TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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REDESIGNED AIR BAG SPECIAL STUDY
DRIVER FATALITY INVESTIGATION

VERIDIAN CASE NO. 2000-12-078A

VEHICLE: 2000 GMC K2500 PICK-UP

LOCATION - MICHIGAN

CRASH DATE - MAY 2000

Contract No. DTNH22-94-07058

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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 of the involved vehicle(s) or their safety systems.

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This investigation focused on the crash of 2000 GMC K2500 Pick-up and the fatal injury mechanisms of the restrained 45 year old male driver. The driver was the sole occupant in a front-to-rear impact with a stopped tractor/semi trailer. The GMC was equipped with a Supplemental Restraint System (SRS) that consisted of redesigned driver and front right passenger air bags. The driver air bag deployed in the above threshold impact. The SRS was monitored and controlled by a Sensing Diagnostic Module with electronic crash data recording capabilities. An OEM on/off switch to suppress the deployment of the front right passenger air bag was also installed. The switch was in the *Air Bag Off* position. The driver was extricated from the vehicle by emergency response personnel and transported to a local hospital. He was pronounced dead upon arrival in the Emergency Room.

The crash was identified and selected for investigation by NASS PSU 12 and was identified by Case No: 078A. The Field Operations Branch of the National Highway Traffic Safety Administration (NHTSA) assigned the Special Crash Investigations team at Veridian Engineering the task of assisting in the investigation and was instructed to download the on-board electronic data to supplement the crash investigation.

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BACKGROUND

This investigation focused on the crash of 2000 GMC K2500 Pick-up and the fatal injury mechanisms of the restrained 45 year old male driver. The driver was the sole occupant in a front-to-rear impact with a stopped tractor/semi trailer. The GMC was equipped with a Supplemental Restraint System (SRS) that consisted of redesigned driver and front right passenger air bags. The driver air bag deployed in the above threshold impact. The SRS was monitored and controlled by a Sensing Diagnostic Module with electronic crash data recording capabilities. An OEM on/off switch to suppress the deployment of the front right passenger air bag was also installed. The switch was in the *Air Bag Off* position. The driver was extricated from the vehicle by emergency response personnel and transported to a local hospital. He was pronounced dead upon arrival in the Emergency Room.

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SUMMARY

Crash Site

This two-vehicle crash occurred during the morning hours of May, 2000. At the time of the crash, it was daylight and the weather was not a factor. The crash occurred in the right turn only lane of a eight-lane east/west undivided roadway. The lanes were configured with three eastbound lanes, one center turn lane and four westbound lanes. The outboard westbound lane was a right turn only lane and funneled traffic at the entrance to a manufacturing plant located on the north side of the road. The plant entrance formed a 3-leg, non-signalized intersection with the primary road. The speed limit of the primary road was 72 km/h (45 mph). **Figure 1** is a westbound trajectory view of the GMC. **Figure 2** is an on-scene police photograph of the vehicles at final rest.

Figure 1: Westbound view approaching the point of impact.

Figure 2: Police photograph of the crash scene.

Pre-Crash

The 2000 GMC K2500 pick-up was westbound driven by a 45 year old male. The driver had a reported height and weight of 178 cm (70 in) and 86 kg (190 lb) and was the sole occupant in the GMC. He was restrained by the vehicle's manual integrated 3-point lap and shoulder restraint. A 1988 Kenworth tractor and semi-trailer was stopped (for unknown reasons) in the outboard right turn lane at the entrance to the manufacturing plant. The vehicle was operated by a 37 year old male.

A witness at the crash scene reported the GMC was westbound in the second lane from the right. Reportedly, the GMC made a lane change to the outboard right turn only lane to avoid conflicting traffic ahead. He indicated traffic was traveling approximately 89 km/h (55 mph).

