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of Transportation

**National Highway  
Traffic Safety  
Administration**



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August 2019

# **Special Crash Investigations On-Site SKT Guardrail End Treatment Investigation Vehicle: 1996 Chevrolet Tahoe Location: Missouri Crash Date: March 2016**

## **Disclaimer**

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15. Supplementary Notes On-site SKT guardrail end treatment investigation involving a 1996 Chevrolet Tahoe.  Each crash represents a unique sequence of events, and generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicles or their safety systems. This report and associated case data are based on information available to the Special Crash Investigation team.					
16. Abstract The report documents the on-site investigation of a 1996 Chevrolet Tahoe impact to a sequential kinking terminal (SKT) guardrail end treatment. This crash occurred on the north roadside of a six-lane, divided interstate highway. The Chevrolet was a 2-door sport utility vehicle (SUV) equipped with a driver's frontal air bag. The vehicle was not equipped with an event data recorder (EDR). An unbelted 19-year-old male driver, unbelted 21-year-old front row passenger, and unbelted 19-year-old second row center passenger occupied the vehicle. The Chevrolet was traveling west in the right westbound lane when the driver attempted to pass a vehicle by traveling onto the right shoulder. The front right corner of the Chevrolet struck the back left corner of a 2006 Saab 9-5 (Event 1), which was parked on the shoulder and unoccupied. The impact caused the Chevrolet to rotate clockwise. The vehicle departed the right side of the roadway and the left front wheel struck the end terminal (Event 2). The vehicle then rolled over (Event 3), left side leading, as the guardrail deformed and the right plane struck a sign post during the rollover (Event 4). The vehicle continued to rollover down an embankment an estimated eight quarter turns, coming to final rest upright at the bottom of the embankment heading southeast. All three unbelted occupants were ejected from the vehicle during the rollover. Each sustained police-reported "serious" injuries and were transported by ambulance to a trauma center for treatment. The driver and second row center passenger were hospitalized for 9 and 13 days, respectively, for severe injuries. The front row passenger was hospitalized for 2 days for serious injuries. The Chevrolet was towed from the crash scene due to damage. The Saab remained at the crash scene and was subsequently towed due to damage.					
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**Indiana University  
Transportation Research Center  
On-Site SKT Guardrail End Treatment Investigation  
Case Number - IN16008  
Location - Missouri  
Vehicle - 1996 Chevrolet Tahoe  
Crash Date - March 2016**

**BACKGROUND**

This report documents the on-site investigation of a sport utility vehicle (SUV) impact to a sequential kinking terminal (SKT) guardrail end treatment (**Figure 1**). This crash was identified by an engineer with the Missouri Department of Transportation (MoDOT), who submitted photographs of the damaged guardrail end treatment to the Federal Highway Administration (FHWA). The FHWA determined that the guardrail end treatment and crash type were of interest. This crash investigation was then initiated by the National Highway Traffic Safety Administration (NHTSA) in March 2016, and assigned to the Special Crash Investigation (SCI) team at the Indiana University Transportation Research Center. This crash involved a 1996 Chevrolet Tahoe (**Figure 2**) and a parked, unoccupied 2006 Saab 9-5. The crash occurred in Missouri in March 2016 during early morning hours and was investigated by a local police agency. The guardrail, crash scene, and Chevrolet were inspected in March 2016. The Saab was not inspected. A telephone interview was conducted with the driver of the Chevrolet in August 2016.



**Figure 1:** The damaged SKT and guardrail, view west



**Figure 2:** The damaged 1996 Chevrolet Tahoe

This crash occurred on the north roadside of a six-lane, divided interstate highway. The Chevrolet was a two-door SUV equipped with a driver's frontal air bag. The vehicle was not equipped with an event data recorder (EDR). An unbelted 19-year-old male driver, unbelted 21-year-old front row passenger, and unbelted

19-year-old second row center passenger occupied the vehicle. The Chevrolet was traveling west in the right westbound lane when the driver attempted to pass a vehicle by traveling onto the right shoulder. The front right corner of the Chevrolet struck the back left corner of the Saab (Event 1), which was parked on the shoulder and unoccupied. The impact caused the Chevrolet to rotate clockwise. The vehicle departed the right side of the roadway and the left front wheel struck the end terminal (Event 2). The vehicle then rolled over (Event 3), left side leading, as the guardrail deformed and the right plane struck a sign post during the rollover (Event 4). The vehicle continued to rollover down an embankment an estimated eight quarter turns coming to final rest upright at the bottom of the embankment heading southeast. All three unbelted occupants were ejected from the vehicle during the rollover. Each sustained police-reported “serious” injuries and were transported by ambulance to a trauma center for treatment. The driver and second row center passenger were hospitalized for 9 and 13 days, respectively for severe injuries. The front row passenger was hospitalized for 2 days for serious injuries. The Chevrolet was towed from the crash scene due to damage. The Saab remained at the crash scene and was subsequently towed due to damage.

## CRASH SUMMARY

### *Crash Site*

This crash occurred during dark early morning hours on the north roadside of a straight, six-lane, divided interstate highway. The weather conditions were cloudy with 16.1 kilometers (10 miles) visibility, south-southeast winds at 33 km/h (10 mph), a temperature of 10.0 °C (50 °F), and a dew point of 1.6 °C (35 °F), according to local weather reports. The interstate had three concrete westbound through lanes that were separated from the three concrete eastbound through lanes by a concrete median barrier. The grade on the Chevrolet’s westbound approach to the area of the crash was positive 1 percent. The right westbound through lane was 3.4 m (11.2 ft) wide. The center and left westbound through lanes were each 3.7 m (12.0 ft) wide. The concrete median shoulder was 3.8 m (12.5 ft) wide and the concrete right shoulder was 3.7 m (12.0 ft) wide. A blocked-out W-beam guardrail equipped with an SKT end treatment was located adjacent to the right shoulder. An embankment that sloped downward for approximately 43 m (141 ft) to a right-of-way fence and a wooded area was located on the field side of the guardrail. The speed limit was 105 km/h



**Figure 3:** Approach of the Chevrolet to impact with the Saab parked on the shoulder (arrow), view west

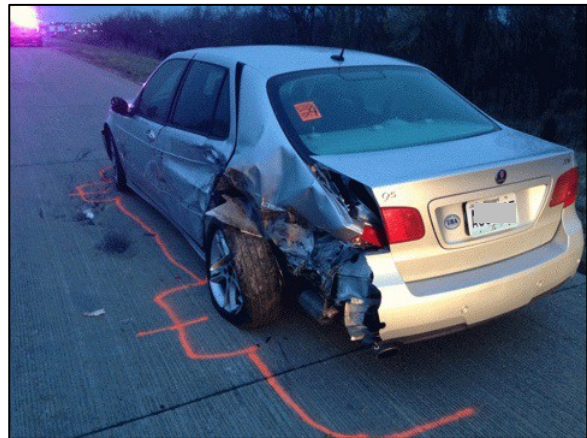
(65 mph). The crash diagram is included at the end of this report on page 16.

