

**TRANSPORTATION SCIENCES  
CRASH DATA RESEARCH CENTER**

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**VERIDIAN ON-SITE REDESIGNED AIR BAG DEPLOYMENT  
INVESTIGATION**

**VERIDIDAN CASE NO: CA02-010**

**VEHICLE: 1998 TOYOTA RAV4**

**LOCATION: NEW YORK**

**CRASH DATE: DECEMBER 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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<b>16. Abstract</b> <p>This on-site investigation focused on the performance of the redesigned frontal air bag system of a 1998 Toyota Rav-4 2 door sport utility vehicle. The 1998 Toyota Rav-4 was equipped with redesigned frontal air bags for the driver and front right passenger positions which deployed as a result of an offset frontal collision with a wooden light support pole. The driver of the Toyota was operating the vehicle westbound on a two lane urban roadway when he apparently fell asleep and allowed the vehicle to depart the right (north) pavement edge in a forward tracking mode. As the Toyota exited the north pavement edge, the front right area impacted a wooden light support resulting in severe damage. The restrained 26-year-old male driver of the 1998 Toyota Rav-4 initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint, knee bolster, and deployed redesigned driver air bag. He was transported to a local hospital for treatment of police reported (unspecified) minor injuries and releases. The unrestrained 28-year-old female front right passenger was leaning to the right against the door panel. At impact, she initiated a forward trajectory in response to the 12 o'clock impact force and loaded the glove compartment door, knee bolster, and the right A-pillar. Loading of the glove compartment door and knee bolster resulted in multiple soft tissue injury to the lower extremities and a fracture to the right femur. Loading of the adjacent instrument panel area resulted in additional soft tissue injury to the upper extremities and a fracture of the left radius/ulna. Contact to the right A-pillar resulted in extensive head injuries to include forehead/scalp lacerations, a right eye avulsion, and multiple skull fractures. Underlying brain trauma involved bilateral cerebral avulsions, subdural and subarachnoid hemorrhages, and a diffuse axonal injury. The front right passenger of the 1998 Toyota Rav-4 was transported to a local trauma center and pronounced deceased upon arrival.</p>			
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**VERIDIAN ON-SITE REDESIGNED AIR BAG DEPLOYMENT  
INVESTIGATION**

**VERIDIAN CASE NO. CA02-010**

**VEHICLE – 1998 TOYOTA RAV-4**

**LOCATION – STATE OF NEW YORK**

**CRASH DATE – DECEMBER 2001**

**BACKGROUND**

This on-site investigation focused on the performance of the redesigned frontal air bag system of a 1998 Toyota Rav-4 2 door sport utility vehicle. The 1998 Toyota Rav-4 was equipped with redesigned frontal air bags for the driver and front right passenger positions which deployed as a result of an offset frontal collision with a wooden light support pole. The driver of the Toyota was operating the vehicle westbound on a two lane urban roadway when he apparently fell asleep and allowed the vehicle to depart the right (north) pavement edge in a forward tracking mode. As the Toyota exited the north pavement edge, the front right area impacted a wooden light support resulting in severe damage. The restrained 26-year-old male driver of the 1998 Toyota Rav-4 initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint, knee bolster, and deployed redesigned driver air bag. He was transported to a local hospital for treatment of police reported (unspecified) minor injuries and releases. The unrestrained 28-year-old female front right passenger was leaning to the right against the door panel. At impact, she initiated a forward trajectory in response to the 12 o'clock impact force and loaded the glove compartment door, knee bolster, and the right A-pillar. Loading of the glove compartment door and knee bolster resulted in multiple soft tissue injury to the lower extremities and a fracture to the right femur. Loading of the adjacent instrument panel area resulted in additional soft tissue injury to the upper extremities and a fracture of the left radius/ulna. Contact to the right A-pillar resulted in extensive head injuries to include forehead/scalp lacerations, a right eye avulsion, and multiple skull fractures. Underlying brain trauma involved bilateral cerebral avulsions, subdural and subarachnoid hemorrhages, and a diffuse axonal injury. The front right passenger of the 1998 Toyota Rav-4 was transported to a local trauma center and pronounced deceased upon arrival.

