OFFICIAL ACCIDENT REPORT

No. 3 Car

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Executive Summary

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INTRODUCTION

When Bill France, Sr. founded NASCAR 53 years ago, one of his primary goals was to make stock car racing safer for NASCAR competitors and fans. Over the years that commitment has resulted in many significant improvements, but it has not eliminated tragedy from the sport. On February 18, 2001, in the fourth turn of the last lap of the Daytona 500, NASCAR lost Dale Earnhardt, a close friend and one of its greatest drivers. In light of a unique failure in the restraint system (a separated belt) and three other recent and equally tragic losses, its desire to provide the best safety data available to NASCAR car manufacturers, drivers and car owners, the availability of extensive information regarding the accident, and consistent with its historic commitment to safety, NASCAR commissioned a comprehensive, scientific study.

The Earnhardt study has generated a wealth of information and tools, including a state-of-the-art computer crash model of a NASCAR Winston Cup car, for car manufacturers, owners and drivers to use in their pursuit of safer vehicles and racing conditions. NASCAR has been and will continue to be involved in those efforts through coordination, encouragement and funding. In addition, as a result of the study and its continuing safety commitment, NASCAR is announcing today in a separate statement several safety-related measures.

SUMMARY OF CONCLUSIONS

NASCAR initiated the Earnhardt study by arranging for the retention of nationally respected experts. Two events provide the principal focus of an automotive accident study: the movement of and impact suffered by the car, and the movement of and impacts suffered by the occupant within the car before and at the time of the impact. Experts for each discipline were retained: a team of professors at the University of Nebraska led by Dr. Dean L. Sicking (the Nebraska Team), who are experts in accident reconstruction, computer crash modeling, and barrier accidents, and Drs. James V. Benedict and James H. Raddin, Jr. of Biodynamic Research Corporation (BRC), who are experts in the field of biomechanical analysis. As the study unfolded, NASCAR retained additional experts as circumstances warranted.

The exhaustive reports of each expert are found in the Appendices. In this document, we provide an overview of the investigation and a summary of their findings. In particular, based on the evidence they were able to review, the experts reached the following principal conclusions:

1. **Dale Earnhardt Most Likely Died From A Blow To The Occipital Portion Of The Skull (The Lower Back Of The Head), Which In Turn Caused A Basilar Skull Fracture.** The blow to the head most likely occurred as a result of contact between the left occipital region and the right side of the steering wheel during the wall impact or between the occipital region and vehicle structure on rebound from that impact. A sequence of complex body motions during the initial impact with the No.36 Car pre-positioned the body and head to the right and slightly rearward, immediately prior to and nearly simultaneous with the wall impact. The body and head then moved in response to both impacts, first generally rightward and then generally forward. The helmet was displaced forward on the head, the left lap belt separated, and the relatively exposed area of the left head severely impacted the right side of the steering wheel or, on rebound, the

posterior region of the head impacted the interior structure behind and left of the driver seat.

2. **It Is Unlikely That Dale Earnhardt s Basilar Skull Fracture Was Caused By Head Whip Or An Impact To The Chin.** While it is possible that neck tension and torsion at the time of the blow to the head contributed to the basilar skull fracture, it is not likely that head whip alone caused the fracture. There is no evidence of injuries to the neck bones, ligaments or muscles that would be expected in association with basilar skull fractures caused by head whip. Basilar skull fractures are not usually ascribed to head whip when there is evidence of significant other blows to the head (such as here). There is also an absence of dramatic injuries to the torso, which would be expected if the restraint system had arrested forward motion of the body while allowing the head to whip forward. In addition, the movement of the occupant in the car (described in detail below and in the expert s report) suggests that head whip was less likely than head impact. With respect to the superficial abrasion found on the right side of the chin, there is no evidence that it was caused by a significant impact. The left side of Dale Earnhardt s head, rather than the right side, was the leading side, making it unlikely that there was any significant impact by the right chin on the steering wheel, or any other impact that could have caused the basilar skull fracture described in the autopsy report. Nor is there any laceration or contusion in the area suggesting a significant blow there. Rather, the superficial abrasion is most likely due to contact with the chin strap as the helmet rotated on the head.

3. **The Left Lap Belt Separated At Some Point During The Wall Impact, Which Increased The Forward And Rightward Motion Of Dale Earnhardt During The Wall Impact**. The physical evidence within the No.3 Car, the pattern of injuries to the body, and other expert analysis, shows conclusively that the left lap belt separated during the wall impact, although the precise point at which it separated cannot be determined. The most likely reason for the belt separation was a phenomenon known as dumping, which can significantly reduce the strength of a belt under severe loads such as that experienced in this case. Dumping of a belt occurs when the belt webbing is pulled or moved significantly to one side of the adjustment device through which the belt webbing travels. When a dumped belt is placed under stress, the load is unevenly distributed to a small group of fibers on one side of the webbing, and if the load is sufficiently great, the belt can begin to separate on that side and then tear across the entire webbing. Dumping and separation can be caused by severe or asymmetric loading during impact, adjuster characteristics, asymmetries from installation, or misadjustment in the tightening process. In this case, Drs. Benedict and Raddin concluded that the dumping was not caused by driver adjustment because the marks on the left lap belt show that it was tightened in a generally symmetrical fashion. The relative contribution of the other factors in this particular case cannot be determined because of the complexities of the occupant kinematics during the two impacts.

4. **No Single Factor Can Be Isolated As The Cause Of Dale Earnhardt s Death.** Dale Earnhardt died as a result of several factors coming together at precisely the wrong moment, including the location of the accident (the turn), the unavoidable collision with the No.36 Car, the pre-positioning of the head that was caused by that collision, the

severity of the wall impact caused by the angle and velocity of the car into the wall, the separation of the seat belt, and the rotation of the helmet forward on the head. These factors operating together resulted in head impact. None of these factors alone can be conclusively isolated as the cause.

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In light of the speculation that has appeared over the last five months, two additional observations are appropriate.

First, Dale Earnhardt was committed to safety. He chose to install his restraint system in a manner that he believed would be the most beneficial to him. His system had served him well over many years in many different types of accidents, some of them quite severe. There is no evidence that Dale Earnhardt was aware of the risks of belt dumping. In fact, prior to the Earnhardt accident, there was no known instance of any belt separating in a NASCAR event as a result of dumping, and therefore the risk of dumping was unappreciated by NASCAR competitors and officials. No restraint system or method of installation, however, is optimally suited for every type of collision, and there are benefits and risks to each depending on the type of impact. In this particular case, because the seat belt separated and the restraint system was compromised, it is impossible to say whether a different system or method of installation would have changed the outcome.

Second, the seat belt separation cannot be isolated as the sole cause of Dale Earnhardt s death. While the separation of the lap belt increased the potential for serious injury, the precise timing of the separation during the impact is unknown. As the experts explain, the crash was very severe, several events coincided in a unique manner to produce a tragic result, and none of them can be singled out as the sole cause. In other words, it is impossible to determine with certainty whether Dale Earnhardt would or would not have survived if the lap belt had remained intact.

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The balance of this report describes the process of the Earnhardt study and the basis for the experts conclusions.

PART ONE
THE LEFT LAP BELT SEPARATED DURING THE ACCIDENT

On February 19, 2001, the Monday morning after the Daytona 500, while the No.3 Car was in Daytona Beach, NASCAR Winston Cup Director Gary Nelson first noticed the separated left lap belt beside the driver seat. The next day (Tuesday), Bobby Hutchens, General Manager of Richard Childress Racing, examined the separated belt and the No.3 Car at NASCAR s research and development facility near Hickory, North Carolina. On Wednesday, Hutchens, Rusty Wallace, Ken Schrader, Dale Earnhardt, Jr., Randy Earnhardt, Mike Helton, Gary Nelson, Bill Simpson (then President of Simpson Race Products, which had supplied the belt), other NASCAR officials, seat belt experts from Autoliv, Inc., and others were able to examine the separated belt. The seat belt experts explained the phenomenon of dumping. Because of the obvious safety issue, NASCAR shortly thereafter disclosed that the seat belt had separated, and it made a concentrated effort before the next NASCAR Winston Cup practice to urge all competitors to inspect their restraint systems.

On April 29, 2001, one of the emergency medical technicians (EMTs) who had attended to Dale Earnhardt immediately after the accident stated that he believed the lap belt had been intact at that time. The direct physical evidence at the time left little doubt in NASCAR s mind that the belt had separated during the accident, but NASCAR was widely criticized, and many questioned the thoroughness of its accident investigation. As a result, NASCAR asked the law firm of Baker Botts, LLP (Baker Botts) to undertake an investigation specific to the seat belt separation. Baker Botts, in turn, retained IPSA International, a private investigations firm, to assist in the investigation.[1]

The Scope Of The Seat Belt Investigation

Baker Botts investigation consisted of three parts.

First, Baker Botts and IPSA studied the videotape of the accident and, with the full cooperation of security and emergency personnel at Daytona International Speedway, identified and interviewed all doctors, EMTs, and police officers, all track security, wrecker and fire crew members, and all drivers and NASCAR officials, known to have been in the proximity of the No.3 Car between the time of the accident and the time that the car was transported to NASCAR s North Carolina facility. Police records regarding the impoundment of the No.3 Car were also obtained. Over 70 interviews were conducted by Baker Botts and IPSA, and many of the more important interviews were tape-recorded. All of the witnesses cooperated fully. The purpose of the interviews was threefold: (1) to determine whether anyone had observed the left lap belt either intact or separated after the accident, (2) to determine whether any other activity, such as cutting in the extrication effort, could have resulted in the separation, and (3) to trace the chain of custody in order to determine whether there was a meaningful opportunity for any person to tamper with the left lap belt after the accident.

[1] In particular, IPSA International s Senior Managing Director, D.C. Page, assisted in the investigation. Mr. Page s CV is attached at Tab 20.

Second, Baker Botts collected all known photographs of the No.3 Car and the left lap belt. Most important were the thirteen photographs of the car taken by the investigator for the Volusia County Medical Examiner s office on Monday morning, February 19. These photographs were the first post-crash images taken of the interior of the No.3 Car, and they were taken while the No.3 Car was still under the custody of the Daytona Beach Police Department. These photographs, taken during a time when the vehicle was still under police custody, provide the first hard evidence with respect to the seat belt separation issue.

Third, Baker Botts submitted the left lap belt to scientific testing, including DNA analysis by a nationally recognized laboratory[2] and microscopic analysis by a trained forensic expert in fiber analysis.[3]

Fourth, on July 19, 2001, NASCAR representatives met with experts retained by Simpson Race Products, which had supplied the belts that Dale Earnhardt used during the race. They were given the opportunity to thoroughly examine the belts, including by microscope, to take photographs of the belts for subsequent analysis and study, and to view and measure the No.3 Car s interior. They subsequently issued reports in which they concluded that the left lap belt separated during the wall impact.

Finally, Baker Botts requested the analysis of Drs. Benedict and Raddin as to whether any forensic evidence within the No.3 Car or resulting from the injuries to Dale Earnhardt could shed light on whether the seat belt separated during the accident.

The Evidence Regarding The Seat Belt Issue

The evidence, physical and otherwise, unquestionably demonstrates that the left lap belt separated during the wall impact and that there was no opportunity for NASCAR or any other third party to fabricate a separated seat belt scenario.[4]

1. **The Belt System Was Found Loose And Displaced To The Right.** Each of the EMTs attending to Dale Earnhardt immediately after the accident recalls seeing the 5-point latching mechanism for the belt positioned between 4 and 8 inches to the right of the center line of Dale Earnhardt s body. The EMT who was inside the car and thus in the best position to see the belt system, observed that it was loose and that the latching mechanism was up to eight inches to the right. It is impossible to move the latching mechanism of a normally adjusted five-point harness 4-8 inches to the right if the left lap belt is intact.

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[2] Baker Botts retained Walter F. Rowe, Ph.D., a professor of forensic evidence at George Washington University in Washington, D.C. to collect samples from the belt and the No.3 Car for the DNA analysis. It also retained Cellmark Diagnostics, a DNA laboratory in Germantown, Maryland, to undertake the actual DNA analysis.

[3] Baker Botts retained Myron T. Scholberg, a retired FBI agent, with eighteen years experience in the FBI lab analyzing fiber evidence.

[4] NASCAR has no reason to doubt the sincerity of the EMT who stated that the left lap belt was intact when he was attending to Dale Earnhardt. All evidence, however, shows that his recollection is mistaken.

2. **There Was No Opportunity For Cutting.** The EMTs uniformly stated that they did not see the belt cut by anyone and they did not cut it themselves. While one attempted to use a pair of scissors to cut the helmet strap in order to remove the helmet, he was unable to do so and laid the scissors on the roof of the No.3 Car. None of the tools used to cut the roof of the No.3 Car in the extrication process was near the floor where the left lap belt was located, nor were they small enough to fit into the space where the belt was anchored to the floor.

3. **No One At The Accident Scene Could Confirm That The Belt Was Intact Or Separated.** No individual in or around the No.3 Car between the time it came to rest on the track apron immediately after the accident until it was photographed by the Medical Examiner investigator on Monday morning, recalls seeing the left lap belt either intact or separated from the latching end to the floor anchor end. The single EMT who believed that the belt was intact based that perception on his recollection that the belt system had tension when he was attempting to unlatch it. He did not trace the belt from the latching mechanism to the floor anchoring location to see if it was separated.

4. **The Medical Examiner Photographs Show A Separated Belt.** The investigator for the Medical Examiner took thirteen photographs of the No.3 Car while it was in a transport trailer and under the custody of the Daytona Beach Police Department. One of the photographs (Tab 3)[5] shows the separated lap belt resting on the floor between the driver s seat and the driver-side structure. The photograph had been posted on the Internet for a short time after the accident and therefore was available to the media and others. In fact, in his April 10, 2001 report (Tab 7), Dr. Barry Myers (the expert appointed by the court in the lawsuit concerning release of the autopsy photos) observed that [r]eview of the vehicle photographs shows that the left (outboard) lap belt webbing is separated and appears torn. Another of the photographs (Tab 4) shows the interior of the driver seat on the driver s left-hand side. If the left lap belt had remained intact, it would be seen in this photograph protruding through the slit in the driver s seat through which the lap belt was normally installed.[6] The left lap belt, however, is not there.

5. **The Left Lap Belt Has Been Secured Since The Accident.** After the photographs were taken by the Medical Examiner s investigator Monday morning, the Daytona Beach Police Department released the No.3 Car into NASCAR s custody for transport to its new research and development facility near Hickory, North Carolina. The car was maintained by NASCAR in a locked facility secured by an independent security firm. Then, over the next two days, the several individuals mentioned above visited the NASCAR facility and observed and studied the separated belt. The belt remained in the custody of NASCAR, locked inside an enclosed and secure room within NASCAR s facility, until April 17, 2001. On that date, NASCAR moved it to a bank safe deposit box in Conover, North Carolina.

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[5] The photograph has been enhanced, but not altered, at the request of Baker Botts by There TV, Inc., a nationally recognized video and photographic enhancement studio. There TV s resume is attached at Tab 24.

[6] For example, in the photograph showing the right side of the driver s seat (Tab 5), the right lap belt can be seen resting on the right armrest.

6. **DNA And Other Evidence Confirms The Separated Left Lap Belt In NASCAR s Possession Is The Belt From the Earnhardt Accident.** On May 8, 2001, at the direction of Baker Botts, Walter F. Rowe, Ph.D. (Professor of Forensic Science at George Washington University) collected various samples of blood from the belt and inside the No.3 Car, both inside the seat and outside the seat.[7] Dr. Rowe then submitted all blood samples to Cellmark Diagnostics, Inc. (Cellmark), an independent accredited DNA testing laboratory, for DNA testing. On May 31, 2001, Cellmark issued its report confirming that all the blood samples came from the same person. Dr. Rowe took the blood samples from, among other locations, the tip ends of the separated portions of the left lap belt. The manner in which Dale Earnhardt s blood was deposited on the separated end of the left lap belt confirms that it separated during the accident. As Dr. Rowe explains, torn fibres at the end of [one part of the left lap belt] are matted with dried blood, while the corresponding end of [the other part of the left lap belt] are not matted. This is consistent with the left lap belt being separated before the blood was deposited on it. [8]

7. **Fiber Analysis Shows That The Belt Was Torn Under Stress And Not Cut.** It has been suggested that the left lap belt may have been cut rather than torn. No evidence has been found that would support this conclusion. First, no eyewitness saw the belt being cut after the accident. Second, the Daytona Beach Police Department in its May 31, 2001 report concluded to the contrary: that closer examination with a magnifying glass (3X and 5X magnification) revealed the belt fibers torn, with some exposed fiber ends in a ball as if melted. There was no indication appearing consistent with a cut from an edged instrument . . . . (Tab 13). Third, Baker Botts submitted the left lap belt to another independent fiber expert, Myron T. Scholberg. Mr. Scholberg is a veteran of eighteen years in the FBI laboratory in Washington, D.C., during eight of which (1977-1985) he headed the Microscopic Analysis Unit. He examined the left lap belt with a medium powered microscope (75 magnifications) and a high powered microscope to a lesser extent and concluded that [m]icroscopic examination of the fiber ends of this separation revealed that these fibers were torn. No fibers were observed with ends that were cut with a sharp instrument. [9]

8. **The Pattern Of Injuries Is Consistent With Separation Of The Belt During Impact.** Drs. Benedict and Raddin explain in their report (Tab 2) that certain of the injuries to the body noted by the Medical Examiner in his autopsy report are consistent with the conclusion that the left lap belt separated during the accident. Tab 12 is a diagram prepared by the Medical Examiner of the external injuries found on Dale Earnhardt. Three abrasion injuries — to the left clavicle area, the left waist area and the right lower abdomen and pelvic area — show the sequence in which Mr. Earnhardt s body came into contact with and loaded up the belt system during the accident. If the belt had remained intact throughout the incident, the normal pattern of abrasions would be

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7 The locations from which the blood samples were taken are shown in the photographs found at Tab 9.

8 A copy of Dr. Rowe s report is found at Tab 8.

9 Mr. Scholberg s CV is found at Tab 23. His Report is at Tab 14.

relatively equally distributed on the left and right shoulder area and the left and right pelvis/hip areas. Instead, there is no marking on the right side pelvis/hip area or the right shoulder area, and there is a significant diagonal abrasion to the right groin area. Drs. Benedict and Raddin conclude that this unusual pattern shows that the left lap belt remained intact during the initial impact with the No.36 Car as the body moved to the right and also during the initial part of the wall impact (causing the abrasion on the left waist area) and then separated, forcing the crotch belt and right lap belt to carry the entire load on the lower right part of the body as the body moved further forward and to the right (causing the significant diagonal abrasion on the lower right groin area). Similarly, the upper part of Mr. Earnhardt s body moved significantly to the right (causing the abrasion to the left shoulder area where the shoulder belt was attempting to restrain further movement of the body). Finally, Mr. Earnhardt s left ankle fractured from an impact to the pedals and/or the forward wall of the occupant compartment (shown by a mark to the area), consistent with the left side of his body being less adequately restrained during the latter part of the wall impact.

9. **The Anchored Portion Of The Left Lap Belt Shows That It Was Dumped.** The end of the left lap belt was found attached to its metal bracket but pulled significantly to the upper end of the adjustment device, as shown in the attached photograph (Tab 6). This is consistent with the left lap belt being dumped.

10. **Simpson Race Products Experts Concur That The Left Lap Belt Separated During The Impact.** After a thorough review of the lap belt system and the interior of the No.3 Car on July 19, 2001, experts retained by Simpson Race Products similarly concluded that the left lap belt separated during the wall impact. They further concluded from microscopic analysis of the fiber ends that the belt had torn and was not cut.

11. **The Chain Of Custody Demonstrates That There Was No Opportunity For Anyone To Invent A Separated Left Lap Belt.** The No.3 Car was immediately impounded after the accident. None of the individuals surrounding the No.3 Car between the time of the accident and the time it was placed in the custody of the Daytona Beach Police Department (7:15 p.m. Sunday night), including numerous independent third parties and officials, saw anyone removing or tampering with the belts. The Medical Examiner photographs showing the separated belt were taken the morning following the accident while the No.3 Car was still under police custody. Finally, the lap belt that has been submitted to further testing, photographic analysis and investigation, including a review by the Daytona Beach Police Department on May 29, 2001, has been confirmed by independent third parties, including Bobby Hutchens (General Manager of Richard Childress Racing) to be the same lap belt examined by the independent third parties mentioned above beginning the morning of February 20, 2001.

<u>Conclusions Regarding The Seat Belt Issue</u>

The evidence is conclusive that the left lap belt separated during the wall impact. There is no eyewitness evidence to the contrary, other than the perception of a single EMT who was focused on saving the life of Dale Earnhardt at the time. All other evidence, including the Medical Examiner investigative photographs, DNA analysis, microscopic fiber examination, the recollections of all EMTs regarding the condition of the belts and the displacement of the latching mechanism, and expert analysis of the injuries to the body, leads to a single conclusion: the left lap belt separated during the accident.

PART TWO
THE ACCIDENT

The Investigative Process

After the accident, and immediately upon its release to NASCAR by the Daytona Beach Police Department, NASCAR impounded the No.3 Car for investigative purposes, and then arranged for the retention of various experts to analyze the accident. The investigation that ensued has been one of the most comprehensive, in-depth investigations of a single accident in the history of motorsports.

The Experts Retained

Determining what happened to the No.3 Car immediately before and during the accident required engineers experienced in the dynamics of automobile crashes and, in particular, barrier impacts, preferably with knowledge regarding auto racing accidents. Prior to the Earnhardt accident, NASCAR already had been working with a team of professors led by Drs. Dean Sicking and John Reid. Both are nationally recognized experts in the field of barrier impacts with a vast amount of experience in accident reconstruction and computer modeling.[10]

Determining what happened to Dale Earnhardt during the accident required a biomechanical medical expert and engineer with expertise in automobile crashes. For that expertise, NASCAR turned to Biodynamic Research Corporation (BRC), located in San Antonio, Texas, and particularly Dr. James V. Benedict and Dr. James H. Raddin, Jr. Dr. Benedict received his Ph.D. in Mechanical Engineering in 1969 and his medical degree in 1976. He has been involved in accident analysis for over twenty-five years, and since 1986 has been a Director and Principal Consultant of BRC. Currently he serves as the President of the Association for the Advancement of Automotive Medicine. Dr. Raddin received his S.B. degree in Aeronautics and Astronautics from Massachusetts Institute of Technology (MIT) in 1967 and his medical degree in 1975. He has been involved in accident analysis for 24 years, has conducted numerous impact tests with volunteer subjects in five-point harnesses, and since 1988 has been a Director and Principal Consultant of BRC.[11]

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[10] Dr. Sicking heads the Midwest Roadside Safety Facility. Both Drs. Sicking and Reid are also professors at the University of Nebraska at Lincoln. The CVs for Drs. Sicking and Reid are found at Tabs 16 and 17 respectively.

[11] The CVs for Drs. Benedict and Raddin appear at Tabs 18 and 19.

Other companies provided technical support to Drs. Sicking, Benedict and Raddin. Autoliv[12] provided its testing facilities for various tests conducted under the supervision of Drs. Sicking, Benedict and Raddin. Also, the television footage of the Earnhardt accident was extensive and provided valuable data that was not available to the same extent for prior accidents. To enhance the television footage, There TV, Inc., with nationally-recognized expertise[13] in video and photographic enhancement, was retained to enhance certain footage of the accident to obtain the best possible data relating to the movement of the car and the occupant during the accident.

In addition, with the cooperation of the major car manufacturers involved in NASCAR racing (General Motors, DaimlerChrysler and Ford), a new computer crash model of a NASCAR Winston Cup Car was created by Altair Engineering, Inc., a nationally recognized automobile computer modeling firm, and then refined and finalized by Dr. Reid and the Nebraska Team. The computer crash model was useful in this investigation, and it will become a tool of great significance for future studies by the manufacturers and others in connection with race car development.

NASCAR s Charge To The Experts

NASCAR asked each of the experts to undertake a thorough analysis of what happened to the No.3 Car and to Dale Earnhardt during the accident. It emphasized that the results of each expert s analysis should be independently-formed, scientifically-based and, above all, factual. It also asked the Nebraska Team and BRC to prepare written reports of their respective findings, which are attached at Tabs 1 and 2 respectively.

Peer Review

NASCAR arranged to have the conclusions of Drs. Benedict and Raddin submitted to peer review by two additional experts, Drs. Robert A. Mendelsohn and Alan M. Nahum. Both are widely respected experts in the field of head injuries. Each reviewed the report and conclusions of Drs. Benedict and Raddin and discussed their findings with them. Each found the report to be thorough, objective and scientifically based, and each concurred in its conclusions (Tab 15).

The Movement And Impact Of The No.3 Car

The Nebraska Team s Investigative Work

The analysis of the movement and wall impact of the No.3 Car was significantly more complex because of the initial impact between the No.3 Car and the No.36 Car. As will be discussed below, the collision with the No.36 Car materially affects the analysis of the No.3 Car occupant s kinematics immediately prior to the impact with the wall.

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12 Autoliv s capabilities are more fully described at Tab 25.

13 Among other projects, in 1998 There TV restored and enhanced the Abraham Zapruder film of the President Kennedy assassination, now in the National Archives. There TV s capabilities are further described in the materials found at Tab 24.

The Nebraska Team began its work with an intensive analysis of the accident scene at Daytona International Speedway. They reviewed, photographed and analyzed all relevant skid marks, wall impact marks and other physical evidence marking the paths of the No.3 Car and the No.36 Car. Next, they undertook a similar, detailed review of the physical damage to the No.3 Car and the No.36 Car, both of which had been impounded and were located in NASCAR s North Carolina facility. They also reviewed the telemetry (vehicle speed and location) that was available through the GPS data created by Sportvision for the special visual effects used during the race telecast.

Thereafter, the Nebraska Team began a detailed photogrammetric analysis, using the footage from the various camera angles. Photogrammetric analysis permits a measurement of the location of a moving object at specific points in time during an event. The analysis is conducted by breaking down each frame of a videotape (approximately 30 frames per second), converting each frame into the equivalent of a still photograph, and then mapping the movement of the object by time and distance on a frame-by-frame basis (approximately 1/30 of a second per frame). The enhanced footage provided by There TV assisted in making this analysis even more precise than it would have been with normal footage.

The Nebraska Team then supervised a barrier impact test of a similarly configured NASCAR Winston Cup car. The purpose of a barrier test is not to recreate an accident, nor is a replication possible with today s available testing techniques. Rather, it is used to confirm and refine preliminary conclusions regarding the closing speed and angle at which an object is moving at the point of impact with the wall. In the barrier test, the test car impacted the barrier at a speed and angle expected to replicate and slightly exceed the wall-closing speed and angle of the No.3 Car. By comparing the ensuing physical damage to the test car at that speed and angle with the actual physical damage to the No.3 Car, and using the data obtained from the instrumentation of the test car, the Nebraska Team then had a real world test against which to compare the results of its photogrammetric and telemetry analysis and its direct physical observations of the No.3 Car and the accident scene. Finally, the barrier test provided useful data for determining the duration of the crash pulse, that is, the length of time during which the test car experienced deceleration from its pre-impact speed.

Finally, the Nebraska Team used the computer crash model to run simulated wall impacts that verified and supported the conclusions drawn from its other studies.

The Nebraska Team s Conclusions

The Nebraska Team concentrated its efforts on the effects of the two principal events in the accident, namely, the collision with the No.36 Car and the almost instantaneous subsequent impact with the wall. Combining the data from the photogrammetric analysis, the telemetry, its on-site physical observations and measurements, its study of the damage to the No.3 Car and the No.36 Car, and the data from the barrier test, the Nebraska Team was able to determine the velocity vector, velocity change (Delta V), trajectory angle [14] and heading angle[15] toward the

[14] The trajectory angle means the angle at which the center of gravity of the car is traveling relative to the wall.

[15] The heading angle means the observable angle between the centerline of the car and the wall.

wall of the No.3 Car at both impacts. Each of these data points provide useful information in determining the movement of the occupant relative to the movement of the interior of the car.

The Nebraska Team s principal conclusions are as follows:

1. As the No.3 Car came around the fourth turn, it made contact with the No.40 Car. At that point, the No.3 Car started down toward the track apron, and then through corrective steering it began to travel back up onto the race track.

2. As the No.3 Car moved up and across the track, Dale Earnhardt was actively steering to correct the trajectory of the car, but as he came up the track banking he came into the path of the No.36 Car. There was an unavoidable collision between the No.36 Car and the No.3 Car. The collision with the No.36 Car had two effects, both of which significantly increased the risk of serious injury.

3. First, the collision significantly increased the heading angle into the wall of the No.3 Car to approximately 55-59 degrees. This increased heading angle made the wall impact much more severe. In most cases, the heading angle will be more shallow and the car will hit the wall twice by rotating counterclockwise. If the heading angle is steeper, the car again will hit the wall twice by rotating clockwise. The energy and forces absorbed by the car, and therefore by the occupant, in a rotational, multiple-impact-point barrier collision will be spread out over time and therefore reduced in severity. In this instance, the heading angle of 55-59 degrees made this a critical angle impact that did not permit the car to rotate. Hence, all of the energy and load forces from the impact were felt in the initial impact, which lasted approximately 80 milliseconds in duration.

4. Second, the collision with the No. 36 Car resulted in an approximately 9-11 mph change in the velocity (Delta V) of the No.3 Car. As explained by Drs. Benedict and Raddin, this Delta V significantly changed the position of the occupant in the No.3 Car, by displacing his torso and head to the right and slightly rearward, which affected his subsequent kinematics within the car when the car hit the wall.

5. At the time of the impact with the wall, the No.3 Car was traveling at approximately 157-160 mph. The car hit the wall at a heading angle of approximately 55-59 degrees. Its trajectory angle at the time of impact was approximately 13-14 degrees.

6. The No.3 Car experienced a crash pulse of approximately 80 milliseconds in duration. In other words, it was in deceleration for approximately 80 milliseconds.

7. The total Delta V of the No.3 Car during the wall impact was approximately 42-44 mph. In other words, its velocity changed by approximately 42-44 mph as a result of the wall impact.

8. The heading angle, trajectory angle, crash pulse duration, lack of rotation and Delta V all made this a very severe impact.

9. By contrast, the No.36 Car hit the wall at a more shallow heading angle and a more shallow trajectory angle, which significantly reduced the energy and loads felt by the No.36 Car and its occupant.

<u>Movement of and Injuries to Dale Earnhardt</u>

<u>BRC s Investigative Work</u>

The task for Drs. Benedict and Raddin included analysis of both movement (engineering) and injuries (medical) to Dale Earnhardt. To that end, they reviewed and studied in detail several sources of information.

<u>First</u>, they undertook a detailed review of the autopsy report and exhibits of the Volusia County Medical Examiner, because that report describes in detail the injuries that Dale Earnhardt suffered.[16] The injuries were caused by his movement in the No.3 Car and the impacts within the interior of the car, including the seat belt system, the seat, the steering wheel, the roll cage bars, and any other part of the driver cocoon. The nature and extent of the injuries, therefore, can provide valuable evidence of what happened to the occupant during the accident.

<u>Second</u>, Drs. Benedict and Raddin undertook an extensive and detailed study of the interior of the No.3 Car. The interior contained numerous physical marks evidencing movement and impact points within the car. For example, there were fabric burns showing rapid movement of the body to the right and back, as well as bending of support structures, which would have occurred when the No.36 Car and the No.3 Car collided and prior to the impact with the wall.

