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ON-SITE POTENTIAL SAFETY-RELATED DEFECT INVESTIGATION

CASE NUMBER - IN-04-025
LOCATION - Missouri
VEHICLE - 2004 SATURN VUE
CRASH DATE - July 2004

Submitted:

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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 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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16. *Abstract*

This report covers an on-site investigation of a potential safety-related defect investigation that involved a 2004 Saturn Vue (case vehicle),which ran-off-road into a ditch and rolled over. This crash is of special interest because the vehicle's owner contacted the Auto Safety Hotline and reported that the case vehicle's right rear wheel collapsed during the crash sequence causing the vehicle to roll over, and the case vehicle's driver (17-year-old, male) and front right passenger (24-year-old female) sustained minor injuries as a result of the crash. The case vehicle was traveling northwest on a two lane county roadway in a left curve at the beginning of an "S-curve". The case vehicle's right side tires departed the edge of the roadway and entered loose gravel in the mouth of an intersecting roadway at the apex of the curve. The driver steered left to regain the roadway and negotiate the curve, and the right rear tire began to slip sideways in the loose gravel. The vehicle began to rotate counterclockwise, and the driver steered right and then left and the case vehicle yawed counterclockwise across the roadway. The front end then entered a ditch on the south side of the roadway and the right front corner and right front wheel impacted the back slope of a ditch causing the vehicle to begin rolling over, passenger side leading. The impact accelerated the counterclockwise rotation, the back end swung around as the vehicle rolled over, and the right rear wheel impacted the back slope of the ditch damaging the wheel and suspension components. The driver and front right air bags did not deploy as a result of the crash. The EDR data indicated the longitudinal deceleration was not severe enough to require deployment of the air bags. The case vehicle rolled over one-quarter turn and came to rest on its right side on the south side of the roadway facing northeast. The evidence indicated that the right rear wheel did not collapse prior to the rollover. Rather, the damage to the right rear wheel and suspension was caused after the vehicle began rolling over when the right rear wheel impacted the back slope of the ditch. The driver and both occupants were restrained by their safety belt systems. The driver sustained an abrasion to his right knee from impact with the center console. The front right passenger sustained bruises to her right upper arm and right lower leg from contact with the right window sill and door. The back right passenger was not injured. None of the occupants were transported from the scene for medical treatment and sought no treatment subsequent to the crash.

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This investigation was brought to NHTSA's attention on or before July 29, 2004 by a call to the Auto Safety Hotline in Washington, D.C. This crash involved a 2004 Saturn Vue (case vehicle), which ran-off-road into a ditch and rolled over. The crash occurred in July, 2004 at 10 p.m., in Missouri and was investigated by the Missouri State Highway Patrol. This crash is of special interest because it was alleged that the case vehicle's right rear wheel collapsed during the crash sequence causing the case vehicle to roll over, and the case vehicle's driver [17-year-old, White (non-Hispanic) male] and front right passenger [24-year-old, White (non-Hispanic) female] sustained minor injuries as a result of the crash. This contractor and representatives of the agency's Office of Defects Investigation (ODI) in Washington, D.C. and General Motors inspected the case vehicle and scene on August 5, 2004. This contractor also downloaded the case vehicle's Event Data Recorder (EDR) and interviewed the case vehicle's driver on August 5, 2004. This report is based on the police crash report, scene and vehicle inspections, interview with the driver, occupant kinematic principles and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling northwest on a two lane county roadway in a left curve at the beginning of an "S-curve". The case vehicle's right side tires departed the edge of the roadway and entered loose gravel in the mouth of an intersecting roadway at the peak of the curve. The driver steered left to regain the roadway and negotiate the curve, and the right rear tire began to slip sideways in the loose gravel. The vehicle began to rotate counterclockwise and travel toward the south side of the roadway. The driver steered the vehicle back to the right and began to travel toward the north side of the roadway, and he steered left as the case vehicle approached the north edge of the roadway. This steer maneuver put the vehicle into a counterclockwise yaw, and the vehicle yawed counterclockwise across the roadway. The front end departed the south side of the roadway as the vehicle continued to rotate counterclockwise. The right front corner and right front wheel then impacted the back slope of the ditch causing the vehicle to begin rolling over, passenger side leading. The impact accelerated the counterclockwise rotation and the back end swung around as the vehicle rolled over, and the right rear wheel impacted the back slope of the ditch. This impact damaged the right rear wheel and suspension components. The driver and front right air bags did not deploy as a result of the crash. The EDR data indicated the longitudinal deceleration was not severe enough to require deployment of the air bags. The case vehicle rolled over one-quarter turn and came to rest on its right side on the south side of the roadway facing northeast.

The evidence on the vehicle and at the scene indicated this crash was an impact-induced, passenger side leading rollover. The rollover was initiated when the right front corner and right front wheel impacted the back slope of the ditch as the case vehicle departed the south side of the roadway in a severe counterclockwise yaw. The right rear wheel did not collapse and cause the rollover. Rather, the damage to the right rear wheel and suspension was caused as the rear end swung around during the rollover impacting the right rear wheel against the back slope of the ditch.

The CDCs for the case vehicle were determined to be: **00-RFEW-2** for the impact to the right front corner of the vehicle with the back slope of the ditch and **00-RDEO-1** for the rollover onto the right side. The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's Delta V because non-horizontal impacts and rollovers are out-of-scope for the WinSMASH program. Based on the damage to the vehicle, this contractor estimates the severity of the right front impact to be minor. In addition, the one quarter turn rollover and resulting damage to the right side of the vehicle indicates that the severity of the rollover was minor. The reconstructed speed of the case vehicle at the beginning of the final yaw that led to the rollover was determined to be approximately 65 km.p.h. (40 m.p.h.).

