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ON-SITE AIR BAG RELATED CHILD FATALITY INVESTIGATION

VEHICLE: 1996 JAGUAR XJS CONVERTIBLE

VERIDIAN CASE NO. CA00-053

LOCATION: TEXAS

CRASH DATE: OCTOBER 1999

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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.

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17. Abstract This on-site investigation focused on the fatal injury mechanisms of a 7 year old male child seated in the front right of a 1996 Jaguar XJS convertible. The vehicle was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front right passenger air bags. The air bags deployed as a result of a front-to-rear impact with a 1995 Mercedes Benz E320. The child was improperly restrained by only the lap portion of the 3-point lap and shoulder restraint. The shoulder webbing was behind the child's back. The child responded to the vehicle's pre-crash braking by jackknifing about the waist over the lap belt. Upon impact, the child's head was in-close proximity to the cover flaps of the passenger air bag module. The upper cover flap struck the child's face causing a fatal skull fracture during the deployment. The driver and the right rear passenger were not injured in the crash.			
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VERIDIAN CASE NO: CA00-053

VEHICLE: 1996JAGUAR XJS CONVERTIBLE
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BACKGROUND

This on-site investigation focused on the fatal injury mechanisms of a 7 year old male child seated in the front right of a 1996 Jaguar XJS convertible. The vehicle was equipped with a frontal Supplemental Restraint System (SRS) that consisted of driver and right passenger air bags. The air bags deployed as a result of a front-to-rear impact with a 1995 Mercedes Benz E320. The child was improperly restrained by only the lap portion of the 3-point lap and shoulder restraint. The shoulder webbing was behind the child's back. The child responded to the vehicle's pre-crash braking by jackknifing about the waist over the lap belt. Upon impact, the child's head was in-close proximity to the cover flaps of the passenger air bag module. The upper cover flap struck the child's face causing a fatal skull fracture during the deployment. The driver and the right rear passenger sustained police reported non-incapacitating injuries.

The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) was informed of the crash through the Fatal Analysis Reporting System (FARS) in November 2000. NHTSA assigned an investigation of the crash to the Special Crash Investigation team at Veridian Engineering. The police investigator and the attorneys representing the vehicle's manufacturer and owner were contacted. The subject vehicle had been in storage pending resolution of the civil litigation and was available for inspection. The SCI inspection was attended by the attorneys representing the driver and the vehicle manufacturer, and by an engineer familiar with the design of the Jaguar's Supplemental Restraint System. The SCI inspection took place in February, 2001.

SUMMARY

Crash Site

This front-to-rear impact occurred during the afternoon hours in October 1999. At the time of the crash, it was daylight and the weather was not a factor. The road surface was dry. The crash occurred in the outboard southbound lane of four-lane divided roadway. Southbound traffic forward of the subject vehicle was stopped for a red traffic signal at a four-leg intersection approximately 76 m (250 ft) south of the area of the crash. The speed limit in the area was 96 km/h (60 mph). **Figure 1** is an on-scene police photograph taken at the time of the crash.

Figure 1: Southbound view of the subject vehicle at final rest.

Pre-Crash

The 1996 Jaguar XJS convertible was southbound in the outboard lane driven by a 39 year old restrained female. The right front seat was occupied by a 7 year old male. His seat was adjusted in a mid-to-forward track position and he was restrained only by the lap portion of the available 3-point lap and shoulder belt system. The shoulder portion of the webbing was placed behind his back. The belt was probably positioned in this manner for comfort; to keep the belt from riding across his neck. The low belt line of the convertible coupled with the child's relatively short seated height would have caused the shoulder belt to ride across the neck. The right rear of the Jaguar was occupied by a 6 year old restrained female

Ahead of the Jaguar was a line of stopped traffic. The stopped traffic backed up from a red traffic signal at the intersection located further to the south. The last vehicle in the line of stopped traffic was a 1995 Mercedes Benz E320 driven by a 56 year old restrained female. A 4 year old female was restrained in a child safety seat in the left rear of the Mercedes. South of the Mercedes was a stopped 1998 Isuzu Hombre pick-up truck. The pick-up truck was driven by a 29 year old restrained male.

