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CALSPAN ON-SITE CHILD RESTRAINT SYSTEM CRASH INVESTIGATION
SCI CASE NO: CA10017

VEHICLE: 2002 TOYOTA RAV4

LOCATION: OHIO

DATE: MAY, 2010

Contract No. DTNH22-07-C-00043

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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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An investigation of the front-to-rear crash of a 2002 Toyota RAV4 into a late-model year Wabash van-body trailer.

16. Abstract

This on-site investigation focused on a front-to-rear crash of a 2002 Toyota RAV4 and the injuries sustained by a 3-year-old restrained within a forward facing Child Restraint System (CRS) secured in the second row right position of the vehicle. The Toyota impacted the rear impact guard of a late model year Wabash van-body trailer hauled by a 2006 Peterbilt tractor. The Toyota was equipped with redesigned frontal air bags that deployed during the crash. The 24-year-old female driver of the Toyota was restrained at the time of the impact and became entrapped by the frontal intrusion. The Toyota required extensive extrication in order to remove the driver. She was transported from the scene by helicopter to a regional trauma center. The driver sustained a liver laceration, a pelvis fracture, a left tibia fracture, lung contusions, and multiple minor soft tissue injuries in the crash. The 3-year-old and CRS were removed from the vehicle by a witness to the crash. The child was then removed from the CRS and transported by ground ambulance to a local hospital. She sustained a small laceration to the left 5th toe and a left shoulder abrasion.

The crash was identified by the Calspan Special Crash Investigations (SCI) team through local media coverage of the crash. The notification was forwarded to the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) on May 10, 2010. The crash was assigned as an on-site investigation the same day. Telephone contact was established with the investigating police department and cooperation was obtained for an on-site investigation that was conducted May 11, 2010. At the time of telephone contact both vehicles were reported as on police-hold pending the conclusion of the police investigation. The subsequent SCI investigation determined that that information was inaccurate and only the Toyota was on-hold. The tractor trailer was released by the police from the crash site; therefore the trailer and rear impact guard were not inspected. The SCI investigation included an inspection of the Toyota, the CRS, and the crash site. Additionally, the driver was interviewed by telephone.

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BACKGROUND

This on-site investigation focused on a front-to-rear crash of a 2002 Toyota RAV4 and the injuries sustained by a 3-year-old restrained within a forward facing Child Restraint System (CRS) secured in the second row right position of the vehicle. **Figure 1** is a left side view of the Toyota. The Toyota impacted the rear impact guard of a late model year Wabash van-body trailer hauled by a 2006 Peterbilt tractor. The Toyota was equipped with redesigned frontal air bags that deployed during the crash. The 24-year-old female driver of the Toyota was restrained at the time of the impact and became entrapped by the frontal intrusion. The Toyota required extensive extrication in order to remove the driver. She was transported from the scene by helicopter to a regional trauma center. The driver sustained a liver laceration, a pelvis fracture, a left tibia fracture, lung contusions, and multiple minor soft tissue injuries in the crash. The 3-year-old and CRS were removed from the vehicle by the first responders. The child was then removed from the CRS and transported by ground ambulance to a local hospital. She sustained a small laceration to the left 5th toe and a left shoulder abrasion.

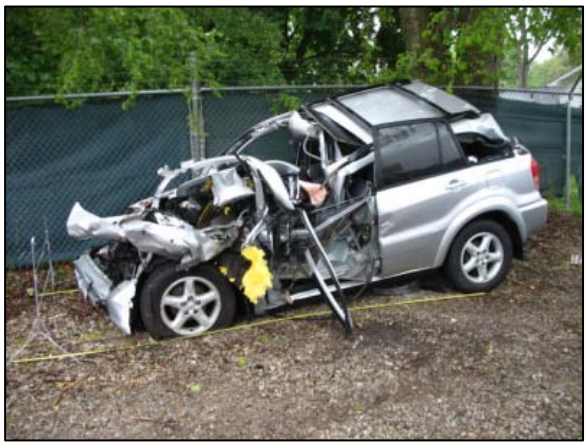

Figure 1: Left side view of the Toyota.

