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Special Crash Investigations On-Site Guardrail End Treatment Impact Investigation
Vehicle: 2000 Volkswagen Jetta
Location: Pennsylvania
Crash Date: December 2016

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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 be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics 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 vehicles or their safety systems.

This report and associated case data are based on information available to the Special Crash Investigation team on the date this report was published.

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16. Abstract This report documents the on-site investigation of the impact to an ET-Plus guardrail end treatment by a 2000 Volkswagen Jetta. The crash occurred when the Volkswagen departed the east edge of a local roadway in a clockwise yaw. The vehicle initiated a left side-leading rollover sequence and impacted the end terminal with its left plane. Crash forces deformed the end treatment, and the vehicle ultimately rolled through the guardrail system and along the roadside. The crash resulted in fatal injuries to the Volkswagen's unbelted 34-year-old female, who was completely ejected during the rollover sequence and contacted by the vehicle as it rolled.			
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TABLE OF CONTENTS

SPECIAL CRASH INVESTIGATIONS
CASE NO.: CR16039
ON-SITE GUARDRAIL END TREATMENT IMPACT INVESTIGATION
VEHICLE: 2000 VOLKSWAGEN JETTA
LOCATION: PENNSYLVANIA
CRASH DATE: DECEMBER 2016

BACKGROUND

This report documents the on-site investigation of an impact into an ET-Plus guardrail end treatment (**Figure 1**) by a 2000 Volkswagen Jetta. The crash occurred when the Volkswagen departed the east edge of a local roadway in a clockwise yaw. The vehicle tripped and initiated a left side-leading rollover sequence and then impacted the end terminal with its left plane. Crash forces deformed the end treatment, and the vehicle ultimately rolled through the guardrail system and along the roadside. The crash resulted in fatal injuries to the Volkswagen's unbelted 34-year-old female, who was completely ejected during the rollover sequence and contacted by the vehicle as it rolled.

Figure 1: North-facing view of the damaged ET-Plus guardrail end treatment.

The crash was identified by the Pennsylvania Department of Transportation (PENNDOT), who in-turn submitted notification to the Federal Highway Administration (FHWA). The FHWA determined that the crash type and guardrail end treatment met the criteria for further research and subsequently forwarded the notification to the Crash Investigation Division (CID) of the National Highway Traffic Safety Administration in December of 2016. The CID assigned an on-site investigation of the crash to the Special Crash Investigations (SCI) team at Crash Research & Analysis, Inc., and the SCI team contacted and established cooperation with PENNDOT in December 2016. The on-site investigation occurred during December 2016, and involved the documentation of the guardrail system and the damage it sustained during the crash. The physical plant of the roadway and the guardrail were documented using a Nikon Nivo 5+M total station system. The Volkswagen was inspected to document its exterior and interior damage, deformation associative to the guardrail end treatment impact, interior occupant contact, and evaluate its manual and supplemental restraint systems. No crash data could be imaged from the Volkswagen, because the model year/model of the vehicle was not supported by the Bosch Crash Data Retrieval tool/software due to its date of manufacture. Following completion of the on-site investigation, the SCI investigator obtained medical record documentation of the driver's injuries from a post-mortem examination.

CRASH SUMMARY

Crash Site

This single-vehicle crash occurred on a two-lane north/south roadway in a rural setting during nighttime hours in December 2016. Environmental conditions in the locale at the time of the crash included light rain with a temperature of 6 °C (42 °F), 70 percent relative humidity, and a 16 km/h (10 mph) southerly breeze. The physical environment of the roadway was documented during the SCI crash site inspection using a Nikon Nivo 5.M+ total station mapping system.

The lanes of the two-lane roadway were both 3.7 m (12.1 ft) wide, and were delineated by a double-solid yellow centerline with single solid-white fog lines. They were supported by 1.9 m (6.2 ft) shoulders. All surfaces of the roadway were asphalt. Due to the environmental conditions at the time of the crash, the roadway was wet. Speed was regulated by a posted limit of 89 km/h (55 mph). The roadway was bordered to the east and west by agricultural fields, rural residences, and grass/tree vegetation. A guardrail system was located along the east roadside that provided protection to traffic from a depressed ravine and small creek. It consisted of W-beam guardrail with steel I-beam posts, and was installed with the ET-Plus end treatment system (see *ET-Plus End Treatment and Guardrail* section of this report).

In the area of the crash, the two-lane roadway was straight and level. However, for the Volkswagen's pre-crash trajectory, the straight portion of the roadway where the crash occurred was preceded by a sweeping, large-radius right curve with positive grade. The curve ended approximately 250 m (820 ft) south of the impacted guardrail end treatment. **Figure 2** depicts a north-facing view of the Volkswagen's pre-crash trajectory on approach to the crash location. A crash diagram is included at the end of this technical report.

Figure 2: View of the Volkswagen's northbound pre-crash travel trajectory.

Pre-Crash

The 34-year-old female operated the Volkswagen northbound on the two-lane roadway. She was not restrained by the vehicle's available 3-point lap and shoulder seat belt system. Specifics concerning the driver's activities preceding the crash remain unknown due to the driver's fatal outcome. Multiple alcoholic beverage glass containers, some opened and empty, were found in the Volkswagen at the time of the SCI vehicle inspection. Based on the evidence gathered during the SCI inspection of the crash site and the SCI reconstruction, the driver maintained a slight right steering input as the vehicle exited the curve and entered the straightaway.

While the Volkswagen continued northbound, it began to drift right. Its right-side tires entered the shoulder. The driver then provided a left steering input in an attempt to maintain the roadway. She overcorrected, and the vehicle was directed left toward the roadway's centerline. The driver then reversed her steering input back to the right as she attempted to maintain control of the vehicle in the northbound lane. However, the back-and-forth movement of the vehicle, combined with the decreased friction of the roadway associated with the rain and corresponding wet surface, resulted in a loss of traction of the vehicle's tires. This produced a clockwise rotation to the Volkswagen about its vertical axis, which initiated a clockwise yaw.

Figure 3: North-facing view of the tire marks from the Volkswagen's left rear, left front, and right front tires that evidenced the vehicle's clockwise yaw and control loss.

The driver lost control of the Volkswagen as it yawed clockwise back across the northbound lane and onto the east shoulder. These dynamics were evidenced by yawing tire marks from the vehicle's left front, left rear, and right front tires. The left rear tire mark began on the roadway's centerline (**Figure 3**) and extended for 36 m (118 ft) onto the east shoulder. The vehicle maintained its clockwise yaw and approached the east road edge. This allowed it to achieve a left side-leading attitude as the left front tire departed the road and entered the grassy roadside.

Crash

Instability was created with respect to the Volkswagen's center of mass by the lateral drag force load on the left front tire/wheel as it began to furrow into the soft soil surface of the roadside. Simultaneously, the left rear tire skidded laterally across the shoulder. This initiated the dynamics of a left-side leading tripped rollover (Event #1). However, the location of the vehicle's roadside departure and its yawing trajectory coincidentally aligned its left plane with the guardrail end treatment. As the left-side rollover began, the left plane of the vehicle then impacted the impact face of the end terminal in the area of the driver's door (Event #2). **Figure 4** depicts a south-facing lookback view of the yawing tire marks and roadside departure, with the ground strut of the end treatment installation visible in the bottom of the image.

