

**TRANSPORTATION SCIENCES
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**GENERAL DYNAMICS ON-SITE SIDE IMPACT INFLATABLE OCCUPANT
PROTECTION INVESTIGATION**

GENERAL DYNAMICS CASE NO: CA04-015

VEHICLE: 2002 GMC YUKON

LOCATION: PENNSYLVANIA

CRASH DATE: MARCH 2004

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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PRTOECTION INVESTIGATION
SCI CASE NO. – CA04-015
SUBJECT VEHICLE – 2002 GMC YUKON
LOCATION - STATE OF PENNSYLVANIA
CRASH DATE – MARCH 2004**

BACKGROUND

This on-site investigation focused on the performance of the side impact inflatable occupant protection system in a 2002 GMC Yukon (**Figure 1**). The system consisted of seat back mounted side impact air bags for the front seating positions. In addition, the GMC was equipped with redesigned frontal air bags that did not deploy and an Event Data Recorder (EDR) that was downloaded (Non-Deployment Event) during this on-site investigative effort. The EDR printout is included as **Attachment A** of this report. The GMC was occupied by an unrestrained 38-year-old female driver. The GMC was involved in a run-off-road collision with a utility pole and brush. As a result of the crash, the left side seat back mounted side impact air bag deployed.



Figure 1. Subject vehicle 2002 GMC Yukon.

The driver sustained moderate severity injuries and was transported to a local hospital where she was hospitalized for one day. The GMC sustained moderate damage and was towed from the crash site.

This crash was identified by the General Estimates System (GES) through the weekly review of Police Accident Reports (PAR). The PAR was forwarded to the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA). Due to the deployment of the side impact air bag in the GMC, NHTSA assigned and on-site investigative effort to the General Dynamics Special Crash Investigations (SCI) team. The GMC was located and cooperation was established with the salvage yard. The GMC and crash site were inspected on April 13, 2004.

SUMMARY

Crash Site

This run-off-road crash occurred during the morning hours of March 2004. At the time of the crash, snow was falling and the asphalt road surface was snow covered. The crash occurred off-road of an east/westbound two-lane, two-way, rural roadway. The east/westbound roadway was delineated by a double-yellow centerline and was bordered by white fog lines. The eastbound lane had a negative grade. The south roadside consisted of a 0.5-meter (1.6 feet) asphalt shoulder, grass, several trees, and a utility that was located 2.4 meters (7.9 feet) south of the road edge. The posted speed limit for the north/south roadway was 72 km/h (45 mph). The scene schematic is included as (**Figure 14**) of this report.

Vehicle Data – 2002 GMC Yukon

The 2002 GMC Yukon was identified by the Vehicle Identification Number (VIN): 3GKEK13Z02 (production sequence omitted). The odometer reading at the time of the inspection was unknown. The vehicle was a large four-door sport utility vehicle that was equipped with a 5.3-liter, V8 engine, 4-speed automatic transmission, four-wheel drive, power-front and rear disc brakes with anti-lock, OEM alloy wheels, power-steering, and a tilt steering wheel. The GMC was configured with Firestone Wilderness LE tires. The manufacturer recommended tire pressure was 241.3 kpa (35.0 psi). The specific tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	227.5 kpa (33.0 psi)	5 mm (6/32)	No	None
LR	248.2 kpa (36.0 psi)	5 mm (6/32)	No	None
RF	117.2 kpa (17.0 psi)	5 mm (6/32)	No	None
RR	237.8 kpa (34.5 psi)	5 mm (6/32)	No	None

The seating positions in the GMC were configured with front buckets seats with height adjustable head restraints. The front seat head restraints were both adjusted to the full-down position at the time of the vehicle inspection. The second row was configured with a three-passenger bench seat with no head restraints. The third row was configured with a two-passenger bench seat with height adjustable head restraints. The third row head restraints were adjusted to the full-down position.

Crash Sequence

Pre-Crash

The unrestrained 38-year-old female driver of the GMC was operating the vehicle downhill on the snow covered eastbound lane (**Figure 2**). As the driver continued eastbound, she lost directional control of the vehicle and began a clockwise rotation. The driver stated to the SCI investigator that she lost control on a patch of “black ice” on the snow-covered road. The GMC departed the south roadside and began to travel in a southeast trajectory. An unrelated tire mark was documented on the roadside that measured 1.1 meters (3.6 feet). Based on the EDR Non-Deployment data, the vehicle speed was 70.8 km/h (44.0 mph) five-seconds prior to Algorithm Enable (AE).



