TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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GENERAL DYNAMICS REMOTE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION SYSTEM CRASH INVESTIGATION

SCI TECHNICAL SUMMARY REPORT

NASS/SCI COMBO CASE NO. 03-45-150J

VEHICLE – 2002 BMW 325i

LOCATION - STATE OF TENNESSEE

CRASH DATE – SEPTEMBER 2003

Contract No. DTNH22-01-C-17002

Prepared for:

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

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

TECHNICAL REPORT STANDARD TITLE PAGE

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16. Abstract This remote investigation focused on the performance of the Side Impact Inflatable Occupant Protection system in a 2002 BMW 325i. The safety system included front door panel mounted side impact air bags and a Head Protection System (HPS) that consisted of roof side rail mounted tubular air bags for the front seating positions. In addition, the BMW was equipped with dual stage frontal air bags, a front right seat occupant presence sensor, and buckle pretensioners. The 2002 BMW 325i was occupied by a restrained 16-year-old female driver. The BMW was involved in a severe intersection-type crash with a 1995 Ford Econoline cargo van. The Ford was occupied by a 26-year-old male driver. The BMW was traveling northbound on a two-lane, two-way roadway approaching a three-leg "T"-type intersection where the driver was intending to turn left. The Ford was traveling eastbound on similar roadway approaching the same intersection. The driver of the BMW failed to detect the approaching Ford and turned left at the intersection. The frontal aspect of the Ford impacted the left passenger compartment area of the BMW. Both vehicles initiated a counterclockwise rotation as a result of the crash and departed the north road edge. As the BMW and the Ford departed the road, the rear aspect of the BMW and the front aspect of the Ford impacted shrubs in a landscaped area. The initial impact resulted in the deployment of the driver's door panel mounted side impact air bag and the left side HPS air bag. No air bags deployed in the Ford as a result of the impact. The driver of the BMW sustained two AIS-4 brain injuries from contact with the front of the Ford van. She also sustained multiple minor to serious severity injuries from contact against the intruding left side surfaces of the BMW. The driver was transported to a local trauma center where she was diagnosed with brain death and expired two days post-crash. The driver of the Ford was not injured as a result of the crash. The BMW sustained severe damage and was towed from the crash site. The Ford sustained minor damage and was towed from the crash site.			
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SUBJECT VEHICLE – 2002 BMW 325i
LOCATION - STATE OF TENNESSEE
CRASH DATE - SEPTEMBER 2003

BACKGROUND

This remote investigation focused on the performance of the Side Impact Inflatable Occupant Protection system **(Figure 1)** in a 2002 BMW 325i. The safety system included front door panel mounted side impact air bags and a Head Protection System (HPS) that consisted of roof side rail mounted tubular air bags for the front seating positions. In addition, the BMW was equipped with dual stage frontal air bags, a front right seat occupant presence sensor, and buckle pretensioners. The 2002 BMW 325i was occupied by a restrained 16-year-old female driver. The BMW was involved in a severe intersection-type crash with a 1995 Ford Econoline cargo van. The Ford was occupied by a 26-year-old male driver. The BMW was traveling northbound on a two-lane, two-way roadway approaching a three-leg "T"-type intersection where the driver was intending to turn left. The Ford was traveling eastbound on similar roadway approaching the same intersection. The driver of the BMW failed to detect the approaching Ford and turned left at the intersection. The frontal aspect of the Ford impacted the left passenger compartment area of the BMW. Both vehicles initiated a counterclockwise rotation as a result of the crash and departed the north road edge. As the BMW and the Ford departed the road, the rear aspect of the BMW and the front aspect of the Ford impacted shrubs in a landscaped area. The initial impact resulted in the deployment of the driver's door panel mounted side impact air bag and the left side HPS air bag. No air bags deployed in the Ford as a result of the impact. The driver of the BMW sustained two AIS-4 brain injuries from contact with the front of the Ford van. She also sustained multiple minor to serious severity injuries from contact against the intruding left side surfaces of the BMW. The driver was transported to a local trauma center where she was diagnosed with brain death and expired two days post-crash. The driver of the Ford was not injured as a result of the crash. The BMW sustained severe damage and was towed from the crash site. The Ford sustained minor damage and was towed from the crash site.

