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OFFICE OF DEFECTS INVESTIGATION

CALSPAN ON-SITE POTENTIAL UNINTENDED ACCELERATION CRASH INVESTIGATION

SCI CASE NO.: CA10010

VEHICLE: 2010 TOYOTA RAV4

LOCATION: MASSACHUSETTS

CRASH DATE: MARCH, 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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16. Abstract This on-site investigation focused on the alleged Unintended Acceleration (UA) crash of a 2010 Toyota RAV4. The Toyota was driven by a restrained 70-year-old female. She was the vehicle's sole occupant. The driver was operating the vehicle in the parking lot adjacent to a physician's office and attempted to park in front of the building. As the driver applied a clockwise (right) steer to maneuver into the parking stall, she lost control of the vehicle. The Toyota overrode the sidewalk and impacted the wall of the wood-frame structure. The Toyota sustained minor abrasions and deformation to the front body panels. The frontal air bags did not deploy. The vehicle was towed from the crash site and impounded by the investigating police department. The driver was transported to a local hospital, examined and released. She was not injured.			
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BACKGROUND

This on-site investigation focused on the alleged Unintended Acceleration (UA) crash of a 2010 Toyota RAV4. The Toyota was driven by a restrained 70-year-old female. She was the vehicle's sole occupant. The driver was operating the vehicle in the parking lot adjacent to a physician's office and attempted to park in front of the building. As the driver applied a clockwise (right) steer to maneuver into the parking stall, she lost control of the vehicle. The Toyota overrode the sidewalk and impacted the wall of the wood-frame structure. **Figure 1** is an on-scene police image of the crash site. The Toyota sustained minor abrasions and deformation to the front body panels. The frontal air bags did not deploy. The vehicle was towed from the crash site and impounded by the investigating police department. The driver was transported to a local hospital, examined and released. She was not injured.

Figure 1: View of the 2010 Toyota RAV4 at final rest. Image supplied by the police investigator.

The investigating police officer contacted the National Highway Traffic Safety Administration's (NHTSA) Office of Defects Investigation (ODI) regarding the crash due to the concerns of potential UA and the on-going Toyota recall. The notification was subsequently forwarded to the Calspan Special Crash Investigations (SCI) team by the NHTSA's Crash Investigation Division and assigned for follow-up research on March 18, 2010. Calspan SCI contacted the investigating police department the same day and arranged for an inspection of the vehicle and crash site. The vehicle had been impounded by the police since the date of the crash. The on-site inspection took place March 22, 2010 and involved the detailed inspection and documentation of the Toyota and crash site. The vehicle's Event Data Recorder (EDR) was also imaged. Interviews with the driver and witnesses within the doctor's office were also conducted. A technical representative from ODI was present and participated in the on-site inspection.

SUMMARY

VEHICLE DATA

2010 Toyota RAV4

The Toyota RAV4 was identified by the Vehicle Identification Number: 2T3DF4DV8AW (production sequence deleted). The date of manufacturer was 11/09. The driver had purchased the vehicle new in December 2009. At the time of the crash, the odometer reading was 3,730 km (2,318 miles). The 4-door, compact Sport Utility Vehicle (SUV) was equipped with a 2.5-liter, inline 4-cylinder engine and a 4-speed automatic transmission with on-demand 4-wheel drive. The vehicle was equipped with 4-wheel disc brakes with anti-lock, electronic brake-force distribution and emergency braking assist. Additional features included traction control, vehicle stability control, a direct tire pressure monitoring system and a "*Smart Key"* push-button ignition system. 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 Certified Advanced 208-Compliant (CAC) frontal air bags, front seat-mounted side impact air bags, and roll-sensing inflatable curtain air bags. The vehicle's recommended tire size was P225/65R17 with a cold tire pressure of 221 kPa (32 PSI), front and rear. The vehicle was equipped with Toyo Open Country A20 P225/65/R17 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	228 kPa (33 PSI)	7 mm (9/32)	No	None
LR	241 kPa (35 PSI)	8 mm (10/32)	No	None
RF	234 kPa (34 PSI)	7 mm (9/32)	No	None
RR	241 kPa (35 PSI)	7 mm (9/32)	No	None

The Toyota RAV4 was subject to the Sticking Pedal Recall (NHTSA Campaign No. 10V01700) announced in January 2010. The driver did not complain that the vehicle displayed any symptoms of UA. Rather, the driver became aware of the recall via news coverage of the issue and took her vehicle back to the dealership in order to schedule the recall remedy on February 16, 2010. The recall remedy was completed on the same day. The odometer reading at the time of the recall service was 3,209 km (1,994 miles). The vehicle had no other service or maintenance prior to the date of the crash. The driver did not express any concerns regarding the vehicle's operation after the recall remedy was performed.