Figure 2. GMC's eastbound approach to the crash site.

Crash

The GMC traveled on the roadside 3.2 meters (10.5 feet) south of the white fog line in a clockwise rotation and impacted a large utility pole (**Figure 3**) with the left passenger compartment area. The left rear door was separated from the vehicle during maximum engagement. The impact to the utility pole caused the pole to fracture at the point of impact, however, the pole did not topple to the ground. The deformed pole created tension to the

attached power lines that were connected to a house on the north roadside. The tension pulled the lines from the house causing minor damage. The WINSMASH barrier equivalent algorithm was used to determine an approximate delta-V for this impact. The left rear door was separated from the vehicle during the crash; therefore, the sill level crush profile was used to compute a delta V using the damage algorithm of the WINSMASH program. The calculated barrier equivalent speed was 18.4 km/h (11.4 mph). The longitudinal and lateral components were -3.1 km/h (-1.9 mph) and 17.7 km/h (11.0 mph), respectively. Since the EDR records only longitudinal deceleration, the Non-Deployment event resulted in a 0.0 km/h delta-V for this side impact.



Figure 3. Impact area with the utility pole.

The impact area was rear of the center of gravity, which redirected the GMC in a counterclockwise rotation. The GMC rotated approximately 270 degrees to final rest and overrode downed branches and vegetation (**Figure 4**) that were located south of the struck utility pole. The GMC came to rest facing a northwest direction approximately 0.7 meters (2.3 feet) east of the utility pole.

Post-Crash

Police and EMS personnel responded to the crash site shortly after the crash. The driver was interviewed by the investigating police officer and was transported by ambulance to a local hospital where she was hospitalized for one day. The GMC sustained moderate damage and was towed from the crash site.

Vehicle Damage

Exterior Damage – 2002 GMC Yukon

The 2002 GMC Yukon sustained moderate damage as a result of the impact with the utility pole. The damaged components consisted of lateral deformation and abrasions to the left front door, left rear door, left sill, left side tubular step rail, left roof, and left roof side rail. Three crush profiles were documented for this impact.



Figure 4. Area of impact with the shrub.

The first crush profile was documented at the sill level (**Figure 5**) due to the separation of the left rear door. The direct contact damage measured 130.0 cm (51.2”) and began 52.0 cm (20.5”) forward of the left rear axle. Six crush measurements were measured along the sill using a combined direct and induced damage width of 168.0 cm (66.1”) and were as follows: C1 = 11.5 cm (4.5”), C2 = 36.0 cm (14.2”), C3 = 30.0 cm (11.8”), C4 = 21.0 cm (8.3”), C5 = 11.0 cm (4.3”), C6 = 8.0 cm (3.1”).

The second crush profile was measured along the mid-door level (**Figure 6**). The direct contact damage measured 78.0 cm (30.7") and began 88.0 cm (34.6") forward of the left rear axle and extended to 48.0 cm (18.9") forward of the rear edge of the left front door. Six crush measurements were recorded using a combined direct and induced damage width of 194.0 cm (76.4") and were as follows: C1 = 7.0 cm (2.8"), C2 = 5.0 cm (2.0"), C3 = 27.0 cm (10.6"), C4 = 18.2 cm (7.2"), C5 = 8.5 cm (3.3"), C6 = 0.0.



Figure 5. Sill level crush profile.



Figure 6. Mid-door crush profile.

The third crush profile was measured along the roof side rail (**Figure 7**). The direct contact damage measured 78.0 cm (30.7") and began 88.0 cm (34.6") forward of the left rear axle and extended forward 48.0 cm (18.9"). The residual deformation was measured using a combined direct and induced damage width of 194.0 cm (76.4") and were as follows: C1 = 26.0 cm (10.2"), C2 = 50.0 cm (19.7"), C3 = 49.0 cm (19.3"), C4 = 25.0 cm (9.8"), C5 = 28.5 cm (11.2"), C6 = 5.5 cm (2.2"). The Collision Deformation Classification (CDC) for the utility pole impact was 09-LPAW-4.