Immediately prior to the initial loss of control, the case vehicle's driver was seated in an upright posture with his back against the seat back, his left foot on the floor, right foot on the accelerator, left hand on the steering wheel and right hand on the gear shift lever. His seat track was located in its middle position, the seat back was slightly reclined, and the tilt steering wheel was located in its down-most position. He was restrained by his manual, three-point safety belt system. The driver steered left, right and left again in an attempt to regain control of the case vehicle prior to the rollover. He did not apply the brakes. The case vehicle's right front impact with the back slope of the ditch caused the driver to move forward and to the right, and he impacted his right knee on the center console abrading his knee. The driver remained restrained in his seat position as the case vehicle rolled over and came to rest on its right side. The driver was able to exit the case vehicle under his own power following the crash. He was not transported from the scene to a medical facility and sought no medical treatment subsequent to the crash.

Immediately prior to the initial loss of control, the case vehicle's front right passenger was seated in an upright posture with her back against the seat back, her feet on the floor and she was holding a cigarette. Her seat track was located in its middle position, and the seat back was slightly reclined. She was restrained by her manual, three-point safety belt system. The front right passenger was most likely up against the right front door due to the counterclockwise yaw as the case vehicle entered the ditch just prior to the rollover. The case vehicle's right front impact to the back slope of the ditch and the rollover caused the passenger to impact her upper right arm on the window sill and her right lower leg on the right front door bruising her arm and leg, and her head contacted the right front window. She stayed in contact with the door as the case vehicle rolled over and came to final rest on its right side. She was able to exit the case vehicle under her own power following the crash. She was not transported from the scene to a medical facility and sought no medical treatment subsequent to the crash.

Immediately prior to the initial loss of control, the case vehicle's back right passenger (6 year-old son of the front right passenger) was seated in an upright position with his back against the seat, his feet hanging over the front edge of the seat, and his hands in an unknown position. His seat track and seat back were not adjustable. He was restrained by his manual, three-point safety belt system with the lap belt low on his lap and the shoulder belt behind his back. The back right passenger was most likely up against the right rear door due to the counterclockwise yaw as the case vehicle entered the ditch just prior to the rollover. He most likely impacted the door and stayed in contact with the door as the case vehicle impacted the back slope of the ditch and rolled onto its right side. He remained restrained in his seat position and was able to exit the case vehicle

following the crash with some assistance from the other occupants. The back right passenger sustained no injury and was not transported from the scene to a medical facility.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the case vehicle was traveling was a two-way, undivided, bituminous county roadway traversing in a northwest and southeast direction. The northwest bound travel lane was 2.9 meters (9.5 feet) wide and the southeast bound travel lane was 3.4 meters (11.2 feet) wide. Each travel lane was bordered by an approximate 0.5 meter (1.6 feet) wide band of pavement and a narrow grass shoulder that sloped into a ditch.. The case vehicle's approach to the crash scene traversed up an approximate 9.3% positive grade and curved left into an "S-curve" (**Figure 1**). The left curve of the "S" had a positive superelevation of about 4%. The right curve of the "S" had an approximate 3.5% positive grade and an approximate 6.4% positive superelevation. In the left curve on the case vehicle's right was a two lane, undivided county roadway that formed a "Tee" intersection with the roadway (**Figure 2**). There was loose gravel in the mouth of this roadway. The case vehicle's roadway pavement markings consisted of double yellow no-passing lines at the center of the roadway and white edge lines. The speed limit was 88 km.p.h. (55 m.p.h.), and the roadway coefficient of friction was estimated to be approximately 0.75. At the time of the crash the light condition was dark, the atmospheric condition was cloudy and the road pavement was dry. Traffic density was light and the site of the crash was rural. See the Crash Diagram at the end of this report.

Figure 1: Approach of case vehicle northwest bound approaching intersecting roadway, arrow shows intersection

Figure 2: Intersecting roadway with loose gravel, arrow shows area of first right rear yaw mark

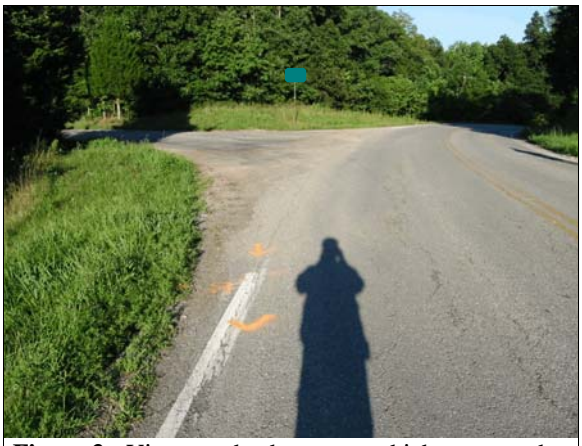


Figure 3: View east back to case vehicles approach, orange paint shows first right rear yaw mark