CRASH SITE

This single-vehicle crash occurred during the daylight hours of March 2010. At the time of the crash, the environmental conditions were clear and dry. The crash occurred in the parking lot adjacent to a single-story office building comprised a of wood-frame construction. The building was located on the north side of the parking area. The south exterior wall of the building was the point of impact. At the time of the SCI inspection, the exterior wall of the building was

undergoing repair. **Figure 2** is a trajectory view of the Toyota looking northward at the building and the general area of impact. The image was taken at the time of the SCI inspection.

The parking stalls were oriented perpendicular to the face of the building and terminated at a 28 cm (11 inch) wide, tapered asphalt curb. The height of the triangular-shaped asphalt curb measured 8 cm (3.0 in). Immediately beyond the asphalt was an 89 cm (35 in) wide gravel landscaped area which bordered a 191 cm (75 in) wide sidewalk. The sidewalk was located along the perimeter of the building. The top surface of the sidewalk measured 8 cm (3.2 in) above the gravel surface. A 9 cm (3.5 in) long tire scuff mark was observed on the outboard edge of the sidewalk. The tire mark measured 17 cm (6.5 in) in width and wrapped onto the vertical face of the sidewalk. The tire mark was caused by the Toyota's right rear tire at final rest (**Figure 3**).

Figure 2: Trajectory view of the Toyota approaching the building and the general area of the impact.

Figure 3: Right rear tire scuff identified at the crash site during the SCI investigation.

CRASH SEQUENCE

Pre-Crash

A schematic of the crash sequence is attached to the end of this report as **Figure 9**. The Toyota completed a left turn from the adjacent roadway and entered the parking lot adjacent to the office building. The Toyota was travelling on a westward trajectory, south of the building, at an EDR reported speed of 10.0 km/h (6.2 mph) 5 seconds prior to the crash. The driver steered clockwise to enter a parking stall and park the vehicle outside of the physician's office. The crash reconstruction indicated that driver over-shot the entry turn into the stall and had to turn beyond 90 degrees in order to remain within the stall. The vehicle approached the curb and sidewalk at approximately 75 degrees (relative to the curb). The Toyota then overrode the curb and sidewalk.

The receptionist seated at the desk within the office recalled seeing the approaching Toyota through the glass panes of the entry door in her peripheral vision. She recalled it was odd because she had never noticed an approaching vehicle through the door before. She remarked that she saw the front left corner and left side of the vehicle and believed that the vehicle was at an angle within the parking stall, not oriented parallel to the parking lines. She looked away from the door, back to her work, and then the crash occurred. She believed the vehicle had stopped, backed-up and then came forward again.

Crash

The front left and center aspects of the vehicle's front plane impacted the south wall of the building. As the vehicle penetrated the structure, the entire width of the frontal plane contacted the wall. The bottom plate of the wood structure separated from its attachment to the concrete floor and cantilevered inboard at the ceiling. The vehicle came to rest approximately 1.2 m (4 ft) inside the building, **Figure 4**. A scuff mark attributed to the left front tire was observed on the office carpet. The mark was arc-shaped and measured 38 cm (15 in) long. The maximum width of the mark was 25 cm (10 in).

Figure 4: On-scene police image of the vehicle at final rest.

Post-Crash

The employees inside the physician's office notified the police of the crash via the 9-1-1 emergency reporting system. The police, fire and medical personnel responded to the crash site. A doctor within the office reported that he responded to the crash and was the first to approach the vehicle. He exited the office through the entry door, walked around the back of the vehicle and opened the right front door. The Toyota's engine was idling. He reported that initially the driver was disoriented. The doctor reached in and pushed the "*Smart Key*" button and shut down the engine. In her confusion, the driver restarted the engine by pressing the "*Smart Key*" button. The doctor again reached in and shut the engine off. The doctor indicated that this happened three times and he repeatedly had to tell the driver to "stop starting the engine". The doctor then assisted the driver over the center console and out through the right front door. The doctor recalled the driver was remorseful for having caused the crash.