The crash was identified by the Calspan Special Crash Investigations (SCI) team through local media coverage of the crash. The notification was forwarded to the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) on May 10, 2010. The crash was assigned as an on-site investigation the same day. Telephone contact was established with the investigating police department and cooperation was obtained for an on-site investigation that was conducted May 11, 2010. At the time of telephone contact both vehicles were reported as on police-hold pending the conclusion of the police investigation. The subsequent SCI investigation determined that that information was inaccurate and only the Toyota was on-hold. The tractor trailer was released by the police from the crash site; therefore the trailer and rear impact guard were not inspected. The SCI investigation included an inspection of the Toyota, the CRS, and the crash site. Additionally, the driver was interviewed by telephone.

SUMMARY

VEHICLE DATA

2002 Toyota RAV4

The Toyota RAV4 was manufactured in November 2001 and was identified by the Vehicle Identification Number: JTEHH20V16 (production sequence deleted). The digital odometer

reading was unknown. The 4-door, compact Sport Utility Vehicle (SUV) was equipped with a 2.0-liter, inline 4-cylinder engine and a 4-speed automatic transmission with 4-wheel drive. The vehicle was equipped with front disc/rear drum brakes with anti-lock, and electronic brake-force distribution. The manual restraint systems consisted of 3-point lap and shoulder belts in all five seat positions. The front restraints were equipped with retractor pretensioners. The Toyota was equipped with redesigned frontal air bags. The vehicle's recommended tire size was P215/70R16 with a cold tire pressure of 200 kPa (29 PSI), front and rear. The vehicle was equipped with Goodyear Assurance Touring P215/70/R16 tires mounted on OEM alloy wheels. The specific tire data at the time of the SCI inspection was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	Tire Flat	7 mm (9/32)	No	Sidewall cut, rim deformed
LR	200 kPa (29 PSI)	7 mm (9/32)	No	None
RF	Tire Flat	7 mm (9/32)	No	None
RR	241 kPa (35 PSI)	7 mm (9/32)	No	None

CRASH SITE

The crash occurred during the daylight hours in May 2010. At the time of the crash, the weather and sight visibility were not factors. The crash occurred in the outboard westbound lane of a 2-lane divided interstate highway. The interstate was straight and level in the area of the crash. The westbound traffic lanes measured 3.6 m (12 ft) in width and were separated by broken centerlines representing a passing zone. A 3.0 m (10 ft) wide shoulder bordered the outboard lane. The posted speed limit in the area of the crash was 105 km/h (65 mph). There was a construction zone located several miles west of the crash site that influenced the traffic flow at the time of the crash. **Figure 2** is an on-scene police image of the crash site. The relationship between the point of impact and final rest locations of the vehicles was not determined by the police investigator. A schematic of the crash is attached to the end of this report as **Figure 8**.

Figure 2: On-scene police image of the crash site depicting the final rest position of the Toyota.

CRASH SEQUENCE

Pre-Crash

The tractor trailer was westbound on the outboard travel lane driven by a 43-year-old male. The trailer was loaded with machined parts. The gross weight of the vehicle was 32,705 kg (72,100 lb). Its reported destination was Illinois. The driver of the tractor trailer reported that he had

been stopped in a back-up in traffic and had just reaccelerated to a speed of 40 to 56 km/h (25 to 35 mph) at the time of the crash.

The Toyota RAV4 was westbound driven by a 24-year-old female and occupied by the 3-year-old female restrained within the CRS that was secured in the second row right position. The CRS was secured by the Lower Anchors and Tethers for CHildren (LATCH). The Toyota was in the outboard traffic lane approaching the back of the tractor trailer. The crash dynamics and damage patterns indicated the driver of the Toyota steered to the right (clockwise) late in an attempt to avoid the trailer. Post-crash, the needles of the speedometer and tachometer were frozen at 113 km/h (70 mph) and 4300 RPM, respectively.

