

CRASH DATA RESEARCH CENTER

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CALSPAN ON-SITE OFFICE OF DEFECTS INVESTIGATION

SCI CASE NO: CA09079

VEHICLE: 2005 SCION tC

LOCATION: ILLINOIS

CRASH DATE: SEPTEMBER 2009

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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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<i>16. Abstract</i> This on-site investigation focused on the rollover of a 2005 Scion tC and the ejection of the restrained driver. The Scion was equipped with dual-stage frontal air bags for the driver and front right passenger positions with manual 3-point lap and shoulder safety belts for the five designated seating positions. The Scion was occupied by a 31-year-old male driver with a reported height of 173 cm (68 in) and a weight of 86 kg (190 lb). The Scion entered the depressed grass median of a divided highway and was involved in a left side leading rollover that involved a minimum of 12-quarter turns. During the rollover sequence, the driver's safety belt webbing tore and the latch plate fractured, releasing the safety belt resulting in the complete ejection of the driver. He sustained multiple AIS4 and 5 level injuries and expired at the scene of the crash.			
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BACKGROUND

This on-site investigation focused on the rollover of a 2005 Scion tC (**Figure 1**) and the fracturing of the driver's safety belt latch plate and the tearing of the safety belt webbing. This led to the release of the driver's safety belt and the complete ejection of the driver. The Scion was equipped with dual-stage frontal air bags for the driver and front right passenger positions with manual 3-point lap and shoulder safety belts for the five designated seating positions. The Scion was occupied by a 31-year-old male driver with a reported height of 173 cm (68 in) and a weight of 86 kg (190 lb). The crash occurred during nighttime hours in dense fog. The Scion entered the depressed grass median of a divided highway and was involved in a left side leading rollover that involved a minimum of 12-quarter turns. The driver sustained multiple AIS-4 and 5 level injuries and expired at the scene of the crash.



Figure 1: Left front oblique view of the rollover damage to the 2005 Scion tC.

A Field Investigator for the State of Illinois provided notification of the crash to a Regional Office of the National Highway Traffic Safety Administration (NHTSA). The notification was forwarded to NHTSA's Crash Investigation Division (CID), which then assigned an on-site investigation to the Calspan Special Crash Investigations (SCI) team on November 10, 2009. The Calspan SCI team established cooperation with the Field Investigator, who secured the vehicle for inspection at a regional vehicle salvage facility. The on-site SCI investigation was performed on November 12-13, 2009, and consisted of the inspection and documentation of the involved Scion and crash site, and the acquisition of the driver's autopsy report.

SUMMARY

Crash Site

The crash occurred during nighttime hours in September 2009. At the time of the crash, the conditions were dark with visibility limited due to dense fog. The asphalt road surface was dry. The crash occurred within the depressed grass median of a four-lane divided north/south interstate trafficway. The Scion was traveling on the level two-lane southbound portion which followed a right radius of curvature of 450 m (1,476 ft). This roadway consisted of an outboard 3.5 m (11.5 ft) wide asphalt shoulder with rumble strip, a 3.6 m (11.8) wide outboard travel lane, a 3.5 m (11.5 ft) wide inboard travel lane, and a 2.1 m (6.9 ft) wide



Figure 2: Southbound view of the roadway depicting the pre-crash travel path of the Scion.

inboard asphalt shoulder with a rumble strip located 0.4 m (1.3 ft) from its right edge. The depressed grass median measured 12.9 m (42.3 ft) wide with a 1.6 m (5.2 ft) wide gravel strip bordering both outboard edges. The posted speed limit was 105 km/h (65 mph). It should be noted that the vegetation within the grass median was mowed between the dates of the crash and the SCI inspection. **Figure 2** depicts the southbound view of the pre-crash trajectory of the Scion within the roadway. The Crash Schematic is included at the end of this report as **Figures 11** and **12**.

Vehicle Data

2005 Scion tC

The 2005 Scion tC was a two-door hatchback that was identified by the Vehicle Identification Number (VIN): JTKDE177350 (production sequence deleted). Due to the jammed left front door, access to the manufacturer's placard could not be obtained; therefore date of manufacture was unknown. The electronic odometer reading could not be obtained due to the compromised electrical system sustained during the crash sequence.