<u>Third</u>, they analyzed the data provided by the Nebraska Team with respect to the reconstruction of the impact between the No.36 Car and the No.3 Car and the impact of the No.3 Car with the wall. This data was useful in determining the likely direction in which Dale Earnhardt moved prior to and at the time of the wall impact, and therefore what he likely hit within the No.3 Car.

<u>Fourth</u>, they reviewed in detail the enhanced video image of the accident.

<u>Fifth</u>, they inspected and examined the driver helmet. The helmet contained clear marks consistent with a significant forward rotation on the head. In addition, the chin strap showed abrasions and folding consistent with the expected forward rotation of the helmet.

<u>Finally</u>, they tested and confirmed their hypothesis regarding the movement of the occupant through the use of a sled test. The sled test demonstrated the motions described by Drs. Benedict and Raddin, namely, that at the time of the wall impact, Dale Earnhardt s head moved forward and somewhat to the right, then swung toward the rim of the steering wheel and finally rebounded back toward the interior rear structures, and that during this time, the helmet was rotated forward on the head in a manner that would tend to expose a portion of the left occipital region of the head to a severe impact.

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[16] The autopsy photographs were unavailable for review. The Medical Examiner was unavailable for consultation pursuant to the instructions of the Volusia County Attorney.

BRC s Conclusions

Based upon their analyses, Drs. Benedict and Raddin reached the following conclusions.[17]

The Blow To The Head Was Most Likely The Fatal Event

A basilar skull fracture is generally caused by forces which distort the floor of the skull through compression, tension or torsion. A blow to the jaw area can transmit compressive force into the lower region of the skull, occasionally fracturing the basilar part of the skull. A head whip can occasionally generate such tension and force on the skull base through the neck that the lower part of the skull fractures. More commonly, a direct blow to the head produces the force that causes a basilar skull fracture, sometimes distant from the point of force application.

Drs. Benedict and Raddin concluded that, of the three potential injury mechanisms, the blow to the chin was not likely.[18] The right side of the chin would not be expected to have a trajectory toward a potential contact point under the circumstances of the accident because the head was left-leading rather than right-leading; if a chin impact of significance had occurred, one would expect to see it on the left side rather than the right. The slight abrasion on the right side of the chin is probably due to contact with the helmet chin strap as the helmet rotated on the head during the accident, and observation of marks on the helmet chin strap were consistent with that scenario. In addition, potential associated injuries to the chin were absent.

Similarly, Drs. Benedict and Raddin conclude that a head whip likely did not cause the basilar skull fracture. Injuries to the neck bones, muscles and ligaments that would be expected in association with basilar skull fractures caused by neck tension were notably absent. The autopsy report states that [p]osterior dissection of the neck demonstrates no injury to the vertebral arteries or to the ligaments of the posterior cervical spine. Tab 11. That description of the injury to the neck muscles and ligaments, according to Drs. Benedict and Raddin, is substantially less than what would be expected in a severe head whip capable of giving rise to a basilar skull fracture. In addition, basilar skull fractures are not generally ascribed to head whip where there is a basis to expect a significant other blow to the head and physical evidence that a blow occurred in an area appropriate for production of the fracture (such as here). Also, the Earnhardt restraint system permitted significant ride down of the body during an impact,

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17 The conclusions of Drs. Benedict and Raddin differ in certain material respects from those of Dr. Myers, who issued a report on April 10, 2001. It should be noted that Drs. Benedict and Raddin developed or had access to much information during the course of their investigation that was not available to Dr. Myers at the time of his report. Any difference in opinions may derive from the differences in the data upon which the two analyses were based.

18 Dr. Myers in his report concluded that Dale Earnhardt s head moved forward and slightly to the right with significant force and that his chin hit the steering wheel, causing the deformation of the steering wheel and resulting in significant forces being transmitted to the floor of the skull. Tab 7. Dr. Myers, however, did not have the benefit of a physical review of the interior of the No.3 Car or the accident reconstruction analysis of Dr. Sicking. Nor was he aware of the velocity change caused by the impact with the No.36 Car, or the enhanced video showing the head disappearing to the right at the time of that impact. All of these facts support the conclusion that before moving forward, the head moved significantly to the right and was not in a position to suffer the kind of chin impact Dr. Myers described in his report.

which means that the torso can displace and there is less likelihood of significant head whip as the body moves forward to a contact point. This is confirmed by the absence of significant injuries to the torso, which would be present if the restraint system had precipitously arrested forward motion of the body while allowing the head to whip forward. Finally, the movement of the occupant in the car, documented by the fabric burns, the pre-positioning caused by the No.36 Car and the impact points on the steering wheel, all suggest that head whip was less likely to cause the basilar skull fracture in this case.

Drs. Benedict and Raddin conclude that the most likely injury mechanism was a blow to the occipital portion of the skull. Tension and torsion on the skull base also would likely be present at the time of and in conjunction with the blow to the head. They base their conclusion in part on the evidence in the autopsy report of a 8.0 cm by 5.5 cm hemorrhage/contusion on the left side of the occipital scalp. The extent of the contusion described in this area suggests a blow sufficient to have caused a basilar skull fracture.[19] Their observation of the helmet showed no signs of significant contact between the helmet and structure, but it did contain markings showing significant forward motion on the head which would tend to leave the back portion of the head unprotected. Their conclusion corresponds to that of the Medical Examiner that death resulted from blunt force injuries of the head. Tab 11.

The Principal Blow To The Head Occurred Either
<u>When It Hit The Steering Wheel Or On Rebound</u>

Drs. Benedict and Raddin also concluded that the blow to the head occurred in one of two ways, when a relatively unprotected portion of the head either hit the steering wheel at wall impact or when the occupant rebounded (after the impact with the wall) into a hard surface behind the driver seat.

First, the No.36 Car collided with the No.3 Car on its right side. At that point, because of the sudden and significant change in the No.3 Car s velocity (approximately 9-11 mph) caused by the impact, the head of the driver moved significantly to the right and it also rotated to the right. Evident fabric burns on the right wing of the driver s seat and the rightward bending of that wing, photographed and explained by Drs. Benedict and Raddin in their report, further support the conclusion that the body moved rapidly to the right and slightly rearward, a motion that could only be caused by the impact with the No.36 Car. At this point, the helmet rotated forward on the head, leaving the lower back of the head relatively exposed, particularly on the left side. Second, a fraction of a second later, the No.3 Car hit the wall, causing the body of the driver to move forward and somewhat to the right. The helmet rotated further forward on the head.

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[19] Dr. Myers in his report discounted the potential for a blow to the back of the head. He did not have the critical data from the vehicle inspection and the accident reconstruction, however, which provides a readily apparent basis for such a blow to the head. Hence, his conclusion as to the relative likelihood of the potential injury mechanisms is understandable.

In the most likely scenario described by Drs. Benedict and Raddin, the restraint system failed as a result of the dumped left lap belt,[20] increasing the movement of the head and the rotation of the helmet. The head swung forward in an arcing motion in a manner that caused it to strike the steering wheel more radially on the left side of the head, in an unprotected region in the location of the left-side contusion described in the autopsy report.[21]

Drs. Benedict and Raddin concluded that it is less probable, but still possible, that the fatal blow to the head occurred when the body rebounded back into the seat after the impact into the wall. Rebound is caused primarily because the remaining seat belt webbing, which had stretched in the wall impact, attempted to regain some of its original form and in doing so pulled the body backwards into the seat, an effect that would be accentuated by the separated seat belt because the occupant would have traveled further forward than expected with an intact belt system. In this scenario, the head likely hit the structure near the left back of the seat, although with less tension force than it would have had when it hit the steering wheel. The autopsy report also records an area of hemorrhage/contusion on the right occipital region (behind the right ear), which likely would have occurred on rebound.

Subsequent motion in either case would ultimately tend to restore the helmet to a more normal location. Not surprisingly, therefore, the driver was found after the accident with his helmet in a relatively normal position.

In either scenario, the force of the blow to the head most likely caused the resulting basilar skull fracture, which in turn killed Dale Earnhardt.

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[20] Drs. Benedict and Raddin conclude that the left lap belt did not dump from improper driver adjustment, because the marks on the webbing of the seat belt show that the left lap was in a generally symmetrical alignment in the adjuster mechanism (not dumped at an angle) at the time the load was first applied. Because of the complexity of the occupant motions during the dual impact, however, it is not possible to determine whether the dumping and separation resulted from asymmetrical loading caused by those movements, the belt s routing, the characteristics of the adjuster, or a combination of these factors.

[21] The sled test confirmed that the body and head are likely to move in this manner with this result.

Appendix

Volume 1

APPENDICES

Volume 2

Tab 1

Accident Reconstruction of

No. 3 Car Crash at Daytona 500

February 18, 2001

by

Dean L. Sicking, Ph.D., P.E.

and

John D. Reid, Ph.D.

August 21, 2001

ABSTRACT

A detailed accident reconstruction of the No. 3 car crash at the Daytona 500 on February 18, 2001 is presented. The reconstruction included a detailed site survey, photogrammetric reconstruction of the video scenes, analysis of on board GPS data, a full-scale crash test to verify preliminary findings, and a detailed computer model of the impact. This analysis identified the vehicle kinematics of both the No.=s 3 and 36 cars throughout the accident event. The impulse imparted to the No. 3 car during its impact with the outside barrier was also estimated. Results of this investigation provide insight into this accident as well as important data to be used in future efforts to develop energy absorbing barrier systems, improved energy management in race vehicles, and improved occupant restraint systems inside the cars.

I. INTRODUCTION

Highway engineers have been studying accidents for decades in an effort to make roadways and vehicles safer for the motoring public. Most of these studies incorporate statistical analyses of thousands of police level accident reports in an effort to determine the causes of accidents and injuries. However, the most successful efforts generally involve detailed investigation of serious accidents. Detailed accident reconstructions of selected accidents is really the only method for determining vehicle kinematics associated with serious injury and fatal accidents. Any effort to develop an improved barrier system, design a more crashworthy vehicle, or develop better driver restraint systems must begin with a definition of vehicle kinematics associated with accidents that cause driver injury or fatality. The reconstruction described herein was undertaken to develop a better understanding of the vehicle kinematics associated with the No. 3 car crash at the Daytona 500 on February 18, 2001.

The objectives of this study included:

! Identify vehicle kinematics of the No.’s 3 and 36 cars prior to and during the barrier impact.

! Determine impact conditions and velocity changes associated with the collision between the No.’s 3 and 36 cars.

! Identify impulse imparted to the No. 3 vehicle during the barrier impact.

! Build a computer simulation model of a Winston Cup car that could aid the reconstruction effort and provide a tool for improving the crashworthiness of these vehicles.

A significant amount of evidence regarding the accident was available at the scene, including tire marks and pavement and barrier gouges. Further, damage to the accident vehicle is another important source of evidence regarding accident conditions. Unlike most accidents, the No. 3 car crash was actually caught on video tape by 8 different cameras and the vehicle carried on board instrumentation which provided Global Positioning System (GPS) based estimates of the location of the crash vehicle every 200 ms. Analysis of available crash evidence is commonly used to develop a preliminary estimate of vehicle kinematics which can then be further verified through full-scale crash testing and/or computer simulation of the impact events. As summarized in the following four sections, the available evidence on the crash was carefully analyzed to provide a preliminary estimate of the crash conditions. Thereafter, both full-scale crash testing and a computer simulation of the accident were conducted in an attempt to verify and further refine the accident analysis.

II. SITE INVESTIGATION

The first phase of the reconstruction effort involved conducting an investigation of the accident scene. The accident occurred approximately half way through turn 4 of the Daytona Speedway and there was sufficient evidence at the scene to identify the exact location of the accident. At the time of the investigation, tire marks were clearly visible on the pavement, but the barrier wall had been repainted. Photos of the scene taken on February 19th, 2001 clearly demonstrated that all of the marks visible immediately after the accident were still present on the day of the investigation. Reviews of video tapes of the accident clearly indicate that the No. 3 car first went out of control when the rear of the vehicle struck the front of the No. 40 car. The No. 3 car moved toward the inside of the track and crossed the yellow line marking the start of the curve=s superelevation. The No. 3 car then corrected back to the race track where it collided with the No. 36 car. After the collision, the two cars remained in contact and traveled along a relatively straight path until striking the outside containment wall. Evidence collected at the scene that documents the two vehicles' motions during the accident is summarized below.

As shown in Figure 1, a single tire mark was found at the point where the No. 3 car first ran off of the inside of the track. The mark, labeled A in the figure, clearly indicates that the vehicle was cornering to the right near its maximum limit. The mark disappeared after re-entering the track, indicating that the driver was no longer correcting to the right. Although it was impossible to document photographically, there appeared to be another single mark indicating that the vehicle later began to steer left.

Figure 1. No. 3 Car Tire Mark Inside of Track

Seven tire marks and one pair of closely spaced scrapes were found leading to the point where the two vehicles struck the wall. These marks, shown in Figure 2, were surveyed and mapped onto a drawing of the track to determine their orientation relative to the barrier. By referring to the video tape scenes of the accident, it was possible to determine that the No. 3 car lost its right rear wheel shortly after impact with the No. 36 vehicle. It was therefore concluded that the scrapes, shown in Figure 3, must have come from the right rear suspension on the No. 3 car. Further reviews of the video helped to identify that tire marks B and C, shown in Figure 4, were deposited by the left front and left rear tires of the No. 3 car respectively. The faint tire mark, labeled with a D in this photograph, was attributed to the right front tire and the scrape mark was made by suspension elements from the right rear of the No. 3 car. Note that the No. 3 car was shown to have a high degree of side slip to the left and the No. 36 car was in contact and lifting up the right front fender, it is not surprising that the right front tire would not leave a dark mark. Similarly, as shown in Figure 5, tire marks E, F, G, and H were identified as being laid down by the right front, left front, right rear, and left rear tires of the No. 36 car respectively. It should be noted that rear tire marks are often made after front tire marks are no longer being made.

Figure 2. Tire Marks at Scene of Collision

Figure 3. Scrapes on Pavement

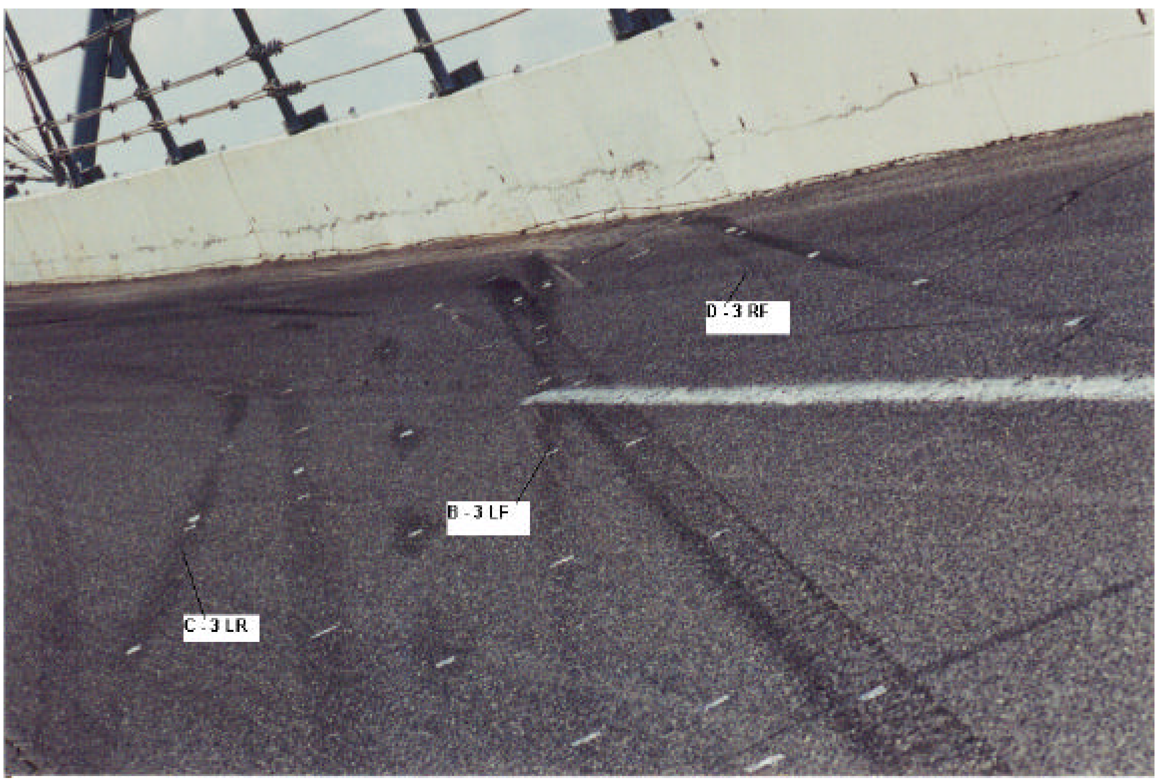


Figure 4. Marks Attributed to No. 3 Car

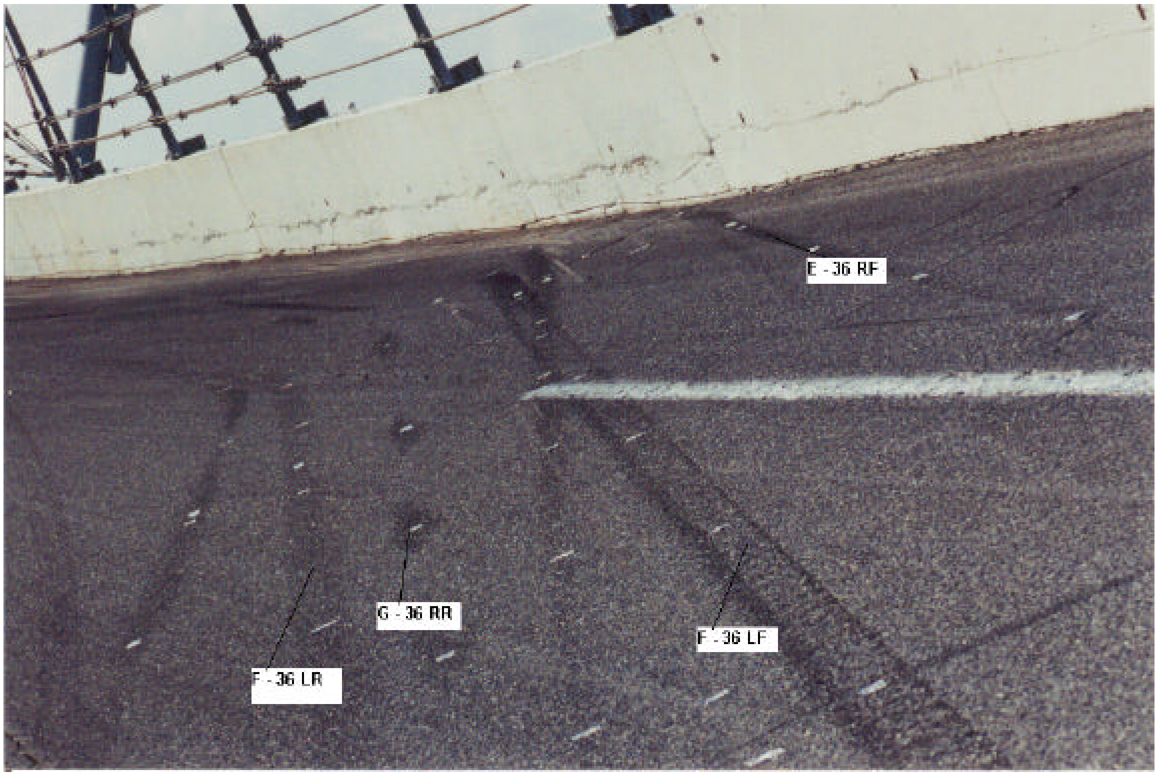


Figure 5. Tire Marks Attributed to No. 36 Car

If a vehicle is not tracking, i.e. the rear tires are not following the same track as the front tires, the movement of the vehicle=s center of gravity will be along a path that has a different angle than the vehicle=s heading angle. The direction and speed of the vehicle=s center of gravity is referred to as the vehicle=s velocity vector. Identifying both the vehicle heading angle and the angle between the vehicle=s velocity vector and the barrier, henceforth described as the trajectory angle, are important components of the reconstruction of the barrier impact. The heading angle and trajectory angles for a vehicle striking a barrier are shown in Figure 6.

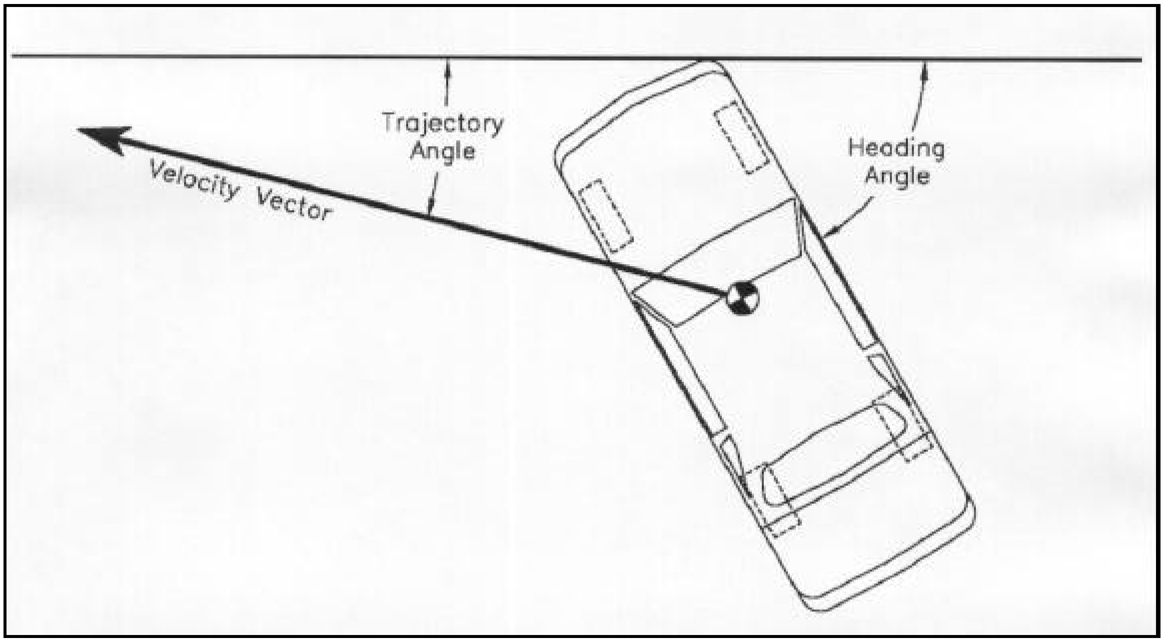


Figure 6. Vehicle Trajectory Definitions

While the vehicle heading angle controls which vehicle components strike the barrier first and the load path for barrier forces applied to the vehicle, the velocity vector controls the severity of the impact. Impact Severity (IS) has been shown to be an excellent measure of the magnitude of a barrier impact.

$$IS = \frac{1}{2} m (V \sin J)$$

where

IS = Impact Severity
m = vehicle mass
V = velocity of impacting vehicle
? = angle between velocity vector and barrier face (trajectory angle).

Hence both heading angle and the angle of the velocity vector relative to the barrier are very important when reconstructing a barrier accident.

As shown in the prior figures, all of the tire marks and the pavement scrape were found to be relatively straight. However, the marks associated with different tires on the same vehicle were found to be at a significantly different angles relative to the barrier. For example, mark B, believed to be from the left front tire of the No. 3 car, was found to have an angle of approximately 15 degrees relative to the barrier while the angles measured from mark C and the scrape were found to be less than 12 degrees. The difference between these angles indicates that the vehicle was undergoing a yaw rotation, a rotation about a vertical axis that changes the vehicle's heading angle. A clockwise yaw rotation brings the front of the vehicle closer to the barrier while it moves the rear of the vehicle farther from the wall. Hence, a clockwise yaw rotation makes the front tires appear to have a higher angle and the rear tires appear to have a lower angle of approach to the barrier. Based on this evaluation it can be concluded that the angle of the velocity vector relative to the barrier face for the No. 3 car was somewhere between 12 and 15 degrees. A similar evaluation of the tracks for the No. 36 car indicated that its impact angle was between 10 and 12 degrees.

An attempt was made to measure the vehicle heading angles using a template for a Winston Cup race car. As shown in Figure 7, this effort involved placing the template over the pavement markings in an attempt to determine vehicle heading angles. This analysis indicated that the No. 3 vehicle heading angle was approximately 48 degrees and the No. 36 car heading angle was near 40 degrees. Note that the side slip of both vehicles would have a tendency to cause the rear suspensions to displace laterally during the period leading up to barrier impact. Lateral displacement of the rear suspension could produce significant error in the heading angles estimated with the vehicle template.

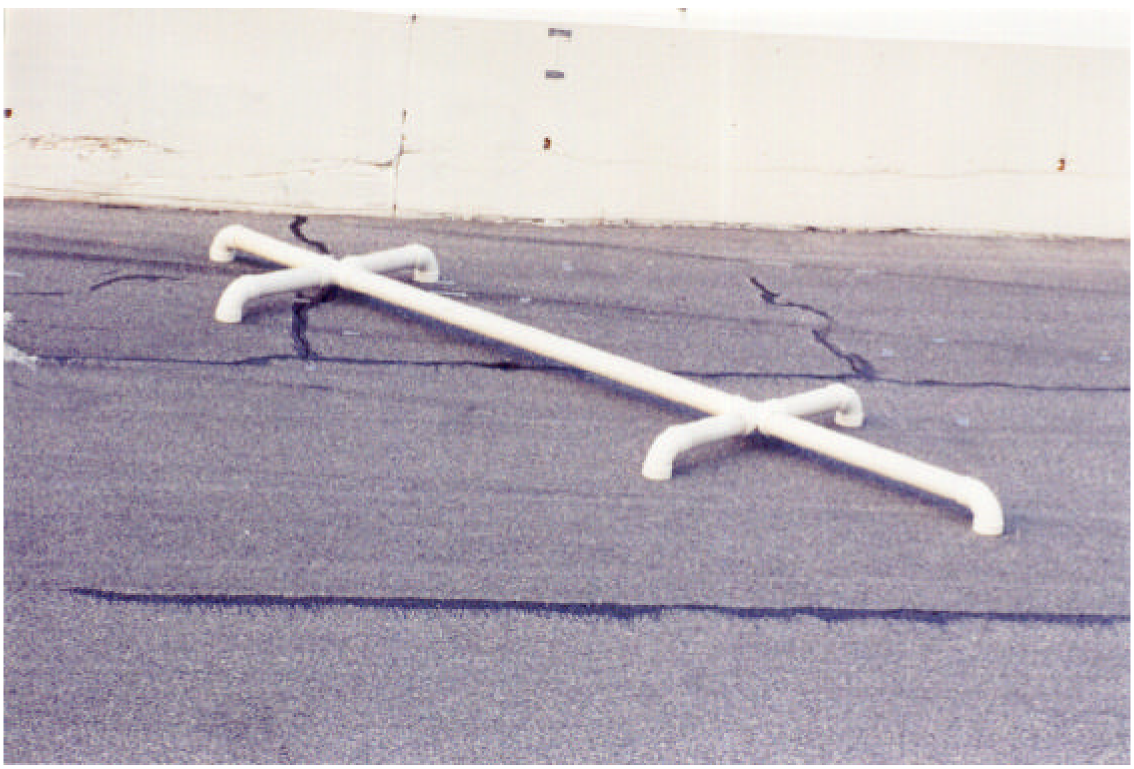


Figure 7. Vehicle Template

A detailed track survey was also conducted. This survey included measurement of the location and height of the posts supporting the containment fence as well as size and locations of the luminaire supports. The positions of all video cameras that captured the accident were also surveyed in order to establish the camera locations for use in completing a photogrammetric reconstruction of the video scenes.

III. Vehicle Inspection

Vehicle inspection is another important source of evidence for use in an accident reconstruction. The inspection can focus on vehicle defects that could have caused the accident, evidence of occupant contact with vehicle interior to better understand injury causation, or structural damage to the vehicle arising from the accident. Video tapes of the pre-crash motions of the No. 3 and No. 36 cars clearly indicate that the accident was not caused by a vehicle defect. Further, investigation of the driver motions inside the vehicle was undertaken by biomechanics experts from Biodynamic Research Corporation. Therefore, the primary goal of the vehicle inspection reported herein was to document structural damage to the vehicle. Documenting the damage to the vehicle can be used to determine the primary load path of forces applied to the vehicle and to better understand the magnitude of both the barrier crash and the impact between the No. 3 and No. 36 vehicles.

Both vehicles involved in the accident were inspected several times during this investigation. With the exception of some damage to the roof caused by the emergency rescue team, the No. 3 car was intact throughout the investigation process. Unfortunately, the front structure of the No. 36 car had been cut apart prior to the first inspection. Even though the structural components were welded back together prior to the final inspection on July 2, 2001, the dismemberment of the No. 36 car limited the evidence available from this crashed vehicle to some degree.

The primary goal of the vehicle inspection was to identify the component damage in an effort to better understand the load path for barrier forces applied to the No. 3 car and to better understand the magnitude of the impact between the No. 3 and No. 36 vehicles. As shown in Figure 8, the Principal Direction of Force (PDOF) appeared to be at an angle of approximately 30 degrees from the centerline of the vehicle or from the 1 O'clock direction with respect to the driver. Significant damage was observed to the right front frame horn and all associated support tubes as shown in Figure 9. However, as shown in Figure 10, the tubes supporting the right frame rail, just behind the suspension mounts were not damaged greatly. Figure 11 shows the undamaged tubes on the left side of the vehicle.

