Certified Advanced 208-Compliant Air Bag Investigation
Dynamic Science, Inc. (DSI), Case Number DS09008
2007 Ford Fusion
Washington
December 2008

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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 on-site investigation focused on the Certified Advanced 208-Compliant (CAC) air bag system in a 2007 Ford Fusion 4-door sedan. The multi-stage air bags were certified by the manufacturer to be compliant with the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. This crash occurred on a straight north/south two-lane roadway. The Ford was being driven north by a restrained 17-year-old male. The other vehicle was a 1995 Lincoln Mark VIII that was being driven south by a restrained 47-year-old female. The front right seat of the Lincoln was occupied by a restrained 49-year-old male. The Ford traveled across the center line into the southbound travel lane. The driver of the Lincoln braked but was unable to avoid the crash. The left front of the Ford impacted the left front of the Lincoln in an offset head-on configuration. The driver's frontal air bag, seat-mounted side air bag, and side inflatable curtain (IC) air bag deployed at impact. The Ford rotated in a counterclockwise direction, crossed the northbound travel lane, and departed the roadway on the east side where it came to rest facing southwest. The Lincoln rotated in a counterclockwise direction, partially departed the roadway on the west side, and came to rest facing east. The driver of the Ford sustained a blunt aortic injury, multiple left leg fractures, an L5 vertebral body fracture, kidney laceration and liver lacerations, a corneal abrasion, and multiple abrasions and lacerations. The driver of the Lincoln was fatally injured. The front right occupant of the Lincoln sustained a fractured left wrist.

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Dynamic Science, Inc.
Crash Investigation
Case Number: DS09008

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BACKGROUND

This on-site investigation focused on the Certified Advanced 208-Compliant (CAC) air bag system in a 2007 Ford Fusion 4-door sedan (**Figure 1**). The multi-stage air bags were certified by the manufacturer to be compliant with the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. This crash occurred on a straight north/south two-lane roadway. The Ford was being driven north by a restrained 17-year-old male. The other vehicle was a 1995 Lincoln Mark VIII that was being driven south by a restrained 47-year-old female (**Figure 2**). The front right seat of the Lincoln was occupied by a restrained 49-year-old male.

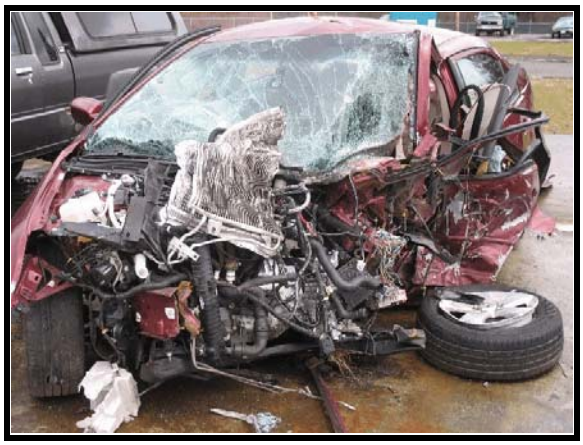


Figure 1. Subject vehicle, 2007 Ford Fusion

Figure 2. Other vehicle, 1995 Lincoln Mark VIII

The Ford traveled across the center line into the southbound travel lane. The driver of the Lincoln braked but was unable to avoid the crash. The left front of the Ford impacted the left front of the Lincoln in an offset head-on configuration. The driver's frontal air bag, seat-mounted side air bag, and side impact inflatable curtain (IC) air bag deployed at impact. The Ford rotated in a counterclockwise direction, crossed the northbound travel lane, and departed the roadway on the east side where it came to rest facing southwest. The Lincoln rotated in a counterclockwise direction, partially departed the roadway on the west side, and came to rest facing east. The driver of the Ford sustained a blunt aortic injury, multiple left leg fractures, an L5 vertebral body fracture, kidney and liver lacerations, a corneal abrasion, and multiple abrasions and lacerations. The driver of the Lincoln was fatally injured. The front right occupant of the Lincoln sustained a fractured left wrist.