Figure 1. Subject vehicle 2002 BMW 325i.

This crash was identified by the National Automotive Sampling System (NASS) PSU 45 during the weekly sampling of Police Accident Reports (PARs). This crash was selected and researched as CDS Case No. 03-45-150J. The NASS PSU performed the vehicle and scene inspections, and conducted the driver/occupant interviews. It should be noted that

the Ford was repaired prior to the NASS inspection process. Due to the deployment of the side impact air bag, HPS, and the injuries sustained by the driver of the BMW, NHTSA assigned the tasks of case review and report preparation to the General Dynamics SCI team on December 16, 2003.

SUMMARY

Crash Site

This two-vehicle crash occurred during the morning hours of September 2003 in the state of Tennessee. At the time of the crash, there were no adverse weather conditions and the asphalt road surface was dry. The crash occurred at a three-leg "T"-type inspection of two local roads. The north/southbound roadway was configured with one travel lane in each direction and was not delineated. The north/southbound roadway was bordered by mountable concrete curbs and had an uphill grade for northbound travel. The east/westbound roadway was a two-lane, two-way roadway that was delineated by a double yellow centerline and bordered by white fog lines. The eastbound lane had an uphill grade. A landscaped area that consisted of grass, shrubs, and trees extended beyond the north road edge. The posted speed limit for the north/southbound roadway was 40 km/h (25 mph). The posted speed limit for the east/westbound roadway was 64 km/h (40 mph).

Vehicle Data

2002 BMW 325i

The 2002 BMW 325i was identified by the Vehicle Identification Number (VIN): WBAEV33432 (production sequence omitted). The odometer reading was unknown at the time of the inspection due to vehicle having no power. The vehicle was a four-door sedan that was equipped with a 2.5-liter, six-cylinder engine linked to a five-speed automatic transmission, four-wheel disc brakes with ABS, traction control, and automatic stability control. The tires on the BMW were Continental Conti Sport Contact, size P225/45R17. The maximum pressure for these tires was 352 kpa (51 psi). The vehicle manufacturer recommended front tire pressure was 207 kpa (30 psi) and the recommended rear tire pressure was 241 kpa (35 psi). The specific tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	165 kpa (24 psi)	9 mm (11/32)	No	None
LR	145 kpa (21 psi)	7 mm (9/32)	No	None
RF	159 kpa (23 psi)	9 mm (11/32)	No	None
RR	159 kpa (23 psi)	6 mm (8/32)	No	None

The BMW was configured with front bucket seats with height adjustable head restraints that were adjusted to the full-down position at the time of the NASS inspection. The second row was configured with a three-passenger bench seat and height adjustable head restraints for the outboard positions. The rear head restraints were adjusted to the full-down position at the time of the NASS inspection.

1995 Ford Econoline

The 1995 Ford Econoline was identified by the VIN: 1FTTEE14HX (production sequence omitted). The odometer reading was unknown at the time of the inspection. The vehicle was a four-door cargo van that was equipped with a 5.8-liter, eight-cylinder engine, four-speed automatic transmission, rear-wheel drive, and rear-wheel ABS. The tires on the Ford were BF Goodrich Commercial T/A, size LT225/75R16. The manufacturer recommended front pressure was 345kpa (50 psi) and the vehicle manufacturer recommended rear tire pressure was 379 kpa (55 psi). The specific tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	352 kpa (51 psi)	12 mm (15/32)	No	None
LR	345 kpa (50 psi)	9 mm (11/32)	No	None
RF	345 kpa (50 psi)	10 mm (13/32)	No	None
RR	338 kpa (49 psi)	8 mm (10/32)	No	None

The Ford was configured with two front box mounted van seats with integrated head restraints. This vehicle was manufactured as a cargo van; therefore it was not configured with rear seating positions.