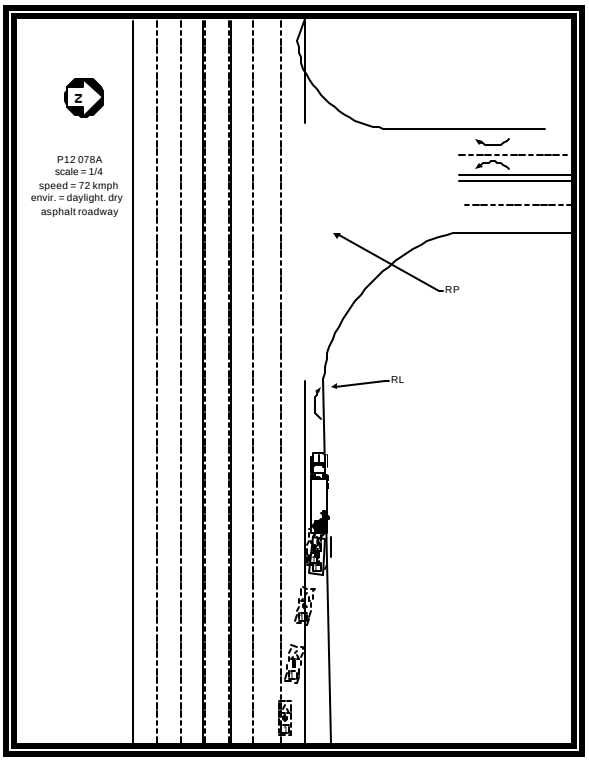


Figure 3: Crash schematic

Crash

The crash occurred with the full front plane of the GMC impacting the back plane of the stopped semi trailer in a 12/6 o'clock impact configuration.. The GMC then under-rode the rear of the trailer and was reportedly lodged underneath it. Both vehicles came to rest approximately at the point of impact. The force of the impact caused the driver air bag to deploy. The front right air bag did not deploy. The front right air bag deployment was suppressed by an OEM on/off switch. It was found in the air bag OFF position upon inspection.

Figure 3 is a schematic of the crash scene. Inspection of the scene identified an area of gouge marks and a fluid spill at the point of impact. The

gouge marks were attributed to undercarriage contact as the GMC impacted and under-rode the trailer. Immediately east of the point of impact, a 3 m (10 ft) scuff mark of the north curb face was identified. The scuff was attributed to the right front tire and was an indication the GMC had fully traversed the width of the outboard lane at impact. No skids marks were identified at the scene.

Post-Crash

The police and ambulance personnel responded to the crash scene. The driver had to be extricated from the vehicle. The medical record indicated the extrication process took approximately 25 minutes. The driver was removed from the vehicle and taken to the emergency room of a Level 1 trauma center located within 16 km (10 miles) of the crash site. The emergency care and resuscitation applied en-route proved unsuccessful and the driver was pronounced dead 36 minutes post-crash.

2000 GMC K2500 PICK-UP

The 2000 GMC K2500 pick-up was identified by the Vehicle Identification Number (VIN): 1GTGK24U8YE (production sequence deleted). The pick-up was configured as a 3/4 ton, conventional cab 4-wheel drive vehicle. It had a Gross Vehicle Weight Rating (GVWR) of 4082 kg (9000 lb). The power train consisted of a 6.0 liter V-8 engine linked to a floor mounted 5-speed manual transmission. The brakes consisted of hydraulic, 4-wheel disc brakes with a 4-wheel anti-lock system. The date of manufacture was October 1999. The vehicle's electronic odometer was inoperative at the time of the inspection due to the collision damage.

