**Crash Site**

This two vehicle crash occurred during the afternoon hours of May, 2001. At the time of the crash, it was daylight with no adverse conditions as the roads were dry. The crash occurred just east of an urban 3-leg intersection; on the westbound inboard lane of a (straight) four lane east/west roadway with a negative grade for westbound traffic (see **Figure 12 - page 13**). The asphalt roadway was bordered by barrier curbs with a 4-leg signalized intersection approximately 107.0 meters (351.1 feet) east of the crash site. Traffic control consisted of a stop sign for northbound traffic. The posted speed limit at the crash site was 56 km/h (35 mph).

### Pre-Crash

The 30 year old female driver of the 1997 Nissan Quest XE was en-route home and operating the vehicle westbound (**Figure 1**) on the inboard lane of a four lane roadway at a (driver reported) speed of 56 km/h (35 mph). The driver became distracted by a conversation with the front right child passenger and failed to observe traffic slowing ahead for the urban connector. Upon recognition of the impending harmful event, the driver braked in avoidance and remained in the westbound inboard lane prior to the collision.



**Figure 1.** Westbound approach for the 1997 Nissan Quest.

### Crash

At this point, the front left area of the Nissan Quest impacted the rear area of the GMC pickup truck resulting in moderate damage to both vehicles. The pre-crash braking actions of both drivers produced an underride/override configuration as the Nissan underrode the GMC which allowed the bumper on the Nissan to engage the structure under the GMC pickup. The impact resulted in deployment of the Nissan's frontal air bag system. The trajectory algorithm of the WinSMASH reconstruction program computed impact speeds of 32.5 km/h (20.2 mph) for the subject vehicle and 7.3 km/h (4.5 mph) for the struck GMC pickup truck. The missing vehicle (damage) algorithm computed velocity changes of 17.3 km/h (10.8 mph) for the subject vehicle and 24.5 km/h (15.2 mph) for the struck GMC. Respective longitudinal components were -17.3 km/h (-10.8 mph) and 24.5 km/h (15.2 mph). The Nissan Quest reportedly traveled 1.5 meters (4.9 feet) as the GMC pickup truck traveled 11.1 meters (36.4 feet) to final rest on the westbound inboard lane facing west.

### Post-Crash

Following the crash, the Nissan driver attended to the injured front right child passenger and subsequently exited the vehicle through the left front door under her own power. The front right child passenger was removed through the right front door by rescue personnel due to perceived serious injury and was transported by ambulance (*accompanied by the driver*) to the emergency room of a local hospital. Within two hours of the crash, he was transferred by air to a nearby trauma center for treatment and admitted for eight days. The 7 year old and 9 year old female rear seated passengers of the Nissan assisted the 3 year old male child passenger as they exited the vehicle through the right rear door under their own power. The 7 year old female second row right occupant sought treatment later at a medical facility. The Nissan Quest was towed from the crash scene due to disabling vehicle damage as the GMC pickup truck was driven from the scene with non-disabling damage.

### VEHICLE DATA

The 1997 Nissan Quest was manufactured on August, 1996 and identified by the vehicle identification number (VIN): 4N2DN1111VD (production number deleted). The driver-owned vehicle was purchased as new in October, 1997. The vehicle was a 3-door minivan equipped with power windows/door locks, front-wheel drive, and a 3.0 liter, V-6 engine. At the time of the crash, the odometer had recorded 67,380 km (41,869 miles). The seating was configured with front box-mounted (van type) bucket seats and a bench (with folding backs) for the second and third row seating

positions. The driver reported one previous crash (rear-end damage) without air bag deployment, and no previous maintenance on the Nissan's frontal air bag system. No cellular phone was present in the vehicle.