This CAC investigation was identified by the National Highway Traffic Safety Administration (NHTSA) during a review of National Automotive Sampling System (NASS) General Estimates System (GES) police reports. On February 6, 2009 DSI was instructed to locate the subject vehicle and to obtain cooperation. The investigating officer was contacted and permission to inspect both vehicles in the crash was obtained. DSI was assigned the case on February 25, 2009 and field work was completed on March 4, 2009. The investigating officer was present during the vehicle inspections. The investigating officer attempted to image data from the Ford's Power Control Module (PCM) but damage to the PCM prevented him from obtaining any data.

SUMMARY

Crash Site

This two-vehicle crash occurred on December 2008 at 2302 hours. The crash occurred on a straight north/south two-lane roadway. There was a negative 4% grade in the northbound direction and at the area of impact. There was a positive 2% grade in the southbound direction approximately 72 m (236 ft) north of the area of impact. The asphalt roadway was bordered on the east and west by solid white fog lines and asphalt shoulders. On the east side of the roadway there was a 3 m (10 ft) wide ditch that was approximately 2.1 m (7 ft) below the level of the road bed. On the west wide of the roadway there was a 1.5 m (5 ft) wide ditch. The travel lanes were separated by solid/dashed yellow lines that allowed passing in the northbound direction. It was dark without streetlight illumination at the time of the crash and the roadway surface was wet. The speed limit was 64 km/h (40 mph).

Figure 3. Northbound approach

Figure 4. Southbound approach

Pre-Crash

The Ford was traveling northbound at approximately 114 km/h (71 mph) and had just passed over a hillcrest (**Figure 3**). The Lincoln was traveling southbound at approximately 64 km/h (40 mph) (**Figure 4**). The speeds were based on the post-crash positions of the speedometer needles in each vehicle (**Figures 5-6**). For unknown reasons, the driver of the Ford crossed the center line and entered the southbound travel lane into the path of the Lincoln.

Figure 5. Ford speedometer needle position

The vehicles had an estimated closing speed of 179 km/h (111 mph)[1].

Figure 6. Lincoln speedometer needle position

Figure 7. Path of Ford to roadway departure

Crash

The driver of the Lincoln braked but was unable to avoid the collision. The police officer reported seeing a single right front skid mark just prior to the point of impact, but the mark was no longer visible at the time of the scene inspection.

The left front of the Ford impacted the left front of the Lincoln in an offset head-on configuration. The impact resulted in the deployment of the Ford's left frontal air bag, the left seat-mounted side air bag, and the left side IC air bag. Both frontal air bags in the Lincoln deployed. For the Ford, the damage algorithm of the WinSMASH program computed a Total Delta-V of 84 km/h (52.2 mph). The longitudinal and lateral components were -83 km/h (-51.4 mph) and -15 km/h (-9.1 mph), respectively. For the Lincoln, the program computed a Total Delta V of 73 km/h (45.4 mph). The longitudinal and lateral components were -73 km/h (-45.4 mph) and 0 km/h, respectively. The Ford initiated a counterclockwise rotation, crossed through the northbound travel lane, departed the east side of the roadway (**Figure 7**), and fell into the ditch adjacent to the roadway. The Ford came to rest facing southwest 20.4 m (67 ft) north of the area of impact. The left rear of the Ford impacted the ground and was damaged from the fall into the ditch. The Lincoln rotated in a counterclockwise direction and partially departed the west side of the roadway. The rear tires of the Lincoln fell into the shallow ditch. The right frame area was damaged as the vehicle fell into the ditch and impacted the ground.

Post-Crash

The driver of the Ford sustained a blunt aortic injury, multiple left leg fractures, an L5 vertebral body fracture, kidney and liver lacerations, a corneal abrasion, and multiple abrasions and lacerations. Responding EMTs reported a Glasgow Coma Score (GCS) of 3 upon arrival. The driver was extricated from the vehicle by emergency personnel and was transported by air to an area trauma center for treatment where he was hospitalized for seven days. The driver of the Lincoln was fatally injured and was pronounced dead at the scene. Her body was entrapped in the vehicle and it took emergency personnel several hours to extricate her. The front right occupant of the Lincoln

[1]See Attachment 2

sustained a fractured left wrist and was transported to a local trauma center for treatment. Both vehicles were towed from the scene due to damage and were placed on a police hold.