Exterior Damage

Figures 4 and 5 are the right front and left lateral views of the GMC. The force of the collision compressed the frontal structures of the vehicle rearward into the engine compartment and firewall. The direct contact damage to the GMC extended across the full 165 cm (65 in) width of the front plane. The deformation was biased to the left corresponding to the slight angular trajectory (<10 deg) of the GMC relative to the tractor trailer. The vehicle's crush profile was measured at the elevation of the front bumper and across the upper radiator support. The under-ride characteristics of the impact resulted in greater deformation at the upper radiator elevation. The average crush profile was as follows: C1=84 cm (33.0 in), C2=80 cm (31.5 in), C3=80 cm (31.5 in), C4=66 cm (26.0 in), C5=53 cm (20.9 in), C6=46 cm (18.1 in). The hood buckled, shifted rearward and impacted the lower aspect of the windshield. The windshield was fractured. The left door was jammed shut by the impact and was opened during extrication. The right door was operational but restricted. The left and right wheelbase were foreshortened 38 cm (15 in) and 15 cm (6 in), respectively. The upper aspect of the left A-Pillar deformed causing the roof to buckle. The lower aspect of the A-pillar deformed and shifted rearward approximately 15 cm (6 in). The left sill was buckled immediately aft of the left A-Pillar. The compressive force of the crash caused contact between the back of the cab and the forward aspect of the pick-up bed.

Figure 4: Right front view of the GMC.

Figure 5: Left lateral view across the front plane.

The Collision Deformation Classification (CDC) of the damage was 12-FDEW-04. Reconstruction of the crash through the use of the Barrier Model of the WINSMASH program determined a barrier equivalent delta V of 53.4 km/h (33.2 mph). The longitudinal and lateral components were -52.6 km/h (-32.7 mph) and -9.3 km/h (-5.8 mph), respectively. This calculation appeared to be underestimated based on SCI experience.

Visually the damage to the subject vehicle appeared similar in magnitude to that of a NHTSA 56 km/h (35 mph) NCAP test at the bumper elevation. However, vehicle damage above the bumper was greater in magnitude due to the under-ride. The magnitude of the longitudinal displacements of the left wheelbase and A-pillar were approximately twice those measured in the NCAP test of a similar vehicle (2000 Chevrolet K1500). The right side deformations were approximately equivalent to the test vehicle at those locations. The greater deformations in the subject crash indicated a greater crash severity than the NCAP test. Additionally, the underlying assumption of the Barrier Model is zero energy absorption by the barrier.

Figure 6 is a view of the damaged trailer. The trailer sustained approximately 178 cm (70 in) of direct contact during the impact sequence.. The bed was buckled down and the under-ride guard was damaged. The right rear trailer tire had aired out indicating possible damage to the rear suspension. The trailer deformation indicated a portion of the GMC's pre-impact energy was absorbed in the crash. All the above factors indicate the severity of the subject crash was underestimated by WINSMASH model. Conservation of Energy principles applied to the crash scenario indicated the approximate delta V of the crash was 80 to 89 km/h (50 to 55 mph).

Figure 6: View of the trailer damage.

Supplemental Restraint System and Electronic Data Recorder

The Supplemental Restraint System in the 2000 GMC consisted of driver and front right passenger air bags. The driver air bag was locate in the typical manner in the center hub of the steering wheel. It deployed as a result of the impact. The front right air bag was a mid-mount design located in the right aspect of the instrument panel. An OEM on/off switch located in the center aspect of the instrument panel controlled the activation of the front right module. The switch was in the air bag OFF position and suppressed the front right air bag deployment. The SRS was controlled by a Sensing and Diagnostic Control Module (SDM) with the capabilities of recording pre-crash and crash event data. The Electronic Data Recorder (EDR) was interrogated during the SCI inspection and crash event data was downloaded through the Beta version of the Vetronix software. The EDR data are included as **Attachment A** at the end of this report.

