

**CRASH DATA RESEARCH CENTER**

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**CALSPAN REMOTE ROLLOVER CRASH INVESTIGATION**

**SCI CASE NO.: CA09063**

**VEHICLE: 2003 LINCOLN AVIATOR**

**LOCATION: MINNESOTA**

**CRASH DATE: AUGUST 2007**

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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**CALSPAN REMOTE ROLLOVER CRASH INVESTIGATION**  
**SCI CASE NO.: CA09063**  
**VEHICLE: 2003 LINCOLN AVIATOR**  
**LOCATION: MINNESOTA**  
**CRASH DATE: AUGUST 2007**

**BACKGROUND**

This remote investigation focused on the rollover crash of a 2003 Lincoln Aviator. The Lincoln was equipped with frontal air bags, Inflatable Curtain (IC) air bags with rollover sensing, 4-wheel antilock brakes, and laminated front door glazing. A 2007 Toyota Sienna minivan crossed the centerline of a two-lane road and struck the Lincoln in an off-set, head-on configuration. The impact caused the Lincoln to rotate in a counterclockwise (CCW) direction onto the grass shoulder where it tripped into a left side leading rollover event. The Lincoln rolled down an embankment and came to rest on its right side.



**Figure 1. Left side view of the 2003 Lincoln Aviator. (Images courtesy of the police department.)**

The Lincoln rolled down an embankment and came to rest on its right side. The 28-year old male driver of the Lincoln, a 26-year-old female front right passenger, and a 7-year-old rear right passenger were restrained by manual safety belt systems. A 3-year-old male was restrained in a child restraint system in the rear left position of the Lincoln. All four occupants of the Lincoln sustained incapacitating injuries and were transported to local hospitals for treatment. The frontal air bags in the Lincoln deployed during the frontal crash event. The IC air bags did not deploy. The laminated side glazing fractured and separated from the window frames. **Figure 1** is a left side view of the Lincoln Aviator.

The crash was identified by the National Highway Traffic Safety Administration (NHTSA) through a search of the Fatal Analysis Reporting System (FARS) of rollover crashes of interest to the agency. The Police Crash Report (PAR) was forwarded to the Calspan Special Crash Investigations (SCI) team and assigned for remote investigation on September 23, 2009. The police reconstruction report and on-scene images of the crash were obtained from the investigating police agency. This report is based on a review and analysis of the available police data. The police agency authorized the SCI team to publish the images in this case report.

**SUMMARY**

***Crash Site***

This two-vehicle head-on/rollover crash occurred on a two-lane rural roadway during daytime hours. At the time of the crash, atmospheric conditions were clear and all travel surfaces were dry. The roadway was oriented in a north/south direction and was asphalt surfaced. The posted speed limit was 89 km/h (55 mph).

In the vicinity of the crash site, the roadway curved to the left for the Lincoln's northbound direction of travel. The southbound Toyota approached the crash site on a curve to the right. The roadway had a slight elevation change for both vehicles, but was less than two-percent. The north and southbound travel lanes were delineated by painted yellow centerlines that permitted passing in the northbound direction of travel. Solid white fog lines denoted the outboard edges of the travel lanes. Narrow asphalt shoulders were present beyond the fog lines and were bordered by grass and dirt shoulders in both directions. The shoulders had a gradual negative slope away from the travel lanes. Down sloped embankments extended outboard of the shoulders. **Figure 2** is an aerial view of the crash site taken from the police helicopter. A schematic of the crash is attached as **Figure 11**.



**Figure 2. Aerial view of the crash site.**

**Vehicle Data**

**2003 Lincoln Aviator**

The case vehicle in this crash was a 2003 Lincoln Aviator, 4-door sport utility vehicle. The PAR did not report the Vehicle Identification Number (VIN) for this vehicle. The Lincoln was powered by a 4.6-liter, V-8 engine, linked to a 5-speed automatic transmission. This Lincoln was equipped with 4-wheel antilock brakes with braking assist and Electronic Brake Force Distribution, dual-stage frontal air bags, IC air bags with rollover sensing, a sunroof, and laminated front door glazing as standard equipment. Electronic Stability Control was not available in this vehicle model. Although the VIN was not available to confirm IC availability, specifications and interior labeling indicated the Lincoln was equipped with IC air bags and rollover sensing.