Vehicle Data - 2007 Ford Fusion

The 2007 Ford Fusion SE 4-door 5-passenger sedan was identified by the Vehicle Identification Number (VIN): 3FAHP07Z17Rxxxxxx. The Ford was equipped with a 2.3-liter, 4-cylinder engine, automatic transmission, front wheel drive, 4-wheel disc brakes, power steering, and a tilt steering column. The Ford was equipped with Continental ContiProContact P215/60R16 tires. The tire manufacturer's stated maximum pressure was 303 kPa (44 psi); the vehicle manufacturer's recommended cold pressure was 241 kPa (35 psi).

The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	Tire Flat	7 mm (9/32 in)	No	Tear in sidewall that measured 30 x 10 cm (11.8 x 3.9 in).
LR	172 kPa (25 psi)	6 mm (7/32 in)	No	None
RR	241 kPa (35 psi)	9 mm (11/32 in)	No	None
RF	290 kPa (42 psi)	5 mm (6/32 in)	No	None

The seating in the Ford was configured with front bucket seats with adjustable head restraints and a rear bench seat with integral head restraints for the outboard seating positions.

Vehicle Damage

Exterior Damage

The Ford sustained severe front end damage from the impact with the Lincoln (**Figure 8**). The direct damage began at the front left bumper corner and extended 80 cm (31.4 in) laterally to the right. The bumper fascia and backing bar were displaced from the vehicle. There was direct contact down the left side of the vehicle that began at the front left corner of the subframe, extended 102 cm (40.1 in) down the left side, and terminated 110 cm (43.3 in) forward of the rear axle. Both left side doors were jammed shut. The left front door was displaced rearward 29 cm (11.4 in) to the mid-point of the left rear door. The left front tire

Figure 8. View of damage from left

rim/wheel assembly was fractured and displaced from the vehicle.

Six crush measurements were documented along the frontal subframe as follows: C_1 = 110 cm (43.3 in), C_2 = 97 cm (38.1 in), C_3 = 84 cm (33 in), C_4 = 47 cm (18.5 in), C_5 = 40 cm (15.7 in), C_6 = 29 cm (11.4 in). Two crush measurements were documented at the bumper mounting brackets as follows: C1 = 147 cm (57.8 in) and C2 = 63 cm (24.8 in). The right frame was shifted 93 cm (36.6 in) to the left. The Collision Deformation Classification (CDC) for the impact with the Lincoln was 12FYEW6.

Figure 9. Left rear bumper damage

The Ford sustained minor damage to the left bumper corner as a result of the non-horizontal impact with the edge of the ditch (**Figure 9**). As the Ford departed the roadway, the back end of the vehicle dropped down into the ditch/embankment area. The direct damage began at the left bumper corner and extended 40 cm (15.7 in) laterally to the right. There was also direct contact up the left side of the vehicle that began at the bumper corner and extended 37 cm (14.6 in) forward along the left side. The CDC for the impact with the ditch was 00BLLE4.

Interior Damage

The Ford sustained severe damage as a result of passenger compartment intrusion and occupant contacts. Contacts were documented to the steering wheel, the left instrument panel/knee bolster, the left kick panel, the ignition switch/key, and the driver's frontal air bag. The lower quarter of the steering wheel rim was deformed forward 3 cm (1.2 in). There was longitudinal intrusion of the A-pillar, toe pan, instrument panel, toe pan, steering wheel and seat back; there was lateral intrusion to the driver's door, the kick panel, and the center console. The driver's seat was deformed in the crash; the seat back was at a 13 degree angle from vertical and the seat cushion was at a 15 degree angle from horizontal.