Analysis of the EDR data indicated the SRS was operating as designed prior to the crash. The SRS warning lamp in the instrument cluster was OFF. There were no faults in the SRS circuitry. Approximately 5 seconds before the crash, the speed of the GMC was 77 km/h (48 mph). Over the next 4 seconds the driver of the GMC accelerated the vehicle to 89 km/h (55 mph). (During this time frame, the driver was in the process of changing lanes to the right.) Immediately prior to impact (t = -1) , the vehicle was traveling 89 km/h (55 mph) and the throttle closed (percent=0). This indicated the driver had removed his foot from the accelerator and was in the process of moving to the clutch and brake. The pre-crash data indicated the brake pedal was not actuated prior to impact, however. The impact occurred with the GMC impacting the semi-trailer at approximately 89 km/h (55 mph). The vehicle came to rest near the point of impact, there was no post-impact movement beyond the point of impact. Vehicle dynamics dictates the delta V of the crash will therefore be close to the 89 km/h (55 mph) impact speed. This was consistent with the 86.3 km/h (53.6 mph) delta V recorded by the EDR. Refer to Attachment A.

Interior Damage

The interior damage to the 2000 GMC K2500 resulted from the exterior force of the crash in addition to the deployment of the driver air bag and occupant contacts within the compartment. **Figure 7** is a left interior view of the driver's position. The left A-pillar and left corner of the instrument panel intruded longitudinally rearward approximately 15 cm (6 in). The left toepan buckled and intruded rearward approximately 24 cm (9 in). The lower aspect of the windshield was fractured due to contact from hood. The center aspect of the windshield's interior surface directly forward of the driver's position was fractured from head contact. Tissue was observed in the fracture site.

Figure 7: Left interior view of the driver's position.

The driver seat was a cloth covered bucket seat with a reclining back rest. It was adjusted in a mid-to-rear track position and measured 15 cm (6 in) rear of full forward. The total seat track travel measured 22.3 cm (8.8 in). Two areas of contact were identified on the rigid left knee bolster. The contacts consisted of scuffs located symmetrical about the steering column centerline as a result of contact from the driver's lower extremities.

The tilt mechanism of the steering wheel was adjusted to the center position and was fractured. The steering wheel rim, **Figure 8**, was completely distorted and deformed forward about the center hub. The rim was fractured in the 6 o'clock sector. The steering column was completely displaced from the shear capsules. The steering wheel rim deformation and shear displacement resulted from the loading of these components by the driver's arms and chest during his forward kinematic displacement. It should be noted the driver was restrained by the integrated 3-point lap and shoulder belt system.

Figure 8: View of the deformed steering wheel.

The driver air bag had deployed as designed from its I-configuration module. There was no evidence of occupant contact to the flaps. The diameter of the driver bag measured 61 cm (24 in) in its deflated state. It was tethered was 2 straps sewn to the face of the bag and was vented by two ports located in the 10/2 o'clock sectors on the back side of the bag. The only contact evidence of the face of the driver bag was a blood transfer on the peripheral seam in the 10 to 12 o'clock sector.

Manual Restraint System

The manual restraint system in the 2000 GMC K2500 was an integrated seat belt system, **Figure 9**. The inertial retractor and D-ring were integrated into the outboard aspects of the seat backs. The lap portion of the webbing was anchored to the outboard aspect of the seat cushion. The inboard buckle anchor was attached to the inboard aspect of the cushion. In this manner, the manual restraint can give the occupant a consistent fit, regardless of seat track position.

Figure 9: View of the integrated left front restraint.

Upon inspection, the sliding latch plate was inserted and latched to the buckle anchor. The webbing had been cut by the EMS personnel during extrication. The lap portion of the cut section was on the seat. The shoulder portion of the webbing had spooled back into the retractor and could not be accessed. Examination of the webbing and hardware surfaces of the latch plate revealed transfer marks and contact evidence. These evidences were consistent with proper belt use in this crash.

DRIVER DEMOGRAPHICS

Age/sex:	45 year old male
Height:	178 cm (70 in)
Weight:	86 kg (190 lb)
Restraint Usage:	manual integrated 3-point lap and shoulder
Usage Source:	SCI inspection
Medical Treatment:	Fatal

DRIVER INJURIES

To date, the medical records available for the driver are very incomplete. The emergency room records obtained do not have an assessment of the driver on admission other than "Traumatic Arrest". He was unresponsive with no vital signs, without respiration and had a Glasgow Coma Scale of 3. The only injuries listed were unspecified severe injuries to the face, head and chest as a result of a high speed motor vehicle crash. No autopsy was performed.

