

Rollover Investigation / Vehicle to Vehicle
Dynamic Science, Inc. / Case Number: DS06022
2006 Toyota 4Runner
California
September 2006

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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.

1. Report No. DS06022	2. Government Accession No.		3. Recipient Catalog No.	
4. Title and Subtitle Rollover Investigation		5. Report Date November 28, 2006		
		6. Performing Organization Report No.		
7. Author(s) Dynamic Science, Inc.		8. Performing Organization Report No.		
9. Performing Organization name and Address Dynamic Science, Inc. 530 College Parkway, Ste. K Annapolis, MD 21401		10. Work Unit No. (TRAVIS)		
		11. Contract or Grant no. DTNH22-01-C-27002		
12. Sponsoring Agency Name and Address U.S. Dept. of Transportation (NRD-32) National Highway Traffic Safety Administration 400 7th Street, SW Washington, DC 20590		13. Type of report and period Covered [Report Month, Year]		
		14. Sponsoring Agency Code		
15. Supplemental Notes				
16. Abstract <p>This on-site investigation focused on a 2006 Toyota 4Runner that was involved in a rollover crash. The 2006 Toyota 4Runner was struck on the front right by a 2004 Audi Allroad. The impact resulted in sufficient longitudinal deceleration of the 4Runner to command the deployment of the driver's air bag. The 4Runner was deflected laterally in a counterclockwise direction and the vehicle overturned onto its left side. The 24-year-old female driver of the 4Runner did not sustain any injuries. The driver of the other vehicle did not sustain any injuries. The other vehicle's two passengers were transported to an area hospital with strains and contusions. Both vehicles were towed from the scene. Both vehicles were also declared total losses by their respective insurance companies.</p>				
17. Key Words Rollover, stability control, ESV, air bag, deployment		18. Distribution Statement		
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price	

Dynamic Science, Inc.
Crash Investigation
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BACKGROUND

This on-site investigation focused on a 2006 Toyota 4Runner that was involved in a rollover crash. The 2006 Toyota 4Runner was struck on the front right by a 2004 Audi Allroad. The impact resulted in sufficient longitudinal deceleration of the 4Runner to command the deployment of the driver's air bag. The 4Runner was deflected laterally in a counterclockwise direction and the vehicle overturned onto its left side. The 24-year-old female driver of the 4Runner did not sustain any injuries.



Figure 1. 2006 Toyota 4Runner

This Rollover Crash case was identified by NHTSA. DSI received a fax from NHTSA on October 20, 2006 that included the police accident report and instructions to locate the case vehicle. On October 23, 2006 DSI located the case vehicle and received permission to inspect the vehicle. On October 24, 2006 DSI obtained a case number from NHTSA. The vehicle inspection took place on October 24, 2006. The scene inspection took place the following week.



Figure 2. 2004 Audi Allroad (insurance photo)

SUMMARY

Crash Site

This two-vehicle crash occurred in September 2006 at 1150 hours in southern California. The crash occurred within the confines of a three leg intersection. At the time of the crash, there were no adverse weather conditions and the asphalt surface was dry. The western leg of the intersection is comprised of two eastbound through lanes, a left turn lane, and two westbound through lanes. The turn lane is separated from the through lanes by double yellow lines. There is a positive 1.5% grade approaching the intersection. The eastern leg of the intersection is comprised of two westbound through lanes, a left turn lane, and two eastbound through lanes. The speed limit is 56 km/h (35 mph) in both directions. Just west of the crash involved intersection, there is a second T intersection with an intersecting road to the



Figure 3. Approach to area of impact

south.

Pre-Crash

The case vehicle is a 2006 Toyota 4Runner SR5 Sport Edition driven by a 24-year-old restrained female. The driver was reportedly using a hand-held cellular phone at the time of the crash. There were no additional occupants in the case vehicle. The case vehicle was traveling eastbound. The other vehicle was a 2004 Audi Allroad, driven by a restrained 42-year-old male. There were two other restrained occupants in the other vehicle. The Audi was traveling westbound at a driver reported speed of 48-56 km/h (30-35 mph). As the case vehicle approached the first T intersection, the driver reportedly observed a car in the roadway which may have been crossing or turning from an intersecting street. The driver of the case vehicle steered to the left. It is not clear if there was any control loss. The driver refused to be interviewed and the other vehicle's driver could not provide any additional clarification when interviewed. The case vehicle crossed the two-way left-turn lane and entered the westbound travel lane.