The driver reported that during her pre-crash travel, the traffic was light. She had no recollection of following the tractor trailer. The driver stated that her first recollection of the tractor trailer was it rapidly slowing down. She did not recall steering, but she believed she applied the brakes. The police investigator reported that there was no evidence of pre-crash braking.

Crash

The front plane of the Toyota struck the rear impact guard attached to the back plane of the trailer. The force of the impact resulted in the actuation of the Toyota driver's safety belt pretensioner and deployment of the redesigned frontal air bags. The impact was biased to the right side of the trailer indicative of the right steering of the Toyota. Based on the damage of the 12/6 impact configuration, the center line of the Toyota was offset 81 cm (32 in) to the right of the centerline of the trailer. The right aspect of the trailer's rear impact guard deformed forward and the Toyota underrode the back plane of the trailer. The Toyota's windshield header impacted the back lane of the trailer. The Toyota rotated approximately 40 degrees counterclockwise and came to rest straddling the fog line. The driver of the tractor trailer felt the impact and responded by braking. The tractor trailer came to a controlled stop in the outboard lane approximately 18 m (60 ft) west of the Toyota. Analysis of the crash severity (delta-V) was beyond the scope of the WinSMASH model due to the underride configuration.

Post-Crash

A passerby/witness following behind the Toyota stopped to render aid. Reportedly this individual extinguished a small engine compartment fire in the Toyota and then assisted the occupants. He removed the child passenger from the right rear position while she was still seated in the CRS. He removed the CRS by cutting the lower anchor and tether straps. The child passenger was then removed from the CRS by the responding emergency medical personnel and transported to a local hospital. She was released from the emergency department the same day with a small laceration/abrasion to the left 5^{th} toe and a left shoulder abrasion. The responding fire rescue removed the driver from the vehicle. She was flown by helicopter to a regional trauma center and hospitalized for 6 days. She sustained a liver laceration, a pelvis fracture, a left tibia fracture, lung contusions and multiple soft tissue injuries. The Toyota was impounded by the police pending the conclusion of their investigation. The tractor trailer was released directly from the crash site.

2002 TOYOTA RAV4

Exterior Damage

The Toyota sustained severe damage as a result of the underride impact. The extent of the damage was biased to the left consistent with the offset impact configuration. **Figure 3** is a left lateral view depicting the extent of crush. The width of the direct and induced damage extended across the entire 150 cm (59 in) frontal end width. The direct contact damage began 48 cm (19.0 in) right of center and extended to 123 cm (48.5 in) to the left front corner. The residual crush measured along the bumper reinforcement bar was as follows: C1 = 25 cm (9.8 in), C2 = 29 cm (11.4 in), C3 = 27 cm (10.6 in), C4 = 23 cm (9.1 in), C5 = 20 cm (7.9 in), C6 =0. [It should be noted that the measurement baseline depicted in the Figure 3 required a negative 27 cm (10.7 in) stand adjustment.] As the vehicle underrode the back plane of the trailer, the Toyota's structures and components above the floor elevation of the trailer were sheared and deformed rearward. The right hinge and center latch of the hood had separated. The greenhouse area of the vehicle impacted the back plane. The maximum longitudinal crush of the header measured 44 cm (17.5 in). The maximum header crush was located 77 cm (12 in) inboard of the right roof side rail. Refer to **Figure 4.** The location of the maximum header deformation was attributed to the right rear corner of the trailer at maximum engagement. The left A-pillar was deformed to a vertical orientation. The left front door buckled in compression and was jammed shut. The left rear door and both right doors remained closed during the crash and were operational post-crash. The windshield was completely fractured. All the roof support pillars were cut and the roof was removed during the extrication. The left and right window glazings in rows 1 and 2 disintegrated in the crash. The side glazing and backlight that surround the cargo area disintegrated as a function of the extrication. There was no change in the wheelbase dimensions. The Collision Deformation Classification was 12FYAA7.

Figure 3: Left lateral view of the Toyota depicting the extent of fontal crush.