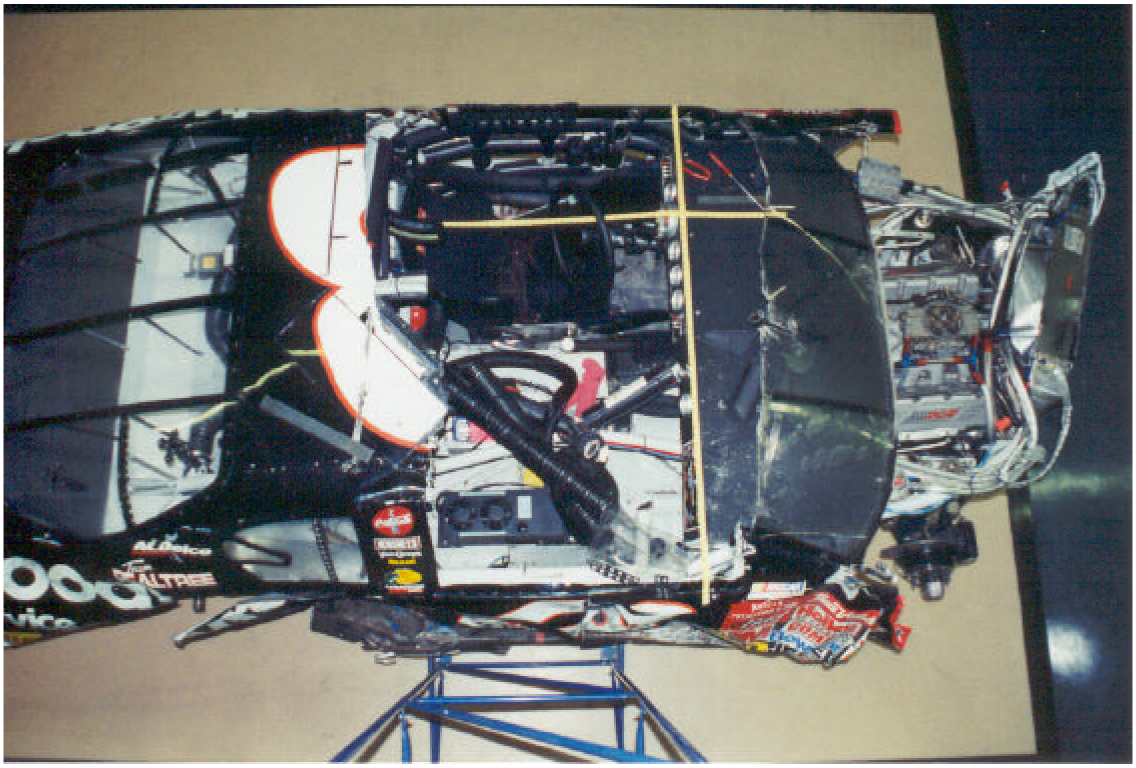


Figure 8. Damage to No. 3 Car

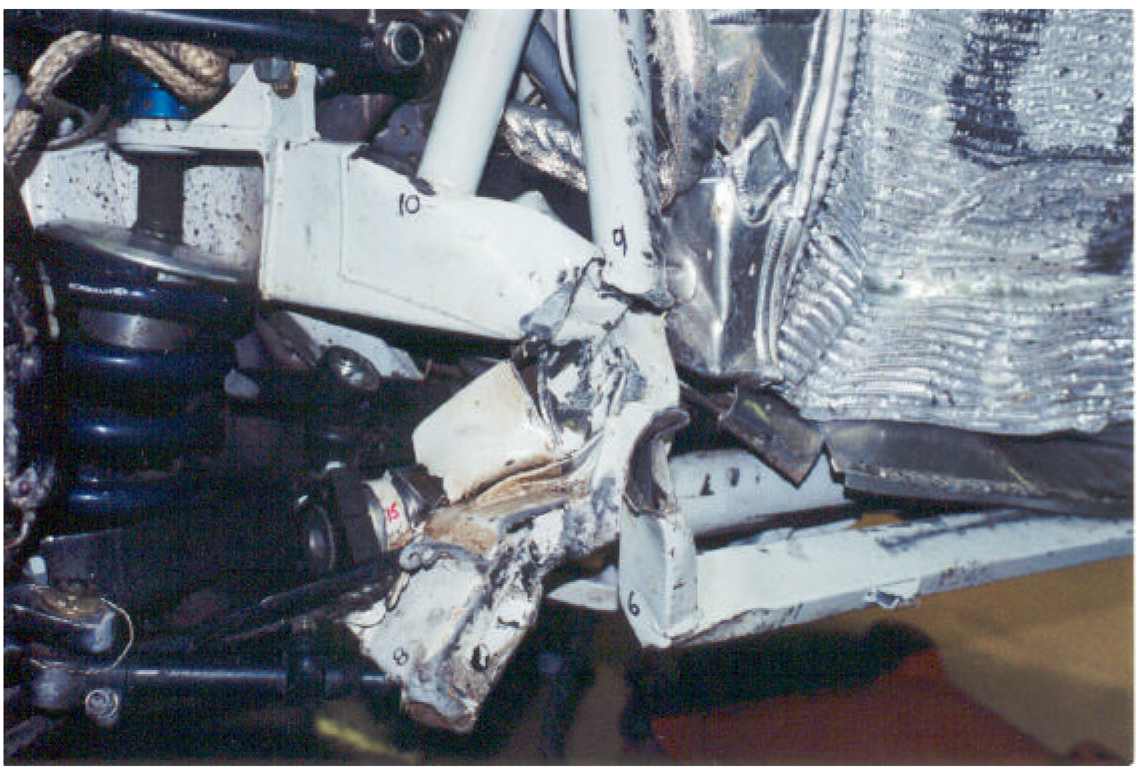


Figure 9. Right Front Damage on No. 3

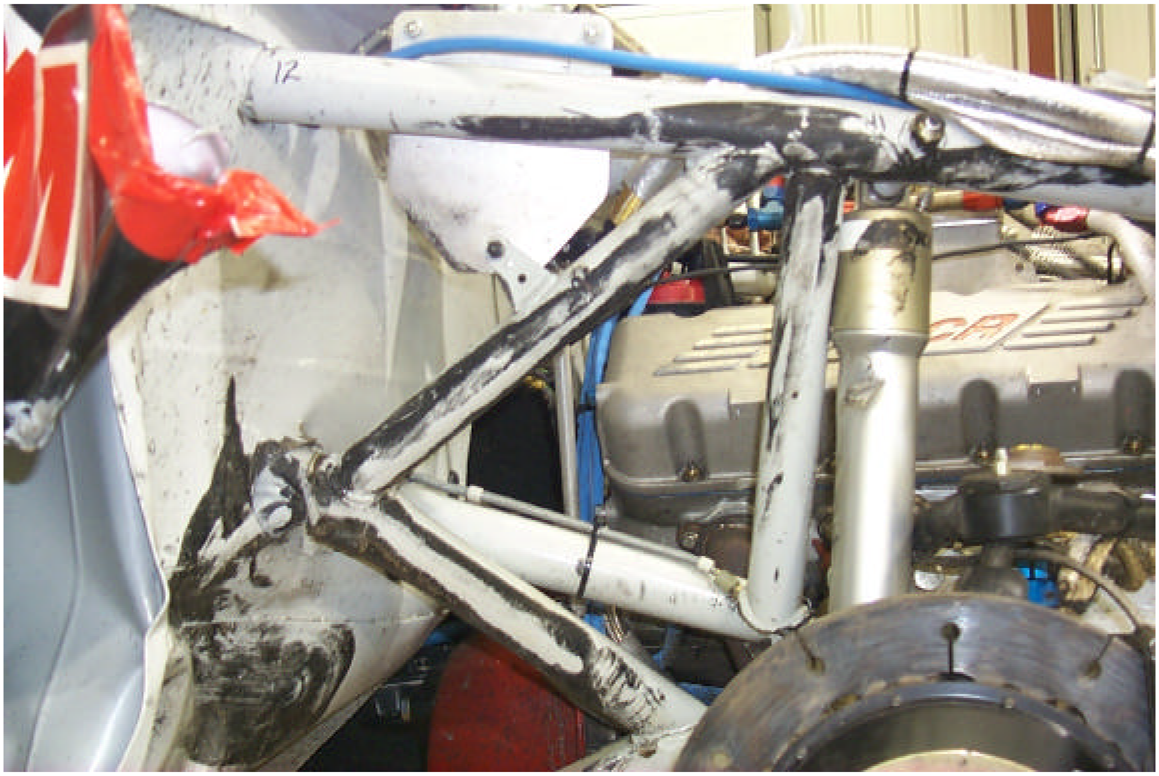


Figure 10. Structural Supports for Right Front Frame Rail.

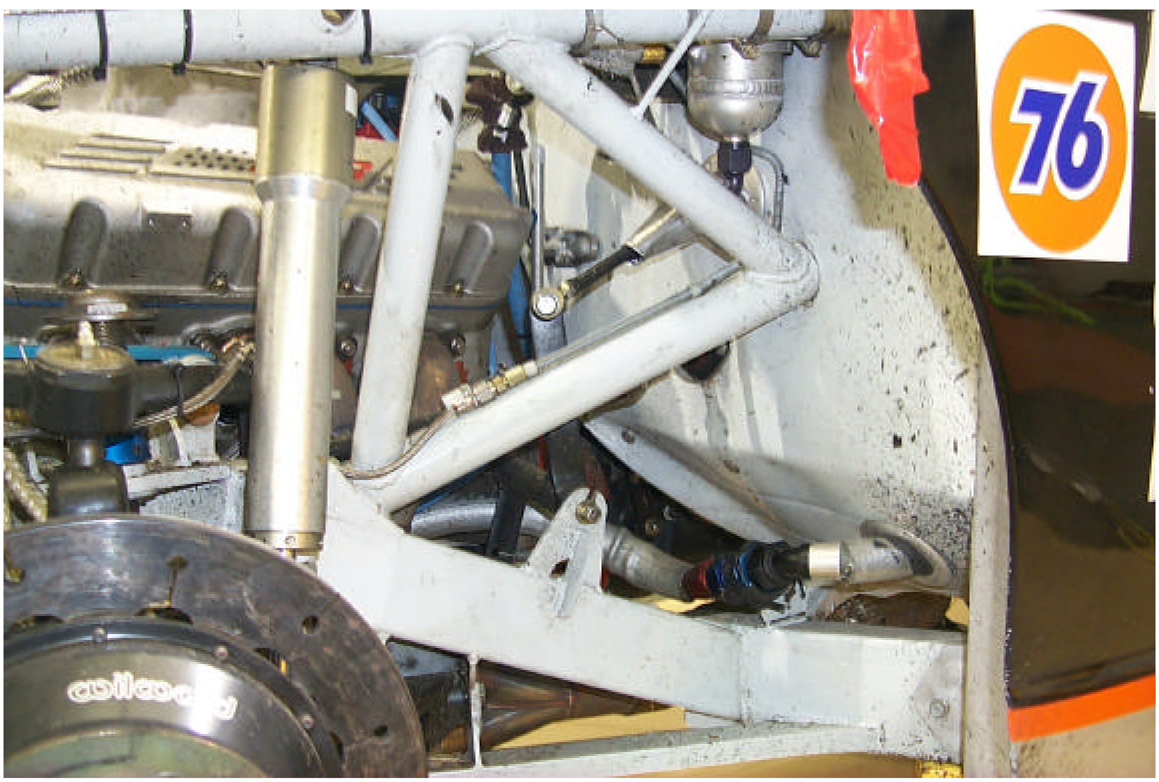


Figure 11. Structural Supports for Left Front Frame Rail

Although it is not readily apparent from the photographs, the engine appeared to have moved rearward approximately 3 in. As shown in Figure 12, the engine motion caused the transmission to move backward by about the same amount. The rearward motion of the transmission caused the drive shaft to be pushed into and deform the transmission housing as shown in Figure 13. Although it was difficult to document photographically, the rear axle housing was bent rearward as well. These deformations indicate that there was a significant force delivered to the front of the engine that caused plastic deformations of stiff structural components all the way to the rear axle of the car. Plastic deformations of this sort indicate that the impact with the barrier was relatively severe when compared to most barrier wall crashes on race tracks. Further documentation of damage to the No. 3 car is reported in Section VI below.

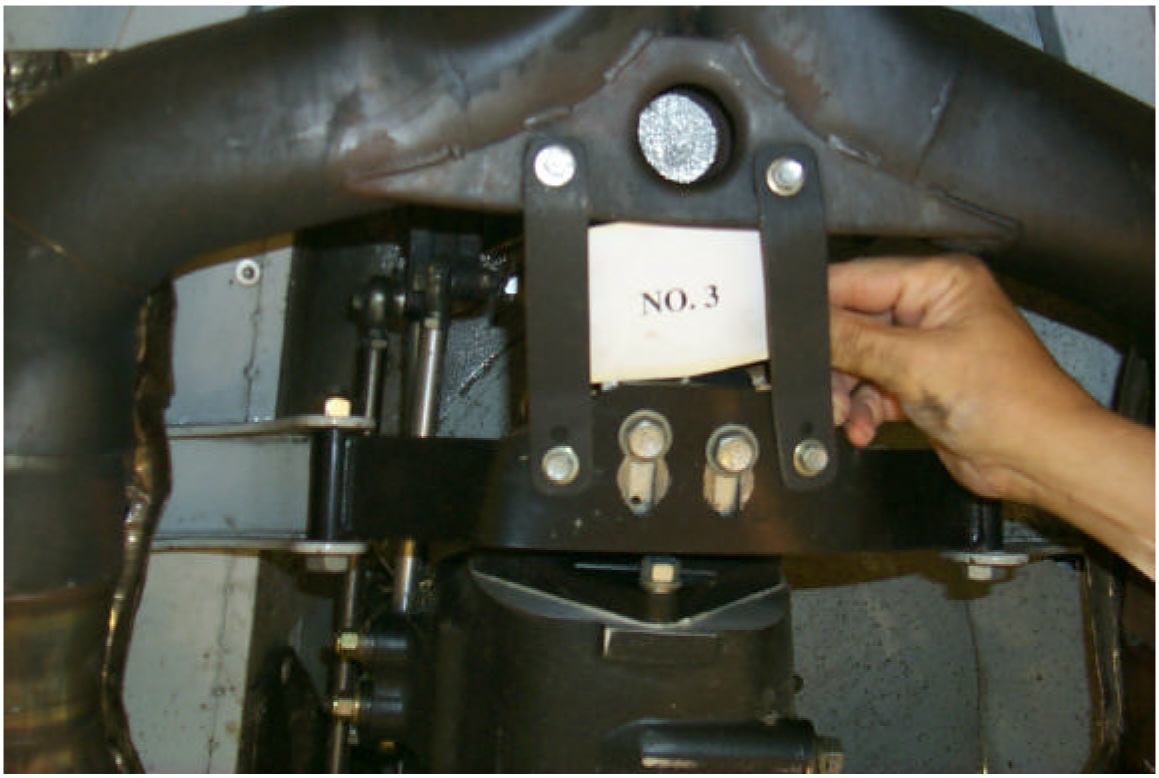


Figure 12. Rearward Movement of Transmission on No. 3 Car

Figure 13. Deformation of Transmission Housing

In addition to a detailed photographic documentation, deformation of major structural components was measured. The detailed measurements showed that there was almost no deformation at the firewall. Although the engine was estimated to have been displaced approximately 3 inches rearward, it apparently did not contact the firewall with sufficient force to cause any permanent deformations. The remaining deformation measurements were conducted in order to provide additional evidence for correlating with the computer simulation model.

The right rear wheel of the No. 3 car had been broken off. As shown in Figure 14, the rear axle housing fractured at the edge of a U-clamp at the rear shock absorber mount. The fracture surface appeared to be relatively ductile with the fracture beginning at the rear of the housing and extending around to the leading surface. This type of fracture would indicate that the wheel had been struck on the leading edge of the rim which loaded the rear of the axle housing in sufficient tension to produce a crack which then propagated around the tubular element. Surprisingly, there was very little other damage to the right rear of the vehicle, as shown in Figure 15. Although there was some minor deformation of the sheet metal and the right side truck arm, shown in Figure 16, there was no discernable damage to any of the cars structural components. The right rear tire was still intact with no apparent loss of air pressure. As shown in Figure 17, there was very little deformation to the rim caused by the impact that broke the axle. All of this evidence indicates that the impact between the No. 3 and No. 36 cars was a relatively low energy event. Although modest impacts of this nature seldom cause occupant injuries, the impact between the No. 3 and No. 36 car could have aggravated the severity of the barrier impact by moving the driver out of the normal seating position, thereby degrading the effectiveness of the occupant restraint system.

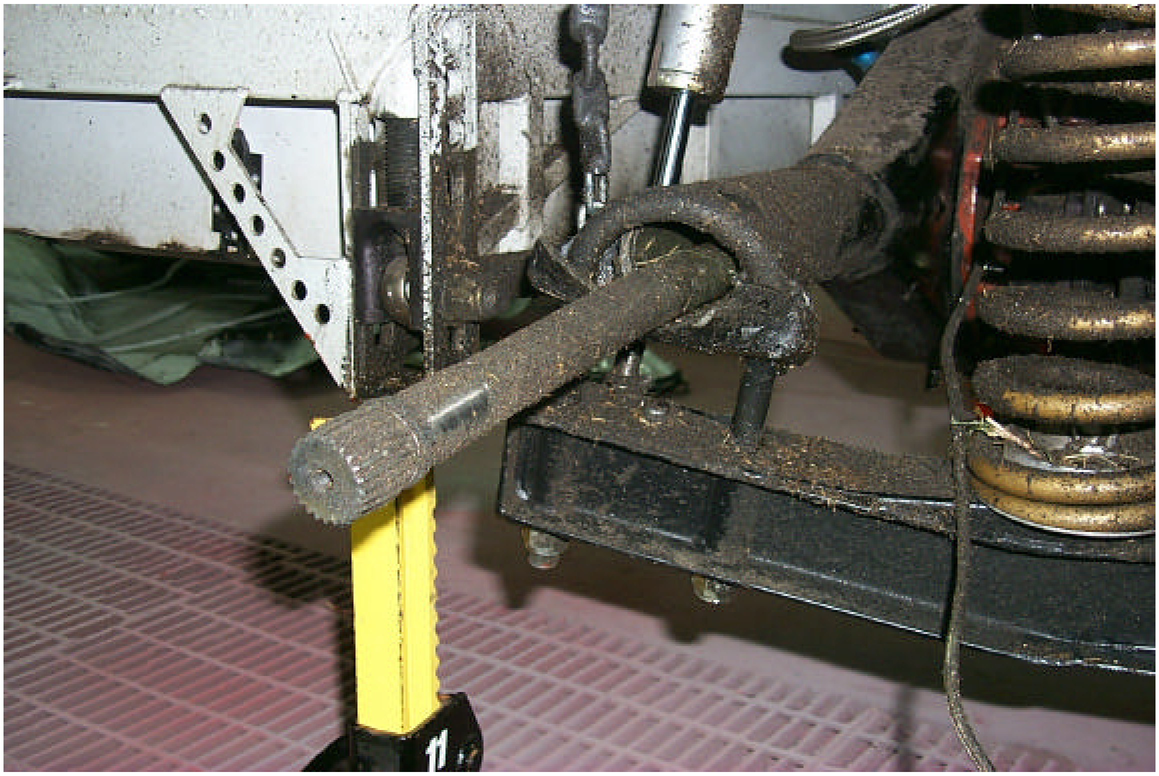


Figure 14. Fractured Rear Axle Housing on No. 3 Car

Figure 15. Right Rear of No. 3 Car

Figure 16. Rear Truck Arm on No. 3 Car

Figure 17. Right Rear Wheel From No.3 Car.

The purpose of inspecting the No. 36 car was to help verify preliminary findings regarding the magnitude of the impact between the two cars and to establish the PDOF arising from the barrier impact. As shown in Figure 18, the vehicle was stripped and all structural components forward of the firewall were removed from the vehicle. Removal of these components eliminated any possibility of identifying damage to the No. 36 car arising from the impact between the two cars. However, by reassembling severed components of the vehicle structure, it was possible to identify the general magnitude of the barrier impact. As shown in Figure 19, damage to the right front frame horn and associated support tubes had a similar pattern as that found on the No. 3 car. However, the extent of the structural deformations appeared to be significantly less than that observed on the other vehicle.

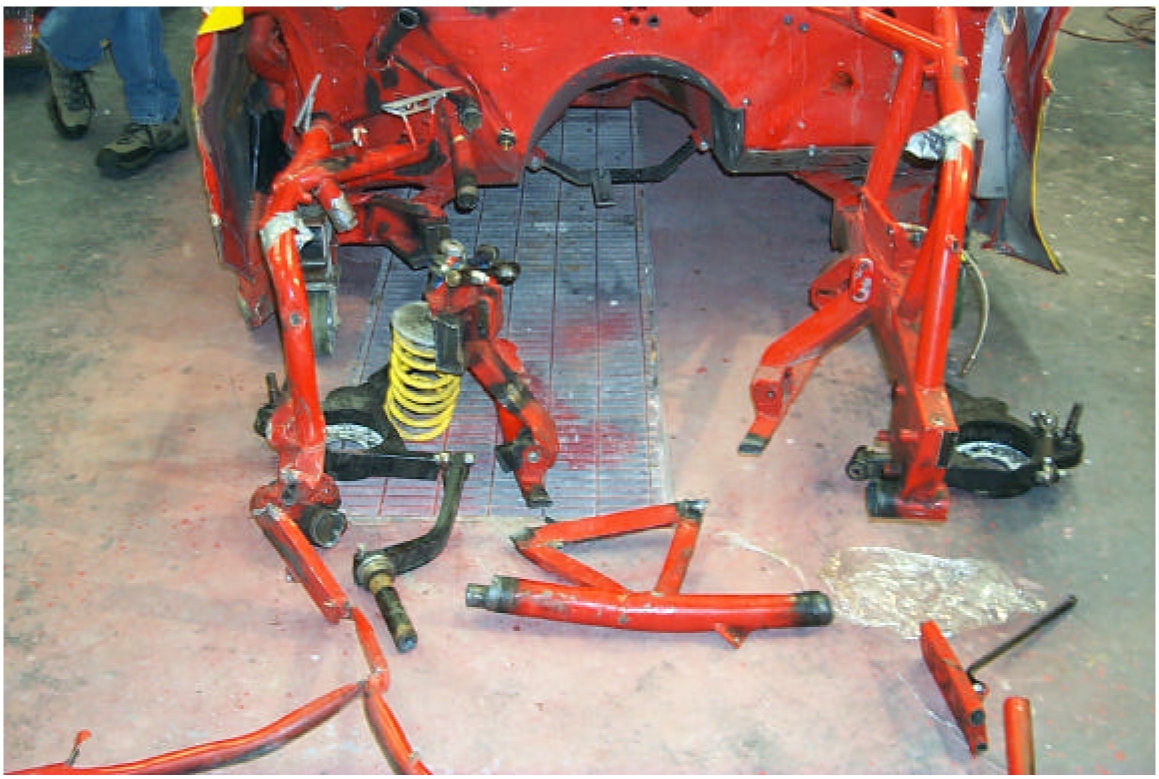


Figure 18. No. 36 Car

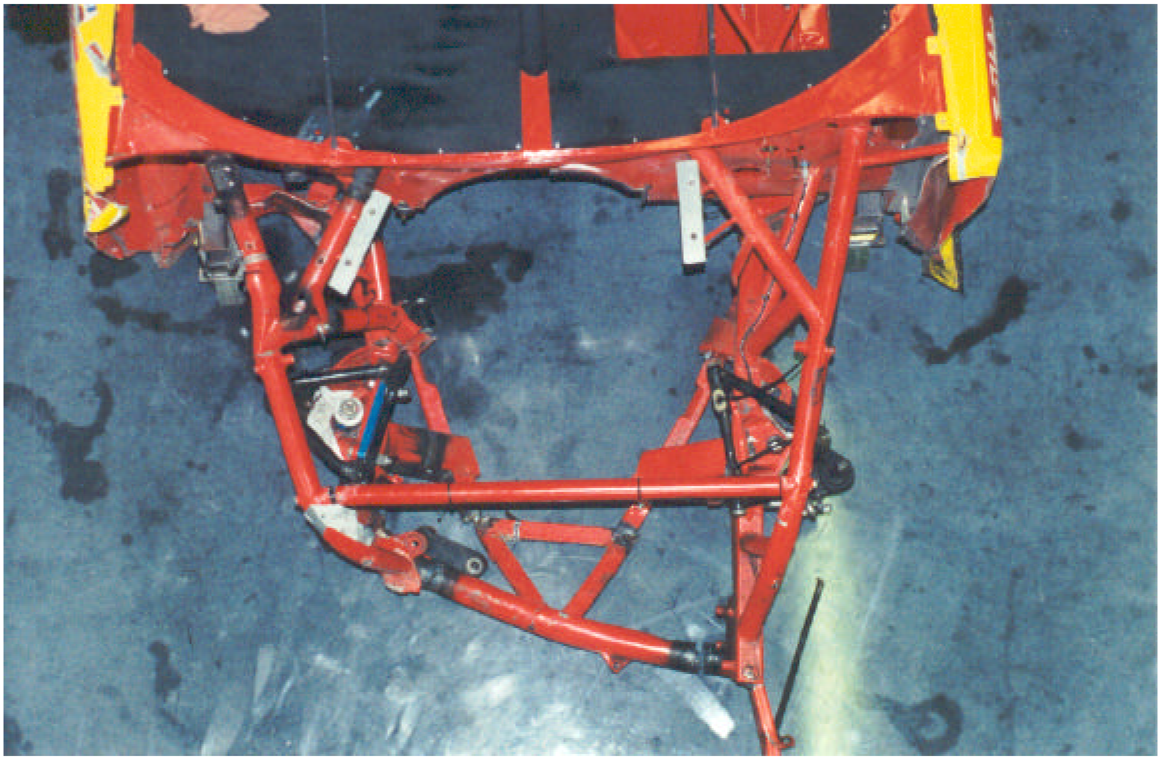


Figure 19. Reassembled Structure of No. 36 Car

IV. Global Positioning Data

All of the cars in the race contained a NovAtel OEM4 L1/L2 RT2 mode GPS receiver that was used to record the positions of the cars 5 times each second. Speed measurements were determined by calculating the distance that the receiver moved between each measurement and dividing by the difference in time between the two measurements (0.2 sec). The direction of travel between each time step is determined in a similar manner.

At the time of the accident, the GPS receivers were operating in RT20 mode. The standard deviation of position error for this mode is 1 meter (3 ft-4 in.). However, experience has indicated that much of that error is in the altitude, which is not important to speed and location measurements for race cars since they are almost always on the track surface. Experience with this type of GPS system indicates that horizontal position measurements are almost always within 1 ft. 6 in. Assuming that horizontal positions are accurate to within 1.5 ft., the theoretical maximum error in speed would occur if the maximum position error occurred in opposite directions from one measurement time to the next. In this scenario, the distance between the one position measurement and the next would be in error by 3 ft. Note that a position error of 3 ft. corresponds to a speed error of approximately 15 ft. sec. or 10 mph. In practice, this maximum error seldom occurs because horizontal position errors are infrequently at the maximum limit and even less frequently is there maximum error in the opposite direction from one time step to the next. Never-the-less, it is possible that speed measurement errors could occasionally be as high as 10 mph.

Unfortunately, the GPS system data becomes corrupted when acceleration is greater than 12 g=s. Hence, GPS data cannot be used to determine vehicle velocity changes after impact with the barrier. Further, because there is only one GPS on each vehicle, the system can only estimate position and velocity of the vehicle without any indication of vehicle heading angle. As mentioned previously, heading angle is important for calculating direction of velocity change relative to the driver and it controls which structural components are loaded during the barrier crash.

The GPS data indicated that both vehicles were traveling approximately 155-161 mph at the time they struck the barrier. At impact, the angle of the velocity vectors between the No. 3 and No. 36 cars and the barrier was shown to be 12-15 degrees and 10-12 degrees respectively. Further, at the time of the collision between the two vehicles, the GPS data showed that the No. 3 car was traveling approximately 161-164 mph with a trajectory angle between 16 and 18 degrees relative to the barrier. At the same time the No. 36 car was traveling approximately 168-170 mph at a trajectory angle between 8 and 10 degrees.

The GPS data indicated a total velocity change of +5.3 mph for the No. 3 car and -5.0 mph for the No. 36 car as a result of the impact between the two vehicles. Note that these numbers may be somewhat high since the duration of the impact was much shorter than the interval between data sampling points on the two cars. However, changes in the velocity vector estimated from GPS data for the both cars appeared to be in error. The No. 3 car was estimated to have a -25 mph change in velocity perpendicular to the barrier wall and the No. 36 car was estimated to have no change in lateral velocity. These two findings are obviously incompatible. Further, the lateral velocity of the No. 3 car was shown to increase by 14 mph during the next time step. Hence, the change in direction of the velocity vectors estimated from the GPS data during the impact between the two cars must be considered unreliable.

Reviews of the video tape of the collision between the two cars indicate that the line of action of the impact forces was not quite aligned with the center of gravity of both cars, meaning that the impact was not quite a central impact where maximum velocity transfer takes place between the two vehicles. Further, the two vehicles remained in contact after the impact, indicating that the crash could be modeled as a plastic collision without any rebound. In an effort to estimate the change in velocity vector during this collision, a Conservation of Momentum analysis was applied to the accident assuming a plastic collision with a central impact. This analysis indicated that the No. 3 car would speed up approximately 3.5 mph and the No. 36 car would slow by approximately 4 mph. Further, the velocity changes in the directions parallel and perpendicular to the barrier would be:

Vehicle	Velocity Change Parallel to Barrier	Velocity Change Perpendicular to Barrier	Resultant
No. 3	+5.9 mph	-8.0 mph	10.0 mph
No. 36	-5.9 mph	+8.0 mph	10.0 mph

Note that if the initial impact speeds are correct, the speed changes shown in the table above should be considered an upper bound estimate, because the accident did not quite qualify as a central impact. Velocity changes for a non-central impact would be less than for a central impact. Finally, the GPS data cannot be used to estimate the velocity changes in vehicle coordinates because it does not give an indication of vehicle orientation.

In summary, the GPS data indicated that at the time of the barrier collision, the No. 3 car was traveling approximately 155-161 mph with an trajectory angle of approximately 12-15 degrees while the No. 36 car was traveling at about the same speed with an trajectory angle of approximately 10-12 degrees. Further, the GPS data provides an estimate of the change in the velocity during the collision between the two cars of approximately 9-11 mph.

V. Photogrammetry

Photogrammetry involves reconstruction of still photos to determine the location of important objects within the photograph. This process involves developing a detailed three dimensional drawing of all of available background information. A camera view is then drawn from the location of the camera taking the photograph. For high power, variable zoom lenses, such as those used on video cameras, lens properties are varied until a camera view is drawn that replicates all of the background information on the photograph. The objects of interest can then be placed on the drawing to overlay the photograph. In the case of a video or film of an accident, the purpose would be to reconstruct individual frames to identify the vehicle locations throughout the event. By determining vehicle locations from one frame to the next, it is possible to determine the velocity of the vehicles in the frames. Accuracy of this process is dependent on the amount and quality of background information available and the size of the objects in the photograph. Close-up shots have little background information and the error associated with reconstructing the original drawing is greater. Conversely, as the shot widens out to include more background information, the size of the vehicles are reduced and the error associated with placement in the drawing is increased.

When utilizing photogrammetry to reconstruct video tapes, it is important to isolate clear images of each frame. Conventional video cameras, such as those used to broadcast the Daytona 500, record 29.967 interlaced frames per second. Essentially every frame is an interlaced composite of two frames which gives a blurry image of moving objects when extracted directly from the tape. Unfortunately, eliminating the interlacing reduces the resolution of the video by 50 percent. Although newer cameras now utilize progressive scan technology that eliminates interlaced frames and doubles the effective resolution, this technology is not yet widely used in broadcast media.

Eight views of the No. 3 car accident were captured on video tape. One view was unusable because it did not capture either of the two impact events. Two other views involved cameras zoomed in tight that were panning rapidly to keep the vehicles in the view. Background information from these two views was very blurred due to the high panning rate. Therefore these two views could not be used without some additional enhancement. In an effort to further refine the analysis one of these two views was enhanced to sharpen the images of the background information incorporated in the analysis. A total of six views could then be used to determine vehicle kinematics associated with the two vehicles involved in the accident. Figure 20 shows a typical photogrammetric reconstruction of one of the accident scenes. In an attempt to estimate the degree of error associated with this analysis, the drawings were adjusted slightly until the background and the vehicles were detectably in error. After examining a series of these photographs that had detectable error and comparing vehicle positions with the best reconstruction of the frame, it was concluded that, for the best available views, the location of each vehicle could be determined to within about 12 in. Since video cameras shoot 29.967 frames per second, the error in speed calculation arising from a 24 in. error (12 in. in each direction) is approximately 40 mph. However, as this error is spread over several frames, the error is reduced. For example, the maximum error between every other frame would be 20 mph and the maximum error between every third frame would be 10 mph, etc. This error can be further reduced by averaging results of several different views. As a point of comparison, there are about 6 video frames for each GPS data point.

