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ON-SITE CHILD SAFETY SEAT INVESTIGATION

CASE NUMBER - IN-05-022
LOCATION - ARKANSAS
VEHICLE - 1999 TOYOTA COROLLA
CRASH DATE - June 2005

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.

Technical Report Documentation Page

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15. *Supplementary Notes* On-site child safety seat investigation involving a 1999 Toyota Corolla equipped with manual safety belts, dual front air bag system and child safety seats installed in the back left and back right seating positions.			
16. *Abstract* This report covers an on-site child safety seat investigation that involved a 1999 Toyota Corolla (case vehicle) and a 2004 GMC K1500 pickup truck (other vehicle), which collided head-on on a three-lane U.S. highway. This crash is of special interest because the case vehicle's back left passenger [2-year-old, White (unknown if Hispanic) female] and back right passenger [5-year-old, White (unknown if Hispanic) male] were restrained in child safety seats, and both passengers sustained fatal injuries as a result of the crash. The case vehicle was traveling south in a right curve in the inside southbound lane. The GMC and a non-contact vehicle were traveling north in the northbound lane. The non-contact vehicle was in front of the GMC. The case vehicle entered the northbound travel lane. The driver of the non-contact vehicle blew his horn and swerved to the right onto the shoulder. The case vehicle continued southbound in the northbound lane approaching the GMC. The case vehicle's driver steered left attempting to avoid the GMC. The driver of the GMC applied his brakes in an attempt to avoid the crash. The front of the case vehicle impacted the front of the GMC causing both vehicle's driver and front right passenger air bags to deploy. The case vehicle was driven backwards by the impact, rotated slightly clockwise and came to rest in the northbound lane heading southwest with its front still in contact with the front of the GMC. The GMC rotated slightly clockwise and came to rest in the northbound lane heading northeast. The case vehicle's back left passenger was restrained with the three-point, lap-and-shoulder belt in a Graco "TurboBooster" high-back, belt-positioning booster seat. The back left passenger sustained an atlanto-axial dislocation with probable severance of the spinal cord at C_6-C_7 due to impact force as her head snapped forward and backward in this high severity crash. The case vehicle's back right passenger was restrained with the three-point, lap-and-shoulder belt in a Graco "TurboBooster", which was being used without the back installed. He sustained fatal injuries. His specific injuries are not known. The driver and front right passenger were both unrestrained and fatally injured.			
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This on-site investigation was brought to NHTSA's attention on June 6, 2005 by an investigator with the National Transportation Safety Board. This crash involved a 1999 Toyota Corolla LE (case vehicle) and a 2004 GMC K1500 pickup truck (other vehicle), which were involved in a high severity head-on crash on a three-lane U.S. highway. The crash occurred in June, 2005 at 2:45 p.m., in Arkansas and was investigated by the Arkansas State Police. This crash is of special interest because the case vehicle's back left passenger [2-year-old, White (unknown if Hispanic) female] and back right passenger [5-year-old, White (unknown if Hispanic) male] were restrained in child safety seats, and both passengers sustained fatal injuries as a result of the crash. This contractor inspected the crash scene and vehicles on June 14-15, 2005 and downloaded the data from the GMC's Event Data Recorder (EDR). This contractor interviewed the GMC driver on July 20, 2005. This report is based on the police crash report, interviews with the GMC driver and responding EMTs, scene and vehicle inspections, EDR data, occupant medical records, occupant kinematic principles, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling south in a right curve in the inside southbound lane of a three-lane, undivided U.S. highway. The GMC and a non-contact vehicle were traveling north in the northbound lane. The non-contact vehicle was in front of the GMC. The case vehicle entered the northbound travel lane. The driver of the non-contact vehicle blew his horn and swerved to the right onto the shoulder. The case vehicle continued southbound in the northbound lane approaching the GMC. According to the driver of the GMC, the case vehicle's driver appeared to steer left attempting to avoid the crash. The driver of the GMC stated that he applied his brakes in an attempt to avoid the crash. The front of the case vehicle impacted the front of the GMC causing both vehicle's driver and front right passenger air bags to deploy. The case vehicle was driven backwards by the impact, rotated slightly clockwise and came to rest in the northbound lane heading southwest with its front still in contact with the front of the GMC. The GMC rotated slightly clockwise and came to rest in the northbound lane heading northeast. At the time of the crash the light condition was daylight, the atmospheric condition was clear and the roadway pavement was dry.

The CDC for the case vehicle was determined to be: **12-FDEW-5** (**0** degrees). The case vehicle's residual maximum crush at the bumper level was measured as 92 centimeters (36.2 inches) occurring at C6. The residual maximum above-bumper crush was measured as 113 centimeters (44.5 inches), also occurring at C_6. The WinSMASH reconstruction program, damage only algorithm, calculated the case vehicle's Total, Longitudinal, and Lateral Delta Vs respectively as: 87.0 km.p.h. (54.0 m.p.h.), -87.0 km.p.h. (-54.0 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). The case vehicle was towed due to damage.

The CDC for the GMC was determined to be: **12-FDEW-3** (**0** degrees). The GMC's residual maximum crush occurred at the bumper level and was measured as 75 centimeters (29.5) occurring at C_6. The WinSMASH reconstruction program, damage only algorithm, calculated the GMC's Total, Longitudinal, and Lateral Delta Vs respectively as: 49.0 km.p.h. (30.0 m.p.h.), -49.0 km.p.h. (-30.0 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). The downloaded EDR data indicated

the GMC's maximum longitudinal Delta V was -53.83 km.p.h. (-33.45 m.p.h.). The GMC was towed due to damage.

The case vehicle's back left passenger (2-year-old, female, unknown height and weight) was restrained in a high-back, belt-positioning booster seat. The booster seat was manufactured by Graco Children's Products, Inc. on August 27, 2004 and identified by model name "TurboBooster," and model number 8495LAD. At the time of the crash, the booster seat was positioned fully upright and the child was restrained with the case vehicle's lap-and-shoulder safety belt system. The child safety seat sustained only minor deformation as a result of the crash. The evidence indicated the child heavily loaded the safety belt during the crash. The back left passenger sustained an atlanto-axial dislocation with probable severance of the spinal cord at C_6-C_7 due to impact force as her head snapped forward and backward in this high severity crash. The back left passenger was transported by helicopter to a hospital and was declared "dead on arrival".

The case vehicle's back right passenger (5-year-old, male, unknown height and weight) was restrained by a belt-positioning booster seat. The booster seat was the same make and model as the back left booster seat; however, it was being used without the seat back installed. The booster seat was manufactured by Graco Children's Products, Inc. on March 2, 2005 and identified by model name "TurboBooster," and model number 8491RGM. At the time of the crash, the booster seat was positioned on the back right seat cushion and the child was restrained with the case vehicle's three-point, lap-and-shoulder safety belt system. The child safety seat sustained only minor deformation as a result of the crash. The evidence indicated the child heavily loaded the safety belt during the crash. In addition, there was deformation and forward displacement of the case vehicle's back right seat back, indicating the seat back was loaded by an object in the trunk during the crash forcing the child forward into the back of the front right passenger's seat back. The back right passenger was declared dead at the crash scene and was not transported to a treatment facility. The back right passenger's injuries are unknown. This contractor was not able to acquire a coroner's report for this passenger.

The case vehicle's driver was not restrained by her manual, three-point, lap-and-shoulder safety belt system. She sustained an unspecified thoracic cavity injury from riding down the air bag and loading the steering wheel. She also sustained a fractured right humerus due to impact with the left instrument panel and fractured right femur due to impact with the knee bolster. She was transported by helicopter to a hospital and expired in the emergency room.

