

**TRANSPORTATION SCIENCES  
CRASH DATA RESEARCH CENTER**

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**ADVANCED OCCUPANT PROTECTION SYSTEM INVESTIGATION**

**VERIDIAN CASE NO: CA02-013**

**VEHICLE: 2002 AUDI ALLROAD QUATTRO**

**LOCATION: COLORADO**

**CRASH DATE: APRIL 2002**

**Contract No. DTNH22-01-C-17002**

**Prepared for:**

**U.S. Department of Transportation  
National Highway Traffic Safety Administration  
Washington, DC 20590**

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

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

## TECHNICAL REPORT STANDARD TITLE PAGE

|   |   |   |                         |
|---|---|---|-------------------------|
| <p>1. <i>Report No.</i><br/>CA02-013</p>  | <p>2. <i>Government Accession No.</i></p>                           | <p>3. <i>Recipient's Catalog No.</i></p>  |                         |
| <p>5. <i>Title and Subtitle</i><br/>Advanced Occupant Protection System Investigation<br/>Vehicle: 2002 Audi Allroad Quattro<br/>Location: Colorado</p>   |   | <p>4. <i>Weights</i></p>  |                         |
|   |   | <p>6. <i>Report Date:</i><br/>September 2002</p>  |                         |
| <p>8. <i>Author(s)</i><br/>Crash Data Research Center</p>   |   | <p>7. <i>Performing Organization Code</i></p>   |                         |
|   |   | <p>9. <i>Performing Organization Report No.</i></p>   |                         |
| <p>10. <i>Performing Organization Name and Address</i><br/>Transportation Sciences<br/>Crash Data Research Center<br/>Veridian Engineering<br/>P.O. Box 400<br/>Buffalo, New York 14225</p>   |   | <p>11. <i>Work Unit No.</i><br/>C00410.0000.0032</p>  |                         |
|   |   | <p>12. <i>Contract or Grant No.</i><br/>DTNH22-94-D-07058</p>                                       |                         |
| <p>13. <i>Sponsoring Agency Name and Address</i><br/>U.S. Department of Transportation<br/>National Highway Traffic Safety Administration<br/>Washington, DC 20590</p>  |   | <p>14. <i>Type of Report and Period Covered</i><br/>Technical Report<br/>Crash Date: April 2002</p> |                         |
|   |   | <p>15. <i>Sponsoring Agency Code</i></p>  |                         |
| <p>16. <i>Supplementary Notes:</i> On-site investigation focused on the performance of the Advanced Occupant Protection System in a 2002 Audi All Road Quattro.</p>   |   |   |                         |
| <p>17. <i>Abstract</i></p> <p>This on-site investigation focused on the performance of the Advanced Occupant Protection System (AOPS) of a 2002 Audi Allroad Quattro. The Audi Allroad was involved in a 12/9 o'clock impact with a 1995 Dodge Neon. The Audi was equipped with an AOPS that consisted of seat belt retractor pretensioners, dual stage driver and front right passenger air bags, front seat side impact air bags and inflatable side curtains. The driver seat belt retractor pretensioner fired and the front right passenger air bag deployed as a result of the impact induced deceleration. The restrained male driver of the Audi sustained lower extremity contusions as a result of contact to the knee bolster. He exited his vehicle and was ambulatory at the scene. The driver and front passenger in the Dodge both sustained a pelvis fracture as their primary injury and required hospitalization.</p> <p>The Special Crash Investigations team at Veridian Engineering was notified of this crash by the investigating Denver police officer. Veridian SCI subsequently notified the Crash Investigations Division of the National Highway Traffic Safety Administration of the crash and was assigned an on-site investigation as part of the Advanced Occupant Protection System Study. The vehicles were in the police impound and available for inspection.</p> |   |   |                         |
| <p>18. <i>Key Words</i><br/>Advanced Occupant Protection System (AOPS)<br/>Manual 3-point Restraint System<br/>Retractor pretensioner<br/>Dual stage frontal air bag<br/>AIS 1 injury</p>   |   | <p>19. <i>Distribution Statement</i><br/>General Public</p>   |                         |
| <p>20. <i>Security Classif. (of this report)</i><br/>Unclassified</p>   | <p>21. <i>Security Classif. (of this page)</i><br/>Unclassified</p> | <p>22. <i>No. of Pages</i><br/>9</p>  | <p>23. <i>Price</i></p> |