The Lincoln was equipped with 6-spoke alloy wheels and Goodyear Wrangler SR-A all-season tires, size P245/65R17. Although the Lincoln was not inspected for this remote investigation, the following tire data was derived from the on-scene police images and the police reconstruction report.

<b>Position</b>	<b>Police Measured Tire Pressure</b>	<b>Police Measured Tread Depth</b>	<b>Tire/Wheel Damage</b>
Left Front	Flat	8 mm (10/32 in)	Inner bead area of the alloy wheel fractured and deformed, tire tread cut
Right Front	207 kPa (30 PSI)	8 mm (10/32 in)	No damage
Left Rear	Flat	8 mm (10/32 in)	Unknown
Right Rear	207 kPa (30 PSI)	8 mm (10/32 in)	No damage

The interior of the Lincoln was configured with leather-surfaced front bucket seats with adjustable head restraints. Both front head restraints were adjusted above the level of the seatbacks. The second row was configured with leather-surfaced bucket seats with adjustable head restraints. Both rear seat head restraints were adjusted to the full-down positions. The third row seat was not visible in the police supplied images and was believed to have been folded down to facilitate the transport of cargo that consisted of personal items and sleeping bags.

The safety systems included 3-point lap and shoulder belts for the five designated seating positions, dual-stage frontal air bags for the driver and passenger positions, front buckle pretensioners, and the IC air bags with rollover sensing. The IC air bags were designed to provide side impact and rollover protection to the four outboard seating positions. The frontal air bags deployed during the initial impact event with Toyota. The IC air bags did not deploy during the subsequent rollover event.

### ***2007 Toyota Sienna***

The other vehicle in this crash was a 2007 Toyota Sienna LE minivan. The Toyota was equipped with a 3.5-liter, transverse-mounted V-6 engine, linked to a 5-speed automatic transmission. The service brakes were four-wheel disc with antilock. The Toyota was equipped with Michelin all-season tires mounted on 6-spoke alloy wheels. The left front tire and wheel sustained probable damage from the off-set impact configuration with the Lincoln and was separated from the vehicle. The remaining three tires and wheels did not appear to be damaged.

The interior of the Toyota was configured with front box-mounted captain chairs with adjustable head restraints, two second row captain's chairs, and a three-person split rear bench seat. The second row and third row right seats were removed from the vehicle during the extrication of the driver.

The safety systems consisted of 3-point lap and shoulder belts for the seven seating positions, Certified Advanced 208-Compliant (CAC) frontal air bags for the driver and right passenger positions, front seatback-mounted side impact air bags, and IC air bags for the three rows. The CAC frontal air bag system consisted of the dual-stage air bags, seat track positioning sensors, safety belt buckle switch sensors, a front right occupant presence sensor, and retractor pretensioners. The manufacturer of the Toyota has certified that the vehicle was compliant to the advanced air bag requirements of Federal Motor Vehicle Safety Standard No. 208. The severe frontal impact event with the Lincoln resulted in the deployment of the CAC frontal air bag system, the driver's seatback-mounted air bag and the left IC air bag.

### ***Crash Sequence***

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

The Lincoln was operated by the 28-year-old male driver. He was wearing the available lap and shoulder restraint. There was no PAR reported alcohol use. The 26-year-old female right front passenger of the Lincoln used the 3-point lap and shoulder restraint system. The 3-year-old male was restrained in a forward facing CRS in the rear left of

the Lincoln. The 7-year-old female was restrained by the lap and shoulder belt system in the rear right position.