The crash notification was provided to NHSTA by the passenger's father on Friday, April 5, 2002 and immediately assigned to the Veridian SCI team as an on-site investigation effort. The SCI investigator departed on Wednesday, April 10, 2002 and completed field activities the same day.

**SUMMARY**

***Crash Site***

The single vehicle crash occurred during the early morning hours of December, 2001. At the time of the crash, it was dark (street lighted by overhead halogen lamps) with no adverse conditions as the road was dry. The crash occurred off the north pavement edge of a (straight and level) two-lane east/west urban roadway (see **Figure 13 – page 10**). The westbound lane measured 3.7 meters (12.1 feet) in width as the eastbound lane measured 5.5 meters (18.0 feet) in width to allow for residential parking. The asphalt surfaced roadway was bordered by barrier curbs and sidewalks with a mountable sidewalk access 1.6 meters (5.2 feet) east of the struck pole. A 50.0 cm (19.7 in) diameter wooden light support post was located 0.5 meters (1.6 feet)

off the north pavement edge. Additional environmental features included driveways, residences, and an adjacent 3-leg intersection to the south; along with a concrete wall/iron fence, and a cemetery to the north. No traffic control was present at the crash site which had a posted speed limit of 48 km/h (30 mph).

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

The 26 year old male driver of the 1998 Toyota Rav-4 sport utility vehicle was en-route to a holiday party and operating the vehicle westbound (**Figure 1**) at a (SCI estimated) speed of 72 km/h (45 mph) when he apparently fell asleep and allowed the vehicle to depart the right (north) pavement edge in a forward tracking mode. This pre-impact event was evidenced by the straight-line trajectory and absence of tire marks at the scene indicative of driver avoidance maneuvers (*no pre-crash braking*).



**Figure 1. Westbound approach for the 1998 Toyota RAV4.**

### ***Crash***

As the Toyota departed the right (north) pavement edge of the two lane urban roadway, the right front tire entered the mountable sidewalk access (left front tire still on the road) as the front right area impacted the 50.0 cm (19.7 in) diameter light support pole (**Figure 2**) resulting in severe damage. The impact-induced deceleration was sufficient to deploy the Toyota's redesigned frontal air bag system. Impact speeds and velocity changes were calculated utilizing the WinSMASH reconstruction program. The trajectory algorithm of the WinSMASH reconstruction program computed as impact speed of 72.3 km/h (44.9 mph) as the damage algorithm computed an overall velocity change of 51.2 km/h (31.8 mph) with a matching negative longitudinal component. At this point, the Toyota rotated 146 degrees clockwise and traveled 6.4 meters (21.0 feet) to final rest in the westbound lane facing northeast. This post-impact trajectory was evidenced by pavement gouge marks documented at the crash site.



**Figure 2. Northwest view of struck pole and southwest view of post-impact trajectory to final rest.**

### ***Post-Crash***

Treatment was rendered at the scene by fire department personnel and emergency medical technicians (EMTs). The exit status of the Toyota driver was unknown, however, he was reported by police as transported to a local hospital for treatment of unspecified minor injuries and released. The front right passenger was removed from the vehicle through the right door in an unconscious state and transported by ambulance to a local trauma center where she was pronounced deceased upon arrival. The Toyota was towed from the crash site due to disabling damage.

### ***Vehicle Data – 1998 Toyota Rav4***

The 1998 Toyota Rav-4 was manufactured in June, 1998 and identified by the vehicle identification number (VIN): JT3YP10V5W0 (production number deleted). The front right passenger was the owner of the vehicle which was initially leased in September, 1997, however, the owner purchased the vehicle outright two months prior to the crash. The vehicle was a 2-door sport utility vehicle equipped with a soft “bikini” top, four-wheel drive, and a 2.0 liter, 4-cylinder engine. The odometer reading at the time of the crash was unknown. The seating was configured with front bucket and rear split bench seat (with folding backs). The surrogate interview reported no previous crashes or maintenance on the Toyota’s frontal air bag system. A cellular phone was present in the vehicle, however, it was unknown if was on or in-use at the time of the crash.