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**ADVANCED OCCUPANT PROTECTION SYSTEM INVESTIGATION  
VERIDIAN CASE NO: CA02-013**

**VEHICLE: 2002 AUDI ALLROAD QUATTRO  
LOCATION: COLORADO  
CRASH DATE: APRIL, 2002**

***BACKGROUND***

This on-site investigation focused on the performance of the Advanced Occupant Protection System (AOPS) of a 2002 Audi Allroad Quattro. The Audi Allroad was involved in a 12/9 o'clock impact with a 1995 Dodge Neon. The Audi was equipped with an AOPS that consisted of seat belt retractor-pretensioners, dual stage driver and front right passenger air bags, front seat side impact air bags and inflatable side curtains. The driver seat belt retractor-pretensioner fired and the front right passenger air bag deployed as a result of the impact induced deceleration. The restrained male driver of the Audi sustained a left lower extremity contusion as a result of contact to the knee bolster. He exited his vehicle and was ambulatory at the scene. The driver and front passenger in the Dodge both sustained a pelvis fracture as their primary injury and required hospitalization.

The Special Crash Investigations team at Veridian Engineering was notified of this crash by the investigating Denver police officer. Veridian SCI subsequently notified the Crash Investigations Division of the National Highway Traffic Safety Administration of the crash and was assigned an on-site investigation as part of the Advanced Occupant Protection System Study. The vehicles were in the police impound and available for inspection.

***SUMMARY***

***Crash Site***

This two-vehicle crash occurred during the nighttime hours of April, 2002. At the time of the crash, it was dark and the roadway was illuminated by overhead street lights. The weather was not a factor and the asphalt road surface was dry. The crash occurred on the outboard lane of an undivided six lane east/west road. There was an apartment complex and private driveway on the north side of the road. The private driveway provided the ingress and egress into the complex's parking lot from the primary roadway. The speed limit in the area of the crash was 72 km/h (45 mph). **Figure 1** is a westbound trajectory view of the crash scene.