Figure 4: View of the deformed windshield header.

WABASH TRAILER

Exterior Damage

Figure 5 is a rear view of the Wabash trailer depicting the damage to the rear impact guard. The rear impact guard was attached to the back plane of the trailer by four vertical supports. The supports were symmetrical about the centerline of the trailer. The center supports were

constructed from what appeared to be a tapered I-beam section reinforced with by a V-shaped support. The ends to the rear impact guard were supported by a channel section that was welded to the end of the guard. The Toyota's avoidance maneuver resulted in the offset impact to the right aspect of the guard. The right end support separated in the crash due to overload and the guard deflected forward, cantilevered by the right central support. The trailer was released prior to SCI involvement and was not inspected. The Truck Deformation Classification was 06BZEWA.

Figure 5: Rear view of the trailer depicting the deformed rear impact guard.

2002 TOYOTA RAV4

Interior Damage

The crash resulted in severe intrusion into the driver's position that entrapped the driver. Extensive extrication was required to remove the driver for medical transport. These rescue efforts involved the hydraulic lifting and repositioning of the instrument panel to free the driver. Refer to **Figure 6**. For reference, the occupant compartment intrusion was measured; however, the measured values are thought be a minimum value. The roof removal hampered the proper documentation of roof and windshield header intrusion. The windshield header intrusion was estimated. The intrusion is listed in the following table:

Figure 6: On-scene police image depicting the extrication required to remove the driver.

Position	Component	Intrusion	Direction
1st Row Left (Driver)	Instrument panel/bolster	30 cm (12.0 in)	Longitudinal
	Steering assembly	29 cm (11.5 in)	Longitudinal
	A-pillar at beltline	19 cm (7.5 in)	Longitudinal
	Windshield header	15 cm (6.0 in)	Longitudinal
1st Row Center	Windshield header	44 cm (17.3 in)	Longitudinal
1st Row Right	Windshield header	28 cm (11.0 in)	Longitudinal

The three-spoke steering wheel rim was not deformed by edge loading. During her ride-down of the crash, the driver loaded the intruding steering column, through the deployed air bag, and completely separated the column's shear capsules. The column had dropped down and was free floating post-crash.

The driver seat was in a mid-track position and was jammed. The seat back had been reclined post-crash by EMS during the removal of the driver. Reportedly, she was removed on a back board through the left rear door. The driver's head restraint had been removed from the seat back. The front right seat was in a forward track position.

The knee bolster was scuffed and fractured from contact with the driver's left lower extremity. The scuff and fracture was located 37 cm to 48 cm (14.5 in to 19.0 in) left of the steering column. This contact resulted in the driver's left tibia fracture. A bolster contact from the right lower extremity was located 15 cm to 23 cm (6.0 in to 9.0 in) right of the steering column.

Manual Restraint Systems

The manual restraint systems in the Toyota RAV4 consisted of 3-point lap and shoulder belts in the 5 seat positions. The driver safety belt consisted of continuous loop webbing, a sliding latch plate, an Emergency Locking retractor and an adjustable D-ring. The safety belt was equipped with a retractor pretensioner that actuated during the crash. The D-ring was adjusted to the full-down position. The belt webbing was cut by the first responders during the removal of the vehicle's roof. It was cut 98 cm (38.5 in) above the outboard floor anchor. A 6 cm (2.2 in) long abrasion from contact with the D-ring was located 54 cm (21.3 in) above the cut point. The latch plate was missing and could be located. Based on the evidence observed during the SCI inspection, the driver was restrained at the time of the crash.

The second row right safety webbing was also cut during the removal of the roof. The webbing was in the stowed position at the time of the roof's removal. It was not in use during the crash. The CRS was secured in the vehicle by the Lower Anchors and Tethers for CHildren (LATCH). Refer to the *Child Restraint System* section of this report for further detail.