Figure 4: South-facing view of the Volkswagen's yawing tire marks and roadside departure from beyond the location of the end terminal impact.

The Volkswagen's left plane engaged the ET-Plus impact head and displaced it along the W-beam, deforming the guardrail system and extruding guardrail from the terminal. The associated forces were not of sufficient magnitude to interrupt the rollover and the vehicle maintained its rollover momentum as it displaced the end terminal. This deflected the impact head downward, while the vehicle continued up and over the end treatment and into the roadside. The Volkswagen rolled at least six quarter-turns through the roadside.

During the rollover event, the unbelted driver became displaced from her pre-crash position in the driver's seat and was completely ejected from the vehicle. Her ejection occurred as the vehicle completed its first complete roll and entered the fifth quarter-turn, which projected the driver forward and into the path of the rolling vehicle's trajectory. This subjected the driver to contact by the vehicle as it rolled. The Volkswagen ultimately came to final rest in the roadside (**Figure 5**), located 20.1 m (65.9 ft) northeast of Post 1 of the installation and 27.0 m (88.6 ft) northeast of the initial left front tire/wheel roadside departure. At rest, the vehicle was on its top plane facing east. An impact diagram is included at the end of this technical report.

Figure 5: Northeast-facing view of the location of the Volkswagen's final rest position in the east roadside.

Post-Crash

Local law enforcement, fire department, and emergency medical services personnel responded to the crash scene. First arriving emergency personnel located the driver completely ejected from the vehicle and lying face-down on the ground, with her right arm beneath the right rear corner of the overturned Volkswagen's roof. She was absent of vital life signs, and pronounced deceased at the crash site by medical personnel. The driver's body was removed by the local coroner for documentation. A post-mortem toxicology screen revealed that the driver had a blood alcohol concentration (BAC) of .279 gram per deciliter. The Volkswagen was removed from the crash site and towed to a local yard, where it was held pending completion of the law enforcement investigation. It remained at that yard at the time of the SCI vehicle inspection.

ET-PLUS END TREATMENT AND GUARDRAIL

The ET-Plus System end terminal was an energy absorbing end treatment that terminated the 43-74 cm (16.9-29.1 in) high W-beam guardrail. The ET-Plus System End Terminal was a tangent system manufactured by Trinity Highway Products. The manufacturer's literature and installation manuals can be found at: http://www.highwayguardrail.com/products/etplus.html. The end terminal was designed to be displaced along the W-beam and absorb impact force by crushing and flattening the W-beam during its movement. The flattened and deformed beam was then projected out of the impact head toward the field (off-traffic) side.

The involved system's installation was a seven-post configuration over 11.5 m (37.7 ft). It consisted of a 10 cm (4 in) version of the ET-Plus rail flattening head assembly, sections of standard W-beam guardrail, a post foundation, and breakaway steel post at Post 1, seven standard steel yielding terminal (SYT) posts at Post locations 2 to 7, a ground strut between Posts 1 and 2, and a tension cable from Post 1 to the W-beam guardrail between Posts 1 and 2. An anchor plate and bolt held the ET-Plus head assembly to breakaway Post 1, while the W-beam guardrail at Post 1 was free-floating. The guardrail itself was supported by a carriage bolt at Post 2, with a composite block-out and carriage bolt providing support at Posts 3 to 7. At Post 8, the guardrail system transitioned from the end treatment into standard guardrail, with steel posts, composite block-outs, and carriage bolts.

Figure 6: Image depicting an exemplar ET-Plus end terminal installation.

Figure 6 depicts an exemplary similar ET-Plus installation. At the time of the SCI inspection of the crash site, the end terminal and guardrail system remained in a damaged state. An unknown individual had marked damaged components with a fluorescent orange safety spray paint. The SCI investigator inspected the damaged components and assessed the performance of the end terminal, impact head, and guardrail system. Data was documented on the FHWA Guardrail Forms, which are included at the end of this report in the **Appendix**.

During the crash, the Volkswagen struck the impact face of the end terminal (originally located at Post 1) and displaced it northward along the W-beam. This flattened the guardrail, and it curled on the field side of the impact head. There was 1.0 m (3.5 ft) of flattened W-beam extruded from the impact head. Due to the configuration of the crash and the initiation of the vehicle's rollover dynamics prior to impact and engagement of the vehicle with the end terminal, the impact head and guardrail were directed toward the east as the system deformed. The lateral (east/west) component of the force exceeded the longitudinal (north/south) component of the force with respect to guardrail system and its installation. This resulted in decreased displacement of the impact head and increased bending displacement of the rail. The impact head's displacement then ceased, and the vehicle deformed the guardrail and system to the east along its crash trajectory. This formed a bend in the system in advanced of the impact head located 2.7 m (9.0 ft) downstream from the system's rail end as the impact head wrapped into the field side. The bend was not classified as a kink due to the direction of the forces involved, as it did not impede the impact head's displacement and was not related to a force directed along the rail. There was no intrusion or penetration of the system into the occupant compartment of the Volkswagen. A Post-Impact Guardrail Diagram is included at the end of this technical report.

Figure 7 depicts an overhead view of the impact head and extruded rail, while **Figure 8** depicts a southeast-facing view of the damaged system.

Figure 7: View of the impact head and extruded rail from an overhead perspective.

Figure 8: Southeast-facing view of the damaged ET-PLUS end treatment.

Post 1 consisted of a 10 x 15 cm (4.0 x 6.0 in) steel I-beam, which was attached via a hinge bolt to a lower post section that was embedded into the ground. The end terminal was attached to the I-beam by two shear bolts. The force of the impact caused the I-beam to shear at the hinged connection, which allowed the post to be displaced with the impact head. It remained connected to the impact head by the upper shear bolt at the time of the SCI inspection. The cable anchor, originally attached between Post 1 and the W-beam, was displaced an unknown distance to the northeast by the impact. The ground strut was not damaged in the crash.

Post 2 consisted of a 10 x 15 cm (4.0 x 6.0 in) I-beam SYT post with weakening holes installed approximately at ground level. At this post, the W-beam was originally bolted through a slot in the flange of the upper section of the post. During the crash, the W-beam separated from the post and the upper section of Post 2 was deformed 90-degrees to the northeast and partially sheared in the area of its weakening holes at ground level. At the time of the SCI inspection, the deformed upper section of Post 2 was in contact with the ground.

Post 3 was a 10 x 15 cm (4.0 x 6.0 in) I-beam SYT post with weakening holes at ground level, and had a composite block-out and carriage bolt that supported the W-beam. During the crash, the head of the carriage bolt pulled through the W-beam by deforming the slot in the rail. The composite block-out was fractured, but remained attached to the post. Post 3 was not deformed or displaced by the crash.

The damage to the end treatment's posts ended at Post 3. Due to the length of the rail sections, however, the W-beam guardrail itself required replacement to Post 5. Neither Post 4 nor Post 5 were damaged by the crash, and the W-beam remained installed with carriage bolts securing the W-beam to Posts 4 and 5 through undamaged composite block-outs.

2000 VOLKSWAGEN JETTA

Description

Figure 9: Front right oblique view of the Volkswagen.