### *Pre-Crash*

The Chevrolet was traveling west in the right westbound through lane at an unknown speed. The driver began to pass an unknown vehicle by traveling to the right of that vehicle and onto the right shoulder (**Figure 3**), according to the police crash report. The Saab was unoccupied and parked on the right shoulder directly in the path of the Chevrolet (**Figure 3**).

### *Crash*

The right corner of the Chevrolet's front bumper struck the back left corner of the Saab (**Figure 4**, Event 1). The force direction on the Chevrolet was in the 12 o'clock sector and the Missing Vehicle algorithm of WinSMASH calculated the total delta-V for the vehicle as 21 km/h (13 mph). The longitudinal and lateral velocity changes were -21 km/h (-13 mph) and 0 km/h, respectively. The results should be considered borderline since the impact involved a corner of each vehicle. The impact caused the Chevrolet to rotate clockwise resulting in tire yaw marks on the roadway and shoulder (**Figure 5**) as it traveled 79.2 m (259.8 ft) to impact with the end terminal (Event 2). The vehicle was rotated clockwise approximately 90 degrees from its original westerly heading at the point of impact between the left front wheel (**Figure 6**) and the end terminal (**Figure 7**). The vehicle continued to rotate clockwise as the guardrail was deformed to the field side displacing five posts and extruding 2.7 m (8.8 ft) of guardrail to the field side. The guardrail impact included contact to the vehicle's left front door and quarter panel, which resulted in a slice in the sheet metal of the quarter panel, and a kink in the guardrail (**Figure 8**) located at the entrance chute of the end terminal penetrated approximately 18 cm (7 in) into the second row left seating position (**Figure 9**). The vehicle then began to roll over (Event 3), left side leading, while in contact with the guardrail and traveled airborne approximately 14 m (46 ft). It landed on its top plane and the right plane struck a break-



**Figure 4:** Damage to the Saab from the impact by the Chevrolet; photo provided by MoDOT; view northwest



**Figure 5:** Path of travel of Chevrolet in clockwise yaw approaching impact with the end terminal, view west

away sign post (Event 4) as the vehicle continued to rollover. The vehicle rolled over an estimated eight quarter turns across a total distance of 57.0 m (187.0 ft) coming to final rest upright at the bottom of the embankment heading southeast. The “rollover initiation” type was classified as “climb over” since the vehicle traveled onto the guardrail as it deformed and rolled over toward the field side of the guardrail.

All three unbelted occupants were ejected from the vehicle during the rollover. The occupant contact evidence observed in the vehicle during the SCI vehicle inspection indicated that the front row passenger was ejected through the disintegrated right front glazing. The second passenger was ejected through the disintegrated right rear glazing. The driver was probably ejected through the disintegrated left front glazing. The occupants’ final rest positions relative to the vehicle’s final rest position are not known.

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

All three occupants sustained police-reported “serious” injuries and were transported by ambulance to a trauma center. The driver and second row passenger were hospitalized for 9 and 13 days, respectively, for severe injuries. The front row passenger was hospitalized for 2 days for serious injuries.

The medical records reported the blood alcohol concentration (BAC) for the driver as .13 grams per deciliter. The Chevrolet was towed from the crash scene due to damage. The Saab remained at the crash scene and was subsequently towed due to damage.



**Figure 6:** Damage to the Chevrolet’s left front wheel rim from the impact with the end terminal



**Figure 7:** Shape of Chevrolet’s left front wheel rim stamped into face of end terminal



**Figure 8:** Kink in guardrail at entrance chute to end terminal

## END TERMINAL AND GUARDRAIL DAMAGE

The Chevrolet's left plane impact to the end terminal extruded 2.7 m (8.8 ft) of guardrail toward the field side of the guardrail. The total length of damaged guardrail was 11.6 m (38.2 ft). An imprint of approximately half of the vehicle's left front wheel rim was stamped into the face of the end terminal. There also was an 18 cm (7.1 in) long slice in the face of the end terminal and transfer of rubber from the vehicle's left front tire. Posts 1 to 5 were separated from the guardrail (**Figure 10**). Post 1 was separated from its metal base and found on the field side of the guardrail between posts 6 and 7. Post 2 was rotated downstream on its pivot bolt to the ground. Post 3 was bent to the ground and its offset block remained attached to the post. Post 4 was pulled out of the ground and found on the field side of the guardrail between posts 7 and 8. Its offset block remained attached to the post. Post 5 was bent downstream approximately 40 degrees and its offset block remained attached to the post. Post 6 was bent approximately 10 degrees downstream and the bolt was pulled through the guardrail. Its offset block remained attached to the post. Post 7 was slightly displaced, but remained attached to the guardrail, and there was a slight bend in the guardrail at this post. MoDOT's paint markings for replacement of the guardrail and posts ended at Post 7. The bolts for Posts 1 to 6 were pulled through the guardrail. The guardrail was kinked in four locations (**Figure 11**). The first kink was located at the entrance to the guide chute on the end terminal. The last kink occurred at post 6 with the other two kinks located between these two. The anchor cable was displaced from the guardrail and found on the field side of the guardrail at post 8. There was no damage to the connection of the feeder channel to the end terminal



**Figure 9:** Area of guardrail kink penetration into second row



**Figure 10:** Guardrail separated from posts 1 - 5, view west



**Figure 11:** Four kinks in the guardrail and extruded guardrail from the end terminal, each black mark on tape is 0.3 m (1.0 ft), view west

head and no broken welds. The FHWA guardrail form is attached to the end of this report as **Appendix A**.

