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VERIDIAN ON-SITE SIDE IMPACT OCCUPANT PROTECTION INVESTIGATION

VERIDIAN CASE NO. CA02-030

VEHICLE - 2001 BMW 740il

LOCATION - STATE OF NEW YORK

CRASH DATE - JULY, 2002

Contract No. DTNH22-01-C-17002

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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.

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16. *Abstract* This on-site investigation focused on the performance of the side impact occupant protection system of a 2001 BMW 740il 4-door sedan. The 2001 BMW 740il was equipped with retractor pretensioners, (head and thorax) side impact, and dual stage advanced frontal air bags for the driver and front right passenger positions. The right side impact occupant protection system deployed as a result of a right angle collision with a 1990 Dodge Shadow 2-door hatchback. The driver of the 1990 Dodge Shadow was operating the vehicle southbound on a two lane rural roadway when she failed to observe the westbound 2001 BMW as she proceeded straight through a 4-leg intersection. As the Dodge entered the intersection, the frontal area impacted the right side surface of the BMW resulting in moderate damage to both vehicles. At this point, the BMW rotated clockwise and began its post-impact trajectory into the southwest sector of the intersection. As the BMW departed the south pavement edge, the left side wheels dug into the soft soil. This tripping mechanism initiated a three quarter turn left side rollover which resulted in moderate top damage. The restrained 49 year old male driver of the 2001 BMW 740il initiated a forward and slightly lateral trajectory in response to the primary 1 o'clock impact force and loaded the manual restraint and knee bolster. The BMW driver complained of unspecified neck/shoulder pain, however, he refused transport to a local medical facility for treatment. The unrestrained 11 year old female front right child passenger of the 2001 BMW 740il initiated a forward and slightly lateral trajectory in response to the primary 1 o'clock impact force and loaded the deployed side impact occupant protection system and door panel. During the subsequent rollover, she initiated movement to the left and struck interior roof components. The child passenger reported to the (driver and) police that she was ejected through the roof glazing during the rollover, and came to rest adjacent to the vehicle's final rest position. This alleged ejection could not be substantiated during the SCI investigation due to the lack of official injury information. She reportedly sustained unspecified bilateral lacerations to the lower extremities and contusions to the lower torso. The front right child passenger was transported to a local hospital and admitted for an unknown duration.			
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BACKGROUND

This on-site investigation focused on the performance of the side impact occupant protection system of a 2001 BMW 740il 4-door sedan. The 2001 BMW 740il was equipped with retractor pretensioners, (head and thorax) side impact, and dual stage advanced frontal air bags for the driver and front right passenger positions. The right side impact occupant protection system deployed as a result of a right angle collision with a 1990 Dodge Shadow 2-door hatchback. The driver of the 1990 Dodge Shadow was operating the vehicle southbound on a two lane rural roadway when she failed to observe the westbound 2001 BMW as she proceeded straight through a 4-leg intersection. As the Dodge entered the intersection, the frontal area impacted the right side surface of the BMW resulting in moderate damage to both vehicles. At this point, the BMW rotated clockwise and began its post-impact trajectory into the southwest sector of the intersection. As the BMW departed the south pavement edge, the left side wheels dug into the soft soil. This tripping mechanism initiated a three quarter turn left side rollover which resulted in moderate top damage.

The restrained 49 year old male driver of the 2001 BMW 740il initiated a forward and slightly lateral trajectory in response to the primary 1 o'clock impact force and loaded the manual restraint and knee bolster. The BMW driver complained of unspecified neck/shoulder pain, however, he refused transport to a local medical facility for treatment. The unrestrained 11 year old female front right child passenger of the 2001 BMW 740il initiated a forward and slightly lateral trajectory in response to the primary 1 o'clock impact force and loaded the deployed side impact occupant protection system and door panel. During the subsequent rollover, she initiated movement to the left and struck interior roof components. The child passenger reported to the (driver and) police that she was ejected through the roof glazing during the rollover, and came to rest adjacent to the vehicle's final rest position. This alleged ejection could not be substantiated during the SCI investigation due to the lack of official injury information. She reportedly sustained unspecified bilateral lacerations to the lower extremities and contusions to the lower torso. The front right child passenger was transported to a local hospital and admitted for an unknown duration.