The 2000 Volkswagen Jetta (**Figure 9**) was a 5-passenger sedan identified by the VIN 3VWSC29M2YMxxxxxx. The electronic odometer was non-functional at the time of the SCI inspection. However, paperwork in the vehicle declared that its last known odometer reading was 361,938 km (224,898 mi) in mid-June 2016. The Jetta's body was configured on a 251 cm (98.8 in) wheelbase with front-wheel drive. It was powered by a 2.0 liter, inline, 4-cylinder gasoline engine linked to an automatic transmission with a center-console-mounted shifter. Deformation to the Volkswagen's left front door relative to impact with the end treatment had jammed the left front door shut. Therefore, the SCI investigator was unable to review the placard containing the vehicle's gross vehicle weight rating or the manufacturer's recommended tire sizes/pressures. At the time of the SCI vehicle inspection, the Volkswagen was equipped with Cooper CS9 Touring tires of size P195/65R15 and mounted on originally equipped aluminum wheels, at all four axle positions. The tires had matching Tire Identification Numbers of U9AE 1CA 4214. All four tires had ample tread, were not damaged or restricted, and remained inflated.

The interior of the Volkswagen was configured with two rows for seating of up to five occupants (2/3). The front seats were bucket seats with manual seat track and seatback recline adjustments, and were equipped with adjustable head restraints. At the time of the SCI inspection, the driver's seat was adjusted to its full-forward track position, with the seatback slightly reclined and the adjustable head restraint 2 cm (0.8 in) upward. The second row consisted of a three-passenger bench seat with adjustable head restraints. Manual restraint systems in the Volkswagen consisted of 3-point lap and shoulder seat belts for all five seat positions. Both front seat belts were adjustable at their respective D-ring locations and were equipped with retractor pretensioners. Supplemental restraints consisted of a driver's frontal air bag, a passenger's frontal air bag, and front-seat side-impact air bags.

Exterior Damage

The rollover (Event 1) was initiated prior to the occurrence of the end terminal impact (Event 2). However, no damage was sustained by the Volkswagen associative to the rollover until after the end terminal impact had occurred. This is because the Volkswagen was likely at least 15 degrees into the rollover before its left plane made contact with the end terminal, but its left and top planes did not make contact with the ground in association to the rollover until after the vehicle had struck, deformed, and passed through the end treatment. The following narrative describes the damage in the order it occurred.

The impact with the ET-Plus end terminal's impact face (Event 2) resulted in a distinct pattern of direct contact to the Volkswagen's left plane that was highlighted by pronounced vertical marks from the protruding outer edges of the impact face. It began on the aft edge of the left front door on the B-pillar 106 cm (41.7 in) forward of the left rear axle, and extended 43 cm (16.9 in) forward to 149 cm (58.7 in) forward of the left rear axle. There were also pronounced marks from the vertical supports of the impact head on the left rear door. **Figure 10** depicts the distinct damage to the Volkswagen from the impact face of the end terminal (highlighted by yellow masking tape). The total length of the direct damage from the impact head and guardrail began 39 cm (15.4 in) rearward of the left rear axle and extended 188 cm (74.0 in) forward.

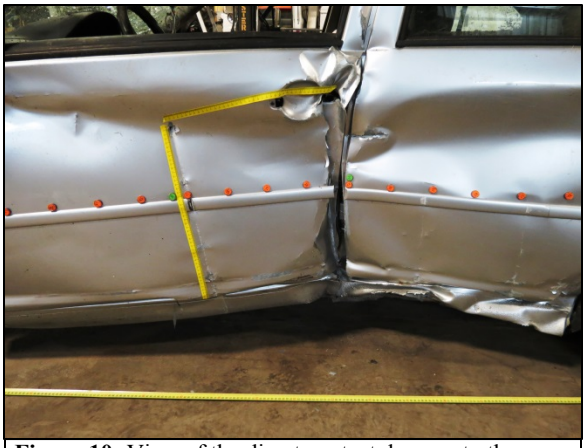


Figure 10: View of the direct contact damage to the Volkswagen from the ET-Plus impact face.

Figure 11: Deformation pattern to the 2000 Volkswagen Jetta from an overhead perspective.

A direct and induced damage length (Field-L) of 269 cm (105.9 in) was used to document a residual crush profile for the Volkswagen's Event 2 damage pattern. The Field-L began 61 cm (24.0 in) rearward of the left rear axle and extended 246 cm (96.9 in) forward. The crush profile (**Figure 11**) was documented by the SCI investigator using a Nikon Nivo 5.M+ total station mapping system, and was measured at mid-door level and adjusted to account for free-space. This profile produced the following measurements: C1 = 3 cm (1.2 in), C2 = 12 cm (4.7 in), C3 = 21 cm (8.3 in), C4 = 18 cm (7.1 in), C5 = 12 cm (4.7 in), and C6 = 2 cm (0.8 in). Maximum crush was located at the left B-pillar, and measured 22 cm (8.7 in). The Collision Deformation Classification (CDC) assigned to the Volkswagen for the ET-PLUS end treatment impact damage was 09LZEW2.

The impact yielded the end treatment, and involved the translation of crash forces to a non-horizontal direction during the later stages of engagement (due to the initiation of the rollover dynamics prior to impact). Although these characteristics were beyond the scope of analysis for the WinSMASH program, its barrier algorithm was used to calculate an estimated delta-V for the impact. The calculated barrier equivalent speed was 22 km/h (14 mph). Based on the visible damage sustained by the Volkswagen and SCI expertise, this appeared reasonable.

Damage associative to the rollover (Event 1) was visible to the top, left, and right planes of the Volkswagen. On the top plane, the roof exhibited minor deformation biased to its forward aspect, between the windshield header and the sun roof. The glazing of the sun roof remained intact, but the entire unit was completely separated from the vehicle. Clumps of soil with grass vegetation covered the roof's exterior surface. Deformation surrounded the windshield header, and the AS-1 laminated windshield glazing was fractured across its entire surface (not holed). Minor scratches and abrasions were visible to the surface of the hood. On the left plane, the side mirror was fractured from the vehicle. Minor deformation was visible to the left rear quarter panel. The side mirror was also fractured from the vehicle on the right plane, with dents in the upper right C-pillar and minor immeasurable deformation to the right front fender.

Figure 12: Vertical deformation to the Volkswagen's windshield header associative to the rollover event.

Maximum deformation to the Volkswagen associative to the rollover measured 10 cm (4.0 in) vertically to the windshield header near the vehicle's centerline. The deformation included 5 cm (2.0 in) from the level of the roof side rails (**Figure 12**) and an additional 5 cm (2.0 in) to account for the concavity of the roof structure. Associated with this deformation was minor vertical interior deformation/intrusion. No lateral deformation associative to the rollover could be discerned. The CDC assigned to the Volkswagen for the rollover damage was 00TDDO2. No WinSMASH calculations could be performed because the rollover crash type was beyond the model's scope for analysis. Based on the observed damage and the SCI reconstruction of the crash, the Volkswagen completed six uninterrupted quarter-turns during the rollover sequence.

Event Data Recorder

The 2000 Volkswagen Jetta was equipped with an air bag control module (ACM) that monitored the diagnostic functions of the vehicle's supplemental restraint systems (air bags and seat belt pretensioners) and controlled the deployment/actuation of those devices dependent upon crash event severity. However, due to the age of its model year/model, the Volkswagen was not supported by the Bosch CDR software and no crash data could be imaged.