Figure 7. Roof side rail crush profile.

The GMC sustained no residual damage as a result of overriding the downed branches and vegetation.

The GMC's windshield was fractured from the lateral deformation of the roof side rail and the left front and left rear glazing were disintegrated from contact with the utility pole. The remainder of the glazing remained intact. The front left door remained closed during the crash. The door would not close post-crash due body distortion and the latch was damaged from forcing the door open post-crash. The left rear door was separated at impact at the hinge points on the B-pillar (**Figure 8**). The right side doors and rear tailgate remained closed during the crash and operational post-crash.



Figure 8. Left rear door B-pillar mounted hinges. Torn during utility pole impact.

Interior Damage – 2002 GMC Yukon

The 2002 GMC Yukon sustained moderate interior damage as a result of occupant contacts and passenger compartment intrusion. The driver’s contacts consisted of a crack to upper left door panel from probable contact with the driver’s left arm/shoulder. The left front door control panel (switches for power windows/locks) was displaced from probable contact with the driver’s left thigh. A probable head contact was noted to the grab handle that was mounted above the B-pillar with body fluid noted on the handle. Two scuffmarks were noted to the knee bolster from probable contact with the driver’s knees. A contact was noted to the left A-pillar plastic trim, which was evidenced by a scuff, scratches, and possible skin transfer. The front left head restraint contained a small spot of dried body fluid that may have resulted from a possible rebound contact from the driver’s head. **Figure 9** is an overall view of the contact points. The passenger compartment intrusions are listed in the table below:



Figure 9. Overall view of contact points.

Seat Position	Intruded Component	Magnitude	Direction
Front left	Door	15.0 cm (5.9")	Lateral
Front left	Sill	11.0 cm (4.3")	Lateral
Front left	Left seatback	17.0 cm (6.7")	Lateral
Front left	A-pillar	26.0 cm (10.2")	Lateral
Front left	Roof side rail	53.0 cm (20.9")	Lateral
Rear left	Door	Est. due to the detached door 15.0 cm (5.9")	Lateral
Rear left	B-pillar	62.5 cm (24.6")	Lateral
Rear left	Sill	10.0 cm (3.9")	Lateral
Rear left	Roof side rail	55.0 cm (21.7")	Lateral
Rear left	Seat cushion	4.0 cm (1.6")	Vertical
Rear left	C-pillar	17.0 cm (6.7")	Lateral

Side Impact Inflatable Occupant Protection System – 2002 GMC Yukon

The 2002 GMC Yukon was equipped with seat back mounted side impact air bags for the front seating positions. The front left side impact air bag deployed as a result of the impact with the utility pole (**Figures 10 and 11**). A single rectangular cover flap that measured 16.0 cm (6.9") in height and 6.0 cm (2.4") wide concealed the air bag module. The air bag membrane measured 40.5 cm (15.9") from the forward edge in relation to the vehicle to the air bag module and was 24.1 cm (9.5") in height. There were several small cuts noted to the air bag membrane from

contact with the shattered side glazing; however, these were superficial and did not compromise the inflation of the air bag. A larger superficial laceration was noted to the air bag membrane that was located 17.0 cm-19.5 cm (6.7"-7.7") rear of the forward edge. There was no occupant contact evidence noted to the air bag; however, dirt was present on the air bag from post-crash handling. A single vertically oriented seam was documented on the outboard aspect of the air bag module that was located 23.5 cm (9.3") rear of the forward edge. The air bag contained no tethers or vent ports.



Figure 10. Outboard aspect of driver's side impact air bag.



Figure 11. Inboard aspect of driver's side impact air bag.

The front right seat back mounted side impact air bag did not deploy in this crash.

Frontal Air Bag System – 2002 GMC Yukon

The 2002 GMC Yukon was equipped redesigned frontal air bags for the driver and front right passenger. The driver's frontal air bag was located in the center of the steering wheel hub. The front right air bag was mid-mounted on the front right instrument panel. The frontal air bags did not deploy in the subject crash (**Figure 12**).



Figure 12. Non-deployed frontal air bag system.