The case vehicle's front right passenger was not restrained by his manual, three-point, lap-and-shoulder safety belt system. The front right passenger was declared dead at the crash scene and was not transported to a treatment facility. The front right passenger's injuries are unknown. This contractor was not able to acquire a coroner's report for this passenger.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which both vehicles were traveling was a curved, three-lane, undivided, U.S. highway, traversing in a generally north-south direction. There were two southbound lanes and one northbound lane and wide bituminous shoulders on each side of the

roadway. The northbound lane was 3.4 meters (11.2 feet) in width. The east shoulder was 2.9 meters (9.5 feet) in width. Each southbound lane was approximately 3.6 meters (11.8 feet) in width. The west shoulder was 4.4 meters (14.4 feet) in width. Roadway pavement markings consisted of solid white edge lines, double yellow no-passing lines and a broken white center line for the southbound lanes. The speed limit was 89 km.p.h. (55 m.p.h.). There was no regulatory speed limit sign posted near the crash site. At the time of the crash the light condition was daylight, the atmospheric condition was clear and the roadway pavement was dry, level bituminous with an estimated coefficient of friction of 0.75. The curve was superelevated 4%. Traffic density was moderate and the site of the crash was rural/residential. See the Crash Diagram at the end of this report.

Figure 1: Approach of case vehicle to impact (arrow), southbound in northbound lane

Pre-Crash: The case vehicle was traveling south in the inside southbound lane and was negotiating the right curve. The GMC and a non-contact vehicle were traveling north in the northbound lane. Both drivers were negotiating the curve and intending to continue northbound. The non-contact vehicle was in front of the GMC. For unknown reasons, the case vehicle entered the northbound travel lane (**Figure 1**). The driver of the non-contact vehicle blew his horn and swerved to the right onto the shoulder. The case vehicle continued southbound in the northbound lane approaching the GMC. According to the driver of the GMC, the case vehicle's driver appeared to steer left attempting to avoid the crash. The driver of the GMC stated that he applied his brakes in an attempt to avoid the crash. This is supported by the GMC's downloaded EDR data, which indicated that the driver applied the brakes just prior to the impact. The crash occurred in the northbound lane.

Figure 2: Overview of front damage to case vehicle due to impact with the GMC, each stripe on rods in 5 cm (2 in)

Crash: The front of the case vehicle (**Figure 2**) impacted the front of the GMC (**Figure 3** below), causing both vehicle's driver and front right passenger air bags to deploy. Based on the GMC's downloaded EDR data, both stages of its dual stage driver and front right passenger air bags deployed as a result of the impact.

Post-Crash: The case vehicle was driven backwards by the impact, rotated slightly clockwise and came to rest in the northbound lane with its front still in contact with the front of the GMC. According to emergency personnel, the case vehicle's left rear wheel was just east of the east fog line with the remainder of the case vehicle in the northbound lane heading slightly southwest. The GMC rotated slightly clockwise and came to rest in the northbound lane (**Figure 4**) heading northeast.

Figure 3: Overview of damage to front of GMC due to impact with the case vehicle

Figure 4: View north (GMC's approach) to impact area and area of final rest

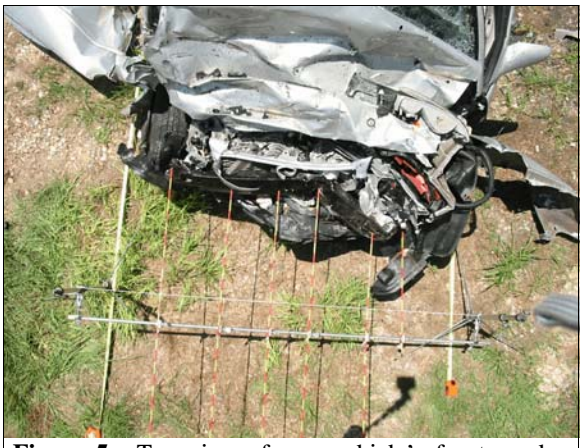


Figure 5: Top view of case vehicle's front crush, baseline is set 42 cm (16.5 in) short, final crush values reflect adjustment for this

CASE VEHICLE

The 1999 Toyota Corolla was a front wheel drive, four-door sedan (VIN: 1NXBR12E6XZ------) equipped with a four cylinder engine, four-speed automatic transmission and driver and front right passenger air bags. The front seating row was equipped with bucket seats with adjustable head restraints and manual, three-point, lap-and-shoulder safety belt systems with retractor mounted pretensioners. The back seating row was equipped with a bench seat with folding backs and adjustable head restraints in both outboard seating positions and manual, three-point, lap-and-shoulder safety belt systems in all three seating positions. Anti-lock brakes were an option on the case vehicle, but it is unknown if it was so equipped. The case vehicle's wheelbase was 246 centimeters (97 inches). The case vehicle's odometer reading at the time of the vehicle inspection is unknown because the vehicle was equipped with an electronic odometer.

CASE VEHICLE DAMAGE

Exterior Damage: The case vehicle's contact with the GMC involved the entire front end. The case vehicle's front bumper, bumper fascia, grille, radiator, turn lamp and headlamp assemblies, left and right fenders and hood were directly damaged and crushed rearward. The direct damage began at the front right bumper corner and extended 114 centimeters (44.9 inches) across the bumper bar. The Field-L was determined to be 112

centimeters (44.1 inches). Residual maximum crush at the bumper was measured as 92 centimeters (36.2 inches) occurring at C_6 (**Figure 5** above). A second set of crush measurement was taken above the bumper with the residual maximum crush measured as 113 centimeters (44.5 inches), also occurring at C_6. The table below shows the average of the case vehicle's bumper and above bumper crush.

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	114	113	112	76	77	95	91	88	103	0	0
in		44.9	44.5	44.1	29.9	30.3	37.4	35.8	34.6	40.6	0.0	0.0

The case vehicle's left side wheelbase shortened 12 centimeters (4.7 inches) while the right side was shortened 35 centimeters (13.8 inches). Induced damage involved both the right and left front doors as well as the windshield glazing, roof, and right A-pillar. Remote buckling was also found on the left C-Pillar. The right A-pillar was cut by rescue personnel. Rescue personnel also cut out the right B-pillar and removed the right front and right rear doors.

The case vehicle's recommended tire size was P185/65R14. The case vehicle was equipped with this size tire on the right front; however, the left front, left rear and right rear tires were size P175/65R14. 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	200	29	207	30	5	6	None	Yes	No
RF	Flat	Flat	207	30	5	6	Cut tread	Yes	Yes
LR	207	30	207	30	6	7	None	No	No
RR	103	15	207	30	5	6	None	No	No

Vehicle Interior: Inspection of the case vehicle's interior (**Figures 6** and **7** below) revealed evidence of occupant contact on the driver and front right passenger air bags, knee bolster, lower and upper right instrument panel and the steering wheel rim. There was significant longitudinal intrusion to the case vehicle's front seating row. The primary intrusions into the front seating row were: 53 centimeters (20.9 inches) of longitudinal and 34 centimeters (13.4 inches) of vertical center instrument panel intrusion, 48 centimeters (18.9 inches) of longitudinal right toe pan intrusion, 31 centimeters (12.2 inches) of longitudinal left toe pan intrusion, 32 centimeters (12.6 inches) of longitudinal and 28 centimeters (11 inches) of vertical right instrument panel intrusion, 29 centimeters (11.4 inches) of longitudinal left instrument panel intrusion, 28 centimeters (11

inches) of longitudinal right A-pillar intrusion and 23 centimeters (9.1 inches) of longitudinal intrusion of the steering wheel. The primary intrusion to the back seating row was 43 centimeters (16.9 inches) of longitudinal intrusion of the back right seat back, which was displaced forward due to an impact by an object in the trunk.