## 1996 CHEVROLET TAHOE

### *Description*

The Chevrolet was a 4-wheel drive, 5- occupant, 2-door SUV with the VIN 3GNEK18RXTGxxxxxx. The vehicle was equipped with a 5.7-liter, V-8 engine, 4-speed automatic transmission and 4-wheel antilock brakes. The vehicle was also equipped with a driver’s single stage frontal air bag and tilt steering column that was adjusted to the center position. The vehicle was not equipped with an EDR. The windshield glazing was AS1 laminated. The left and right front glazing was AS2 tempered. The remaining glazing was AS3 tempered with original tinting. The specified wheelbase was 283 cm (111.4 in).

The vehicle manufacturer’s recommended tire size was P235/75R15. The vehicle was equipped with BF Goodrich Radial Mud-Terrain T/A size 35x12.50R15LT on the left front and General Grabber size 35x12.50R15LT on the right rear and right front. The vehicle manufacturer’s recommended cold tire pressure for the front and rear tires was 241 kPa (35 psi). The left rear wheel was displaced from the vehicle during the crash and was not present at the SCI vehicle inspection. The right rear and right front wheels were also displaced from the vehicle and were present at the SCI vehicle inspection. The tires on the vehicle were approximately 20 percent larger diameter than the manufacturer’s recommended tire size and possibly contributed to the vehicle’s control loss following the impact with the Saab. The tire data for the Chevrolet are presented in the table below.

<b>Position</b>	<b>Measured Pressure</b>	<b>Measured Tread Depth</b>	<b>Restricted</b>	<b>Damage</b>
LF	Flat	4 mm ( 5/32 in)	Yes	Tire cut
LR	Unknown	Unknown	Unknown	Unknown
RR	Flat	6 mm ( 8/32 in)	Unknown	Tread cut
RF	Flat	6 mm ( 8/32 in)	Unknown	Side wall cut

The front row was equipped with driver and front passenger cloth-covered bucket seats with adjustable head restraints. The second row was equipped with a cloth-covered bench seat with folding backs and adjustable head restraints in the outboard seating positions. The driver’s and front passenger’s seat tracks were each adjusted between the middle and rear-most positions and each seat back was reclined 30 degrees aft of vertical.

## ***Exterior Damage***

**Exterior Damage Event 1:** The right corner of the Chevrolet's front bumper was directly damaged when it struck the back left corner of the Saab. The direct damage began at the right corner of the bumper and was 17 cm (6.7 in) long. The direct damage also extended down the right plane and onto the right front door as evidenced by longitudinal scratches on the door. Crush measurements were taken on the bumper and the maximum residual crush was 26 cm (10.2 in) occurring 95 cm (37.0 in) right of the vehicle's centerline. The crush values were:  $C_1 = 0$  cm,  $C_2 = 0$  cm,  $C_3 = 0$  cm,  $C_4 = 6$  cm (2.4 in),  $C_5 = 14$  cm (5.5 in),  $C_6 = 26$  cm (10.2 in).

**Damage Classification Event 1:** The Collision Deformation Classifications (CDC) was 12FREE8 (0 degrees). The extent zone was based on the damage down the right plane of the vehicle as required by CDC protocol. The severity of the damage was moderate.

**Exterior Damage Event 2:** The left front wheel and wheel well were directly damaged when the left plane struck the end terminal. Approximately half of the rim was directly damaged and the shape of the rim was stamped into the face of the end terminal. The end terminal and guardrail also contacted and damaged the left front door and the sheet metal rear of the door as the guardrail deformed during the impact. The sheet metal was sliced and a kink in the guardrail located at the entrance to the guide chute on the end terminal penetrated approximately 18 cm (7 in) into the second row left seating position where it contacted and deformed the second row seat back. The slice in the sheet metal was 64 cm (25.2 in) long and began 188 cm (74.0 in) rear of the left front axle. The area where the guardrail kink penetrated into the second row was located 240 cm (94.5 in) rear of the left front axle. The total length of the direct damage was 322 cm (126.8 in) beginning at the left front axle. A crush profile was measured at the mid-door level and the maximum residual crush was 26 cm (10.2 in) occurring 240 cm (94.5 in) rear of the left front axle. The crush values were:  $C_1 = 0$  cm,  $C_2 = 24$  cm (9.4 in),  $C_3 = 26$  cm (10.2 in),  $C_4 = 13$  cm (5.1 in),  $C_5 = 5$  cm (2.0 in),  $C_6 = 0$  cm.

**Damage Classification Event 2:** The CDC was 10LDEW3 (290 degrees). WinSMASH was used to calculate a barrier equivalent speed (BES) of 31 km/h (19 mph) based on the damage to the left plane. The result appeared reasonable.

**Exterior Damage Event 3:** The entire vehicle sustained direct and induced damage during the rollover. The maximum vertical crush was 50 cm (19.7 in) occurring in the backlight header zone at the left C-pillar. The maximum lateral crush was 40 cm (15.7 in) occurring at the right C-pillar.

**Damage Classification Event 3:** The CDC was 00TDDO5. The severity of the damage was severe.

**Exterior Damage Event 4:** The vehicle's right plane sustained an impact with a break-away sign post during the rollover. The direct damage began 260 cm (102.4 in) rear of the right front axle and extended 47 cm (18.5 in) rearward on the quarter panel. A crush profile was taken on the quarter panel and the maximum residual crush was 10 cm (4.0 in) occurring 335 cm (131.9 in) rear of the right front axle. The crush values were:  $C_1 = 0$  cm,  $C_2 = 1$  cm (0.4 in),  $C_3 = 5$  cm (2.0 in),  $C_4 = 10$  cm (3.9 in),  $C_5 = 6$  cm (2.4 in),  $C_6 = 2$  cm (0.8 in). There was overlapping damage from the rollover, but the measured crush profile appeared to reasonably depict the crush from the sign post impact.

**Damage Classification Event 4:** The CDC was 00RPAW2. The severity of the damage was minor.

### ***Interior Damage***

The interior of the Chevrolet sustained severe intrusion of the roof during the rollover. The most severe intrusion of the roof was approximately 45 cm (17.7 in) and occurred in the cargo area. The most severe intrusion in the second row resulted from penetration of a kink in the guardrail, which intruded laterally approximately 18 cm (7 in) into the second row left seating position. The most severe intrusion in the front row involved the windshield header, which intruded vertically 16 cm (6.3 in) in the center of the front row. Vertical intrusions of the roof and windshield header also occurred in the driver's and front passenger's seating positions.

