On-Site Child Restraint System Investigation
Dynamic Science, Inc. (DSI), Case Number DS09022
2008 Ford Taurus X
California
April 2009

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

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

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16. Abstract

This on-site child restraint system investigation focused on the occupants and child restraints in a vehicle that was involved in a rollover crash. The crash occurred in April 2009 in the state of California. The subject vehicle was a 2008 Ford Taurus X crossover utility vehicle that was being driven by a 33-year-old male. The front row right seat was occupied by a 30-year-old female. The second row left seat was occupied by a 3-year-old male who was restrained in a child restraint system (CRS), and the second row right seat was occupied by an 8-month-old male who was restrained in a CRS. The Ford was traveling northbound on an undivided north/south state highway. The other vehicle was a 1993 Honda Civic that was being driven by a 21-year-old male. The Honda entered the southbound lane and attempted to pass the Ford. The Honda returned to the northbound lane without sufficient clearance and the right rear of the Honda impacted the left front of the Ford. Both vehicles departed the right side of the roadway, impacted an embankment, and overturned. The four occupants of the Ford were transported to a local hospital. The driver and the front right passenger sustained non-incapacitating injuries and they were treated and released. The 8-month-old male and the 3-year-old male reported no injuries and after being examined were released. The subject vehicle was towed due to damage and was later declared a total loss by the insurance company.

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BACKGROUND

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Figure 1. Subject vehicle, 2008 Ford Taurus X

The other vehicle was a 1993 Honda Civic that was being driven by a 21-year-old male. The front row right seat and the second row left seat were occupied by unidentified males. The second row right seat was occupied by a 27-year-old male. The Honda was traveling northbound behind the Ford.

The Honda entered the southbound lane and attempted to pass the Ford. The Honda returned to the northbound lane without sufficient clearance and the right rear of the Honda impacted the left front of the Ford. Both vehicles departed the right side of the roadway, impacted an embankment, and overturned.

The four occupants of the Ford were transported to a local hospital. The driver and the front right passenger sustained non-incapacitating injuries and they were treated and released. The 8-month-old male and the 3-year-old male reported no injuries and after being examined were released. The subject vehicle was towed due to damage and was later declared a total loss by the insurance company.

During the crash, the 27-year-old male seated in the second row right position of the Honda was fully ejected from the vehicle. He was air transported to a hospital where he was pronounced deceased. After the crash, the driver of the Honda and the remaining two passengers exited the vehicle and attempted to leave the scene on foot. The driver was detained by a witness and was later arrested on suspicion of driving while intoxicated and hit-and-run. The remaining occupants left the scene and were not identified by police. The Honda was towed due to damage and its subsequent disposition was not known.

This on-site CRS investigation was initiated by DSI during a review of an internet news article and information obtained from a preliminary police report. On April 30, 2009, a California Highway Patrol officer notified DSI of a rollover crash in which two child occupants were restrained in child seats. DSI obtained the preliminary police report and an internet news article that reported the incident. The police reported that two occupants of a 2008 Ford Taurus X, a 3-year-old male and

an 8-month-old male, were restrained in CRSs in a crash where the vehicle overturned.

On April 30, 2009, DSI forwarded the police report and information obtained from the news article to the NHTSA. On May 6, 2009, the NHTSA instructed DSI to pursue cooperation for an on-site investigation. The child seats were being held in evidence by the police and permission was given for DSI to inspect the child seats. The subject vehicle was being held at an auto body facility and DSI obtained permission to inspect the vehicle on May 20, 2009. The case was assigned on May 21, 2009. The field work was completed on May 27, 2009.

SUMMARY

Crash Site

The crash site was a two-lane north/south state highway which had one lane in each direction (**Figure 2**). Outboard of the lanes were paved shoulders, followed by ascending dirt embankments. The lanes were separated by solid double-yellow stripes, and bordered by solid white fog lines. The widths of the northbound lane and shoulder measured 3.8 m and 1.2 m (12.5 ft and 4.0 ft), respectively. The paved shoulder abutted a dirt embankment that ascended at a 45-degree angle. The embankment was 3.7 m (12 ft) in width and ascended to 1.4 m (4.7 ft) above the roadway grade. The southbound lane and shoulder widths measured 3.7 m and 1.3 m (12.1 ft and 4.3 ft).

Figure 2. Crash site, northbound approach

The roadway alignment was straight, and the profile maintained a positive grade in the northbound lane. Profile measurements were taken at intervals over a 91 m (300 ft) distance which included the areas of pre-crash, impacts and final rest. The profile within the field measured positive grades of 3.0 percent for pre-crash, 2.6 percent for the area of impact (Event 1) and 2.3 percent for the final rest location of the subject vehicle. The roadway composition was asphalt and was dry at the time of the crash. Conditions were daylight with no street lights illuminated and the weather was clear. The posted speed limit was 80 km/h (50 mph).

Pre-Crash

At the time of the crash, the Ford was traveling in the northbound lane at a police reported speed of 72-80 km/h (45-50 mph). The Honda was traveling behind the subject vehicle in the northbound lane at a police reported speed of 113-129 km/h (70-80 mph). The driver of the Honda was reported by police to be driving under the influence of alcohol and/or drugs. The driver of the Honda steered left, entered the southbound travel lane, and passed the Ford on the left side. The Honda then steered back to the right, crossed the centerline and reentered the northbound lane.