Figure 3: Right front oblique view of an exemplar 2005 Scion tC.

The Scion was powered by a 2.4-liter, transverse-mounted inline 4-cylinder gasoline engine, linked to a 5-speed manual transmission with front-wheel drive. The Scion was equipped with a four-wheel anti-lock disc braking system. The vehicle manufacturer's recommended tire size was P225/40ZR18 front and rear, with cold tire pressures of 221 kPa (32 PSI) and 200 kPa (29 PSI), respectively. At the time of SCI inspection, the vehicle was equipped with Pirelli Zero

Nero tires of size P225/40R18, mounted on OEM 7-spoke alloy wheels. Specific tire data at the time of SCI inspection was as follows:

Position	Pressure	Tread Depth	Tire Damage
LF	Tire Flat	7 mm (9/32 in)	Outer wheel bead abrasion
LR	200 kPa (29 PSI)	4 mm (5/32 in)	None
RF	Tire Flat	3 mm (4/32 in)	Tread/sidewall cut 180 degrees opposite of valve stem
RR	Tire Flat	4 mm (5/32 in)	Outer wheel bead abrasion

The interior of the Scion was configured with cloth-surfaced front bucket seats and a three-passenger rear bench seat with split forward-folding seatback. All five seating positions were equipped with 3-point lap and shoulder safety belt systems. Supplemental restraints included a dual-stage frontal air bag system with front retractor pretensioners. The roof of the Scion consisted of two large glazing panels, of which the forward section served as an operational sunroof.

At the time of the SCI inspection, the interior seating was documented as follows: The front seats were equipped with adjustable head restraints, which were in the full-up positions, 8 cm (3.25 in) above the seatbacks. The driver’s seatback was reclined to an angle of 55 degrees aft of vertical, while the front right seatback was reclined 33 degrees. The rear seatbacks were folded forward at the time of the SCI inspection, a position attributed to post-crash adjustment by emergency response personnel for the placement of separated vehicle components within the passenger compartment during towing and recovery efforts.

Crash Sequence

Pre-Crash

The restrained driver of the Scion was traveling at a high speed in the outboard travel lane of the southbound portion of the interstate. As previously stated, the nighttime visibility was hampered by a dense fog. While the driver began negotiating the right curve of the dry roadway, he lost directional control as the vehicle crossed into the inboard lane. The Scion initiated a clockwise (CW) yaw, evidenced by corresponding left front and left rear tire marks on the asphalt surface that began on the right side of the inboard travel lane and extended 15.5 m (51 ft) and 4 m (13 ft) to the roadway edge, respectively.

The vehicle maintained its CW yaw on the same trajectory as it proceeded across the inboard shoulder and departed the left roadway edge as it entered the depressed grass median. Based on the speed of the Scion, coupled with the slope of the median and its soft surface composition, the Scion rotated CW over a distance of approximately 21 m (69 ft) within the median as it translated to a left side-leading attitude. The low profile left rear tire began to furrow into the

soft grass and soil surface of the median. Based on data obtained at the crash site and from the vehicle inspection, the SCI reconstruction calculated the Scion's speed at that time to have been approximately 109 km/h (68 mph).

Crash

Instability was created due to the lateral force load on the left side axle positions with respect to the Scion's center of gravity as the low profile left rear tire furrowed into the soft grass and soil surface of the median. The furrowing initiated a trip-over into a left side leading rollover event, the location of which was evidenced by a gouge mark from the left rear wheel within that axle position's documented trajectory. The vehicle rotated predominantly about its longitudinal axis, contacting both inclined sides of the depressed median during the course of its rollover sequence. Nine gouge marks were documented within the median which, in conjunction with associated vehicle damage patterns and the information obtained from on-scene law enforcement, indicated that the Scion completed a minimum of twelve-quarter turns during the rollover event. All vehicle glazing shattered or disintegrated as its respective plane contacted the ground throughout the rollover event.