The driver of the Jaguar failed to recognize the stopped traffic and attempted to avoid the crash by locking the brakes. The police investigation documented two pre-crash skid marks attributed to the left and right side tires of the Jaguar leading to the point of impact. The left and right skid mark measured 8.1 m (26.5 ft)and 5.7 m (18.6 ft), respectively. The improperly restrained front right child passenger responded to the pre-crash braking by initiating a forward trajectory and then jackknifing over the lap belt. The driver of the Mercedes reported she heard the Jaguar's skidding tires prior to the impact. The driver of the Isuzu similarly reported that he heard the skidding tires prior to the crash.

Crash

The crash occurred with the front of the Jaguar impacting the rear of the Mercedes in a 12/6 o'clock impact configuration. **Figure 2** is the investigating officer's schematic of the crash scene. The force of the impact collapsed the trunk of the Mercedes and resulted in approximately 15 cm (6 in) of longitudinal deformation to the Jaguar. The Jaguar's delta V calculated by the Damage Algorithm of the WINSMASH model was 24.3 km/h (15.1 mph). The force of the impact was above the threshold to cause the deployment of the Jaguar's Supplemental Restraint System. The vehicle's driver and front passenger air bag deployed. A review of the on-scene police photographs indicated the Jaguar came to rest approximately 2 to 3 m (7 to 10 ft) south of the point of impact.

The southward momentum of the Jaguar displaced the Mercedes forward into a secondary collision with the Isuzu pick-up truck. The front of the Mercedes and rear of the Isuzu both sustained minor damage. The Isuzu then drove forward and pulled over to the right shoulder after the secondary collision, as depicted in the schematic. The Mercedes came to rest 5.6 m (18.5 ft) south of the Jaguar in the outboard southbound lane as documented by the police investigation.