Crash

The driver of the Audi saw the 4Runner and began braking and steering to the right. The driver was unable to avoid the collision. The front of the 4Runner struck the left front of the Audi. The impact resulted in sufficient longitudinal deceleration of the 4Runner to command the deployment of the driver's air bag. The WinSmash program computed a total delta V of 19.0 km/h (11.8 mph). The longitudinal and lateral components were -14.6 km/h (-9.0 mph) and -12.2 km/h (-7.6 mph), respectively. Both frontal air bags in the Audi also deployed. The 4Runner was deflected laterally in a counterclockwise direction and the vehicle overturned onto its left side.

Post-Crash

Neither driver sustained any injuries. The Audi's two passengers were transported to an area hospital with strains and contusions. The 49-year-old male front right occupant of the Audi arrived at the hospital at 1223 hours with a Glasgow Coma Scale score of 15. He was treated and then discharged at 1555 hours. The 53-year-old female second row right occupant of the Audi arrived at the hospital at 1225 hours with a GCS of 15. She was treated and then released at 1630 hours.

Both vehicles were towed from the scene. Both vehicles were also declared total losses by their respective insurance companies.

VEHICLE DATA -2006 Toyota 4Runner

The 2006 Toyota 4Runner was identified by the Vehicle Identification Number (VIN: JTEZU14R4600xxxxx). The vehicle mileage at the time of inspection was 3,788 km (2,354 miles). The 4Runner was a four-door sport utility vehicle that was equipped with a 4.0 liter, six-cylinder engine, front/rear disc brakes with ABS, power steering, and a tilt steering wheel. All 4Runners come with Toyota's Star Safety System, which includes Vehicle Stability Control (VSC), traction control, anti-lock brakes (ABS), Electronic Brake-force Distribution (EBD) and Brake Assist. All models also feature a Hill-start Assist Control (HAC) while 4WD units add Downhill Assist Control (DAC). The 4Runner was configured with Bridgestone Dueler H/T P26570R16 tires. The manufacturer's recommended tire pressure was 303 kPa (44 psi). The specific tire information is as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	214 kPa (31 psi)	10 mm (12/32 in)	No	No
RF	221 kPa (32 psi)	9 mm (11/32 in)	Yes	No
LR	214 kPa (31 psi)	9 mm (11/32 in)	No	No
RR	214 kPa (31 psi)	10 mm (12/32 in)	No	No

The seating in the 4Runner was configured with front bucket seats and a rear 60/40 split bench seat with folding backs. The driver's seat was located 13.0 cm (5.1 in) rear of the fully forward track position. The front right seat was located 20.0 cm (7.9 in) rear of the fully forward track position. The driver's seat back was at a 27 degree angle from vertical; the seat bottom was at a 9 degree angle from horizontal. The front right passenger seat back was at a 30 degree angle from vertical; the seat bottom angle was at a 15 degree angle from horizontal. The rear seat was equipped with adjustable head restraints. The rear seat back was at a 26 degree angle from vertical; the seat bottom was at a 17 degree angle from horizontal.



Figure 4. Front right, 2006 Toyota 4Runner



Figure 5. Exemplar view, 2006 Toyota 4Runner

VEHICLE DAMAGE

Exterior Damage - 2006 Toyota 4Runner

The 2006 Toyota 4Runner sustained moderate frontal damage as a result of the impact with the Audi. The direct contact began at the front right bumper corner and extended 65.0 cm (25.6 in) laterally along the bumper fascia. Measurements were taken to the end of the bumper mounting bracket and to the end of the frame. The two crush measurements at the frame level were as follows: C1 = 2.0 cm (0.8 in) and C2 = 18.0 cm (7.1 in). Both bumper mounting brackets were shifted to the left, with the right bracket shifted 45.0 cm (17.7 in). The right frame end was shifted to the left 28.0 cm (11.0 in). The left frame end remained in place. Six crush measurements were taken along the radiator support as follows: C1= 0 cm (0 in), C2 = 0 cm (0 in), C3 = 3.0 cm (1.2 in), C4 = 11.0 cm (4.3in), C5 = 17.0 cm (6.7 in), C6 = 32.0 cm (12.6 in). The Collision Deformation Classification (CDC) for the impact with the Audi was 01FZEW2.

The 4Runner sustained minor left side damage as a result of the quarter turn rollover. The direct damage began 83.0 cm (32.7 in) rear of the rear axle and extended 408.0 cm (161 in) forward along the left side plane. The left mirror was knocked off. The CDC for the rollover was 00LDAO2.