During the course of the uninterrupted rollover sequence, the driver induced severe loading forces on the manual restraint system. These forces were compounded exponentially by the centrifugal acceleration of the driver away from the vehicle's center of gravity, causing the driver to lift from the seatback and cushion. Despite the engagement of the Emergency Locking Retractor (ELR), the severe loading forces began to spool out webbing from the retractor and caused severe loading on the latch plate. The slack created in the webbing was immediately pulled taut by the force load of the driver, thus causing more webbing to be pulled from the retractor. The combination of the centrifugal forces of the Scion's rotation, the violent impacts with the ground during the rollover sequence, and the increased belt length caused the driver to repeatedly load the safety belt webbing. These repetitive tensile forces caused the latch plate to fracture in two separate locations while engaged within the locking mechanism of the belt buckle assembly.

The fractured latch plate subsequently released from the locking mechanism of the buckle, allowing the driver's movement to become unrestricted. Accordingly, the centrifugal forces directed the driver laterally, entangling the driver within the webbing as he contacted and loaded the interior of the left front door and the left roof side rail. The force of this loading caused a 10 cm (4 in) extrusion to the center aspect of the left door, though the door remained closed. The combination of the extruded door deformation and the disintegrated glazing created an ejection portal for the driver. However, the driver remained tethered to the Scion by the entangled belt webbing that was wrapped horizontally across his abdomen. As the vehicle continued its rollover sequence, the driver was violently whipped about for sufficient time to cause severe evisceration injuries to his abdomen.

The rollover dynamics and driver kinematics maintained severe loading forces on the belt webbing, which ultimately yielded in two separate sections during the latter stages of the rollover sequence. Finally released from the belt webbing, the driver separated from the vehicle and came to rest on the east side of the median. The Scion completed its rollover sequence and came to rest upright, 78 m (256 ft) south of the point of initial trip point, facing northwest.

Post-Crash

The local emergency response system was notified of the crash and dispatched law enforcement, the local fire department, and Emergency Medical Services (EMS) to the scene. First arriving emergency response personnel found the Scion upright within the grass median, with both doors closed. The driver was located within the median, 71 m (233 ft) south of the initial trip point, lying face down with his feet facing in an easterly direction (**Figure 4**). He sustained fatal injuries during the crash sequence and was pronounced deceased at the scene. His body was transported to a local mortuary service facility where the Medical Examiner performed an autopsy.



Figure 4: Westward view of the Scion at final rest. Image provided by investigating law enforcement agency.

Emergency response personnel at the scene collected the separated vehicle components and placed them within the passenger compartment prior to the vehicle's removal from the scene. The Scion was towed from scene and impounded by the local law enforcement agency. It was later released from impound and transferred to the regional vehicle salvage facility where it was being held at the time of this SCI investigation. Separated vehicular components were removed from the interior for photographic purposes by the salvage facility and were subsequently discarded prior to the SCI inspection.

Vehicle Damage

Exterior

The 2005 Scion tC sustained extensive damage to all exterior surfaces as a result of the rollover crash, with corresponding separation of multiple body components. **Figure 5** depicts a left side view of the damaged Scion. Damage from the initial trip-over was located on the left rear wheel, which consisted of grass wedged between the tire bead and wheel with abrasions to the wheel face. Due to



Figure 5: Left side view of damaged Scion.

overlapping damage on all planes of the vehicle, the initial plane of contact with the ground during the rollover sequence is unknown. Numerous vehicular components separated completely from the Scion during the course of the rollover sequence, including the hood, left front fender, left outer door panel, front and rear bumper fascias, grille, and both headlamp assemblies. The left and right front axle positions were also separated from the vehicle, including both wheels and tires with their corresponding brake, suspension, and drive axle components.

The hood latch striker sheared from the sheet metal of the hood during the rollover sequence, which enabled the hood to move without restriction. As a result, the outer hood panel had separated from the inner panel as the hood deformed during repeated contact with the ground. Due to the released status of the hood, under hood components, such as the battery, were subjected to separation from the vehicle by the centrifugal forces of the rollover.