The crash was provided to the National Highway Traffic Safety Administration (NHTSA) on July 10, 2002, and immediately assigned to the Veridian SCI team as an on-site investigative effort. Although the BMW driver refused SCI attempts at establishing cooperation, associated fieldwork was completed July 17, 2002, as the subject vehicle was obtained through local salvage contacts and inspected August 15, 2002.

SUMMARY

Crash Site

This two vehicle crash occurred during the early evening hours of July, 2002. At the time of the crash, it was daylight with no adverse conditions as the roads were dry. The crash occurred in the westbound

lane of a (straight) 4-leg rural intersection which was controlled by stop signs for north/southbound traffic **(see Figure 14 - page 11)**. The westbound lane had a positive grade with a hillcrest located just west of the intersection. The asphalt surfaced intersection was bordered by 1.2 meter (3.3 feet) paved shoulders with a 4.0 cm (1.6 in) vertical apron. Environmental features included grass fields to the north and shallow ditches, residential lawns/driveways, and tree clusters to the south. The posted speed limit for north/southbound traffic was 56 km/h (35 mph), and 64 km/h (40 mph) for east/westbound traffic.

Pre-Crash

The restrained 16 year old female driver of the 1990 Dodge Shadow 2-door hatchback was operating the vehicle southbound **(Figure 1)** at a (police reported) unknown speed, and on approach to the rural 4-leg intersection. She came to a complete stop, and failed to observe the westbound 2001 BMW as she proceeded straight through the intersection. The police reported no tire marks at the scene indicative of driver avoidance maneuvers, however, the damage pattern sustained to the Dodge confirmed a low pre-impact speed or acceleration from a stop. The front right passenger position was occupied by a restrained 17 year old female.

The 49 year old male driver of the 2001 BMW 740il was operating the vehicle westbound **(Figure 2)** at a (police reported) unknown speed when he observed the Dodge cross his path of travel. The BMW driver reported through the surrogate interview no avoidance maneuvers in anticipation of the impending crash.

Figure 1. Southbound approach for the 1990 Dodge Shadow.

Figure 2. Westbound approach for the 2001 BMW 740il.

Crash

As the Dodge Shadow entered the rural 4-leg intersection, the frontal area impacted the right side surface of the BMW resulting in moderate damage to both vehicles. The damage algorithm of the WinSMASH reconstruction program computed velocity changes of 18.9 km/h (11.7 mph) for the subject vehicle and 30.7 km/h (19.1 mph) for the striking Dodge. Respective longitudinal components were -14.5 km/h (-9.0 mph) and -19.8 km/h (-12.3 mph). The impact induced deceleration was sufficient to deploy the Dodge's driver frontal air bag and BMW's right side impact occupant protection system.

At this point, the 1990 Dodge Shadow rotated clockwise 70 degrees and traveled 5.2 meters (17.1 feet) to final rest in the northwest sector of the intersection facing southwest. The 2001 BMW 740il

rotated clockwise 50 degrees and began its post-impact trajectory into the southwest sector of the intersection **(Figure 3)**. The vehicle began to move laterally as the left side wheels dug into the asphalt surface. The BMW was tipped *(leaning)* slightly to the left as it exited the south pavement edge and traversed an adjacent grassy area. The left side wheels began digging into the soft soil as the BMW continued 15.4 meters (50.5 feet) in a southwesterly direction across a shallow ditch and residential lawn. This tripping mechanism initiated a three quarter turn left side rollover *("tripover")* resulting in moderate top damage. This trajectory was evidenced by the extensive physical evidence documented at the crash site. The 2001 BMW came to rest (on its right side) adjacent to a residential driveway off the south pavement edge of the east/westbound lanes facing northwest.