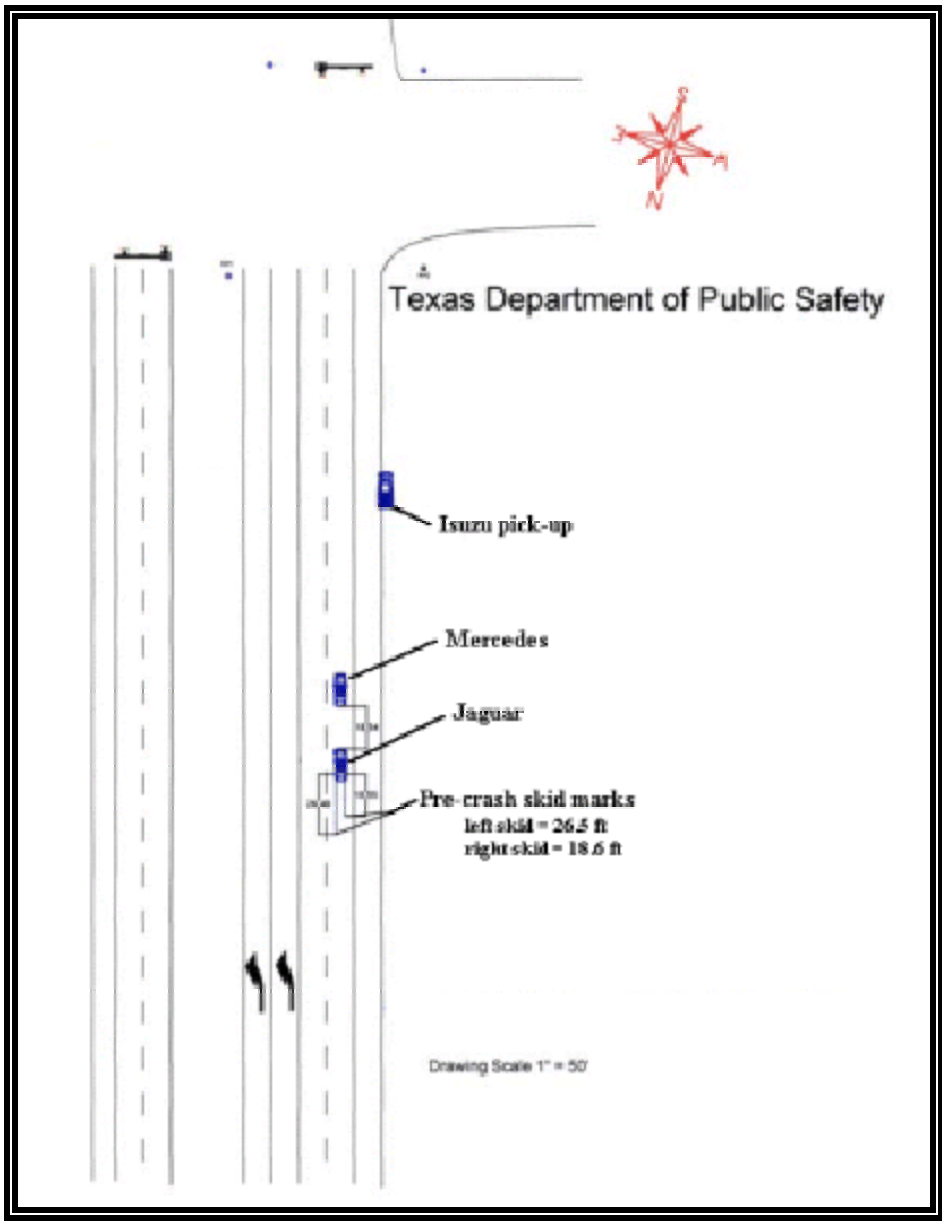

Figure 2: Police schematic of the crash.

Post-crash

The police and EMS responded to the scene. Reportedly, the EMS services arrived on-scene approximately 14 minutes post-crash. The front right child passenger was immediately transported due to the severity of his injury to a pediatric hospital within 12 km (8 miles) of the crash scene. He was pronounced dead 38 minutes post-crash. The driver and right rear passenger of the Jaguar were transported to the hospital with police reported non-incapacitating injuries. The driver of the Mercedes had a complaint of pain but refused treatment. The left rear occupant of the Mercedes was uninjured. The driver of the Isuzu did not suffer any injury and drove the pick-up truck from the scene at the conclusion of the police investigation.

1995 MERCEDES BENZ E320

The 1995 Mercedes Benz E320 was identified by the Vehicle Identification Number (VIN): WDBEA66E7SC (production sequence deleted). The power train of the 2-door convertible consisted of a 3.2 liter, I-6 engine linked to a 4-speed automatic transmission. The vehicle was equipped with a Supplemental Restraint System that consisted of driver and front right passenger air bags. An anti-lock braking system (ABS) was standard equipment.

Exterior Damage

Figures 3 and 4 are left side and right side views of the vehicle taken at the time of the on-scene investigation. Due to the delay in crash notification, the Mercedes Benz was not available for inspection. Analysis of the photographs indicated the vehicle sustained direct contact damage across the entire end width of the vehicle. The impact collapsed the vehicle's rear bumper and trunk space. During the impact sequence, the trunk lid opened and was not damaged. The estimated crush at the left rear (C1) and right rear (C6) bumper corners were 30 cm (12 in) and 25 cm (10 in), respectively. The WINSMASH model calculated a damaged based delta V of 27.3 km/h (17.0 mph) for the Mercedes. The estimated Collision Deformation Classification was 06-BDEW-3. The secondary collision with the rear of the Isuzu pick-up truck resulted in no residual deformation.

Figure 3: Left side view of the damaged Mercedes.

Figure 4: View of the right side damage.

1996 JAGUAR XJS CONVERTIBLE

The 1996 Jaguar XJS Convertible was identified by the Vehicle Identification Number (VIN): SAJNX2745TC (production sequence deleted). The 2-door convertible was equipped with a 4.0 liter, I-6 engine linked to a 4-speed automatic transmission. The transmission selector was mounted in the center console. The braking system consisted of power-assisted 4-wheel disc brakes with ABS (anti-lock brake system).

Exterior Damage

Figures 5 and 6 are the left front and left lateral views of the Jaguar. The vehicle sustained 161.3 cm (63.5 in) of direct contact damage that extended across its full frontal width. The energy of the impact was

managed primarily by the front bumper system and vehicle structures forward of the radiator support plane. The damaged components included the front bumper, grille, headlamp assemblies and hood. The front bumper was a hollow, rectangular cross section constructed out of aluminum and covered with a hard plastic. The bumper system was mounted to the vehicle's frame by Energy Absorbing Devices (EAD's) that fully stroked as a result of the impact. The EAD's returned to their original length through full restitution. The stroke of the EAD's measured 3.8 cm (1.5 in). The residual crush profile measured at the elevation of the front bumper (including the EAD stroke) was as follows: C1=15.2 cm (6.0 in), C2=12.7 cm (5.0 in), C3=12.4 cm (4.9 in), C4=11.4 cm (4.5 in), C5=11.4 cm (4.5 in), C6=11.9 cm (4.7 in). At maximum engagement, the extent of the longitudinal direct contact between the vehicle's measured 53.3 cm (21.0 in) and 47.0 cm (8.5 in) at the left and right front fenders, respectively. This engagement is depicted in **Figure 7**. The (forward opening) hood buckled at impact. There was no measurable change in the wheelbase dimensions. The vehicle's doors remained operational and were not restricted. The Collision Deformation Classification of the Jaguar was 12-FDEW-1. The delta V calculated by the Damage Only algorithm of the WINSMASH model was 24.3 km/h (15.1 mph).