The windshield glazing was fractured and holed from the impact forces with approximately two-thirds of the left glazing separated from the Scion. All other glazing panels were disintegrated during the rollover event, inclusive of the two roof panels. The frame of the forward sunroof was deformed rearward and toward the right of the vehicle.

The direct contact and induced damage extended the full width and length of the vehicle on all planes. Accompanying damage consisted of abrasions and isolated dents, with soil and other debris embedded within the seams. The maximum vertical roof crush was located on the right side of the backlight header (Figure 6) and measured 6 cm (2.4 in) in depth, while the maximum lateral crush was located at the top of the left A-pillar (Figure 7) and measured 3 cm (1.2 in) in depth. The Collision Deformation Classification (CDC) for the rollover was 00TDDO3.



Figure 6: Vertical crush to right rear backlight header of the Scion.



Figure 7: Maximum lateral crush to the right A-pillar of the Scion.

Interior

Interior damage to the Scion was attributed to occupant contact and passenger compartment intrusion. The driver contact points consisted of abrasions, fabric transfers, and load induced deformation to the left door panel and front left seatback. There was loading deformation to the frame of the seatback from the driver, evidenced by the compression of the fabric above the right hinge point. The extent of occupant-induced deflection could not be determined due to the reclined position of the seat back at the time of the SCI inspection and unknown status of its pre-crash condition. Deformation to the left front door panel from driver contact consisted of a 10 cm (4 in) bowed extrusion at its center aspect, though the inner door panel was intact. The driver's movement and contact within the Scion did not involve the steering wheel, column, center console, or the manual shift lever. None of these components was deformed, and each maintained proper alignment within the interior.

Intrusions into the passenger compartment were attributed to non-horizontal forces sustained during the rollover sequence. Intrusions measured at the time of SCI inspection included:

Position	Component	Magnitude	Direction
Rear right	Backlight header	6 cm (2.4 in)	Vertical
Front left	Roof	4 cm (1.6 in)	Vertical
Front left	A-pillar	3cm (1.2 in)	Lateral
Rear right	C-pillar	2 cm (0.8 in)	Vertical

Manual Restraint System

The Scion was equipped with 3-point lap and shoulder safety belt systems for all five seat positions. The driver's safety belt system consisted of continuous loop webbing, a sliding latch plate, rigid belt buckle affixed to the inboard aspect of the seat frame, a fixed B-pillar mounted D-ring, an ELR, and a retractor pretensioner system.

At the time of SCI inspection of the driver's safety belt system, the webbing was found in an extended position with an obvious separation into two distinct sections. The lower portion of the webbing (lap section) measured 119 cm (47 in) in length from the lower anchor to the frayed tear, while the upper webbing portion (shoulder section) measured 107 cm (42 in) from the D-ring to the tear. The torn edge of both sections was severely frayed, indicating that the webbing had sustained severe stress loading. When placed adjacent to one another, the frayed overlap of the torn edges measured 10 cm (4 in) in length.



Figure 8: Upper safety belt webbing loading striations and B-pillar abrasions.

The upper portion of the webbing was gathered in the leading corner of the D-ring, with deep frictional abrasions to the forward aspect of the plastic D-ring housing and B-pillar trim panel (**Figure 8**). Longitudinal striations 30 cm (12 in) in length were identified on both sides of the upper portion of the webbing, originating just below the D-ring. These findings were attributed to the loading forces sustained by the webbing during the ejection of the driver.



Figure 9: Latch plate loading evidence and fractured lock clasp.

Attached to the upper portion of the belt webbing was the latch plate, located 97 cm (38 in) from the D-ring anchor. Inspection of the latch plate revealed frictional abrasions to the full width of the plastic surface, and the webbing was folded in half and gathered to one side of the latch plate. The latch plate was fractured in two places at the lock clasp section (**Figure 9**), which produced a “J” shaped metal shard that was found fastened within the belt buckle locking mechanism.

The lower section of the belt spanned 79 cm (31 in) in length from the lower anchor to the webbing tear point (**Figure 10**). Strands of blue fabric were found embedded in the underside aspect of the webbing, which matched the color shade of the shirt that the driver was wearing at the time of the crash.