Figure 3. Southwest post-impact trajectory and pavement gouging for the 2001 BMW 740il.

Post-Crash

Treatment was rendered at the scene by fire department personnel and emergency medical technicians (EMTs). Although the exit status of the Dodge occupants were unknown, they complained to police of unspecified pain and were subsequently transported by ambulance to the emergency room of a local hospital for an unknown level of treatment.

The BMW driver exited the vehicle under his own power (port unknown). The BMW driver complained to police of unspecified shoulder pain, however, he refused transport to a local medical facility for diagnosis and possible treatment. In addition, the surrogate interview reported no later treatment with a private physician. The front right passenger of the BMW was reported by police as fully ejected during the crash, coming to rest adjacent to the final rest position (exterior roof area) of the vehicle in a semi-conscious state. The lack of the BMW driver's cooperation and official injury data prohibits an exact interpretation of the (police/driver reported) child passenger ejection. The child passenger of the BMW was subsequently transported by ambulance to the emergency room of a local hospital and admitted for an unknown duration. Both vehicles were towed from the crash site with disabling damage.

VEHICLE DATA

The 2001 BMW 740il was manufactured in January, 2001 and identified by the vehicle identification number (VIN): WBAGH834X1D (production number deleted). The driver was the owner of the vehicle which was a 4-door sedan equipped with power windows/door locks/front seats, tilt/telescoping steering column, on-board navigation system, rear-wheel drive, four wheel anti-lock

brakes (ABS), and a 4.4 liter, V-8 engine. The odometer reading was unknown at the time of the crash, however, low vehicle mileage was reported. The seating was configured with front bucket and a rear bench seat. Although the BMW driver refused the SCI interview, the surrogate reported no previous crashes or maintenance on the BMW's frontal or side impact occupant protection system.

VEHICLE DAMAGE

Exterior

The 2001 BMW 740il sustained moderate right side surface damage as a result of the impact with the 1990 Dodge Shadow **(Figure 4)**. The direct contact damage began at the right rear axle and extended 290.0 cm (114.2 in) forward. The combined direct and induced damage length (Field L) also began at the right rear axle and extended 306.0 cm (120.5 in) forward. Six crush measurements were documented at the level of the mid-door: C1= 0, C2= 30.0 cm (11.8 in), C3= 27.0 cm (10.6 in), C4= 14.0 cm (5.5 in), C5= 10.0 cm (3.9 in), C6= 0. A maximum crush value of 33.0 cm (13.0 in) was identified 13.0 cm (5.1 in) forward of the C2 position. The Collision Deformation Classification (CDC) assigned for this initial impact to the BMW was 01-RYEW-3 with a principal direction of force of (+)40 degrees. White paint transfers were noted along the direct contact damage which extended vertically to the upper door area. The right side doors were jammed as the tempered glazings were disintegrated. The right rear wheel/tire was restricted by sheet metal displacement and partially deflated. Induced contact damage produced buckling along the right roof and side rail areas. Reduction in the right side wheelbase measured 7.0 cm (2.8 in).

Figure 4. Right side surface damage to the 2001 BMW 740il 4-door sedan from the initial impact.

Direct contact damage was also identified along the top and (left/right) side surfaces of the vehicle and attributed to the rollover **(Figure 5)**. A maximum crush value of 8.0 cm (3.1 in) was documented along the left roof side rail. Distinct directional striations in the deformation allowed for accurate separation of impact damage for correct assignment of CDC's. The CDC assigned to this secondary impact to the BMW was 00-TDDO-2. Extensive scratches and indentations were documented along both side rails and support pillar areas. Additional roof displacement was attributed to the rollover with buckling identified along the mid-sections and the roof tempered glazing disintegrated. The windshield was fractured in multiple locations from exterior impact forces (only) as the backlight remained undamaged. The exterior roof structure was meticulously analyzed for evidence of occupant ejection, however, none was identified. The left side leading edge of the hood was deformed upward during the rollover with no direct contact damage identified to the remainder of the hood surface or trunk hatch. The rear bumper

fascia separated from the vehicle during the crash sequence. Heavy deposits of grass, soil, and asphalt were noted in the left side wheels, as the edges of the rim were scarred from bituminous pavement interaction during the initial stages of the tripping mechanism. Additional scarring, asphalt and soil deposits were noted in the right front wheel, however, none was identified on the right rear.