Crash Sequence

Pre-Crash

The restrained 16-year-old female driver of the BMW was operating the vehicle northbound approaching the three-leg "T"-type intersection **(Figure 2)** where the driver was intending to turn left. The driver of the Ford was operating the vehicle eastbound approaching the same intersection **(Figure 3)**. The driver of the BMW failed to detect the Ford and turned left across the path of the Ford. The NASS researcher documented approximately 11.5 meters (38.0 feet) of left front pre-impact skid marks and approximately 9.0 meters (29.5 feet) of right front pre-impact skid marks that indicated the driver of the Ford detected the BMW entering the intersection and attempted to avoid the impending crash by braking. The NASS scene schematic is included as **Figure 18** of this report.

Figure 2. BMW's northbound approach to the intersection.

Figure 3. Ford's eastbound approach to the intersection.

Crash

As the vehicles entered the intersection the frontal aspect of the Ford impacted the left passenger compartment area of the BMW **(Figure 4)**. The impact resulted in severe damage to the left side of the BMW and minor damage to the Ford. The resultant direction of force was within the 10 o'clock sector for the BMW and unknown for the Ford due to the vehicle being repaired prior to the NASS inspection. The WINSMASH missing vehicle algorithm was used to calculate an approximate delta V for this impact due to the repair status of the Ford. The total calculated delta V for the BMW was 35.0 km/h (21.7 mph). The longitudinal and lateral components for the BMW were -22.5 km/h (-14.0 mph) and 26.8 km/h (16.7 mph), respectively. The total calculated delta V for the Ford was 23.0 km/h (14.3 mph). The longitudinal and lateral components for the Ford were -21.6 km/h (-13.4 mph) and -7.9 km/h (-4.9 mph), respectively. As a result of the impact, the drivers side impact air bag and left HPS deployed in the BMW. The driver's frontal air bag in the Ford did not deploy in this crash.

Figure 4. Eastbound view of point of impact. Note Ford's pre-impact skid marks.

As result of the initial impact, both vehicles were deflected in a northeast direction. The NASS researcher documented multiple centrifugal skid marks from the BMW as it traveled northeast rotating counterclockwise. The NASS researcher also documented two post-impact skid marks from the Ford as it traveled northeast. As the BMW rotated approximately 90 degrees counterclockwise, it departed the north road edge and traveled approximately 6.0 meters (20.0 feet) where its back plane impacted a shrub as it came to rest **(Figure 5)**. The Ford continued in a forward trajectory approximately 10.0 meters (30.0 feet) from the initial impact and departed the north road edge where it impacted a shrub with its frontal area prior to coming to rest.

Figure 5. Approach to final rest and shrub impacts for both vehicles.

Post-Crash

Police and rescue personnel arrived on scene and removed the driver from the BMW. She sustained two AIS-4 brain injuries and additional multiple injuries from the crash. The driver of the BMW was transported to a local trauma center where she was diagnosed with brain death and expired two days post-crash. The driver of the Ford was not injured or transported to a hospital. The BMW sustained severe damage and was towed from the crash site. The Ford sustained minor damage and was towed from the crash site.