**Figure 1:** Westbound trajectory view.

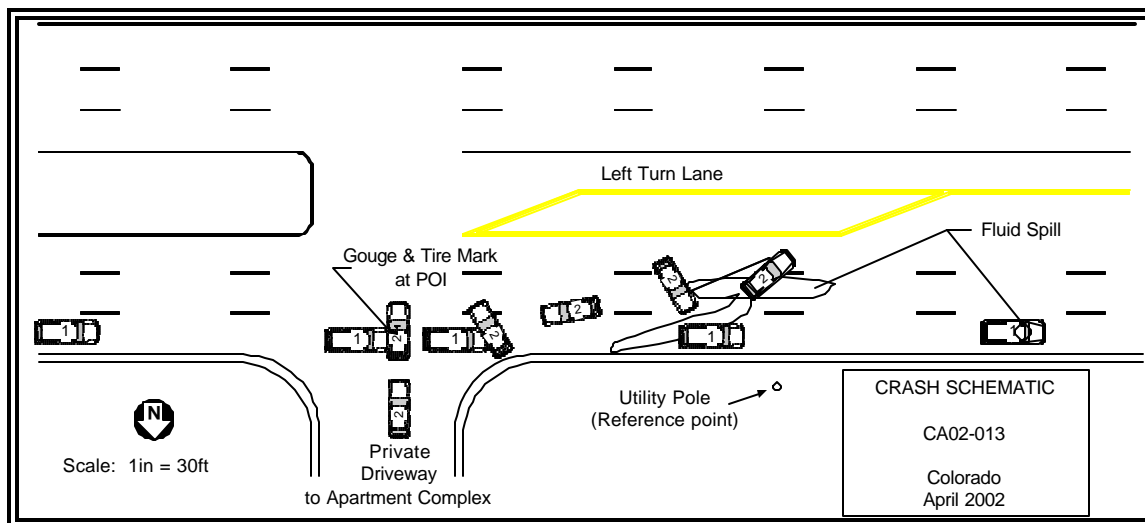
### *Pre-crash*

The 2002 Audi Allroad Quattro was driven by a 37 year old restrained male. The driver's estimated height and weight were 183 cm (72 in) and 100 kg (220 lb). He was the Audi's sole occupant. The Audi was westbound in the outboard lane of the road at a police reported speed of 113 km/h (70 mph). An off-duty police officer, traveling behind and in pursuit of the Audi, provided the speed estimate to the police investigation. The Dodge Neon was exiting south out of the apartment complex on the Audi's right, via its private driveway. The Dodge was occupied by a 21 year old unrestrained male driver and a 19 year old unrestrained male front right passenger. It was the intension of the driver to turn left and travel eastbound. The trailing off-duty officer reported the Audi's brake light came on immediately prior to impact. A 1 m (3 ft) skid mark attributed to the left front tire of the Audi and a gouge mark adjacent to the tire mark identified the point of impact. It should be noted that the long tire mark depicted in Figure 1 was not related to this crash.

### *Crash*

The crash occurred when the Dodge accelerated forward into the outboard lane of the primary road directly into the path of the Audi. The front plane of the Audi impacted and penetrated the left side of the Dodge, centered on its B-pillar. The westbound momentum of the Audi forced the Dodge to slide laterally to its right and rotate counterclockwise approximately 330 degrees as the it slid to rest. The Dodge came to rest straddling the center and inboard westbound lanes approximately 30 m (97 ft) west of the point of impact. The Audi continued its westbound trajectory in the outboard travel lane and came to a controlled stop approximately 53 m (174 ft) from the POI.

Upon impact, the Audi's driver's seat belt retractor pretensioner fired and the front right passenger air bag deployed. The total velocity changes (delta Vs) calculated by the Damage algorithm of the WINSMASH model were 35.3 km/h (21.9 mph) and 52.8 km/h (32.8 mph) for the Audi and Dodge, respectively. The impact speeds for the Audi and Dodge calculated by a Conservation of Momentum analysis were 87 km/h (54 mph) and 10 km/h (6 mph), respectively. **Figure 2** is a schematic of the crash.



**Figure 2:** Crash schematic.

### ***Post-crash***

The police, fire and EMS personnel responded to the crash scene. The Audi driver suffered a minor left lower extremity contusion and exited the vehicle under his own power. He was ambulatory at the scene and remained on-scene throughout the police investigation. He was then transported to a local hospital for a blood test. The police investigation revealed the driver was alcohol impaired at the time of the crash. The driver of the Dodge Neon was contacted by the intruding left door, overrode the front right passenger and was ejected out the right front door of the Neon as it came to rest. He was found on the pavement, adjacent to the right side of the Neon at final rest. Reportedly, the front right passenger remained within the vehicle. Both occupants of the Dodge suffered police reported pelvis fractures and were hospitalized.

### ***2002 AUDI ALLROAD QUATTRO***

The 2002 Audi Allroad Quattro, **Figure 3**, was identified by the Vehicle Identification Number (VIN) WA1YP64B42N (production sequence deleted). The Audi was equipped with a 2.7 liter, V6 engine linked to a 6-speed manual transmission. The 4-wheel disc braking system was ABS equipped. The manual restraint system consisted of 3-point lap and shoulder belts with retractor pretensioners for the five seat positions. The Supplemental Restraint System consisted of dual stage frontal air bags and side impact air bags for the front occupants and inflatable side curtains. The vehicle's date of manufacture was January 2002 and was leased by the driver's employer in March 2002. The electronic odometer could not be read at the time of the inspection due to the lack of electrical power.