Crash

The right rear of the Honda impacted the left front of the Ford (Event 1). After the initial vehicle-to-vehicle impact, the Honda initiated a clockwise rotation and traveled to the right. The vehicle departed the roadway on the right side and its left side tires engaged the dirt embankment with sufficient lateral resistance to initiate a left side leading trip rollover (Event 2). The vehicle rolled an estimated eight quarter-turns on the embankment. During the rollover, the 27-year-old male occupant seated in the second row right position was fully ejected from the vehicle. He sustained fatal injuries, was transported to a hospital and pronounced deceased. The vehicle came to final rest on the embankment on its wheels facing east.

After the initial vehicle-to-vehicle contact, the Ford was displaced to the right and initiated clockwise rotation. The vehicle's left rear rim contacted the roadway and deposited two gouge marks as the vehicle departed the roadway on the right side. The gouge mark measured 2.6 m (8.5 ft) and 1.6 m (5.2 ft) in length. The front end of the Ford then impacted the ascending dirt embankment (Event 3). The front tires were on the embankment and the rear tires remained on the roadway. The left side tires' engagement of the respective surfaces induced a left side leading trip rollover (Event 4). The vehicle rolled two quarter-turns while rotating approximately 180 degrees clockwise; its back end impacted the embankment (Event 5), then a wooden sign post (Event 6). The back end impact with the embankment interrupted the rollover, and the Ford was then displaced to the left and reentered the roadway while on its roof. The vehicle traveled across the northbound lane, and came to final rest in the southbound lane on its roof and facing west.

A WinSMASH computation was generated for the vehicle-to-vehicle impact (Event 1).

For the Ford, the Missing Vehicle algorithm of the WinSMASH program calculated a Total Delta-V of 3 km/h (2 mph); the longitudinal and lateral components were 2 km/h (1 mph) and 2 km/h (1 mph), respectively. The results generated by WinSMASH appear reasonable, based on the minor left side damage.

For the Honda, the Missing Vehicle algorithm of the WinSMASH program calculated a Total Delta-V of 5 km/h (3 mph); the longitudinal and lateral components were - 3 km/h (- 2 mph) and - 4 km/h (-2 mph), respectively. The results generated by WinSMASH appear reasonable, based on the minor right side damage.

For the Ford's frontal impact with the embankment, the Barrier algorithm of the WinSMASH program calculated a Total Delta-V of 9 km/h (6 mph); the longitudinal and lateral components were - 6 km/h (- 4 mph) and 7 km/h (4 mph), respectively. The results generated by WinSMASH appear reasonable.

Post-Crash

The Ford came to final rest on its roof in the southbound lane facing west. The doors remained closed during the crash but several side windows disintegrated. The driver and front right occupant unbuckled their safety belts and lowered themselves onto the roof. They moved to the second row of the vehicle and unbuckled the CRS harnesses that restrained the second row occupants and assisted the children from the child seats. All four occupants exited the vehicle through the second

row right window opening, which had disintegrated during the crash. All of the occupants were mobile at the scene and none had sustained incapacitating injuries.

All four occupants were then transported by ground ambulance to a local hospital, were treated for minor injuries, and were then released. Their length of stay in the emergency room was approximately six hours.

Vehicle Data - 2008 Ford Taurus X

The 2008 Ford Taurus X was identified by the Vehicle Identification Number (VIN): 1FMDK05WX8Gxxxxxx. The vehicle's date of manufacture was January 2008. The odometer reading was not obtained due to the electronic odometer and the absence of power to the vehicle. The vehicle was equipped with a 3.5-liter, 6-cylinder engine, automatic transmission, all wheel drive, and power steering with tilt column functionality.

The Ford's standard equipment included front and rear ventilated disc brakes, anti-lock braking system (ABS), electronic stability control (ESC), and traction control. The fuel system was included a single metallic fuel tank.

The vehicle manufacturer's recommended tire size was P215/65R17 and the recommended cold tire pressure was 241 kPa (35 psi). The vehicle was equipped with Continental Contitouring P215/65R17 tires, which had a manufacturer's recommended maximum tire pressure of 300 kPa (44 psi). The vehicle was equipped with a tire pressure monitoring system. The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	Tire flat	4 mm (5/32 in)	No	De-beaded, Sidewall abraded
LR	Tire flat	6 mm (8/32 in)	No	De-beaded
RR	207 kPa (30 psi)	5 mm (6/32 in)	No	None
RF	221 kPa (32 psi)	4 mm (5/32 in)	No	None

The Ford's interior was configured with seating for six occupants. The front row consisted of outboard bucket seats with adjustable head restraints. The second row consisted of outboard bucket seats with folding backs and adjustable head restraints. The third row consisted of a bench seat with separate folding backs that were in the stowed position during the crash.

Vehicle Damage - 2008 Ford Taurus X

Exterior Damage

The Ford sustained direct and induced damage to the front and back ends, the left and right sides, and the top. The left side rims were fractured due to contact with the roadway, and the left side tires were flattened and de-beaded. The left side view mirror was fractured and displaced during the rollover, and the front bumper fascia was displaced. The left side wheelbase was shortened by 3 cm (1.2 in).