Vehicle Damage

Exterior – 2002 BMW 325i

The 2002 BMW 325i sustained severe left side damage as a result of the collision with the Ford **(Figure 6)**. The maximum crush was located at the mid-door level near the B-pillar and measured 48.0 cm (18.9”). The direct contact damage measured 192.0 cm (75.6”) and began 4.0 cm (1.6”) forward of the left rear axle and extended forward. The damage involved the left side doors, sill, left A-pillar, left B-pillar, roof, roof side rail, windshield, and left rear quarter panel. Six crush measurements were documented along the mid-door level using a combined direct and induced damage width of 212.0 cm (83.5”) and were as follows: C1 = 4.0 cm (1.6”), C2 = 24.0 cm (9.5”), C3 = 48.0 cm (18.9”), C4 = 46.0 cm (18.1”), C5 = 38.0 cm (15.0”), C6 = 5.0 cm (2.0”). The Collision Deformation Classification (CDC) for this impact was 10-LPAW-3. The left side doors were jammed closed by deformation and the right side doors remained closed and operational post-crash. The windshield was fractured at the left A-pillar from the lateral deformation of the A-pillar and roof. The left front and left rear glazing were disintegrated from damage. The left quarter, backlight, and right side glazing remained intact.

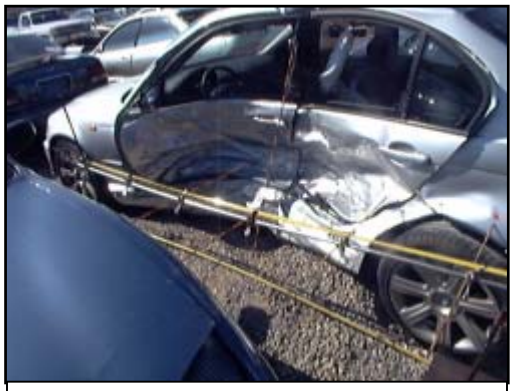

Figure 6. 2002 BMW 325i damage profile.

Figure 7. Rear area no residual damage from shrub impact.

The BMW sustained no damage from the back plane impact with the shrub **(Figure 7)**. The CDC for this impact was 99-B999-9.

Interior – 2002 BMW 325i

The 2002 BMW 325i sustained moderate interior damage **(Figure 8)** as a result of intrusion and occupant contacts. The maximum documented intrusion was the front of the Ford intruding approximately 40.0 cm (15.7”) into the front left passenger compartment area. The occupant contacts consisted of the driver’s left shoulder contacting the upper aspect of the left door that was evidenced by deformation to the door panel. A contact was noted to the lower aspect of the door panel from the driver’s left leg that deformed the door panel. Also noted

Figure 8. Intrusion into driver's position.

was body fluid to the deployed door panel mounted side impact air bag; however, this does not appear to be an occupant contact. A transfer was noted to the HPS from contact with the left head restraint. The documented intrusions were as follows:

Seat Position	Intruded Component	Magnitude	Direction
Front Left	Ford's hood through left front glazing (Approximately)	40.0 cm (15.7")	Lateral
Front Left	Front left door panel	30.0 cm (11.8")	Lateral
Front Left	Front left seat cushion	20.0 cm (7.9")	Lateral
Front Left	Front left seat back	22.0 cm (8.7")	Lateral
Front Left	Side panel forward of the A-pillar	9.0 cm (3.5")	Lateral
Front Left	Front left roof	2.0 cm (0.8")	Vertical
Front Left	Front left roof side rail	10.0 cm (3.9")	Lateral
Front Left	Front left window frame	8.0 cm (3.1")	Lateral
Front Left	Left A-pillar	3.0 cm (1.1")	Lateral
Front Left	Left B-pillar	25.0 cm (9.8")	Lateral
Rear Left	Left rear roof side rail	6.0 cm (2.4")	Lateral
Rear Left	Rear left seat back	16.0 cm (6.3")	Lateral
Rear Left	Rear left seat cushion	25.0 cm (9.8")	Lateral
Rear Left	Rear left door panel	38.0 cm (14.9")	Lateral
Rear Left	Rear left roof	2.0 cm (0.8")	Vertical

Exterior – 1995 Ford Econoline

The 1995 Ford Econoline was repaired prior to the NASS inspection; therefore the damage severity was unknown for the frontal impact with the BMW **(Figure 9)**. The CDC for this impact was 99-F999-9.