CDC:	Event 1: 01FZEW2	
	Event 2: 00LDAO2	
Delta V (Event 1):	Total	19.0 km/h (11.8 mph)
	Longitudinal	-14.6 km/h (-9.0 mph)
	Latitudinal	-12.2 km/h (-7.6 mph)
	Energy	73,370 joules (54,115 ft lbs)

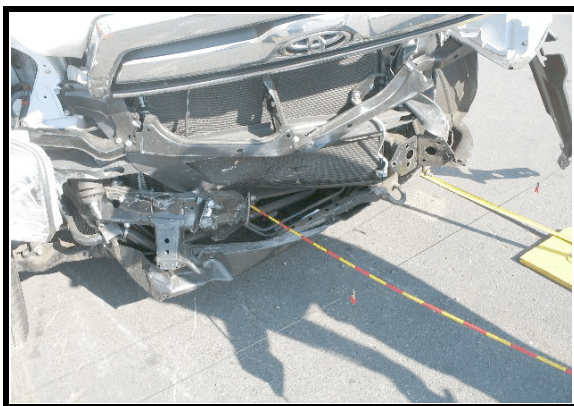


Figure 7. Close up of frame ends and mounting brackets



Figure 6. Left side rollover damage, 2006 Toyota 4Runner

Interior Damage - 2006 Toyota 4Runner

The 2006 Toyota 4Runner did not sustain any significant impact related damage. Hand print smudges were found on the driver's side window. The fuse panel cover near the left knee bolster was dislodged. There were abrasions to the right side of the center console from an unknown source. All the doors remained closed and operational. There was no intrusion nor any integrity loss.

MANUAL RESTRAINT SYSTEMS - 2006 Toyota 4Runner

The 2006 Toyota 4Runner was configured with manual 3-point lap and shoulder belts for each seating position. Both front seat safety belts were equipped with retractor pretensioners and adjustable D rings that were in the full-down position. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR). The remaining safety belts were configured with sliding latch plates and switchable ELR/Automatic Locking Retractors (ALR).



Figure 8. Smudges to driver's side window

Supplemental Restraint Systems - 2006 Toyota 4Runner

The 2006 Toyota 4Runner was equipped with Certified Advanced 208-Compliant (CAC) frontal air bags and safety belt retractor pretensioners for the driver and front right passenger positions. A CAC vehicle is certified by the manufacturer to be compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

The driver's air bag and safety belt pretensioner deployed as a result of the longitudinal deceleration of the 4Runner during the impact with the Audi.

The driver's air bag deployed from the center of the steering wheel hub through asymmetrical H-configuration module cover flaps. The top flap measured 13.0 cm (5.1 in) wide by 11.0 cm (4.3 in) high. The bottom flap measured 13.0 cm (5.1 in) by 9.0 cm (3.5 in). The deployed driver's air bag measured 50.0 cm (19.7 in) in diameter in its deflated state. The air bag was tethered by a single internal strap. Two circular vent ports were located at the 11 and 1 o'clock aspects on the rear of the air bag. A brown make-up smudge/transfer was present on the air bag face. The transfer was located 5.0 cm (2.0 in) below the horizontal center line and measured 16.0 cm (6.3 in) wide and 10.0 cm (3.9 in) high.



Figure 9. Driver's air bag (top of air bag to left of image)



Figure 10. Driver's safety belt D ring

Rollover Discussion

The 2006 Toyota 4Runner was equipped with Toyota's Star Safety System, which includes Vehicle Stability Control (VSC), traction control, anti-lock brakes (ABS), Electronic Brake-force Distribution (EBD) and Brake Assist. VSC is designed to prevent front-wheel slip and rear-wheel slip. The 4Runner had a static stability factor of 1.15 with a risk of rollover between 20 and 30% (NHTSA rating of three stars).

As the 4Runner approached the first T intersection, the driver reportedly observed a car in the roadway which may have been crossing or turning from an intersecting street. The driver attempted to steer left. It is not clear if there was any control loss. The 4Runner crossed the two-way left-turn lane and entered the westbound travel lane. After the initial front to front impact, the 4Runner was redirected in a counterclockwise rotation and tripped. The stability features would not have had any effect. The 4Runner rotated approximately 80 degrees before tripping. The 4Runner began a left side leading rollover along its longitudinal axis and completed one quarter turn before coming to rest on its left side.