The driver was treated at the scene by the ambulance personnel. She complained of safety belt related chest pain and lower back pain. The lower back pain resulted from a pre-existing

condition. As she was being treated, the investigating police officer overhead communication from the first responders to the driver regarding the recalled status of the Toyota RAV4 and the possibility of an unintended acceleration. The investigating police officer intervened and ended further communication between the first responder and the driver. The driver was subsequently transported by ground ambulance to a local hospital, examined and released. The vehicle was loaded onto a flat bed tow truck and subsequently transported to the police impound for storage pending this SCI investigation.

RECONSTRUCTION

After inspecting the crash site and interviewing the witnesses at the physician's office, a substitute vehicle (Dodge Durango) was used to reconstruct the pre-crash position of the Toyota based on their statements. With the receptionist seated at her desk, the substitute vehicle was positioned approximately where the receptionist recalled observing the Toyota immediately prior to the crash. It was determined that in order for the vehicle to reach its observed orientation, the Toyota had to approach the building at an acute angle. Therefore, the driver of the Toyota had to steer the vehicle beyond 90 degrees during the parking maneuver; thus over-shooting the entry turn into the parking stall. The reconstruction was consistent with the statements of the receptionist, the vehicle damage and the tire marks observed at the scene.

DRIVER INTERVIEW

The driver was a 70-year-old female with a stated height and weight of 170 cm (67 in) and 59 kg (130 lb). At the time of the crash, she was wearing jeans, a blouse, a jacket and athletic-style walking shoes (size 9). She had purchased the Toyota RAV4 as a new vehicle in December 2009. Prior to the purchase, the driver owned and had been driving a 2004 Buick Lucerne. The driver traded the Buick during the purchase transaction. She preferred the higher/upright driving position of the Toyota RAV4, as it allowed for easy entry/exit of the vehicle, particularly with her lack of flexibility due to her unspecified pre-existing lower back condition. The driver reported that she only operated the vehicle's foot controls (accelerator and brake) with her right foot. The driver owned no vehicle, other than the Toyota RAV4.

The driver was familiar with the general area surrounding the crash site; however, this was her first visit to this physician's office. This doctor was a specialist and she had been referred to him by her primary doctor. The driver reported that she turned left and entered the parking lot from the main road. She drove straight down the center aisle and intended to park in the stalls located to her right. The parking stalls were located in front of the physician's building. There were other vehicles parked in the lot; however, no other vehicles were moving at the time of the incident. The driver had arrived several minutes prior to her appointment and she was not rushed. She estimated her speed was "slow" and that she was braking with her right foot (modulating the speed of the vehicle). The radio and the HVAC controls were "Off" and she was not using a cellular phone. She did not report any distractions.

The driver turned the vehicle to the right and was maneuvering into the parking space when the incident occurred. The driver reported that she applied the brakes and the vehicle came to a stop, parallel to and within the painted lines of the parking space. (It should be noted that her statement regarding the position of the vehicle conflicted with the results of the reconstruction.) Then as she reached to shift the transmission from *Drive* to *Park*, the vehicle lurched forward for unknown reasons. After the crash had occurred, she recalled the doctor assisting her from the right front door and corroborated the doctor's statements regarding stopping and restarting the vehicle several times.

2010 TOYOTA RAV4

Exterior Damage

The Toyota RAV4 sustained minor severity damage to the front plane, hood, and the forward aspect of the left side plane due to the yielding impact with the building wall. **Figure 5** is a front view of the Toyota. The damage primarily consisted of surface abrasions to the body panels and deformation of the bumper fascia. Examination of the bumper reinforcement beam revealed 3 cm (1.2 in) of crush to the right end of the beam. The center and left aspects of the reinforcement beam were undamaged. Surface abrasions were noted across the hood, along the left A-pillar, on the body of the left mirror and on the leading edge of the left door panel. There was no change in the wheelbase dimensions. There was no damage to the windshield or side glazing. All the doors remained closed during the impact and were operational post-crash. The residual crush profile at the front bumper elevation was as follows: C1 = 2 cm (0.8), C2 = 1 cm (0.4), C3 = 1 cm (0.4), C4 = 0, C5 = 1 cm (0.4), C6 = 5 cm (2.0 in). An analysis of the crash severity (delta-V) was beyond the scope of the WinSMASH program due to the yielding impact. The Barrier Equivalent Speed based on the damage profile was 14 km/h (8.7 mph). The Collision Deformation Classification was (CDC) 12FDEW1.