Figure 5. Rollover damage to the 2001 BMW 740il 4-door sedan.

The 1990 Dodge Shadow 2-door hatchback sustained moderate frontal damage as a result of the impact with the 2001 BMW 740il **(Figure 6)**. The direct contact damage encompassed the entire front end width resulting in a combined direct and induced damage length (Field L) of 130.0 cm (51.2 in). Six crush measurements were documented at the level of the reinforcement bar *(bumper fascia separation)*: C1= 34.0 (13.4 in), C2= 33.0 cm (13.0 in), C3= 36.0 cm (14.2 in), C4= 36.0 cm (14.2 in), C5= 34.0 cm (13.4 in), C6= 33.0 cm (13.0 in). The CDC assigned for this impact to the Dodge was 70-FDEW-2 with a principal direction of force of (-)50 degrees {principal direction of force incremented by 70 to reflect 13.0 cm (5.1 in) of lateral shifting of the end structure to the right}. Light colored paint transfers were identified along the direct contact damage. Black rubber transfers were documented on the leading edge of the hood which was also deformed up and rearward from engagement against the side surface of the BMW. Direct damage was also noted to the left fender and attributed to spinout contact following vehicle maximum engagement. The right fender was displaced rearward and to the right, which restricted the right front wheel/tire (not deflated). Induced contact damage produced minor roof buckling at the right B-pillar. Pre-existing fractures were noted to the mid-windshield as none were attributed to *this* crash. In addition, pre-existing damage was found on the right rear quarter panel with heavy rust deposits. Reduction in the right side wheelbase measured 7.5 cm (3.0 in) while elongation of the left side wheelbase measured 2.0 cm (0.8 in). All tempered glazings remained undamaged. It should be noted that a small leak was identified on the master brake cylinder, which resulted in somewhat “soft” brakes.

Figure 6. Frontal damage to the 1990 Dodge Shadow 2-door hatchback.

Interior

Interior damage to the 2001 BMW was moderate and attributed to component intrusions and occupant contact. Scuff marks were documented on the left roof and side rail, door panel, knee bolster, and center console. The roofliner was abraded in several areas, however, no distinct evidence of ejection was identified **(Figure 7)**. Multiple indentations, blue scuff and scratch marks were documented on the right front door panel. Distinct strands of gray and black hair were noted to the left of the (disintegrated) roof glazing, adjacent to the left roof side rail. An elongated scratch mark was documented along the windshield header which began at the right sunvisor and extended into the driver space. The rear view mirror was out-of-place, but, along with the vanity mirrors, remained undamaged. This contact pattern was a clear indication of (right to left) occupant movement within the vehicle during the rollover, and confirmed the lack of belt use by the child passenger.

Figure 7. Contact evidence along the interior roof structure of the 2001 BMW 740il 4-door sedan.