The specific passenger compartment intrusions were documented as follows:

Position	**Intruded Component**	**Magnitude of Intrusion**	**Direction**
First row left	Lower A-pillar	47 cm (18.5 in)	Longitudinal
First row left	Toe pan	47 cm (18.5 in)	Longitudinal
First row left	Left instrument panel	43 cm (16.9 in)	Longitudinal
First row left	Steering wheel	37 cm (14.6 in)	Longitudinal
First row middle	Center instrument panel	33 cm (12.9 in)	Longitudinal

Position	Intruded Component	Magnitude of Intrusion	Direction
Second row left	Driver seat back	30 cm (11.8 in)	Longitudinal
First row left	Kick panel	28 cm (11.0 in)	Lateral
First row right	Center console	10 cm (3.9 in)	Lateral
First row left	Door, lower forward quadrant	4 cm (1.6 in)	Lateral

Manual Restraints

The Ford was configured with 3-point manual lap and shoulder belts for all five seating positions. The vehicle was equipped with driver and front passenger safety belt retractor pretensioners. The driver's seat belt anchorage adjustment was in the full-down position; the front right passenger's seat belt anchorage adjustment was in the full-up position. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR); it was being used at the time of the crash. There was evidence of occupant loading to the belt webbing. The loading marks measured 8 cm (3.1 in) in length and began 20 cm (7.9 in) from the stop button **(Figure 10**). There was also a 5 cm (1.9 in) area of the belt that was trapped by the latch plate. The seat belt anchor was not visible due to the door intrusion.

Figure 10. Loading to driver's safety belt

Supplemental Restraint Systems

The Ford's supplemental restraint system (SRS) consisted of driver and passenger dual-stage air bags, left and right IC air bags, left and right seat-mounted side air bags, front outboard safety belts with retractor pretensioners, safety belt buckle switch sensors, a driver's seat position sensor, a front passenger sensing system, a front crash severity sensor, side impact sensors, and a Restraints Control Module (RCM) with impact and safing sensors. Crash and occupant sensors provide information to the RCM. During a crash, the RCM actuates the safety belt pretensioners and/or either one of both stages of the frontal air bags based on the crash severity. When the Power Control Module (PCM) receives a Restraint Deployment Signal (RDS) from the RCM indicating a seatbelt or air bag deployment event occurred, the PCM will lock 20

Figure 11. Damaged PCM

seconds of "pre-crash" and record 5 seconds of "post crash" data in the PCM's memory. The PCM was located on the left side of the firewall. Efforts were made by the investigating officers to image the data from PCM while it was still attached to the vehicle and then later after it had been removed, but the PCM was too badly damaged to provide any data (**Figure 11**).

Figure 12. Driver's frontal air bag

During the impact with the Lincoln, the driver's frontal air bag, the driver's seat-mounted side air bag, and the left IC air bag deployed.

The driver's frontal air bag deployed from the center of the steering wheel hub through H-configuration module cover flaps (**Figure 12**). The top flap measured 17.5 cm (6.9 in) in width and 5 cm (1.9 in) in height; the lower flap measured 17.5 cm (6.9 in) in width and 8 cm (3.1 in) in height. The deployed air bag measured 53 cm (20.8in) in width in its deflated state. The air bag was tethered by a single internal flap. The tether was attached to stitched circle in the center of the air bag face. Two X-shaped vent ports that measured 5 cm (1.9 in) in diameter were located at the 11 and 1 o'clock aspects on the rear of the air bag. There was an area of linear scuffing to the upper air bag face that measured 23 cm (9 in) in width by 15 cm (5.9 in) in height. Within this area, there was 2 cm (0.8 in) deposit of dried fluid that may have been blood. In the center of the stitched circle on the face of the air bag there was a linear burn mark that measured 11 cm (4.3 in) in length by 0.5 cm (0.2 in) in width.