Figure 5: Front right oblique view of the Toyota RAV4.

Interior Damage

There was no interior damage or intrusion as a result of the crash. No interior occupant contact points were identified. At the time of the SCI inspection, the driver seat was adjusted to a rear-track position that measured 3 cm (1.0 in) forward of full rear. The seat track travel measured 24 cm (9.5 in). The seat back angle measured 18 degrees aft of vertical. The horizontal distance between the seat back and the center of the steering wheel rim measured 58 cm (23 in). During her interview, the driver was not able to explain or describe her typical seat adjustment. Given

the care taken by the police investigator to preserve and store the vehicle, this was probably the at-crash adjustment of the seat. The front interior was equipped with the OEM carpeted floor mats. The driver mat was secured by the hooks to the floor. **Figure 6** is an interior view of the driver floor mat and the foot controls.

The Toyota was equipped with the CTS accelerator pedal and was subject to the Sticky Pedal Recall. The Toyota was serviced for the recall on February 16, 2010. The service record indicated that a 2.0 mm shim was inserted into the pedal assembly. **Figure 7** is a view of the accelerator and brake pedals taken during the SCI inspection. The accelerator pedal was identified by the following:

78110-0R020
09315A2A X
51836742801
LHD

Figure 6: View of the driver interior and floor mats.

Figure 7: View of the foot controls.

Manual Restraint Systems

The Toyota RAV4 was equipped with 3-point lap and shoulder belts in the five seat positions. The driver's restraint consisted of continuous loop webbing, a sliding latch plate, an adjustable D-ring and an Emergency Locking Retractor. The driver's D-ring was adjusted to the full-up position. The retractor was equipped with a pretensioner. The pretensioner did not actuate during the crash. The webbing was stowed on the retractor at initial inspection. The retractor was operational. Examination of the latch plate revealed minor indications of historical use. There was no crash related evidence. Crash related evidence would not be expected given the low-level severity of the impact. Based on the driver's statement to the police officer and the SCI investigator, it was determined that she was restrained at the time of the crash. Additionally, the imaged EDR data recorded that the driver safety belt was buckled at the time of the crash.

Air Bag Systems

The Toyota RAV4 was equipped with Certified Advanced 208-Compliant (CAC) frontal air bags for the driver and front right passenger. A CAC air bag is certified by the vehicle manufacturer to be compliant with the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The Toyota was also equipped with front seat-mounted side impact air bags and Inflatable Curtain air bags. None of the air bags deployed during the crash. The air bag systems were controlled by an Air bag Control Module (ACM) located under the center console. The ACM had event data recording capabilities.

Event Data Recorder

The vehicle's Event Data Recorder (EDR) data was imaged at the time of the crash through the use of a proprietary hardware interface and software version 1.10 supplied by Toyota. The data was imaged through the Diagnostic Link Connector (DLC) located under the left aspect of the instrument panel using the vehicle's onboard 12-volt electrical power. The EDR was imaged prior to starting the vehicle's engine. The imaged data has been reanalyzed with software version 1.4.1.0 and is summarized below.

The EDR in the 2010 Toyota RAV4 had the capability and capacity to record and store two longitudinal events, two lateral crash events and two roll over events. The two events were designated "Latest" and "Next Most-Recent", respectively. A 5-second pre-crash data buffer stored data elements regarding the vehicle's operation. When a crash event was triggered, the pre-crash data was saved and linked to the respective event.

The Toyota's EDR had only one stored event (designated "Latest"). The recorded data indicated the driver's safety belt was buckled and the driver seat was in a rearward position. The front right seat was not occupied. The stored event consisted of two (closely spaced) triggers. The EDR initially triggered due to a right side event followed 14 milliseconds later by the frontal event. The imaged data recorded that the vehicle's air bags were not deployed. The safety belt pretensioner did not actuate. A flag within the recording indicated the data was completely written. The maximum recorded delta-V was 5.0 km/h (3.1 mph) at 200 milliseconds.

The recorded pre-crash data of the "Latest" event is displayed in the following table. An application of the accelerator was recorded immediately prior to the crash. The EDR reported accelerator pedal position was broken into three ranges, "Off, Middle and Full". The reported pedal position was based on the voltage measured at the accelerator pedal. An increase in voltage indicated an increase in relative position. The brake status was recorded as "Off" throughout the pre-crash recording.