## VEHICLE DAMAGE

### Exterior

The 1997 Nissan Quest XE sustained moderate frontal damage as a result of the impact with the GMC Sonoma pickup truck (**Figures 2 & 3**). Although the vehicle was partially dismantled by insurance personnel prior to the SCI inspection, crush dimensions were accurately obtained for reconstructive purposes (*the hood, fenders and bumper assembly were removed from the vehicle and were not available for SCI inspection*). The direct contact damage began at the front left bumper corner and extended approximately 103.0 cm (40.6 in) inboard. The impact deformed the entire front end width resulting in an combined direct and induced damage length (Field L) of 101.0 cm (39.8 in). Six crush measurements were documented at the level of the bumper and 13.0 cm (5.1 in) above the level of the bumper to capture the underride damage, which resulted in an *averaged profile of*: C1= 16.0 cm (6.3 in), C2= 10.0 cm (3.9 in), C3= 11.0 cm (4.3 in), C4= 10.0 cm (3.9 in), C5= 0 cm, C6= 0 cm. The Collision Deformation Classification (CDC) for this impact to the Nissan was 12-FYEW-2 with a principal direction of force of 0 degrees. The windshield was fractured at the right lower A-pillar from exterior impact forces and the right mid-windshield area from the passenger air bag deployment. No wheelbase reduction was identified.



Figure 2. Front left damage to the 1997 Nissan Quest XE.

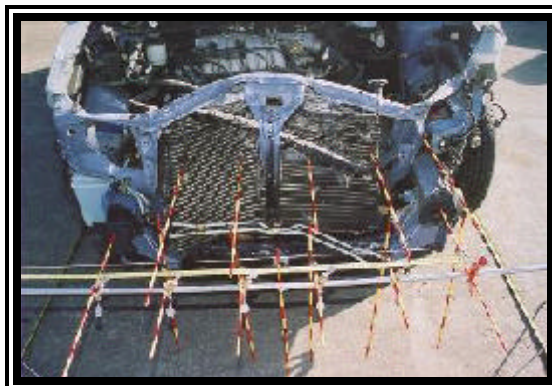


Figure 3. Gauge overview.

### Interior

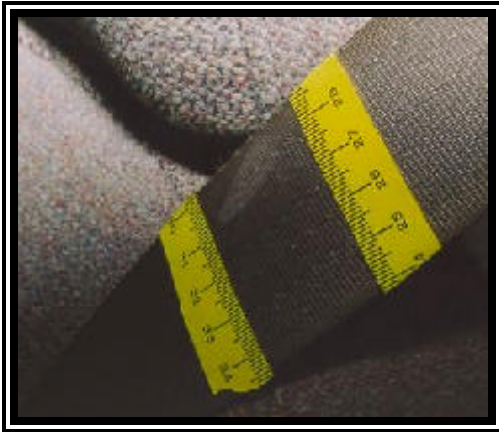
Interior damage to the Nissan was moderate and was attributed to occupant contact. Scuff marks were documented on the left knee bolster and glove compartment door with an indentation surrounding the contact site. Abrasions and small indentations were also identified on the rear aspect of the front seat backs from second row occupant loading. The second row seat back was deformed forward 13.0 cm (5.1 in) to an upright position from third row occupant loading. Occupant interaction with the expanding front right passenger air bag fractured the right mid-windshield area with a white scuff mark surrounding the fracture site (**Figure 4**). No component intrusions were found in the vehicle.



Figure 4. Interior view.

## **MANUAL RESTRAINT SYSTEMS**

The interior of the Nissan Quest consisted of an seven passenger seating configuration with front box-mounted (van type) bucket seats and a bench (with folding backs) for the second and third row seating positions. The driver's 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). A tissue transfer was documented on the shoulder portion of the driver restraint along with abrading to the latchplate and D-ring (**Figures 5 & 6**). 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. Although slight dimpling was noted to the shoulder portion of the front right restraint, no loading evidence was identified on the webbing, D-ring, or latchplate of the passenger restraint systems to substantiate usage by any of the child occupants (*children reported by driver as restrained*). The third row center seat was equipped with a 2-point manual lap belt and a locking latchplate.



**Figure 5. Tissue transfer to the driver shoulder restraint.**



**Figure 6. Loading marks to the D-ring of the driver restraint.**

## **CHILD SAFETY SEAT (CSS)**

The 3 year old male child passenger of the 1997 Nissan Quest was positioned in a forward-facing child safety seat (FFCSS) in the second row left seat of the vehicle. The child safety seat was destroyed after the crash and unavailable for SCI inspection, however, limited model data was obtained as a like unit was purchased as a replacement. The child safety seat was manufactured by Cosco Products (date of manufacture unknown) and identified by the model number: 02-443-PRI with a weight rating of 10-18 kg. (22-40 lb.). The FFCSS consisted of a molded plastic shell, fabric covered padding, and an integral 5-point harness system. Warning labels were affixed to the shell of the seat with additional warning labels found on the vehicle sunvisors and restraint systems.