Figure 6: Overview of case vehicle's steering wheel, instrument panel and windshield

Damage Classification: Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FDEW-5** (**0** degrees). The WinSMASH reconstruction program, damage only algorithm, was used to reconstruct the case vehicle's Delta V. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 87.0 km.p.h. (54.0 m.p.h.), -87.0 km.p.h. (-54.0 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). The case vehicle was towed due to damage.

Figure 7: Overview of case vehicle's front interior and front right passenger air bag

AUTOMATIC RESTRAINT SYSTEM

The case vehicle driver's air bag was located in the steering wheel hub. An inspection of the air bag module cover flaps and the air bag fabric revealed that the cover flaps opened at the designated tear points. Damage occurred to the air bag during the deployment. Small holes were found on the upper, upper, center portion of the air bag, as well as a one centimeter (0.4 inch) cut at the left center portion of the air bag. Larger holes and cuts were also found on the back, upper, left portion of the air bag. These holes were most likely due to interaction of the air bag with the broken windshield during the crash. The air bag module cover consisted of "H"-configuration cover flaps made of medium thickness pliable vinyl. The upper cover flap was 16 centimeters (6.3 inches) in width and 6 centimeters (2.4 inches) in height. The Toyota logo was located in the center of the flap. A semicircular portion of the logo extended down from the upper flap and fit into a corresponding cut-out on the lower flap. The lower flap was 16 centimeters (6.3 inches) in width at the tear seam, 12 centimeters (4.7 inches) in width at the bottom and 9 centimeters (3.5 inches) in height. The deployed driver's air bag (**Figure 8**) was round with a diameter of approximately 64 centimeters (25.2 inches), and was

Figure 8: Case vehicle's driver air bag

designed with two tethers, each approximately 11 centimeters (4.3 inches) in width. The driver's air bag had two vent ports, each approximately 2 centimeters (0.8 inches) in diameter, located at the 11 and 1 o'clock positions.

Figure 9: Damage to case vehicle's front right air bag

The front right passenger's air bag was located in the top of the instrument panel. An inspection of the air bag module cover flaps revealed that the cover flaps opened at the designated tear points. The air bag module cover consisted of two rectangular cover flaps. The upper flap was approximately 22 centimeters (8.7 inches) in width and 6 centimeters (2.4 inches) in height. The lower flap was approximately 23 centimeters (9.1 inches) in width and 6 centimeters (2.4 inches) in height. The cover flaps were severely bent due to the intrusion and deformation of the instrumental panel. Inspection of the front right passenger air bag revealed two very large tears, both starting at the right vent port (**Figure 9**). One tear extended approximately 53 centimeters (20.9 inches)toward the air bag module, and the other extended approximately 40 centimeters (15.7 inches) to the left across the back of the air bag. In addition, there were numerous cuts on the front and top of the air bag. The source of the large tear in the right side of the air bag may have been the result of rescue activities when the right "A"-pillar was cut and the doors were removed. The source of the cuts to the front and top of the air bag were most likely due to its interaction with the broken windshield during the crash. The front right passenger's air bag was designed without tethers and had two vent ports, each approximately 5.5 centimeters (2.2 inches) in diameter. Location of these vent ports could not be precisely determined due to the extent of damage to the air bag, but they appeared to be located on the sides of the air bag at the approximate 3 and 9 o'clock positions. The deployed front right air bag was rectangular but it's height and width could not be determined because of the damage to the air bag.

Figure 10: Overview of case vehicle's back left belt-positioning booster seat

CHILD SAFETY SEAT

Child Safety Seat, Back Left Passenger: The case vehicle's back left passenger (2-year-old, female, unknown height and weight) was restrained in a high-back, belt-positioning booster seat (**Figure 10**). The booster seat was manufactured by Graco Children's Products, Inc.

on August 27, 2004 and identified by model name "TurboBooster," and model number 8495LAD. It is not known when the booster seat was purchased, or how often it was used. It is also not known if the driver or the front right passenger (i.e., the child's mother and father) had read the booster seat instruction manual or the case vehicle owner's manual regarding installation of child seats. The booster seat was designed without a LATCH system. It was designed to be used with the vehicle's lap-and-shoulder safety belt system. At the time of the crash, the booster seat was positioned fully upright and the child was restrained with the case vehicle's lap-and-shoulder safety belt system. The lap belt was routed across the child's lap via the lap belt guides located below the arm rest on each side of the booster seat. It is not known if the shoulder belt was routed across the child's chest via the shoulder belt guide located on the left side of the head restraint, or if it was routed through the space below the head restraint.

The belt-positioning booster seat consisted of a two-piece plastic base with arm rests and retractable cup trays on each side. The base was screwed together and covered by an approximate 2 centimeter (0.8 inches) thick, detachable foam cushion. The booster seat was designed with a removable back with head restraint. The seat back and head restraint were contoured to form protective "wings" at the head and shoulder level, and was designed with shoulder belt guides on each side of the head restraint and lap belt guides on each side of the booster seat under the arm rests. The height of the head restraint was adjustable. It was found adjusted to its lowest position. The distance from the child seat cushion to the top of the head restraint was measured as 61 centimeters (24 inches). The seat back was non-adjustable and was covered with an approximate 1 centimeter (0.4 inch) thick cloth cover. The head restraint was constructed of a foam pad approximately 5 centimeters (2 inches) thick. It was also covered with an approximate 1 centimeter (0.4 inches) thick cloth cover.

Warning and information labels that gave age, weight and height restrictions, safety belt usage instructions and head restraint adjustment instructions were located on the back, bottom and both sides of the booster seat. Age, weight and height restrictions with the seat back installed were given as: 3-10 years, 14-45 kilograms (30- 100 pounds) and 97-145 centimeters (38-57 inches). Age, weight and height restrictions with the seat back not installed were given as: 4-10 years, 18-45 kilograms (40-100 pounds) and 102-145 centimeters (40-57 inches). The head restraint usage instruction label indicated that the bottom of the head restraint must be even with the top of the shoulders. In addition, there was a warning label that indicated the booster seat should never be used with only a lap belt. The warning and usage information was also provided in Spanish.

Inspection of the belt-positioning booster seat revealed only minor deformation of the seat as a result of the crash. A small stress mark (white discoloration of the gray plastic shell) was found at the right front corner of the seat as well as a separation of the two sections of the base on the right side (**Figure 11** below). In addition, there were three small stress marks in the plastic of the seat cushion as well as a stress line that extended 13.5 centimeters (5.3 inches) from the right side to the middle of the seat (**Figure 12** below). A probable occupant scuff mark was found at the end of the right arm rest as well as a deep, perpendicular scratch at the center of the right arm rest (**Figure 12**). No other stress marks or damage was found on the belt positioning booster seat. No information regarding the installation and historical usage of the seat was obtained because both of the child's parents were fatally injured in the crash.

The stress marks in the plastic of the booster seat and the separation of the two sections of the booster seat base were most likely due to loading of the seat during this high severity crash. The occupant loaded against the safety belt and the child seat loaded against the occupant during the crash most likely causing these deformations.