### ***Vehicle Damage – 1998 Toyota Rav4***

#### ***Exterior***

The 1998 Toyota Rav-4 sport utility vehicle sustained severe frontal damage as a result of the impact with the wooden light support pole (**Figure 3**). The direct contact damage began at the front right bumper corner and extended 38.0 cm (15.0 in) inboard. The impact deformed the entire front end width resulting in an combined direct and induced damage length (Field L) of 94.0 cm (37.0 in). Six crush measurements were documented at the level of the reinforcement bar (*bumper fascia separation*): C1=0 cm, C2=0 cm, C3=21.0 cm (8.3 in), C4=39.0 cm (15.4 in),

C5=66.0 cm (26.0 in), C6=66.0 cm (26.0 in). The Collision Deformation Classification (CDC) for this impact to the Toyota was 12-FREE-4 with a principal direction of force of 0 degrees. Wooden pole transfers were identified along the direct indentation. The right reinforcement bar corner was deformed rearward to the brake rotor as the left corner was displaced outward. The right fender was deformed rearward which restricted/deflated the right front wheel/tire and jammed the right door (tempered glazing disintegrated). Induced contact damage also produced roof buckling along the right side support pillars and outward displacement of the right door/window frame resulting in 34.5 cm (13.6 in) of passenger compartment integrity loss.



**Figure 3. Front right damage to the 1998 Toyota RAV4.**

The hood was deformed up and rearward from the impact force as the rear edge penetrated 7.0 cm (2.8 in) through the right lower windshield area (fractured by exterior impact forces only). Reduction in the right side wheelbase measured 29.5 cm (11.6 in) as elongation in the left wheelbase measured 3.0cm (1.2 in). Pry marks were noted to the right door frame and attributed to occupant extrication activities post-crash. Pry marks were also noted to the upper left fender and attributed to engine compartment access post-crash.

#### ***Interior – 1998 Toyota Rav4***

Interior damage to the Toyota was severe and was attributed to occupant contacts and component intrusions (**Figure 4**). Deep indentations and scuff marks were identified on the left knee bolster and glove compartment door. The floor-mounted transmission selector lever and console were deformed to the right, with a heavy accumulation of scuff marks noted on both side aspects. The left aspect of the front right seat back was displaced rearward approximately 5.0 cm (2.0 in). The heavy concentration of contact evidence noted to the right of each occupant space was indicative of both occupants leaning to the right pre-crash. Multiple indentations and scuff marks were documented on the instrument panel and forward portion of the right door panel, which clearly outlined extremity and pelvic regions. Tissue and hair strands were identified on the right A-pillar with a distinct head imprint and scratch marks surrounding the contact site (**Figure 5**).



**Figure 4. Interior view of the 1998 Toyota RAV4.**



Passenger head loading of the right A-pillar extended onto the right upper window frame with outward displacement of the sheet metal noted. Spots of hand lotion were noted along the lower right instrument panel and right door panel (*plastic bottle found fractured on the right sill area*). No rim deformation or column compression was identified. Longitudinal component intrusions into the front right passenger space included 10.0 cm (3.9 in) of instrument panel, 17.0 cm (6.7 in) of toepan, and 5.0 cm (2.0 in) of hood/windshield intrusion. Longitudinal component intrusions into the front center space included 6.0 cm (2.4 in) of instrument panel, and 7.0 cm (2.8 in) of hood/windshield intrusion.



**Figure 5. Occupant contact evidence to the front right passenger space.**

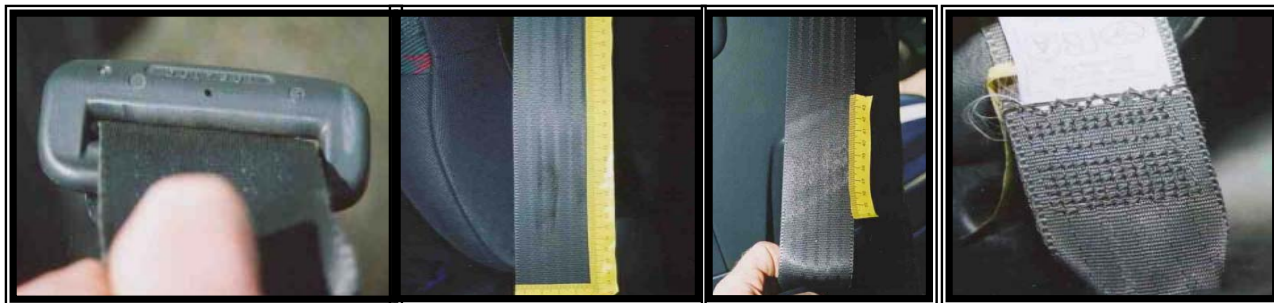
#### ***Manual Restraint System – 1998 Toyota Rav4***