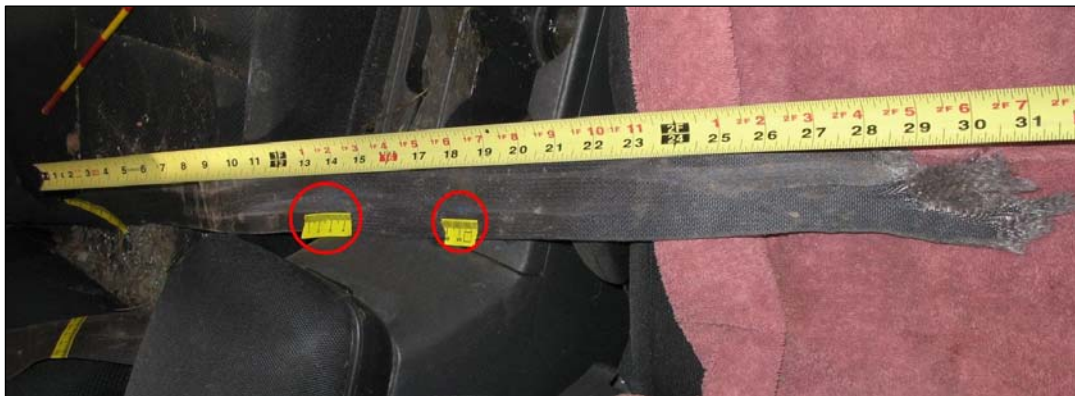


Figure 10: Lower section of belt. *Note blue fabric transfer (encircled) and frayed end.*

Based on SCI findings, the fracturing of the latch plate and separation of the belt webbing were attributed to the severe stresses sustained by the safety belt system as a result of the loading forces associated with the driver’s kinematics during the rollover sequence.

Supplemental Restraint System

The Scion was equipped with a supplemental restraint system that consisted of dual-stage frontal air bags. This system included a steering wheel hub-mounted driver's air bag, an instrument panel-mounted driver's knee bolster air bag, and an instrument panel-mounted right front passenger air bag. Due to the dynamics of the crash and the non-horizontal impact forces, none of the air bags deployed.

The air bag system was controlled by a center tunnel-mounted Air bag Control Module (ACM) mounted beneath the center console. The ACM had advanced electronics with crash sensing, fault detection, and Event Data Recording (EDR) capabilities. At the time of inspection, however, the SCI team did not have access to the proprietary Toyota scan tool and software to image the EDR.

OCCUPANT DATA

Driver Demographics

Age/Sex: 31-year-old/male
Height: 173 cm (68 in)
Weight: 86 kg (190 lb)
Seat Track Position: Rear track position, 3 cm (1.25 in) forward of full-rear
Safety Belt Usage: 3-point lap and shoulder safety belt
Usage Source: SCI vehicle inspection
Egress from Vehicle: Complete ejection prior to final rest
Type of Medical Treatment: None, pronounced deceased at scene

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Spinal cord separation between T12 - L1 vertebrae	Critical (640644.5, 8)	Safety belt webbing
Multiple anterior liver lacerations (15 cm x 10 cm)	Severe (541826.4, 1)	Safety belt webbing
Right parietal subdural hematoma (7 cm x 5 cm)	Severe (140650.4, 1)	Ground
Flail chest including right and left hemothorax	Severe (450232.4, 3)	Driver door
Separation of the pubic symphysis of the pelvis	Serious (853000.3, 5)	Ground
Subarachnoid hemorrhage of the left brain hemisphere	Serious (140684.3, 2)	Left roof side rail
Subarachnoid hemorrhage of the right brain hemisphere	Serious (140684.3, 1)	Ground
Multiple disruptions of the small intestine	Moderate (541499.2, 8)	Safety belt webbing
Multiple disruptions of the large intestine	Moderate (540899.2, 8)	Safety belt webbing