Child Safety Seat, Back Right Passenger: The case vehicle's back right passenger (5-year-old, White (unknown if Hispanic) male; unknown height and weight) was restrained in a belt-positioning booster seat (**Figure 13**). The booster seat was the same make and model as the back left booster seat; however, it was being used without the seat back installed. The booster seat was manufactured by Graco Children's Products, Inc. on March 2, 2005 and identified by model name "TurboBooster," and model number 8491RGM. It is not known when the booster seat was purchased, or how often it was used. It is also not known if the driver or the front right passenger had read the booster seat instruction manual or the case vehicle owner's manual regarding installation of child seats. At the time of the crash, the booster seat was positioned on the back seat cushion and the child was restrained with the case vehicle's three-point, lap-and-shoulder safety belt system. The lap belt was routed across the child's lap via the belt guide located below the arm rest on each side of the booster seat. The position of the shoulder belt is not known.

Inspection of the belt-positioning booster seat revealed a few small stress marks in the plastic of the seat cushion. Stress marks, a scuff mark, and a few strands of hair and cloth threads were also found on the inside of the left arm rest (**Figure 13**). In addition, there was a small area of separation and damage (**Figure 14** below)at the assembly seam on the left side of the booster seat. Finally, a scrape in the booster seat base was observed on the right side. The warning and information labels were the same as indicated above for the back left booster seat.

Figure 11: Displacement of seam on right side of case vehicle's back left booster seat

Figure 12: Yellow tape shows stress marks in plastic of case vehicle's back left booster seat, arrows show probable occupant contact scuff on end of right arm rest and a scratch at center of arm rest

Figure 13: Case vehicle's back right belt-positioning booster seat, yellow tape on booster seat shows small stress marks in plastic and possible occupant contact scuff and few strands of hair and cloth threads on inside of left arm rest

The stress marks in the plastic of the booster seat and the small area of separation and compression at the assembly seam on the left base of the booster seat were most likely due to loading of the seat during this high severity crash. The passenger loaded against the safety belt and the child seat loaded against the occupant during the crash most likely causing these deformations.

Figure 14: Displacement and damage at assembly seam on left base of case vehicle's back right booster seat

CASE VEHICLE BACK LEFT PASSENGER KINEMATICS

Immediately prior to the crash, the case vehicle's back left passenger [2-year-old, White (unknown if Hispanic) female; unknown height and weight] was seated in an unknown position in her belt-positioning booster seat. Her feet were most likely hanging over the front edge of the seat cushion. The position of her hands and arms is not known. There was no seat track and the vehicle's seat back was not adjustable.

Figure 15: Load marks on case vehicle's back left safety belt

Based on this contractor's vehicle inspection, the case vehicle's back left passenger was restrained by her manual, three-point, lap-and-shoulder safety belt system. Inspection of the safety belt webbing and latch plate showed significant friction burns to the shoulder belt webbing (**Figure 15**), as well as the sliding latch plate belt guide. In addition, the belt was bunched up in a corner of the latch plate belt guide due to loading.

According to the GMC's driver, the case vehicle's driver appeared to steer left to avoid the impending crash.. As a result, and independent of the use of her safety belt, the back left passenger may have moved slightly to her right just prior to impact due to the driver's left steer. The case vehicle's impact with the GMC caused the back left passenger's safety belt retractor to lock and she continued forward opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated, and she heavily loaded her safety belt system. The severe force of the impact caused the child's head to snap forward and downward and rebound backward and she sustained an atlanto-axial dislocation with probable severance of the spinal cord at C_6-C_7. The back left passenger remained restrained in her booster

seat as the case vehicle rotated slightly clockwise to final rest. The back left passenger was removed from the case vehicle by rescue personnel, most likely through the left rear door.

CASE VEHICLE BACK LEFT PASSENGER INJURIES

The back left passenger was transported by helicopter to a hospital. She sustained fatal injuries. The table below shows the back left passenger's injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Dislocation atlanto-axial {AA}, not further specified	serious 650206.3,6	Seat back, front right passenger's {indirect injury}	Probable	Emergency room records
2	Dislocation {separation, displacement}, complete–greater than 2.5 cm (>1 in), C_6 anteriorly to C_7 with probable severance of spinal cord at C_6-C_7 and marked swelling inferior neck	moderate 650204.2,6	Seat back, front right passenger's {indirect injury}	Probable	Emergency room records
3	Hemothorax, bilateral, not further specified {by ultrasound[1]}	serious 442202.3,3	Torso portion of safety belt system	Probable	Emergency room records
4	Contusion, longitudinal, lower abdomen, not further specified	minor 590402.1,8	Lap portion of safety belt system	Certain	Emergency room records
5	Contusions anterior upper thighs, not further specified	minor 890402.1,3	Lap portion of safety belt system	Probable	Emergency room records

CASE VEHICLE BACK RIGHT PASSENGER KINEMATICS

Immediately prior to the crash, the case vehicle's back right passenger [5-year-old, White (unknown if Hispanic) male; unknown height and weight] was seated in an unknown position in his booster seat. His feet were most likely hanging over the edge of the seat cushion. The position of his hands and arms is not known. There was no seat track and the vehicle's seat back was not adjustable.

Based on this contractor's vehicle inspection, the case vehicle's back right passenger was restrained by his manual, three-point, lap-and-shoulder safety belt system. Inspection of the safety belt webbing and latch plate showed significant friction burns to both the shoulder belt (**Figure 16** below) and the sliding latch plate belt guide. In addition, the belt was bunched up in a corner of the latch plate belt guide due to loading.

[1] This child occupant arrived via helicopter at the medical facility with no cardiac activity and no respirations. She was examined, ultrasound performed, and at least one cervical radiograph was taken. She was declared "dead-on-arrival" and sent to the coroner; however, no autopsy was performed.

According to the GMC's driver, the case vehicle's driver appeared to steer left to avoid the impending crash. As a result, and independent of the use of his safety belt, the back right passenger may have moved slightly to his right just prior to impact due to the driver's left steer. The case vehicle's impact with the GMC caused the back right passenger's safety belt retractor to lock and he continued forward opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated, and he heavily loaded his safety belt system. The length of the load markings on the passenger's safety belt and the deformation and forward displacement of the case vehicle's back right seat back (**Figure 17**) indicate the seat back was loaded by an object in the trunk during the crash pushing the seat back forward and most likely forcing the back right passenger's head into the back of the front right passenger's seat back. Following the impact, the back right passenger most likely rebounded back into his booster seat and remained restrained in the booster seat as the case vehicle rotated slightly clockwise to final rest. The back right passenger was removed from the case vehicle by rescue personnel. The evidence indicates that rescue personnel removed the right rear door from the vehicle and most likely removed the passenger through the right rear door opening.

Figure 16: Load marks on case vehicle's back right safety belt

Figure 17: Forward displacement of back right seat back

CASE VEHICLE BACK RIGHT PASSENGER INJURIES

The back right passenger was declared dead at the crash scene and was not transported to a treatment facility. The back right passenger's injuries are unknown. This contractor was not able to acquire a coroner's report for this passenger.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash, the case vehicle's driver [30-year-old, White (unknown if Hispanic) female; unknown height and weight] was seated in an unknown position. It is likely that

her left foot was on the floor and her right foot was on the accelerator or brake, and at least one hand was on the steering wheel. The driver's seat track and seat back position could not be determined due to the damage to the seat. The seat back was twisted counterclockwise and moved forward.

Based on this contractor's vehicle inspection, the case vehicle's driver was not restrained by her manual, three-point, lap-and-shoulder safety belt system. Inspection of the driver's safety belt webbing, "D"-ring, and latch plate showed no evidence of usage during the crash. In addition, the retractor mounted pretensioner activated during the crash, drawing the safety belt webbing very tightly into the B-pillar.