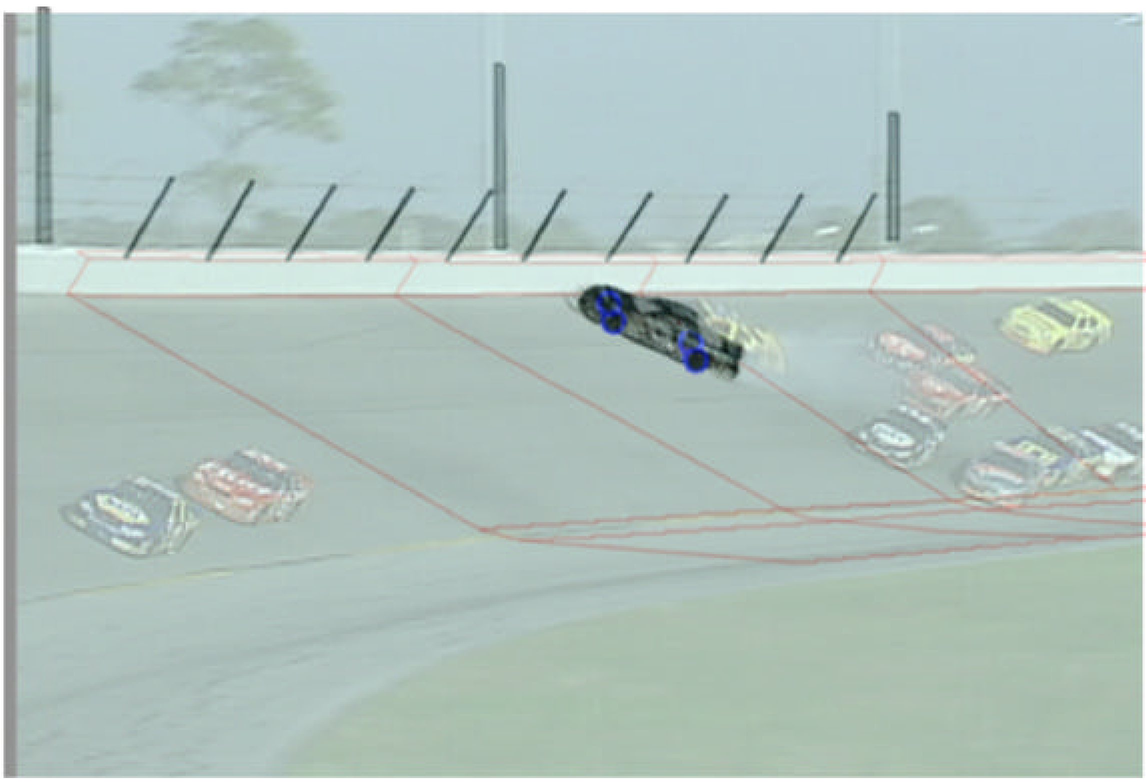


Figure 20. Typical Photogrammetric Reconstruction.

Results of the photogrammetric analyses are shown in Table 1. Note that the analysis compared very favorably to the GPS data for both barrier impact conditions and for the predicted magnitude of the collision between the No. 3 and No. 36 cars. This analysis predicted an impact speed of approximately 157-160 mph for both vehicles and the estimated trajectory angle for the two vehicles was approximately 13-14E and 10.5-11.5E for the No. 3 and No. 36 cars respectively. Recall that the GPS analysis indicated similar velocities. IS values calculated from the middle of the speed and trajectory angle ranges for the two vehicles were found to be 705 and 576 kip-ft for the No. 3 and 36 cars respectively. The 22 percent increase in IS value from the No. 36 car to the No. 3 car represents a significantly more severe impact.

Table 1. Average of Findings From Photogrammetric Analysis.

Time (ms)	Event Description	No. 3 Car			No. 36 Car		
		Velocity (mph)	Trajectory Angle (deg.)	Heading Angle (deg.)	Velocity (mph)	Trajectory Angle (deg.)	Heading Angle (deg.)
-734	No. 3 Re-entering Track	165	17.4	28.0	170.9	11.8	11.4
-667	No. 3 Entirely Above Warning Line	164	17.6	29.1	170.8	10.6	10.8
-601	No. 3 In Front of No. 2 Car	164	17.9	28.2	170.5	10.5	10.2
-534	No. 3 Enters Path of No. 36	164	17.9	27.0	169.8	9.9	9.5
-467	Impact Between No. 3 & No. 36	163	17.6	25.6	168.9	9.4	9.4
-400	Near End of Impact	165	13.7	28.5	165.7	11.4	15.6
-334	Cars Moving Together Toward Wall	164	13.7	33.7	164.4	11.1	21.8
-267	Cars Moving Together Toward Wall	163	13.6	38.5	163.7	10.7	24.2
-200	Cars Reach White Line Near Wall	162	13.7	43.2	162.6	11.0	28.0
-134	Front Tires on White Line Near Wall	161	13.7	47.9	161.2	11.2	33.0
-67	No. 3 Within 3' of Barrier	160	13.6	52.5	159.8	11.0	38.7
0	No. 3 Impacts Barrier	158	13.6	57.1	158.5	10.9	43

Heading angles for the No. 3 and No. 36 cars were initially estimated to be 53-55E and 41-45E respectively as shown in Figure 21. Note that, as shown in this figure, both vehicles were not tracking when they struck the barrier because the heading angles and the velocity vectors were not coincident. Both vehicles were turned into the barrier so that the impact forces were more frontal than would otherwise be the case. Again the increase in heading angle from the 36 to the 3 car represents a significant difference in the direction of the load applied to the two cars.

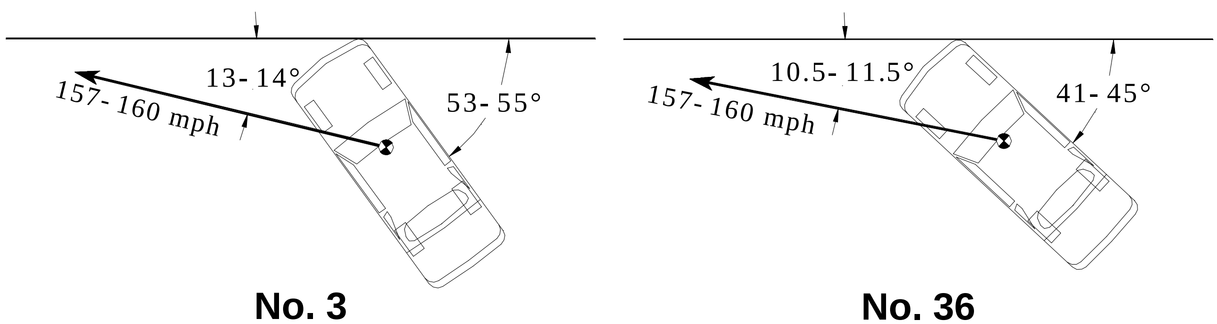


Figure 21. Vehicle Trajectories

Based on the photogrammetric analysis the total speed changes of the No. 3 and No. 36 vehicles during their impact were 2.0 and -3.2 mph respectively. Recall that the Conservation of Momentum analysis of impact speeds from GPS data indicated speed changes of +3.5 and -4.0 mph respectively for these vehicles. Just as in the GPS analysis, both vehicles were speeding up in one direction and slowing in another such that the velocity change was greater than the speed change because the direction of the speed was altered. The best estimate of the velocity changes are shown below:

Vehicle	Velocity Change Parallel to Barrier	Velocity Change Perpendicular to Barrier	Resultant
No. 3	+4.8 mph	-10.0 mph	11.1 mph
No. 36	-4.7 mph	+8.2 mph	9.5 mph

Again, these findings compare relatively well with the COM analysis from the GPS data. Because the photogrammetric analysis indicates vehicle heading angles as well as the trajectory, these velocity changes can be converted to vehicle coordinates. When these components are resolved into vehicle coordinates, the estimated velocity changes become:

Vehicle	Longitudinal Velocity Change	Lateral Velocity Change	Resultant
No. 3	+0.9 mph	-11.1 mph	11.1 mph
No. 36	-2.9 mph	+9.0 mph	9.5 mph

These findings indicate that the impact between the two vehicles created a much greater lateral velocity change for both vehicles than their respective longitudinal velocity changes. Note that the figures shown above may imply much greater precision than is appropriate for this analysis. Generally, all velocity changes are estimated to be within a 2 mph range.

Overall, there appeared to be excellent agreement between the GPS data and the photogrammetric reconstructions. This level of correlation between two entirely separate analyses lends a high degree of confidence to the overall reconstruction.

VI. Full-Scale Crash Test

In order to further verify the estimated barrier impact conditions for the No. 3 car and to begin to quantify the type of impulse that was imparted onto the vehicle during the accident, it was decided to conduct a full-scale crash test. However conducting a full-scale crash test under identical conditions as the No. 3 car would be very difficult. As shown in Figure 21 above, the vehicle was traveling at approximately 157-160 mph in a non-tracking configuration, i.e., the rear wheels do not follow behind the front. In addition to the fact that no full-scale crash testing has ever involved such a high impact speed, all high speed testing is currently conducted with tracking vehicles. Therefore, an exact replication of the accident was deemed to be impractical under the current study.

Two primary forces are applied to a vehicle during a barrier impact, a normal force perpendicular to the barrier and a friction force acting along the barrier. The normal force is generated by the crushing of the vehicle structure against the barrier while the friction force is merely the effect of sliding friction acting on the contact surface between the vehicle and the barrier. If the crushing forces can be estimated, the frictional forces that are generated therefrom become quantifiable.

Careful review of video tapes of the crash indicated that the No. 3 car did not rotate significantly after it struck the barrier. It was not known whether this failure to rotate during the impact was due to the effect of the No. 36 car or not. It was believed to be possible that the No. 3 car would have spun out with the vehicle continuing to rotate in a clockwise direction if the No. 36 car had not prevented it by pushing the front of the 3 car down the barrier. Similarly, it is possible that the No. 3 car would have rotated counter clockwise to become parallel with the barrier if the No. 36 car had not been there to prevent the vehicle from rotating about the point of contact with the wall. It should be noted that either result, spin out or redirection, reduces the lateral velocity change on the vehicle during the primary impact. If the vehicle rotates after impacting the barrier, the car's center of gravity will still have some lateral velocity to carry the side of the car up against the barrier after the primary impact is over. A secondary impact then occurs when the side of the vehicle slaps the barrier. However, by separating the impulse into two events, the peak decelerations are reduced significantly.

Never-the-less, in this accident, the vehicle moved into the barrier at a heading angle of approximately 53-55 degrees and it remained near that angle until the vehicle's velocity perpendicular to the barrier was stopped. With regard to vehicle crush, this crash should not be much different than a vehicle striking the barrier with the same perpendicular velocity as was estimated for the No. 3 car, provided no rotation took place after impact. Therefore, a full scale crash test was conducted at Autoliv to attempt to replicate the vehicle crush observed in the No. 3 car and provide a tool for estimating the lateral impulse imparted to the vehicle during the actual crash. At the time that the crash test was conducted, the best estimate of impact conditions were 158.5 mph with a trajectory angle of 13.6 degrees and a heading angle of 54 degrees. Note that an automobile traveling 158.5 mph and impacting a barrier at an angle of 13.6 degrees would have a speed of 154.5 mph along the barrier and 37.3 mph perpendicular to it. In order to assure that the vehicle crush during the test was at least as great as that observed in the actual crash, a 39.5 mph impact speed perpendicular to the barrier was selected for the test.

This test involved mounting a vehicle on skid plates so that it could be dragged at a 54 degree angle into the wall. The vehicle was propelled by a chain attached to the frame rails under the engine. The chain was attached to a slide mechanism that was connected to a high powered winch for towing the vehicle. The slide mechanism was designed to become detached from the vehicle just before impact with the wall. When the front of the car impacts the wall at a 54 degree angle, the vehicle would normally rotate in a counter-clockwise direction. In order to prevent the rotation a restraining bar was attached to the rear of the frame rail on the left side. The restraint system was mounted in a longitudinal track so that it would offer little resistance to sliding into the barrier, but could prevent movement along the face of the barrier. Figure 22 shows the configuration for this test.

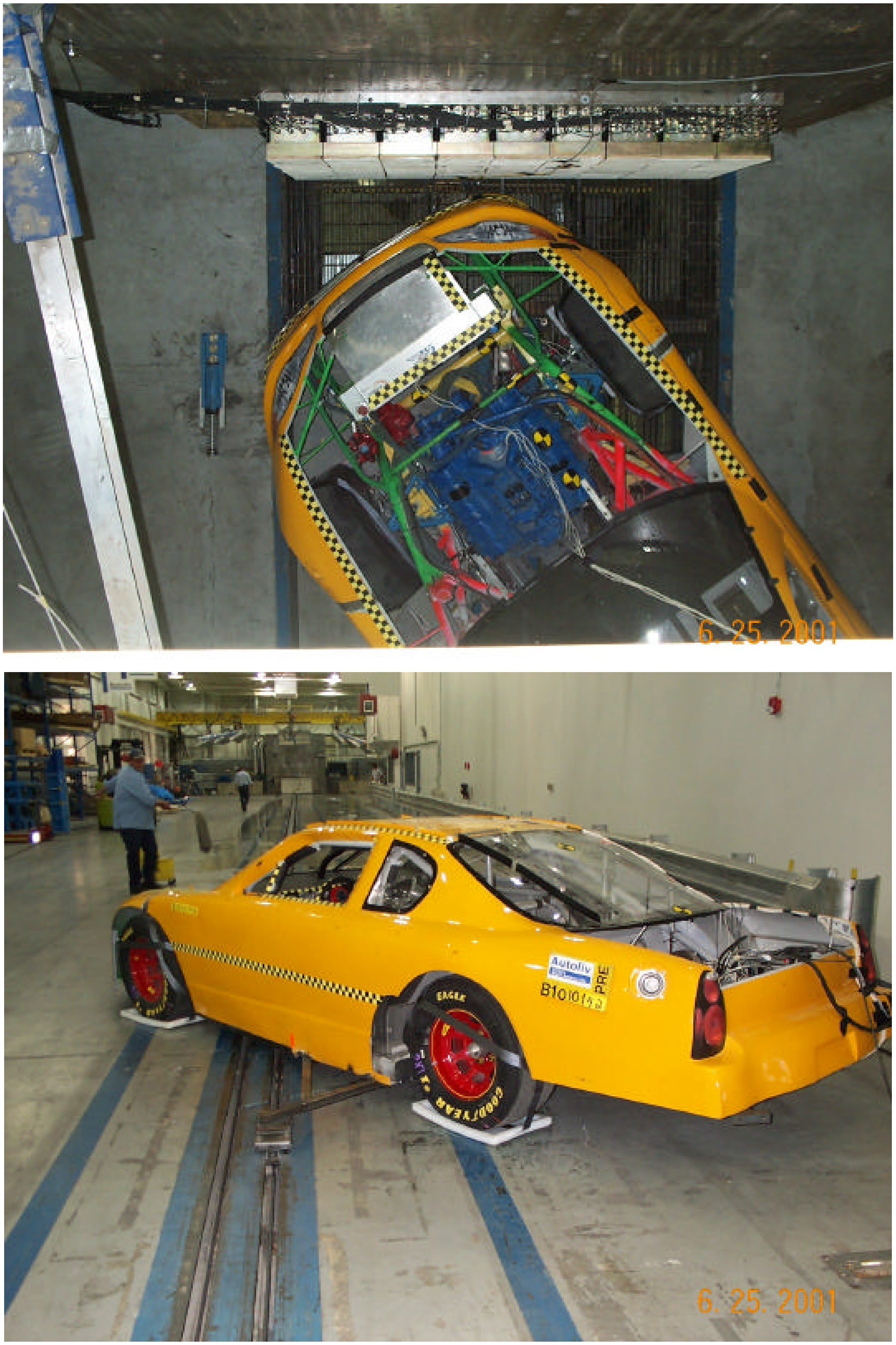


Figure 22. Test Setup for Full-Scale Crash.

Note that the vehicle was instrumented with 36 accelerometers and two displacement transducers to provide data for calibrating the computer simulation model as well as identifying the magnitude of the forces that may have been applied to the No. 3 car during its crash. The test also incorporated an instrumented wall with 36 impact zones, each with load cells in the x and y directions, that provided a measure of the magnitudes and locations of forces applied to the barrier. Figure 23 shows the configuration of the load cells in the instrumented wall.

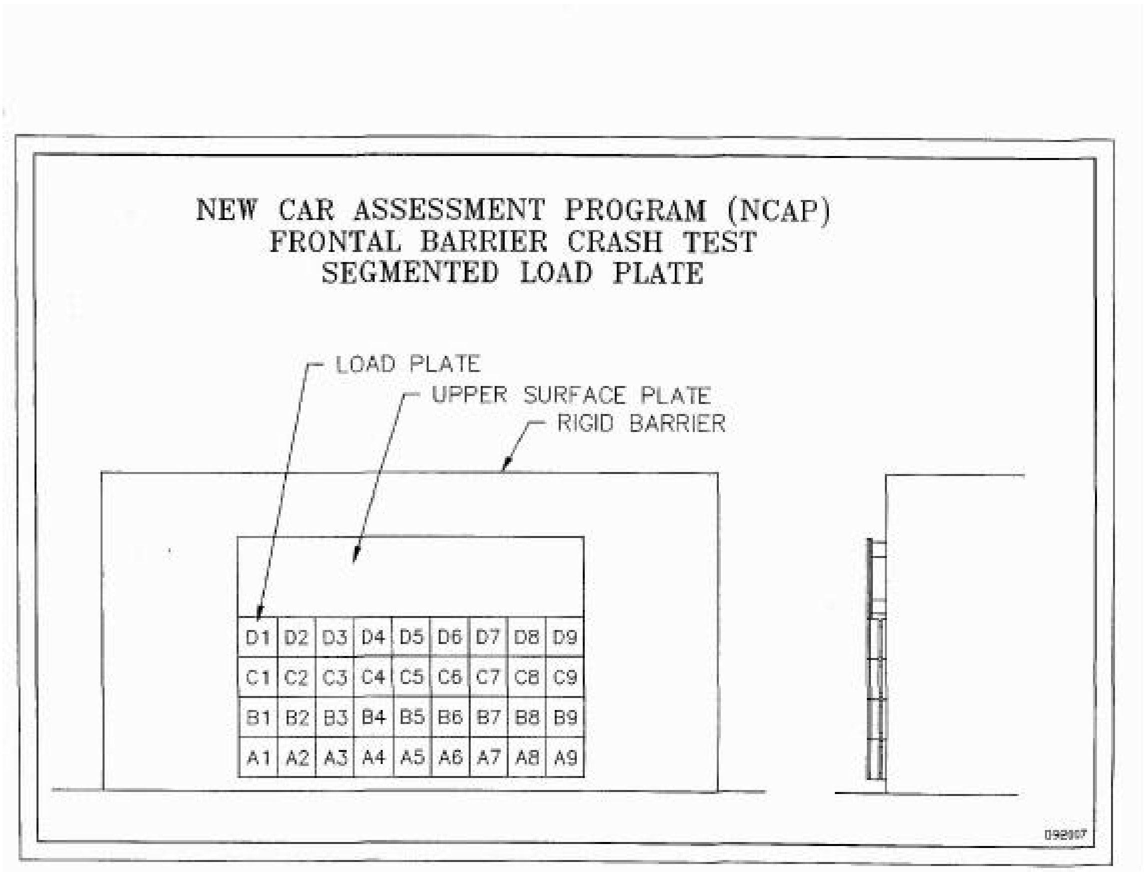


Figure 23. Instrumented Barrier Wall.

As shown in the sequential photos in Figure 24, the vehicle impacted the barrier at an angle of approximately 54 degrees. As intended, the lateral restraint system prevented rotation of the vehicle until the very end of the impact event when the welds on the lateral strut broke and some rotation was allowed. Figure 25 shows the vehicle accelerations normal to the barrier face measured at the center of gravity of the car. As shown in this figure, when the accelerometer data was filtered through a SAE J211 - CFC Class 60 filter, the peak deceleration measured at the vehicle c.g. was approximately 68 g's. Since an occupant restraint system often cannot respond to accelerations in the 60-100 Hz range, it is sometimes useful to examine the same data when filtered at 30 Hz as shown in Figure 26. When filtered at 30 Hz the peak magnitude is reduced to 48 g's. Integrating the accelerometer data produced a total velocity change of 45.4 mph. The duration of this impact event was found to be approximately 80 ms. If the damage to the two vehicles was found to be similar, there is no reason to believe that the duration of the two events would not be similar.

Note that the total velocity change is greater than the initial speed due to rebound caused by the restitution of elastic strain energy in the vehicle structure after motion into the wall is brought to a stop. In this case, the 5.9 mph observed rebound velocity would indicate a coefficient of restitution of 0.02 which is within the normal range for an impact of this magnitude.

Figure 24. Sequential Photos from Full-Scale Crash Test

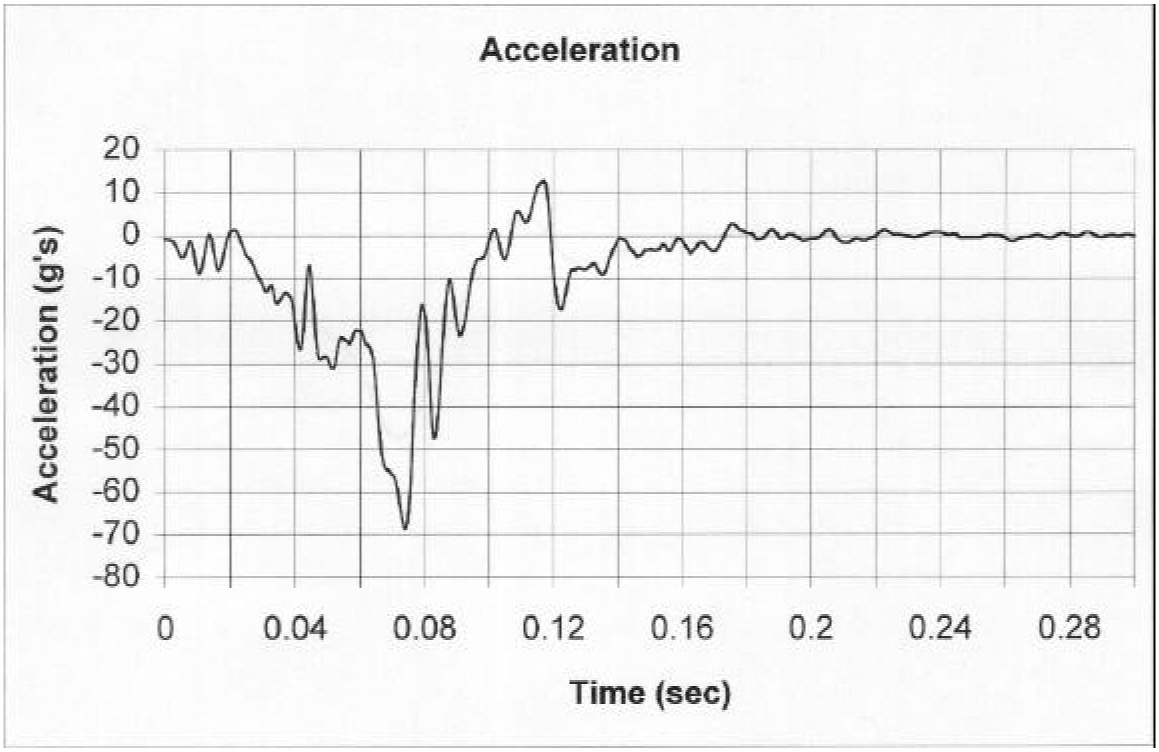


Figure 25. Vehicle Accelerations from Test – 60 Hz

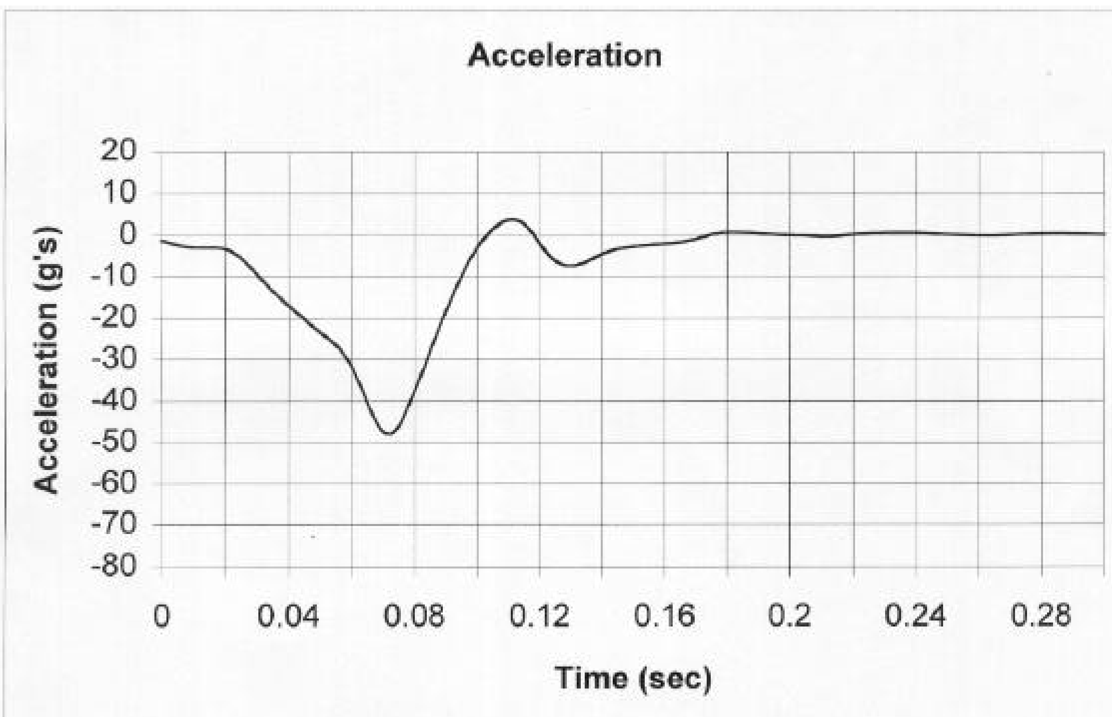
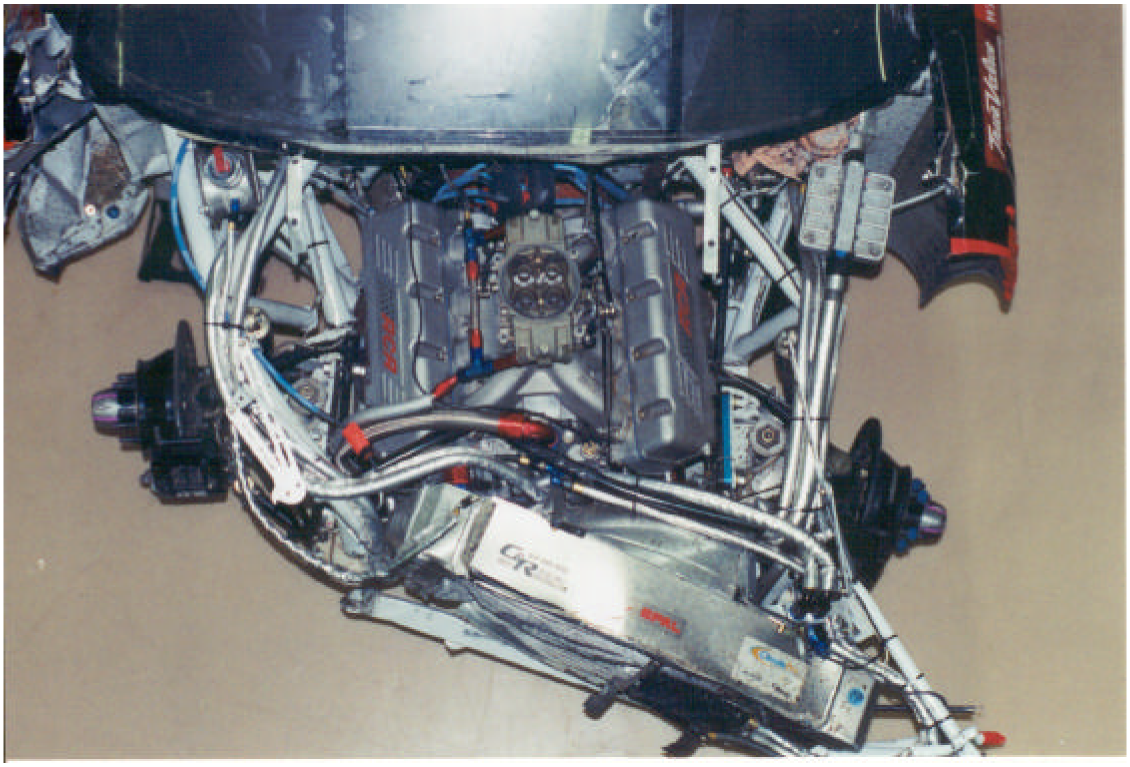


Figure 26. Vehicle Accelerations from test – 30 Hz Filter

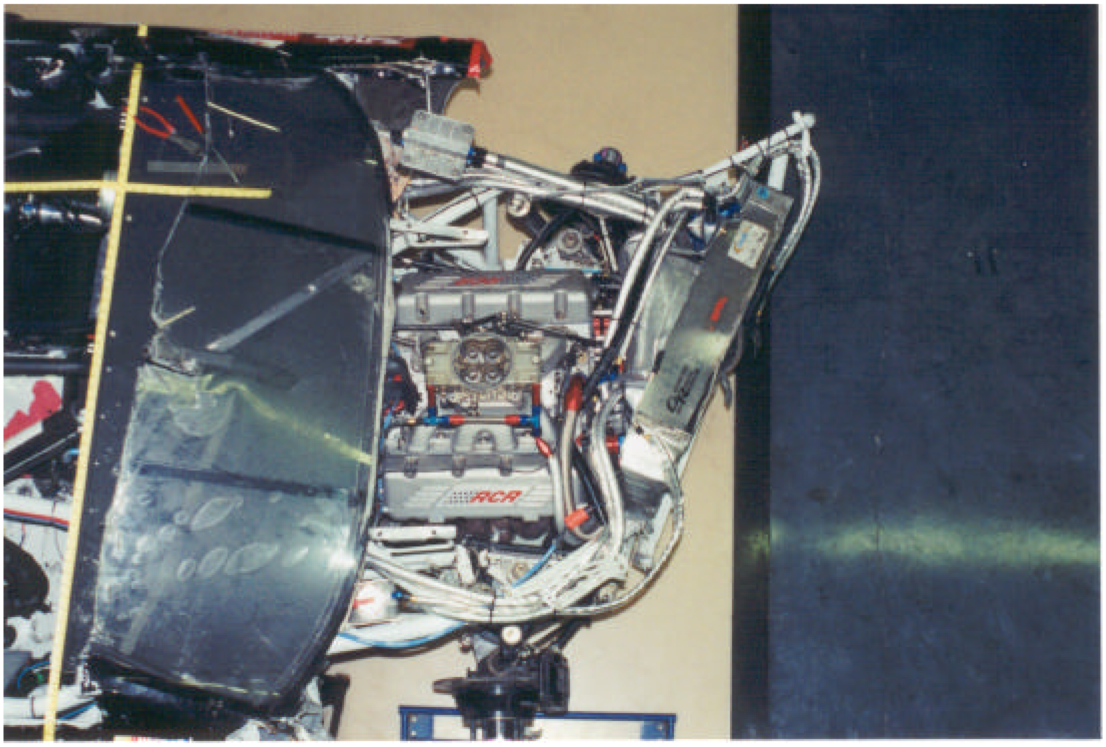
In order to verify that the impact conditions utilized in the full-scale crash test reasonably replicated the crash conditions, damage to the two vehicles was carefully compared. Figures 27 and 28 show that the overall crush pattern of the two vehicles was quite similar. The most notable difference shown in these photos is that the extent of crush on the test vehicle is greater than that observed on the No. 3 car. Recall that the test vehicle crash was conducted at a higher speed to assure that the vehicle crush was at least as great as that observed in the No. 3 car. Hence, it can be concluded that the actual estimated crash speed and the angle of the velocity vector relative to the barrier of 158.5 mph and 13.6 degrees was probably very accurate. Figures 27 and 28 also show that the angle of crush for the test vehicle may have been 3-6 degrees lower than the crashed car. Therefore, the vehicle orientation relative to the wall may have been closer to 55-59 degrees rather than the 54 deg. impact angle utilized in the crash test.