Figure 13. Driver's seat-mounted side air bag

Figure 14. Left IC air bag

The driver's seat-mounted side air bag deployed from the seat back through a rectangular module cover flap (**Figure 13**). The flap measured 11.5 cm (4.5 in) in length by 32 cm (12.6 in) in height. The deployed air bag was oval-shaped and measured 29 cm (11.4 in) in width and 18 cm (7 in) in height. There was a 1 cm (0.4 in) vent port on the outboard aspect of the bag. There were areas of blood located on the inner aspect of the air bag. The first area was located at the lower rear portion of the air bag and measured 9 cm (3.5 in) in height by 7 cm (2.5 in) in width. The second area was located at the forward middle portion of the air bag and measured 4 cm (1.6

in) in height by 9 cm (3.5 in) in width.

The left IC air bag deployed through the roof rail cladding from a module located at the roof side rail (**Figure 14**). The air bag was generally rectangular and measured 136 cm (53.5 in) in length and 40 cm (15.7 in) in height. The forward aspect of the air bag was attached to the left A-pillar by a triangular sail that measured 33 cm (12.9 in) in length and was 22 cm (8.7 in) in height at the point it attached to the air bag; the rear aspect of the bag was attached to the left C-pillar. The longitudinal area of coverage began near the midpoint A-pillar and extended to the C-pillar. The air bag's vertical coverage began at the roof rail and extended to approximately 3.0 cm (1.2 in) below the bottom of the side glass. There were no contacts or damage to the air bag. There was dirt, fluids, and glass fragments located on the outboard aspect of the air bag.

Vehicle Data - 1995 Lincoln Mark VIII

The 1995 Lincoln Mark VIII 2-door 5-passenger coupe was identified by the VIN: 1LNLM91V0SYxxxxxx. The Lincoln was equipped with a 4.6-liter, 8-cylinder, rear-wheel drive, 4-wheel ABS, 4-speed automatic transmission, and power steering. The Ford was equipped with Goodyear Eagle LS P225/60R16 tires. The tire manufacturer's stated maximum pressure was 303 kPa (44 psi); the vehicle manufacturer's recommended cold pressure was 241 kPa (35 psi). The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	Tire Flat	7 mm (9/32 in)	Yes	Tire cut and torn
LR	Tire Flat	6 mm (7/32 in)	No	None
RR	303 kPa (44 psi)	5 mm (6/32 in)	No	None
RF	No pressure reading (valve problem)	6 mm (8/32 in)	No	None

Vehicle Damage

Exterior Damage - 1995 Lincoln Mark VIII

The Lincoln sustained severe front end damage from the impact with the Ford (**Figure 15**). The direct damage began at the front left bumper corner and extended 80 cm (31.4 in) to the right. There was extensive damage due to extrication efforts; the roof and left door were cut off the vehicle. Six crush measurements were documented at the bumper level as follows: C_1 = 133 cm (52.4 in), C_2 = 108 cm (42.5 in), C_3 = 103 cm (40.5 in), C_4 = 78 cm (30.7 in), C_5 = 14 cm (5.5 in), C_6 = 0 cm. The CDC for the impact with the Ford was 12FYEW6.

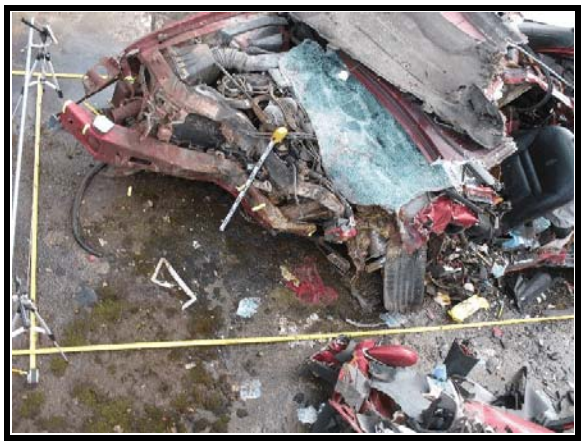


Figure 15. Overview of frontal damage

The Lincoln sustained minor right undercarriage damage from contact with the ditch as the vehicle left the roadway and bottomed out. The damage began 91 cm (35.8 in) rear of the front axle and extended rearward 32 cm (12.6 in). The vertical crush measured 7 cm (2.8 in). The CDC for the impact with ditch was 00UPRN02.