Lateral intrusions into the rear right occupant space, and attributed to the initial impact, consisted of 43.0 cm (16.9 in) of right rear door panel, 41.0 cm (16.1 in) of window frame, 20.0 cm (7.9 in) of seat cushion, 10.0 cm (3.9 in) of sill, 4.0 cm (1.6 in) of roof side rail, and 2.0 cm (0.8 in) of C-pillar intrusion. Lateral intrusions into the front right passenger space consisted of 12.0 cm (4.7 in) of B-pillar, 10.0 cm (3.9 in) of kick panel, 7.0 cm (2.8 in) of sill, 5.0 cm (2.0 in) of door panel and seat back/cushion, 3.0 cm (1.2 in) of window frame, and 1.0 cm (0.4 in) of roof side rail intrusion. *Vertical intrusions* into the interior compartment, and attributed to the secondary (rollover) impact, consisted of 4.0 cm (1.6 in) of left A-pillar/roof side rail, 2.0 cm (0.8 in) of left B and C-pillar, 6.0 cm (2.4 in) of left roof, 4.0 cm (1.6 in) of right roof, and 3.0 cm (1.2 in) of center roof intrusion.

MANUAL RESTRAINT SYSTEMS

The interior of the BMW consisted of a five passenger seating configuration with front bucket and a rear bench seat. The driver 3-point manual lap and shoulder belt system consisted of a continuous loop belt webbing with a sliding latchplate and a dual mode retractor (inertial lock/belt sensitive). Dimpling was documented on the shoulder portion of the driver restraint and attributed to latchplate loading **(Figure 8)**. Light abrading was also identified on the driver D-ring and latchplate webbing sleeve. The driver retractor was noted to be still operable with the shoulder webbing shortened by the pretensioner

deployment. The front right (and rear outboard) seating position was equipped with a 3-point manual lap and shoulder belt system which consisted of a continuous loop belt webbing with a sliding latchplate and a retractor equipped with an inertial and switchable lock mechanism. The front right restraint was noted to be restricted in the stowed position by the B-pillar and seat intrusions **(Figure 9)**. The rear center position was equipped with a 2-point manual lap belt system which consisted of a sewn-on latchplate with an inertial and switchable locking retractor.

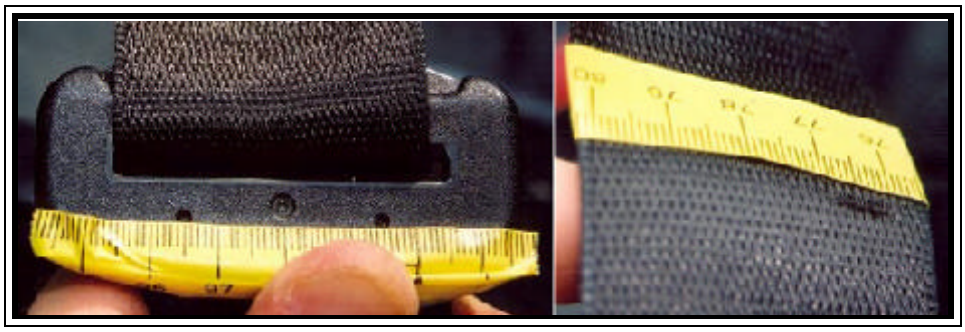

Figure 8. Loading evidence on the BMW driver restraint.

SUPPLEMENTAL RESTRAINT SYSTEMS

The 2001 BMW 740il was equipped with dual stage advanced frontal air bags for the driver and front right passenger positions which did not deploy as a result of the crash. The driver air bag was housed in the center of the steering wheel with a horizontally oriented flap tear seam (H-configuration). The front right passenger air bag was housed in the right mid-instrument panel area with a single cover flap design hinged at the top aspect.

Figure 9. BMW front right restraint restricted in the stowed position by lateral component intrusions.

The 2001 BMW 740il was equipped with door mounted side impact air bags for the front seated positions. The right front side impact air bag deployed as a result of the initial impact with the Dodge Shadow **(Figure 10)** and was identified by the Autoliv part number: >PA6.6/Si< with a bar coded lot number of: 0314860035438939. The air bag modules were housed in the door panel above the armrest [42.5 cm (16.7 in) above floor level or 14.3 cm (5.6 in) above the level of the seat cushion] with a single cover flap design hinged at the lower aspect. The flap was trapezoidal in shape and measured 25.0 cm (9.8 in) in width along the top portion, 15.0 cm (5.9 in) in width along the lower portion, and 11.5 cm (4.5 in) in height. No contact evidence was identified on the exterior surface of the module cover flap, however, a pronounced smudge mark was documented along the aft (inboard) portion of the air bag face. The air bag was rectangular in

shape and measured 46.0 cm (18.1 in) in width and 32.0 cm (12.6 in) in height in its deflated state. The bag was tethered by a horizontal stitch pattern which extended across the face of the membrane. No vent ports were present. The side impact air bag sensors were located in the front door cavities.