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Gaping laceration of the anterior aspect of the lower abdomen (74 cm x 25 cm)	Moderate (590804.2, 8)	Safety belt webbing
Gaping laceration to posterior aspect of lower abdomen (74 cm x 25 cm)	Moderate (690804.2, 8)	Safety belt webbing
Palpable fracture of the right humerus	Moderate (752600.2, 1)	Ground
Palpable fracture of the left ulna	Moderate (753200.2, 2)	Ground
Contusion surrounding the left eye (4 cm x 3 cm)	Minor (297402.1, 2)	Ground
Three linear abrasions to the right cheek (10 cm x 8 cm)	Minor (290202.1, 1)	Ground
Horizontal laceration to the left forehead (3 cm x 1 cm)	Minor (290602.1, 7)	Disintegrated glass
Multiple dicing incisions to the left cheek (8 cm x 8 cm)	Minor (290202.1, 2)	Disintegrated glass
Contusion to the back of the right hand (4 cm x 3 cm)	Minor (790402.1, 1)	Unknown
Contusion to the right chest area (11 cm x 8 cm)	Minor (490202.1, 1)	Safety belt webbing
Gaping laceration to the left ear (5 cm x 4 cm)	Minor (290602.1, 2)	Safety belt webbing
Abrasion to the right upper chest area (3 cm x 2 cm)	Minor (490202.1, 1)	Safety belt webbing
Abrasion to the left abdomen (18 cm x 3 cm)	Minor (590202.1, 2)	Safety belt webbing
Abrasion to the lower chest area (18 cm x 3 cm)	Minor (490202.1, 2)	Safety belt webbing
Diagonally oriented abrasion across the left aspect of the anterior neck (19 cm x 3 cm)	Minor (390202.1, 2)	Safety belt webbing
Abrasion to the left aspect of the face (9 cm x 8 cm)	Minor (290202.1, 2)	Safety belt webbing

Source: Autopsy Records

Driver Kinematics

The 31-year-old male driver of the Scion was seated in a rear-third track position and restrained by the manual 3-point lap and shoulder safety belt. The post-crash condition of the belt system confirmed belt use. Although the driver's pre-crash placement of the shoulder belt is unknown, based on his injuries, it is possible that the shoulder belt was positioned under his left arm.

The driver responded to the initial rollover forces by initiating a left lateral trajectory. This abrupt inertial shift immediately engaged the ELR as the driver's pelvis and chest loaded the safety belt webbing. Multiple fragments of tempered glass contacted the driver causing minor superficial injuries as the left front glazing disintegrated from non-horizontal impact forces sustained during the first quarter turn of the rollover event. As the vehicle accelerated about its

longitudinal axis and completed its first revolution, the centrifugal forces of the driver induced increased loading stress on the safety belt webbing. The driver loaded the seatback with his torso, evidenced by the aforementioned component deformation.

Severe loading stresses caused the metal tab of the latch plate to fracture as the vehicle entered its second complete roll. With the driver's movement no longer restricted, his body succumbed to the centrifugal force and accelerated laterally to contact the left door panel and roof side rail. Contact with the door resulted in multiple bilateral rib fractures, while the driver's head contact to the left roof side rail resulted in a serious traumatic head injury. As the vehicle completed its second roll, the driver was ejected through the left door glazing opening. However; due to the location of the safety belt and dynamics of the crash, the driver remained tethered to the rotating vehicle by the entanglement of the safety belt webbing around his abdomen. His body was tossed violently as the Scion entered its third revolution, which caused further superficial injuries, separation of the spinal cord, multiple thoracic injuries, and further head injury.

The stress load on the safety belt webbing placed extreme compressive force around the driver's abdomen. This resulted in severe level internal injuries, bilateral hemothoraces, gaping lacerations of the abdomen, and the evisceration of multiple internal organs. The belt webbing began to fray as it tore in two, releasing the driver from the grasp of the violently rotating vehicle. The ejected driver forcibly contacted the ground, which induced an exacerbation of the crushing injuries to his thorax and head. At final rest, the driver was face down on the east side of the center median with his head facing a westerly direction. This position was 71 m (233 ft) south of the initial trip point, and 7 m (23 ft) northeast of the Scion's final rest location. The driver was pronounced deceased upon arrival of EMS personnel at the scene.