Injury	***Severity (AIS 90)***	***Injury Mechanism***
Blunt head trauma	unknown (115999.7,0)	Windshield
Blunt chest trauma	unknown (415999.7,0)	Steering wheel/column

OCCUPANT KINEMATICS

Immediately prior to the crash, the restrained driver of the GMC was seated in a normal posture with his seat adjusted to a mid-to-rear seat track position consistent with his stature. The vehicle was traveling westward at approximately 89 km/h (55 mph). At impact, the force of the impact caused the deployment of the vehicle's driver air bag system. The driver responded to the 12 o'clock direction of the impact force by initiating a forward trajectory.

The driver contacted, loaded the 3-point restraint and began to ride-down the crash. As the driver loaded the restraint, the increasing belt forces were reacted by the turning loop and retractor mounted to the seat back. Due to the compliant structure of the seat back, the loading of the shoulder restraint caused the seat back to deflect forward. This in-turn allowed the driver to translate further forward into fuller contact with the driver air bag and the forward structures of the interior. Instead of "shared restraint" between the seat belt and driver air bag, the driver air bag had to contribute a larger component to the driver's restraint. As a result, the driver's chest loaded and bottomed out the bag. This loading displaced the column from the shear capsules and deformed the steering wheel rim. The driver sustained severe unspecified chest injuries. The forward translation of the driver also allowed his head to contact and fracture the windshield resulting in unspecified head trauma.

ATTACHMENT A

EDR DATA

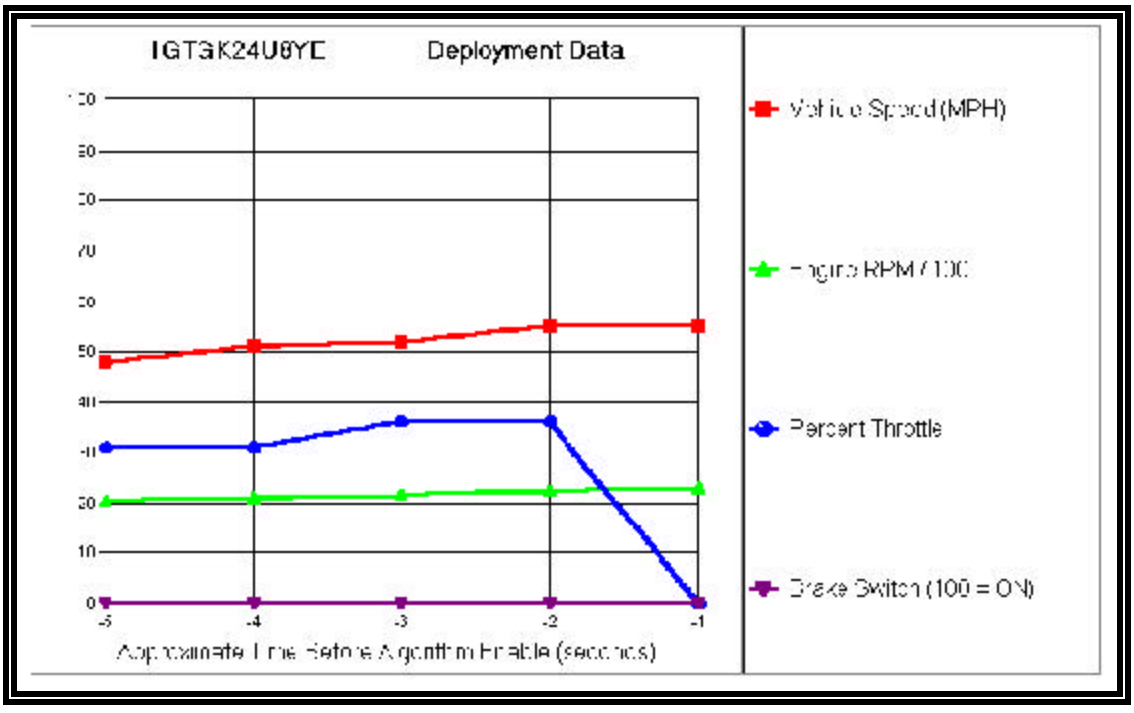
1GTGK24U8YE	System Status At Deployment
SIR Warning Lamp Status	OFF
Driver's Belt	BUCKLED
Passenger Front-Air Bag	ON
Ignition Cycle At Deployment	1232