The interior of the Toyota Rav-4 consisted of a four passenger-seating configuration with front bucket and a rear split bench seat (with folding backs). The driver 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 dual mode retractor (inertial lock/belt sensitive). Extensive loading evidence was documented on the driver restraint system which included abrasions to the D-ring and latchplate webbing sleeve with associated transfers embedded into the webbing (**Figure 6**). Dark colored fabric transfers were also embedded into the shoulder belt webbing. Frayed stitching was noted at the lower anchorage attachment point and abrasions to the outboard seat frame from belt friction. Deployment of the retractor pretensioner only slightly restricted the webbing in the used (out) position. The front right and rear seating positions were equipped with a 3-point manual lap and shoulder belt system which consisted of a continuous loop belt webbing with a sliding latchplate and a retractor equipped with an inertial and switchable lock mechanism. There was no



**Figure 7. Front right restraint system restricted in the stowed position.**

loading evidence identified on the D-ring, latchplate, or webbing of the front right restraint to suggest belt usage by the passenger. Furthermore, the front right restraint was found restricted in the stowed position by retractor pretensioner deployment (**Figure 7**).



**Figure 6. Loading evidence to the driver restraint system.**

#### ***Supplemental Restraint System – 1998 Toyota Rav4***

The 1998 Toyota Rav-4 was equipped with redesigned frontal air bags for the driver and front right passenger positions which deployed as a result of the crash (**Figure 8**). The driver air bag was identified by the part number: 9860214V0523 and housed in the center of the steering wheel with a horizontally oriented flap tear seam (H-configuration). The flaps were rectangular in shape as the upper flap measured 15.0 cm (5.9 in) in width and 6.0cm (2.4 in) in height as the lower flap measured 15.0 cm (5.9 in) in width and 4.5 cm (1.8 in) in height. A vertical split was noted on the lower flap. No contact evidence was identified on the exterior surface of the module cover flaps. Although the surface of the air bag seemed lightly abraded and discolored from driver interaction, light blood spattering across the upper face of the membrane masked any possible contact evidence. The diameter of the driver air bag measured 59.0 cm (23.2 in) in its deflated state (**Figure 9**). The bag was tethered by two internal straps and vented by two 2.5 cm (1.0 in) ports located at the 11 o'clock and 1 o'clock positions on the rear aspect. Air bag excursion measured 28.0 cm (11.0 in) from the steering wheel hub.



**Figure 8. 1998 Toyota RAV4 deployed redesigned frontal air bag system.**

The front right passenger air bag deployed from the right mid-instrument panel area with a single cover module cover flap design hinged at the top aspect. The flap was rectangular in shape and measured 34.0 cm (13.4 in) in width and 22.0 cm (8.7 in) in height. No contact evidence was identified on the exterior surface of the cover flap. Most of the membrane was soaked with blood as extensive spattering was noted along the top portion and left side surface. Tissue transfers were identified at the left lower quadrant and right mid-portion of the air bag face. Dark colored fabric transfers were documented on the upper right quadrant and side surface of the air bag. Spots of hand lotion were noted across the center portion. The passenger air bag measured 74.0 cm (29.1 in) in width and 66.0 cm (26.0 in) in height in its deflated state (**Figure 10**). The bag was tethered by two internal straps and vented by two 4.0 cm (1.6 in) diameter

ports located at the 3 o'clock and 9 o'clock sectors on the side aspect of the air bag. Air bag excursion measured 46.0 cm (18.1 in) from the aft portion of the mid-instrument panel.