Pre-Crash: The case vehicle was traveling northwest in the northwest bound lane in a left curve at the beginning of the "S-curve". The case vehicle's driver was intending to negotiate the "S-curve" and continue northwest bound. A striated tire mark was found on the north edge line of the roadway just west of the "Tee" intersection (**Figure 2** above). The tire mark striations indicate a tire that is rotating and slipping sideways, the signature of a yaw mark. This indicates the vehicle was beginning to yaw counterclockwise as it exited the left curve. Projecting the tire mark back to the vehicle's approach (**Figure 3** above) indicates that the right side tires departed the edge of the roadway and entered the loose gravel in the mouth of the intersecting roadway. As the driver steered left to regain the roadway and negotiate the curve, the right rear tire began to slip sideways in the loose gravel, and the vehicle began to rotate counterclockwise and travel toward the south side of the roadway. A left rear yaw mark was found on the south edge line of the roadway (**Figure 4**) indicating the driver then steered the vehicle back to the right and began to travel toward the north side of the roadway. A right rear yaw mark was found on the north edge line of the roadway (**Figure 5**) indicating the driver then steered left. This steer maneuver put the vehicle into a counterclockwise yaw and the right rear wheel departed the north edge of the roadway. The right rear wheel then reentered the roadway and the vehicle continued to yaw counterclockwise across the roadway toward the ditch on the south side of the roadway (**Figure 6**). The crash occurred in the ditch on the south side of the roadway.

Figure 4: View west to left rear yaw mark on south edge line of roadway (orange arrow), red arrow shows area of second right rear yaw mark

Figure 5: View west to second right rear yaw mark on north edge line of roadway and in grass, red arrow shows location of crash

Figure 6: View southwest to case vehicle's yaw path leading to the area of rollover, indicated by arrow

Figure 7: Front fender damage, grass in right front wheel bead from impact with ditch back slope

Crash: The case vehicle had rotated counterclockwise about 90 degrees as the front end departed the south side of the roadway. As the front of the vehicle traveled down the front slope of the ditch, the right rear wheel entered the grass shoulder as the vehicle continued to rotate. The right front corner and right front wheel (**Figure 7** above and **Figure 8**) impacted the back slope of the ditch (**Figure 9**) causing the vehicle to begin rolling over, passenger side leading. The impact accelerated the counterclockwise rotation of the vehicle, the back end swung around to the right, and the right rear wheel impacted the back slope of the ditch (**Figure 10**) as the vehicle was rolling over. This impact damaged the right rear wheel and suspension components bending the wheel in at the bottom and angling it inward at the front. The vehicle was rolled right due to the counterclockwise yaw as it entered the ditch. However, it is this contractor's opinion that the impact of the front right corner and right front wheel into the back slope of the ditch was the primary mechanism that tripped the vehicle and caused it to roll over one-quarter turn onto its passenger side. The driver's air bag and front right air bag did not deploy as a result of the crash because there was no longitudinal deceleration of sufficient severity to require their deployment.

Figure 8: Case vehicle's front bumper cover showing dirt transfer and ground contact damage to right half of the bumper cover

Figure 9: Right front corner and wheel impacted at safety cone on left, right rear wheel impacted at safety cone on right, arrow shows area of rest

Post-Crash: The case vehicle came to rest on its right side on the south side of the roadway facing northeast (**Figure 9**). The passengers were able to exit the vehicle under their own power.

Figure 10: View to south at divot in back slope of ditch from impact of case vehicle's right rear wheel

CASE VEHICLE

The 2004 Saturn Vue was a front wheel drive, four-door sport utility vehicle (VIN: 5GZCZ23D44S------) equipped with a 2.2 L, four cylinder engine and a five-speed manual transmission. Braking was achieved by power assisted front disc and rear drum brakes. The front bucket seats were equipped with adjustable head restraints; height adjustable, manual, three point, lap-and-shoulder safety belts with safety belt buckle switch sensors, pretensioners and

energy absorbing retractors. The driver and front right passenger positions were also equipped with dual stage air bags. The back seat was equipped with a split bench seat with folding backs, adjustable head restraints in the outboard seat position and manual, three-point, lap-and-shoulder safety belts in all three seat positions. In addition, the case vehicle was equipped with an EDR housed within the air bag system's Sensing and Diagnostic Module (SDM) and a LATCH system for securing child safety seats. Side curtain air bags, anti-lock brakes and traction control were options, but the case vehicle was not so equipped. The case vehicle's wheelbase was 271 centimeters (106.7 inches), and the odometer reading at the time of the inspection was 7,766 kilometers (4,826 miles).

Figure 11: Direct damage scratches began at front of right front fender, grass in right front wheel bead

Figure 12: Case vehicle's right front and right rear doors were undamaged

Figure 13: Overview of case vehicle's right side doors, right rear wheel and quarter panel, arrow shows grass/dirt jammed in quarter panel seam

CASE VEHICLE DAMAGE

Exterior Damage: The case vehicle's initial contact with the back slope of the ditch involved the right front wheel, right portion of the front bumper and right fender. The bumper cover, right headlamp/turn lamp assembly, right edge of the hood and right fender were directly damaged. The direct damage involved about half the width of the front bumper. There was no residual crush to the front bumper; however, the right fender frame and radiator frame were displaced. The direct damage to the right side began at the right bumper corner and hood and extended approximately 70 centimeters (27.6 inches) rearward on the edge of the hood and 81 centimeters (31.9 inches) rearward on the front fender, beginning at the front edge of the fender (**Figure 11**). The center portion of the vehicle's right side did not show any signs of direct damage (**Figure 12**), although the right side mirror was turned in against the window. There was direct ground contact to the right rear wheel, and the wheel was bent it in at the bottom and displaced forward. The right quarter panel was also directly damaged. Grass and dirt were lodged in the seam between the back bumper cover and lower quarter panel (**Figure 13**). The case vehicle's left side wheelbase was unaltered, but the right side

wheelbase was shortened 10 centimeters (3.9 inches). Induced damage involved the hood, front bumper cover, and suspension components of the right rear wheel. The right side panels of the vehicle where constructed of plastic, which was most likely the reason there was no induced damage to these components.