Figure 3. Maximum rollover vertical crush measurement

The direct damage from the vehicle-to-vehicle impact (Event 1) began at the front left bumper corner and extended rearward an estimated distance of 45 cm (17.7 in). The front bumper and the left front fender were missing and could not be examined. One crush measurement was taken at the left end of the bumper backing bar as follows: C_1 = 5 cm (2.0 in). For Event 1 the estimated CDC was 08LFMW1.

The Ford impacted the dirt embankment with its front end (Event 3). The front bumper was displaced, and direct contact to the bumper backing bar was present. The direct damage was distributed from bumper corner to bumper corner and measured 140 cm (55.1 in). The damage was primarily surface scratching with no residual crush. Two crush measurements were documented to the backing bar ends as follows: C_1 = 0, C_2 = 2 cm (0.8 in). Maximum crush was located at C_2 and measured 2 cm (0.8 in). The CDC for Event 3 was 10FDLW1.

After the impact with the embankment, the vehicle initiated a left side leading trip rollover (Event 4). Direct damage from the rollover was located on the vehicle's left and right sides, and top. Maximum lateral crush was located at the right roof side rail just aft of the A-pillar and measured 10 cm (3.9 in). Maximum lateral crush was located at the right roof side rail just aft of the A-pillar and measured 16 cm (6.3 in) (**Figure 3**). For Event 4 the CDC was 00TDDO3.

During the first and second quarter-turns, the vehicle rotated clockwise approximately 160 degrees and its back end impacted the dirt embankment in a non-horizontal impact (Event 5). The vertical aspect of direct damage to the back end began at the back bumper, extended 116 cm (45.7 in) upward, and ended at the backlight header. The lateral aspect of direct damage was distributed across the back end and measured 145 cm (57.1 in) in width. Maximum vertical crush was located at the left backlight header and measured 20 cm (7.9 in). The CDC for Event 5 was 00BDAW3.

A posted speed limit sign was positioned on the embankment and was impacted by the Ford's back end (Event 6) during the rollover. The sign post was a 10 x 10 cm (4 x 4 in) wood post, and was sheared during the impact. The location of the direct damage was on the vehicle's backlight header and roof. The direct damage began 30 cm (11.8 in) left of the right roof side rail and extended 10

cm (3.9 in) to the left. The damage overlapped rollover damage but maximum crush was estimated to be 2 cm (0.8 in). For Event 6 the CDC was 00BRHN1.

Interior Damage

The Ford sustained moderate interior damage as a result of intrusions and occupant contacts. The windshield was cracked and holed, and the backlight was disintegrated. The left and right side glass of the first, second and third rows disintegrated. The rear view mirror was detached from the windshield and the roof mounted controls above the front row were displaced. The right rear door would not close or latch and the rear hatch was jammed shut.

Evidence of occupant contact was documented on the following components: the roof, left and right roof side rails, windshield, instrument panel, right A-pillar, frontal air bags and IC air bags. The specific occupant contacts are discussed in the Kinematics section of this report.

The following components intruded into the first row of the passenger compartment: the roof, windshield header, right A-pillar, right roof side rail, backlight header, and left D-pillar. The roof intruded into the second and third rows, and the backlight header and left D-pillar intruded into the third row.

Manual Restraints

The front row seating was configured with 3-point manual lap and shoulder safety belts with sliding latch plates, adjustable anchorage assemblies, and buckle pretensioners. The driver's safety belt had an Emergency Locking Retractor (ELR), and the front right passenger's safety belt had a switchable ELR/Automatic Locking Retractor (ALR).

The driver's safety belt anchorage was in the full-up position, and the metal D-ring presented no evidence of occupant loading. The latch plate exhibited light scratches indicating historical usage and the plastic cover of the latch plate exhibited slight evidence of occupant loading. The safety belt buckle pretensioner actuated during the crash compressing the stalk 5 cm (2.0 in).

The driver's safety belt webbing yielded scuffs and fluid deposits that further indicated occupant usage. A scuff mark measuring 2 cm (0.8 in) in length and oriented laterally across the webbing was located 32 cm (12.6 in) above the stop button. The scuff was in the proximity of the buckled latch plate when worn by the driver and was therefore determined to be a result of contact with the latch plate. Above the scuff mark were four small transfers 1 cm (0.4 in) or less and distributed across a 31 cm (12.2 in) length of belt webbing. The transfers were faint and reddish in color and were determined to be blood stains. Based on loading evidence it was determined that the safety belt was in use at the time of the crash.

The front row right passenger's safety belt anchorage was set to the full-up position and the metal D-ring presented no evidence of occupant loading. The latch plate exhibited light scratches indicating historical usage. The buckle pretensioner actuated during the crash compressing the stalk 5 cm (2.0 in). The belt webbing, latch plate and anchorage assembly exhibited no evidence of occupant loading; however, two 1 cm (0.4 in) fluid deposits were located at 76 cm (29.9 in) above the lower anchorage. With the occupant in the seated and restrained position, the deposits would

have been located in the vicinity of the lower left torso. Based on the vehicle inspection and occupant kinematics, it was determined that the safety belt was in use at the time of the crash.

The second row seats were equipped with 3-point manual lap and shoulder belts with sliding latch plates and non-adjustable D-ring anchorages. The safety belt retractors were switchable ELR/ALR.