Interior Damage

The interior of the Volkswagen sustained minor damage that consisted of air bag deployment, occupant contact, and occupant compartment intrusion. Air bag deployment was limited to deployment of the left front seat-mounted air bag. Occupant contact evidenced the driver's kinematic response and ejection path. Intrusion was related to impact damage sustained during impact and engagement with guardrail end treatment, with no penetration of the guardrail into the vehicle.

All the Volkswagen's doors remained closed during the crash. Although the left front door and left rear door were jammed shut due to deformation sustained during the crash, the right side and were operational. The left front glazing was disintegrated during the end treatment impact, while the right front glazing disintegrated during the rollover sequence. Other glazing damage included the windshield and sun roof as previously described. All other glazing remained intact.

The steering column was equipped only with tilt adjustment, and was positioned between center and fully-upward at the time of the SCI inspection. No deformation was observed to the steering wheel rim or column. The area surrounding the driver's seat position (**Figure 13**) was inspected for occupant contact. Evidentiary of the lateral nature of the associated crash forces, no contact evidence was found on any of the forward components. However, several strands of the driver's hair were found captured in the weather stripping along the upper aspect of the left front door near the left roof side rail (**Figure 14**). There was also obvious deformation and displacement of the armrest and controls of the left front door panel (**Figure 15**) with scuffing on the upper rear aspect of the left front door panel. The combination of these three areas of occupant contact evidenced the driver's left lateral loading of the door during the impact and engagement with the ET-Plus end treatment, as well as her path of complete ejection through the left front glazing opening during the rollover sequence.

Figure 13: Interior of the Volkswagen as viewed from the driver's perspective during the SCI vehicle inspection.

Figure 14: Image depicting strands of hair captured in the weather stripping near the left roof side rail from contact by the driver's head during her ejection.

Figure 15: View of the Volkswagen's left front door with contact evidence from the driver to the armrest and rear upper quadrant.

Intrusion into the Volkswagen's interior was related to both the lateral impact with the end treatment and the rollover crash events. Primary areas of intrusion included the left front door, left B-pillar, left rear door, and windshield header. The maximum lateral intrusions associated with these components included 16 cm (6.3 in) of the left B-pillar at sill level, 13 cm (5.1 in) of the left front door at the rear lower quadrant, and 14 cm (5.5 in) of the left rear door at the forward lower quadrant. Maximum vertical intrusion of the windshield header measured 8 cm (3.2 in) at the centerline of the vehicle.

Manual Restraint Systems

The Volkswagen was equipped with 3-point lap and shoulder seat belts for all five seat positions. Each front seat belt system consisted of continuous-loop webbing, a sliding latch plate, and an adjustable D-ring. At the time of the SCI vehicle inspection, the driver's D-ring was adjusted fully downward. The driver's seat belt webbing retracted onto an emergency locking retractor (ELR), while the front right and all three rear seat belt systems used switchable automatic locking retractors (ALR)/ELR. Both front seat belt systems were further equipped with retractor pretensioners.

Inspection of the driver's seat belt system found the webbing retracted against the left B-pillar (**Figure 16**). Actuation of the retractor pretensioner had pulled the seat belt system taught against the B-pillar. Although there was evidence of historical use, no loading evidence could be found on the driver's seat belt system. Based on the retracted status of the belt system and lack of loading evidence, combined with the driver's completely ejected status, it was apparent to the SCI investigator that the system was not in use at the time of the crash.

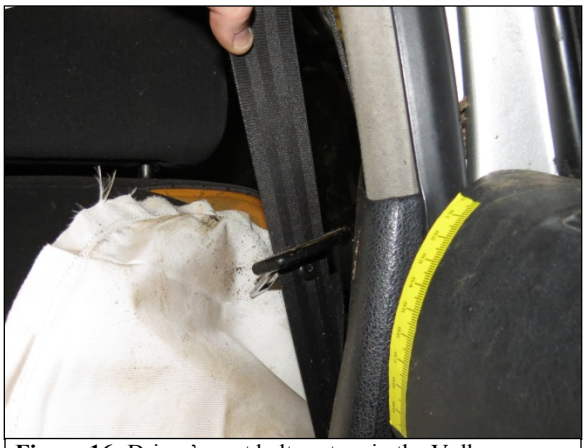


Figure 16: Driver's seat belt system in the Volkswagen at the time of the SCI vehicle inspection.

Supplemental Restraint Systems

The Volkswagen was equipped with multiple inflatable supplemental restraints. The first of these systems was a frontal air bag system for the driver and front right passenger positions. It consisted of a steering wheel hub-mounted driver's frontal air bag and a top instrument panel-mounted passenger's frontal air bag, with front seat belt retractor pretensioners. Additional occupant protection in the Volkswagen was provided by front seat-mounted side impact air bags. Only the driver's seat-mounted air bag deployed in the crash.

Figure 17: Driver's deployed seat-mounted side impact air bag in the Volkswagen at the time of the SCI vehicle inspection, with post-crash dirt/debris.

The driver's seat-mounted side impact air bag (**Figure 17**) deployed through the stitching on the leading edge of seatback. In its deflated state, the air bag measured 58 cm (22.8 in) in overall height and 24 cm (9.4 in) in overall width. A 4 cm (1.6 in) vent was located on the forward lower aspect of the air bag. There was no discernable occupant contact to the seat-mounted air bag. Despite the lack of physical evidence, the driver contacted and loaded the air bag during the crash sequence. It should be noted that the air bag had dirt and dry leaves on it at the time of the SCI inspection.

2000 VOLKSWAGEN JETTA OCCUPANT DATA

Driver Demographics

Age/Sex:	34 years/female
Height:	165 cm (65 in)
Weight:	82 kg (181 lb)
Eyewear:	Unknown
Seat Type:	Forward-facing bucket seat with adjustable head restraint
Seat Track Position:	Fully forward
Manual Restraint Usage:	3-point lap and shoulder seat belt system available; Not used
Usage Source:	Vehicle inspection
Air Bags:	Frontal air bag available, but not deployed; Seat-mounted side impact air bag available and deployed
Alcohol/Drug Involvement:	Alcohol (BAC= .279 g/dL)
Egress From Vehicle:	Completely ejected during crash sequence
Transport From Scene:	None
Type of Medical Treatment:	Pronounced deceased at the crash scene

Driver Injuries

Injury No.	Injury	AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
1	Step-off fracture to back of neck	650298.9	Ground and vehicle contact following ejection	Probable
2	Hip fractures, NFS	856100.2	Ground and vehicle contact following ejection	Probable
3	Pelvic fracture, right side	856200.2	Ground and vehicle contact following ejection	Probable
4	Right wrist fracture	751900.2	Ground and vehicle contact following ejection	Probable