The Toyota was operated by the restrained 47-year-old male driver. There was no PAR reported alcohol use. The front right passenger of the Toyota was a 43-year-old female who utilized the available lap and shoulder restraint system. Four female passengers, ages 7, 9, 12, and 14 occupied the second and third row seats of the Toyota. All rear seat passengers wore the available lap and shoulder restraint systems according to the police report.

The driver of the Lincoln was northbound in the appropriate travel lane at a speed consistent with the posted speed limit of 89 km/h (55 mph). The Lincoln driver maintained his lane of travel as he negotiated the left curve. The driver of the Toyota was traveling southbound as he entered the right curve for his direction of travel. For an unknown reason, the driver of the Toyota allowed the vehicle to drift to the left and cross the centerline into the northbound travel lane. There were no known avoidance actions initiated by the driver of the Toyota. The driver of the Lincoln braked and steered right onto the east shoulder in an attempt to avoid the impending crash. A right front skid mark from the Lincoln arced from the travel lane onto the asphalt shoulder, ending at the edge of the pavement. A subtle left front skid mark was present on the travel lane. This evidence marked the trajectory of the Lincoln and supported the pre-crash avoidance actions by the driver (**Figure 3**).



**Figure 3. Pre-crash avoidance actions and resultant skid marks from the Lincoln.**

### ***Crash***

The vehicles impacted in an off-set, head-on configuration in the northbound lane near the fog line with approximately 60 percent frontal engagement of both vehicles. As the frontal structures crushed, the forward momentum of the vehicles resulted in engagement of the left side surfaces. The offset impact configuration caused the Lincoln to rotate 180 degrees CCW onto the grass shoulder. The left rear tire de-beaded and the wheel dug into the ground, tripping the Lincoln into a left side leading rollover event. The Lincoln rolled three-quarter turns down the negative slope, coming to rest on its right side. At rest, the Lincoln was facing south approximately 10.6 m (35 ft) from the trip point. The roof damage did not appear to be extensive; however, rescue personnel cut the left side pillars and partially removed the roof from the vehicle. The rollover was classified as tripped and uninterrupted. The Toyota rotated 360 degrees counterclockwise; coming to rest in the northbound lane approximately 7.6 m (25 ft) from the point of impact. Both frontal air bags in the Lincoln deployed during the initial impact. The Lincoln's IC air bags did not deploy in the rollover crash. The frontal, left seat back and the IC air bags in the Toyota deployed during the frontal impact. The frontal and side engagements did not



result in a common velocity, therefore the initial crash event was outside the scope of the WinSMASH reconstruction program.

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

The investigating officer reported that all four occupants of the Lincoln sustained incapacitating injuries and were transported from the scene. None of the occupants were ejected. The driver of the Toyota sustained fatal injuries and expired at the scene. The five passengers of the Toyota sustained injuries of varying severity. **Figures 4 and 5** are views of the vehicles at final rest.



**Figure 4. Final rest positions of the involved vehicles.**



**Figure 5. Final rest position of the Lincoln Aviator.**

### ***Vehicle Damage***

#### ***Exterior – 2003 Lincoln Aviator***

*Primary* - The Lincoln Aviator sustained severe frontal damage from the initial impact event with the Toyota. The direct contact damage began approximately 15 cm (6 in) right of the centerline and extended to the front left corner. The left corner of the bumper beam and the frontal structure was crushed rearward approximately 102 cm (40 in). As the frontal structure crushed rearward, the vehicles were deflected to their right allowing the left corner areas to engage the left sides of the opposing vehicle. During this engagement, the left front suspension and drive axle of the Lincoln completely separated. The contact damage on the left side extended onto the left rear door, terminating at the lower C-pillar area. A frontal crush profile was estimated at the level of the bumper beam and was as follows: C1 = 102 cm (40 in), C2 = 81 cm (32 in), C3 = 66 cm (26 in), C4 = 48 cm (19 in), C5 = 30 cm (12 in), C6 = 13 cm (5 in). The Collision Deformation Classification (CDC) for this event was estimated at 12-FYEW-4.