The Ford sustained unknown severity frontal damage from the impact with the shrub as it came to rest. The CDC for this impact was 99-F999-9.

Figure 9. Repaired 1995 Ford Econoline.

Manual Restraint Systems – 2002 BMW 325i

The 2002 BMW 325i was equipped with manual 3-point lap and shoulder safety belts for the outboard seating positions. The rear center seating position was configured with a manual 2-point lap belt. The driver's safety belt was configured with a height adjustable D-ring that was in the full-up position at the time of NASS inspection, sliding latch plate, and Emergency Locking Retractor (ELR). The driver's safety belt was also equipped with a buckle pretensioner that did not fire in this crash. The driver utilized the safety belt in this crash which was evidenced by EMS personnel cutting the safety belt **(Figure 10 and 11)**. The shoulder portion was retracted into the B-pillar and the lap portion remained attached to the latch plate that was found in the buckled position at the time of the NASS inspection. The front right safety belt was configured with an adjustable D-ring; sliding latch plate, buckle pretensioner, and a switchable ELR/Automatic Locking Retractor (ALR). The front right safety belt pretensioner did not fire in this crash. The rear outboard safety belts were configured with sliding latch plates and switchable ELR/ALR retractors. The rear center safety belt was configured with a locking latch plate and no retractor.

Figure 10. Shoulder belt portion retracted in B-pillar cut by rescue

Figure 11. Cut lap belt portion remained buckled.

Side Impact Air Bags – 2002 BMW 325i

The 2002 BMW 325i was equipped with door panel mounted side impact air bags for the front seating positions. In this crash, the driver's door panel side impact air bag deployed **(Figure 12)**. The air bag was concealed by a leather cover flap that measured 8.0 cm (3.2") in height and 34.0 cm (13.4") in width. The air bag membrane measured 12.0 cm (4.7") in height and 40.0 (15.7") in width at the top aspect and 30.0 cm (11.8") in width at the lower aspect. The air bag contained a single circular tether on the center aspect of the air bag. No vent ports were noted on the air bag. The NASS researcher documented a large area of body

Figure 12. Deployed driver's door panel mounted side impact air bag. Noted the blood on the air bag is from driver bleeding onto it at final rest not an occupant contact.

fluid that was located left of the tether. The body fluid appears to be from the driver bleeding onto the air bag and not as a result of contact. No damage or failure was noted to the air bag.

Head Protection System (HPS) – 2002 BMW 325i

The 2002 BMW 325i was equipped with a Head Protection System (HPS) for the front seating positions. The system included two tubular air bags that deployed from the roof side rails and were designed to protect the occupants in the event of a side impact. As a result of the subject crash, the left side HPS deployed **(Figure 13 and 15)** from the left roof side rail. The air bag membrane was 12.7 cm (5.0") diameter and 112.0 cm (44.1") in width. The HPS was tethered at the left A- and C-pillars and was tensioned by inflation. The NASS researcher documented a transfer on the air bag, which was located near the front left head restraint. The transfer was black in color and consistent with contacting the head restraint, therefore it was not considered and occupant contact **(Figure 14)**. Rescue personnel cut the air bag at the A-pillar tether during the removal of the driver **(Figure 16 and 17)**. There also appears to be several small cuts and frayed air bag material from contact with glass and the front of the Ford. The NASS researcher noted no failures or damage to the air bag.

Figure 13. Deployed driver's HPS air bag.

Figure 14. Head restraint contact to HPS air bag.

Figure 15. HPS air bag from out side.

Figure 16. Damage from rescue personnel cutting the HPS air bag. Also, the air bag sustained minor cuts from contact with flying glass.

Figure 17. Area of HPS that rescue personnel cut.