Evidence of occupant contact was observed on six interior components. The upper half of the steering wheel rim was bent approximately 4 cm (2 in), probably from contact by the driver's chest. The deflated frontal air bag also was scuffed from possible contact by the driver's chest. The right front door window sill was scuffed, probably from contact by the front row passenger's right flank during his ejection from the vehicle. The right rear window sill and second row right head restraint were scuffed, probably from contact by the second row passenger during his ejection from the vehicle. The second row passenger also contacted his head on the roof as indicated by hair adhering to the roof in the second row right seating position.

The left front and right front doors and the tailgate were jammed shut. Police on-scene photographs showed the vehicle in its final rest position and the windshield was in place and cracked from damage. The windshield was separated from the bonding at the top and both A-pillars and collapsed into the occupant compartment at the SCI vehicle inspection. The remaining glazing was disintegrated from impact forces.

### ***Manual Restraint Systems***

The driver's and front row right occupant's seating positions were equipped with three-point lap and shoulder seat belts. The second row was equipped with three-point lap and shoulder seat belts in the outboard seating positions and a lap belt in the center seating position. Inspection of all the seat belts revealed no evidence of usage during the crash. The front row seat belts were locked in the retracted position from damage to the B-pillars. The driver stated during the SCI interview that neither he nor the other two occupants were belted at the time of the crash.

### ***Supplemental Restraint Systems***

The Chevrolet was equipped with a single stage driver's frontal air bag that deployed during the crash. The air bag sustained no damage during the crash and there was no discernable evidence of occupant contact.

## **1996 CHEVROLET TAHOE OCCUPANTS**

### ***Driver Demographics***

Age/Sex:	19 years/male
Height:	173 cm (68 in)
Weight:	69 kg (151 lbs)
Eyewear:	None
Seat Type:	Bucket
Seat Track Position:	Between middle and rear-most
Manual Restraint Usage:	None
Usage Source:	Vehicle inspection, driver interview
Air Bags:	Frontal, deployed
Alcohol/Drug Involvement:	Alcohol, BAC = .13 g/dL
Egress From Vehicle:	Ejected from vehicle
Transport From Scene:	Ambulance to trauma center
Medical Treatment:	Hospitalized 9 days

### Driver Injuries

Injury No.	Injury	AIS 2015	Involved Physical Components (IPC)	IPC Confidence Level
1	Concussion with loss of consciousness, not further specified	161003.2	Critical IPC configuration Roof, left front side rail Ground	Possible Probable
2	Fractured left 1st rib anteriorly and right 3rd and 4th ribs anteriorly, not further specified	450203.3	Critical IPC configuration Steering wheel hub and/or spokes and rim Left front window sill Ground	Possible Possible Possible
3	Contusions, lungs (pulmonary), bilateral involving right upper, middle, and lower lobes and left upper and lower lobes	441412.4	Critical IPC configuration Left front window sill and/or left front door panel, forward upper quadrant Ground	Possible Probable
4 5	Pneumothoraces, small, bilaterally; right apical, left basilar, not further specified	442202.2 442202.1	Critical IPC configuration Left front window sill and/or left front door panel, forward upper quadrant Ground	Possible Probable
	Pneumatoceles <sup>1</sup> right upper lobe and left lower lobe (traumatic)	Not coded	Ground	Probable
	Atelectasis (collapsed) left lung <sup>2</sup> , due to blood clot, shifting the heart and mediastinum to the left; dependent atelectasis right lower lobe	Not coded	Ground	Probable
6	Fracture right 3rd molar tooth socket <sup>3</sup> and fractured tooth, not further specified	250200.2	Ground	Probable

<sup>1</sup> See <https://en.wikipedia.org/wiki/Pneumatocele> and <http://medicine.medscape.com/article/1003289-overview> for different perspectives. This condition was also described as a hydropneumothorax

<sup>2</sup> With “whiteout” left lung..

<sup>3</sup> See [www.dictionary.com/browse/alveolar-ridge](http://www.dictionary.com/browse/alveolar-ridge), [https://en.wikipedia.org/wiki/Dental\\_alveolus](https://en.wikipedia.org/wiki/Dental_alveolus), and <http://cda-dc.ca/jcda/vol-70/issue-1/39.pdf>.

7	Fracture, completely displaced, through posterior right mandibular (jaw) body and angle requiring ORIF <sup>4</sup> and fracture mandibular bulb body requiring manipulation	250615.2	Ground	Probable
8	Fractured, non-displaced, upper sternum, not further specified	450804.2	Critical IPC configuration Steering wheel hub and/or spokes Left front window sill Ground	Possible Possible Probable
9	Strain, acute, cervical myofascial, not further specified	640278.1	Ground	Probable
10	Abrasions, several to face, not further specified	210202.1	Ground	Probable
11	Contusion with swelling left eye/periorbital area, not further specified	210402.1	Ground	Probable
12	Lacerations, multiple, mouth including gingiva and mucosa	243099.1	Ground	Probable
13		243204.1		
14	Abrasions neck, not further specified	310202.1	Ground	Probable
15	Abrasions anterior chest, not further specified	410202.1	Ground	Probable
16	Abrasion left upper back, not further specified	410202.1	Ground	Probable
17	Abrasion, large, left lateral midback, not further specified	410202.1	Ground	Probable
18	Abrasion, large, left flank, not further specified	510202.1	Ground	Probable
19	Abrasion right hip/inguinal area, not further specified	510202.1	Ground	Probable
20	Abrasion left upper arm, not further specified	710202.1	Ground	Probable
21	Abrasions all extremities, upper greater than lower	710202.1	Ground	Probable
22		710202.1		
23		810202.1		
24		810202.1		

Sources: Emergency room records, hospitalization records, and interviewee data—same person. Injury Numbers 14 through 20 came only from emergency room records. Injury numbers 1, 6, 8, 9, 12, and 13 came only from hospitalizations records. Injury numbers 21 to 24 came from a combination of interviewee data and emergency room records. Injury number 7 came from a combination of interviewee data and hospitalization records. Injury numbers 3 to 5, 10, and 11 came from a combination of emergency room and hospitalization records. Injury number 2 came from a combination of all three sources.