The recommended tire size was: P235/65R16 and the vehicle was equipped with tires of this size. The case vehicle's tire data are shown in the table below.

Tire	*Measured Pressure*		*Recommend Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kpa	psi	kpa	psi	milli-meters	32nd of an inch			
LF	241	35	207	30	6	7	None	No	No
RF	138	20	207	30	7	9	None, but grass in bead	No	No
LR	241	35	207	30	7	9	None	No	No
RR	0	0	207	30	7	9	Abrasions and dirt on rim, grass in bead	Partial, rubs trailing arm	No

Vehicle Interior: Inspection of the case vehicle's interior revealed occupant contacts on the center console trim, front right roof, glove box door and right front door and window (**Figure 14** and **Figure 15** below). Some of these contacts could have occurred as the occupants were exiting the vehicle. There was an obvious shoe print on the right roof side rail that apparently occurred as the occupants were climbing out of the vehicle. There were no intrusions of the passenger compartment and no evidence of compression to the energy absorbing steering column or deformation of the steering wheel rim was observed (**Figure 16** below).

Figure 14: Overview of windshield, steering wheel and instrument panel

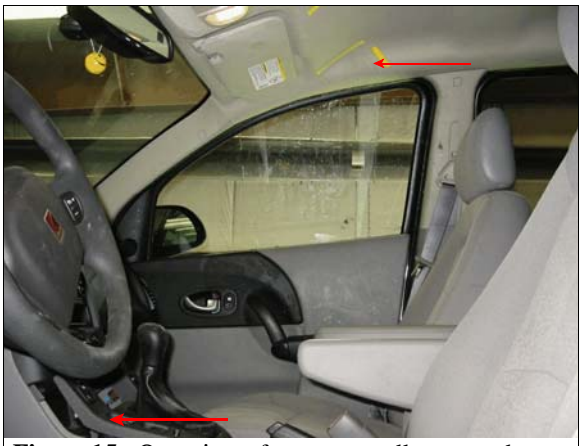


Figure 15: Overview of contacts, yellow tape shows marks on roof, arrows show shoe print on roof and displaced floor console trim

Figure 16: Overview of the case vehicle's steering wheel and steering column

Figure 17: Damage to right rear suspension, toe link bent in V-shape, right rear tire against bent trailing arm, arrow shows upper control arm

Figure 18: Overview of back and right side of case vehicle showing condition of right rear wheel

Damage Classification: Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **00-RFEW-2** for the right front impact with the back slope of the ditch and **00-RDEO-1** for the rollover onto the right side. The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's Delta V because non-horizontal impacts and rollovers are out-of-scope for the WinSMASH program. Based on the damage to the vehicle, this contractor estimates the severity of the right front impact to be minor. In addition, the one quarter turn rollover and resulting damage to the right side of the vehicle indicates that the severity of the rollover was minor. The case vehicle was towed due to damage.

ANALYSIS OF ALLEGED RIGHT REAR SUSPENSION FAILURE

The case vehicle's owner stated in the Auto Safety Hotline, Vehicle Owner's Questionnaire that when the case vehicle went into the ditch, the right rear wheel collapsed and the vehicle overturned. This contractor's inspection of the case vehicle revealed that the right rear toe link and trailing arm were badly bent (**Figure 17**), and the right rear tire was against the trailing arm and front of the wheel house. The upper control arm appeared to be deformed as well. The right rear wheel was observed to be bent in at the bottom about 20 degrees (**Figure 18**) and angled to

the left due to the toe control link and trailing arm damage. There also were scratches and dirt residue found on the wheel rim and lug nuts (**Figure 19**). In addition, the scene inspection revealed a ground divot in the back slope of the ditch (**Figure 10** above) that corresponded to an impact by the right rear wheel during the rollover. Based on the evidence, this contractor concludes that this was an impact- induced, passenger side leading rollover that occurred as the case vehicle departed the south side of the roadway and entered a ditch in a severe counterclockwise yaw. The right rear wheel did not collapse causing the rollover. The rollover was initiated when the right front corner and right front wheel impacted the back slope of the ditch. The right rear wheel and suspension damage was caused as the back of the case vehicle swung around during the rollover and the right rear wheel impacted the back slope of the ditch.

Figure 19: Right rear wheel, dirt on lug nuts and rim, arrow shows scratches on rim

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with dual stage air bags at the driver and front right passenger positions. The case vehicle's driver air bag was located in the steering wheel hub and the front right passenger air bag was located in the middle instrument panel above the glove box door (**Figure 20**). Neither of these air bags deployed during the crash. The evidence and the EDR data indicate that the frontal impact was not severe enough to require their deployment.

Figure 20: Front right air bag located in middle of instrument panel above glove box door

CRASH DATA RECORDING

The download of the case vehicle's EDR was done during the vehicle inspection via connection to the case vehicle's diagnostic link connector. The EDR recorded a non-deployment event. The EDR reports (**Figures 21 - 23**) are presented at the end of this report. It is this contractor's opinion that the crash sensing algorithm was activated when the case vehicle's right front corner impacted the back slope of the ditch. The system status report indicates the case vehicle sustained a longitudinal deceleration just severe enough to wake up the crash sensing algorithm as indicated by the maximum recorded velocity change of -0.02 km.p.h. (-0.01 m.p.h). The system status report also recorded the SIR warning lamp as off and the driver's seat belt switch circuit as unbuckled. The pre-crash data shows the brake switch circuit was off for the five, one-second sample periods prior to algorithm enable (AE). It also recorded the case vehicle traveling 72 km.p.h. (45 m.p.h.) at 0% throttle five seconds prior to algorithm enable. The speed then begins to decrease and the percent throttle

remain a 0% until two seconds prior to algorithm enable when it is recorded as 23%, and then drops to 3% throttle at one second prior to AE.