*Secondary* – The secondary event for this crash involved the rollover of the Lincoln following its separation from the Toyota. The Lincoln initiated a lateral rollover to the left as it rotated 180 degrees CCW down the embankment onto the roadside, completing three-quarter turns. The rescue personnel cut the left A- and B-pillars and the roof at the location of the left C-pillar to remove the occupants. Although the roof was repositioned during the towing process, the specific vertical and lateral crush of the roof could not be determined. The front laminated side glazing remained intact, but cracked and fell from the window frames. The left rear door glazing was disintegrated. The right rear door, rear quarter windows and the backlight glazing remained intact. The Lincoln was

equipped with a sunroof; however, the status of this glazing was unknown. The CDC for this tripped rollover was 00-TDDO-3.

***Interior – 2003 Lincoln Aviator***

The interior of the Lincoln was reduced in size by longitudinal intrusion of the frontal components into the driver's position. The intrusion buckled the instrument panel upward and displaced the steering column rearward and vertically. The left B-pillar appeared to have been displaced laterally right into the driver's seat back. The interior images did not provide the detail required to determine specific occupant contact points.

**Figure 6 and 7** are views of the Lincoln's interior.



**Figure 6. Intrusion into the driver's position.**



**Figure 7. Interior view of the Lincoln at final rest.**

***Exterior – 2007 Toyota Sienna***

The Toyota Sienna minivan sustained severe frontal crush that was associated with the frontal engagement with Lincoln. The direct contact damage began near the centerline of the frontal plane and extended to the front left corner. As the frontal structure of the Toyota crushed rearward, the left side engaged with the Lincoln. Based on the available images, the direct damage extended to the left B-pillar area as evidenced on the sill of the Toyota. The combination of the severe frontal impact and the post-crash altering of the vehicle by the fire department precluded an estimated crush profile. The bumper fascia was separated from the vehicle and the bumper beam was exposed. The right mounting point of the bumper beam separated as it was displaced laterally left. The left frame rail and bumper beam appeared to have crush to the original position of the left A-pillar. The left front tire and wheel assembly separated from the suspension and steering systems.

**Figures 8 and 9** are views of the frontal deformation to the Toyota.



**Figure 8. Frontal view of the Toyota Sienna.**



**Figure 9. Left lateral view of the frontal deformation to the Toyota.**

Extrication efforts by the fire department resulted in the cutting of the left A- and B-pillars at the sill and the right A- and B-pillars at the level of the roof side rail. All four side doors were removed and the roof was deflected rearward at the C-pillars. The frontal components forward of the driver's position were displaced forward. The CDC for the Toyota was estimated at 12-FYEW-5.

#### ***Frontal Air Bag System – 2003 Lincoln Aviator***

The Lincoln was equipped with dual-stage frontal air bags that deployed as a result of the initial crash event with the Toyota. The driver's air bag deployed from a module within the center hub of the steering wheel rim through asymmetrical H-configuration cover flaps. The front right air bag deployed from a mid-mount module within the right instrument panel. The images did not provide sufficient detail to discuss damage and or contact evidence to the air bags. The Lincoln was not supported by an Event Data Recorder.

#### ***Side Impact / Rollover Air Bag Systems***

The Lincoln was equipped with roof side rail-mounted IC air bag that had dual sensing for both side impact and rollover crashes. Air bag labels were present on the upper B-pillars of the Lincoln indicating the vehicle was equipped with the IC air bags. The IC air bags did not deploy in this rollover crash. It should be noted that the vehicle's 12-volt battery and the fuse panel were located on the left side of the engine compartment of the Lincoln. This area was severely damaged from the impact with the Toyota resulting in a probable loss of power prior to the IC deployment command.