<sup>4</sup> ORIF = open reduction and internal fixation

### ***Driver Kinematics***

The driver was unbelted and his seat track was adjusted between the middle and rear-most positions with the seat back reclined 30 degrees aft of vertical. The frontal impact with the Saab displaced the driver forward. He was then redirected to the left as the vehicle rotated clockwise and decelerated as it approached impact with the end terminal. The left plane impact with the end terminal redirected the driver slightly forward and to the left. He was then redirected in multiple directions during the rollover and ejected from the vehicle, probably through the disintegrated left front glazing. He sustained a concussion with loss of consciousness from possible contact with the left roof side rail, roof, and ground. Possible contact with the steering wheel, left front window sill, and ground caused three fractured ribs. He sustained contusions to both lungs with bilateral pneumothoraces, probably from contacting the ground with possible contribution from contact with the left front door and window sill. The driver's face probably contacted the ground resulting in fractures of the right third molar tooth socket and tooth and a displaced fracture of the right jaw. His chest probably contacted a combination of the steering wheel, left front window sill, and ground causing a fractured sternum. He also sustained multiple contusions, abrasions, and lacerations from ground contact. The driver was transported by ambulance to a trauma center where he was admitted for nine days.

### ***Front Row Right Occupant Demographics***

Age/Sex:	21 years/male
Height:	183 cm (72 in)
Weight:	68 kg (150 lbs)
Eyewear:	None
Seat Type:	Bucket
Seat Track Position:	Between middle and rear-most
Manual Restraint Usage:	None
Usage Source:	Vehicle inspection, driver interview
Air Bags:	None
Alcohol/Drug Involvement:	Alcohol, BAC = .136 g/dL
Egress From Vehicle:	Ejected from vehicle
Transport From Scene:	Ambulance to trauma center
Medical Treatment:	Hospitalized 2 days

**Front Row Right Occupant Injuries**

<b>Injury No.</b>	<b>Injury</b>	<b>AIS 2015</b>	<b>Involved Physical Components (IPC)</b>	<b>IPC Confidence Level</b>
1	Fracture, closed, severely displaced mid-shaft left femur, requiring ORIF <sup>5</sup>	853251.3	Critical IPC configuration Center lower instrument panel Right front window sill and/or right front door panel, forward upper quadrant Ground	Probable  Possible  Probable
2	Hemorrhage, subarachnoid, minimal, not further specified	140693.2	Critical IPC configuration Roof, right and/or roof right side rail Ground	Possible Probable
3	Abrasions to scalp including on occiput, not further specified	110202.1	Ground	Probable
4	Abrasion left forehead, not further specified	210202.1	Ground	Probable
5	Contusion, face, not further specified	210402.1	Ground	Probable
6 7	Abrasions mid-chest left of center and upper abdomen, not further specified	410202.1 510202.1	Ground	Probable
8	Contusion left lower chest, not further specified	410402.1	Ground	Probable
9	Contusion/hematoma, large, 8.7 cm by 3.4 cm (3.4 x 1.3 in) right anterior abdominal wall, not further specified	510402.1	Ground	Probable
10	Laceration below scapula on right mid-back, not further specified	410600.1	Ground	Probable
11 12 13 14	Abrasions bilateral wrist/hands, not further specified	710202.1 710202.1 710202.1 710202.1	Ground	Probable

<sup>5</sup> ORIF = open reduction and internal fixation; distal fragment was displaced posteriorly

15	Abrasions bilateral lower extremities near knee areas, not further specified	810202.1	Ground	Probable
16		810202.1		
17	Contusion right leg, not further specified	810402.1	Ground	Probable

Sources: Emergency room records, hospitalization records, and interviewee data—driver. Injury Numbers 3, 4, 6 to 8, and 10 to 17 came only from emergency room records. Injury Numbers 2, 5, and 9 came from a combination of emergency room and hospitalization records. Injury Number 1 came from a combination of all sources.

### ***Front Row Right Occupant Kinematics***

The front row right occupant was unbelted and his seat track was adjusted between the middle and rear-most positions with the seat back reclined 30 degrees aft of vertical. The frontal impact with the Saab displaced the occupant forward and he probably contacted the instrument panel. He was then redirected to the left as the vehicle rotated clockwise and decelerated as it approached impact with the end terminal. The left plane impact with the end terminal redirected the occupant slightly forward and further to the left and he probably contacted the center instrument panel and center console. He was then redirected in multiple directions during the rollover and ejected from the vehicle through the disintegrated right front glazing. He sustained a displaced fracture of the left femur, probably from a combination of contacts with the center lower instrument panel and ground. Possible contact with the right front window sill and right front door contributed to the injury. His head probably contacted the ground with possible contact to the roof and right roof side rail resulting in a subarachnoid hemorrhage. The front row right occupant also sustained multiple contusions, abrasions, and a laceration from contacting the ground. The occupant was transported by ambulance to a trauma center and hospitalized for two days. His BAC was reported as 0.136.

### ***Second Row Center Occupant Demographics***

Age/Sex:	19 years/male
Height:	175 cm (69 in)
Weight:	73 kg (160 lbs)
Eyewear:	None
Seat Type:	Bench with folding backs
Seat Track Position:	Fixed track
Manual Restraint Usage:	None
Usage Source:	Vehicle inspection, driver interview
Air Bags:	None
Alcohol/Drug Involvement:	Alcohol, BAC = .163 g/dL
Egress From Vehicle:	Ejected from vehicle
Transport From Scene:	Ambulance to trauma center
Medical Treatment:	Hospitalized 13 days

**Second Row Center Occupant Injuries**

<b>Injury No.</b>	<b>Injury</b>	<b>AIS 2015</b>	<b>Involved Physical Components (IPC)</b>	<b>IPC Confidence Level</b>
	Cerebral concussion with patient unresponsive on arrival with GCS = 3; initially reported was intermittent decerebrate rigidity and leftward gaze deviation; subsequently gaze was midline with sluggish pupils, minimal response to painful stimuli, and minimal purposeful movements	Not coded		
1	Hemorrhage, subdural, small, up to 4 mm (0.16 in), left frontal area, not further specified	140651.3	Critical IPC configuration B-pillar, left Roof Ground	Possible Probable Possible
2 3	Hemorrhage, subarachnoid overlying bilateral frontal lobes, as well as in interpeduncular cistern <sup>6</sup> and along anterior portion of falx of cerebrum <sup>6</sup>	140693.2 140693.2	Critical IPC configuration B-pillar, left Roof Ground	Possible Probable Possible
4 5	Fracture, displaced, comminuted, anterior symphysis and left parasymphysis of mandible, obliquely oriented, involving teeth with one tooth (#6) missing; required ORIF <sup>7</sup>	250200.2 250606.1	Critical IPC configuration B-pillar, left Ground	Possible Probable

<sup>6</sup> The following terms are defined in Dorland's Illustrated Medical Dictionary as follows:

**cistern:** a closed space serving as a reservoir for fluid

**cisterna:** a cistern -- a closed space serving as a reservoir for lymph or other body fluid, especially one of the enlarged subarachnoid spaces containing cerebrospinal fluid.