## **SUPPLEMENTAL RESTRAINT SYSTEMS**

The 1997 Nissan Quest XE was equipped with frontal air bags for the driver and front right passenger positions which deployed as a result of the crash (**Figure 7**). The driver air bag was identified by the part number: \*U1C0207J158G5\* with a bar coded lot number of: \*WMB63968050069\* and housed in the center of the steering wheel with a horizontally oriented flap tear seam (H-configuration). The flaps were nearly symmetrical in shape as the upper flap measured 19.0 cm (7.5 in) in width and 10.3



cm (4.1 in) in height while the lower flap measured 19.0 cm (7.5 in) in width and 9.0 cm (3.5 in) in height. No contact evidence was identified on the exterior surface of the module cover flaps. The diameter of the driver air bag measured 64.0 cm (25.2 in) in its deflated state (**Figure 8**). Makeup transfers were identified at the upper left quadrant of the air bag face along with multiple black vinyl transfers to the rear aspect from expansion within the module. The bag was tethered by four internal straps and vented by two 4.5 cm (1.8 in) diameter ports located at the 10 o'clock and 2 o'clock sectors on the rear aspect of the air bag. Rearward bag excursion measured 27.0 cm (10.6 in) from the steering wheel hub.



**Figure 7. 1997 Nissan Quest XE deployed frontal air bag system.**

The front right passenger air bag deployed from the right top instrument panel area with a single cover flap design hinged at the forward aspect. The aluminum-reinforced cover flap was rectangular in shape and measured 46.3 cm (18.2 in) in width and 23.5 cm (9.3 in) in height. No contact evidence was identified on the exterior surface of the cover flap or surrounding instrument panel area. The passenger air bag measured 52.0 cm (20.5 in) in width and 73.0 cm (28.7 in) in height in its deflated state (**Figure 9**). The bag was tethered by two internal straps and vented by two 2.5 cm (1.0 in) diameter ports located at the 10 o'clock and 2 o'clock sectors on the side aspect of the air bag. Passenger interaction with the expanding air bag re-directed the proper deployment path of the membrane and produced the noted fracture and scuffs to the right mid-windshield area. The top portion of the air bag was also slightly abraded from engagement against the windshield. Contact evidence to the membrane consisted of extensive abrading along the left side aspect and upper left quadrant of the air bag face. Light deposits of skin tissue were also identified on the membrane surrounding the left vent port (**Figure 10**).



**Figure 8. 1997 Nissan Quest deployed driver air bag.**



**Figure 9. 1997 Nissan Quest deployed passenger air bag.**



**Figure 10. Contact evidence to the left side aspect of the passenger air bag.**

**DRIVER DEMOGRAPHICS**

Age/Sex: 30 year old female  
Height: 155 cm (61 in)  
Weight: 54 kg (120 lb)  
Seat Track Position: Middle position  
Manual Restraint Use: 3-point lap and shoulder belt system  
Usage Source: Vehicle inspection, police report  
Eyeware: None  
Type of Medical Treatment: None

**Driver Injuries**

<i>Injury</i>	<i>Severity (AIS 90)</i>	<i>Injury Mechanism</i>
None	N/A	N/A

**Driver Kinematics**

The 30 year old female driver of the 1997 Nissan Quest XE was restrained by the available 3-point manual lap and shoulder belt system, seated in an upright posture with her hands placed at the 10 o'clock and 2 o'clock sectors on the steering wheel rim. The seat track was adjusted to the middle position with the seat back reclined 18 degrees off vertical. Belt usage was confirmed by the tissue transfer identified on the shoulder belt webbing and loading marks documented to the latchplate/D-ring of the front left restraint. The driver reported during the SCI interview that upon recognition of the impending crash, she leaned over to the right with both arms extended in a bracing position for the front right child passenger, however, contact evidence would not substantiate this abnormal posture.