#### ***Manual Safety Belt Systems – 2003 Lincoln Aviator***

The Lincoln was equipped with continuous loop, 3-point lap and shoulder belts at the four designated seating positions. All belt systems utilized sliding latch plates. The driver's safety belt retracted onto an Emergency Locking Retractor (ELR) while the other belt systems utilized switchable ELR/Automatic Locking Retractors (ALR). The front belt systems were equipped with adjustable D-rings and buckle mounted pretensioners. The pretensioners should have actuated with the deployment of the frontal air bags since both occupants were restrained.

#### ***Child Restraint System – 2003 Lincoln Aviator***

The 3-year-old male was restrained in a forward facing CRS in the rear left position of the Lincoln. Images of the CRS indicated that it was secured by the 3-point lap and shoulder belt system that was routed through the proper forward-facing belt path. The child was restrained within the CRS by the tray shield 3-point harness system. The harness straps were routed through the top slots of the CRS. Rescue personnel cut the harness straps to remove the child from the CRS. The tray shield was separated from the shell of the CRS at the pivot points.

**Occupant Demographics – 2003 Lincoln Aviator**

**Driver**

Age/Sex: 28-year-old/Male  
 Height: Unknown  
 Weight: Unknown  
 Seat Track Position: Unknown  
 Safety Belt Use: 3-point lap and shoulder belt  
 Usage Source: PAR, vehicle images  
 Egress from Vehicle: Extricated from vehicle by rescue personnel  
 Mode of Transport from Scene: Helicopter  
 Type of Medical Treatment: Admitted to a regional trauma center for treatment

**Driver’s Injuries**

<b>Injury</b>	<b>Injury Severity AIS 90/Update 98)</b>	<b>Injury Source</b>
Spleen injury , NFS	Moderate (544299.2,2)	Safety belt webbing
Multiple rib fractures NFS w/collapsed lung	Moderate (450210.2,9)	Safety belt webbing
Fracture of the lower right extremity NFS	Moderate (852002.2,1)	Intruding knee bolster
Fracture of the lower left extremity NFS	Moderate (852002.2,2)	Intruding knee bolster
Fracture of the left ankle NFS	Minor (852002.2,2)	Intruding toe pan
Fracture of T-12 NFS	Moderate (650416.2,7)	Rebound into seat back
Fractured sacrum NFS	Minor (852600.2,6)	Loading of the seat cushion
Lower back abrasion	Minor (690202.1,9)	Rebound into seat back
Laceration of the left ear NFS	Minor (290600.1,2)	Laminated left side glazing
Scalp laceration, NFS	Minor (190600.1,9)	Unknown

*Source – Police interview with driver*

*Note: All injury sources have a confidence level of possible as a detailed inspection/documentation of the vehicle was not performed.*

**Driver Kinematics**

The driver of the Lincoln was seated in an unknown track position with the head restraint adjusted above the top of the seatback. He was restrained by the manual safety belt system as reported by the investigating officer. The driver responded to the frontal crash forces by initiating a forward trajectory with respect to the vehicle. He loaded the safety belt system and the deployed air bag. His lower extremities loaded the intruding knee bolster and the toe pan, possibly resulting in the extremity fractures. The sacrum fracture possibly resulted from his vertical loading of the seat cushion. The driver’s rebound into the seat back during the crash events possibly resulted in the T-12 fracture and the lower back abrasion.

***Front Right Passenger***

Age/Sex: 26-year-old/Female  
Height: Unknown  
Weight: Unknown  
Seat Track Position: Mid-track  
Safety Belt Use: 3-point lap and shoulder belt  
Usage Source: PAR, vehicle images  
Egress from Vehicle: Extricated from vehicle by rescue personnel  
Mode of Transport from Scene: Ambulance  
Type of Medical Treatment: Transported to a local hospital for treatment

***Front Right Passenger's Injuries***

<b>Injury</b>	<b>Injury Severity (AIS 90 Update 98)</b>	<b>Injury Source</b>
Fractured foot, NFS	Moderate (852000.2,9)	Floor/Toe pan
Lacerations, NFS	Minor (990600.1,9)	Unknown
Contusions, NFS	Minor (990400.1,9)	Unknown

*Source – Police report*

***Front Right Passenger Kinematics***

The front right adult passenger of the 2003 Lincoln Aviator was seated in a mid-track position and was police reported as restrained by the 3-point lap and shoulder belt system. At initial impact with the Toyota, the frontal air bag system in the Lincoln deployed. The front right passenger initiated a forward trajectory in response to the impact force and loaded the safety belt webbing and the deployed front right air bag. Her lower extremities loaded the intruding floor/pan that resulted in the fractured foot.