Air Bag Systems

The Toyota's air bag system consisted of redesigned driver and front right passenger air bags. The air bags deployed as a result of the crash. The system was controlled by an Air bag Control Module (ACM) located under the center instrument stack. The ACM was located and accessed for an attempted imaging of any stored crash event data. Repeated attempts using the proprietary hardware and software provided by the manufacturer were unsuccessful. It was determined that this module did not have event recording capabilities.

The driver air bag deployed from a tri-flap module design. The upper flap measured 15 cm x 10 cm (6 in x 3.8 in), width by height. The two lower flaps were triangular in shape. There was no contact evidence to the flaps. The deployed driver air bag measured 61 cm (24 in) in diameter. It was tethered by two straps and vented by two 3 cm (1.3 in) diameter ports located on the back side of the bag in the 11/1 o'clock position. The air bag received several minor lacerations during the crash sequence from contact with the fractured windshield. The lacerations were located on the back side of the bag between vent ports. There was an 11 cm (4.5 in) long tear on the face of the bag at the 2 o'clock upper peripheral seam. Post-crash body fluid evidence was observed at the 5 to 7 o'clock sectors.

The front right passenger air bag deployed from a top-mount module located in the right aspect of the instrument panel. The face of the air bag measured 41 cm x 48 cm (16 in x 19 in). It was not tethered and was vented by two 5 cm (2.0 in) diameter ports located on the side panels. The air bag was soiled from exposure to the elements.

CHILD RESTRAINT SYSTEM

The 3-year-old female was restrained in a forward-facing mode by the 5-point harness of a Dorel Eddie Bauer Deluxe Booster CRS that was secured in the second row right position (**Figure 7**). The CRS was secured by LATCH. The cut sections of the lower anchor and tether straps were attached to the vehicle.

Figure 7: View of the CRS repositioned in the second row right.

The CRS was manufactured on November 1, 2007 and was identified as Model No. 22868-LRS, Serial No. B102 A 009259. The CRS was a booster seat designed for forward-facing use with an internal 5-point harness or as belt positioning booster (without the internal harness). In the forward-facing mode the seat was compatible with children over 1 year of age weighing 10 - 18 kg (22 - 40

lb) and 85 – 110 cm (34 – 43 in) in height. The seat was compatible with the reported age, height and weight of the child occupant in this crash.

The CRS was found loose within the second row of the vehicle. The adjustable foot was in the folded position at the time of the inspection. The illustrated CRS directions indicated the foot should be extended for forward-facing use. The at-crash position of the foot could not be determined. The inspection of the CRS was unremarkable for crash-related evidence. The harness straps were adjusted to the middle slots. There was no loading evidence on the straps.

In her interview, the driver reported that she had purchased the CRS approximately 1 year prior to the date of the crash. After purchasing the seat, she read the instruction manual and familiarized herself with the installation. She recalled learning of LATCH from birthing classes, but had no other instruction about LATCH use (other than the manual) since that time. She was not familiar with Child Safety Seat Checkpoints. To install the seat, she indicated that she simply placed the CRS in the vehicle, attached the tether and lower anchor straps and pulled them as tight as she could. She did not compress the CRS into the seat cushion. The driver estimated that there was approximately 3 cm to 5 cm (1 in to 2 in) of side-to-side movement of the installed CRS and she reported that there was "some" forward tipping. The harness straps were "snug" on the child and the chest clip was adjusted to the child's arm pit level.

2002 TOYOTA RAV4

Driver Demographics

	Driver
Age/Sex:	24-year-old/Female
Height:	163 cm (64 in)
Weight:	52 kg (115 lb)
Seat Track Position:	Mid-track
Safety Belt Usage:	3-point lap and shoulder belt
Usage Source:	SCI vehicle inspection
Egress from Vehicle:	Removed by first responders
Type of Medical Treatment:	Hospitalized for 6 days

Driver Injuries

Injury	**Injury Severity (AIS 2005/Update 08)**	**Injury Source**
Large liver laceration	Serious (541824.3,1)	Steering wheel/column
Left acetabular fracture (stable anterior wall fracture)	Moderate (856251.2,2)	Intruding knee bolster, indirect