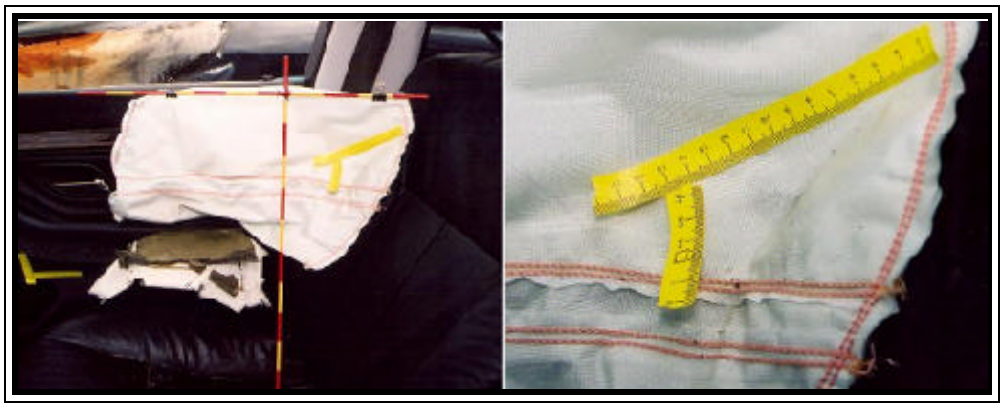

Figure 10. 2001 BMW 740il deployed right front side impact air bag (thorax).

The BMW was also equipped with a head protection air bag for the outboard seated positions. The right side head protection air bag also deployed as a result of the initial impact with the Dodge **(Figure 11)** and was identified by the Autoliv part number: 857001 4260 4N with a bar coded lot number of: ASG 01B0111A00490. The head air bag was housed between the interior roof headliner and structural roof side rail with a horizontal seam measuring 146.0 cm (57.5 in) in length (separation of the headliner versus an actual flap). Inflation was achieved by the use of a cold gas (stored) inflator located in the C-pillar. The air bag measured 7.0 cm (2.8 in) in diameter and 105.0 cm (41.3 in) in length in its deflated state. The air bag was tethered by two external straps connected to the left A-pillar and left rear roof side rail. The front outboard restraint systems also included retractor pretensioners mounted in the lower B-pillars. The activation of both front restraint pretensioners reduced the slack in both the lap and shoulder belt webbing.

Figure 11. 2001 BMW 740il deployed right side head protection air bag.

DRIVER DEMOGRAPHICS

Age/Sex:	49 year old male
Height:	178 cm (70 in)
Weight:	82 kg (180 lb)
Seat Track Position:	Full rearward position
Manual Restraint Use:	3-point lap and shoulder belt
Usage Source:	Vehicle inspection, police report
Eyeware:	Prescription glasses
Type of Medical Treatment:	Refused treatment

Driver Injuries

Injury	*Severity (AIS 90)*	*Injury Mechanism*
*None (unspecified complaint of neck/shoulder pain only)	N/A	N/A

*Sources: police/SCI interview**

Driver Kinematics

The 49 year old male driver of the 2001 BMW 740il was restrained by the available 3-point manual lap and shoulder belt system, and presumed to be seated in an upright posture with the seat track adjusted to the full rearward position. Belt usage was confirmed by the loading marks documented on the webbing and D-ring of the driver restraint.