Both vehicles had significant displacement of the engine and drive train. Although the dynamic displacement of the engine on the test vehicle was much higher, as shown in Figure 24, the best estimate of permanent set was 3 in. which is the same as that for the No. 3 car. Figure 29 shows the rearward displacements of both transmissions during the impact. Note that in both vehicles, the transmission first moved to the back of the slots on the mounting plate and then deformed the mounting plate itself. As shown in this photo, the extent of rearward displacement was very nearly the same. Figure 30 shows that the rear of both transmission housings were broken off when they were driven into the first U-joint. Again the extent of displacement and overall damage appeared to be very similar. Although it was difficult to document visually, both rear housings were bent as well. Many local vehicle deformations, such as those shown in Figure 31 and 32 showed similar damage patterns and magnitudes as well. The figures shown above clearly demonstrate that the overall damage patterns for these vehicles is very similar. Further, both engines and drive trains were displaced rearward in a similar manner and with similar magnitude. Finally, there were many similarities in local deformations as well. All of this evidence demonstrates that, although the speed may have been a little high and the vehicle heading angle may have been a little low, the impact conditions used in the full-scale crash test replicated the actual crash very well.



No. 3 Car

Test Vehicle
Figure 27. Overview of Vehicle Crush


No. 3 Car

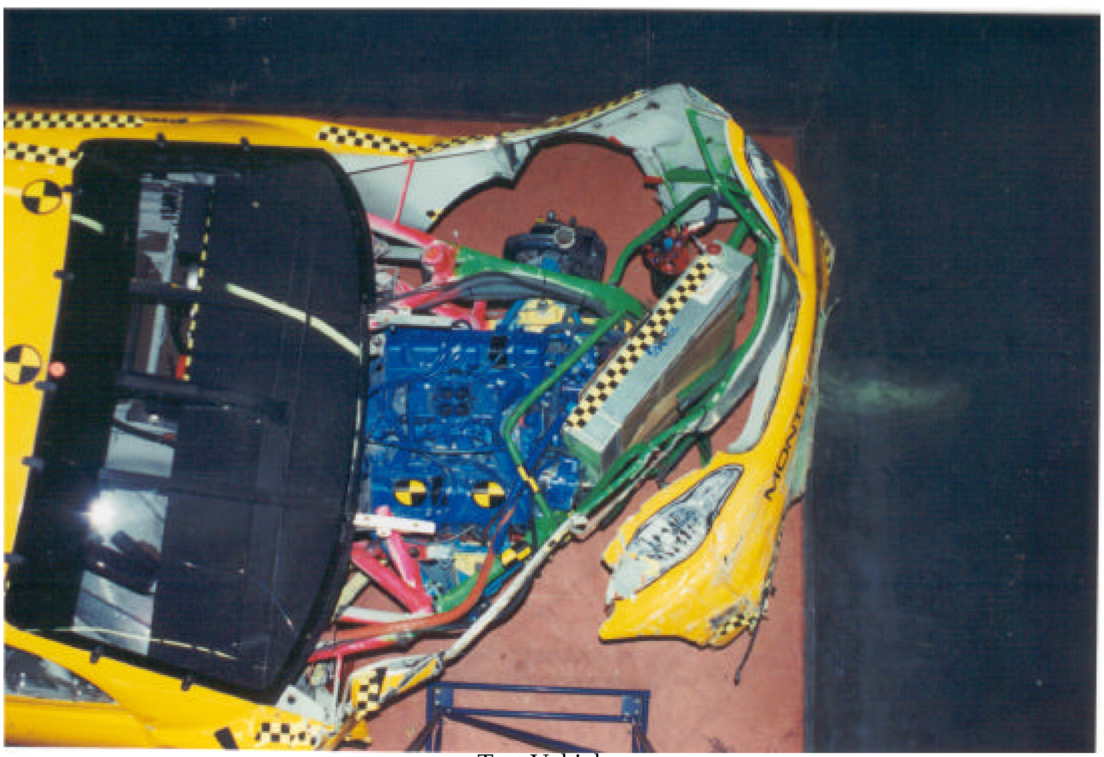
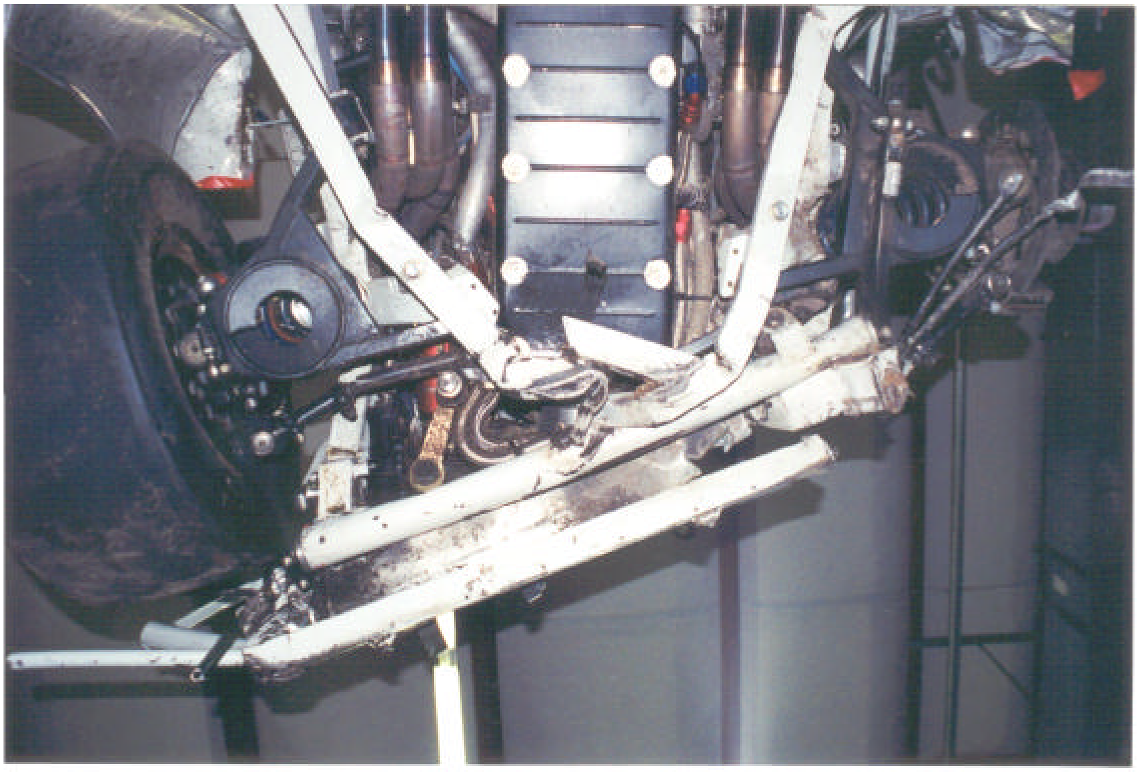
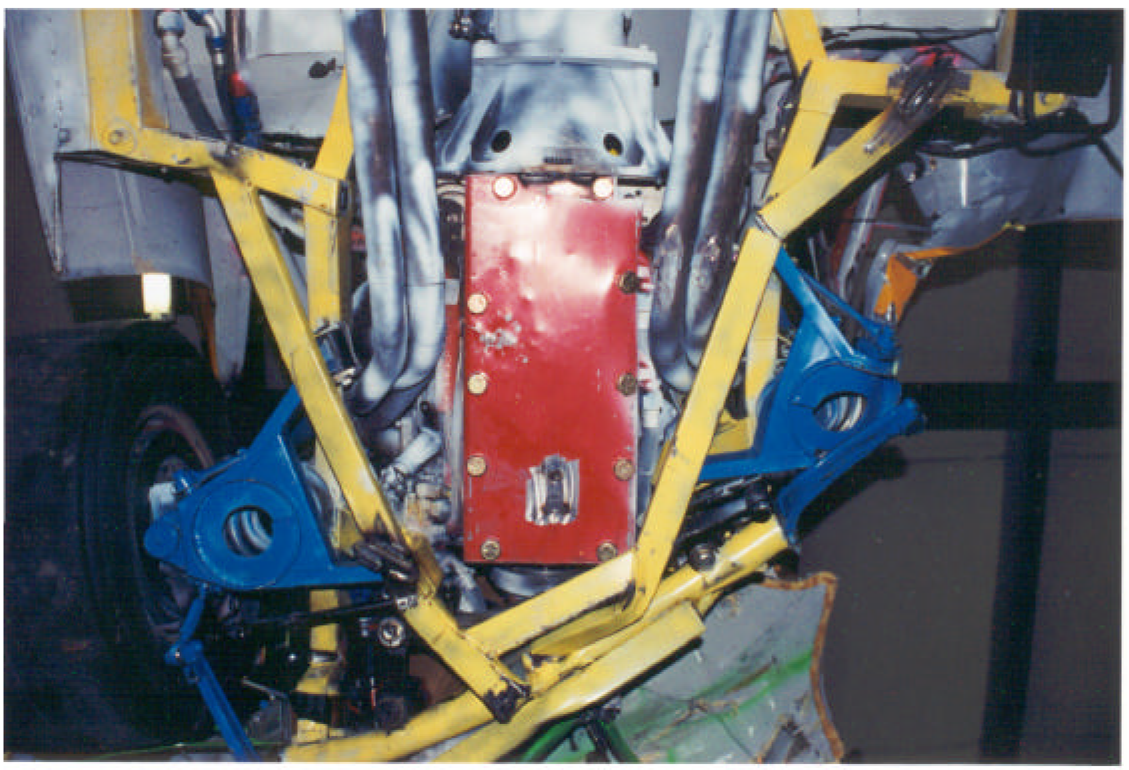

Test Vehicle

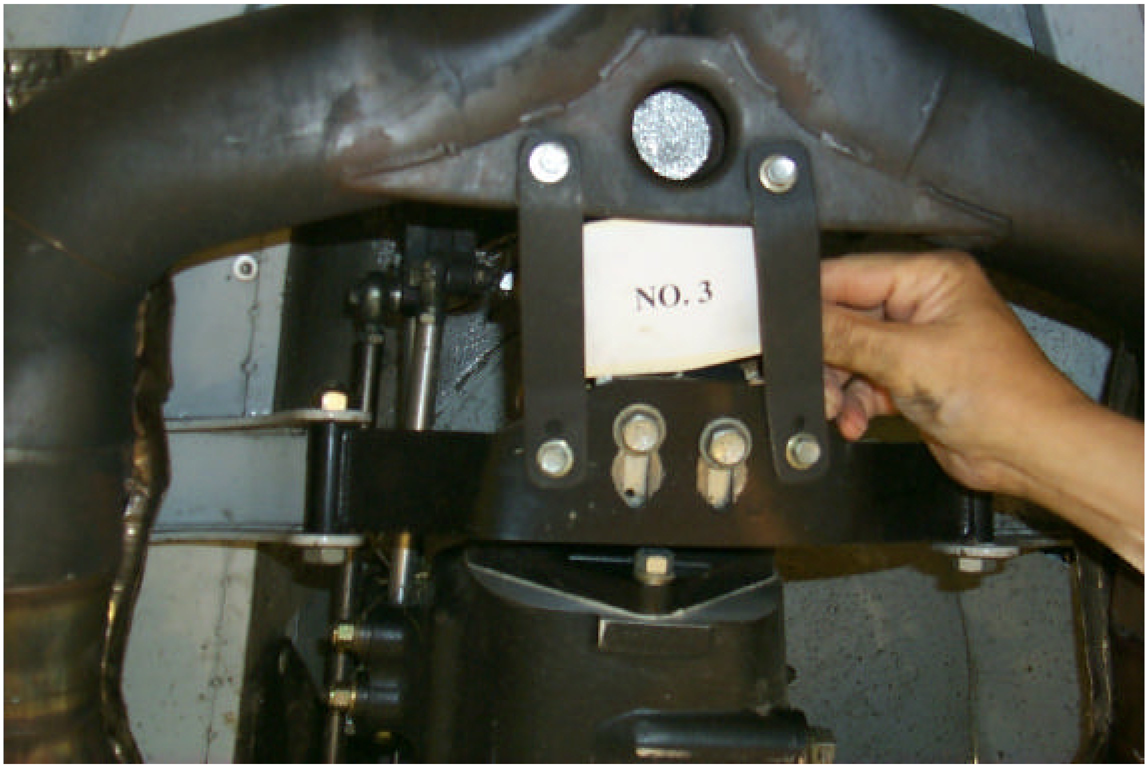
Figure 27. Overview of Vehicle Crush (Continued)



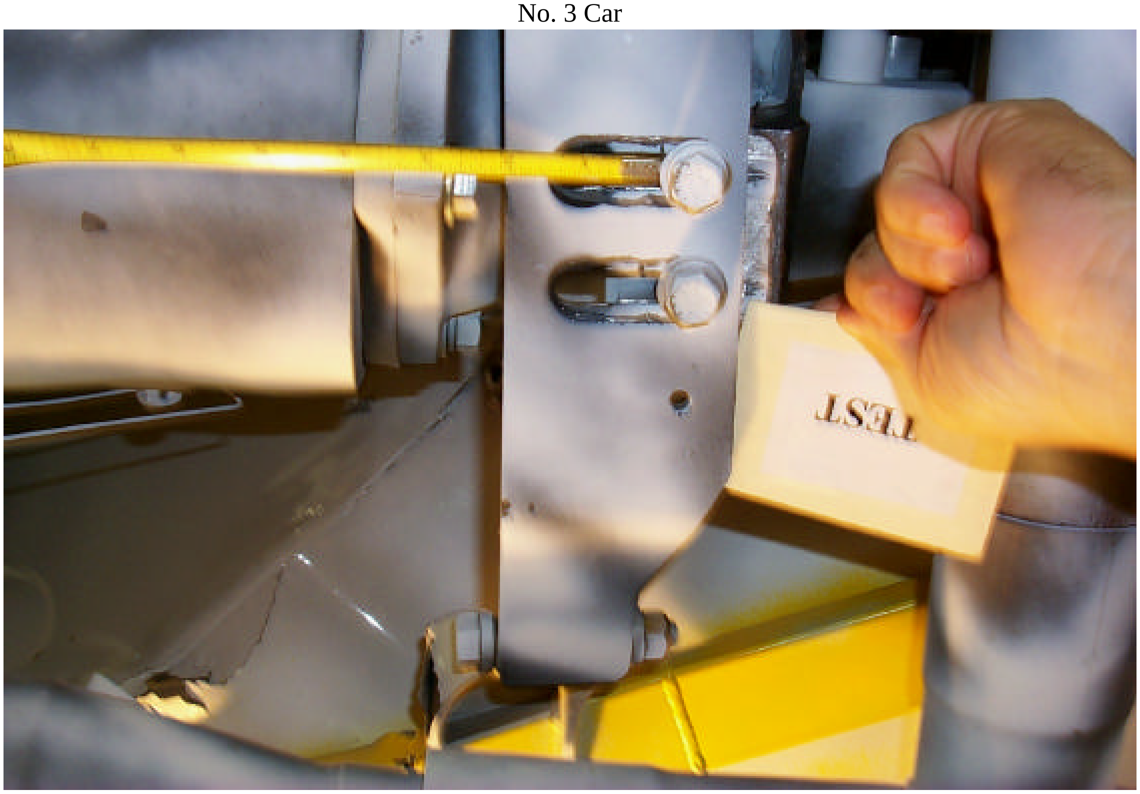
No. 3 Car



Test Vehicle
Figure 28. Underside View of Frontal Damage



No. 3 Car

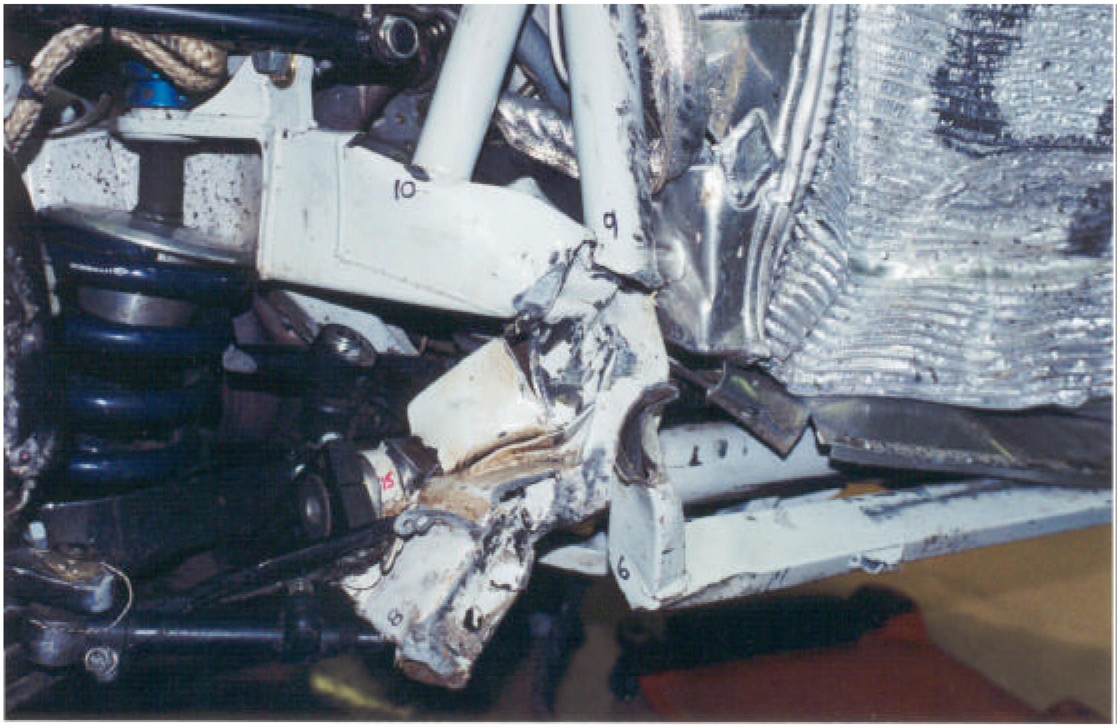


Test Vehicle

Figure 29. Rearward Displacement of Transmission.

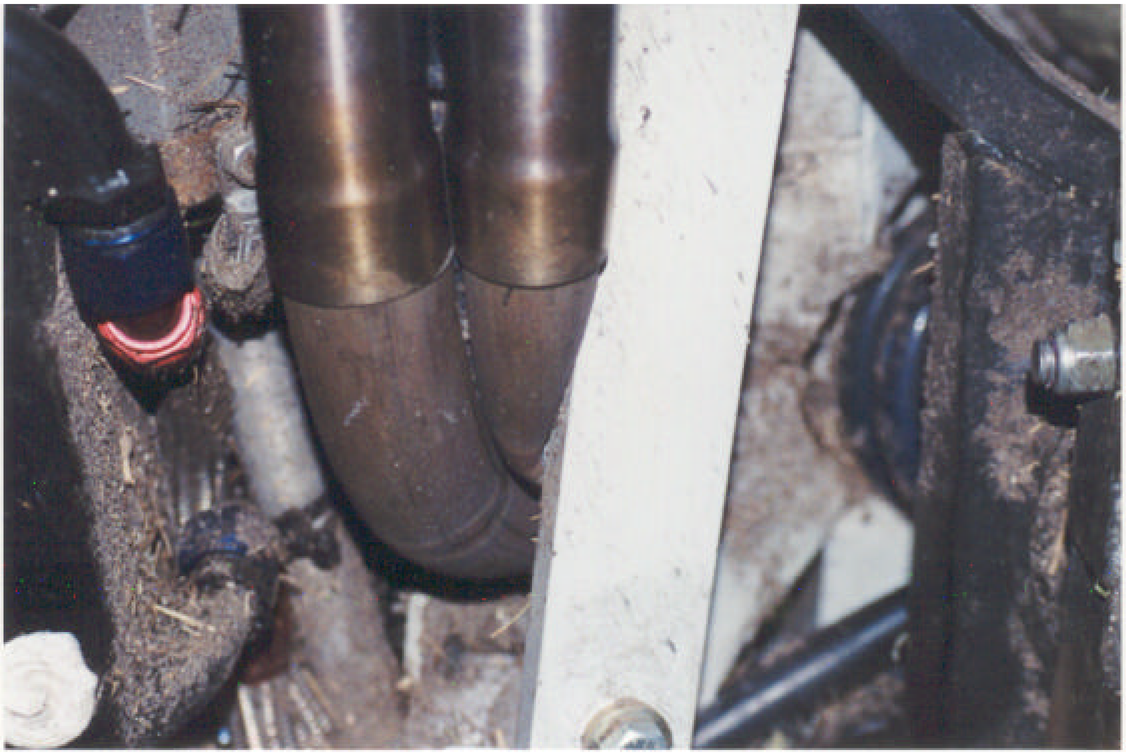
No. 3

Test Vehicle
Figure 30. Damage to Rear of Transmission Housing.

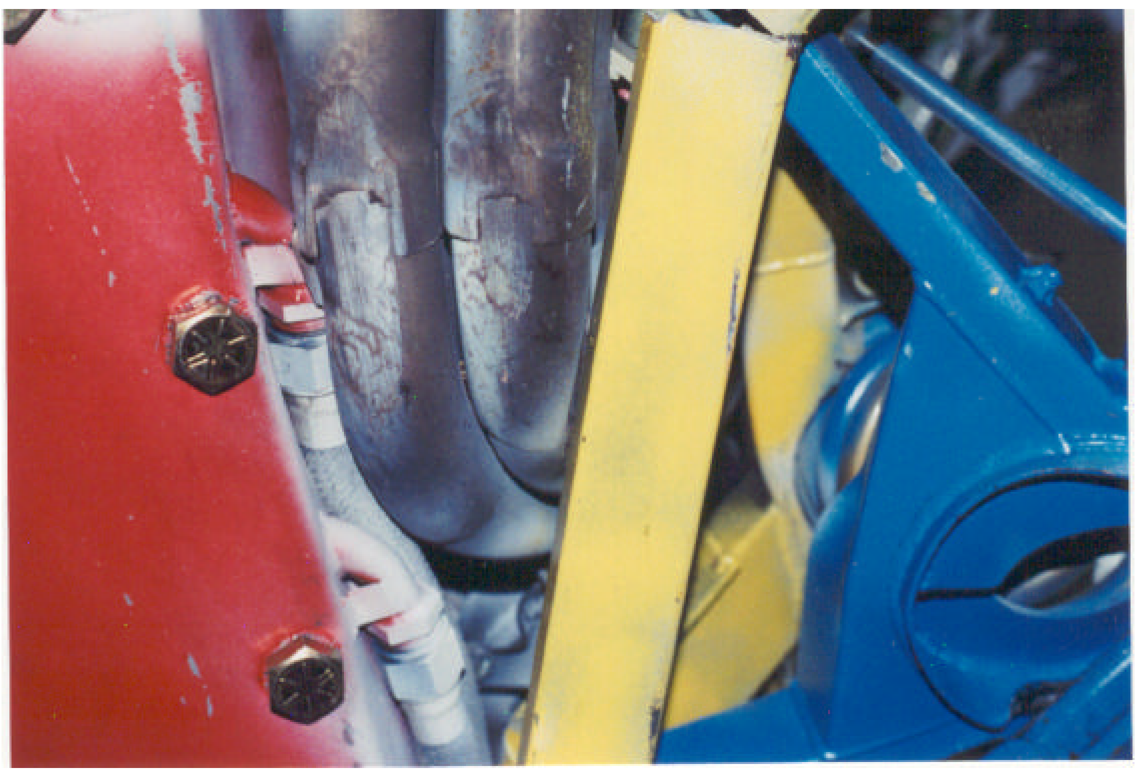


No. 3 Car

Test Vehicle
Figure 31. Damage to Left Frame Horn End



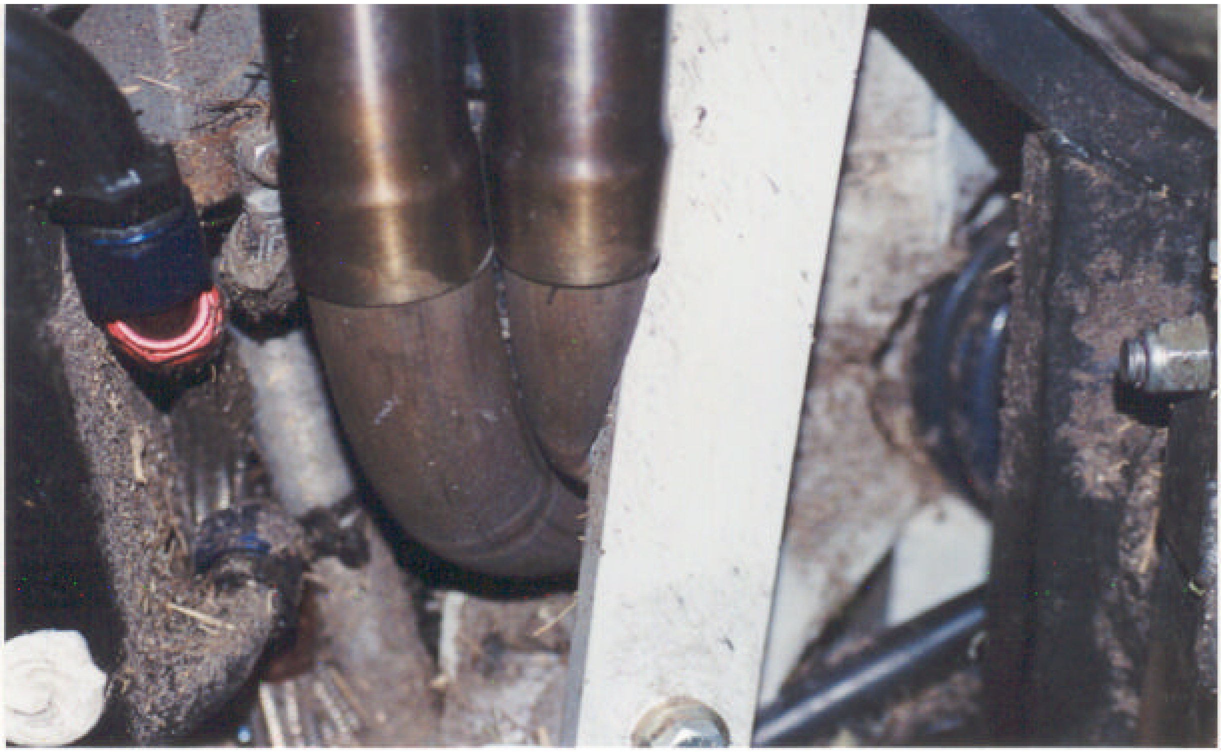
No. 3 Car



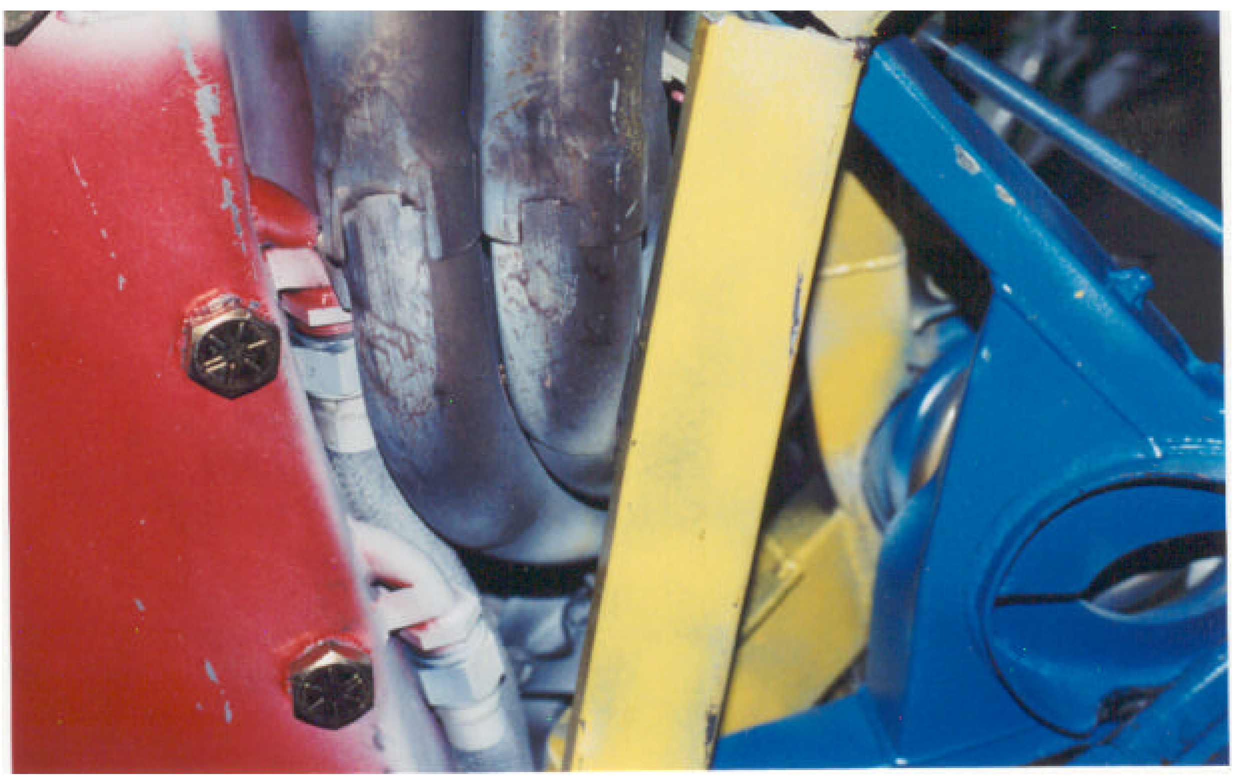
Test Vehicle

Figure 32. Damage to Vehicle Headers.

One area of significant difference in the damage of the two vehicles was in the structural tubes supporting the right frame horn or front clip. As shown in Figure 33, the structural support tubes on the two vehicles had somewhat different configurations. Notice the truss configuration used to connect several of the support tubes used in the No. 3 car compared to the individual tubes employed with the test vehicle. The truss configuration would be believed to be significantly stiffer initially than the separate tube construction. As shown in Figure 34, the truss arrangement in the No. 3 car exhibited little damage during the impact, while several of the tubes on the test vehicle were either ruptured or severely damaged. Structural differences in the two vehicles would be expected to cause some differences in the impulse applied to the two vehicles during the crash. These differences would not be expected result in more than a 10-20 percent change in the peak decelerations filtered at 60 Hz. The expected magnitude of the differences between the impulse would be reduced significantly for lower frequency filters. Further, since the vehicle used in the full-scale crash test is representative of many vehicles currently running on the Winston Cup circuit, the crash pulse data from this test would be appropriate for use in further efforts to design better occupant restraint systems, more crashworthy vehicles, and energy absorbing barriers. Finally, this crash test and all of the data collected contributed greatly to the validation of the computer model described in the next section.