The restrained front right passenger subsequently engaged the center console and the front right door panel as the vehicle rotated CCW and overturned. She sustained unspecified police reported lacerations and contusions from unknown sources. The passenger was transported to a local hospital where she was treated for her injuries.

***Rear Left Passenger***

Age/Sex: 3-year-old/Male  
Height: Unknown  
Weight: Unknown  
Seat Track Position: Fixed  
Restraint Use: Restrained in a forward facing child safety seat  
Usage Source: PAR, vehicle images  
Egress from Vehicle: Removed from vehicle by rescue personnel  
Mode of Transport from Scene: Helicopter  
Type of Medical Treatment: Admitted to a regional trauma center

***Rear Left Passenger’s Injuries***

<b>Injury</b>	<b>Injury Severity (AIS 90/Update 98)</b>	<b>Injury Source</b>
Skull fracture, NFS	Moderate (150400.2,9)	Unknown

*Source – Police report*

***Rear Left Passenger Kinematics***

The 3-year-old male rear left passenger was restrained in a forward facing child safety restraint system (CRS). The specific make and model of the CRS could not be determined from the available on-scene police images. The CRS was equipped with a tray shield and was restrained by the vehicle’s 3-point lap and shoulder belt system with the webbing routed through the proper forward facing belt path. The harness straps were routed through the top slots of the CRS. The shoulder belts of the harness system were cut post-crash by the first responders to facilitate the removal of the child passenger from the vehicle. **Figure 10** is a post-crash view of the CRS secured in the rear left position of the Toyota.



**Figure 10. View of the CRS in the rear left position of the Lincoln.**

Damage to the CRS involved the separation of the tray shield from the pivot points. The left aspect of the CRS shell appeared to be fractured as visible lateral compression of the upper aspect of the CRS was present.

The child remained restrained in the CRS during the frontal impact sequence. He initiated a forward trajectory and loaded the integral harness system. He was possibly struck by an internal loose object during the crash sequence. The police report listed his injury as a skull fracture of an unspecified location. The child was removed from the Lincoln by the first responders and transported by helicopter to a regional trauma center where he was admitted for treatment of his injury.

***Rear Right Passenger***

Age/Sex:	7-year-old/Female
Height:	Unknown
Weight:	Unknown
Seat Track Position:	Fixed
Safety Belt Use:	3-point lap and shoulder belt
Usage Source:	Police report
Egress from Vehicle:	Unknown
Mode of Transport from Scene:	Ambulance
Type of Medical Treatment:	Treated at a local hospital