CASE VEHICLE SPEED RECONSTRUCTION

A critical speed analysis was performed on the case vehicle's reconstructed final yaw path that led to the south road edge departure and rollover. The speed at the onset of the final yaw based on this analysis was approximately 65 km.p.h (40 m.p.h). The reconstructed speed was consistent with the EDR recorded pre-crash speed of 69 km.p.h. (43 m.p.h) recorded at four seconds prior to AE (i.e., impact with the back slope of the ditch), which, based on the reconstruction, occurred near the beginning of the final yaw. The critical speed equation and data used in the calculation are presented in **Figure 24** at the end of this report.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the initial loss of control, the case vehicle's driver [17-year-old, White (non-Hispanic) male; 175 centimeters and 70 kilograms (69 inches, 155 pounds)] was seated in an upright posture with his back against the seat back, his left foot on the floor, right foot on the accelerator, left hand on the steering wheel and right hand on the gear shift lever. His seat track was located in its middle position, the seat back was slightly reclined, and the tilt steering wheel was located in its down-most position.

Based on this contractor's vehicle inspection and supported by the EDR data, the case vehicle's driver was not using his manual, three-point, lap-and-shoulder safety belt system. Inspection of the driver's seat belt assembly showed no evidence of loading.

The tire mark evidence at the scene indicates the case vehicle's driver steered to the left as the case vehicle's right side tires were in the gravel in the mouth of the intersecting roadway. The driver then steered right as the vehicle was crossing the roadway and heading to the south edge of the roadway. The driver then steered left again as the vehicle was crossing the roadway and heading to the north edge of the roadway. The driver did not apply the brakes. As a result of the steering maneuvers, the driver most likely moved to his right, then left, then back to the right again as the vehicle yawed counterclockwise just prior to the impact. The case vehicle's right front impact with the back slope of the ditch caused the driver to move forward and to the right, and he impacted his right knee on the center console abrading his knee. The driver remained restrained in his seat position as the case vehicle rolled over and came to rest on its right side. The driver was able to exit the case vehicle under his own power following the crash.

CASE VEHICLE DRIVER INJURIES

The police crash report indicated that the case vehicle's driver did not sustain any injury as a result of the crash and was not transported from the scene to a medical facility. The driver did not seek any medical treatment subsequent to the crash, and was not working at the time of the crash. The driver reported injury and injury mechanism is shown in the table below.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Abrasion, small, less than 2.5 cm (< 1 in) right knee, not further specified	minor 890202.1,1	Floor, center console	Certain	Interviewee (same person)

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

Immediately prior to the initial loss of control, the case vehicle's front right passenger (sister of the driver) [24-year-old, White (non-Hispanic) female; 155 centimeters and 64 kilograms (61 inches, 140 pounds)] was seated in an upright posture with her back against the seat back, her feet on the floor and she was holding a cigarette. Her seat track was located in its middle position, and the seat back was slightly reclined.

The driver stated that the he was not sure if the front right passenger was using her manual, three-point, lap-and-shoulder safety belt system. However, the police crash report indicated she was restrained. There was insufficient evidence to verify that this passenger was in fact restrained in this crash. Inspection of the front right passenger's seat belt assembly showed no evidence of loading.

The front right passenger most likely moved to the right, then left and back to the right again as the case vehicle's driver attempted to regain control of the vehicle prior to the crash. The front right passenger was most likely up against the right front door due to the counterclockwise yaw as the case vehicle entered the ditch just prior to the rollover. The case vehicle's right front impact to the back slope of the ditch and the rollover caused the passenger to impact her upper right arm on the right front door window sill and her right lower leg on the right front door bruising her arm and leg. In addition, her head contacted the right front window. She stayed in contact with the door as the case vehicle rolled over and came to final rest on its right side. The front right passenger was able to exit the case vehicle under her own power following the crash.

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The police crash report indicated that the front right passenger did not sustain any injury as a result of the crash and was not transported from the scene to a medical facility. The front right passenger did not seek any medical treatment subsequent to the crash and was not working at the time of the crash. The interviewee reported injuries and injury mechanisms for the front right passenger are shown in the table below.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Contusion {bruise}, 10.2 cm (4 in) in diameter lateral right up-per arm, not further specified	minor 790402.1,1	Right front window sill	Certain	Interviewee (driver)
2	Contusion {bruise}, 10.2 cm (4 in) in diameter lateral right upper lower leg, not further specified	minor 890402.1,1	Right side interior surface, excluding hardware and/or armrest	Certain	Interviewee (driver)

CASE VEHICLE BACK RIGHT PASSENGER KINEMATICS

The case vehicle's back right passenger (son of the front right passenger) [6-year-old, White (non-Hispanic) male; 91 centimeters and 27 kilograms (36 inches and 60 pounds)] was seated in an upright position with his back against the seat, his feet hanging over the front edge of the seat, and his hands in an unknown position. His seat track and seat back were not adjustable.

According to the driver, the back right passenger was wearing his manual, three-point, lap-and-shoulder safety belt system with the lap belt low on his lap and the shoulder belt behind his back. Inspection of the seat belt assembly showed no evidence of loading.