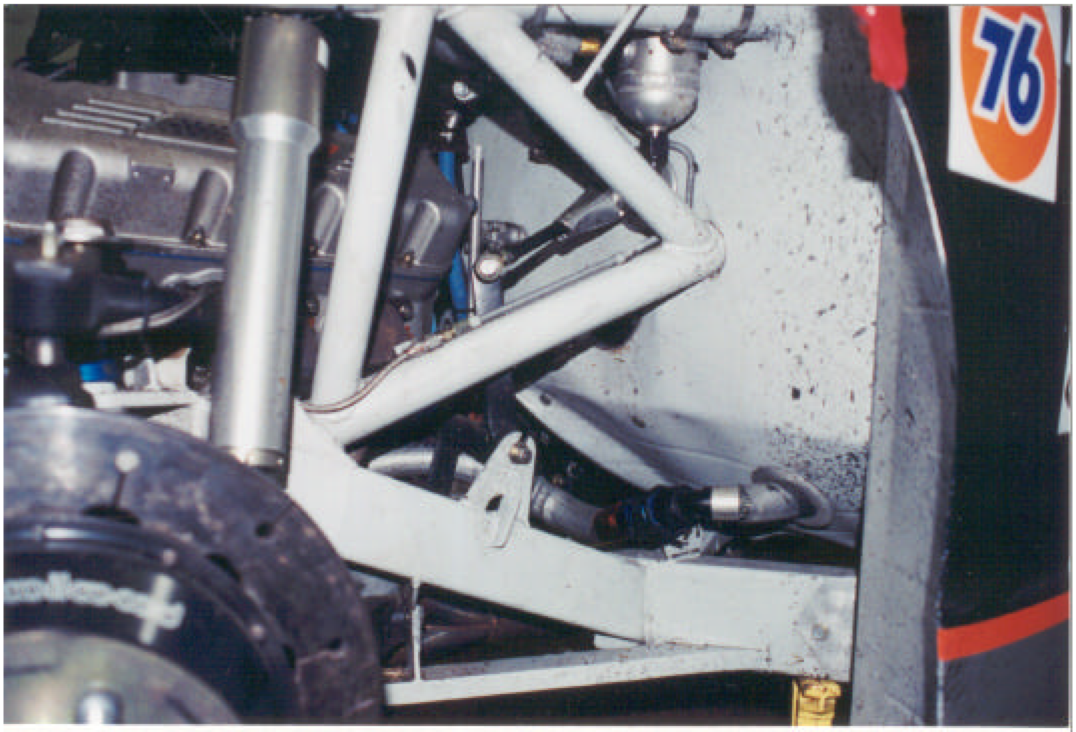


No. 3 Car

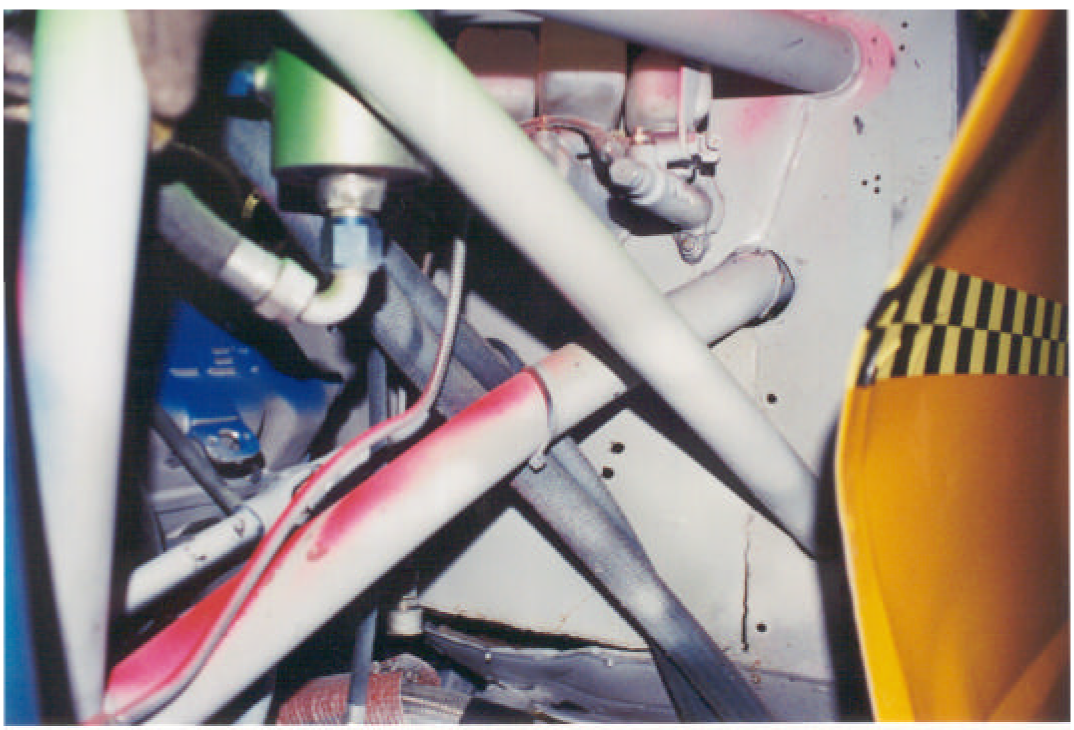


Test Vehicle

Figure 33. Damage to Vehicle Headers.



No. 3 Car



Test Vehicle
Figure 34. Frame Horn Support Tubes

Based on the great similarity in damage between the test vehicle and the No. 3 car and the fact that the damage to the test vehicle was slightly greater, it was concluded that the original estimated impact conditions were very accurate. Using the 0.02 coefficient of restitution found in the full scale crash test, the resulting velocity change perpendicular to the barrier would be approximately 41-43 mph. The photogrammetric analysis was used to estimate the velocity change parallel to the barrier to be between 7 and 10 mph. When the two velocities were added together, the total velocity change of the No. 3 car was estimated to be approximately 42-44 mph.

VII. Computer Modeling

A validated computer model is one of the best tools available for reconstructing accidents. In many cases, including this one, computer simulation is the only method currently available for reproducing the actual impact conditions. Further, an accurate vehicle model is the foundation of any effort to improve vehicle crashworthiness or develop energy absorbing barrier systems. Therefore, an effort was undertaken to develop a reasonably well validated computer model that could be used to aid in the reconstruction of the No. 3 car crash and support development of more crashworthy cars and barriers in the future.

Modern computer modeling involves utilizing finite element analysis (FEA) programs to predict vehicle deformations and loadings during a crash event. FEA modeling of an automobile involves breaking the entire vehicle into thousands of small elements (finite elements). The load displacement characteristics of these elements are then characterized individually. In that way the behavior of extremely complex structures can be reduced to analyzing the load deformation properties of very simple elements, many thousands of times. Crash modeling utilizes a non-linear, explicit analysis FEA methods first developed by the national laboratories for defense purposes. This type of analysis has been shown to be capable accurately predicting vehicle deformations and loadings during high speed crash events.

LS-Dyna3D represents the state of the art in explicit finite element analysis software for crash simulation. It is used by all domestic and a wide assortment of foreign automobile manufacturers for all of their crashworthiness design work. Further, almost all roadside safety developers (barrier designers) utilize this program to design safety hardware. Based on its wide acceptance in the crashworthiness field, LS-Dyna3D was identified as the analysis tool of choice for the computer modeling effort.

The modeling effort involved contracting with Altair Engineering to develop an initial Ls-Dyna3D model of a NASCAR Winston Cup vehicle. Figure 35 shows the structural frame and the associated computer model generated by Altair Engineering. Initial validation was undertaken by the authors of this report at a very early stage in the model development process in order to expedite completion of the reconstruction. The model was then completed through a series of steps by adding additional structural and non-structural components that were found to contribute to the vehicle crush behavior. Ultimately, Altair supplied the model shown in Figure 36 for validation against the full-scale crash test described above and replication of the actual No. 3 car accident. This model incorporates approximately 87,000 elements to study the behavior of the NASCAR Winston Cup race car. Note that the model shown in this figure incorporates the structural support for the frame horn found in the vehicle used for the full-scale crash test.

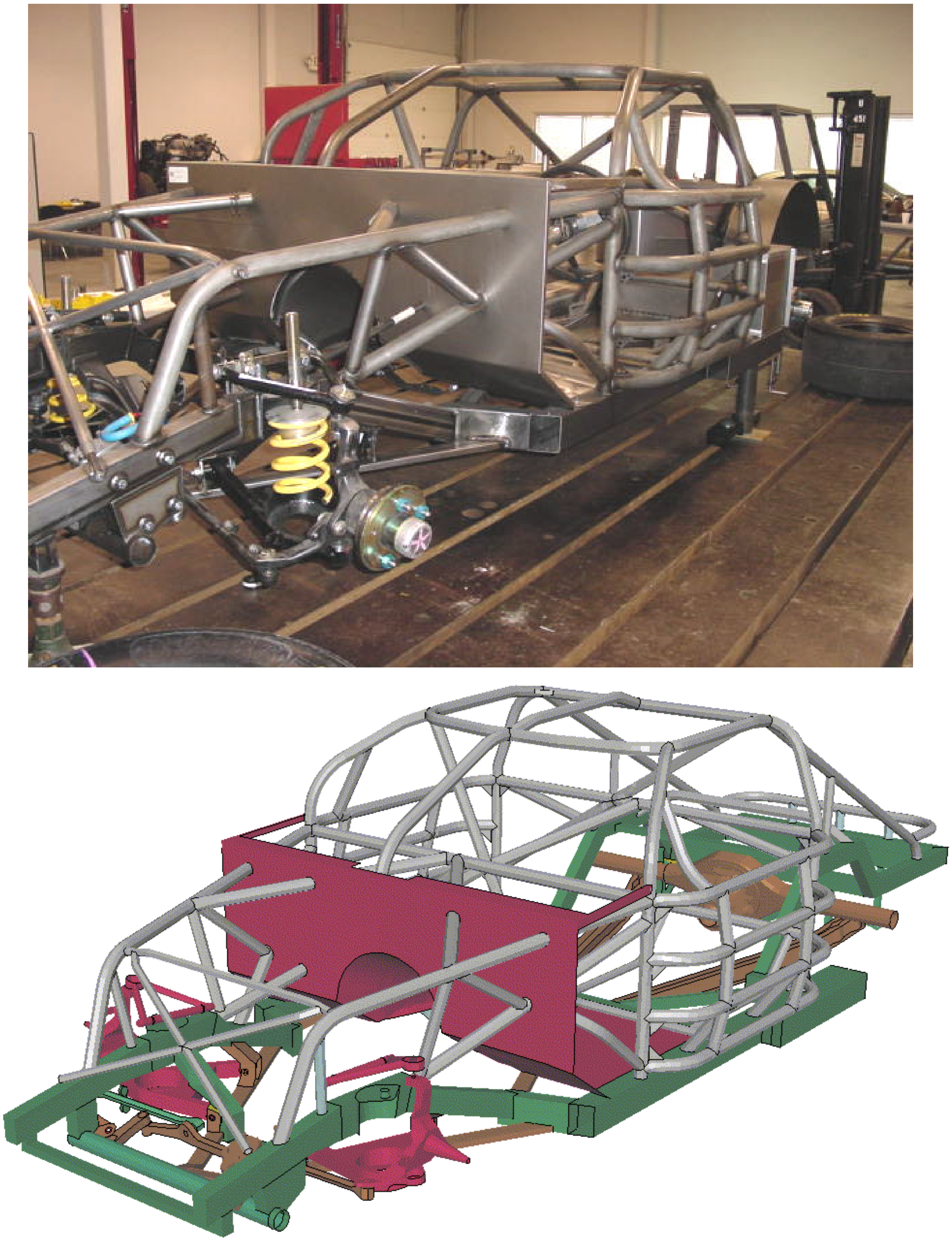


Figure 35 Frame of Initial Model.

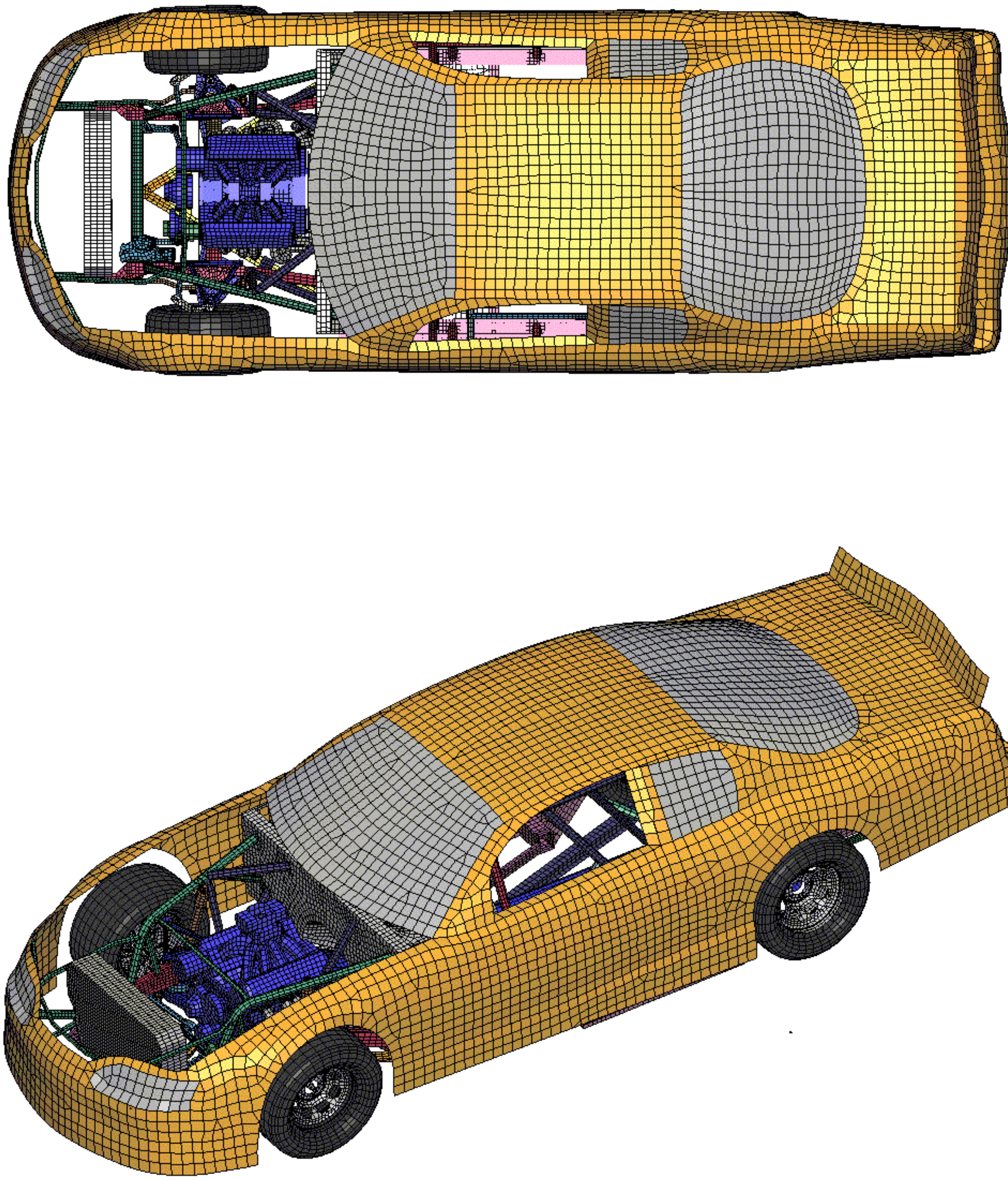


Figure 36 Model of Test Car.

Validation of a computer model can normally be segregated into three different stages. The first stage involves replicating phenomological behavior of the crash which requires that overall structural deformations match pretty well. In the first stage, the only evaluation criteria is that the nature and magnitude of predicted vehicle deformation should match the test results. After achieving this goal, it then becomes important to compare the timing of impact with the various vehicle components between the simulation and the test. Only after the simulated deformations and impact timings compare favorably with the test does the modeler begin to consider evaluating whether the overall acceleration levels correlate. Even in the final stage, velocity changes are generally considered a more reliable tool for evaluating model validity than is the acceleration trace.

After some iterations involving modeling refinement, the NASCAR vehicle model was used to simulate the full-scale crash test described above. As shown in Figure 37, the overall vehicle deformations from the computer model matched test results reasonably well. Further, as shown in Figures 38-41, deformations of most important structural components matched test results reasonably well. Further, as shown in Figure 42, sequential photos of the simulation and the full-scale test, timing of the component impacts with the wall appear to be fairly well correlated. Finally, as shown in Figure 43, the velocity versus time curves from the test and the simulation are generally in agreement. Based on these findings, it was concluded that the computer simulation model was sufficiently accurate to begin studying the No. 3 car crash.

Figure 44 shows sequential slides from the No. 3 car barrier crash simulation. Recall that initially it was believed that the No. 3 car did not rotate when it struck the barrier due to the influence of the No. 36 car impact. The computer simulation model indicates that this assumption is likely to be in error. As shown in Figure 44, the model replicates the overall behavior of No. 3 car reasonably well, even though the No. 36 car was not included in the simulation. This finding is very significant in that it indicates the No. 3 vehicle struck the barrier under a critical impact scenario wherein the resultant barrier forces act through the vehicle center of gravity so that vehicle does not rotate. As mentioned previously, vehicle rotation upon impact with the barrier reduces the magnitude of the primary impact by separating the crash into two distinct events. Impacts with barriers under critical impact conditions represent a worst case scenario from an occupant risk standpoint because the accelerations applied to the occupant compartment are maximized.

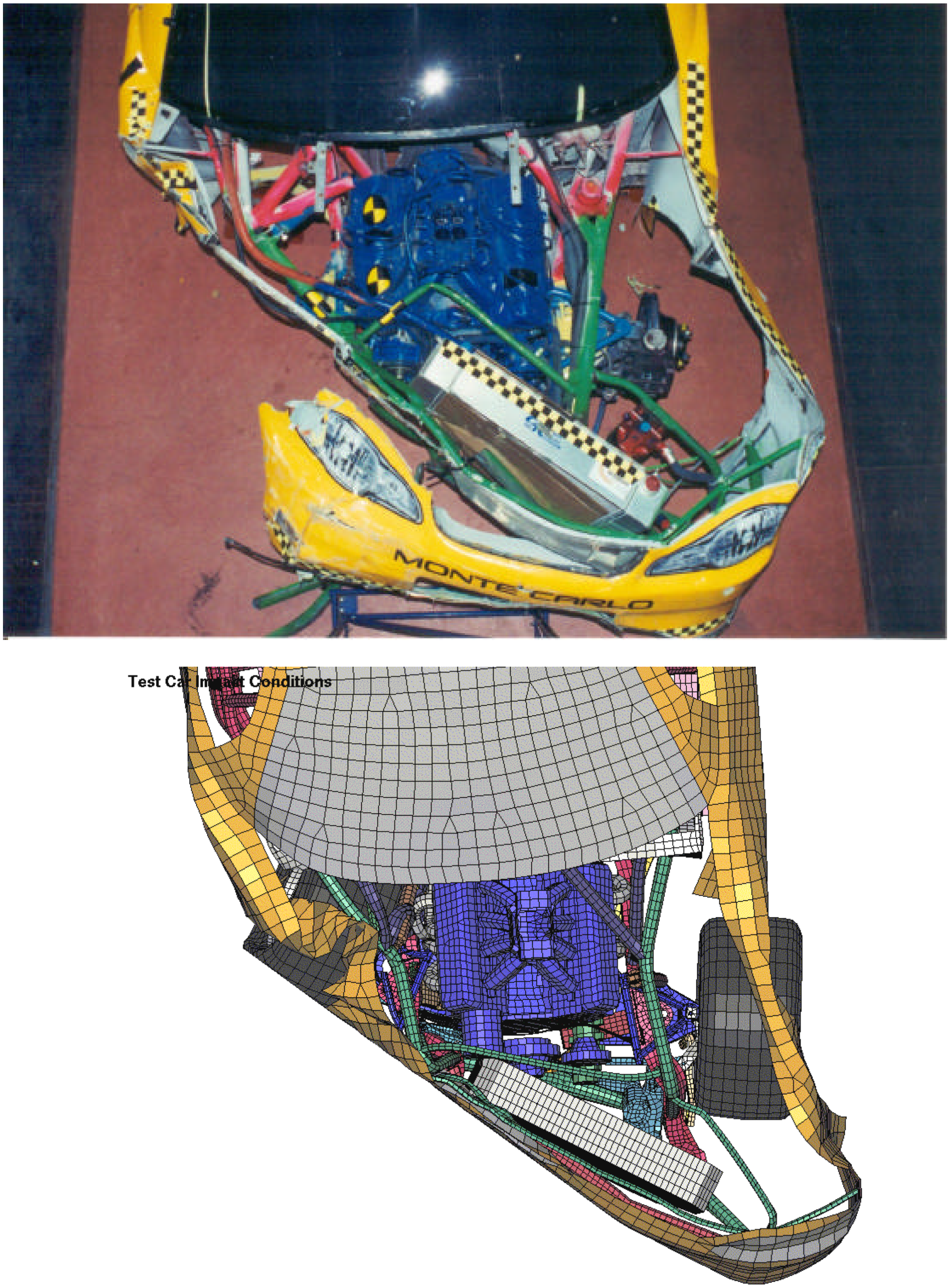


Figure 37. Frontal Overhead Crush View

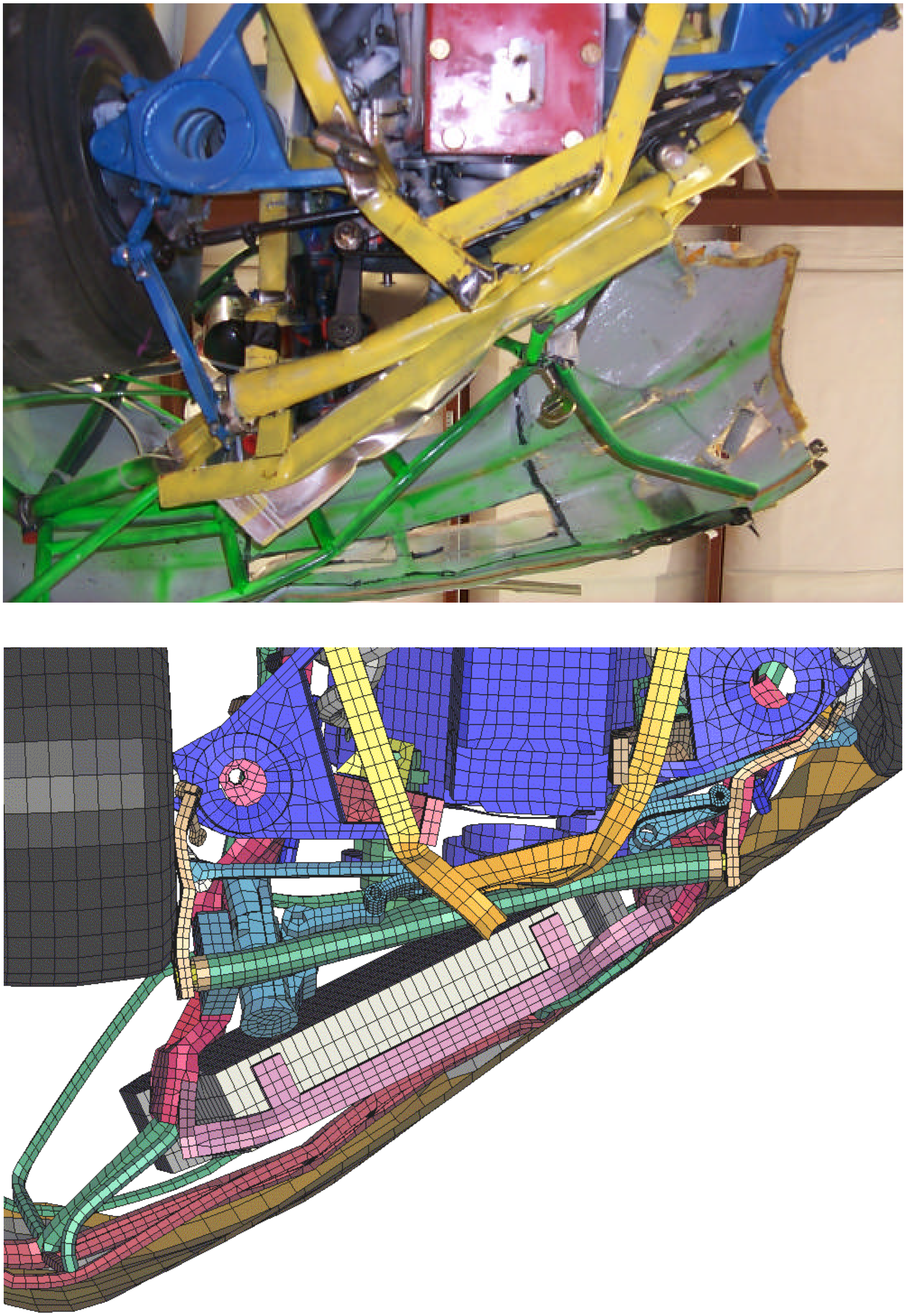


Figure 38. Bottom View – Test vs. Simulation.

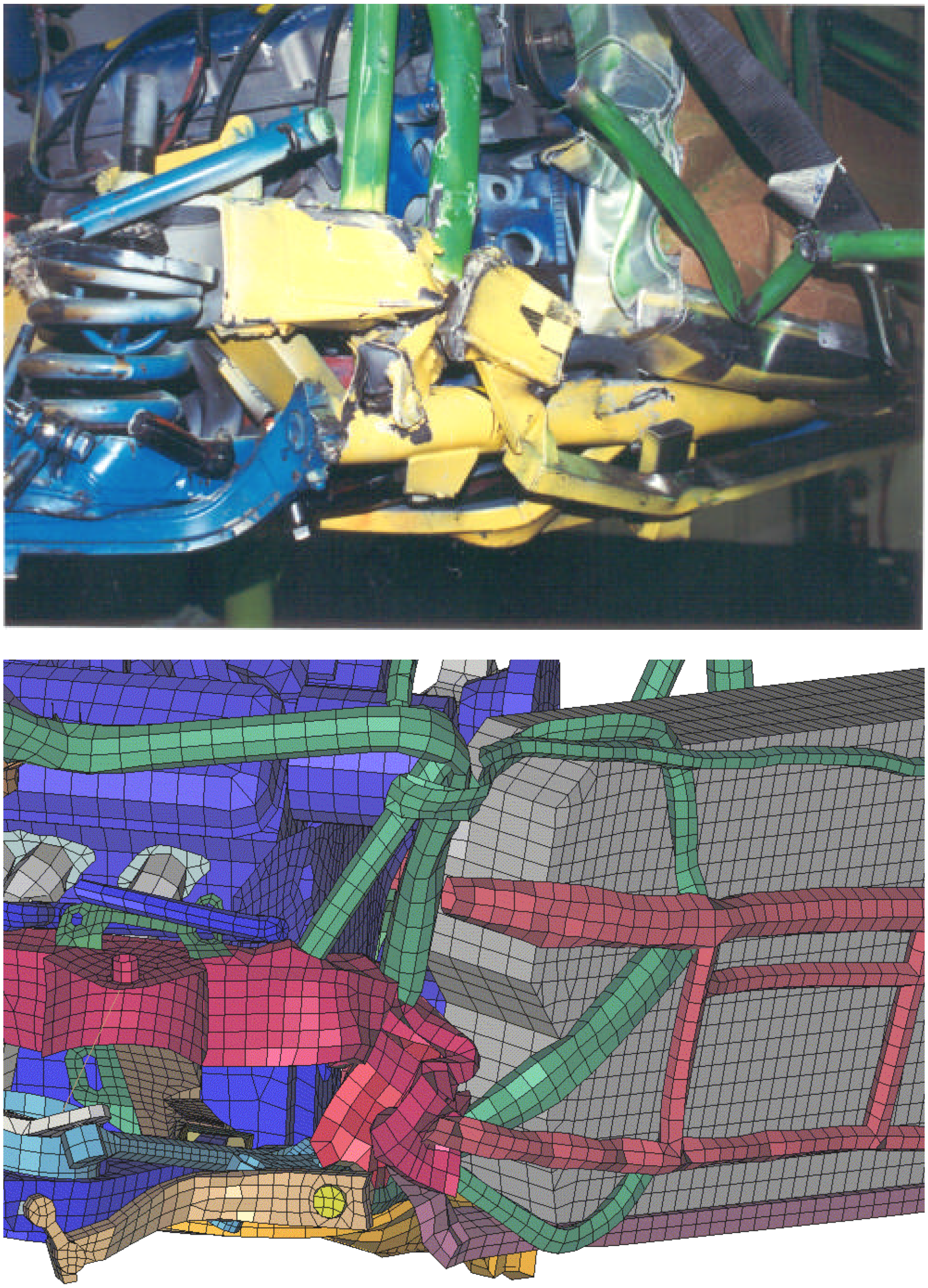


Figure 39. Right Front Corner – Test vs. Simulation

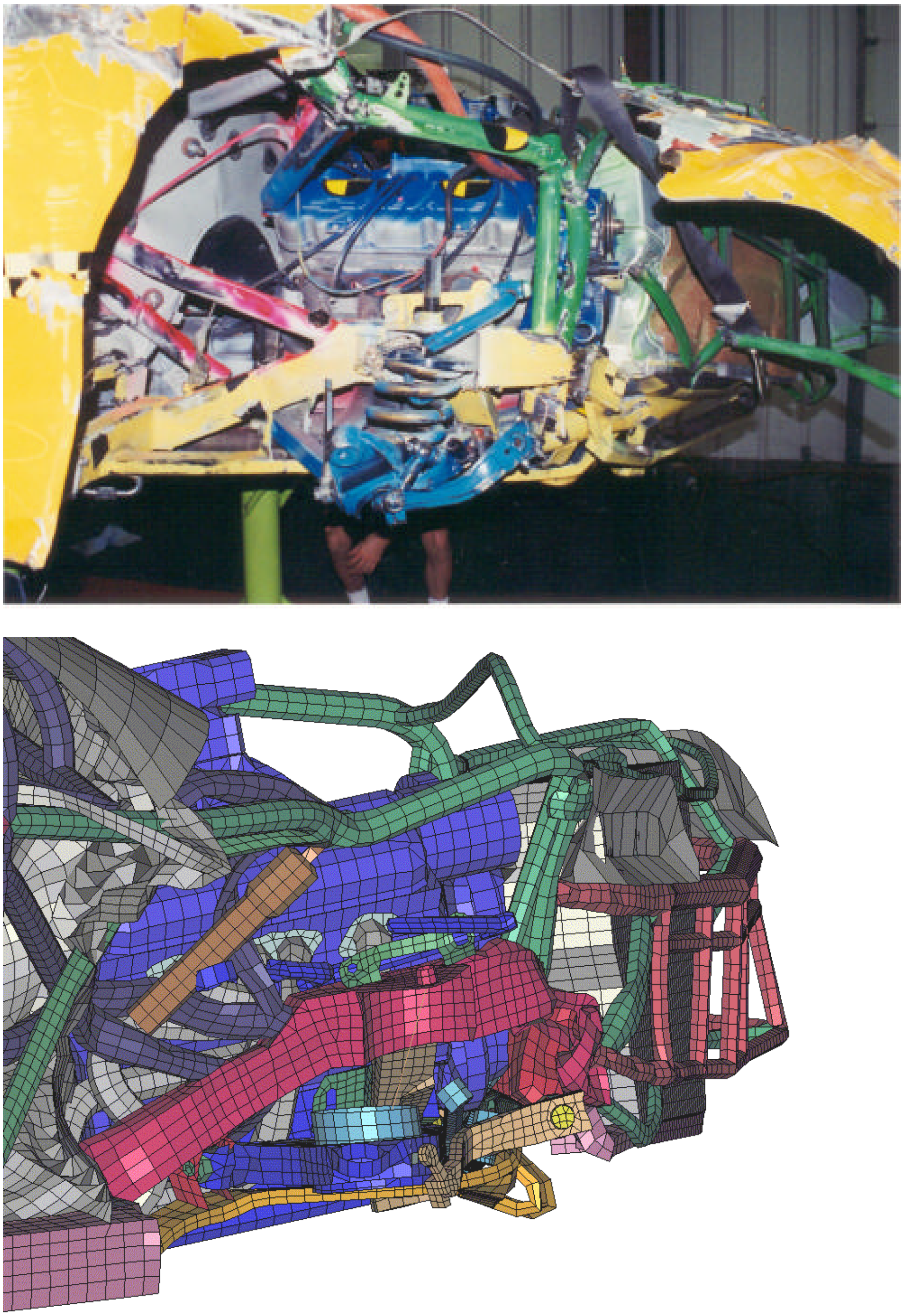


Figure 40. Right Front Side – Test vs. Simulation.