Injury	Injury Severity (AIS 2005/Update 08)	Injury Source
Left tibia fracture (non displaced, mid shaft, transverse fracture)	Moderate (854251.2,2)	Intruding knee bolster
Concussion with loss of consciousness NFS	Moderate (161002.2,0)	Windshield header
Right lung contusion (minimal)	Moderate (441406.2,1)	Steering wheel/column
Right pneumothorax (tiny)	Moderate (442202.2,1)	Steering wheel/column
Right 5th finger fracture (middle phalanx, non displaced, extraarticular)	Minor (752653.1,1)	Mid instrument panel
Right 5th finger ecchymosis	Minor (710402.1,1)	Mid instrument panel
Left 5th toe avulsion injury	Minor (810800.1,2)	Foot controls
Left mid-tibia superficial abrasion	Minor (810202.1,2)	Intruding knee bolster
Right posterolateral hip and thigh ecchymosis	Minor (810402.1,1)	Center console
Right wrist abrasion (over volar surface of wrist)	Minor (710202.1,1)	Mid instrument panel
Right wrist laceration (over volar surface of wrist)	Minor (710602.1,1)	Mid instrument panel
Right upper forehead laceration	Minor (210600.1,7)	Windshield header
Right upper scalp laceration	Minor (110600.1,1)	Windshield header
Right cheek (large abrasion)	Minor (210202.1,1)	Windshield header
Right mid inner thigh puncture wound, 1.75cm x 1.4cm x 1cm deep	Minor (810602.1,1)	Other interior object (separated trim), possible

Source: Hospital Discharge Summary and Radiology

Driver Kinematics

The 24-year-old female driver of the Toyota was restrained and seated in a mid-track position. She steered to the right in a late attempt to avoid the crash. At impact, the safety belt pretensioner actuated and the frontal air bags deployed. The safety belt pretensioner removed potential slack from the belt system and tightened the webbing around the driver. The driver responded to the 12 o'clock direction of force with a forward trajectory. Coincident to her

forward kinematic pattern, the vehicle's structures forward of her position were intruding. The driver's lower extremities contacted the bolster. This contact resulted in a left tibia fracture and an indirect fracture of the pelvis. The driver's chest and abdomen contacted and loaded the steering wheel. This loading resulted in the driver's liver laceration and her pulmonary injuries. The steering column completely separated from the shear capsules due to the loading. The driver's head was contacted by the windshield header resulting in the concussion and the minor lacerations to the scalp and forehead. The driver was trapped within the vehicle by the intrusion and was removed from the vehicle by the first responders after vehicle extrication. She was transported to a trauma center by helicopter and hospitalized for 6 days.

Child Passenger Demographics

	Second Row Right Position
Age/Sex:	3-year-old/Female
Height:	94 cm (37 in)
Weight:	14 kg (30 lb)
Seat Track Position:	Not adjustable
Safety Belt Usage:	Restrained by the 5-poibnt harness of a CRS
Usage Source:	SCI vehicle inspection
Egress from Vehicle:	Removed by first responders while in CRS
Type of Medical Treatment:	Treated and released

Child Passenger Injuries

Injury	***Injury Severity (AIS 2005/Update 08)***	***Injury Source***
Left shoulder abrasion (per interview)	Minor (710202.1,2)	CRS harness strap
Left toe laceration and abrasion, NFS (per medical record)	Minor (810600.1,2) (810202.1,2)	Flying glass

Source: Driver interview and Emergency room records

Child Passenger Kinematics

The 3-year-old female was restrained by the 5-point harness in a forward-facing CRS. At impact, the child responded to the frontal crash by initiating a forward trajectory. The child loaded the harness straps with her shoulders and chest and rode down the force of the crash. The harness strap loading resulted in a left shoulder abrasion. Flying glass from the disintegrated side windows caused a small laceration/abrasion of the left 5th toe. The child came to rest within the CRS and was removed from the vehicle by a passerby. She was transported by ground ambulance to a local hospital, treated and released.