OCCUPANT DEMOGRAPHICS – 2002 BMW 325i

Driver

Age/Sex:	16-year-old female
Height:	173.0 cm (68.0”)
Weight:	48.0 kg (106.0 lbs)
Seat Track Position:	Between mid and full rear
Manual Restraint Use:	Manual 3-point lap and shoulder belt
Usage Source:	Vehicle inspection
Eyewear:	Unknown
Type of Medical Treatment:	Transported to a local trauma center where she expired two days post-crash.

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Moderate cerebrum swelling, unknown aspect	Severe (140664.4,9)	Front of striking vehicle
Small left subdural cerebrum hematoma/hemorrhage	Severe (140652.4,2)	Front of striking vehicle
Lung contusion, NFS, unknown aspect	Serious (441402.3,9)	Intruding left door panel
Left orbit fracture open/displaced/comminuted	Serious (251204.3,2)	Front of striking vehicle
Cerebrum subarachnoid hemorrhage, unknown aspect	Serious (140684.3,9)	Front of striking vehicle
Left anterior closed pelvis fracture	Moderate (852602.2,2)	Intruding left door panel
Left posterior closed pelvis	Moderate (852602.2,2)	Intruding left door panel

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
fracture		
Closed left pelvis fracture	Moderate (852602.2,2)	Intruding left door panel
Minor 8.0 cm (3.1") left cheek laceration and multiple lacerations totaling 12.0 cm (4.7")	Minor (290602.1,2)	Flying glass
Left eyelid laceration	Minor (297602.1,2)	Flying glass
Left chest contusion (OIS Grade 1)	Minor (490402.1,2)	Intruding left door panel
Minor 2.0 cm (0.8") lower lip laceration through the superior vermillion border	Minor (290602.1,2)	Flying glass
Inferior gingiva laceration	Minor (243204.1,8)	Flying glass
Minor left spleen laceration	Moderate (544222.2,2)	Intruding left door panel
Unknown location minor spine fractures, NFS	Not coded under AIS	Unknown

Source- Post emergency room records

Driver Kinematics

The 16-year-old female driver of the 2002 BMW 325i was seated in an upright driving posture and was restrained by the manual 3-point lap and shoulder belt. The seat track was adjusted to the mid to full rear position. At impact with the Ford van, the side impact air bag and the HPS air bag deployed. The restrained driver initiated a left trajectory in response to the 10 o'clock direction of force. Coincident with her lateral trajectory, the left door panel and left B-pillar intruded laterally 30.0 cm (11.8") and 25.0 cm (9.8"), respectively. The driver's head either loaded through the deployed HPS, or the HPS was directed upward by the front of the Ford van exposing the driver's head to the front of the Ford van. As a result, she sustained the cerebrum subarachnoid hemorrhage, left orbit fracture, small subdural cerebrum hematoma/hemorrhage, and moderate cerebrum swelling. The left side impact air bag deployed upward and offered protection to the driver's upper torso; however, there was no protection to the driver's pelvic region and lower extremities. As a result, the driver's lower torso, hip, and left leg contacted and loaded the intruding door panel, which resulted in the lung contusion, left anterior closed pelvis fracture, left posterior closed pelvis fracture, closed left pelvis fracture, left chest contusion, and minor left spleen laceration. No distinct contact evidence was noted to the mid-door. The driver also sustained multiple injuries from flying glass that consisted of a minor 8.0 cm (3.1") left cheek laceration and multiple lacerations totaling 12.0 cm (4.7"), left eyelid laceration, minor 2.0 cm (0.8") lower lip laceration through the superior vermillion border, and an inferior gingiva laceration. The medical report also stated that

minor spine fractures where found; however, the exact location and type of fractures were not stated, therefore the injury mechanism could not assigned.

Medical Treatment

The driver was transported to a local trauma center where she was mechanically supported on a ventilator. She was diagnosed with brain death and following medical consultation with the family; she was removed from life support and expired two days following the crash. Due to the combination of the high delta V and vehicle incompatibility, the HPS was not able to offer sufficient head protection to the driver.