OCCUPANT DEMOGRAPHICS

	Driver
Age/Sex:	17/Male
Seated Position:	Front left
Seat Type:	Bucket
Seat Track Position:	Mid-track
Height:	165 cm (65 in)
Weight:	65 kg (143 lbs)
Alcohol/Drug Involvement:	None
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder

Occupant Injuries

Driver: Injuries obtained emergency room records and discharge summary.

Injury	AIS Code	Injury Mechanism	Confidence Level
Thoracic aorta pseudoaneurysm[2] (blunt aortic injury) with periaortic hemorrhage	420299.4,4	Steering wheel rim	Probable
Left femoral shaft fracture (comminuted)	851801.3,2	Lower instrument panel	Probable
Left Weber C ankle fracture/fibular fracture (comminuted)	851606.2,2	Toe pan	Probable
L5 vertebral body fracture	650630.2,8	Seat cushion	Probable
Left renal laceration, Grade 3	541624.3,2	Steering wheel rim	Probable
Liver laceration, Grade 1	541822.2,1	Steering wheel rim	Probable

[2]A psesudoaneurysm is a leakage of arterial blood from an artery into the surrounding tissue with a persistent communication between the originating artery and the resultant adjacent cavity. Source: www.usmc.ucdavis.edu/vascular/lab/exams/psesudoaneurysm.html.

Injury	AIS Code	Injury Mechanism	Confidence Level
Right corneal abrasion	240602.1,1	Driver air bag	Probable
Left navicular fracture (foot)	852002.2,2	Toe pan	Probable
Abdominal wall abrasions	590202.1,9	Steering wheel rim	Probable
Right knee laceration	890600.1,1	Lower instrument panel	Certain
Right lower leg abrasions	890202.1,1	Lower instrument panel	Probable