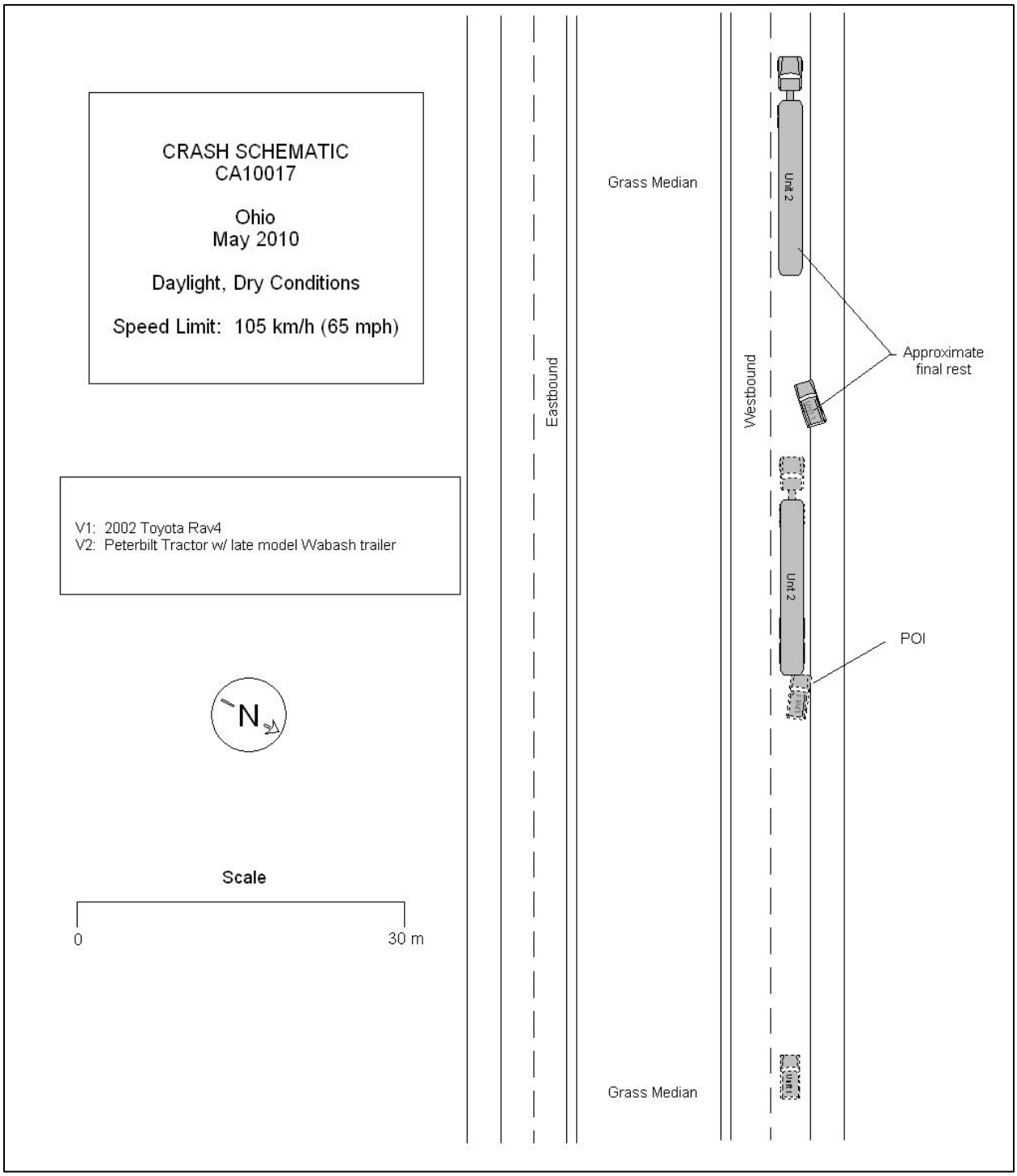

Figure 8: Crash schematic.