As the 4Runner rolled, the driver likely contacted the door and side glass, but there were no injuries. She was not transported and was able to exit the vehicle under her own power.

VEHICLE DATA - 2004 Audi Allroad

Description:	2004 Audi Allroad	
VIN:	WA1YD64B74Nxxxxxxx	
Odometer:	34,184 km (21,242 miles)	
Engine:	2.7 liter, 6 cylinder	
Reported Defects:	None noted	
Cargo:	None	
Damage Description:	Moderate front end damage. Vehicle towed from scene. Declared total loss by insurance company.	
CDC:	12FYEW1	
Delta V:	Total	20.0 km/h (12.4 mph)
	Longitudinal	-19.7 km/h (-12.2 mph)
	Latitudinal	3.5 km/h (2.2 mph)
	Energy	16,376 joules (12,078 ft lbs)



Figure 11. 2004 Audi Allroad



Figure 12. Driver's and front right passenger's air bag, Audi Allroad

OCCUPANT DEMOGRAPHICS - 2006 Toyota 4Runner

	Driver
Age/Sex:	24/Female
Seated Position:	Front left
Seat Type:	Bucket seat. 13.0 cm (5.1 in) rear of the fully forward track position. Between mid and fully forward position.
Height:	168 cm (66 in)
Weight:	59 kg (130 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Unknown
Body Posture:	Presumed, upright
Hand Position:	Unknown, actively steering
Foot Position:	Left on floor, right on brake
Restraint Usage:	Lap and shoulder belt available, used
Air bag:	Steering wheel mounted air bag, deployed

OCCUPANT DEMOGRAPHICS - 2004 Audi Allroad

	Driver	Occupant 2	Occupant 3
Age/Sex:	42/Male	49/Male	53/Female
Seated Position:	Front left	Front right	Second row right
Seat Type:	Bucket	Unknown	Unknown
Height:	173 cm (68 in)	178 cm (70 in)	157 cm (62 in)
Weight:	70 kg (154 lbs)	75 kg (165 lbs)	54 kg (118 lbs)
Occupation:	Unknown	Unknown	Unknown
Pre-existing Medical Condition:	None noted	None noted	None noted
Alcohol/Drug Involvement:	None	NA	NA
Driving Experience:	Unknown	NA	NA
Body Posture:	Normal, upright	Normal, upright	Normal, upright
Hand Position:	Both hands on steering wheel	Unknown	Unknown
Foot Position:	Left on floor, right on brake	Both feet on floor	Both feet on floor
Restraint Usage:	Lap and shoulder belt available, used	Lap and shoulder belt available, used	Lap and shoulder belt available, used

OCCUPANT INJURIES - 2006 Toyota 4Runner

Driver: Not injured.

OCCUPANT INJURIES - 2004 Audi Allroad

Driver: Not injured.

Front row right passenger: Injuries obtained from ER Records, Work Release Form and Discharge Instructions.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Contusion, right knee	850802.1,1	Unknown	Unknown
Sprain, right knee	850826.2,1	Unknown	Unknown
Strain, cervical spine	640278.1,6	Impact forces	Probable

Second row right passenger: Injuries obtained from ER Records, Discharge Instructions and EMS/Fire Department Report.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Contusion, chest	490402.1,4	Seat belt webbing	Probable
Strain, thoracic spine	640478.1,7	Impact forces	Probable

OCCUPANT KINEMATICS - 2006 Toyota 4Runner

Driver Kinematics

The 24-year-old female driver was seated in an upright posture and was restrained by the 3-point manual lap and shoulder belt. The seat track was positioned 13.0 cm (5.1 in) rear of the fully forward track position. As the 4Runner approached the first T intersection, the driver reportedly observed a car in the roadway which may have been crossing or turning from an intersecting street. The driver attempted to steer left. It is not clear if there was any control loss. The case vehicle crossed the two-way left-turn lane and entered the westbound travel lane. At impact, the driver's air bag deployed and the seat belt pretensioner actuated. The female driver initiated a forward and slightly right trajectory. She loaded the safety belt and her face contacted the air bag. There were no resultant injuries. As the vehicle was pushed laterally, it tripped and rolled onto its left side. The driver likely contacted the door and side glass, but there were no injuries. She was not transported and was able to exit the vehicle under her own power.



Figure 13. Driver's seated position

Attachment 1. Scene Diagram