Event Data Recorder – 2002 GMC Yukon

The 2002 GMC Yukon was equipped with an Event Data Recorder (EDR). The EDR was downloaded during the SCI inspection and the printout is included as **Attachment A** of this report. The GMC's battery and wiring harness were not damaged during the crash; however, the battery cables were loosely attached and power was not supplied to the vehicle. The SCI investigator adjusted the battery cables and power was restored to the vehicle. This allowed the SCI investigator to download the EDR through the Diagnostic Link Connector (DLC).

The EDR recorded a Near Deployment for the subject crash. The data indicated the driver safety belt switch circuit status was unbuckled and the vehicle speed was 70.8 km/h (44.0 mph) five seconds prior to Algorithm Enable (AE). The brake switch status was in the "Off" position five, four and two second's prior to AE and in the "On" position three and one second's prior to AE.

Since the EDR records only longitudinal deceleration, the Non-Deployment event resulted in a 0.0 km/h delta-V for this side impact.

Manual Restraints System– 2002 GMC Yukon

The 2002 GMC Yukon was equipped with integrated manual 3-point lap and shoulder safety belts for the front seating positions. The second row outboard positions were equipped with manual 3-point lap and shoulder safety belts and a center 2-point manual lap belt. The third row was equipped with integrated manual 3-point lap and shoulder safety belts. The driver’s safety belt (**Figure 13**) was configured with a sliding latch plate, and an Emergency Locking Retractor (ELR). Historical usage evidence was noted to the driver’s latch plate, which consisted of minor scratches. Although the driver stated to the SCI investigator that she used her lap and shoulder safety belt. There was no crash related usage evidence such as transfers or stretching on the driver’s safety belt which indicated that the driver did not utilize her safety belt in the crash. Furthermore, the EDR data also indicated that the driver’s safety belt switch circuit status was unbuckled.



Figure 13. Driver’s integrated 3-point manual lap and shoulder safety belt.

The front right, second row outboard, and third row outboard safety belts were configured with sliding latch plates and switchable ELR/Automatic Locking Retractor (ALR). The second row center safety belt was configured with a locking latch plate and no retractor.

Driver Occupant Demographics – 2002 GMC Yukon

Driver

Age/Sex:	38-year-old female
Height:	157.5 cm (62.0”)
Weight:	68.0 kgs (150.0 lbs)
Seat Track Position:	Full forward [(22.0 cm (8.7”)) of track travel]
Manual Restraint Use:	None Used
Usage Source:	Vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Transported to a local hospital where she was hospitalized.

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Two parallel oblique lacerations overlying the left middle finger extensor tendon zone 6 with 25% transection proximal to the metacarpal joint. Complete transaction of the second laceration 3.0 cm (1.2") proximal to metacarpal joint.	Moderate (740200.1,2)	Left A-pillar trim panel
3.0 cm (1.2") laceration to the lower lip	Minor (290602.1,8)	Steering wheel
Chin contusion, NFS	Minor (290402.1,8)	Steering wheel
Dorsal right hand 2.0 cm (0.8") contusion	Minor (790402.1,1)	Center instrument panel

Driver Kinematics

The 38-year-old female driver of the 2002 GMC Yukon was seated in a presumed upright posture with the seat track adjusted to a full-forward track position. The driver stated to the SCI investigator that she was restrained by the vehicle safety belt. Historical usage evidence was noted to the driver's latch plate, which consisted of minor scratches. There was no crash related usage evidence such as transfers or stretching on the driver's safety belt which indicated that the driver did not utilize her safety belt in the crash. Furthermore, the EDR data also indicated that the driver's safety belt switch circuit status was unbuckled.

The driver stated to the SCI investigator that she pulled her knees up toward her when she realized the impact with the utility pole was imminent. At impact with the utility pole, the left side impact air bag deployed. The driver initiated a lateral left trajectory towards the front left door. The driver's left hand contacted the left A-pillar trim panel, which resulted in the two-tendon lacerations of the left middle finger. As the GMC rotated counterclockwise the driver initiated a forward and right trajectory. Her lower lip and chin contacted the steering wheel rim which resulted in the lower lip laceration and the chin contusion. The driver's right hand contacted the center instrument panel resulting in the dorsal right hand 2.0 cm (0.8") contusion.