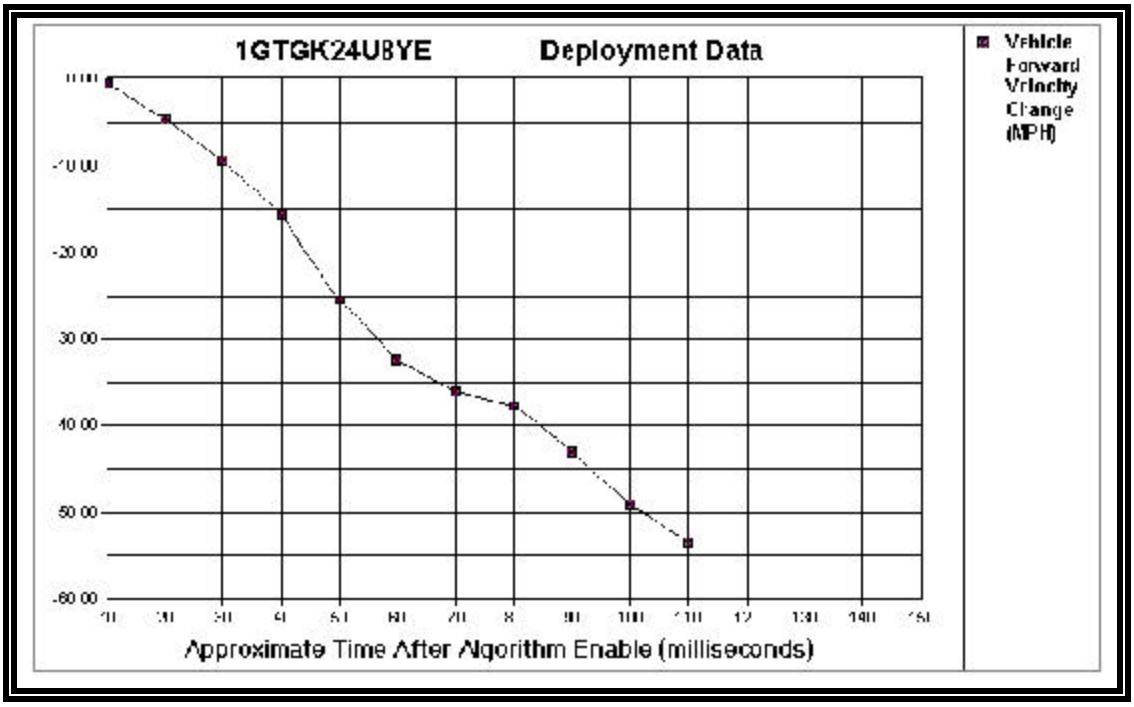
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Status
-5	48	3048	31	OFF
-4	51	3112	31	OFF
-3	52	2176	36	OFF
-2	55	2240	100	ON
-1	55	2374	0	OFF

DEPLOYMENT DATA

Milliseconds After AE	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Velocity Change (MPH)	0.50	4.97	9.28	15.35	25.61	32.33	36.05	37.59	43.07	43.00	53.61	N/A	N/A	N/A	N/A

Time Between Deployment and Most Deployment Event (msec)	N/A

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Approximate Time After Algorithm Enable (milliseconds)
Vehicle Forward Velocity Change (MPH)