Figure 5: Left front view of the Jaguar.

Figure 6: Left lateral view across the front plane.

Figure 7: Longitudinal extent of the direct contact.

Interior Damage

The interior damage to the vehicle was limited to the deployment of the vehicle's Supplemental Restraint System and the associated occupant contacts to the interior components. There was no intrusion into the occupant space as a result of the exterior crash forces. The left front glazing shattered upon impact. The right front glazing was intact. The right aspect of the windshield was fractured. The fracture site was located 25.4 cm (10.0 in) inboard of the right A-pillar and 20 .8 cm (8.2 in) below the windshield header. The fracture resulted from contact with the posterior aspect of the front right passenger's head during the air bag deployment sequence. **Figure 8** is a right interior view into the Jaguar.

Figure 8: Right interior view of the Jaguar.

Seat Configuration

The Jaguar was configured as a 5-passenger vehicle and had a leather trimmed interior. The front seating system consisted of 6-way power adjustable bucket seats. The driver's seat was adjusted in a forward track position and measured 5 cm (2 in) rear of full forward. The total seat track travel measured 18 cm (7 in). The seat back was reclined 30 degrees aft of vertical. The horizontal distance between the driver air bag module and the seat back measured 56.4 cm (22.2 in).

The electric motor that adjusted the front right seat would not operate during the inspection. Symmetrical measurements taken of the driver seat and front right seat indicated the seat was also in a forward track position. The track position measured 2.5 cm (1.0 in) rear of full forward. This seat position was consistent with the police investigation that determined the vehicle's right rear position was occupied. The front right seat was probably moved forward in order to give some room to the rear seated occupant. The seat back was reclined 25 degrees. The horizontal distance from the passenger air bag module to the seat back measured 64.5 cm (25.2 in).

Manual Restraint System

The Jaguar was equipped with manual 3-point lap and shoulder restraints with sliding latch plates for the four outboard seat positions. The front seat buckle anchors were attached to the inboard aspect of the seat cushions. The center rear position was equipped with a lap belt. The driver's belt was stowed in the retractor at inspection and was operational. Inspection of the latch plate yielded marks consistent with historical use. There was no direct evidence of occupant loading to the left front restraint as a result of the crash. The driver indicated she was restrained during the crash event. Although there was no direct evidence to support her statement, the driver's kinematic pattern and her lack of injury, in light of her forward seat track, were consistent with proper restraint use.

The driver reported the front right child passenger was restrained. However, the evidence identified on the restraint webbing during the inspection coupled with the child's kinematic and injury patterns indicated he was improperly restrained. The child was restrained only by the lap portion of the webbing. The shoulder webbing was behind his back. The front right restraint was stowed in its retractor upon inspection and was operational. The latch plate exhibited signs of historical use and was blood stained. Two blood stained regions were identified on the webbing. A 1.9 cm (0.8 in) wide blood stain measuring 8 cm (3 in) in length began 65.2 cm (25.8 in) from the floor anchor. A 6.4 cm (2.5 in) wide stain began 78.1 cm (30.8 in) from the floor anchor and measured 8.1 cm (3.2 in) in length. These regions were located in the area of the latch plate with the restraint in the buckled condition.

The design of a convertible necessitates that the roof be retractable and that there can be no upper B-pillars. Therefore, the front restraints had no upper anchorage (D-ring). The vertical elevation of the webbing's exit path from the B-pillar was low, relative to the seat back and an occupant's seated height. The shoulder belt path would not naturally travel down and across the shoulder, as compared to a vehicle with a conventional upper anchorage (D-ring). The natural belt path would be similar to that depicted in Figure 8. It was unlikely the child would properly position the belt webbing up onto his shoulder. Additionally, given the relatively short seated height of an adolescent, the shoulder belt probably would have cut across his neck. All the evidence identified during the inspection indicated the child was improperly restrained by the only the lap portion of the 3-point restraint. The shoulder belt webbing was positioned behind his back.