The left safety belt was used to secure a Graco ComfortSport convertible CRS. The latch plate was scratched from historical use. The safety belt webbing exhibited evidence of occupant loading in the form of a scuff mark and stretch marks. A scuff mark was located where the webbing contacted a seat adjustment lever on the outboard aspect of the seat cushion near the lower anchorage. The scuff was light in color, measured 1 x 5 cm (0.4 x 2.0 in), and was distributed across the width of the webbing. At 54 cm (21.3 in) above the lower anchorage a 29.5 cm (9.8 in) section of webbing was stretched (**Figure 4**). The stretched section of belt was in contact with the latch plate and the CRS shell during the crash. The driver stated during the interview that the safety belt retractor was set to ALR mode during the crash.

Figure 4. Second row left safety belt showing stretch marks

Figure 5. Second row right safety belt showing scuff marks

The right safety belt was used to secure an Evenflo Embrace rear-facing CRS. The latch plate was scratched indicating historical usage and exhibited abrasions from CRS loading. The belt webbing exhibited evidence of occupant loading in the form of scuffs and stretch marks. Two scuff marks were located where the webbing contacted a seat adjustment lever on the outboard aspect of the seat cushion near the lower anchorage. The scuffs were light in color and crossed in an X pattern (**Figure 5**). The scuffs measured 1 x 5 cm (0.4 x 2.0 in) and 1 x 6 (0.4 x 2.4 in), respectively, and were distributed across the width of the webbing. At 85 cm (33.5 in) above the lower anchorage a 30 cm (11.8 in) section of webbing was stretched. The loaded section of belt was routed through the CRS shell at the time of the crash. Based on the driver interview and loading evidence to the belt webbing, it was concluded that the safety belt retractor was set to ALR mode during the crash.

The third row seats were equipped with 3-point manual lap and shoulder belts with sliding latch plates and non-adjustable D-ring anchorages. The safety belt retractors were switchable ELR/ALR. The latch plates were smooth and neither revealed historical usage. There was slack in each belt and they would not retract completely. There was damage to the left and right D-pillars and the deformation probably restricted the retractor and webbing. The third row seats were stowed and the safety belts were not in use at the time of the crash.

Supplemental Restraint Systems

The Ford's Supplemental Restraint System (SRS) included an air bag control module, driver and passenger frontal air bags, IC air bags, seat-mounted side air bags, and safety belt buckle pretensioners for the front row. The Ford was a Certified Advanced 208 Compliant (CAC) vehicle. A CAC vehicle is certified by the manufacturer to be compliant with the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. Based on the interview with the driver, the vehicle's air bags were original equipment and had never been serviced.

Figure 6. Driver's deployed air bags

The driver's air bag module was located in the steering wheel hub (**Figure 6**), and the air bag deployed through I-configured cover flaps. The flaps opened at their tear points and were not damaged. The air bag was circular in shape and measured 54 cm (21.3 in) in diameter in its deflated state. The air bag had one internal tether that terminated at the bag's front center. Two vent ports that measured 3 cm (1.2 in) in diameter were located at the 11 and 1 o'clock positions on the air bag's back panel.

Figure 7. Passenger's deployed air bags

The air bag exhibited occupant loading evidence in the form of a fabric transfer and blood deposits. The transfer measuring 1 cm (0.4 in) in length was located near the seam in the upper left quadrant, and four droplets of blood were deposited in the lower right quadrant. The air bag was not damaged during the crash. Based on the driver interview, injury data and contact evidence, the driver loaded the frontal air bag during the crash and sustained minor air bag related injuries. The injuries included abrasions to the left wrist and hand.

The right passenger's frontal air bag deployed through a module in the top right instrument panel (**Figure 7**). The air bag deployed through a single rectangular cover flap measuring 25 cm x 12 cm (9.8 in x 4.7 in). The flap opened at its tear points and was undamaged. The air bag was generally rectangular in shape and measured 60 cm (23.6 in) in height and 42 cm (16.5 in) in width in its deflated state. The air bag was configured with two vent ports that measured 6 cm (2.4 in) in diameter and a single internal tether.

The air bag exhibited occupant contact evidence in the form of transfers and blood deposits, and damage in the form of vinyl striations, tears, abrasions, and burn marks. Three tan-colored fabric transfers were located on the air bag's front panel in the lower right quadrant. The transfers were linear in shape and measured 1 - 2 cm (0.4 - 0.8 in) in length. Blood splatter was located on the back side of the air bag in the upper and lower left quadrants. The scattered droplets all measured less that

1 cm (0.4 in) in diameter.

The air bag sustained several small tears and abrasions during the crash. The tears and abrasions were grouped in the upper right and lower left quadrants. The damage consisted of holes that measured 1 cm (0.4 in) or less. The upper right quadrant included three holes and three abrasions, and the lower left quadrant included four holes and two abrasions. The damaged areas were otherwise unremarkable and were determined to be caused by flying or broken glass. The front panel of the air bag exhibited two areas of vinyl striations that were deposited by the module cover flap during deployment.

The vent ports and internal seams exhibited dark burn marks on their edges consistent with thermal damage during deployment.