According to the GMC's driver, the case vehicle's driver appeared to steer left to avoid the impending crash. As a result, the driver may have moved slightly to her right just prior to impact. The impact with the GMC caused the case vehicle's driver to continue forward opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated and her face and chest impacted her deployed air bag. The driver rode down the air bag and loaded the steering wheel, significantly deforming the lower rim and causing an unspecified thoracic cavity injury. The driver's knees also impacted and deformed the knee bolsters fracturing her right femur. In addition, the driver's right upper arm impacted the left instrument panel fracturing her right humerus. The driver most likely rebounded back into her seat and most likely remained in her seat as the case vehicle rotated slightly clockwise to final rest.

CASE VEHICLE DRIVER INJURIES

The case vehicle's driver was airlifted to a hospital and expired in the emergency room. The driver's injuries and injury mechanisms 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	Injury thoracic cavity[2] with left side hemothorax < 50 milliliters	serious 442202.3,2	Steering wheel hub and/or spokes and rim	Probable	Emergency room records
2	Fracture, closed, right humerus, not further specified	moderate 752602.2,1	Left instrument panel and below	Probable	Emergency room records
3	Fracture, closed, right femur, not further specified	serious 851800.3,1	Knee bolster, driver's, right of steering column {indirect injury}	Probable	Emergency room records
4	Fracture, closed, right lower leg, not further specified	moderate 852002.2,1	Left instrument panel and below	Probable	Emergency room records

[2] Patient arrived in cardiac arrest (asytole) with no pulse, pupils fixed and dilated, agonal respirations, and was unresponsive. No autopsy was ordered.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
5	Contusion abdomen, not further specified	minor 590402.1,9	Steering wheel rim	Probable	Emergency room records
6	Laceration {wound}, long, open, right lateral thigh, involving subcutaneous tissue and muscle, not further specified	moderate 890604.2,1	Center instrument panel and below	Probable	Emergency room records
7	Contusion left thigh, not further specified	minor 890402.1,2	Steering wheel rim	Probable	Emergency room records
8	Contusion left lower leg, not further specified	minor 890402.1,2	Left instrument panel and below	Probable	Emergency room records

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

Immediately prior to the crash, the case vehicle's front right passenger [27-year-old, White (unknown if Hispanic) male; unknown height and weight] was seated in an unknown position. It is likely that both of his feet were on the floor, but the position of his hands and arms is not known. The position of the passenger's seat track and seat back could not be determined due to the damage to the seat.

Based on this contractor's vehicle inspection, the case vehicle's front right passenger was not restrained by his manual, three-point, lap-and-shoulder safety belt system.

According to the GMC's driver, the case vehicle's driver appeared to steer left to avoid the impending crash. As a result, the front right passenger may have moved slightly to his right just prior to impact. The impact with the GMC caused the case vehicle's front right passenger to continue forward opposite the case vehicle's 0 degree direction of prinicpal force as the case vehicle decelerated. His face and chest impacted his deployed air bag, his knees impacted the knee bolster and his feet loaded the toe pan. The front right passenger most likely rebounded back into his seat following the impact. The front right passenger most likely remained in his seat as the case vehicle rotated slightly clockwise to final rest. Rescue personnel removed the right front door and removed the front right passenger from the vehicle through the right front door opening.

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The case vehicle's right front passenger was declared dead at the crash scene and was not transported to a treatment facility. The front right passenger's injuries are unknown. This contractor was not able to acquire a coroner's report for this passenger.

The 2004 GMC K1500 was a four wheel drive, four-door pickup truck (VIN: 1GTEK19T74E------) equipped with a 5.3L, V8 engine. The GMC was equipped with driver and front right passenger Certified Advanced 208-Compliant air bag systems which deployed as a result of this vehicle's front impact. This vehicle was also equipped with an Event Data Recorder (EDR) located in the air bag system's Sensing and Diagnostic Module (SDM). The GMC's wheelbase was 364 centimeters (143.3) inches. The GMC's odometer reading was not determined because the interior was not inspected.

Exterior Damage: The GMC's impact with the case vehicle involved the front end. The front bumper, grille, left headlamp/ turn signal assembly and hood were directly contacted and crushed rearward. The direct damage began at the front right bumper corner and extended 149 inches across the front of the vehicle. The residual maximum crush was measured as 75 centimeters (29.5) occurring at C_6 (**Figure 18**). The table below shows the GMC's front crush profile.

Figure 18: Right side view of crush to front of GMC

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	149	75	148	13	34	52	64	65	75	8	0
in		58.7	29.5	58.3	5.1	13.4	20.5	25.2	25.6	29.5	3.2	0.0

The GMC's recommended tire size was P265/75R16, and the vehicle was equipped with tires of this size. The GMC'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	262	38	241	35	9	11	None	Yes	No
RF	Flat	Flat	241	35	9	11	Unknown	Yes	Yes
LR	255	37	241	35	8	10	None	No	No
RR	Flat	Flat	241	35	8	10	None	No	Yes

Damage Classification: Based on the vehicle inspection, the CDC for the GMC was determined to be: **12-FDEW-3** (**0** degrees). The WinSMASH reconstruction program, damage only algorithm, was used to reconstruct the GMC's Delta V. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 49.0 km.p.h. (30 m.p.h.), -49.0 km.p.h. (-30 m.p.h.), and 0 km.p.h. (0 m.p.h.). The downloaded EDR data indicated the GMC's maximum longitudinal Delta V was -53.83 km.p.h. (-33.45 m.p.h.). The GMC was towed due to damage.

Crash Data Recording: The GMC's EDR was downloaded via direct connection to the SDM. The downloaded data indicated that a non-deployment and a deployment event were recorded. The EDR reports for both events are presented in **Figures 19-26** at the end of this report.

The system status report for the deployment event shows that the SIR warning lamp was recorded as off, and the driver's safety belt switch circuit were recorded as buckled. The EDR recorded the maximum SDM forward velocity change as -25.73 km.p.h. (-33.45 m.p.h.) occurring 97.5 milliseconds after algorithm enable (AE). The system status report also showed that the first and second stage deployment criteria for the driver's and front right passenger's air bags were met, respectively at 7.5 milliseconds and 10 milliseconds after AE.

The pre-crash data indicates that five seconds prior to AE, the case vehicle was at 9% throttle traveling at 97 km.p.h. (60 m.p.h.), and the brake switch was recorded as off. The recorded speed remains at 60 m.p.h. and brake the switch is recorded as off for the next three, one second sample periods. At one second prior to AE, the GMC's speed is recorded as 89 km.p.h. (55 m.p.h.) and the brake switch is recorded as on indicating the driver reacted to the impending crash and applied the brakes.

GMC's Occupants: According to the police crash report and driver interview, the GMC's driver [24-year-old, White (non-Hispanic) female] was restrained by her manual, three-point, lap-and-shoulder, safety belt system. The driver was transported by ambulance to the hospital where she was admitted for one day.

According to the police crash report and driver interview, the GMC's front right passenger [24-year-old, White (non-Hispanic) male] was restrained by his manual, three-point, lap-and-shoulder, safety belt system. The front right passenger was transported by ambulance to the hospital where he was admitted for one day.