Supplemental Restraint System

The Supplemental Restraint System (SRS)in the Jaguar XJS convertible consisted of driver and front right passenger air bags that deployed as a result of the above threshold crash. The SRS was designed and developed by *Breed Inc*. The SRS was an independent system. The driver and passenger air bags were actuated independently by mechanical ball-in-tube sensors located in the respective modules. There was no central control module or safing sensor in the design of this system.

The driver air bag, **Figure 9**, was located in the typical manner in the center hub of the steering wheel rim. The air bag deployed from the symmetrical H-configuration cover flaps. The cover flaps were not contacted or damaged during the deployment sequence. The diameter of the driver bag measured 71 cm (28 in), in its deflated state. It was tethered by 6 straps sewn to the face of the bag. The diameter of the tether circle measured 18 cm (7 in). It was vented by a single 3.0 cm (1.2 in) diameter port located in the 12 o'clock sector of the back side of the bag. The perimeter of the bag was blood stained across its 10/4 o'clock sectors from post-crash incidental contact by the driver. There was no evidence of direct occupant contact to the face of the air bag.

Figure 9: Driver air bag.

The front right passenger air bag was a mid-mount design located in the right aspect of the instrument panel. The horizontal top surface of the instrument panel extended approximately 3.1 cm (1.2 in) rearward of the vertical face of the air bag module, slightly recessing the module relative to the front right passenger. The power of the inflator was first generation and designed with two stages. Approximately one-third of the bag's deployed travel occurred during the first stage of inflation. The inflator's second stage fired after a fixed delay of 15 ms completing the air bag's expansion.

The H-configuration cover flaps were symmetrical and measured 8.9 cm x 35.6 cm (3.5 in x 14.0 in). The rigid cover flaps were constructed of vinyl trimmed with an exterior wood finish. The interior surface of the flap was backed by styro-foam. The upper cover flap deformed as a result of contact to the child's head at the time of the deployment, **Figure 10.** The exterior wood trim panel was cracked. The width of the deformed section approximately 20 cm (8 in). The maximum deflection along the centerline of the flap measured approximately 6.4 mm (0.25 in). A single strand of blonde hair was embedded in the flap. The hair strand was located 11.4 cm (4.5 in) inboard of the right edge of the flap. Examination of the lower cover flap revealed it was not damaged.

Figure 10: View of the deformed upper cover flap.

The passenger air bag was cut from the module during the police investigation for unknown reasons. **Figure 11** is a view of the face of the bag. The face of the bag measured 43 cm x 66 cm (17 in x 26 in), width by height. The side panels of the bag were egg-shaped. The rearward extension of the bag measured approximately 46 cm (18 in). The bag was tethered by a single strap sewn across the bag's full width. The primary tether stitching was a 2.5 cm (1.0) band located 16.5 cm (6.5 in) below the top of the bag. Located 31.8 cm (12.5 in) below the top surface of the bag was a secondary tether. The attachment of the tether in this manner and the fold pattern of the bag caused the deploying air bag to expand rearward and down. The air bag vented internally back through the module.

Figure 11: View of the face of the passenger air bag.

OCCUPANT DEMOGRAPHICS

1996 Jaguar XJS Convertible

	Driver	***Front Right Passenger***	***Right Rear Passenger***
Age/Sex:	39 year old/Female	7 year old/Male	6 year old/Female
Height:	165 cm (65in)	119 cm (47 in)	unknown
Weight:	59 kg (130 lb)	20 kg (43 lb)	unknown
Restraint Use:	3-point lap & shoulder belt	Improperly restrained, using only the lap portion of 3-pt lap & shoulder belt	3-point lap & shoulder belt
Usage Source:	SCI inspection	SCI inspection	SCI inspection
Medical Treatment:	Treated & released	Transported by ambulance to a local hospital where he was pronounced dead 38 minutes post-crash	Treated & released

FRONT RIGHT PASSENGER INJURIES

Injury	**Injury Severity (AIS 98 Update)**	**Injury Mechanism**
Broad facial abrasion - encompassing both halves of the face, extending from the eyebrows to the mandibular region	Minor (290202.1,0)	Deploying front right passenger air bag module cover flap and expanding passenger air bag
Extensive facial contusion incorporated with the abraded region (see above injury)	Minor (290402.1,0)	Deploying front right passenger air bag module cover flap
Facial laceration extending from the right temporal region, across the right orbit, crossing the bridge of the nose and into the left malar region	Moderate (290604.2,0)	Deploying front right passenger air bag module cover flap
Visible fracture of the bones of the mid-face	Moderate (251004.2,4)	Deploying front right passenger air bag module cover flap

Extensive basilar skull fracture involving both frontal fossa and extensive comminuted fracture of right anterior middle and posterior fossa	Severe (150206.4,8)	Deploying front right passenger air bag module cover flap
Extensive basilar subarachnoid hemorrhage	Serious (140684.3,9)	Deploying front right passenger air bag module cover flap

Note: These injuries were identified in the Medical Examiner's autopsy report conducted the day after the crash.