**Figure 3:** Front view of the Audi A6.

### ***Exterior Inspection***

**Figures 4 and 5** are the left side and left lateral views of the Audi All Road. The direct contact damage pattern to the frontal plane extended across the entire 137 cm (54 in) end width of the vehicle. The impact damage was managed by the vehicle's bumper system and the forward portion of the sub-frame. The damage pattern was biased to the left indicative of the right-to-left lateral direction of the Dodge. The hood and left front fender were buckled. Surface abrasions on the Audi's hood, indicative of direct contact to the Dodge, extended longitudinally rearward 84 cm (33 in) from the front of the vehicle. The location of these abrasions was an indicator of the Audi's maximum penetration into the left side of the Dodge. The frontal damage wrapped around the left front corner and extended along the left front fender to the forward aspect of the left front door. This contact pattern measured 89 cm (35 in) and was consistent with the post-impact counterclockwise rotation and separation of the Dodge. White transfers were identified within the contact pattern and were linked to the fiberglass repair of the left front fender of the Dodge. All four doors and the rear hatch remained operational and there was no damage to the side glazings. The left

wheelbase was foreshortened 4.8 cm (1.9 in). The right wheelbase was unchanged. The right front tire was punctured and had aired out. The crush profile measured at the bumper elevation was as follows: C1 = 14.7 cm (5.8 in), C2 = 10.2 cm (4.0 in), C3 = 11.4 cm (4.5 in), C4 = 9.1 cm (3.6 in), C5 = 2.5 cm (1.0 in), C6 = 0. The Collision Deformation Classification was 12-FDEW-1.

The total velocity change (delta V) of the Audi was calculated utilizing the Damage Algorithm of the WINSMASH model. During the impact, the front of the Audi impacted and penetrated the left side of the Dodge. The damage profile of the Dodge was documented at the mid-door elevation and along the lower sill. Refer to the Exterior Damage section of the Dodge Neon on page seven for further information. Utilizing an average of these profiles for the Dodge and the afore mentioned bumper crush profile for the Audi, the calculated total delta V of the Audi was 43.8 km/h (27.2 mph). Based on SCI field experience, this calculation over-estimated the Audi's delta V.

An analysis using the sill crush measurements of the Dodge and the Audi's bumper profile calculated the delta V of the Audi to be 35.2 km/h (21.9 mph). The longitudinal and lateral components were -34.6 km/h (-21.5 mph) and -6.1 km/h (-3.8 mph), respectively. This calculation was more representative of the Audi's crash severity.



Figure 4: Left side view of the Audi.



Figure 5: Left lateral view.

### ***Interior Inspection***

The vehicle's interior damage was related to the deployment of the front right passenger air bag. The right aspect of the windshield was fractured by the module cover flap during the deployment sequence. There was no damage or intrusion attributed to the exterior forces of the crash.

The Audi's interior was trimmed with leather and consisted of five seat positions. The front row consisted of powered bucket seats for the driver and front right passenger. The second row consisted of a 60/40 split fold rear seat. The driver's seat was adjusted to a rear track position. The horizontal distance between the center hub of the steering wheel and the driver's seat measured 66 cm (26 in).



A probable left lower extremity contact was identified on the driver's knee bolster. A 5 cm x 5 cm (2 in x 2 in) scuff was located 20 cm (8 in) left of the steering wheel center line. No other occupant contacts were identified during the interior vehicle inspection. There was no steering wheel rim deformation and there was no separation of the steering column's shear capsules. The lack of driver interior contact evidence supported the use of the manual restraint system.

### ***Manual Restraint System***

Each seat position was equipped with a manual 3-point lap and shoulder belt system with retractor-pretensioners. The retractors were designed with a force limiting feature. The driver's restraint was stowed within the retractor and the retractor was operational upon initial inspection. Examination of the latch plate revealed minimal historical usage evidence, however, this was consistent with the age of the vehicle. Examination of the friction surfaces of the latch plate hardware revealed a full width abrasion to the plastic surface. A corresponding abrasion to the lap portion of the webbing was identified by extending the webbing into a simulated buckled condition, **Figure 6**. The abraded webbing measured 13 cm (5 in) in length and began 69 cm (27 in) above the outboard anchor, **Figure 7**. A 8 cm (3 in) abrasion from D-ring contact was identified on the shoulder section of the webbing, **Figure 8**. This transfer began 160 cm (63 in) above the outboard anchor. Although the retractor was operational at inspection, it was probable that the retractor-pretensioner fired during the crash, considering the operating logic of the AOPS system. The retractor had subsequently relaxed over time. It was not possible to disassemble the restraint system at the time of the inspection.