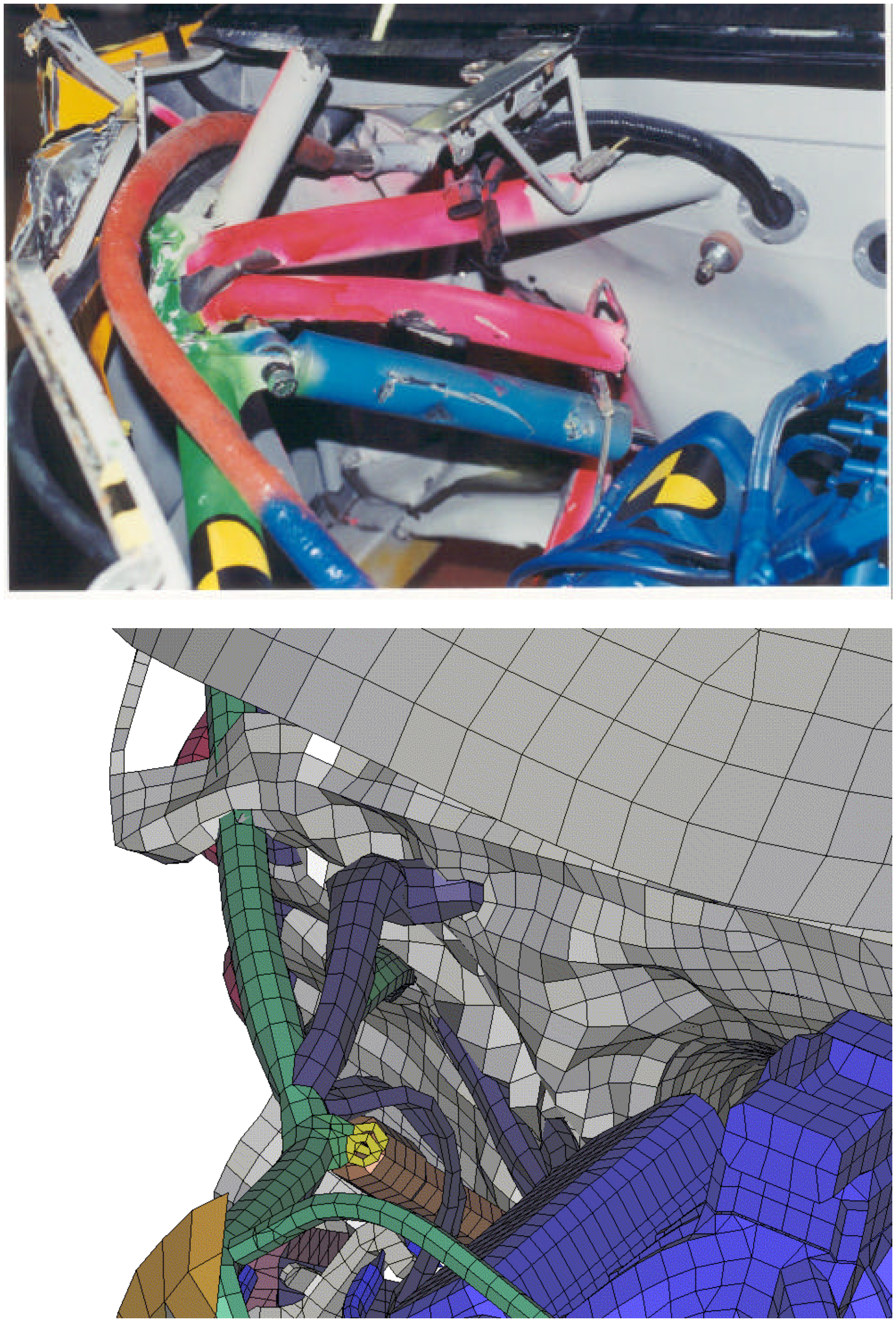


Figure 41. Firewall – Test vs. Simulation.

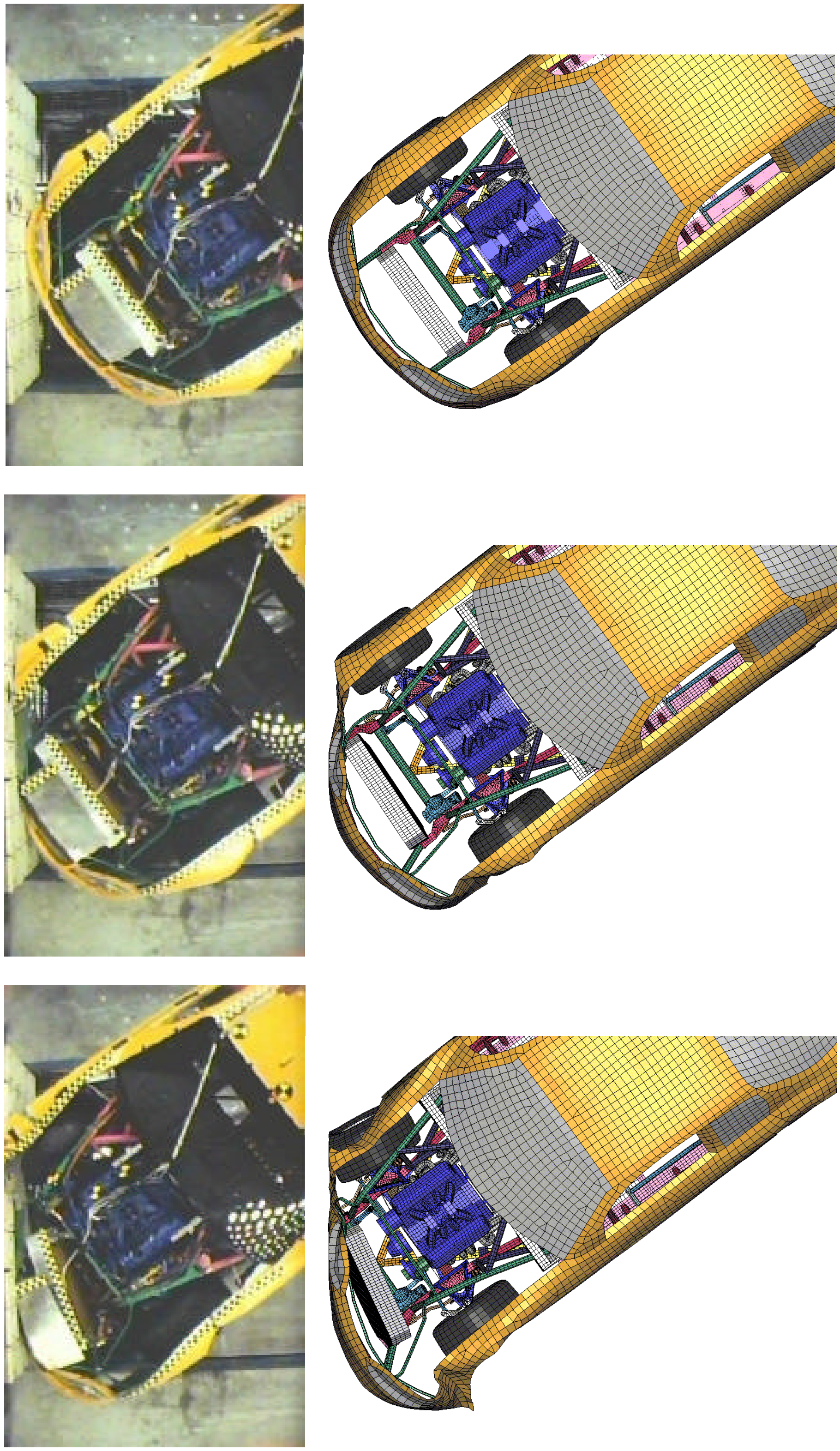


Figure 42. Sequentials – Test vs. Simulation.

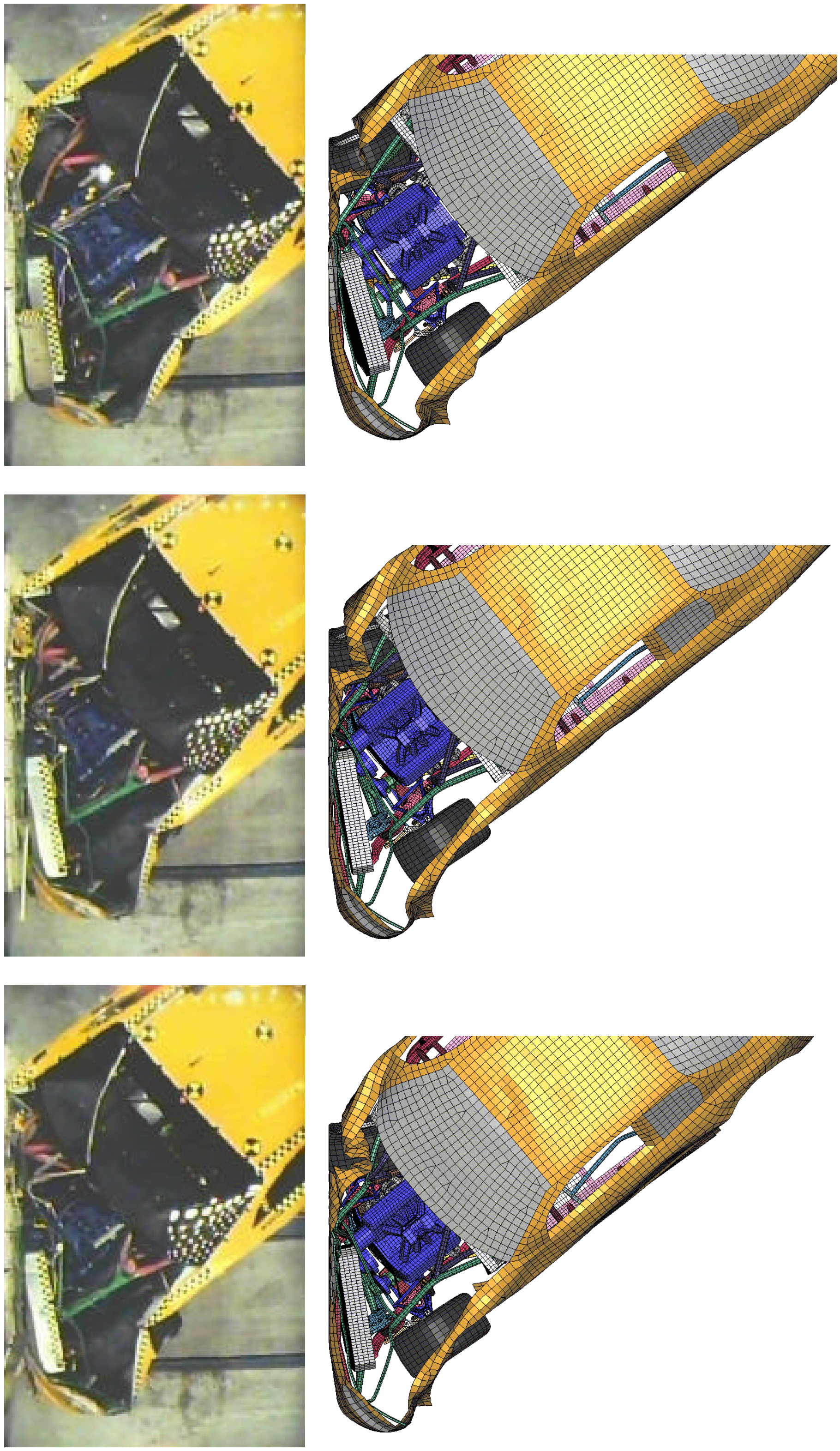


Figure 42. Sequentials – Test vs. Simulation (continued)

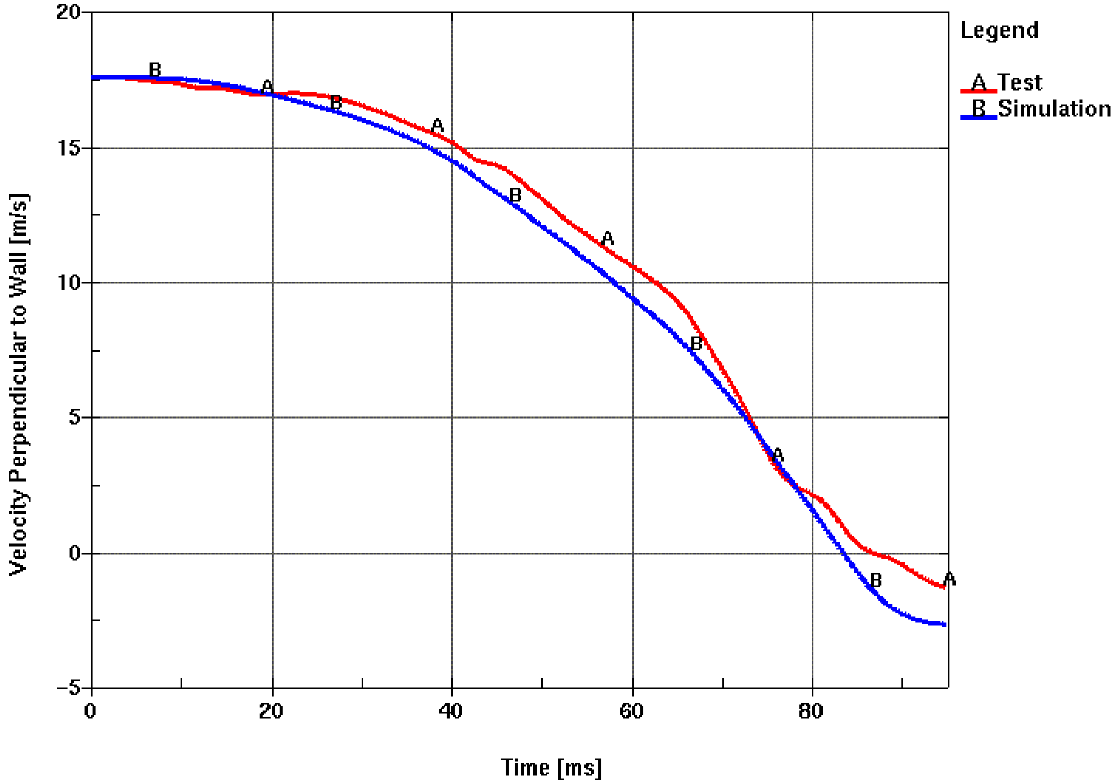


Figure 43. C.G. Velocity – Test vs. Simulation.

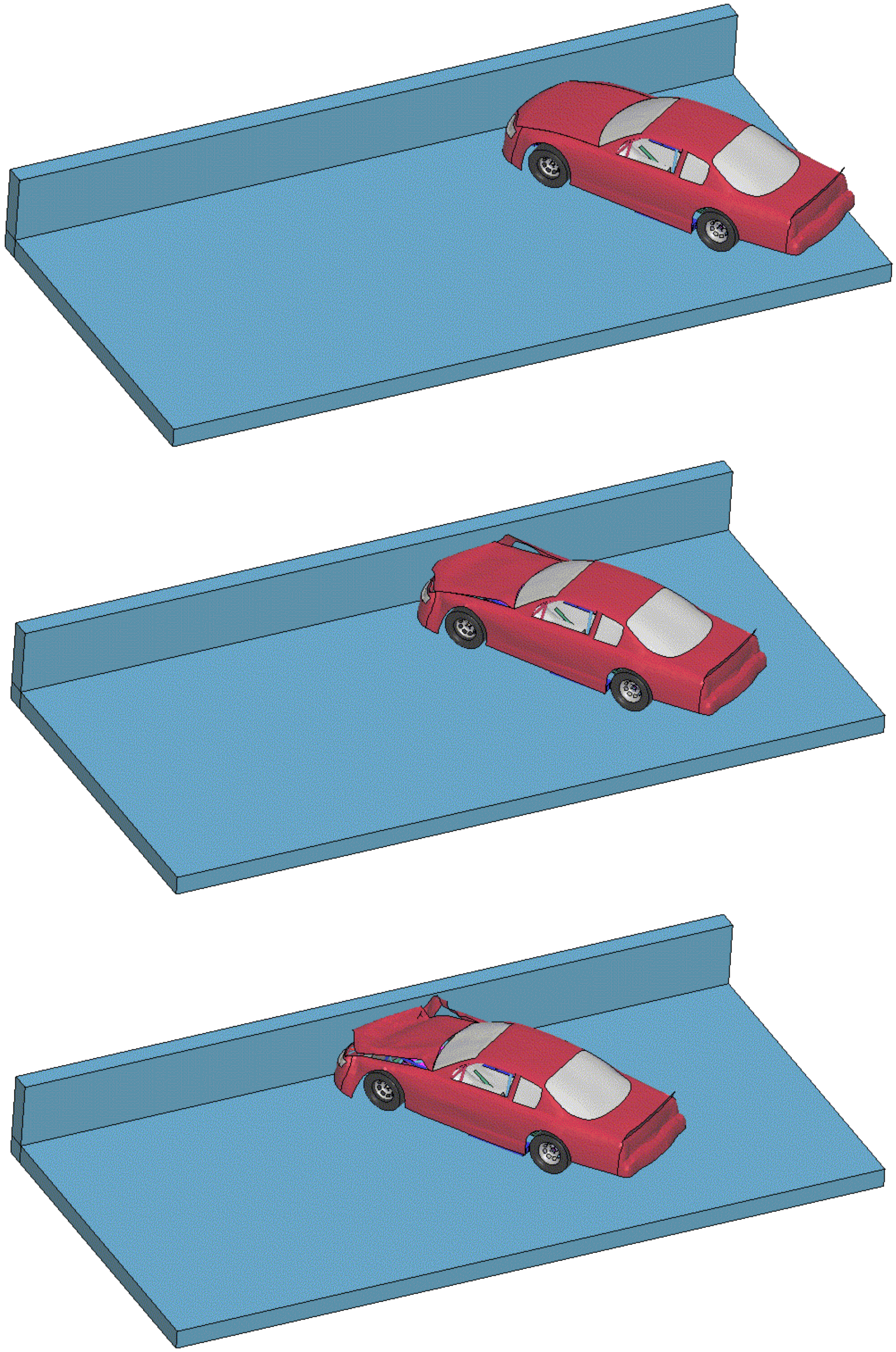


Figure 44. Sequentials – Simulation of No. 3 Impact.

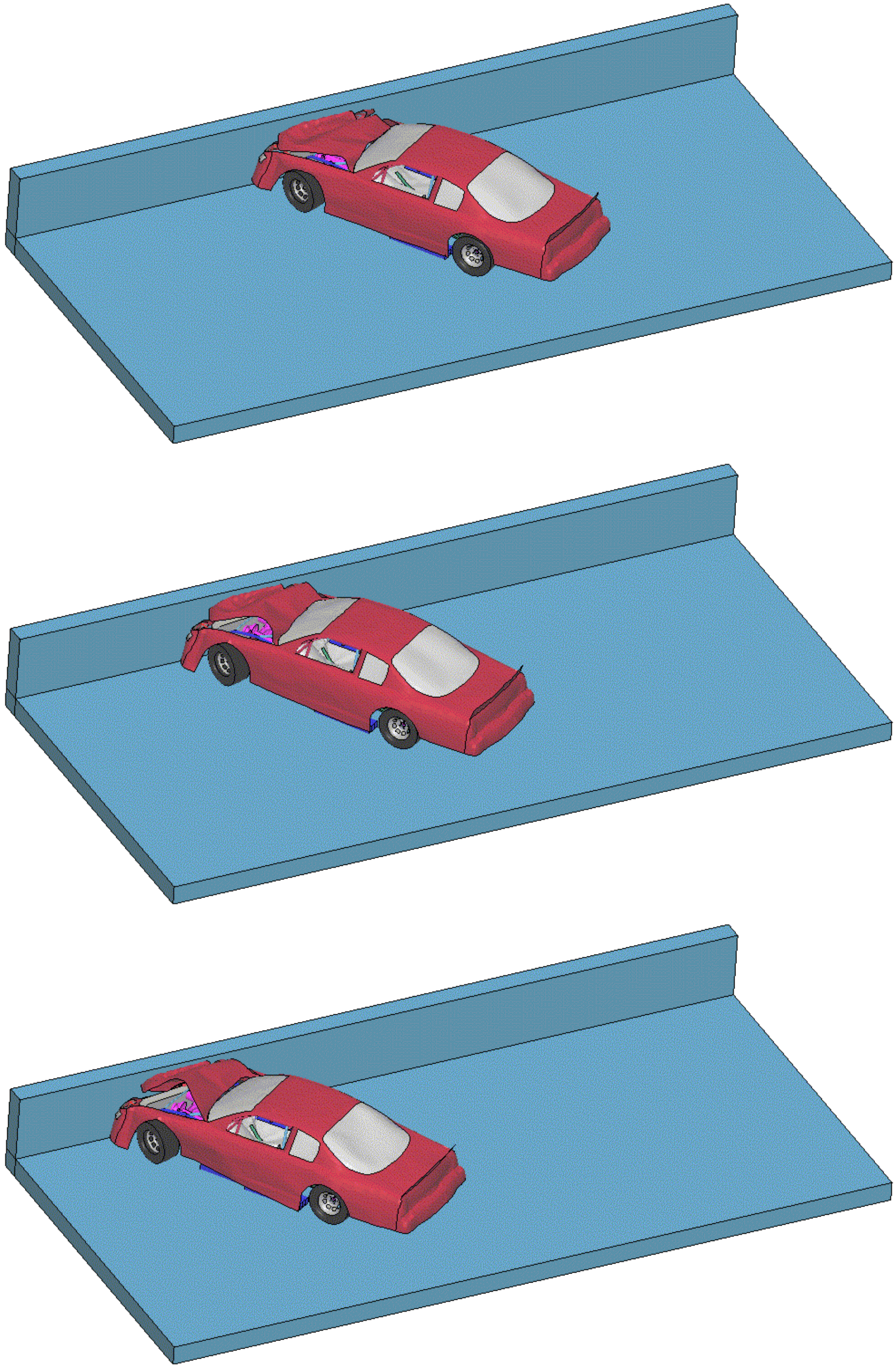


Figure 44. Sequentials – Simulation of No. 3 Impact (continued)

As shown in Figures 45-50 simulated vehicle damage compared reasonably well with the damage observed on the No. 3 car. These figures demonstrate that the computer model has achieved the first stage of validation for the actual crash modeling, i.e. replication of the overall phenomenon observed during and after the crash. The available data on the actual crash, including GPS and photogrammetry, do not provide detailed information regarding the timing of the impact or the impulse imparted on the vehicle. As a result, it is not possible to evaluate the computer model's validity on these levels. Never-the-less, the acceleration impulse calculated from the simulation of the No. 3 crash was passed through an SAE J211-CFC Class 60 filter and presented in Figure 51. As shown on this figure, the maximum deceleration was predicted to be 64 g's during the barrier crash.

Based on the correlation between the computer model, the full-scale crash test, and the No. 3 car crash evidence, it can be concluded that the computer model has reached a sufficient level of validity to begin being used in crashworthiness studies. The model has already begun to be used in efforts to design an energy absorbing barrier system and it will soon begin to be used to evaluate variations in crashworthiness of existing Winston Cup chassis designs. Ultimately this model will become a valuable tool for improving the designs of occupant restraint systems, crash worthy chassis's, and energy barrier systems.

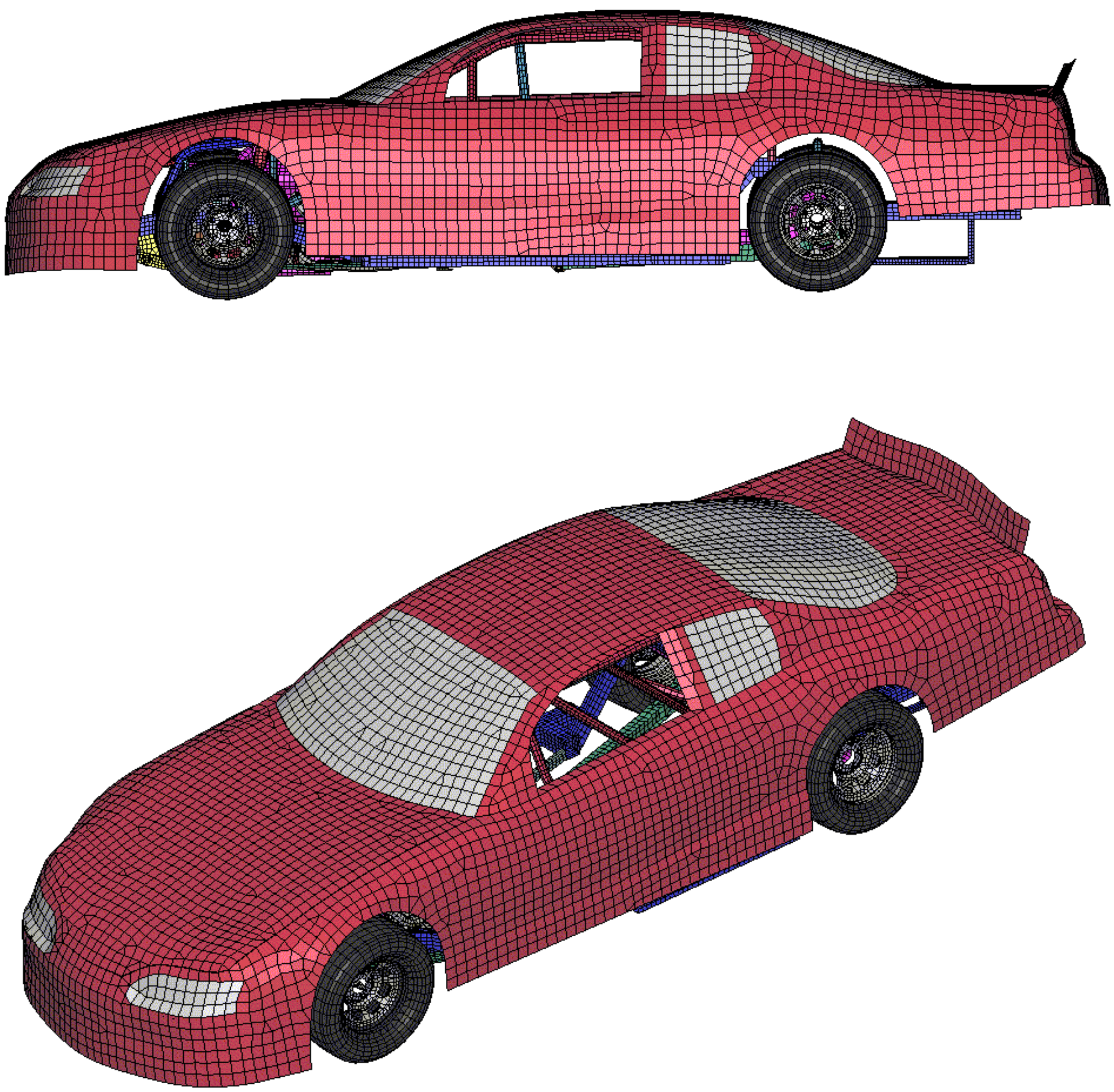


Figure 45. Model of No. 3 Car.

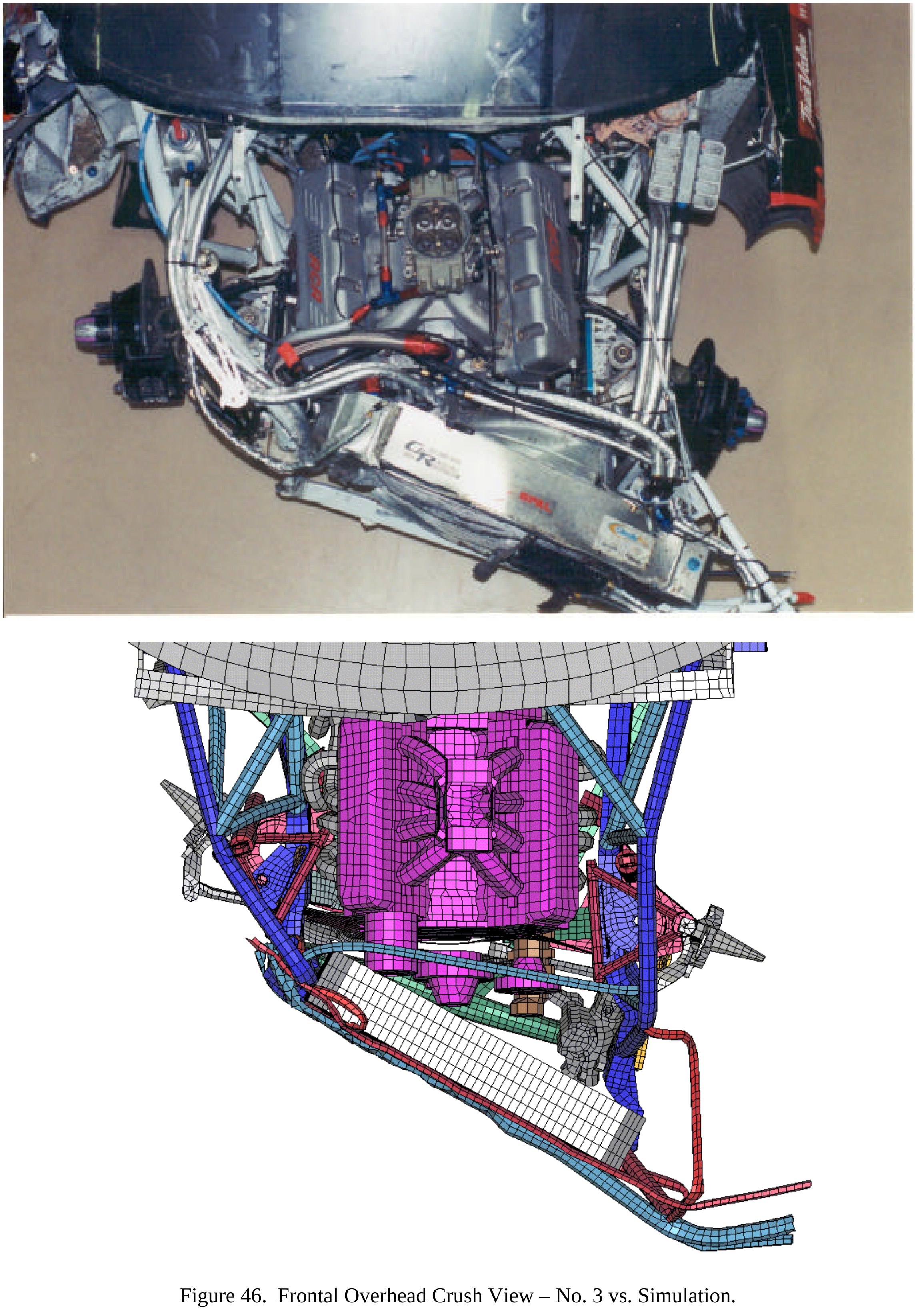


Figure 46. Frontal Overhead Crush View – No. 3 vs. Simulation.