**Figure 9. 1998 Toyota RAV4 deployed redesigned driver air bag.**



**Figure 10. 1998 Toyota RAV4 deployed redesigned passenger air bag.**

#### ***Driver Demographics***

Age/Sex:	26-year-old male
Height:	Unknown
Weight:	Unknown
Seat Track Position:	Full rearward position
Manual Restraint Use:	3-point lap and shoulder belt system
Usage Source:	Vehicle inspection
Eyeware:	Unknown
Type of Medical Treatment:	Transported to a local hospital and released.

#### ***Driver Injuries***

<b><i>Injury</i></b>	<b><i>Severity (AIS 90)</i></b>	<b><i>Injury Mechanism</i></b>
Unknown	N/A	N/A

### ***Driver Kinematics***

The 26 year old male driver of the 1998 Toyota Rav-4 was restrained by the available 3-point manual lap and shoulder belt system, and presumed to be leaning to the right, against the center armrest (*asleep*) with the seat track adjusted to the full rearward position. Belt usage was determined by the extensive loading evidence identified on the latchplate, D-ring, and webbing of the front left restraint.

At impact, the driver initiated a forward trajectory in response to the 12 o'clock impact force and loaded the manual restraint, knee bolster, and deployed redesigned driver air bag (**Figure 11**). Contact to the deployed driver air bag was confirmed by the discoloration and abrasion pattern identified across the face of the air bag. Loading of the knee bolster was evidenced by the deformation documented to this component; however, injury information is unknown. His right lower extremity subsequently struck the center console and floor-mounted transmission selector lever, as evidenced by the displacement (forward and to the right) documented to these components. The occupant kinematics and relative concentration of contacts to the right of the driver space clearly defined that he was leaning to the right pre-crash. In addition, tissue transfers documented along the left lower quadrant of the *front right passenger air bag* were indicative of driver right upper extremity interaction. Contact to the deployed redesigned passenger air bag was further evidenced by the contrasting transfer patterns across the face of the membrane. The exit status of the driver was unknown, however, he was reported by police as transported to a local hospital for treatment of unspecified minor injuries and released. The redesigned driver air bag provided additional protection against further contact to the steering wheel hub/rim, and potential serious injury.



**Figure 11. Driver seating area.**

### ***Front Right Passenger Demographics***

Age/Sex:	28-year-old female
Height:	168 cm (66 in)
Weight:	61 kg (135 lb)
Seat Track Position:	Full rearward position
Manual Restraint Use:	None
Usage Source:	Vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Pronounced deceased upon arrival (DOA)



<b><i>Front Right Passenger Injuries</i></b>		
<b><i>Injury</i></b>	<b><i>Severity (AIS 90)</i></b>	<b><i>Injury Mechanism</i></b>
*Diffuse axonal injury (right/left frontal lobes pulpified)	Critical (140628.5,3)	Right A-pillar
*Subdural hemorrhage – bilateral cerebrum	Critical (140654.5,3)	Right A-pillar
*Cerebral avulsion – NFS	Severe (140688.4,9)	Right A-pillar
*Vault fracture (frontal bone) (multiple comminuted/depressed FX)	Severe (151406.4,5)	Right A-pillar
*Basilar skull fracture (multiple FX-anterior/middle cranial fossa)	Serious (150202.3,8)	Right A-pillar
*Subarachnoid hemorrhage-right cerebrum	Serious (140684.3,1)	Right A-pillar
* Subarachnoid hemorrhage-left cerebrum	Serious (140684.3,2)	Right A-pillar
*Contusion bilateral cerebrum (frontal lobes-inferior aspect)	Serious (140620.3,3)	Right A-pillar
*Fracture right femur – NFS	Serious (851800.3,1)	Right Knee Bolster (indirect contact injury)
*Laceration left frontal scalp (5’')	Moderate (190604.2,5)	Right A-pillar
*Laceration right eyebrow/forehead (5’')	Moderate (290604.2,7)	Right A-pillar
*Avulsion globe right eye (posterior avulsion-diffusely hemorrhagic)	Moderate (240402.2,1)	Right A-pillar
*Laceration posterior spleen – multiple (1’' and ½’' lacerations)	Moderate (544222.2,2)	Front right seat back (occupant rebound)
*Contusion posterior liver – NFS (at the inferior vena cava)	Moderate (541810.0,1)	Front right seat back (occupant rebound)
*Fracture left radius – NFS	Moderate (752800.2,2)	Right instrument panel
*Fracture left ulna – NFS	Moderate (753200.2,2)	Right instrument panel
*Laceration right eyelid (1/2’')	Minor (297602.1,1)	Right A-pillar
*Laceration right eye conjunctivae	Minor (240416.1,1)	Right A-pillar
*Contusion left posterior arm – NFS	Minor (790402.1,2)	Right instrument panel
*Contusion right posterior arm – NFS	Minor (790402.1,1)	Right door panel
*Contusion left anterior thigh – NFS	Minor (890402.1,2)	Glove compartment door
*Contusion right anterior thigh – NFS	Minor (890402.1,1)	Right knee bolster