**c. interpeduncularis:** interpeduncular cistern -- a dilatation of the subarachnoid space between the cerebral peduncles; called also basal cistern.

**falx:** a sickle-shaped organ or structure

**f. cerebri:** the sickle-shaped fold of dura mater that extends downward in the longitudinal cerebral fissure and separates the two cerebral hemispheres.

<sup>7</sup> Open reduction and internal fixation was required for the unstable anterior and posterior ring fracture. A percutaneous transiliac transsacral screw was placed from left to right traversing

6	Contusions, lungs, bilaterally, left greater than right with on-set of acute respiratory distress syndrome	441411.3	Critical IPC configuration Seat back, driver's Ground	Possible Probable
7	Pneumothorax, tiny, left apical lung region, not further specified	442202.2	Critical IPC configuration Seat back, driver's Ground	Possible Probable
8	Hemomediastinum, anterior, adjacent to sternal fracture, not further specified	442208.2	Critical IPC configuration Seat back, driver's Ground	Possible Probable
9	Fracture sternum, non-displaced, adjacent to mediastinal hematoma, not further specified	450804.2	Critical IPC configuration Seat back, driver's Ground	Possible Probable
10	Fracture L <sub>2</sub> vertebral body, compression type, extending through body, not further specified	650632.2	Critical IPC configuration Second row seat cushion Ground	Possible Probable
11	Fracture, comminuted, left pelvis including left superior and inferior pubic rami and left sacrum extending through central canal requiring ORIF <sup>7</sup> for the pelvic fractures	856172.4	Critical IPC configuration Left side interior surface rearward of left B-pillar Ground	Possible Probable
12	Contusion (hematoma) spleen, sub-capsular, not further specified	544212.2	Critical IPC configuration Seat back, front right passenger's Ground	Possible Probable

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through the sacrum and, because of a previous sacral fracture, a subcutaneous pedicle screw fixation device was also used.

13 14	Contusions about the head and facial trauma, not further specified	110402.1 210402.1	Ground	Probable
15	Laceration, small, left ear, not further specified	210602.1	Ground	Probable
16	Contusion (hematoma) left flank, not further specified	510402.1	Left side interior surface rearward of left B-pillar	Probable
17	Laceration, 3 cm (1.2 in), into subcutaneous tissue, left lower quadrant of abdomen, not further specified	510602.1	Left side interior surface rearward of left B-pillar	Probable

*Sources: Emergency room records, hospitalization records, and interviewee data–driver. Injury Number 16 came only from emergency room records. Injury Numbers 13 to 15 came only from hospitalization records. Injury Numbers 1 to 9, 11, 12, and 17 came from a combination of emergency room and hospitalization records. Injury Number 10 came from all three sources.*

### ***Second Row Center Occupant Kinematics***

The second row center occupant was unbelted. The frontal impact with the Saab displaced the occupant forward and his knees probably contacted the backs of the front seats. He was then redirected to the left as the vehicle rotated clockwise and decelerated as it approached impact with the end terminal. The left plane impact with the end terminal redirected the occupant slightly forward and further to the left and he possibly contacted the intruded left side surface rear of the B-pillar causing a contusion to his left flank and a 3 cm (1.2 in) long laceration to his left lower abdomen. He was then redirected in multiple directions during the rollover and contacted his head on the roof in the second row right seating position as evidenced by hair transfer on the roof. His head also possibly contacted the left B-pillar and then the ground following his ejection through the disintegrated right rear glazing. These contacts resulted in subdural and subarachnoid hemorrhages and a comminuted fracture of the left mandible involving the teeth. Probable contact with ground and possible contact with the back of the driver’s seat caused bilateral lung contusions with pneumothorax and a fractured sternum with hemomediastinum. Probable ground contact and possible contact with the second row seat cushion caused a fracture of L<sub>2</sub>. Probable ground contact in conjunction with possible contact with the left side surface caused a comminuted fracture of the left pelvis. Probable contact with the ground and possible contact with the front row right passenger’s seat back caused a contusion to the spleen. Probable contact with the ground also resulted in contusions to the head and face,

and a laceration to the left ear. The occupant was transported by ambulance to a trauma center and hospitalized for 13 days. His BAC was reported as .163 g/dL and he tested positive for methamphetamine.

## **2006 SAAB 9-5**

### ***Description***

The Saab was a front-wheel-drive, 4-door sedan with the VIN YS3EH49G663xxxxxx equipped with a 2.3-liter, I-4 engine, 4-wheel antilock brakes with electronic brake force distribution, traction control, and electronic stability control. The vehicle was also equipped with dual-stage frontal air bags and front side-mounted side impact air bags with head protection chambers.

### ***Exterior Damage***

The Saab sustained direct damage to the left corner of the back bumper that extended down the left side of the vehicle to the left front door based on the on-scene photographs of the vehicle.