Injury No.	Injury	AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
5	Left wrist fracture	751900.2	Ground and vehicle contact following ejection	Probable
6	Laceration to right 4th knuckle	710600.1	Ground and vehicle contact following ejection	Probable
7	Circular contusion to right 3rd knuckle	710402.1	Ground and vehicle contact following ejection	Probable
8	Multiple abrasions to the back of the left hand	710202.1	Ground and vehicle contact following ejection	Probable
9	Multiple irregular-shaped contusions to the left forehead	210402.1	Left roof side rail	Probable
10	Contusion to the left chin	210402.1	Ground and vehicle contact following ejection	Probable
11	Multiple circular contusions on the inner aspect and lateral aspect of the left leg	810402.1	Ground and vehicle contact following ejection	Probable
12	Contusion to the right thigh	810402.1	Ground and vehicle contact following ejection	Probable
13	Hematoma, lower back	410402.1	Ground and vehicle contact following ejection	Probable
14	Contusion/erythematous lesion to the abdomen, irregularly shaped	510402.1	Ground and vehicle contact following ejection	Probable
15	Abrasions (soil patterns) vertically-oriented, to the entire abdomen, concentrated on the right side and extending to the back, 51 cm long and 5 cm wide at greatest dimension	510202.1	Ground and vehicle contact following ejection	Probable
16	Oblique linear abrasion to left upper lateral quadrant of abdomen	510202.1	Ground and vehicle contact following ejection	Probable
17	Curvilinear and linear abrasions along right back, measuring approximately 51 cm long and 5 cm wide at greatest dimension	410202.1	Ground and vehicle contact following ejection	Probable
18	Curvilinear abrasion pattern over right hip	810202.1	Ground and vehicle contact following ejection	Probable
19	Curvilinear abrasion pattern over left hip	810202.1	Ground and vehicle contact following ejection	Probable
20	Abrasion, vertically oriented, to the left lateral leg	810202.1	Ground and vehicle contact following ejection	Probable
21	Abrasion to the right lateral thigh	810202.1	Ground and vehicle contact following ejection	Probable

Injury No.	Injury	AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
22	Abrasion to the right lateral knee	810202.1	Ground and vehicle contact following ejection	Probable
23	Abrasion to the right lateral leg	810202.1	Ground and vehicle contact following ejection	Probable

Source – Coroner's report

Driver Kinematics

The 34-year-old female was seated in the driver's seat of the Volkswagen. She had adjusted the seat to its forward-most track position, with the seat back reclined and the adjustable head restraint 2 cm (0.8 in) upward. Based on the observations of the SCI inspection, the driver was not restrained by the available 3-point lap and shoulder seat belt system. Toxicology performed by the coroner revealed that the driver had a measured BAC of .279 g/dL. The SCI investigator found multiple glass containers, some opened and empty, in the Volkswagen at the time of the SCI vehicle inspection.

While the driver operated the Volkswagen northbound on the local roadway and exited the sweeping right curve, she allowed the vehicle to drift right from its travel lane. The driver detected the vehicle's right drift and steered left to maintain the roadway. She then over-corrected, and as the vehicle approached the centerline, the driver steered back to the right in an attempt to maintain the travel lane. This back-and-forth movement, in conjunction with the wet roadway surface and corresponding decreased friction, resulted in a loss of traction of the vehicle's left side tires. The Volkswagen initiated a clockwise yaw as it was directed back toward the right side of the roadway. The vehicle yawed across the travel lane and onto the shoulder, with the driver unable to correct the vehicle's trajectory. She was directed slightly to her left as the vehicle achieved a left side-leading attitude, and maintained that trajectory as the vehicle entered into the dynamics of a left side-leading rollover sequence.

At impact with the guardrail end treatment, the seat belt pretensioner actuated and the driver's seat-mounted side impact air bag deployed. However, the driver's lack of manual restraint usage subjected her to unrestricted movement about the vehicle. Deformation to the left front door by the guardrail end treatment impact disintegrated the left front glazing. The driver's left trajectory was accentuated by the lateral impact forces, and her left flank contacted and loaded the deployed air bag. Her left leg contacted the forward aspect of the left front door panel.

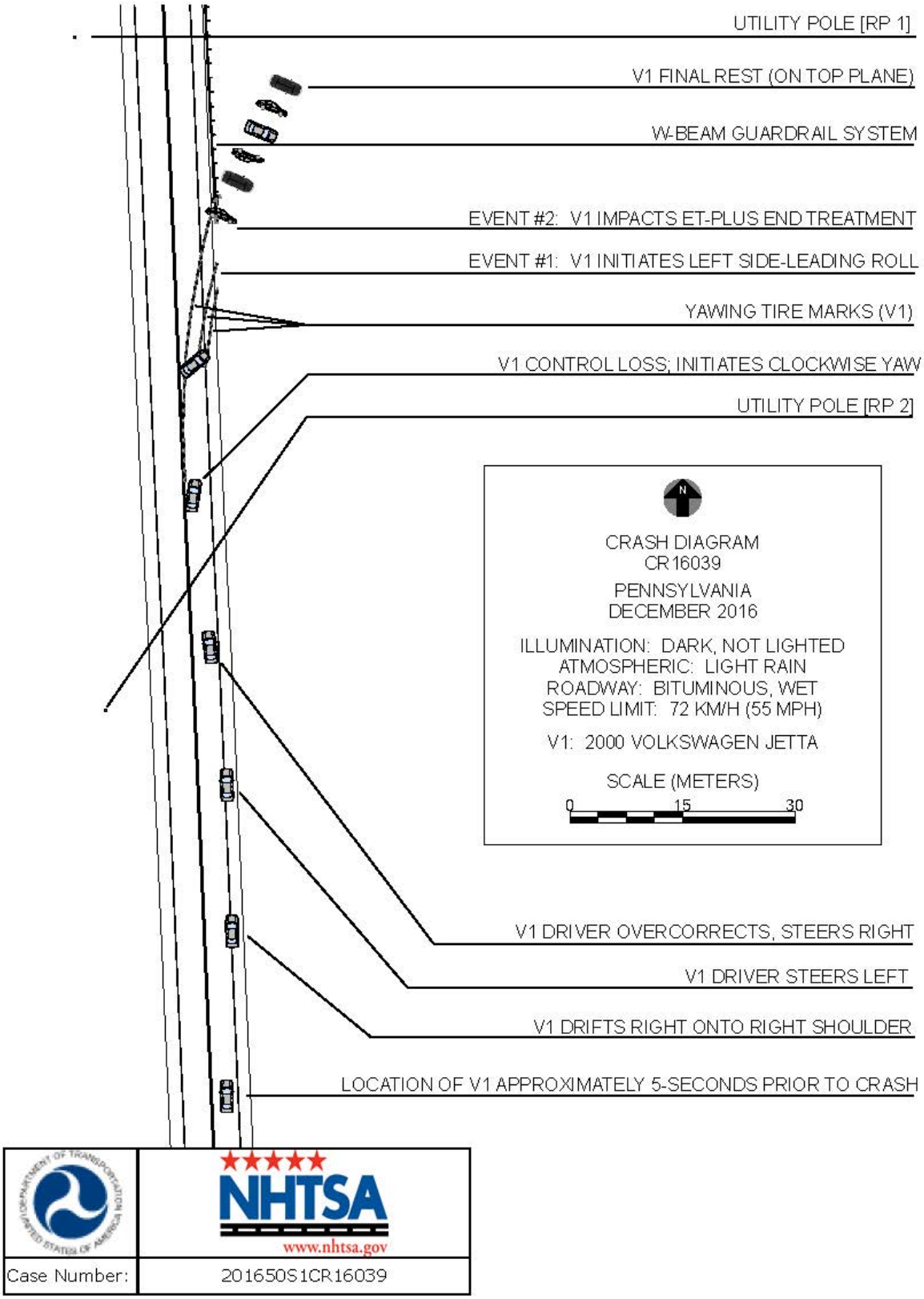
The driver remained in a left trajectory as the vehicle engaged the end treatment and the left front door intruded. It is unknown if this contact and loading produced any injuries to the occupant, as the driver's complete ejection resulted in significant injuries that otherwise masked and/or exacerbated any other previously sustained injuries. The Volkswagen maintained its left side-leading rollover dynamics as it engaged the end treatment. With the driver out of position to the

left as a result of the end treatment engagement, she maintained her left trajectory as the vehicle rolled. Centrifugal forces of the rollover and the loss of integrity of the left front glazing, combined with the driver's lack of restraint use, created the foundation for the driver's subsequent complete ejection. As the vehicle completed its first full revolution, the driver was ejected through the left front glazing opening and projected forward of the vehicle's rolling trajectory and into its path.