The Ford was equipped with a canopy system consisting of left and right IC air bags. A roll sensor monitors the vehicle's roll angle and roll rates. Once deployed, the side curtain air bags are designed to stay inflated for several seconds. The IC air bags also deploy during side impacts[1]. The system is designed to increase head protection in both rollovers and side impacts and is monitored by both roll sensors and side impact sensors.

During the rollover (Event 4), both of the IC air bags deployed from modules located in the roof side rails, which extended across all three rows of seating. They were constructed of woven nylon and were configured without vent ports. The air bags measured 264 cm (103.9 in) in width and 45 cm (17.7 in) in height. At their leading edge, a non-inflatable triangular sail-panel and a short tether connected the air bags to the A-pillars. At their trailing edge, a short tether attached the air bags to the D-pillars. In their deflated state, the IC air bags' vertical area of coverage extended from the roof side rail to approximately 8 cm (3.2 in) below the bottom of the side window glazing.

The left IC air bag exhibited an area of occupant contact containing body fluid and light abrasions. The dried deposit measured 4 x 4 cm (1.6 x 1.6 in) and was located 4 cm (1.6 in) below the roof side rail and 10 cm (3.9 in) forward of the left B-pillar. Included in the contact area were faint abrasions to the fabric. The driver stated that during the rollover his head and left shoulder contacted the vehicle's roof. It is probable that he loaded the left IC air bag during the first quarter turn. There was no other damage or contacts observed on the front row segment of the air bag.

In the second row, the left IC air bag exhibited a fabric transfer that measured 5 x 6 cm (2.0 x 2.4 in). The specific location of the transfer was 12 cm (4.7 in) below the roof rail and 52 cm (20.5 in) rearward of the left B-pillar. The transfer consisted of a pattern of thin gray lines that were oriented vertically. The source of the contact was unknown as the occupant was seated in a CRS and did not contact the IC air bag.

The right IC air bag exhibited evidence of contact from the front row right occupant in the form of fluid deposits, which were over an area of 8 x 8 cm (3.2 x 3.2 in) and located at the air bag's forward

[1] Protection from Multiple Angles, Ford Motor Company, http://ford.com/innovation/car-safety/protecting-family/side-impact-protection/safety-canopy-369p

aspect, 15 cm (5.9 in) above its bottom edge. The deposits were light red in color and were determined to be blood based on their location, the occupant's injury data, and the interview. A second possible occupant contact consisted of three black transfers measuring 1 cm (0.4 in) in total that were located 25 cm (9.8 in) aft of the blood deposits. The source of the transfer was not determined.

The right IC air bag exhibited copious amounts of reddish-brown fluid transfers that were deposited in the second row segment. These fluid transfers were over a 45 x 57 cm (17.7 x 22.4 in) area and extended from the roof side rail to the bottom edge of the air bag. The second row right occupant was restrained in an CRS and did not contact the air bag or sustain injuries that resulted in bleeding. It is possible that some of these transfers were the result of post-crash movements of the exiting occupants.

The vehicle was equipped with seat-mounted side air bags that did not deploy during the crash.

Lower Anchors and Tethers for Children (LATCH)

The Ford was equipped with lower anchor hardware in the second and third row seating. The lower anchors in the second row were used to install a CRS on the right seat and a CRS on the left seat. Both sets of anchors exhibited pronounced scratch marks indicating historical usage. There were tether anchors present in the vehicle behind the two rear seats.

Child Restraint Systems

Graco ComfortSport (Occupant 3)

The second row left occupant was a 3-year-old male who was seated in a Graco ComfortSport CRS (**Figure 8**). The CRS model number was 8C00TMB and the date of manufacture was 6/28/2006. The ComfortSport was equipped with a 5-point harness system with a chest retainer clip and buckle, padded cushion, a non-detachable base, locking clip, and LATCH hardware.

Figure 8. Graco ComfortSport CRS

The CRS was placed on the seat cushion in a forward facing orientation. The driver of the vehicle installed the CRS using the vehicle's lap and shoulder belt as well as the CRS lower anchor hardware. The vehicle's safety belt was routed through the forward facing slots in the CRS base, and the safety belt retractor was set to ALR mode. The locking clip was not used as part of the installation. The harness shoulder straps were routed through the top set of slots and the center buckle strap was routed through the slot closest to the child. The retainer clip was used to fasten the harness and according to the driver was positioned between chest and armpit level of the child.

The usage label on the CRS indicated that when used in a forward facing orientation, the user should

meet the following criteria:

- 102 cm (40 in) or less in height
- 9 - 18.1 kg (20 - 40 lb) in weight
- greater than one year in age

The 3-year-old occupant's father estimated the child to be 91 cm (36.0 in) in height and 16.8 kg (37.0 lb) in weight at the time of the crash. The usage label on the CRS indicated that the harness shoulder strap should be routed through the top slots for occupants who weigh between 13.6 - 18.1 kg (30.0 - 40.0 lb). Based on the child's height, weight and age, as well as the CRS usage instructions, the child met the usage requirements and the shoulder straps were in the appropriate slots.

The CRS was inspected for damage and evidence of occupant loading. The harness straps did not sustain any deformation due to intrusion or loading. The occupant's safety belt webbing exhibited loading evidence, but there was no corresponding damage to the CRS frame along the belt routing path. A 1 cm (0.4 in) scuff was located on the upper right side of the CRS adjacent the headrest; a 2 cm (0.8 in) scuff was located on the mid right side adjacent the arm rest. Some discoloration of the plastic frame was documented across the front of the CRS base which indicated stress to that area. No further damage to the CRS was observed.