*Source: autopsy report\**

### ***Front Right Passenger Kinematics***

The unrestrained 28-year-old female front right passenger of the 1998 Toyota Rav-4 was seated leaning to the right against the door panel (*possibly asleep*) with the seat track adjusted to the mid-to-rear position. The lack of belt use was determined by the trajectory of the occupant, contact points within the vehicle, and the front right restraint restricted in the stowed position by the retractor pretensioner deployment. It should be noted that the passenger was wearing blue jeans, brown/blues socks, a black sweater, and maroon boots at the time of the crash.

At impact, the front right passenger initiated a forward trajectory in response to the 12 o'clock impact force (**Figure 12**) as her lower extremities loaded the glove compartment door and knee bolster. The distinct indentations clearly outlined lower leg and pelvic regions with subsequent (continued) occupant loading into the forward aspect of the right door panel. Loading of these components resulted in bilateral thigh contusions and a (indirect contact) fracture of the right femur. Her left upper extremity struck the adjacent right instrument panel resulting in a posterior contusion and an unspecified radius/ulna fracture. Her right upper extremity contacted the forward portion of the right door panel resulting in additional posterior soft tissue injury. These injury mechanisms were evidenced by the narrow indentations and scuff marks documented on these components. The occupant kinematics and relative concentration of contacts to the right of the passenger space clearly defined an out-of-position pre-impact posture. The contact pattern identified on the outboard and right side aspect of the membrane indicated only minimal occupant interaction with the deployed redesigned front right passenger air bag. Fabric transfers documented along the upper right quadrant and side aspects of the membrane were attributed to probable left torso/upper arm interaction. At this point, she struck the right A-pillar which resulted in extensive multiple head trauma, evidenced by the indentations, hair strands, and tissue surrounding the contact site. Soft tissue injury involved a 12.7 cm (5.0 in) laceration that extended from the left frontal scalp diagonally across the forehead to the right eyebrow, and a 1.3 cm (0.5 in) right eyelid laceration. The globe of the right eye was also diffusely hemorrhagic and avulsed posteriorly into the skull. Multiple skull fractures were sustained to the (basilar) anterior/middle cranial fossa along with comminuted and depressed fractures of the frontal bone (vault). Underlying brain trauma included acute cerebral contusions, a cerebral avulsion across multiple regions, a diffuse axonal injury, with subdural and subarachnoid hemorrhages.