**Figure 6:** Driver's restraint.



**Figure 7:** Webbing abrasion at the latch plate.



**Figure 8:** View of the webbing abrasions.

### ***Advanced Occupant Protection System***

The Audi's AOPS consisted of manual restraints with retractor-pretensioners, dual stage frontal air bags, seat back mounted side impact air bags for the front occupants, and inflatable side curtains. The system was controlled by a module located under the center aspect of the instrument panel. The front seat belt buckles incorporated buckle switches. The position of the buckle switch (open/closed) indicated to the control module the status of the front seat belt use. The AOPS was designed to vary the frontal air bag deployment threshold based on the use of the manual restraints. The frontal air bag deployment threshold of a particular front seat position was elevated to a slightly higher deceleration threshold when the seat belt at that position was in use. The Audi air bag control module was not compatible with the available EDR software and could not be downloaded. Information regarding the specific thresholds for the subject vehicle were not known.

In this crash, the AOPS control module sensed a restrained driver and assumed there was an unrestrained front right passenger (based on the buckle switch status). The fact that the driver was restrained elevated the driver air bag threshold; where as, the front right air bag was set to an unrestrained threshold. The impact severity warranted that only the driver's seat belt pretensioner, and front right air bag fire. Post-crash damage analysis indicated that the Audi's delta V was approximately 35 km/h (22 mph). The magnitude of that delta V is above the driver air bag deployment threshold typically seen in similar intersection-type crashes. However, the dynamics of this impact suggest that the subject crash occurred over a (relatively) long time duration. The extended time duration reduced the measured deceleration(s) such that the elevated driver air bag threshold was not exceeded.

The driver air bag was designed into the center hub of the steering wheel rim and was not deployed. The front right passenger air bag was a top mount design located in the right aspect of the instrument panel. The module cover flap measured 24.9 cm x 14.0 cm (9.8 in x 5.5 in), width by height. The forward rotation of the flap during the deployment sequence contacted and fractured the right aspect of the windshield. The face of the passenger air bag was trapezoidal in shape. It measured 41 cm (16 in) in width along the top surface and tapered to 25 cm (10 in) over a 50 cm (20 in) height. The rearward excursion of the air bag measured 46 cm (18 in). It was tethered by a 12 in wide strap sewn to the face of the bag. The tether seam was located 18 cm (7 in) below the top surface. The bag was vented by a single 7.0 cm (2.8 in) diameter port located on the top forward aspect of the bag adjacent to the module. There was no evidence of occupant contact to the passenger air bag.

## ***1995 DODGE NEON***

The 1995 Dodge Neon was identified by the Vehicle Identification Number (VIN): 1B3E547C7SD (production sequence deleted). The 4-door sedan was equipped with a 2.0 liter, I4 engine linked to a four speed automatic transmission. The manual restraint system consisted of 3-point lap and shoulder belts in the four outboard positions. The Supplemental Restraint System consisted of driver and front right passenger air bags. The Dodge was not equipped with side impact air bags.

### ***Exterior Inspection***

**Figure 9** is a left side view of the Dodge. The vehicle sustained 190 cm (75 in) of direct contact damage that began at the hinge pillar of the left front door and extended to trailing edge of the left rear door. The Audi's direct contact was centered on the left B-pillar. An imprint of the Audi's license plate was identified on the Neon's sheet metal at that location. The combined length of the direct and induced damage measured 281 cm (110.5 in). The induced damage began on the left rear quarterpanel 41.9 cm (16.5 in) aft of the left front axle and extended forward onto the left front fender 17.8 cm (7.0 in) aft of the left front axle. The roof buckled downward due to the B-pillar intrusion. The left wheelbase was reduced 16.3 cm (6.4 in) due to bending of the unibody structure. The right wheelbase was unchanged. The right front door opened from occupant loading. The right rear door was operational.