Medical Treatment

The driver was transported to a local hospital where she was hospitalized for one day. She underwent reconstructive surgery to repair the lacerated tendons in her left hand.

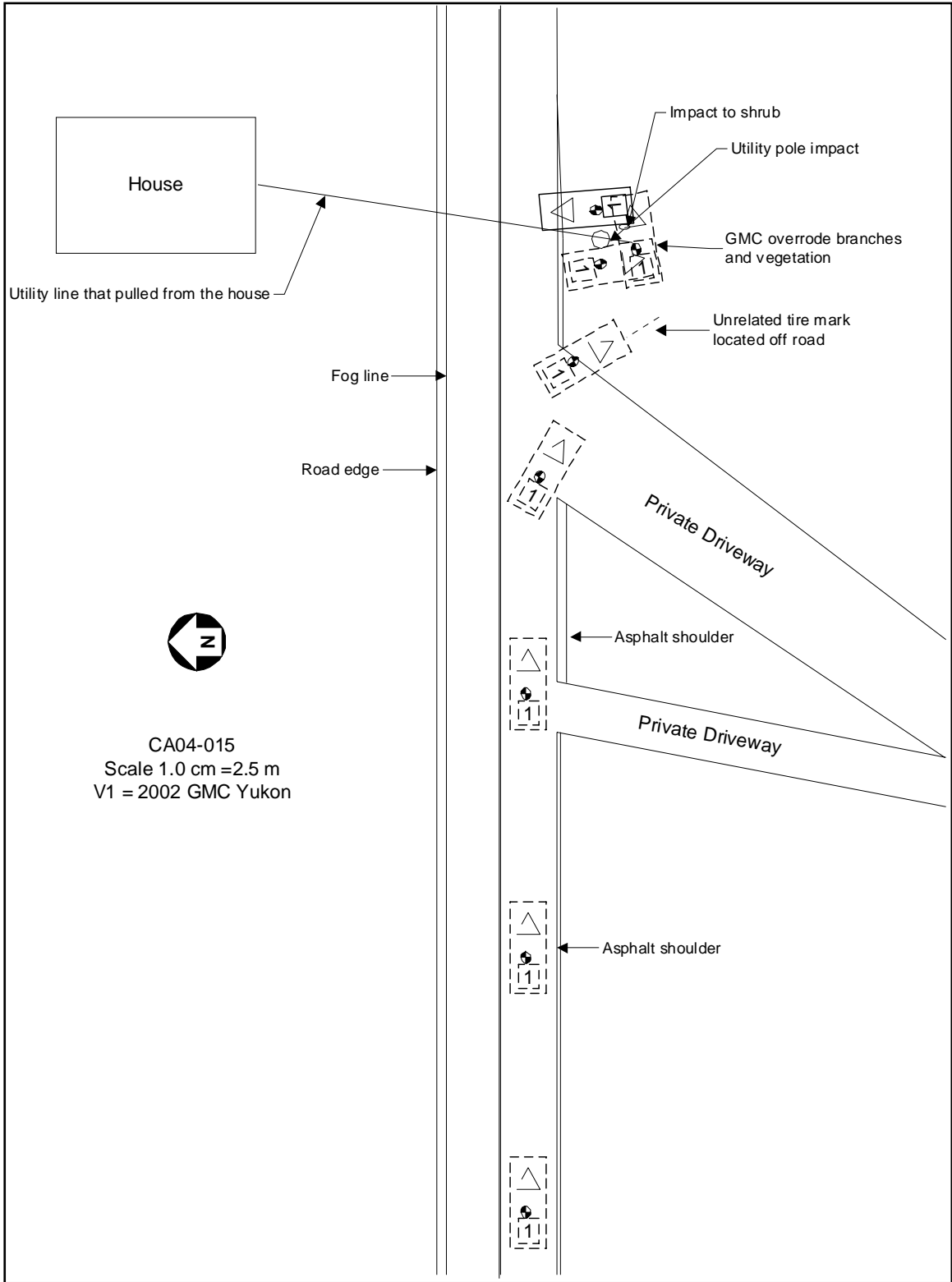


Figure 14. Scene schematic

Attachment A: GMC's EDR Printout