***Damage Classification:*** The CDC was 06BLEE9 (180 degrees).

# CRASH DIAGRAM

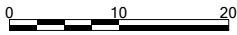
RP2 →



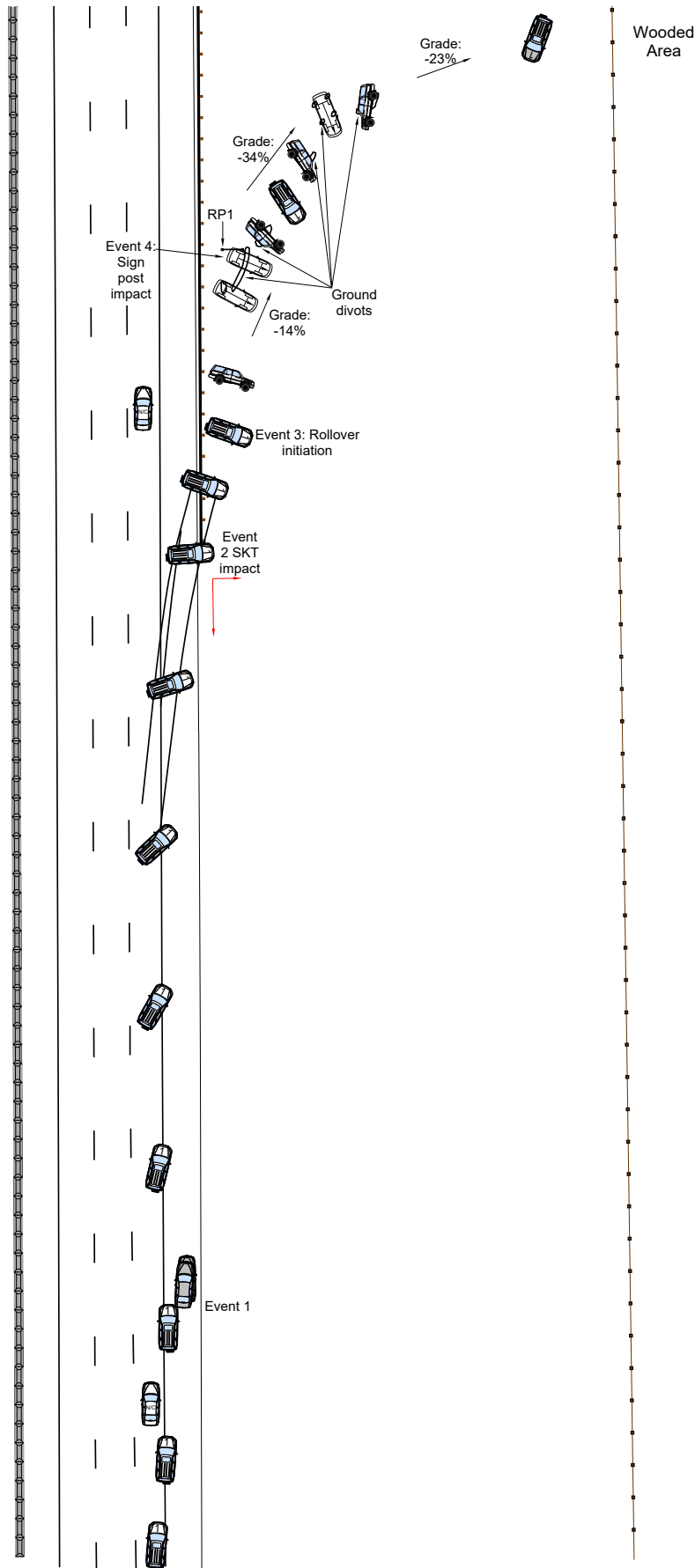
IN16008

Dark, Cloudy, and Dry  
Westbound Lanes of Concrete  
Interstate Highway  
Speed Limit = 105 km/h (65 mph)

1 = 1996 Chevrolet Tahoe  
2 = 2006 Saab 9-5



Meters



<p>Case Number:</p>	<p>IN16008</p>

**APPENDIX A:  
FHWA GUARDRAIL FORM**

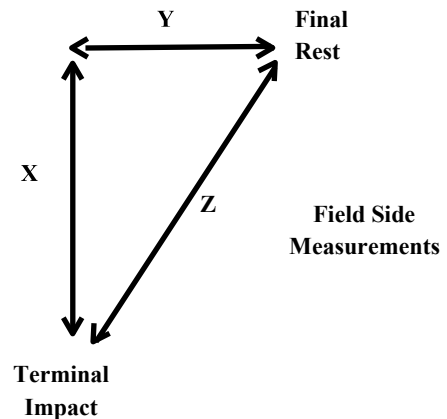
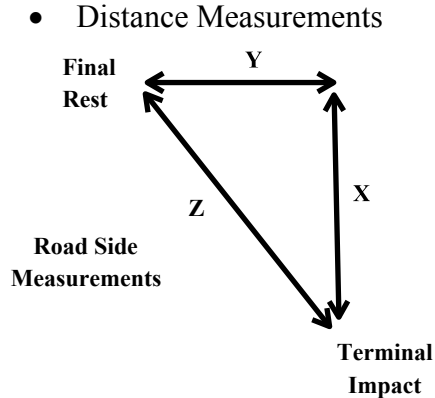
Case No.: IN16008

PREPOPULATED DATA (BY OTHERS)			
Date of Crash	March 2016	TIME OF CRASH (MILITARY)	Early morning
Case Number	IN16008	State	Missouri
Traffic Route	Interstate Highway	Direction (Southbound = SB)	WB
Ambient Conditions (at time of crash)			
Temperature (°F)	50	Lighting	Dark
Atmospheric	Dry & Cloudy		

SCENE INFORMATION	
Type of area where crash occurred	<input type="checkbox"/> Urban <input type="checkbox"/> Rural <input checked="" type="checkbox"/> Suburban
Terminal on a horizontal curve?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Curve/LT <input type="checkbox"/> Curve/RT
Estimated or Reconstructed Speed at Impact (MPH)	Unknown
Est. distance (straight line) from terminal impact to COM final rest position (ft.)	Z = 203 ft
Est. distance (longitudinal) along guardrail from terminal impact to COM final resting location (ft.)	X = 171 ft
Est. distance (normal) from either 1. the white paint line; or 2. roadway/shoulder/pavement edge to COM rest position (ft.)	Y = 128 ft
Super elevation	<input type="checkbox"/> +2% <input type="checkbox"/> -2% <input checked="" type="checkbox"/> NONE or FLAT
Curve Radius (ft.)	N/A

**KEY:**

- COM - Center of Mass of Vehicle
- Distance Measurements



Case No.: IN16008

ON-SCENE INFORMATION	
End Treatment Type	<input checked="" type="checkbox"/> Extruder <input type="checkbox"/> ET2000 <input type="checkbox"/> ET-PLUS 4in <input type="checkbox"/> ET-PLUS 5in <input checked="" type="checkbox"/> SKT <input type="checkbox"/> FLEAT <input type="checkbox"/> SOFT STOP <input type="checkbox"/> Telescope <input type="checkbox"/> X-LITE <input type="checkbox"/> X-TENSION
Curb? s	<input checked="" type="checkbox"/> No <input type="checkbox"/> AASHTO Type A <input type="checkbox"/> AASHTO Type B <input type="checkbox"/> AASHTO Type C <input type="checkbox"/> AASHTO Type D <input type="checkbox"/> AASHTO Type E <input type="checkbox"/> Yes <input type="checkbox"/> AASHTO Type F <input type="checkbox"/> AASHTO Type G <input type="checkbox"/> AASHTO Type H
Curb Height:	