**Figure 9:** Left side view of the Dodge.

The vehicle's crush profile measured at the mid-door level (Field L = 281 cm) was as follows: C1 = 0, C2 = 20 cm (8 in), C3 = 77 cm (30 in), C4 = 93 cm (37 in), C5 = 70 cm (28 in), C6 = 0. It was noted during the inspection that the left front door hinge failed by overload. The structural failure overstated the residual crush at the trim elevation. Therefore, the crush profile was also documented along the sill (Field L= 137 cm). The damage profile at that elevation was: C1 = 58 cm (23 in), C2 = 66 cm (26 in), C3 = 61 cm (24 in), C4 = 50 cm (20 in). Initially, an average of the measured profiles was used to analyze the crash. The averaged profile used in the analysis was as follows: C1 = 0, C2 = 39 cm (15 in), C3 = 77 cm (30 in), C4 = 77 cm (30 in), C5 = 60 cm (24 in), C6 = 0. However as previously discussed, the use of the averaged crush profile over-estimated the severity of the crash. A more representative delta V was calculated using the crush profile measured along the sill. Using that profile, the Damage Algorithm of the WINSMASH model determined the total velocity change of the Dodge was 52.8 km/h (32.8 mph). The longitudinal and lateral delta V components were -9.2 km/h (-5.7 mph) and -52.0 km/h (-32.2 mph), respectively. The Collision Deformation Classification (CDC) was 09-LPEW-6.

### ***Interior Inspection***

The left side intrusion reduced the interior space within the vehicle by approximately 50 percent. Refer to **Figure 10**. The left B-pillar overrode the driver's seat cushion and rotated the seat back

counterclockwise. The post-impact location of the B-pillar was at the center console. The lateral distance from the deformed pillar to the right B-pillar measured 67.8 cm (26.7 in). The intrusion of the forward aspect of the left front door impacted and deformed the steering wheel rim. The tilt mechanism was fractured and the steering wheel shifted to the right. The horizontal distance between the steering wheel center line and the right corner of the instrument panel was 74 cm (29 in).



**Figure 10:** Rear view depicting the intrusion.

The front seats were adjusted to a mid-track position.

The manual 3-point restraints for the front seated occupants were both stowed within their respective retractors at the time of the inspection. The left side deformation had captured the webbing within the retractor; it was not accessible. The right front retractor also was locked with the webbing in the stowed position. Neither restraint was in use at the time of the crash. Both occupants of the Dodge were unrestrained. An unoccupied child safety seat was restrained in the left rear position.

**2002 AUDI ALLROAD QUATTRO**

**DRIVER DEMOGRAPHICS**

|                    |                          |
|--------------------|--------------------------|
| Age/Sex:           | 37 year old/Male         |
| Height:            | 183 cm (72 in)           |
| Weight:            | 100 kg (220 lb)          |
| Restraint Use:     | 3-point lap and shoulder |
| Usage Source:      | SCI inspection           |
| Medical Treatment: | None                     |

**DRIVER INJURY**

| <i>Injury</i>                       | <i>Injury Severity (AIS 2000)</i> | <i>Injury Mechanism</i> |
|-------------------------------------|-----------------------------------|-------------------------|
| Left lower extremity contusion, NFS | Minor (890402.1,2)                | Knee bolster contact    |

Note: the above injury was identified during a conversation with the Audi driver’s attorney. An interview with the driver was refused.

**DRIVER KINEMATICS**

The 37 year old male driver of the Audi was seated in a rear track position with a presumed normal posture. He was restrained at the time of the crash by the 3-point manual safety belt system. Upon impact,

the retractor locked and the retractor-pretensioner fired. The fired pretensioner removed the slack within the belt system and tightened the webbing about the driver.

The driver exhibited a forward trajectory in response to the 12 o'clock direction of the impact force and loaded the manual restraint. The restraint loading was evidenced by the documented webbing transfers. His lower extremities probably contacted the knee bolster evidenced by identified possible minor scuff marks. The contact to the bolster resulted in the left lower extremity contusion. The use of the 3-point restraint maintained the driver within his interior space, minimizing his contact to the interior and his injury potential. The driver then rebounded back into his seat and brought the Audi to a controlled stop. He then exited his vehicle under his own power.