At impact, the driver initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint and deployed driver air bag. Contact to the deployed driver air bag was confirmed by the makeup transfers documented at the left upper quadrant of the air bag face. She loaded the knee bolster as evidenced by the scuff marks documented to this component, however, no resulting injury was reported. Following the crash, the driver unbuckled her seat belt and attended to the injured front right child passenger until rescue personnel arrived on-scene within minutes of the crash. She subsequently exited the vehicle through the left front door and accompanied the injured child passenger to the hospital.

**FRONT RIGHT PASSENGER DEMOGRAPHICS**

Age/Sex: 9 year old male  
Height: 147 cm (58 in)  
Weight: 32 kg (70 lb)  
Seat Track Position: Full rearward position  
Manual Restraint Use: None  
Usage Source: Vehicle inspection, medical report, police report  
Eyeware: None  
Type of Medical Treatment: Transported to the emergency room of a local hospital and subsequently transferred to a nearby trauma center for treatment and admitted for eight days.

## Front Right Passenger Injuries

<i>Injury</i>	<i>Severity (AIS 90)</i>	<i>Injury Mechanism</i>
*Crush injury right subclavian artery (also severely contused)	Severe (421408.4,1)	Expanding front right air bag
*Crush injury right subclavian vein	Severe (421606.4,1)	Expanding front right air bag
^Transection/avulsion right axillary artery	Serious (720208.3,1)	Expanding front right air bag
#Spinal nerve root avulsion between C5-C7	Serious (630266.3,6)	Expanding front right air bag (indirect contact injury)
*Avulsion injury right brachial plexus (all 3 divisions torn and exposed: superior/inferior/posterior)	Serious (630226.3,6)	Expanding front right air bag (indirect contact injury)
^Fracture right 1 <sup>st</sup> and 2 <sup>nd</sup> ribs with small anterior pneumothorax at right apex (oblique fracture through base of proximal 1 <sup>st</sup> and 2 <sup>nd</sup> ribs posteriorly, mildly displaced inferiorly)	Serious (450222.3,1)	Front right seat back (indirect air bag contact injury)
^Fracture right distal humerus (lateral epicondyle mildly displaced with radial nerve involvement)	Serious (752606.3,1)	Expanding front right air bag
#Spinal nerve root stretch injury at C8	Moderate (630202.2,6)	Expanding front right air bag (indirect contact injury)
#Spinal nerve root stretch injury at T1	Moderate (630402.2,7)	Expanding front right air bag (indirect contact injury)
^Partial tearing of the trapezius muscle	Moderate (740400.2,1)	Expanding front right air bag (indirect contact injury)
^Partial tearing of the rhomboideus muscles	Moderate (740400.2,1)	Expanding front right air bag (indirect contact injury)
^Partial tearing of the subscapularis muscle	Moderate (740400.2,1)	Expanding front right air bag (indirect contact injury)
^Partial tearing of the serratus muscle	Moderate (740400.2,1)	Expanding front right air bag (indirect contact injury)
^Fracture right clavicle	Moderate (752200.2,1)	Expanding front right air bag
^Cervical disc injury - NFS	Moderate (650299.2,6)	Expanding front right air bag (indirect contact injury)
*Right globe injury (eye) NFS (with hyphema and irregular pupil)	Minor (240499.1,1)	Expanding front right air bag
<Contusion to right eyelid/orbital area	Minor (297402.1,1)	Expanding front right air bag

## Front Right Passenger Injuries (con't.)

<i>Injury</i>	<i>Severity (AIS 90)</i>	<i>Injury Mechanism</i>
#Abrasion to right eyelid/orbital area	Minor (297202.1,1)	Expanding front right air bag
+Laceration between eyebrows extending into forehead (small)	Minor (290602.1,7)	Passenger's right thumbnail (air bag fling injury)
+Contusion right forehead (minor: semi-circular)	Minor (290402.1,7)	Posterior aspect of passenger's right hand (air bag fling injury)
<Contusion right face	Minor (290402.1,1)	Expanding front right air bag
+Abrasions to face - multiple (includes: right eyebrow/forehead - superior right nose - central right cheek - right right upper lip - inferior)	Minor (290202.1,0)	Expanding front right air bag
>Contusion right neck (base of jaw to shoulder)	Minor (390402.1,1)	Expanding front right air bag
#Contusion anterior right upper chest (over area of clavicle FX)	Minor (490402.1,1)	Expanding front right air bag
^Contusion posterior right upper chest (over area of rib FX)	Minor (490402.1,1)	Front right seat back (indirect air bag contact injury)
#Contusion right anterior shoulder/arm/elbow	Minor (790402.1,1)	Expanding front right air bag
#Lacerations to right forearm/upper arm (multiple - small)	Minor (790602.1,1)	Expanding front right air bag
#Abrasions right anterior forearm	Minor (790202.1,1)	Expanding front right air bag
#Multiple thermal burns (2 <sup>nd</sup> degree burns to right anterior forearm and upper arm. Burn to right pupil.)	Minor (992006.1,9)	Venting passenger air bag gases (left vent port)