GUARDRAIL INSTALLATION										
Post No.	Post		Offset Block		PRE-Existing Damage			Offset to post or post hole (ft.)		Spacing to next post (ft. -in.)
	Type	Dim.	Type	Dim.	Yes No Unknown	Describe	Travel way	Curb		
	Steel Wood Other	D x W (in.) or Dia. (in.)	Steel Wood Composite	D x W (in.)						
0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1	Steel	6 x 6	None	N/A	Unk	Unknown	13.1	N/A	6ft 2 in	
2	Steel	5 7/8 x 4	None	N/A	Unk	Unknown	12.8	N/A	6 ft 2 in	

Case No.: IN16008

Post No.	Post		Offset Block		PRE-Existing Damage		Offset to post or post hole (ft.)		Spacing to next post (ft. -in.)
	Type	Dim.	Type	Dim.	Yes No Unknown	Describe	Travel way	Curb	
	Steel Wood Other	D x W (in.) or Dia. (in.)	Steel Wood Composite	D x W (in.)					
3	Steel	5 7/8 x 4	Composite	7 7/8 x 3 7/8	Unk	Unknown	13.5	N/A	6 ft 3 in
4	Steel	5 7/8 x 4	Composite	7 7/8 x 3 7/8	Unk	Unknown	13.5	N/A	6 ft 3 in
5	Steel	5 7/8 x 4	Composite	7 7/8 x 3 7/8	Unk	Unknown	13.3	N/A	6 ft 2 in
6	Steel	5 3/4 x 3 3/4	Composite	7 3/4 x 3 3/4	No	None	13.5	N/A	6 ft 0 in
7	Steel	5 7/8 x 4	Composite	7 7/8 x 3 3/4	No	None	13.3	N/A	6 ft 0 in
8	Steel	5 7/8 x 4	Composite	7 1/2 x 3 7/8	No	None	13.1	N/A	6 ft 3 in

Case No.: IN16008

Post No.	Post		Offset Block		PRE-Existing Damage		Offset to post or post hole (ft.)		Spacing to next post (ft. -in.)
	Type	Dim.	Type	Dim.	Yes No Unknown	Describe	Travel way	Curb	
	Steel Wood Other	D x W (in.) or Dia. (in.)	Steel Wood Composite	D x W (in.)					
9	Steel	5 7/8 x 4	Composite	7 1/2 x 3 7/8	No	None	13.1	N/A	6 ft 3 in
10									
11									
12									

Additional Comments: Posts 10 – 12 were not documented since this form, which added posts 10 – 12, was not issued until after this investigation was conducted.

Case No.: IN16008

<b>EXTRUDER</b>			
Feeder Channel Width at impact head	<input type="checkbox"/> 4 inches <input type="checkbox"/> 5 inches <input checked="" type="checkbox"/> Other 4 1/2 in		
Guide Chute Exit Height (in.)	13 1/2 in		
Connection of feeder channels to head damaged?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes	Are Welds Broken?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes
Anchor Cable Present?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes	Connected?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes
Rail Extrusion?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes	Length (ft. in.)	8 ft 9 in
Rail Extrusion Direction	<input type="checkbox"/> Traffic Side <input checked="" type="checkbox"/> Field Side		
Total Length of Rail Damaged (ft.) [total length would include extruded rail plus damaged rail downstream from head.]	38 ft 2 in		

<b>TELESCOPE</b>			
Rail Displacement	<input type="checkbox"/> No	<input type="checkbox"/> Yes; Length:	No of Panels Displaced <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6

<b>ALL-SYSTEM PERFORMANCE</b>			
Railkinks Downstream of Head?	<input type="checkbox"/> No	<input checked="" type="checkbox"/> Yes	No. of Kinks in Rail: 4
Was there intrusion into the Occupant Compartment by foreign object (guardrail)?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes		
Did vehicle impact other objects after impact with terminal?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes		
Object Contacted	Break-away sign post and ground		

<b>ALL-SYSTEM PERFORMANCE ENVIRONMENT</b>			
SIDESLOPE	50 ft in advance of Post 1	At Post 1	50 ft Past Post 1
Percent - %	-15%	-21%	-21%
Adjacent Lane Width (ft)	11.2 ft		
Lane Type (NAS EDS Variable: Sur. Type)	Concrete		
Shoulder Type	Concrete		

Case No.: IN16008

Shoulder Width (ft)	12 ft
Guardrail Height (in)	25.6 in

VEHICLE INFORMATION	
Vehicle Type (NHTSA Input)	Sport Utility Vehicle
Vehicle Identification Number (VIN)	3GNEK18RXTGxxxxxx
Vehicle Mass (NASS var.: veh.wgt)	4458 lbs
Vehicle orientation upon impact	<input type="checkbox"/> Case Type 1 <input type="checkbox"/> Case Type 2 <input checked="" type="checkbox"/> Case Type 3 <input type="checkbox"/> Case Type 4 <input type="checkbox"/> Case Type 5 <input type="checkbox"/> Case Type 6 <input type="checkbox"/> Case Type 7 <input type="checkbox"/> Case Type 8 <input type="checkbox"/> Other
If "Other," describe	
Collision Deformation Classification	10LDEW3
Delta-V	Estimated range: 16 -25 mph
Occupant Compartment Penetration of rail	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes   Describe: Kink in guardrail at entrance to guide chute penetrated 7 in into second row left seating position
Quarter Turns (NASS EDS variable: Rollover)	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input checked="" type="checkbox"/> 8 <input type="checkbox"/> 9 <input type="checkbox"/> 10 <input type="checkbox"/> 11 <input type="checkbox"/> 12 <input type="checkbox"/> 13 <input type="checkbox"/> 14 <input type="checkbox"/> 15 <input type="checkbox"/> 16 <input type="checkbox"/> 17+
Object Precipitating Rollover, (NASS EDS variable: Rollobj)	Guardrail
Rollover Type, Terhune Scale, (NASS EDS variable: rolintyp)	Climb Over

DOT HS 812 621  
August 2019



U.S. Department  
of Transportation  
**National Highway  
Traffic Safety  
Administration**