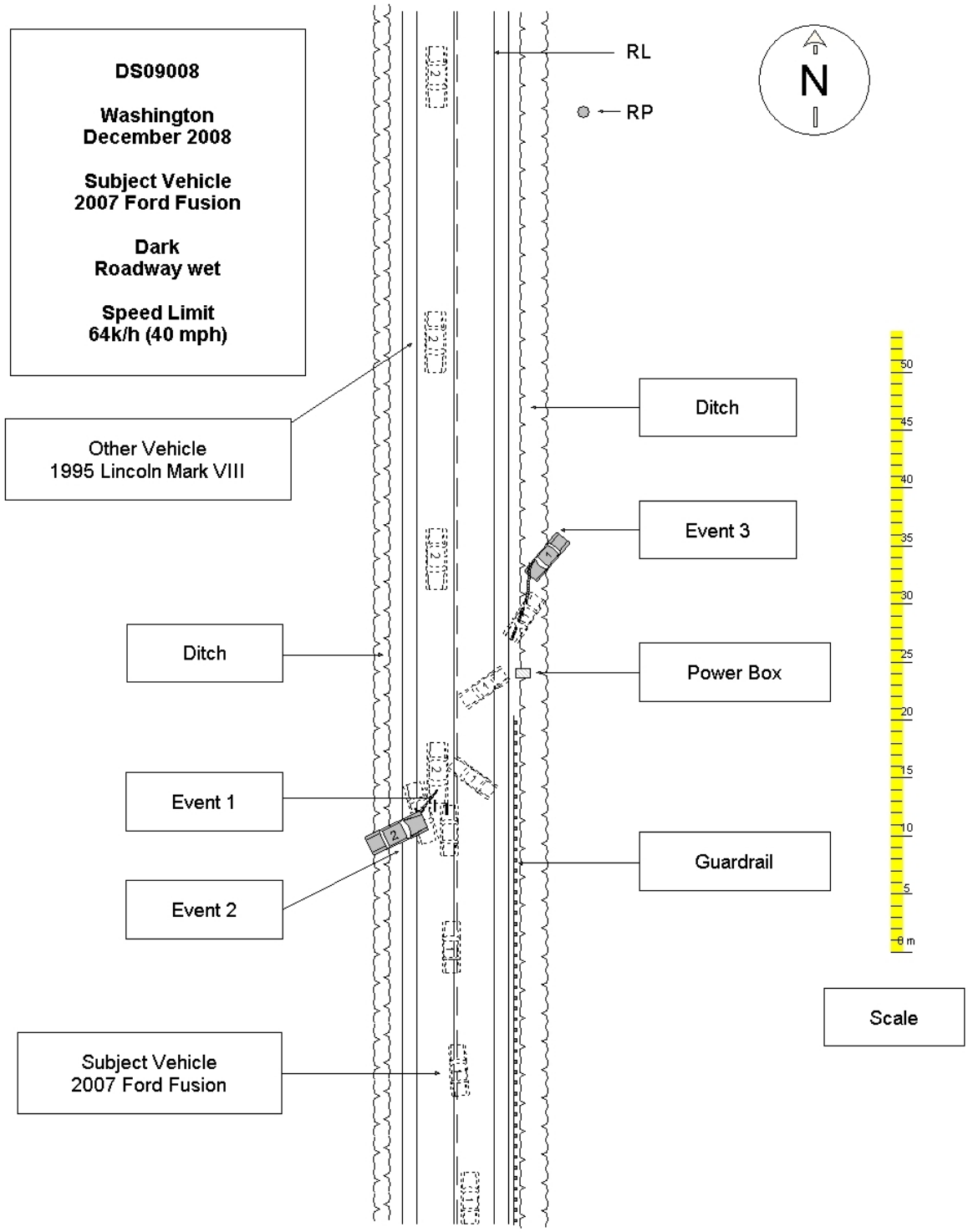
OCCUPANT KINEMATICS

Driver Kinematics

The 17-year-old male driver of the Ford was seated in an unknown posture and the seat was adjusted to the mid-track position (**Figure 16**). He was restrained by the 3-point manual lap and shoulder belt and the safety belt anchorage was in the full-down position. There were no indications that the driver braked prior to impact. His right foot was probably on the accelerator and the left was on the floorboard. At impact with the Lincoln, the driver was displaced forward. He loaded the safety belt and contacted the frontal air bag. He sustained a corneal abrasion from the contact with the air bag. He also loaded and deformed the steering wheel rim causing a blunt aortic injury and liver and kidney lacerations. His left knee engaged the lower instrument panel causing an indirect left femur fracture. His right knee and lower leg contacted and deformed the lower instrument panel resulting in a knee laceration and abrasions to the lower leg. His left foot flexed upward while in contact with the toe pan area and his sustained a fracture to the navicular bone. He required extrication from the vehicle and was transported to an area trauma center for treatment and was hospitalized for seven days. The driver reported that he was amnesiac for events immediately before and after the crash.

Figure 16. Driver's seated position

Attachment 1. Scene Diagram



Attachment 2. Calculations

Comments: Closing speed calculation

*** * CLOSING SPEED, ANY ANGLE * ***

$Sc = \sqrt{(S1^2 + S2^2) - (2 \times S1 \times S2 \times \text{Cos}\,\Theta)}$

$Sc = \sqrt{(71.00^2 + 40.00^2) - (2 \times 71.00 \times 40.00 \times -1.00)}$

$Sc = \sqrt{(5041.00 + 1600.00) - (2 \times 71.00 \times 40.00 \times -1.00)}$

$Sc = \sqrt{6641.00 - -5680.00}$

$Sc = \sqrt{12321.00}$

$Sc = 111.00$

Sc = The Closing Speed in MPH.
S1 = The Speed of Veh 1 in MPH.
S2 = The Speed of Veh 2 in MPH.
2 = A Constant.
Θ = The Approach Angle in Degrees.

INPUTS:	
The Spd of Veh 1 in MPH is:	71.00
The Spd of Veh 2 in MPH is:	40.00
The Angle of Approach (°) is:	180.00

RESULTS:	
The Closing Speed is:	111.00
The Velocity in FPS is:	162.80

7.70.7