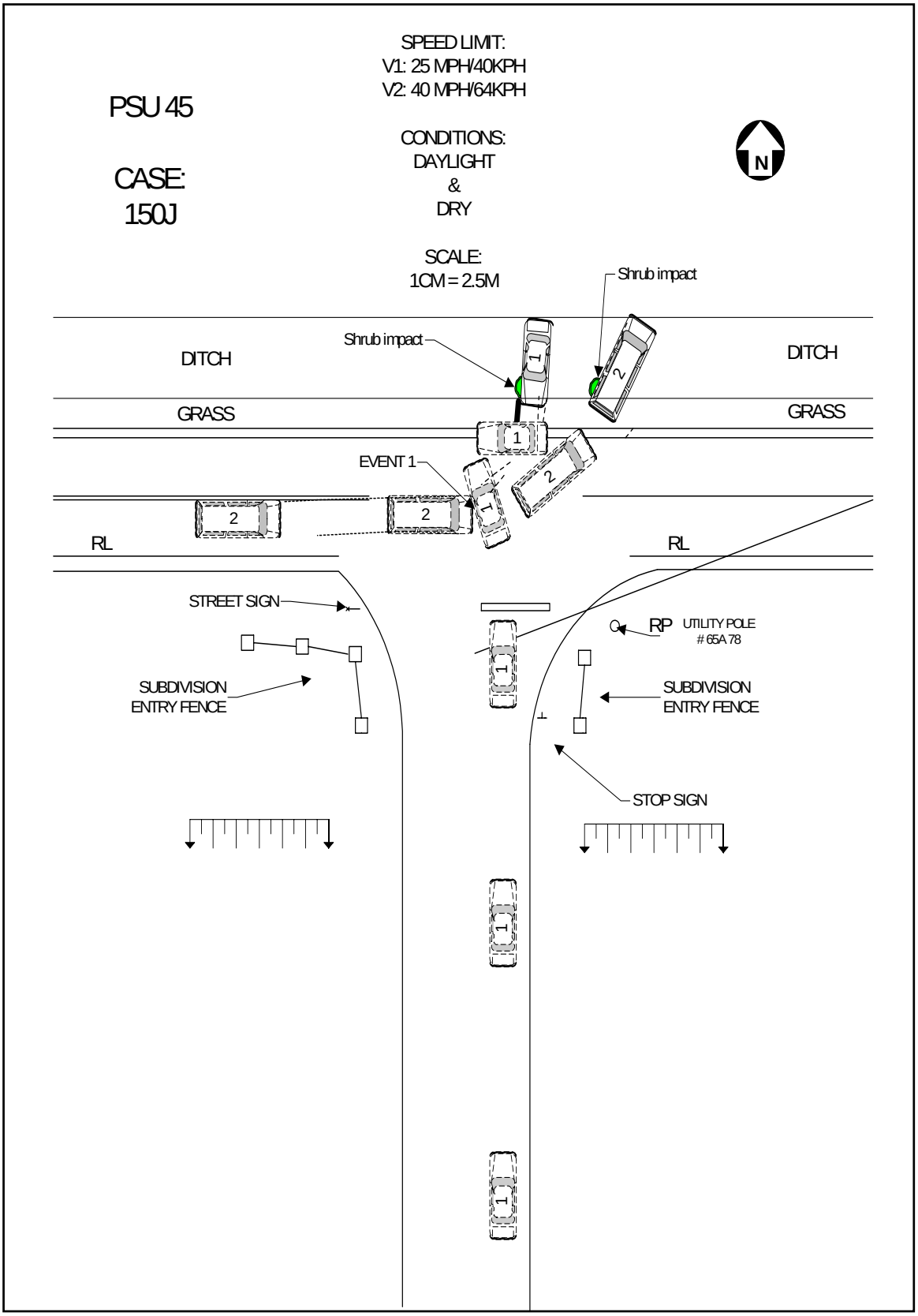

Figure 18. NASS Scene Schematic