Figure 12. 2001 BMW 740il driver contact evidence.

At impact with the 1990 Dodge Shadow, the BMW driver initiated a forward and slightly lateral trajectory in response to the 1 o'clock impact force and loaded the manual restraint, knee bolster, and center console. This kinematic response was evidenced by the scuff marks documented on these components, however, no specific injury was reported as a result. At this point, the BMW driver initiated movement to the left in response to the vehicle's post-impact clockwise rotational trajectory. As the vehicle tripped into the left side rollover, he loaded the door panel **(Figure 12)** as his head may have "grazed" the roofliner, evidenced by the scuff marks identified just above the armrest and hair strands noted to the left roof area. Following the crash, he exited the vehicle under his own power (port unknown). The BMW driver complained to police (and the surrogate later) of unspecified neck/shoulder pain, however, he refused subsequent transport to a local medical facility for diagnosis and possible treatment. Use of the available 3-point manual lap and shoulder belt system minimized driver movement during the crash, thus reducing the risk of potential serious injury.

FRONT RIGHT PASSENGER DEMOGRAPHICS

Age/Sex:	11 year old female
Height:	147 cm (58 in)
Weight:	42 kg (93 lb)
Seat Track Position:	Full rearward position
Manual Restraint Use:	None
Usage Source:	Vehicle inspection, police report
Eyeware:	None
Type of Medical Treatment:	Transported to a local hospital and admitted *(unknown duration)*

Front Right Passenger Injuries

Injury	*Severity (AIS 90)*	*Injury Mechanism*
*Unknown	N/A	N/A

(unspecified multiple leg lacerations and lower torso contusion: possibly sustained post-crash)

*Sources: police/SCI interview**

Front Right Passenger Kinematics

The unrestrained 11 year old female front right child passenger of the 2001 BMW 740il was presumed to be seated in an upright posture with the seat track adjusted to the full rearward position. Contrary to the police accident report, the lack of belt usage was determined by the trajectory of the child, interior contact points, and the front right restraint found in the stowed position restricted by lateral component intrusions.

Figure 13. Lateral view of the 2001 BMW 740il front right passenger contact evidence.

At impact with the 1990 Dodge Shadow, the child passenger of the BMW initiated a lateral and slightly forward trajectory in response to the 1 o'clock impact force and loaded the deployed side impact occupant protection system (head and thorax) and door panel. Bag interaction was confirmed by the light abrading and smudge marks documented on the inboard surface of the membrane. Distinct indentations and scuff marks clearly placed the lower extremities against the door panel during this kinematic response **(Figure 13)**, however, the lack of official injury data prohibits an exact analysis of injury sources related to this impact or the subsequent rollover.

At this point, the child passenger initiated movement to the left in response to the vehicle's post-impact clockwise rotational trajectory. As the vehicle tripped into the left side rollover, she continued the kinematic response pattern into the driver's space as evidenced by the hair strands and elongated scuff marks identified on the windshield header and roof areas. Although not witnessed by the BMW driver, he reported to police that the child passenger was ejected through the roof glazing and found outside of the vehicle adjacent to the (exterior roof area) vehicle's final rest position in a semi-conscious state. She sustained unspecified multiple lacerations to the lower legs (aspect unknown) and contusion to the lower torso. Contact evidence suggested that the child passenger came to rest in the front left occupant

space, on top of the driver, as the injuries were probably sustained during the child's *subsequent egress from the vehicle through the disintegrated roof glazing*. Following the crash, the front right child passenger of the 2001 BMW 740il was transported by ambulance to the emergency room of a local hospital and admitted for an unknown duration. Treatment included over 100 stitches and possible plastic surgery to repair the leg lacerations. The use of the vehicle's available 3-point manual lap and shoulder belt system would have mitigated the risk of ejection and possible compounding injuries sustained from the subsequent rollover impact.