According to the police crash report and driver interview, the GMC's back center passenger [18-month-old, White (non-Hispanic) male] was restrained in his Evenflo "Horizon V" convertible child safety seat with five-point harness. The child safety seat was secured in the GMC by the two-point, lap belt routed through the belt path on the back of the child safety seat. The back center passenger was transported by ambulance to the hospital where he was treated and released. The table below shows the back center passenger's injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Abrasions to left forehead and above right eye	minor 290202.1,7	Seat back, driver's	Probable	Emergency room records
2	Contusions to left forehead and above right eye	minor 290402.1,7	Seat back, driver's	Probable	Emergency room records
3	Abrasions right neck, not further specified	minor 390202.1,1	Child safety seat harness straps	Probable	Emergency room records
4	Abrasions, tiny, lower chest, not further specified	minor 490202.1,4	Noncontact injury: flying glass, unknown source	Possible	Emergency room records
5	Abrasions on abdomen, not further specified	minor 590202.1,8	Child safety seat harness straps	Probable	Emergency room records
6	Abrasions on {top} right shoulder, not further specified	minor 790202.1,1	Child safety seat harness straps	Probable	Emergency room records
7	Contusion {bruise], small, on upper right thigh	minor 890402.1,1	Child safety seat harness straps	Probable	Emergency room records

CDR File Information

Vehicle Identification Number	1GTEK19T74Exxxxxx
Investigator	
Case Number	
Investigation Date	
Crash Date	
Filename	IN05022EDR.CDR
Saved on	Wednesday, June 15 2005 at 09:50:39 AM
Collected with CDR version	Crash Data Retrieval Tool 2.70
Collecting program verification number	70812808
Reported with CDR version	Crash Data Retrieval Tool 2.800
Reporting program verification number	9238B95E
Interface used to collected data	Block number: 00 Interface version: 41 Date: 11-04-04 Checksum: 9E00
Event(s) recovered	Deployment Non-Deployment

SDM Data Limitations

SDM Recorded Crash Events:
There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded vehicle forward velocity change. This event will be cleared by the SDM after the ignition has been cycled 250 times.
The second type of SDM recorded crash event is the Deployment Event. It also contains Pre-Crash and Crash data. The SDM can store up to two different Deployment Events, if they occur within 25.4 seconds of one another. Deployment Events cannot be overwritten or cleared from the SDM. Once the SDM has deployed the air bag, the SDM must be replaced.
The data in the Non-Deployment Event file will be locked after a Deployment Event, if the Non-Deployment Event occurred within 5 seconds before the Deployment Event. If multiple Non-Deployment Events occur within 5 seconds prior to a Deployment Event, then the most severe Non-Deployment Event will be recorded and locked. If multiple Non-Deployment Events precede a Deployment Event, and multiple Non-Deployment Events occur within 5 seconds of each other (but not necessarily all within 5 seconds of the Deployment Event), and subsequent Non-Deployment Events are less severe than prior Non-Deployment Events, and the last of the multiple Non-Deployment Events occurs within 5 seconds of a Deployment Event, then the most severe of the Non-Deployment Events (which may have occurred more than 5 seconds prior to the Deployment Event) will be recorded and locked.

SDM Data Limitations:
-SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. SDM Recorded Vehicle Forward Velocity Change is the change in velocity during the recording time and is not the speed the vehicle was traveling before the event, and is also not the Barrier Equivalent Velocity. This data should be examined in conjunction with other available physical evidence from the vehicle and scene when assessing occupant or vehicle forward velocity change. For Deployment Events and Deployment Level Events, the SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. For Non-Deployment Events, the SDM will record the first 150 milliseconds of data after algorithm enable.
-Event Recording Complete will indicate if data from the recorded event has been fully written to the SDM memory or if it has been interrupted and not fully written.
-SDM Recorded Vehicle Speed accuracy can be affected if the vehicle has had the tire size or the final drive axle ratio changed from the factory build specifications.
-Brake Switch Circuit Status indicates the status of the brake switch circuit.
-Pre-Crash Electronic Data Validity Check Status indicates "Data Invalid" if the SDM receive an invalid message from the module sending the pre-crash data.
-Driver's and Passenger's Belt Switch Circuit Status indicates the status of the seat belt switch circuit. If the vehicle's electrical system is compromised during a crash, the state of the Belt Switch Circuit may be reported other than the actual state.
-The Time Between Non-Deployment and Deployment Events is displayed in seconds. If the time between the two events is greater than 25.4 seconds, "N/A" is displayed in place of the time.
-If power to the SDM is lost during a crash event, all or part of the crash record may not be recorded.
-Multiple Events Associated with this Record: This parameter will indicate whether one or more associated events

Figure 19: GMC's CDR File Information and SDM Data Limitations

preceded the recorded event.
-One or More Associated Events Not Recorded: If a single event is recorded, this parameter will indicate whether one or more associated events, prior to the recorded event, was not recorded.
If two associated events are recorded, this parameter for the first event will indicate whether one or more associated events, prior to the first event, was not recorded.
If two associated events are recorded, this parameter, for the second event, will indicate whether one or more associated events, between the first and second events, was not recorded.

SDM Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the vehicle's communication network, to the SDM.
-Brake Switch Circuit Status data is transmitted once a second by either the ABS module or the PCM, via the vehicle's communication network, to the SDM.
-The SDM may obtain Belt Switch Circuit Status data a number of different ways, depending on the vehicle architecture. Some switches are wired directly to the SDM, while others may obtain the data from various vehicle control modules, via the vehicle's communication network.

Figure 20: GMC's SDM Data Limitations continued

1GTEK19T74Exxxxxx System Status At Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Deployment	917
Ignition Cycles At Investigation	918
Maximum SDM Recorded Velocity Change (MPH)	-33.45
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	97.5
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	7.5
Driver Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Passenger First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	7.5
Passenger Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Time Between Non-Deployment And Deployment Events (sec)	N/A
Frontal Deployment Level Event Counter	1
Event Recording Complete	Yes
Multiple Events Associated With This Record	No
One Or More Associated Events Not Recorded	No

Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-1.24	-4.03	-8.06	-14.57	-18.91	-23.25	-27.90	-30.69	-31.93	-33.17	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	60	1664	9	OFF
-4	60	1664	15	OFF
-3	60	1664	15	OFF
-2	60	1664	15	OFF
-1	55	1600	0	ON