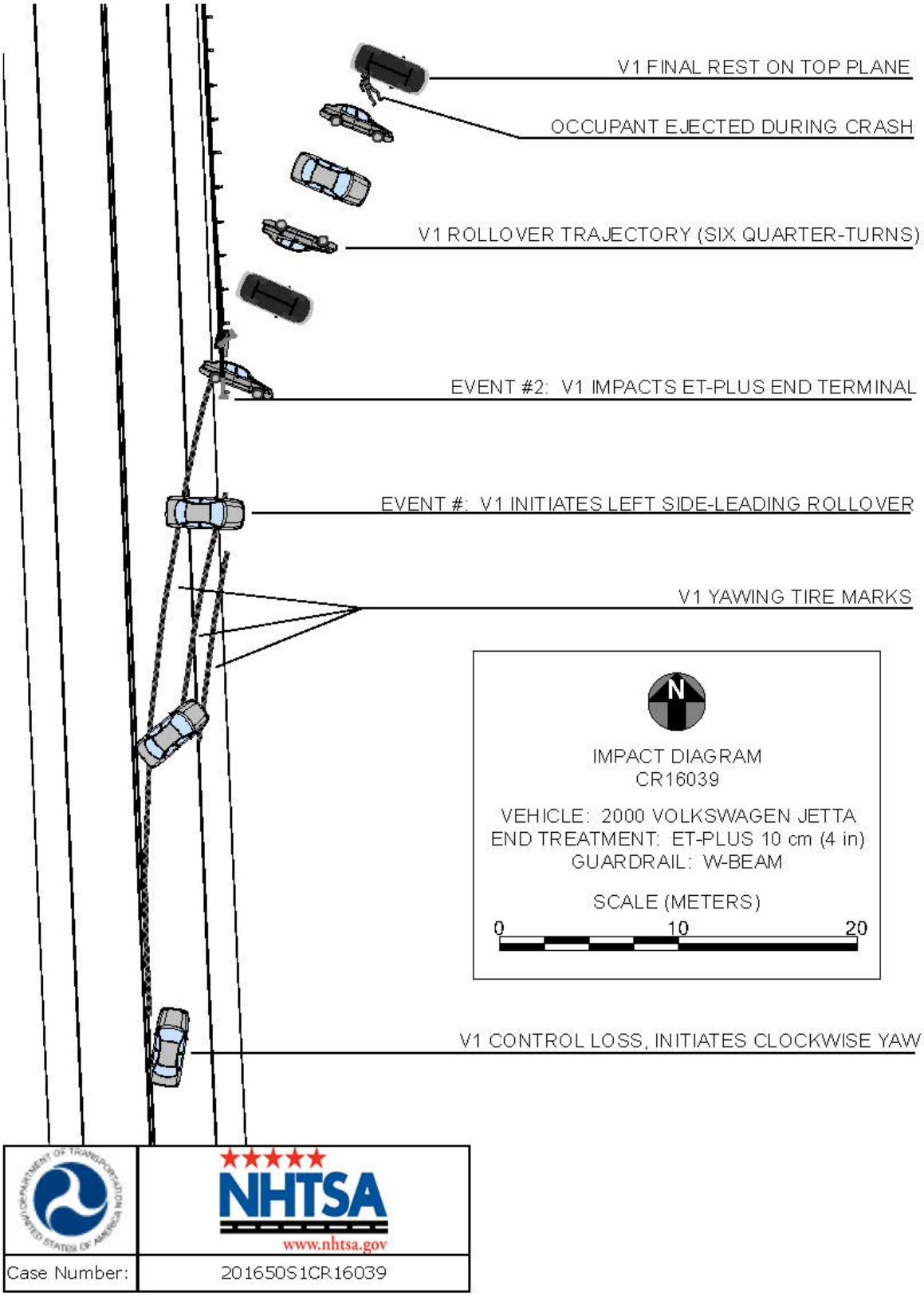
During her ejection, the driver's head struck the upper aspect of the left front door near the left roof side rail, evidenced by hair captured in the vehicle's weather stripping. Her left hip loaded and scuffed the rear upper quadrant of the left front door. It is unknown if these contacts and loading produced injuries to the occupant, as the driver's complete ejection resulted in significant injuries that otherwise masked and/or exacerbated other previously sustained injuries.

The driver landed on the ground in advance of the rolling Volkswagen. She was then contacted by the vehicle as it maintained its rolling trajectory, and the vehicle rolled nearly completely over her before coming to final rest. The driver was found unresponsive and lying face-down on the ground at the crash site, with the right roof side rail of the overturned vehicle on top of her outstretched right arm. The driver sustained numerous crushing traumatic injuries as a result of her complete ejection, from contact with ground and contact by the Volkswagen as it rolled over her. She was pronounced deceased at the crash site, and did not receive any medical treatment or transport. A local coroner removed the driver's body from the crash scene for post-mortem examination.