Pelvic skin contusion near left iliac crest	Minor (590402.1,2)	Inertial contact to the lap belt webbing

Note: The above injury was identified from a police photograph taken prior to the autopsy and was not clinically diagnosed.

DRIVER KINEMATICS

Immediately prior to the crash, the driver was seated in a presumed normal posture with her seat adjusted in a forward track position. The driver applied the brakes in an attempt to avoid the stopped traffic ahead of her vehicle. The vehicle sensitive retractors locked the seat belt system. It was likely she braced against the steering wheel with her arms. Upon impact, the vehicle's Supplemental Restraint System detected the crash and deployed the air bags.

The driver exhibited a forward trajectory in response to the 12 o'clock direction of the impact force. She contacted and loaded the 3-point restraint and the deployed driver air bag. The proper use of the 3-point lap and shoulder belt supplemented by the driver air bag effectively restrained the driver. The vehicle's restraint system effectively mitigated the driver's contact with the steering wheel and other interior components, particularly in light of her forward seat position.

FRONT RIGHT PASSENGER KINEMATICS

Immediately prior to the crash, the Jaguar's front right passenger was seated with a presumed upright normal posture. His seat was adjusted in a forward track position. The track position measured approximately 2.5 cm (1.0 in) rear of full forward. He was improperly restrained by only the lap belt portion of the available 3-point lap and shoulder restraint. The shoulder belt webbing was behind his back.

Late in the pre-crash sequence, the driver of the Jaguar recognized the stopped traffic ahead of her and aggressively applied the brakes in an attempted to avoid the crash. The vehicle sensitive retractors in the 3-point lap and shoulder belt system locked. The front right passenger responded to the pre-crash braking

by exhibiting a forward trajectory. The child contacted the lap belt with his pelvis and the inertia of his unrestrained torso caused him to jackknife forward about the waist. This kinematic pattern positioned the child's head in-close proximity to the upper cover flap of the front right passenger air bag module.

Upon impact, the two independent ball-in-tube sensors in the respective air bag modules recognized the force of the crash was above the design threshold and commanded deployment. The cover flaps of the front right module rotated open. The rotating upper cover flap impacted the child passenger's face, across the bridge of his nose, causing the extensive facial fractures (AIS 2) and skull fractures (AIS 4), identified above. This region was extensively abraded, contused and lacerated. The impact of the cover flap also caused the associated basilar subarachnoid hemorrhage. The initial expansion of the passenger air bag abraded the child's face. As the air bag continued to expand, the child was lifted slightly and the posterior aspect of his head contacted and fractured the windshield. The windshield contact did not result in an injury. As the child's torso was lifted, the pelvic skin contusion occurred as a result of contact with the lap belt. The child then rebounded back into the seat and came to rest over the center sole evidenced by the blood stains in this region and on the inboard seat buckle anchor.

RIGHT REAR PASSENGER KINEMATICS

Prior to the crash, the child passenger was seated with a normal posture and restrained by the available 3-point lap and shoulder belt. The passenger responded to the vehicle's pre-crash braking by exhibiting a forward trajectory. She contacted and loaded the locked seat belt system. At impact, she responded to the 12 o'clock direction of the impact forces by continuing to load the belt system. The proper use of the 3-point restraint effectively restrained this passenger and spread the force of the crash over her body mitigating injury.

CONCLUSION

In this crash, the devastating injuries sustained by the child passenger resulted from the direct contact to the deploying upper cover flap of the front right passenger air bag module. However, the child's contact with the cover flap resulted from the consequences of improper use of the 3-point lap and shoulder belt system. This crash was probably survivable had the child been restrained with the shoulder belt positioned over his shoulder. Alternatively, he could have been seated in the rear of the vehicle where his outcome probably would have similar to the uninjured right rear passenger.