Parameter	-5 sec	-4 sec	-3 sec	-2 sec	-1 sec	-0.3sec
Speed	10.0 km/h (6.2 mph)	10.0 km/h (6.2 mph)	8.0 km/h (5.0 mph)	8.0 km/h (5.0 mph)	12.1 km/h (7.5 mph)	15.9 km/h (9.9 mph)
Engine	400 RPM	400 RPM	400 RPM	400 RPM	2000RPM	2400 RPM
Accelerator Pedal Position	Off 0.82 volts	Off 0.78 volts	Off 0.78 volts	Off 1.13 volts	Full 3.05 volts	Full 3.40 volts
Brake Status	Off	Off	Off	Off	Off	Off

ODI Inspection

The technical representative of NHTSA's ODI office also inspected the Toyota RAV4. Proprietary diagnostic software from Toyota was used by the ODI investigator to interrogate the Electronic Control Units (ECU) within the vehicle's power train. The software was similar to that used by Toyota service technicians to retrieve and service Diagnose Trouble Codes (DTC's) during maintenance procedures. During the SCI/ODI inspection, the three DTC's were identified. Code B1000 related to an air bag ECU malfunction and was stored in the vehicle's "History". The code was set at some unknown time prior to the crash. It was not an active code. Two DTC's were in "Current" memory. The codes were B1421 and B1424. A Toyota service technician indicated that these codes related to the solar sensors of the vehicle's air conditioning system and were active due to the fact the vehicle was located in a garage at the time of the inspection. The software interrogation provided no data that could be related to the crash event. Additional activities of the ODI inspection included: measurements of the location of the vehicle's foot controls (relative to the centerline of the driver seat), an inspection of the accelerator and brake pedals, and brake pedal-force measurements.

Mechanical Inspection

At the conclusion of the SCI inspection, the Toyota was started and driven. In order to be started, the transmission selector had to be shifted into *Park* or *Neutral.* Additionally, the vehicle would not start unless the brake pedal was depressed. The *Smart Key* system required the presence of the vehicle's key fob. The *Smart Key* ignition button was depressed and held momentarily to start the engine. The vehicle immediately started; the cold idle was 1500 RPM and gradually dropped to 1100 RPM after approximately 1 minute. The idle speed was recorded with the vehicle's transmission in "Park", without a transmission load on the engine. The engine responded properly to input from the accelerator and the throttle immediately closed to idle upon release of the pedal. There were no illuminated Malfunction Indicator Lamps (MIL) in the instrument cluster, except for a low washer fluid indicator. The vehicle was driven around the parking lot and operated properly. The *Smart Key* had to be depressed and held for approximately 3 seconds to stop the engine.

During the SCI inspection, the left front wheel/tire was removed in order to assess the condition of the brakes. The surface of the rotor was lightly rusted from exposure to the environment. There was no sign of prolonged heating to the rotor or pads. The brake pads had adequate thickness. The brake fluid reservoir (at the master cylinder) was full of brake fluid and there were no apparent leaks in the brake system. **Figure 8** is a view of the left front rotor and brake assembly.

Figure 8: Left front rotor and brake assembly of the Toyota.

DRIVER DEMOGRAPHICS/DATA

	Driver
Age/Sex:	70-year-old/Female
Height:	170 cm (67 in)
Weight:	59 kg (130 lb)
Eyewear:	None
Seat Track Position:	Rear track
Restraint Use:	3-point lap and shoulder safety belt
Restraint Usage Source:	PAR, SCI interior inspection, EDR, Interview
Mode of Transport From Scene:	Transported via ground ambulance to a local hospital
Type of Medical Treatment	Examined and released

Driver Injury

Injury	**Injury Severity (AIS – 2005/08)**	**Injury Source**
Complaint of chest pain	Not codeable under AIS rules	Safety belt loading

Driver Kinematics

The 70-year-old female was restrained and seated with an upright posture. The driver seat was adjusted 3 cm (1.0 in) forward of full-rear. The driver was operating the Toyota in the parking lot and applied a clockwise (right) steering input to maneuver the vehicle into a marked parking space. A reconstruction of the crash indicated that the driver over-shot the entry to the parking space. As the vehicle approached the curb, the driver lost control and the vehicle's front plane impacted the south wall of the building. The imaged EDR data recorded an application of the vehicle's accelerator one second prior to the impact. The brakes were recorded as "Off".