Sources: Discharge Summary\*/History and Physical#/Radiology report^/Operative report>/SCI interview+/EMS report<

## Front Right Passenger Kinematics

The unrestrained 9 year old male front right child passenger of the 1997 Nissan Quest XE was seated in an upright posture (*against the seat back/legs extended over the seat cushion*) with his right hand/arm raised in front of his face in a shielding posture. The seat track was adjusted to the full rearward position with the seat back reclined 22 degrees off vertical. Contrary to driver statements made during the SCI interview, the lack of belt usage was determined by the absence of loading evidence on the front right restraint system and trajectory of the child. It should be noted that the child was holding an open spiral notebook and papers in his lap prior to the collision. Clothing worn by the child consisted of long cotton shorts, sneakers/socks, and a short sleeve cotton camouflage t-shirt.

The front right child passenger was displaced out-of-position forward due to the pre-crash braking actions of the driver. At impact, he was forward in close proximity to the passenger air bag module as

he initiated a forward trajectory in response to the 12 o'clock impact force. The driver reported during the SCI interview that she observed the child "slide" forward on the seat and into the expanding air bag. Although he was not struck by the module cover, the expanding air bag membrane contacted the anterior aspect of his right forearm (and elbow), neck/shoulder, and face which resulted in multiple soft tissue injury. The child's medical reported a large expanding hematoma which extended from base of jaw to the top of the shoulder, indicative of air bag expansion trauma. Associated skeletal trauma involved a displaced fracture of the right distal humerus at the area of the lateral epicondyle with radial nerve involvement. Initial chest trauma involved contusions to the right upper chest at the location of an underlying clavicle fracture. Venting passenger air bag gases resulted in a thermal burn to the right pupil and an extensive 2<sup>nd</sup> degree thermal burn to the anterior aspect of the right forearm. The child's medical report also indicated the presence of an unspecified right globe injury and associated hyphema (*corneal blood staining*), which is indicative of a corneal contusion directly related to the aforementioned bag interaction. These injury mechanisms were evidenced by the location of the injuries relative to the passenger's stated pre-crash shielding posture. In addition, the skin tissue transfers and abrasion characteristics surrounding the left vent port suggested occupant interaction during the late stages of expansion as membrane fold patterns determined initial strike areas. The history and physical medical reported the presence of a "seat belt sliding burn" on the right shoulder, however, this injury was determined to be related to bag expansion against the shoulder/neck, as the pattern did not exhibit typical webbing characteristics across the remainder of the torso and abdominal areas. This pronounced linear abrasion was attributed to layered stitching along the membrane seams. The child's left foot struck the glove compartment door as evidenced by the height of the contact above floor level, lack of soft tissue trauma to the knee/shin, and pre-impact posture against the seat back. No injury was reported as a result of this contact.

At this point, the right hand recoiled off the membrane as the posterior aspect struck the forehead resulting in a large (semi-circular) contusion. At this position, the child's right thumbnail was exposed to the area between the eyebrows resulting in a small vertical laceration which extended into the forehead. Continued expansion of the air bag membrane propelled the arm up and rearward which hyper-extended the arm well beyond the normal range of motion resulting in a multitude of extensive internal skeletal, nerve and muscular trauma. Crush injuries of the right subclavian artery/vein were sustained along with transection/avulsion of the right axillary artery and brachial plexus. This indirectly produced an avulsion of the cervical nerve roots off the spinal cord with stretch injuries at the C8 and T1 vertebral locations. The child's medical report described the trauma as "*avulsed directly off the spinal cord; each had nerve roots coming out of the ends like a spray of telephone wires*". Underlying damage reached the third layer of muscles with partial tearing and unspecified higher grade injury to the trapezius, rhomboideus, subscapularis, and serratus muscles. Furthermore, his interaction with the expanding air bag re-directed the proper deployment path of the membrane and produced the noted fracture and scuff marks to the right mid-windshield area.