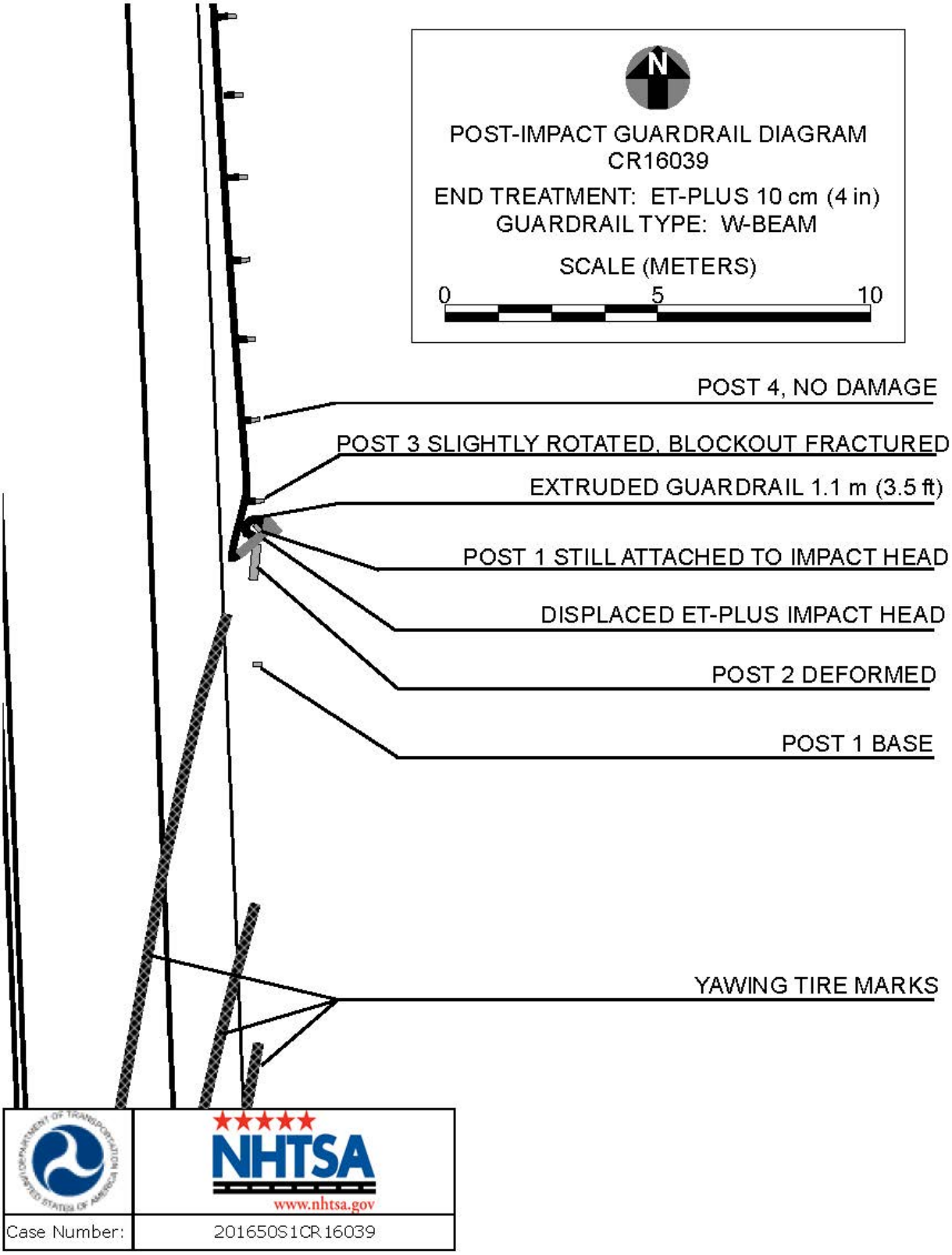
CRASH DIAGRAM



IMPACT DIAGRAM



POST-IMPACT GUARDRAIL DIAGRAM



APPENDIX A:

Federal Highway Administration Guardrail Form

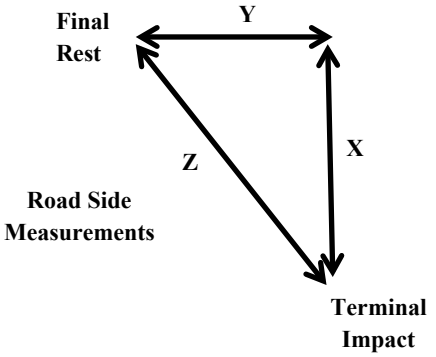
Case No.: CR16039

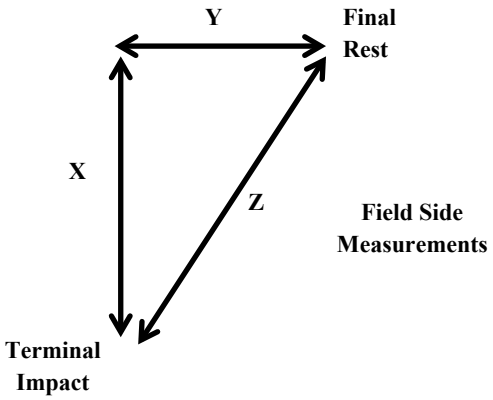
PREPOPULATED DATA (BY OTHERS)			
Crash Date	December 2016	**Time of Crash**	Late Evening
Case Number	CR16039	**State**	PA
Traffic Route	SR 441	**Direction (Southbound = SB)**	NB
Ambient Conditions (at time of crash)			
Temperature (°F)	41 °F	**Lighting**	Dark, not lighted
Atmospheric	Light rain		

SCENE INFORMATION	
Type of area where crash occurred	❒Urban ■Rural ❒Suburban
Terminal on a horizontal curve?	■No ❒Curve/LT ❒Curve/RT
Estimated or Reconstructed Speed at Impact (mph)	40 mph
Est. distance (straight line) from terminal impact to COM final rest position (ft)	Z = 68.0 ft ❒Road side ■Field Side
Est. distance (longitudinal) along guardrail from terminal impact to COM final resting location (ft)	X = 58.0 ft
Est. distance (normal) from either 1. the white paint line; or 2. roadway/shoulder/pavement edge to COM rest position (ft)	Y = 35.5 ft
Super elevation	❒+2% ❒-2% ■ NONE or FLAT
Curve Radius (ft)	N/A

KEY:

- COM - Center of Mass of Vehicle
- Distance Measurements





ON-SCENE INFORMATION		
End Treatment Type	■Extruder	❒ET2000 ■ET-PLUS 4in ❒ET-PLUS 5in ❒SKT ❒FLEAT ❒SOFT STOP
	❒Telescope	❒X-LITE ❒X-TENSION
Curb?	■No ❒Yes	❒AASHTO Type A ❒AASHTO Type B ❒AASHTO Type C ❒AASHTO Type D ❒AASHTO Type E ❒AASHTO Type F ❒AASHTO Type G ❒AASHTO Type H
Curb Height: N/A		

GUARDRAIL INSTALLATION									
Post No.	Post		Block-Out		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	-	-	-	-	-	-	-	-	-
1	Steel I-beam	6 x 4	N/A	N/A	NO	N/A	7 ft 5 in	N/A	6 ft 7 in
2	Steel I-beam	6 x 4	N/A	N/A	NO	N/A	7 ft 5 in	N/A	5 ft 11 in
3	Steel I-beam	6 x 4	Composite	8 x 4	NO	N/A	7 ft 11 in	N/A	6 ft 4 in

GUARDRAIL INSTALLATION									
Post No.	Post		Block-Out		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.)					
4	Steel I-beam	6 x 4	Composite	8 x 4	NO	N/A	7 ft 11 in	N/A	6 ft 2 in
5	Steel I-beam	6 x 4	Composite	8 x 4	NO	N/A	7 ft 9 in	N/A	6 ft 2 in
6	Steel I-beam	6 x 4	Composite	8 x 4	NO	N/A	7 ft 7 in	N/A	6 ft 4 in
7	Steel I-beam	6 x 4	Composite	8 x 4	NO	N/A	7 ft 5 in	N/A	6 ft 2 in
8	Steel I-beam	6 x 4	Composite	8 x 4	NO	N/A	7 ft 5 in	N/A	6 ft 3 in
9	-		-		-	-	-	-	-

GUARDRAIL INSTALLATION									
Post No.	Post		Block-Out		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.)					
10	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-