The driver responded to the impact by initiating a forward trajectory. The driver loaded the locked safety belt system and rode down the force of the crash. She complained of chest pain that was related to the safety belt loading. The driver was transported by ground ambulance to a local hospital where she was examined and release.

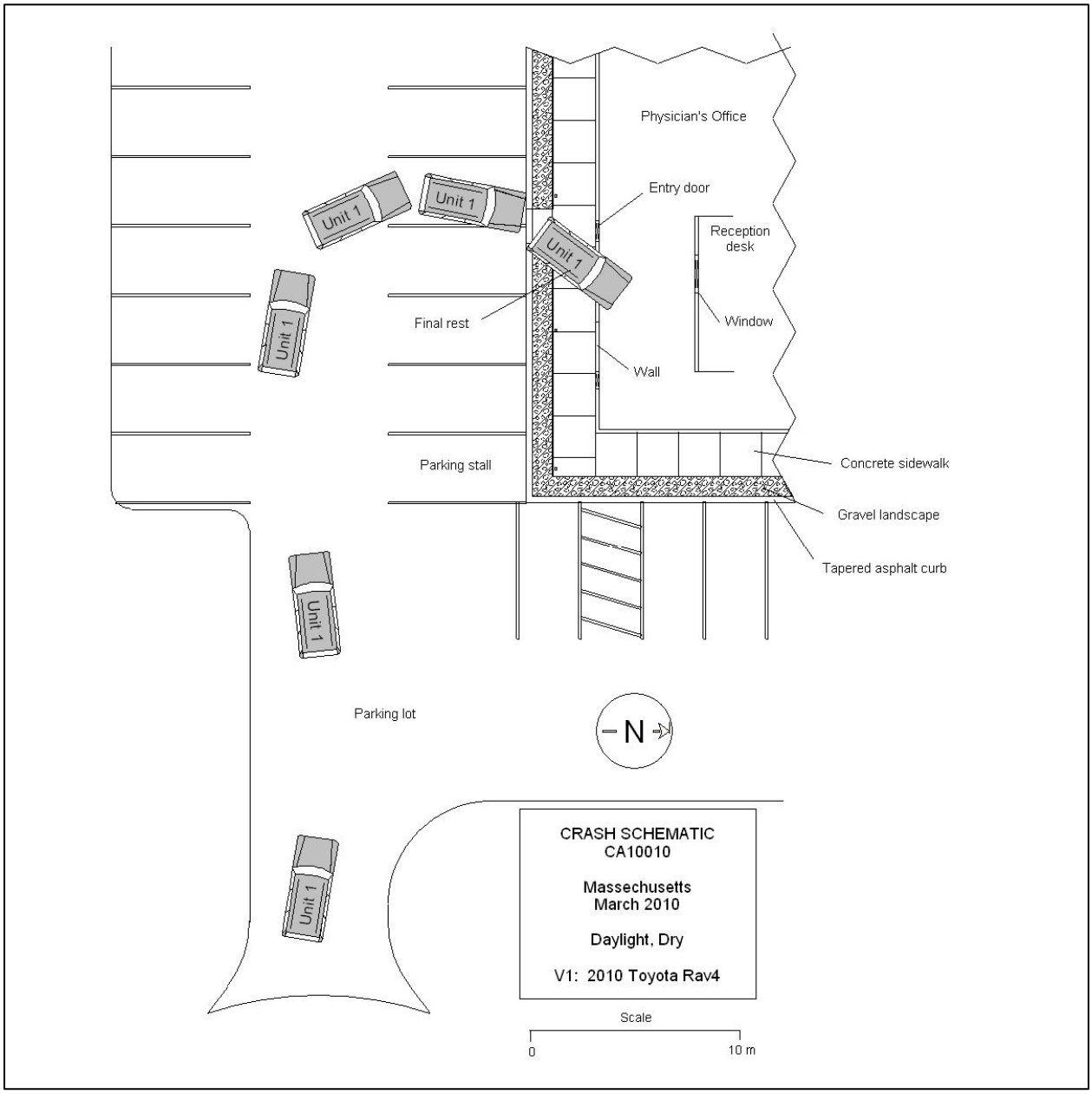

Figure 9: Crash schematic.