***Rear Right Passenger Injuries***

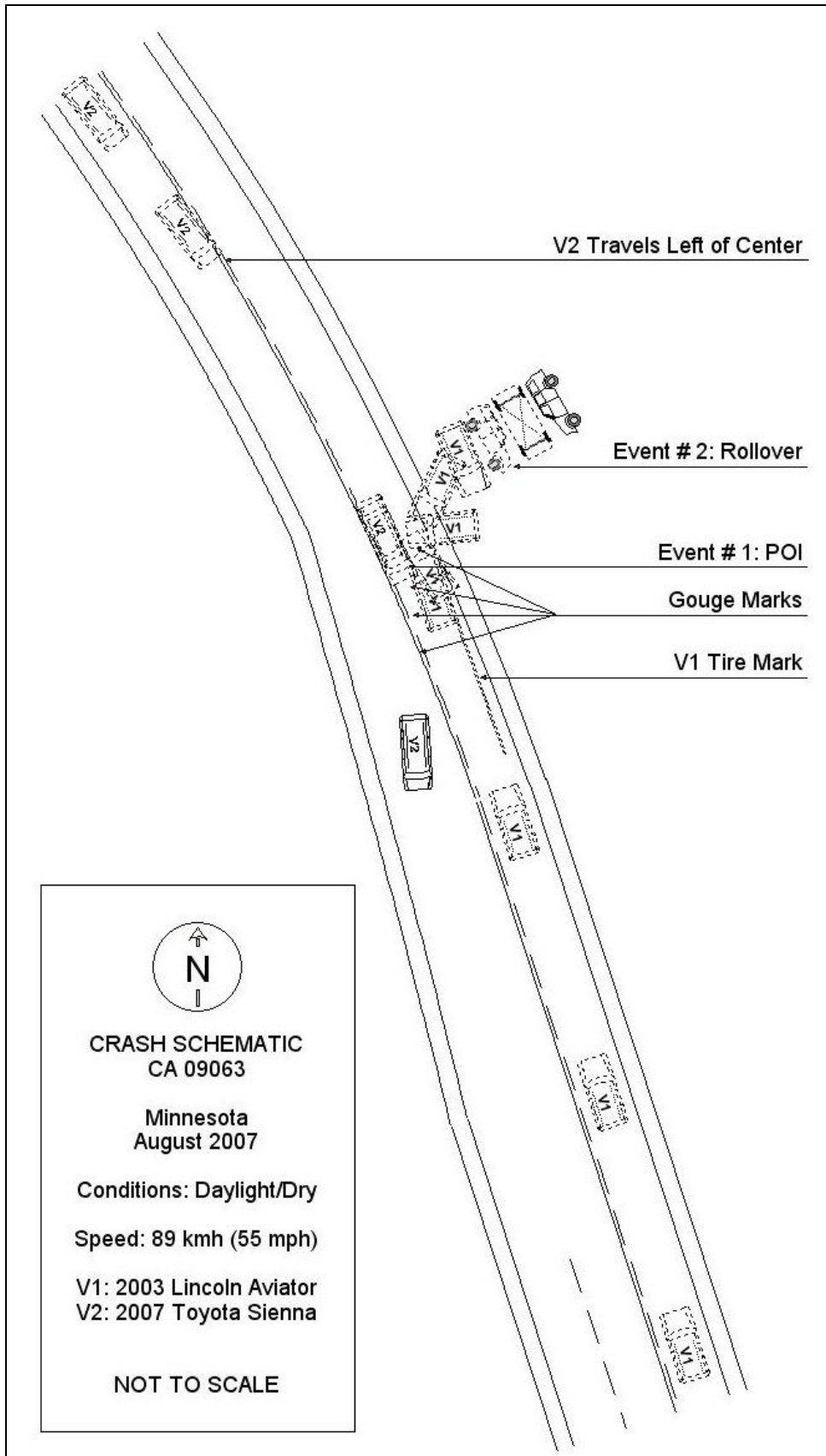
<b>Injury</b>	<b>Injury Severity (AIS 90/Update 98)</b>	<b>Injury Source</b>
Fractured wrist, NFS	Minor (751800.2,9)	Unknown

*Source – Police report*

***Rear Right Passenger Kinematics***

The rear right female passenger was police reported as restrained by the vehicle's 3-point lap and shoulder belt system. She would have responded to the frontal crash forces by initiating a forward trajectory and loading the safety belt webbing. During the subsequent CCW rotation and the lateral rollover to the left, the child passenger possibly contacted the right rear door panel and/or the rear center armrest. She sustained a police reported fractured wrist (aspect unknown) from contact within the vehicle. The source was the injury could not be determined. Loose cargo was also present within the vehicle and was scattered at the site of the rollover.

Following the crash, the rear right passenger was probably assisted from the vehicle and was transported by ambulance to a local hospital for treatment of her fracture.



**Figure 11. Crash Schematic**