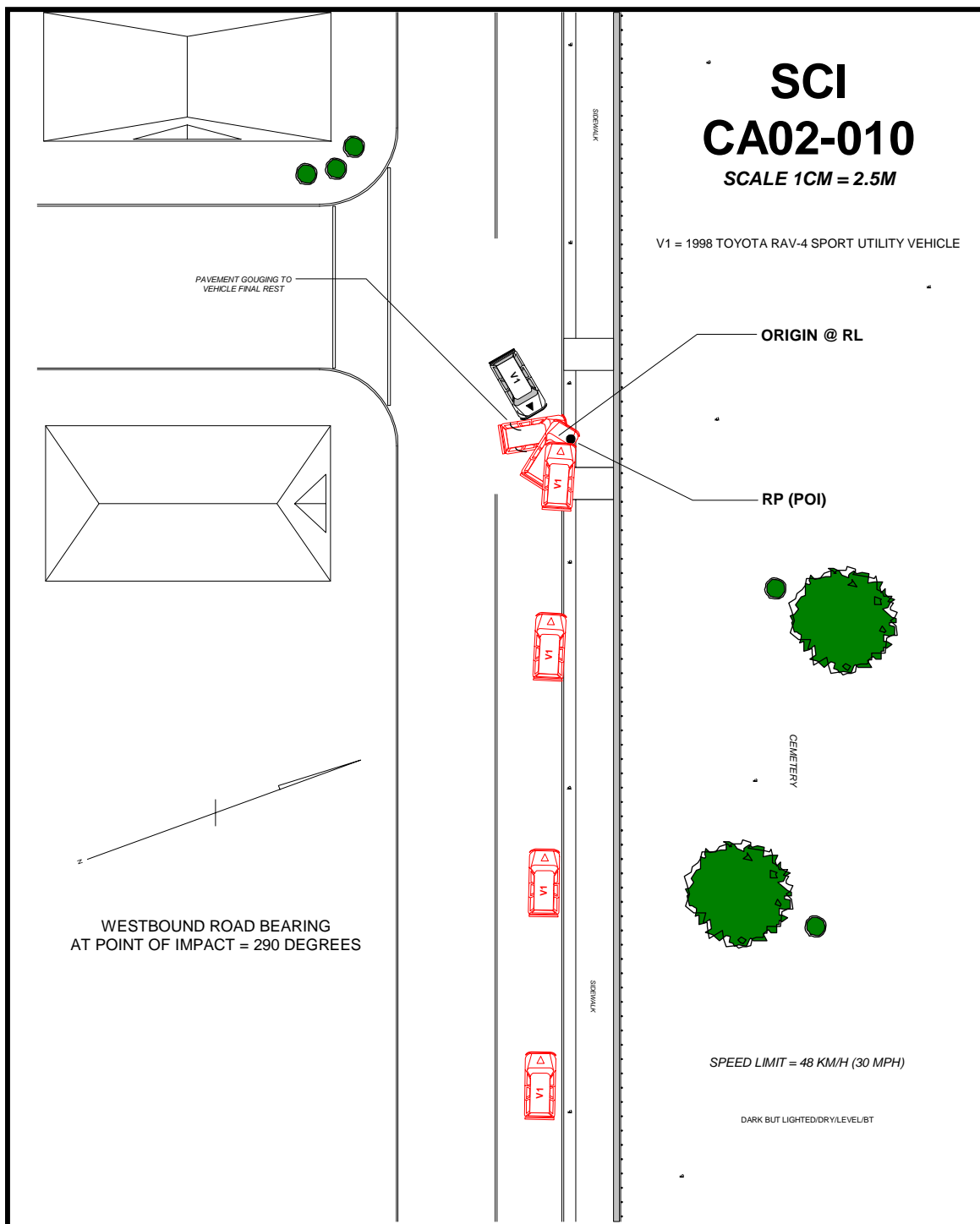


**Figure 12. Front right passenger space.**

During the vehicle's (clockwise) rotational post-impact trajectory to final rest, the front right passenger rebounded into the seat back as she initiated a lateral trajectory to the left. This trajectory was evidenced by the deformation documented to the left portion of the front right seat back, and scuff marks noted to the right portion of the center console, in conjunction with the rotational occupant kinematics to vehicle rest. *It should be noted that the passenger probably*

*struck the driver during the vehicle's clockwise post-impact trajectory; however, this could not be verified without driver injury information.* She came to rest partially on the front right seat cushion with her head positioned over the deflated front right passenger air bag, evidenced by the extensive blood pooling noted along the top and left side aspect of the membrane.

Although death was probably immediate, the passenger was removed by rescue personnel through the right door in an unconscious state and in cardio-pulmonary arrest. Rescue personnel initiated CPR at the scene and subsequently transported the passenger by ambulance to the emergency room of a local trauma center. She arrived in the emergency room with no vital signs present and pronounced deceased approximately thirty minutes following the crash. Although abnormal pre-impact occupant posturing minimized the effectiveness of the deployed redesigned front right passenger air bag, use of the available 3-point manual lap and shoulder belt system would have restrained the occupant from further contact to frontal components, thus, mitigating any fatal injuries.



**Figure 13. Scene Diagram.**