The back right passenger most likely moved to the right, then left and back to the right again as the case vehicle's driver attempted to regain control of the vehicle prior to the crash. The back right passenger was most likely up against the right rear door due to the forces acting on the vehicle as it yawed counterclockwise across the roadway and departed the south side of the roadway. He most likely impacted the right rear door and stayed in contact with the door as the case vehicle impacted the back slope of the ditch and rolled onto its right side. The back right passenger remained restrained in his seat position and was able to exit the case vehicle with some assistance from the other occupants following the crash.

CASE VEHICLE BACK RIGHT PASSENGER INJURIES

The police crash report indicated that the back right passenger did not sustain any injury as a result of the crash and was not transported from the scene to a medical facility. The interviewee reported that the back right passenger sustained no injuries in the crash and did not seek any medical treatment subsequent to the crash.

5GZCZ23D44Sxxxxxx System Status At Non-Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Ignition Cycles At Non-Deployment	689
Ignition Cycles At Investigation	699
Maximum SDM Recorded Velocity Change (MPH)	-0.01
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	0
A Deployment was Commanded Prior to this Event	No

Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
SDM Recorded Velocity Change	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

PRE-CRASH DATA				
Seconds Before AE	**Vehicle Speed (MPH)**	**Engine Speed (RPM)**	**Percent Throttle**	**Brake Switch Circuit Status**
-5	45	2304	0	OFF
-4	43	1536	0	OFF
-3	36	1152	0	OFF
-2	17	1024	23	OFF
-1	5	2048	3	OFF