The expanding air bag membrane propelled the child rearward into the front right seat back. Although the *posterior aspect* and *inferior displacement* of the fractured 1<sup>st</sup> and 2<sup>nd</sup> right ribs suggested this may be indirectly associated with arm hyper-extension, the presence of soft tissue injury surrounding the fracture site indicated this was rebound trauma resulting from direct contact to the front right seat back. He came to rest slightly slumped to the right against the right door panel (buttocks almost to the edge of

the seat cushion) as the driver subsequently rendered assistance until police and rescue arrived within six minutes of the crash. Although there was no reported loss of consciousness, the driver described the child's immediate condition as somewhat lethargic, but responded well to verbal commands as he was transported by ambulance to the emergency room of a local hospital. Within two hours of the crash, the child was transferred by air to a nearby trauma center and admitted for eight days for evaluation and definitive treatment of diminished pulses in his right arm. The child was discharged to inpatient care at a local rehabilitation facility for an additional four days before allowed to return home.

### **Front Right Passenger Medical Treatment**

Treatment during the child's eight day admit at the trauma center included immediate surgery to repair the damaged arm and shoulder. Upon further inspection, it was noted that all three major divisions of the brachial plexus, the superior, inferior, and posterior divisions were torn. Each of them reportedly had nerve roots coming out the ends "*like a spray of telephone wires*", indicative of an avulsion directly off the spinal cord. The junction of the dural sleeve was also noted in these three major trunks. Each of the trunks was intraoperatively inspected and then tacked with 4-0 Prolene onto the inferior border of the subclavius muscle with fairly long Prolene tags left to allow their future identification. An attempt at a limb salvage operation was felt to be advisable as he underwent cable grafting of his superior trunk with a bilateral sural nerve graft to the right arm. The right thigh artery was subsequently harvested for repair of the brachial artery. The subclavian artery was repaired with a saphenous vein interposition graft. The child's right hand was casted per orthopedics to protect the forearm which was removed in mid-June. After surgery the child was transferred to pediatric intensive care for two days of observation. The child developed some tachypnea (*abnormal respiratory rate*) associated with the pleural effusion (*blood in the lobe*) on hospital day six. It should be noted the hospital progress notes indicated that the abdomen was free of trauma.

Initial nerve conduction studies on the right median, ulnar, and radial nerves revealed no motor or sensory responses. An MRI scan was used to evaluate the spinal cord as an EMG was later used to confirm the lack of electrical function in his right arm. His sensation diminished to light touch between vertebra C5-C8 on the right side, as the sensation was normal above C4 and below T1. Follow-up tests conducted approximately two months after the crash showed partial sensation present on the posterior and medial aspect of the right arm indicative of only a stretch injury of the C8 and T1 nerve roots, which reportedly may preserve hand function eventually. Diagnosis showed denervation of the C8 nerve root; and that at least part of T1 was still intact, however, there was no function or sensation at vertebra C5-C7 with no finger sensation at all. The EMG and nerve conduction velocity studies were repeated after six weeks to check for improvement, however, physicians felt the long term functional outlook for this extremity was extremely poor given the nerve root avulsions. A brachial plexus injury leaves the arm completely paralyzed and anesthetic, as the presence of Horner Syndrome implies poor prognosis for improvement.

The child's medical reported that the cranial nerves showed evidence of a very obvious Horner Syndrome with ptosis on right eye (*drooping of the eyelid*) and myosis of the right pupil (*pupil constriction*). Horner Syndrome is defined as a paralysis of the superior cervical sympathetic nerve, or,

an interruption of the oculosympathetic nerve pathway somewhere between its origin in the hypothalamus and the eye. Classic symptoms include: ptosis, pupillary myosis, facial or oral anhidrosis (*abnormal deficiency of sweat: non-sweating or reduced sweating*), and drooping facial features (*i.e. sunken eye*). The child was discharged to inpatient care at a local rehabilitation facility for an additional four days before allowed to return home. Following his release, the child was instructed to follow-up with ophthalmology for treatment of the unspecified right globe injury and thermal burn to the pupil (injury was non-operative as vision returned to normal). The child received additional corrective surgery in July, 2001 with six to eight weeks of follow-up rehabilitation.