Evenflo Embrace (Occupant 4)

The second row right occupant was a 8-month-old male who was seated in an Evenflo Embrace CRS (**Figure 9**). The model number was 5982076P1 and the date of manufacture was 7/18/2005. The Embrace is designed for infants and was equipped with a 5-point harness system with a chest retainer clip and buckle, padded cushion, detachable base with adjustable tilt settings, LATCH hardware, and handle for carrying the CRS. The Embrace was designed to be used rear-facing only and proper installation required the use of the base in combination with the CRS shell.

Figure 9. Evenflo Embrace CRS

The CRS was placed on the seat cushion in a rear-facing orientation. The driver of the vehicle installed the CRS using the vehicle's lap and shoulder belt as well as the CRS lower anchor hardware. The vehicle's safety belt was routed through the rear facing slots in the CRS base, and the safety belt retractor was set to ALR mode. A locking clip was not used as part of the installation. The 5-point harness shoulder straps were routed through the top set of slots and the center buckle strap was routed through the slot furthest from the child. The retainer clip was used to fasten the harness and was positioned between chest and armpit level of the child. The CRS recline was adjusted to the "2" setting, which positioned the seat back at a 45-degree angle. The vehicle's seat cushion angle measured 7 degrees above horizontal. The installed CRS seat back was approximately 52 degrees above horizontal. The usage label on the CRS indicated that the user should meet the following criteria:

- 66 cm (26.0 in) or less in height
- 2.3 - 10.0 kg (5.0 - 22.0 lb) in weight

The 8-month-old occupant's father estimated the child to be 76 cm (30.0 in) in height, and 7.7 kg (17.0 lb) in weight at the time of the crash. Based on the child's estimated height and weight, and the CRS user criteria, the occupant met the weight criteria yet exceeded the height criteria for proper usage. The harness straps were routed through the most appropriate slots, based on the child's height.

The harness straps did not reveal any deformation due to contacts or loading. The occupant's safety belt webbing and latch plate exhibited loading evidence, but there was no corresponding damage to the CRS frame along the belt routing path. A 2 cm (0.8 in) scuff was located on the lower right side. There were no fractures or deformity present. The CRS exhibited a few dried liquid deposits that were consistent with food. No further damage to the CRS was observed.

Rollover Discussion

The Ford had a Static Stability Factor (SSF) of 1.32. The SSF of a vehicle is an at-rest calculation of its rollover resistance, which is based on its track width and center of gravity height. The vehicle had a rollover resistance rating of 4 out of 5 stars, and had a 13% chance of rollover.[2]

The stability control and traction control features were incorporated into the vehicle's front and rear suspension systems. The vehicle's ESC was designed to engage the traction control feature and anti-lock brakes in an attempt to control skidding. The right rear of the Honda impacted the left front of the Ford and the Ford was displaced to the left. The impact was forward of the vehicle's center of gravity and it initiated a clockwise rotation.

The vehicle departed the roadway on the right side and its front end impacted an ascending dirt embankment. Immediately following the frontal impact, the vehicle's left side tires engaged the roadway and the embankment with sufficient force as to induce a left side leading trip rollover. The vehicle continued to rotated clockwise as it rolled onto its roof, and then its back end impacted the embankment and a sign post. The back end impact interrupted the rollover and displaced the vehicle back onto the roadway. The vehicle came to final rest on its roof, after having rolled for an estimated distance of 16 m (52.5 ft). The roll distance was mitigated due to the vehicle's rotation and the back end-to-embankment impact sustained during the rollover.

In the interview, the driver of the Ford indicated that he did not apply brakes during the crash or have control of the vehicle's steering after the vehicle-to-vehicle impact (Event 1). The vehicle's front end and front left tire engaged the ascending embankment when the vehicle's front end was significantly higher that its rear end. This abnormal shift in balance further destabilized the vehicle and increased the likelihood of a rollover.

The vehicle's tire tread depths measured between 4 - 5 mm (5 - 7/32 in) and the tire pressure of the

[2] http://www.safercar.gov

two undamaged tires measured 207 and 221 kPa (30 and 32 psi), respectively. The vehicle manufacturer's recommended tire pressure was 240 kPa (35 psi); based on the vehicle inspection, the tires were slightly underinflated. It is a generally accepted axiom that a passenger car tire with 1.6 mm (2/32 in) or more of tread is safe for traveling at highway speed on dry pavement. It is also accepted that passenger car tires underinflated by 41 kPa (6 psi) or more can result in rapid tire wear, possible tire failure, and loss of steering precision and cornering stability.[3] Based on the tire inspection, it was determined that tire wear and underinflation contributed to the rollover, but were not the primary cause of it.

Vehicle Data - 1993 Honda Civic

The 1993 Honda Civic EX Coupe was identified by the Vehicle Identification Number (VIN): 1HGEJ125XPLxxxxxx. The vehicle's date of manufacture and its odometer reading were not known. The vehicle was equipped with a 1.5-liter, fuel-injected 4-cylinder engine, automatic transmission, front-wheel drive, and manual steering. The vehicle was configured with seating for five occupants.