Figure 21: GMC's System Status at Deployment report

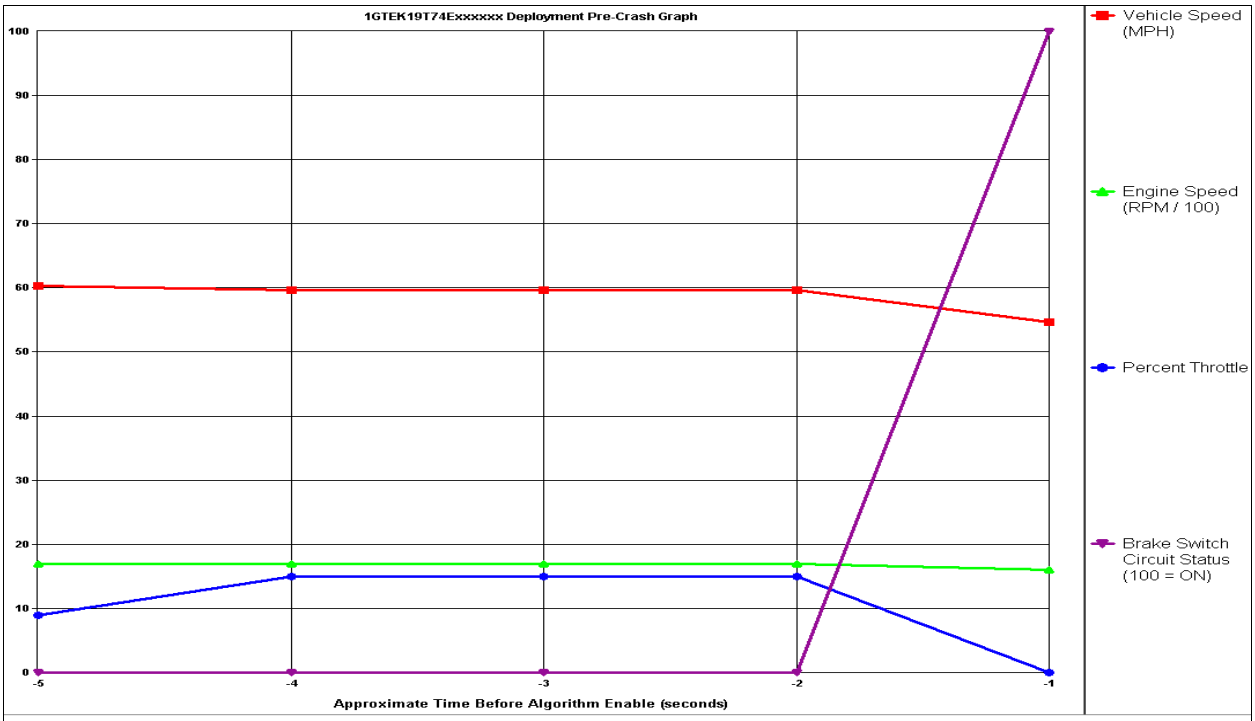


Figure 22: GMC's Deployment Pre-Crash Graph

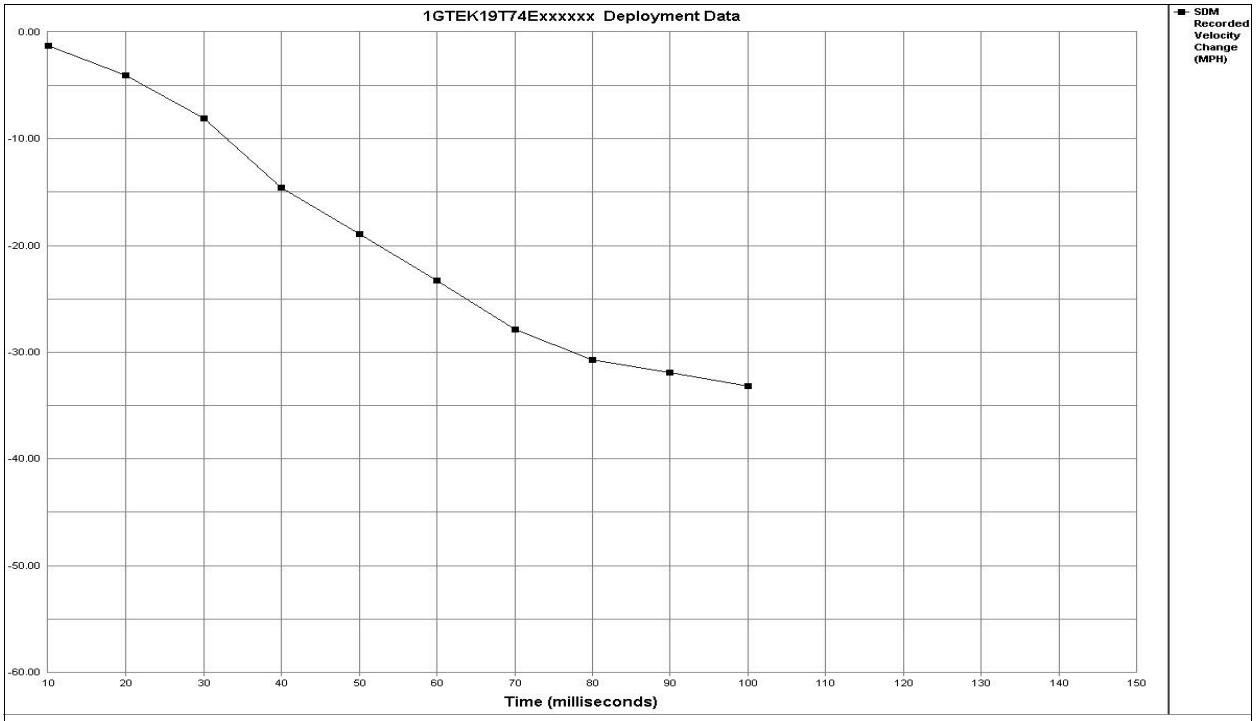


Figure 23: GMC's Deployment SDM Recorded Velocity Change graph

1GTEK19T74Exxxxxx System Status At Non-Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Non-Deployment	917
Ignition Cycles At Investigation	918
Maximum SDM Recorded Velocity Change (MPH)	-1.03
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	75
Event Recording Complete	Yes
Multiple Events Associated With This Record	Yes
One Or More Associated Events Not Recorded	Yes

Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	0.00	0.00	0.00	-0.31	-0.62	-0.62	-0.93	-0.93	-0.93	-0.93	-0.62	-0.62	-0.62	-0.62	-0.31

PRE-CRASH DATA				
Seconds Before AE	**Vehicle Speed (MPH)**	**Engine Speed (RPM)**	**Percent Throttle**	**Brake Switch Circuit Status**
-5	60	Invalid	15	OFF
-4	60	Invalid	15	OFF
-3	60	1600	15	OFF
-2	55	1216	0	ON
-1	42	0	0	ON