**SECOND ROW LEFT INFANT PASSENGER DEMOGRAPHICS**

Age/Sex: 3 year old male  
 Height: 61 cm (24 in)  
 Weight: 15 kg (32 lb)  
 Seat Track Position: Fixed  
 Manual Restraint Use: 3-point lap and shoulder belt system  
 Child Safety Seat Use: Cosco FFCSS Model #02-443-PRI  
 Usage Source: Vehicle inspection, driver interview, police report  
 Eyeware: None  
 Type of Medical Treatment: None

**Second Row Left Infant Passenger Injuries**

<i>Injury</i>	<i>Severity (AIS 90)</i>	<i>Injury Mechanism</i>
+Abrasions bilateral upper chest	Minor (490202.1,3)	CSS harness

Source: driver+

**Second Row Left Infant Passenger Kinematics**

The 3 year old male child passenger of the 1997 Nissan Quest XE was positioned in a Cosco child safety seat (CSS). This child restraint was designed exclusively as a forward-facing restraint. The driver secured the restraint shell with the vehicle’s 3-point manual lap and shoulder belt system in the second row left seat which was not used in the switchable mode. The driver stated during the SCI interview that she was unaware of the vehicle restraint system’s switchable mode, and found it very difficult to obtain a snug installation. A locking clip was also not utilized, which was required with the retractor in the primary emergency locking retractor (ELR) mode. The child was restrained within the CSS by the integral 5-point harness system. The harness utilized a plastic harness positioning clip that was positioned at the level of the mid-chest and adjusted to fit the child with some slack reported at the shoulder level. Manufacturers’ recommend no more than a finger’s thickness of slack in the straps at the shoulder level.

At impact, the child passenger initiated a forward trajectory in response to the 12 o’clock impact force and loaded the harness system resulting in bilateral abrasions to the upper chest. This injury mechanism was evidenced by the bilateral location of the injury in relation to the driver’s stated inadequate harness placement on the child, which allowed for excessive occupant movement within the CSS itself. Contact

evidence documented on the rear aspect of the driver seat back was also indicative of inadequate CSS installation as the designated ELR retractor mode allowed excessive shifting or movement of the CSS in response to crash forces. Furthermore, rear occupant loading of the second row seat back would have increased the risk of rebound trauma for this child passenger. Following the crash, the child was removed from the vehicle with assistance from the female child occupants and received no subsequent treatment for his injuries.

### ***REAR SEATED OCCUPANT DEMOGRAPHICS / INJURIES***

The second row right seating position was occupied by 7 year old female who was restrained by the available 3-point manual lap and shoulder belt system and seated in an upright posture. Although no loading evidence was identified on the second row right restraint system, belt usage was determined by the nature of the clavicle fracture sustained in conjunction with the lack of associated soft tissue injury expected from occupant loading against the front right seat back. Conversely, the clavicle fracture seemed consistent with the loading pattern documented to the second row seat back, indicative of possible incorrect seating assignments (occupants #4 and #5 reversed); however, driver and police statements confirmed the child's actual seat assignment at this location. At impact, the child passenger initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint which resulted in the right clavicle fracture.



**Figure 11. Deformation to the second row seat back.**

Her arms and feet probably struck the rear aspect of the front right seat back as evidenced by the deformation documented to this component, however, no injury was reported as a result. Following the crash, she unbuckled her seatbelt and attended to the 3 year old male passenger as she exited the vehicle under her own power through the right rear door. She sought treatment later for her injury at a medical facility.

The third row right seating position was occupied by a 9 year old female who was unrestrained (3-point manual lap and shoulder belt system available) and seated in an upright posture. The lack of restraint usage was determined by the trajectory of the child and extensive loading pattern documented to the second row seat back (**Figure 11**). At impact, she initiated a forward trajectory in response to the 12 o'clock impact force and loaded the second row seat back. She was reported by the driver as uninjured in the collision. The extensive loading pattern to the second row seat back and absence of resulting injury was also indicative of possible incorrect (reversed) seating assignments; however, driver/police statements confirmed the child's actual seat assignment at this location. Following the crash, she attended to the 3 year old male passenger as she exited the vehicle under her own power through the right rear door.