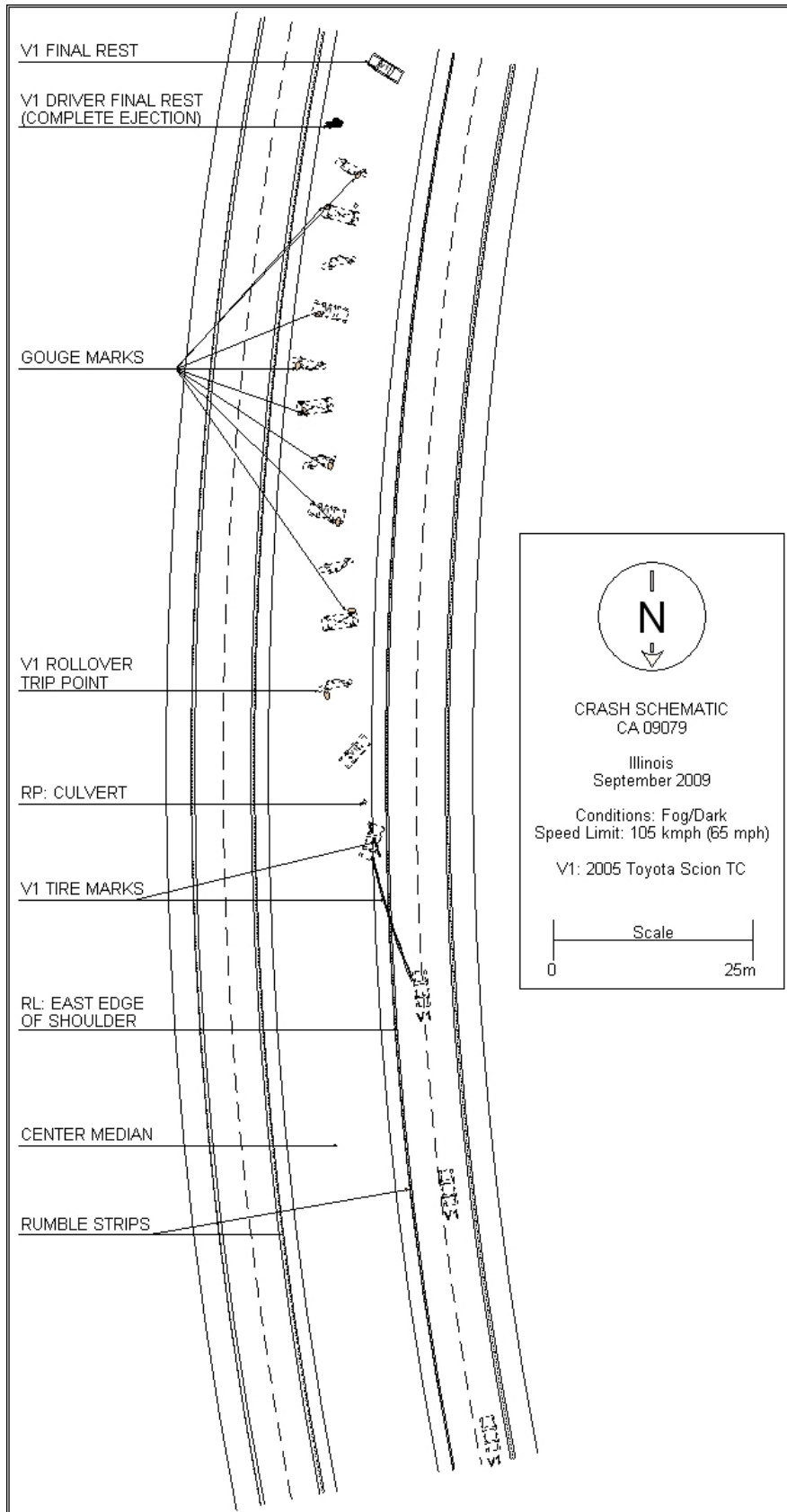


Figure 11: Crash Schematic.