Figure 24: GMC's System Status at Non-Deployment Report

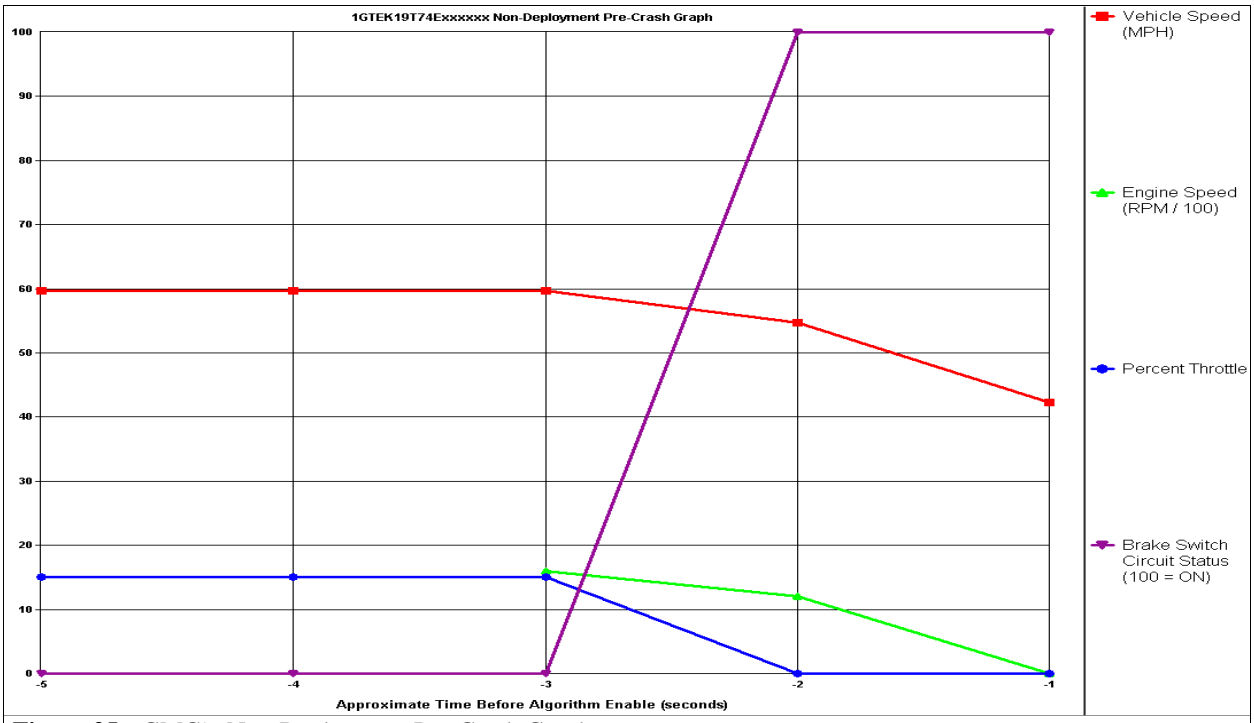


Figure 25: GMC's Non-Deployment Pre-Crash Graph

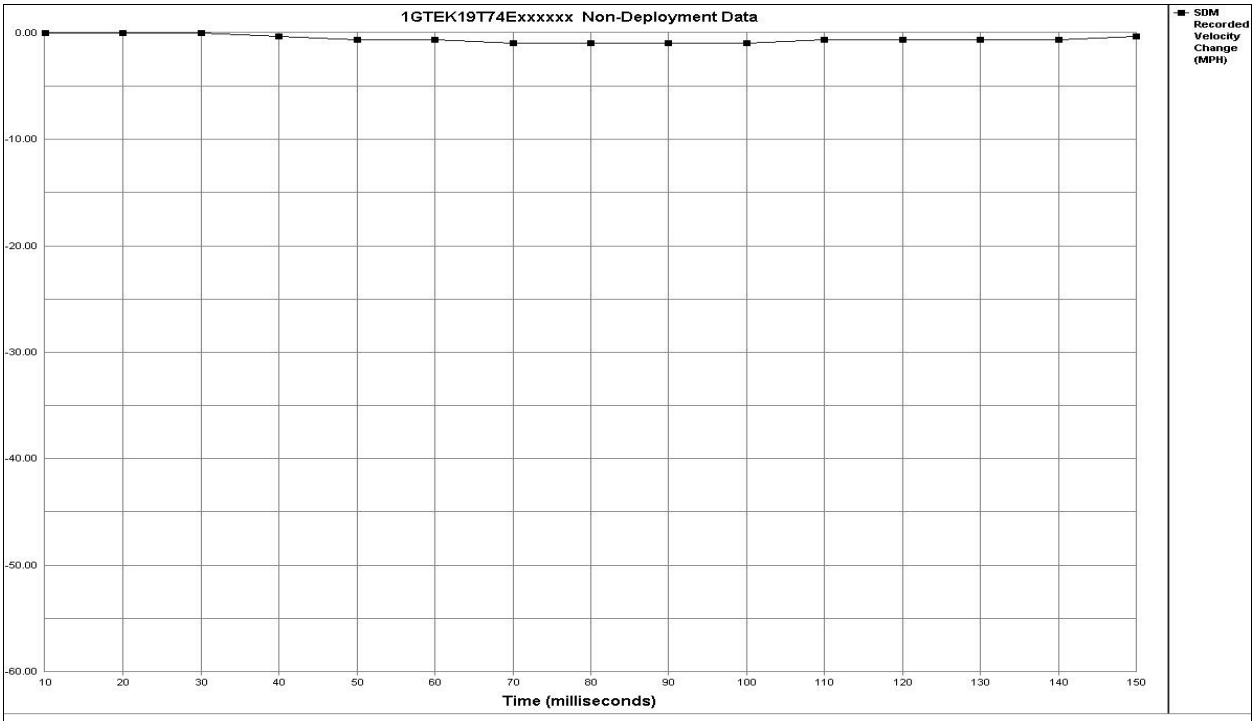
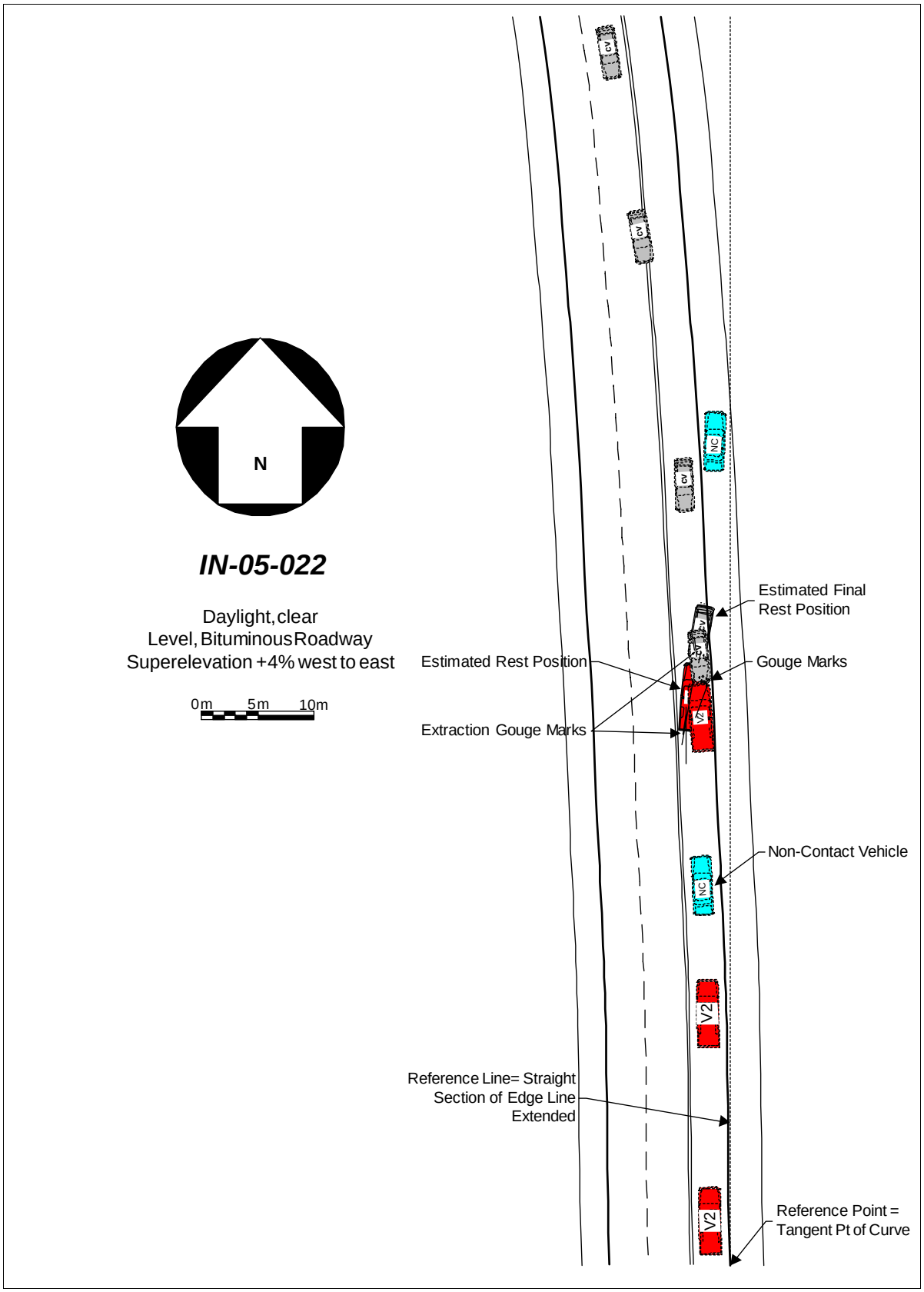


Figure 26: GMC's Non-deployment SDM Recorded Velocity Change graph


N
IN-05-022
Daylight, clear
Level, Bituminous Roadway
Superelevation +4% west to east
0m 5m 10m
CV
CV
NC
CV
V1
V2
NC
V2
V2
Estimated Final Rest Position
Estimated Rest Position
Gouge Marks
Extraction Gouge Marks
Non-Contact Vehicle
Reference Line= Straight Section of Edge Line Extended
Reference Point = Tangent Pt of Curve