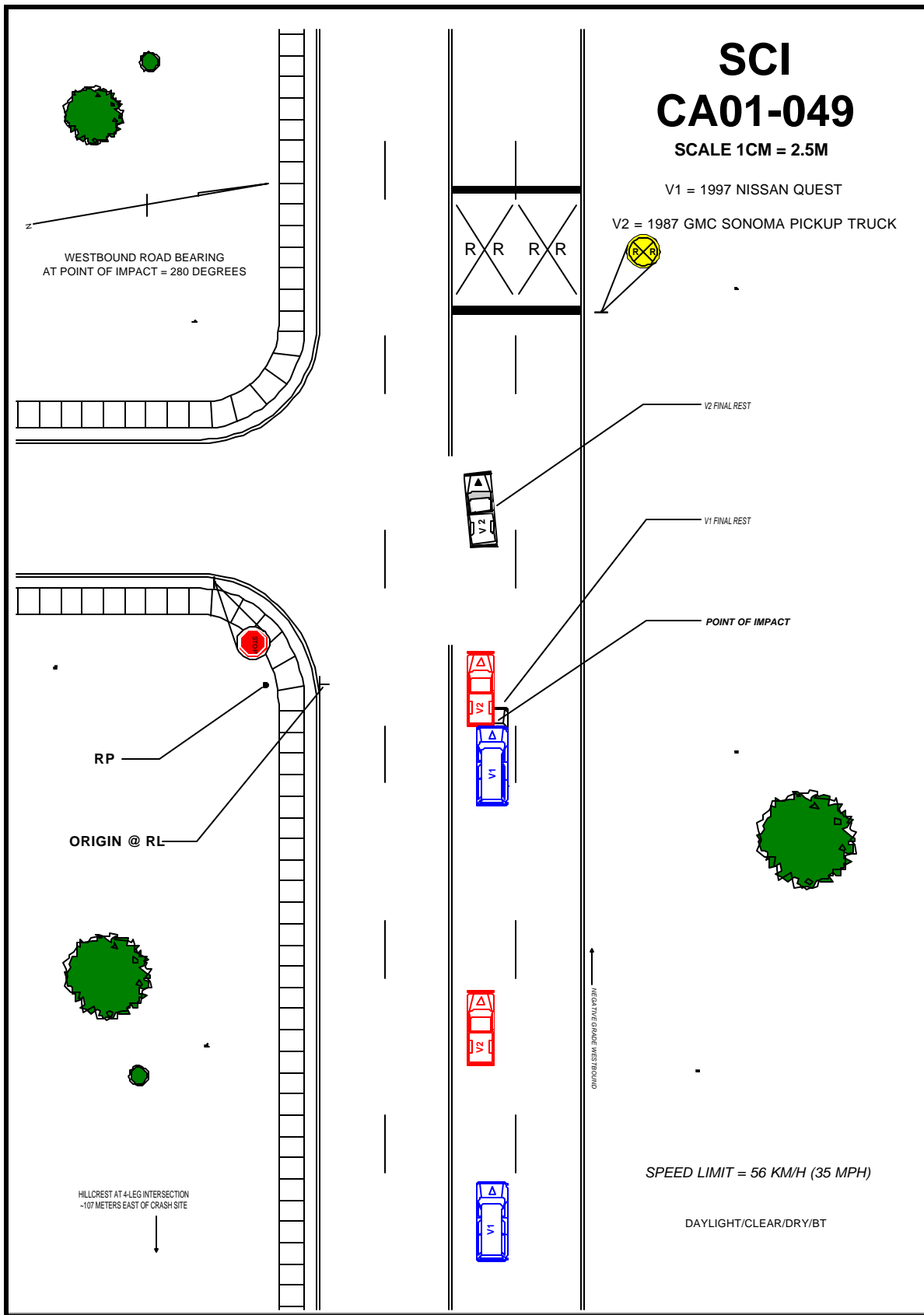


Figure 12. Scene Diagram.