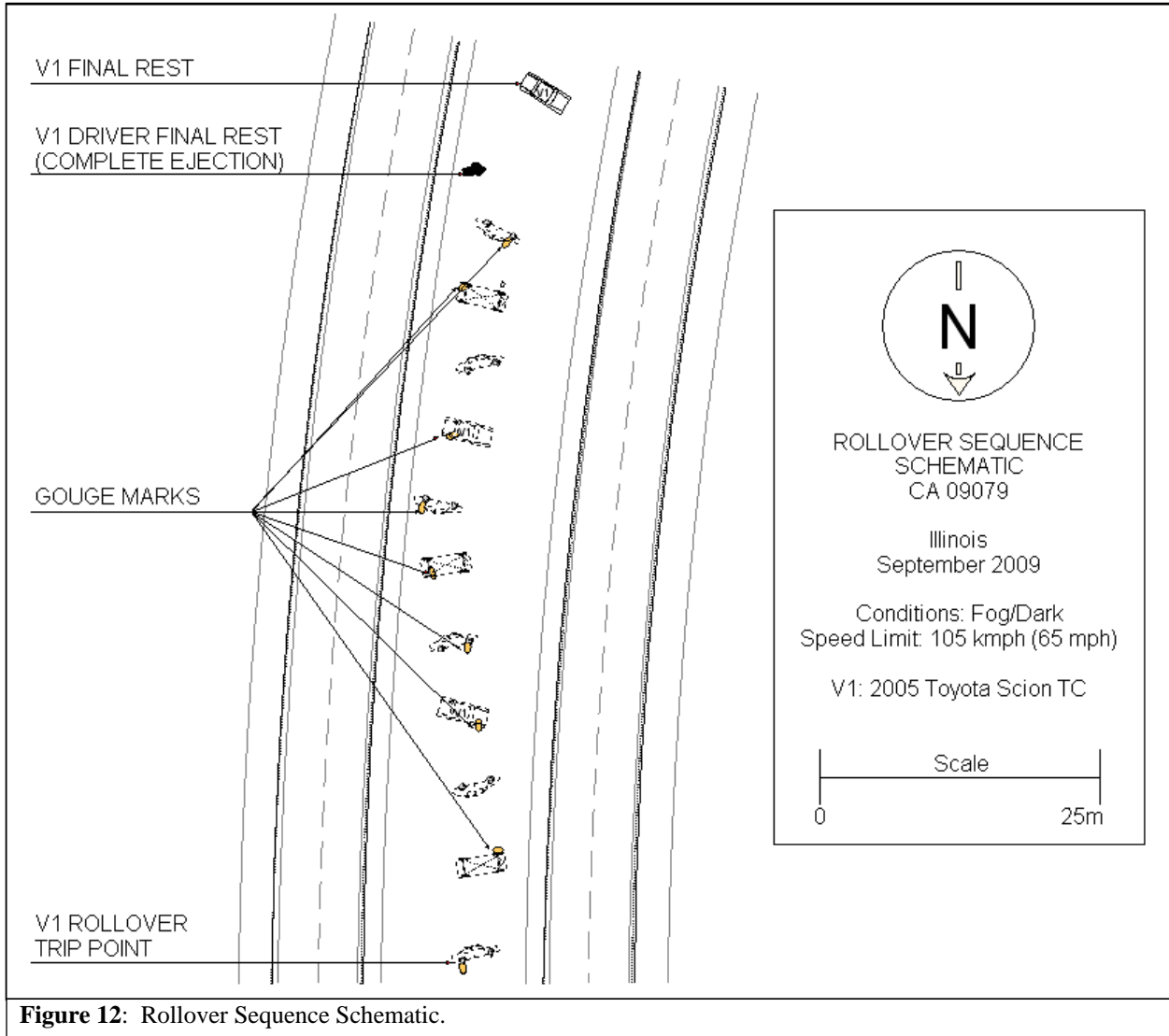


Figure 12: Rollover Sequence Schematic.