Figure 21: Case vehicle's System Status at Non-Deployment report

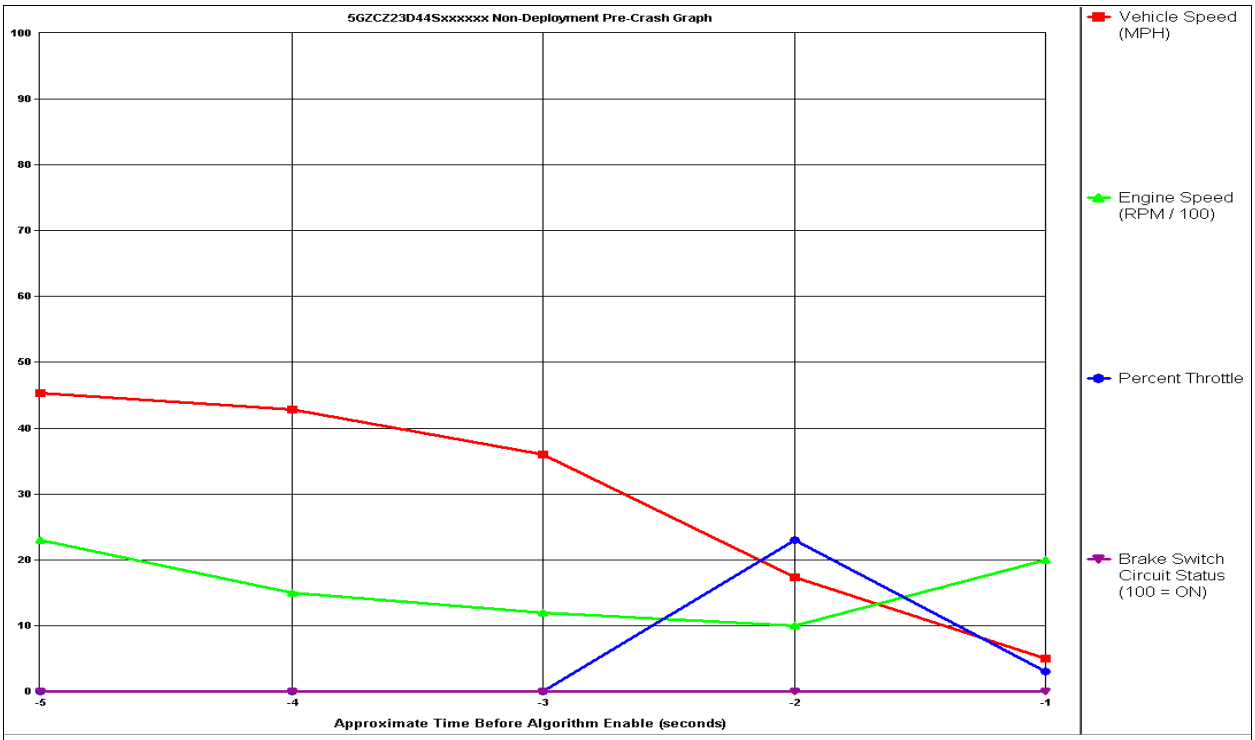


Figure 22: Case vehicle's Non-Deployment Pre-Crash Graph

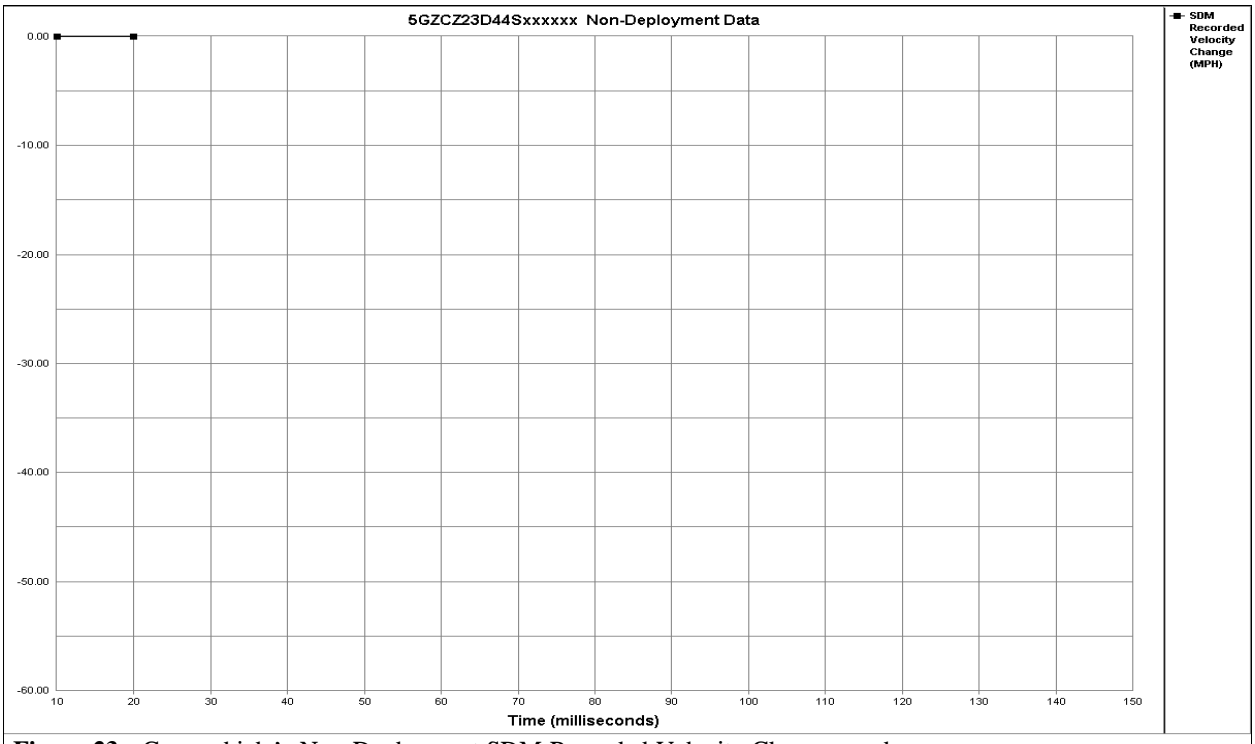


Figure 23: Case vehicle's Non-Deployment SDM Recorded Velocity Change graph

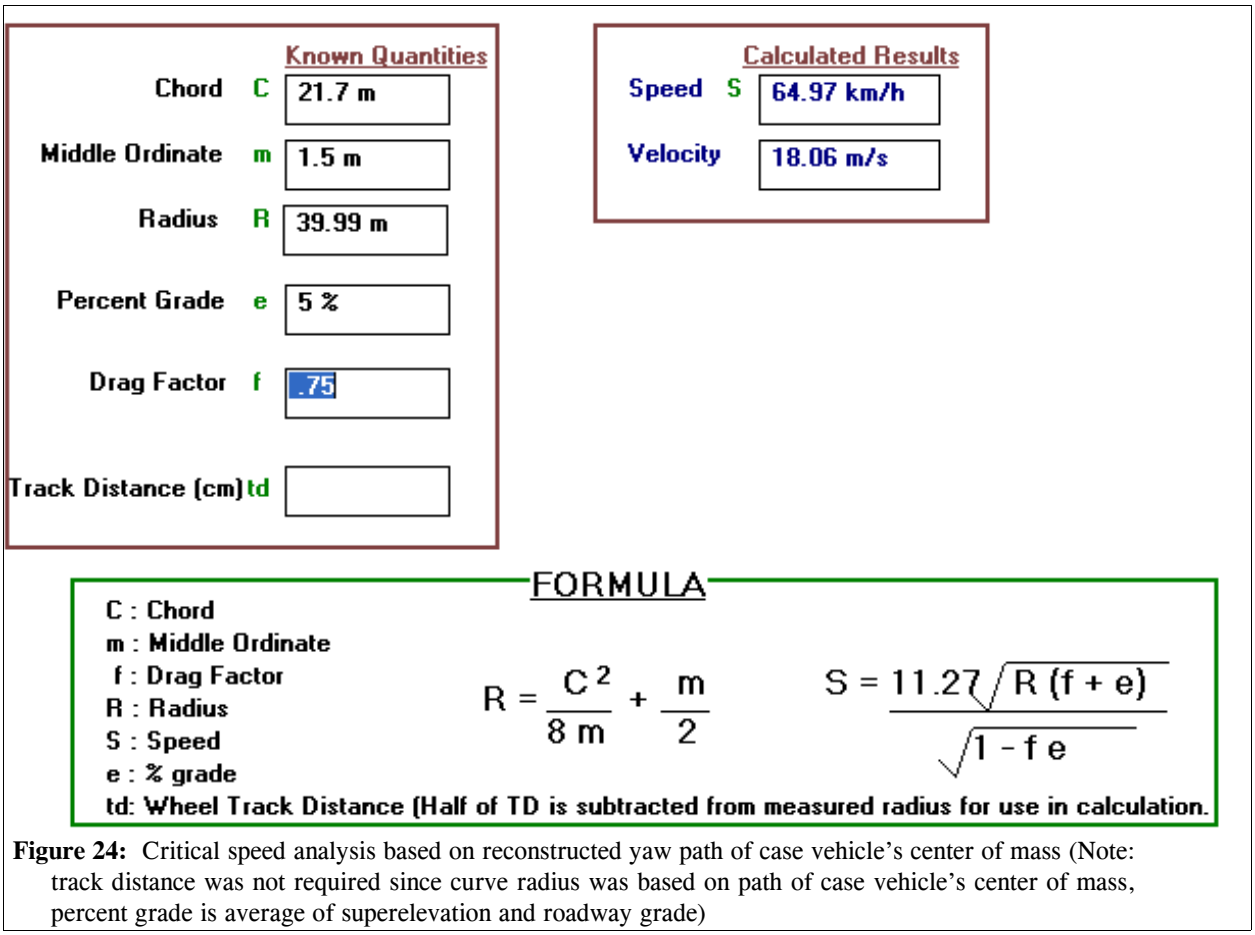
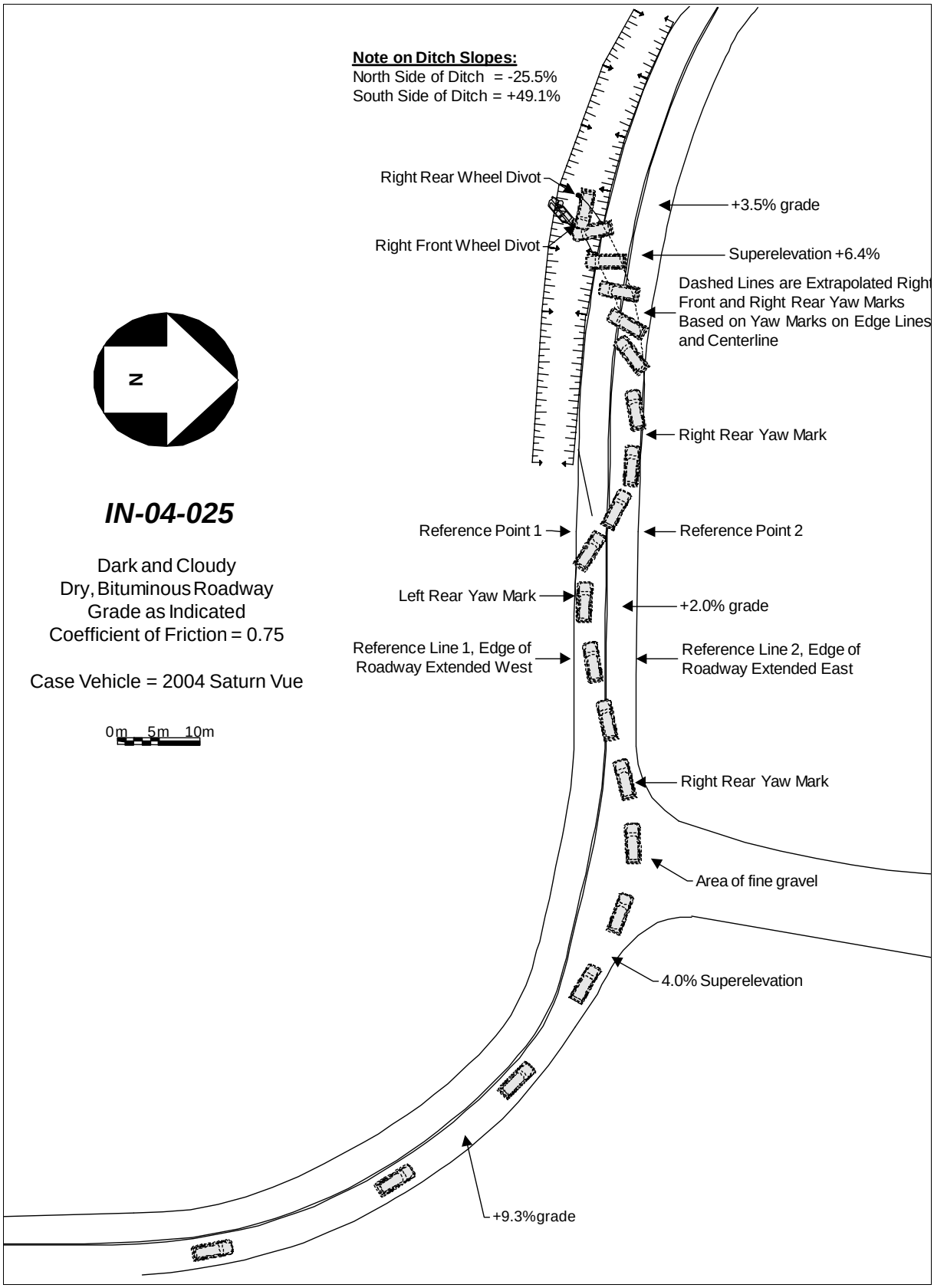


Figure 24: Critical speed analysis based on reconstructed yaw path of case vehicle's center of mass (Note: track distance was not required since curve radius was based on path of case vehicle's center of mass, percent grade is average of superelevation and roadway grade)


Note on Ditch Slopes:
North Side of Ditch = -25.5%
South Side of Ditch = +49.1%
Right Rear Wheel Divot
Right Front Wheel Divot
+3.5% grade
Superelevation +6.4%
Dashed Lines are Extrapolated Right Front and Right Rear Yaw Marks Based on Yaw Marks on Edge Lines and Centerline
N
IN-04-025
Dark and Cloudy
Dry, Bituminous Roadway
Grade as Indicated
Coefficient of Friction = 0.75
Case Vehicle = 2004 Saturn Vue
0m 5m 10m
Right Rear Yaw Mark
Reference Point 1
Reference Point 2
Left Rear Yaw Mark
+2.0% grade
Reference Line 1, Edge of Roadway Extended West
Reference Line 2, Edge of Roadway Extended East
Right Rear Yaw Mark
Area of fine gravel
4.0% Superelevation
+9.3%grade