Additional Comments

NONE

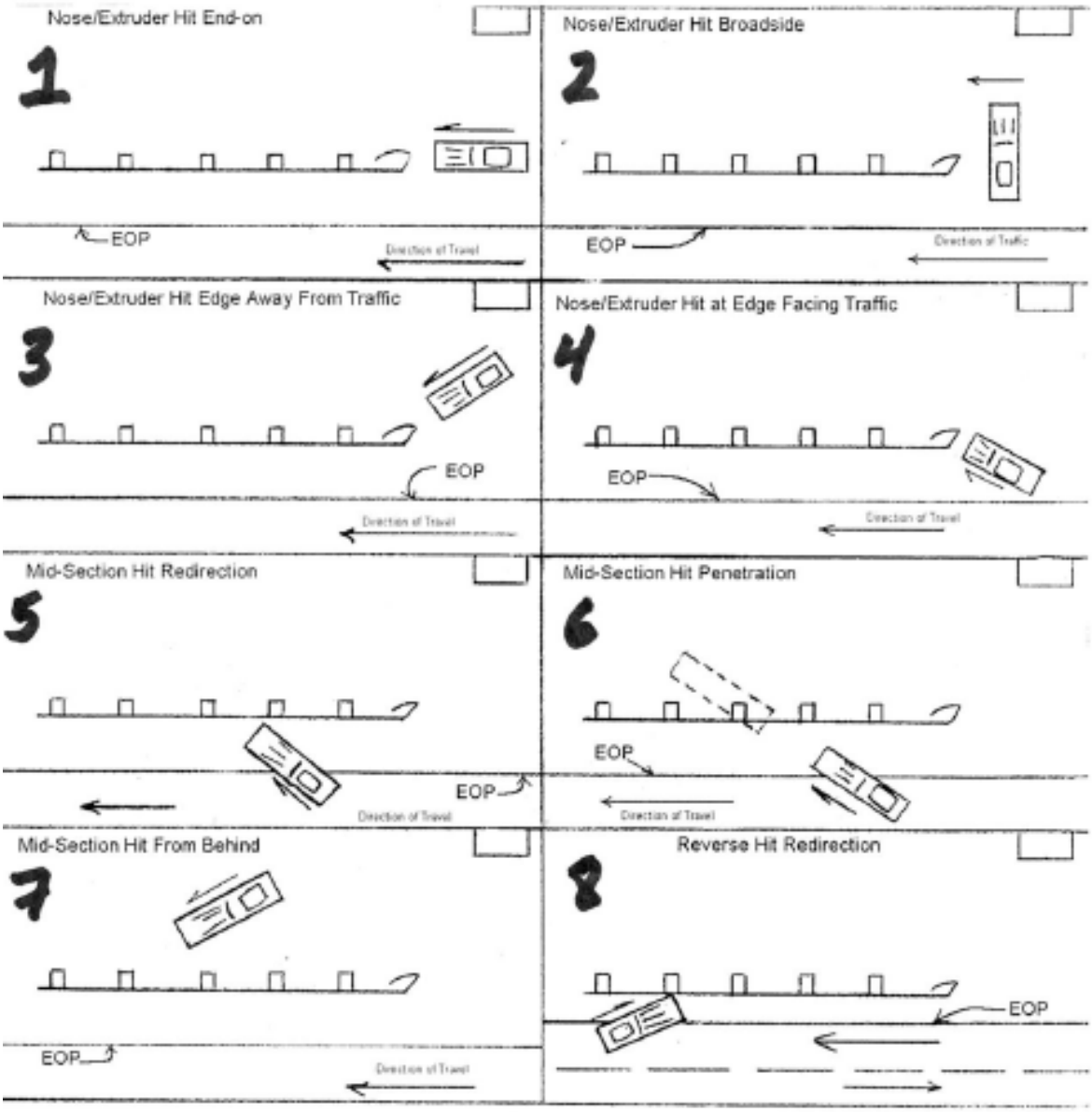
EXTRUDER			
Feeder Channel Width at impact head	■4inches ❒5 inches ❒Other _____		
Guide Chute Exit Height (in)	17 – 29 in		
Connection of feeder channels to head damaged?	■No ❒Yes	Are Welds Broken?	■No ❒Yes
Anchor Cable Present?	❒No ■Yes	Connected?	❒No ■Yes
Rail Extrusion?	❒No ■Yes	Length (ft. in.)	3 ft 6 in
Rail Extrusion Direction	❒Traffic Side ■Field Side		
Total Length of Rail Damaged (ft) [total length would include extruded rail plus damaged rail downstream from head.]	15 ft 0 in		

TELESCOPE				
Rail Displacement	❒No	❒Yes Length:	No of Panels Displaced	❒1 ❒2 ❒3 ❒4 ❒5 ❒6

ALL-SYSTEM PERFORMANCE				
Railkinks Downstream of Head?	■No	❒Yes	No. of Kinks in Rail:	N/A
Was there intrusion into the Occupant Compartment by foreign object (guardrail)?	■No ❒Yes			
Did vehicle impact other objects after impact with terminal?	❒No ■Yes			
Object Contacted	Ground (Rollover)			

ALL-SYSTEM PERFORMANCE ENVIRONMENT			
SIDESLOPE	**50 ft in advance of Post 1**	**At Post 1**	**50 ft Past Post 1**
Percent - %	+11%	0%	-25%
Adjacent Lane Width (ft)	12 ft 2 in		
Lane Type (NAS EDS Variable: Sur. Type)	Asphalt (wet)		
Shoulder Type	No shoulder		
Shoulder Width (ft)	6 ft 3 in		
Guardrail Height (in)	17 – 29 in		

VEHICLE INFORMATION		
Vehicle Type (NHTSA Input)	2000 VOLKSWAGEN JETTA	
Vehicle Identification Number (VIN)	3VWSC29M2YM049109	
Vehicle Mass (NASS var.: veh.wgt)	2,870 lbs	
Vehicle orientation upon impact	❒Case Type 1 ■Case Type 2 ❒ Case Type 3 ❒ Case Type 4 ❒ Case Type 5 ❒ Case Type 6 ❒ Case Type 7 ❒ Case Type 8 ❒ Other	
If "Other," describe	N/A	
Collision Deformation Classification	09LZEW2; 00TDDO2	
Delta-V	15 mph (*WinSMASH estimated*)	
Occupant Compartment Penetration of rail	■No	❒Yes; Describe:
Did the Vehicle Rollover?	■Yes ❒No	
Quarter Turns (NASS EDS variable: Rollover)	❒1 ❒2 ❒3 ❒4 ❒5 ■6 ❒7 ❒8 ❒9 ❒10 ❒11 ❒12 ❒13 ❒14 ❒15 ❒16 ❒17+	
Object Precipitating Rollover, (NASS EDS variable: Rollobj)	Ground	
Rollover Type, Terhune Scale, (NASS EDS variable: rolintyp)	Trip-over	


Nose/Extruder Hit End-on
1
EOP
Direction of Travel
Nose/Extruder Hit Broadside
2
EOP
Direction of Traffic
Nose/Extruder Hit Edge Away From Traffic
3
EOP
Direction of Travel
Nose/Extruder Hit at Edge Facing Traffic
4
EOP
Direction of Travel
Mid-Section Hit Redirection
5
EOP
Direction of Travel
Mid-Section Hit Penetration
6
EOP
Direction of Travel
Mid-Section Hit From Behind
7
EOP
Direction of Travel
Reverse Hit Redirection
8
EOP

DOT HS 812 595
August 2018

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

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