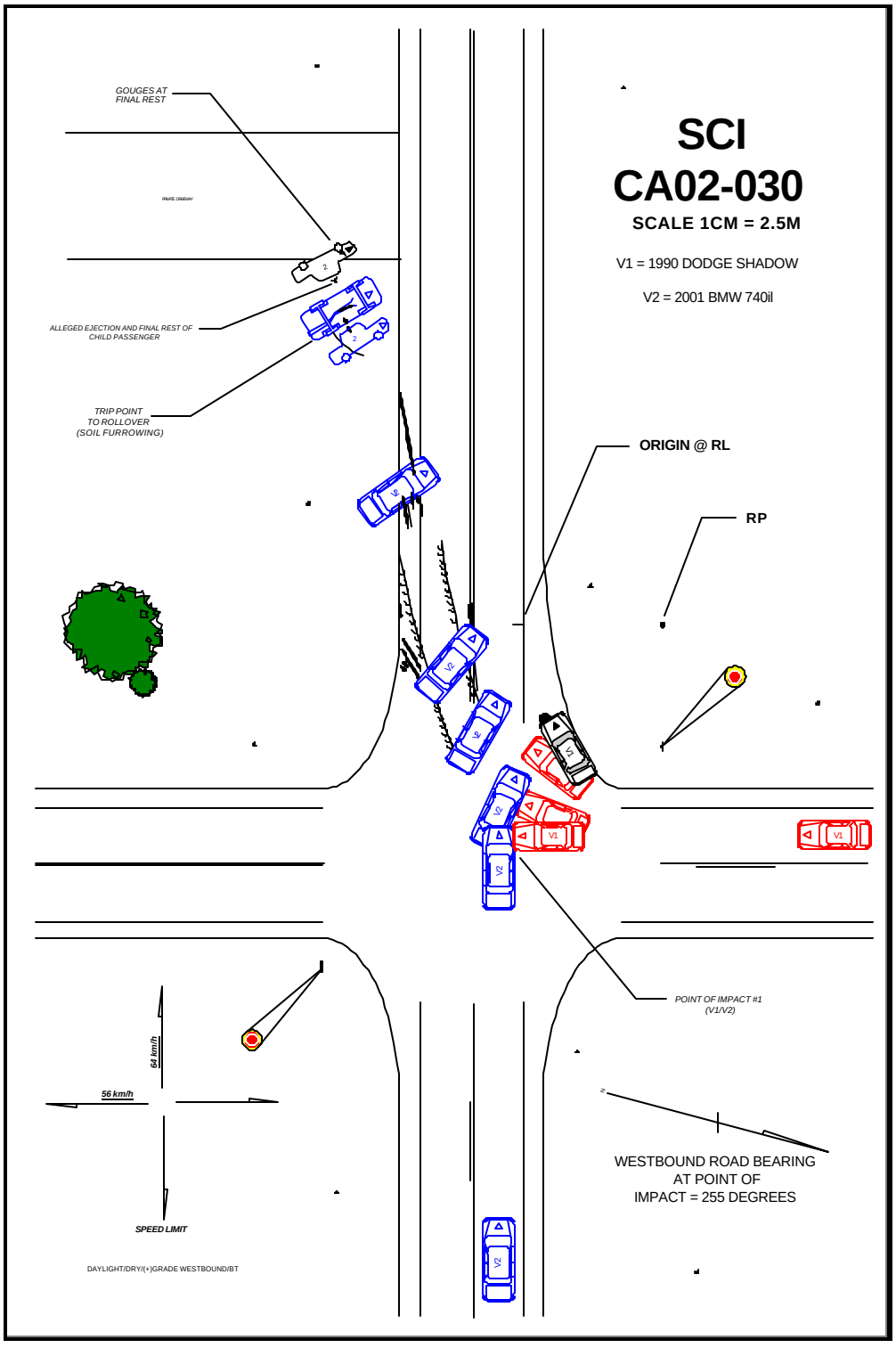

Figure 14. Scene Diagram.