The vehicle manufacturer's recommended tire size was P215/65R17 for the front and the rear; the recommended tire pressure was 240 kPa (35 psi) for the front and the rear. No tire data was available for the Honda.

Exterior Damage - 1993 Honda Civic

The Honda's exterior damage data was determined based on police photographs only (**Figure 10**). The vehicle sustained minor damage to the right side during the vehicle to vehicle impact (Event 1). The damage distribution was wide and comprised surface scratches; lateral crush was not determined but the overall damage was minor. For Event 1, the estimated Collision Deformation Classification (CDC) for the Honda was 02RBLW1.

Figure 10. 1993 Honda Civic, Police photo

After the initial impact, the Honda overturned with its left side leading (Event 2). The rollover resulted in direct and induced damage to the left and right sides, and the top; induced damage extended to the front and back ends. Deformation of the left rear wheel resulted in a positive camber of approximately 40 degrees. The front bumper was displaced from the vehicle and the rear bumper was detached on the left side. The moon roof was displaced, the windshield was cracked and holed, and the side glass and backlight were disintegrated.

The direct damage to the top began on the hood and ended on the trunk. The maximum lateral crush

[3] Air Pressure - Correct, Underinflated and Overinflated, TireRack.com, http://www.tirerack.com/tires/tiretech/techpage.jsp?techid=1.

was located at the left C-pillar and the maximum vertical crush was located at the left backlight header. For Event 2, the estimated CDC was 00TDDO2.

Occupant Demographics

	Driver	**Right Front Occupant**
Age/Sex:	33/Male	30/Female
Seated Position:	Front row left	Front row right
Seat Type:	Bucket	Bucket
Seat track position:	Between mid- and rear track	Between mid- and forward track
Height:	180 cm (71 in)	170 cm (67 in)
Weight:	102 kg (225 lbs)	59 kg (130 lbs)
Alcohol/Drug Involvement:	None	N/A
Body Posture:	Upright	Upright
Hand Position:	On steering wheel, 10 and 2 o'clock position	At sides
Foot Position:	Left on floor, right on accelerator	Both on floor
Restraint Usage:	Lap and shoulder belt	Lap and shoulder belt
Air bags:	Front and side IC air bag deployed	Front and side IC air bag deployed

	Second Row Left Occupant	**Second Row Right Occupant**
Age/Sex:	3/Male	8 month/Male
Seated Position:	Second row left	Second row right
Seat Type:	Bucket	Bucket
Seat track position:	Not adjustable	Not adjustable
Height:	91 cm (36 in)	76 cm (30 in)
Weight:	17 kg (37 lbs)	8 kg (17 lbs)
Alcohol/Drug Involvement:	N/A	N/A
Body Posture:	In CRS	In CRS

Hand Position:	Unknown	Unknown
Foot Position:	Feet forward	Feet forward
Restraint Usage:	Lap and shoulder belt with CRS	Lap and shoulder belt with CRS
Air bags:	IC air bag deployed	IC air bag deployed

Occupant Injuries

Driver Injuries

Injury	OIC Code	Injury Mechanism	Confidence Level
Left shoulder contusion	751010.1,2	Safety belt webbing	Probable
Left wrist abrasion	790202.1,2	Air bag	Probable

Front Right Occupant Injuries

Injury	OIC Code	Injury Mechanism	Confidence Level
Cervical strain	640278.1,6	Impact forces	Probable
Multiple minor lacerations, left hand and wrist	790602.1,2	Broken glass	Probable

Second Row Left Occupant Injuries

No injuries reported.

Second Row Right Occupant Injuries

No injuries reported.

Occupant Kinematics

Driver Kinematics

The 33-year-old male driver was seated in an upright posture and was restrained by the vehicle's lap and shoulder safety belt. The D-ring anchorage was adjusted to the full-up position, which was appropriate for his height, and the belt webbing was snug against his shoulder, torso, and hips. The seat track setting was adjusted between the mid- and rear-track setting. He was actively steering the vehicle with his hands in the 10 and 2 o'clock position; his right foot was on the accelerator and his left foot was on the floor. He was not wearing eyewear. The vehicle was traveling in the northbound

lane at a police reported speed of 72-80 km/h (45-50 mph). The other vehicle entered the southbound lane, passed the Ford, and reentered the northbound lane. As the other vehicle traveled past the Ford, the driver of the Ford removed his right foot from the accelerator in an attempt to reduce the vehicle's speed.

The right rear of the Honda impacted the left front of the Ford. The Ford initiated a clockwise rotation and was displaced to the right. At impact, the driver was displaced to the left and rearward in response to the 8 o'clock direction of force. The driver lost control of the vehicle and initiated no further steering or braking inputs.

The Ford rotated approximately 90 degrees clockwise, departed the roadway, and the front end contacted an ascending dirt embankment. The frontal impact was of sufficient magnitude to deploy the vehicle's frontal air bags and the front row safety belt pretensioners. The driver was displaced forward and left in response to the 10 o'clock PDOF, and his left wrist loaded the air bag resulting in an abrasion. He loaded the safety belt webbing resulting in an abrasion to the left shoulder. There was no deformation to the steering wheel or column due to occupant contact.

The vehicle then initiated a left side leading trip roll over, and the driver was displaced to the left. During the rollover, the vehicle's left IC air bag deployed and the driver contacted the air bag.

The frontal impact and the rollover only slightly mitigated the vehicle's clockwise rotation, and during the second quarter turn of the rollover, the vehicle's back end impacted the embankment. The back end impact occurred while the vehicle was on its roof, and the driver remained suspended upside down in his seat and restrained by the safety belt.

After the impact to the back end, the vehicle was displaced forward and returned to the roadway. It traveled on its roof across the north and southbound lanes, while it rotated clockwise. The driver stated in the interview that his head contacted the intruded roof during the rollover. The roof exhibited blood, soil deposits, and scuff marks. However, the deposits and scuffs occurred during extrication and the driver's medical data did not identify any head or neck injuries. The driver stayed in his seat until the vehicle came to final rest on its roof in the southbound lane.

The driver unbuckled his safety belt, moved to the second row, and assisted his family from the vehicle through the second row right window opening. There was a significant amount of broken glass in the vehicle, and during the post-crash activity the driver's knees contacted the glass kernels and sustained bilateral abrasions.

Front Row Right Occupant Kinematics

The 30-year-old female occupant was seated in an upright posture and was restrained by the vehicle's lap and shoulder safety belt. The D-ring anchorage was adjusted to the full-up position, and the safety belt was snug against her shoulder, torso and hips. The seat track setting was adjusted between the mid- and forward-track setting; she adjusted her seat in a forward setting in order to allow more space between the seat back and the CRS in the second row right position. The occupant's hands and arms were at her sides and her feet were on the floor. She was not engaging in any activity other than normal conversation.

At impact with the other vehicle, the occupant was slightly displaced left and rearward in response to the PDOF. The vehicle rotated clockwise and was displaced to the right, during which time the occupant's weight remained displaced to the left as the vehicle's front end impacted the dirt embankment, the occupant's frontal air bag deployed and her safety belt pretensioner actuated. She was displaced forward and left in response to the direction of force. She loaded the safety belt and remained in place in her seat due to the safety belt.

As the vehicle overturned, the occupant continued to be displaced to the left in response to the rollover dynamics. During the second quarter turn, the driver's head contacted the intruded roof. The back of the vehicle then impacted the dirt embankment, and she was displaced rearward in response to the direction of force. The occupant sustained a cervical strain during the rollover sequence. During the rollover, the right IC air bag deployed. The air bag contained evidence of occupant contact in the form of blood deposits and a small black transfer. The source of the black transfer was not determined. Her left hand and wrist contacted broken or flying glass and sustained multiple minor lacerations. The blood was deposited on the IC air bag after the vehicle came to final rest and the occupants left hand and wrist transferred blood to the air bag. Based on the interview and the injury data, it was determined that most or all of the blood deposits left on the vehicle's roof and the right frontal air bag was deposited by the front row right occupant after the vehicle had come to final rest. The occupant was ground transported to a local hospital and arrived with a Glasgow Coma Score (GCS) of 15.

Second Row Left Occupant Kinematics

The 3-year-old male was seated in a forward-facing CRS and was restrained by the 5-point harness system. The CRS was tightly installed and the child was an appropriate height, weight and age for the CRS. The CRS was secured by the vehicle's lap and shoulder belt and the lower anchor LATCH hardware. The retractor was set to ALR mode and the CRS remained in place on the seat cushion. The child was in a normal posture with his feet forward and arms at his side. At impact with the Honda, the occupant was displaced left and rearward in response to the direction of force.

As the vehicle initiated a clockwise rotation and impacted the dirt embankment, the child was displaced forward and left and the CRS loaded the safety belt. The belt webbing exhibited a pronounced scuff mark near the lower anchor and stretch marks over a length of 29.5 cm (9.8 in) that was routed through the CRS. As the vehicle overturned, the child was displaced to the left. The vehicle came to final rest on its roof. The occupant remained suspended upside down until the driver unbuckled the CRS harness retainer clip and assisted the child from the vehicle. The CRS was not damaged during the crash, and on-scene photographs documented the CRS anchored to the seat in the vehicle at the rest position. The occupant was transported to a local hospital and his medical records reported no injuries.

Second Row Right Occupant Kinematics

The 8-month-old male was seated in a rear-facing CRS and was restrained by the 5-point harness system. The CRS was secured by the vehicle's lap and shoulder belt and the lower anchor hardware; the retractor was set to ALR mode and the CRS remained in place on the seat cushion. The CRS was tightly installed; the child was an appropriate weight, but was slightly taller than the recommended height outlined by the CRS usage guidelines. The child was in a normal posture with his feet

forward (relative to the CRS) and arms at his side. At impact with the other vehicle, the occupant was displaced left and rearward in response to the direction of force.

As the vehicle impacted the dirt embankment with its front end, the child was displaced forward and left and the CRS loaded the safety belt. The safety belt webbing exhibited a scuff mark near the lower anchor and stretch marks over a length of 30 cm (11.8 in) that was routed through the CRS. As the vehicle overturned, the child was displaced to the left. The vehicle came to final rest on its roof. The occupant remained suspended upside down until the driver unbuckled the CRS harness retainer clip and assisted the child from the vehicle. The CRS was not damaged during the crash and remained in the vehicle post-crash. The occupant was transported to a local hospital for precautionary reasons and was not injured.

Attachment 1. Scene Diagram