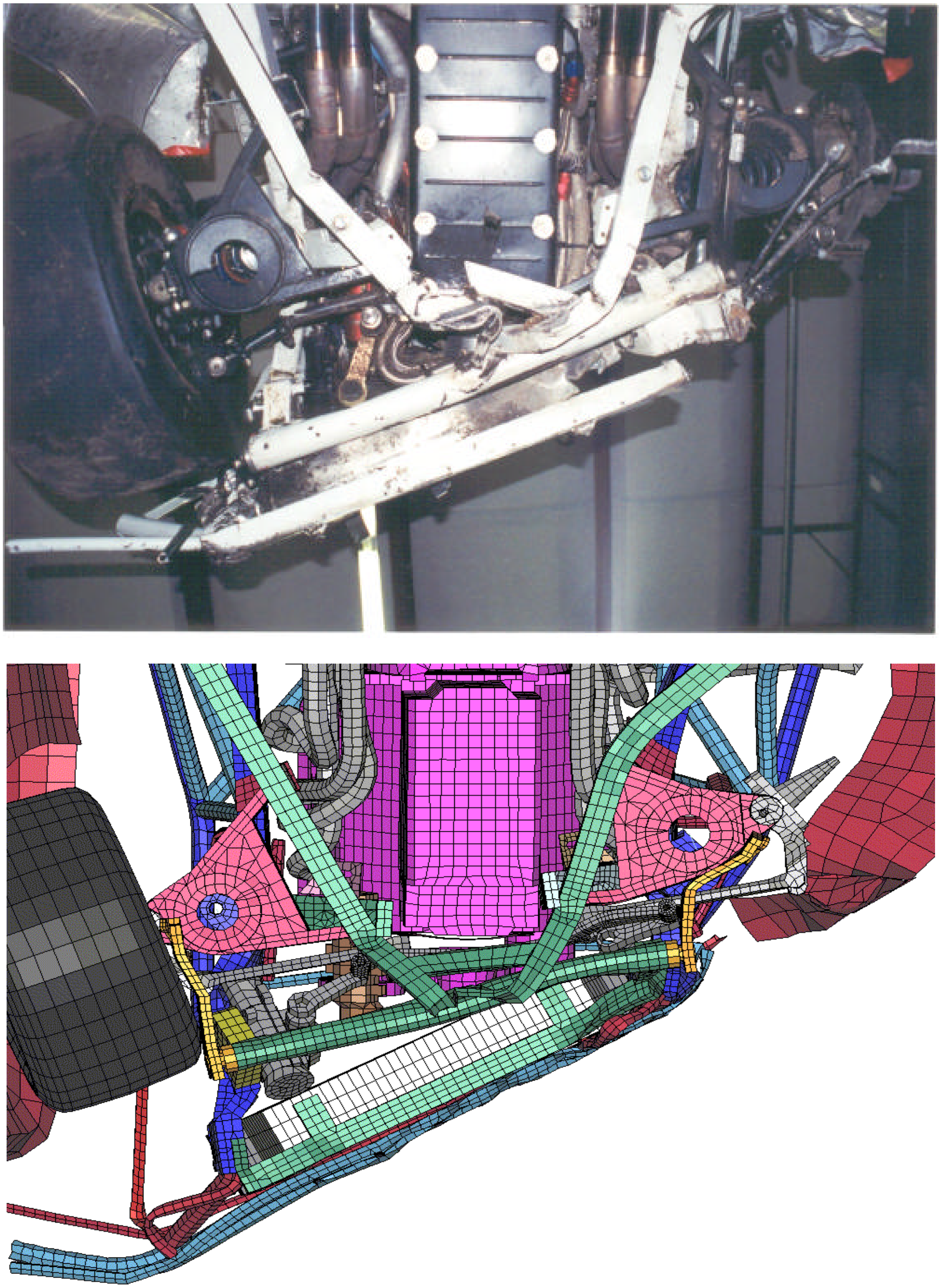


Figure 47. Bottom View – No. 3 Car vs. Simulation.

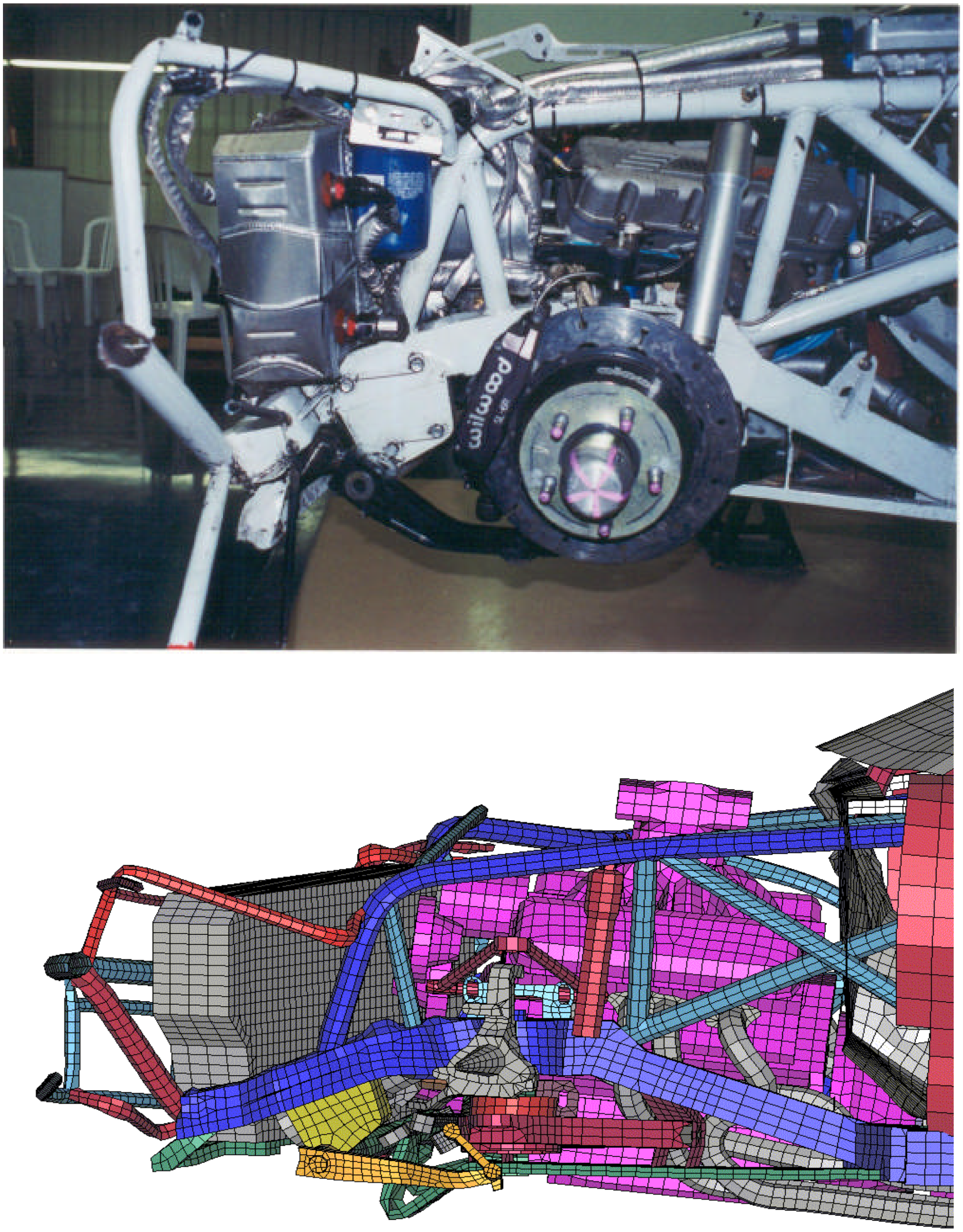


Figure 48. Driver Side Deformation – No. 3 Car vs. Simulation.

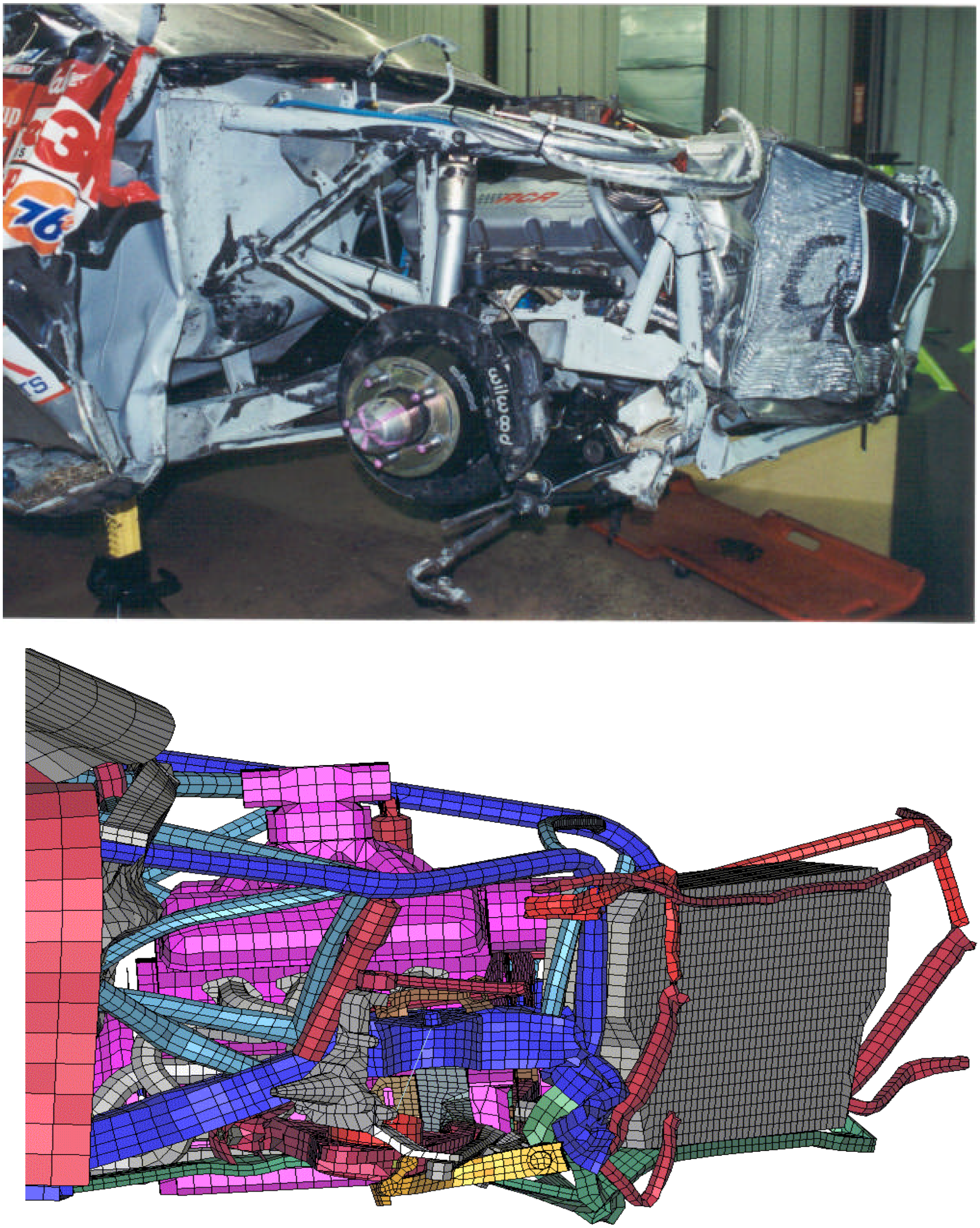


Figure 49. Passenger Side Deformation – No. 3 Car vs. Simulation.

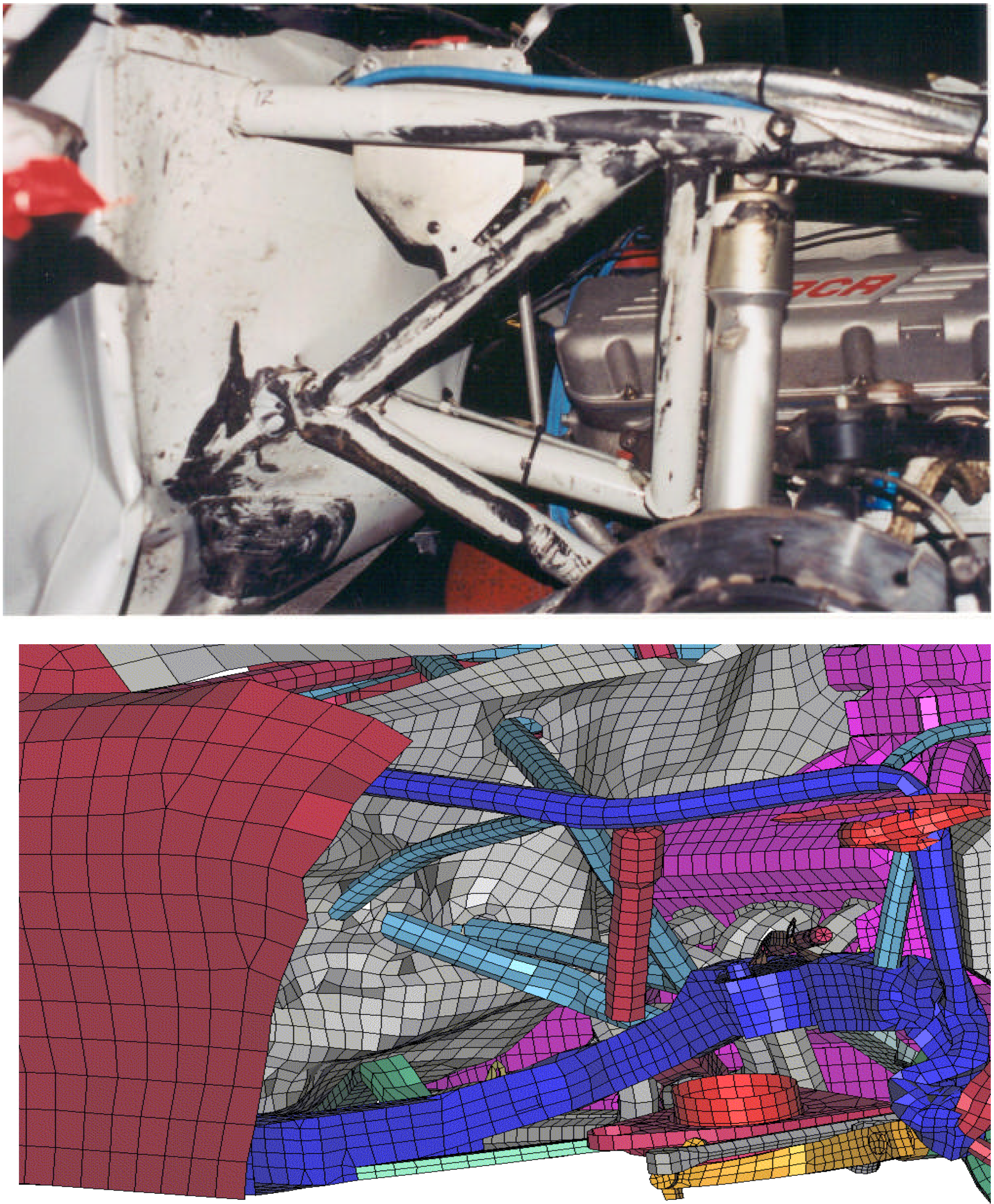


Figure 50. Passenger Side Firewall – No. 3 Car vs. Simulation.

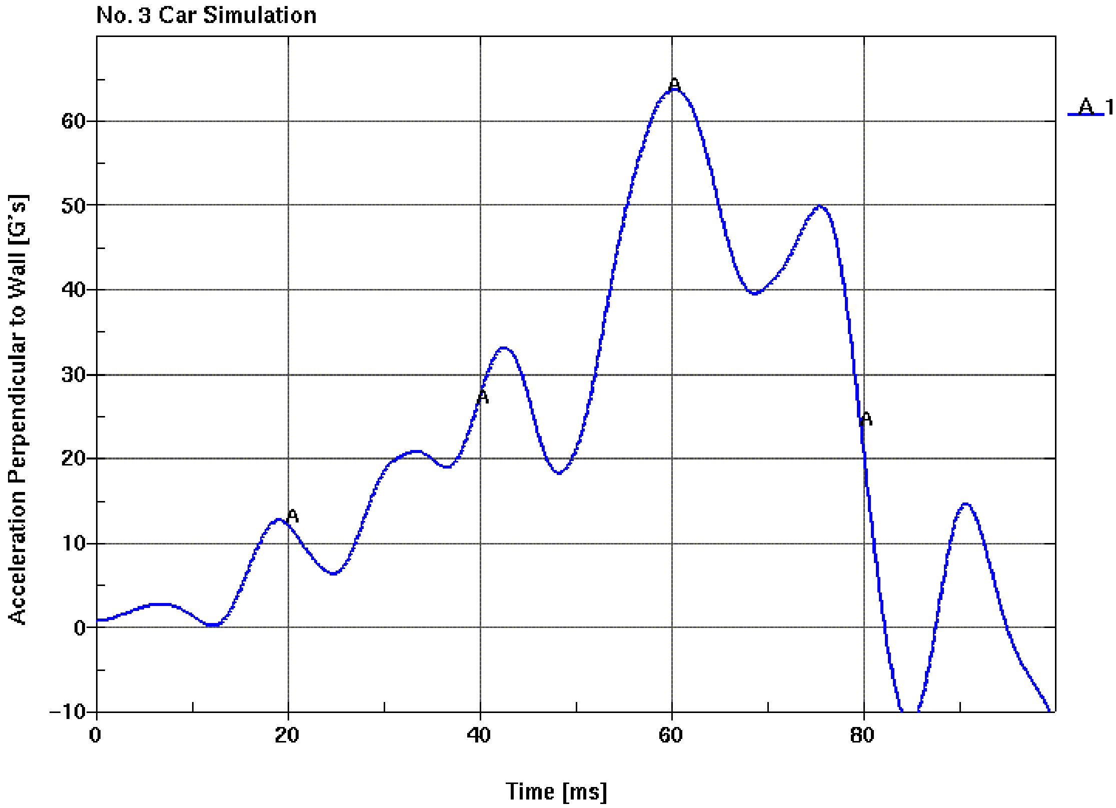


Figure 51. Acceleration Trace of No. 3 Car Simulation.

VIII. Summary and Conclusions

As summarized above, the No. 3 car crash was reconstructed sufficiently to determine the impact speed, heading angle, and the angle of the velocity vector throughout the event. Upon impact with the barrier, the No. 3 car was traveling at a speed of approximately 157-160 mph and its trajectory had an angle relative to the barrier of approximately 13-14 degrees. Further, the heading angle of the vehicle was approximately 55-59 degrees relative to the barrier at the time of impact. This heading and trajectory angle combination represent a critical impact condition in which the vehicle would not have rotated during the barrier impact, even if the No. 36 car had not been in contact with the No. 3 car. This critical impact condition lead to a total velocity change during the primary barrier impact of 42-44 mph over a period of approximately 80 ms.

The collision between the No.'s 3 and 36 cars was found to have two major effects. First, the impact caused the No. 3 car to have a total change in speed of approximately 2-4 mph which actually involved the vehicle speeding up parallel to the barrier and slowing down perpendicular to the barrier. Each of the two components were actually greater than the speed change and when the components are added vectorially, it was estimated that the total velocity change for this vehicle was approximately 9-11 mph. Although this level of velocity change would not be expected to cause occupant injuries, it could have an effect on occupant position upon impact with the barrier. The collision with the No. 36 car also caused both vehicles to rotate clockwise which lead to the high heading angle associated with the barrier impact. The photogrammetric reconstructions indicated that the barrier impact occurred approximately 400 ms after the collision with the No. 36 car.

The estimated barrier impact conditions were originally determined from tire marks on the track, on board GPS data, and photogrammetric reconstructions of video tapes. Confidence in the estimated impact conditions was greatly enhanced by findings from one full-scale crash test and a sophisticated computer model.

The crash test results and computer simulation model developed during this investigation will provide tools for evaluating occupant restraint systems, improved chassis designs, and development of energy absorbing barrier systems.

Tab 2

Injury Causation Analysis of 18 February 2001

Racecar Accident Involving The No.3 Car

James V. Benedict, Ph.D., M.D.
James H. Raddin, Jr., M.D.
BIODYNAMIC RESEARCH CORPORATION
San Antonio, Texas

21 August 2001

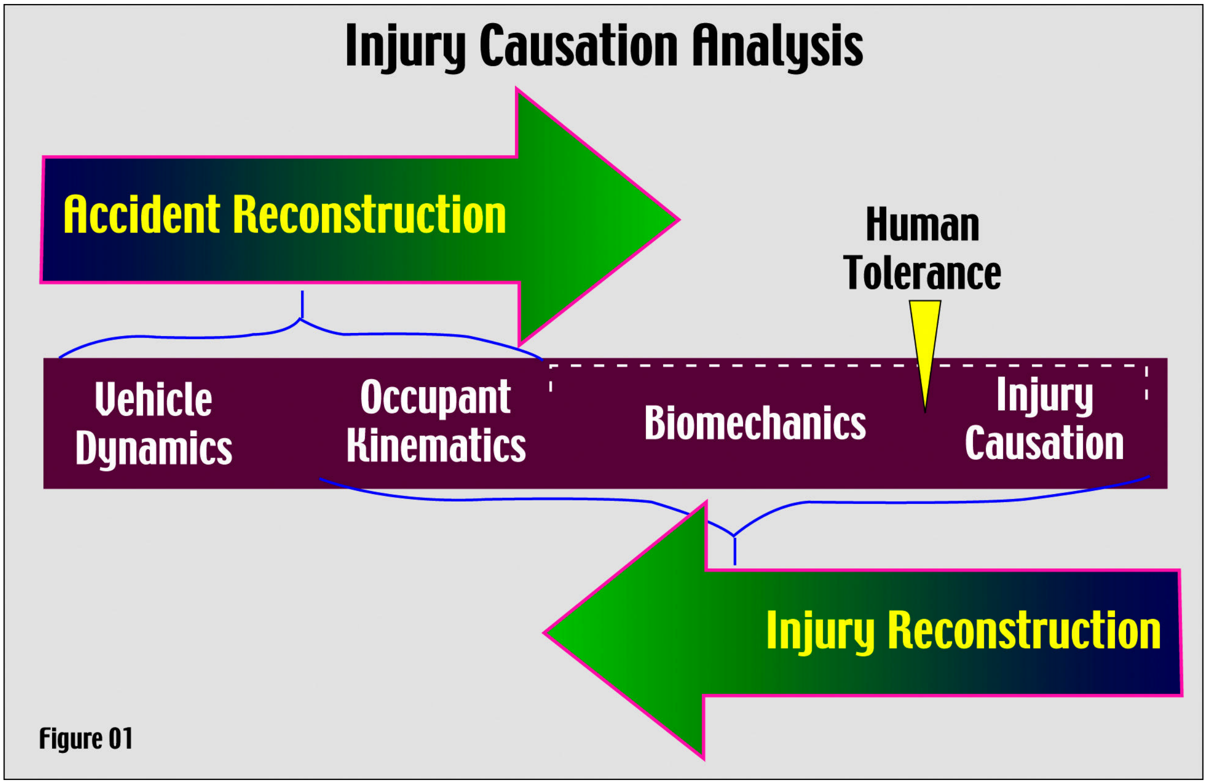
ABSTRACT

An injury causation analysis is presented for the February 18, 2001 crash involving Dale Earnhardt. Findings and conclusions are presented which relate the accident vehicle dynamics to the resulting occupant kinematics, biomechanics and clinical injuries. Dale Earnhardt's death was most likely caused by a blow to the back of the head not from one single cause but from a combination of unusual factors. These included the uncommon severity and trajectory of the car's impact with the wall, an immediately prior collision with another car that put him out of position and a separation of the left lap belt under load that allowed greater motion within the car.

I. Introduction

On 18 February 2001, Mr. Ralph Dale Earnhardt died of injuries sustained in a crash during the last lap of the Daytona 500 Winston Cup automobile race. Biodynamic Research Corporation (BRC) has been retained by representatives of NASCAR, the sanctioning body, to perform an injury causation analysis to assess how the injuries occurred. The work by BRC proceeded independently and parallel to the work of other consultants in other areas such as accident reconstruction. Data from these analyses were utilized by BRC in the conduct of the injury causation analysis and form a portion of the basis for some of the conclusions.

BRC is a professional services firm in San Antonio, Texas, engaged in the performance of injury causation analyses relating most commonly to vehicular impacts. The analysis involves assessments in four separate but cause-and-effect related areas. These areas are outlined in Figure 1. The first area, vehicle dynamics, involves an assessment of the change in motion of the vehicle. This area is typically analyzed by accident reconstructionists. When a vehicle undergoes a sudden change in its motion, the occupant of that vehicle undergoes displacements with respect to the vehicle. These displacements are analyzed under the second heading of occupant kinematics. Occupant displacements result in contacts with restraints, vehicle structure, or other objects resulting in stresses on the body which are analyzed under the area of biomechanics. When those stresses exceed human tolerance for the occupant, clinical injury results. An injury causation analysis, therefore, employs medical and engineering analyses to elucidate the sequential relationships in the four areas. Some background on the general approach is outlined, with some specific examples relating to aircraft crash issues, in the two references by Raddin (1997).



Principal consultants from BRC engaged in the present analysis are Dr. James V. Benedict and Dr. James H. Raddin, Jr., with support from other members of the BRC staff.

The data upon which the analysis is based will be described in the next section. The overall findings will then be reported with a description of the analytical basis for each.

II. Analysis Data Sources

A. Materials Reviewed

1. Vehicle Data

Various sources of data were available to assess the impact events for the Three Car occupied by Mr. Earnhardt. These sources of data include:

- Film and/or video camera coverage of the crash from various angles;
- GPS data recorded from the Three Car;
- Crash scene marks observed and measurements performed by the crash reconstruction analysis team ("The Nebraska Team");
- The actual wreckage of the Three Car;
- Dismantled portions of wreckage from the Thirty-Six Car;
- An exemplar vehicle for the Three Car;
- Enhanced video of the crash from one angle;

- Photographs of the Three Car taken by the Medical Examiner's office and by NASCAR officials.

Vehicle data, for the most part, were quantitatively analyzed by Dr. Dean Sicking and the Nebraska team. However, helpful information for the injury causation analysis was derived from review of crash footage and study of the actual wreckage. Output from the analysis of the reconstruction team also formed a basis for the injury causation analysis.

2. Occupant Data

Sources of data to understand the occupant injuries include:

- Video coverage of portions of the rescue and emergency care efforts;
- Information from members of the emergency response team;
- Autopsy report with diagram;
- The actual crash–involved helmet
- Report of injury causation conclusions by Dr. Barry Myers.

Photographs taken at the time of autopsy are under seal and not available for examination.

B. Vehicle Inspection

After reviewing the basic crash footage, the available autopsy data, and the injury causation analysis report by Dr. Myers, a vehicle inspection was performed on 29 May 2001 by Dr. Raddin. This inspection was performed in Hickory, North Carolina. On the following day, discussions took place with various members of the Rescue and Emergency Response Teams. On 3 July 2001, an additional vehicle inspection was performed by Drs. Benedict and Raddin. During the vehicle inspections, photographs were taken to document specific findings. During the initial vehicle inspection, the restraint system was available, analyzed, and photographed.

C. Helmet Examination

On 20 June 2001, the crash-involved helmet and two additional helmets were CT scanned at North Carolina Baptist Hospital. This was undertaken for the purpose of assessing potential areas of crush to the impact-protective liner within the helmet. The crash–involved helmet was physically examined by Dr. Raddin at a later date.

D. Testing Activities

The Nebraska team performed activities in the areas of modeling, crash reconstruction analysis, and full-scale crash testing of an exemplar vehicle into a barrier. Data from these efforts were utilized to define parameters for a sled test which was performed on July 20, 2001 at Autoliv in Auburn Hills, Michigan. Testing was also carried out at Autoliv to define force–deflection characteristics of exemplar steering wheels and separation characteristics of exemplar belts. Information from these activities were taken into account in the injury causation analysis.

III. Findings and Conclusions

A. Vehicle Dynamics

1. The impact with the wall was a severe crash.

The severity of a crash when a car hits a wall is determined not so much by the speed of the car at wall contact but rather by the component of that speed which is directed towards the wall. If a car going at 150 miles an hour simply brushes against a flat wall because its speed is primarily parallel to the wall, the impact may be very modest. If, on the other hand, a car going 150 miles an hour directly towards a flat wall makes contact with that wall, the crash is vastly different. To assess the severity of wall contact, therefore, it is necessary to assess the velocity (speed with consideration of its direction) and the component of that velocity that is perpendicular to the wall. In the crash of the Three Car, the speed was in excess of 150 miles an hour, but the velocity was such that the component directed towards the wall was approximately 37 to 38 miles per hour, based on the crash reconstruction analysis.

The component of the velocity parallel to the wall at the impact point does not have to be reduced all at once because the car can slide along the wall. This reduces its speed as a result of friction against the wall in a relatively gradual manner. The component of velocity towards the wall, however, must be reduced rapidly during the crash event. That velocity component is reduced not just to zero but actually continues to be reduced even more to the point that the vehicle develops a velocity away from the wall on rebound. The total velocity change in the impact is a combination of the component of velocity towards the wall prior to the impact plus the rebound velocity. An additional contribution to the total velocity change may also occur on the basis of wall curvature towards the vehicle as the vehicle slides along the wall during the crash. This contribution is made proportionate to the wall curvature throughout the time the vehicle is in contact with the wall. The total velocity change during the crash of the Three Car was approximately 42 to 44 miles per hour.

This is a severe velocity change for a vehicular impact. By comparison, Federal Motor Vehicle Safety Standards governing performance of protection systems in passenger vehicles mandate testing with barrier impacts at 30 miles per hour. These impacts produce velocity changes typically in the range of 32 to 33 miles per hour. This range is tested routinely, but it is not a minor event. It is equivalent to sitting in a parked car which is struck head-on by a similar car traveling at 60 miles per hour.

Even more strenuous tests are performed to assess protection performance at higher limits. These are generally conducted at 35 miles per hour into a barrier, producing velocity changes in the neighborhood of 38 miles per hour. These differences and the difference between these levels and a velocity change in the 42 to 44 miles per hour range are highly significant since the work required to stop a vehicle and an occupant in a crash is related to the energy of the crash rather than a simple linear relationship to velocity change. The energy associated with a 38 miles per hour velocity change is approximately 37 percent higher than the energy associated with a 32.5 miles per hour velocity change. The energy associated with a 43 miles per hour velocity change is about 75 percent greater than that associated with a 32.5 miles per hour velocity change. The 43 miles per hour velocity change is equivalent to the velocity developed in a fall from approximately 62 feet, neglecting air friction. It compares to sitting in a parked car which is struck head-on by a similar car traveling over 75 miles per hour. Impacts of this severity are extremely rare and are beyond the range of generally expected protection using conventional passenger vehicle protection techniques. When assessing outcomes with conventional passenger car restraints, a substantial portion of conventional passenger car occupants in such a crash would be expected to experience fatalities or serious injuries. In fact, the vast majority of fatal outcomes in motor vehicle traffic accidents involving frontal collisions occur at velocity changes below 43 miles per hour. A comparison of the severity in terms of drop height equivalent is shown in Figure 2.

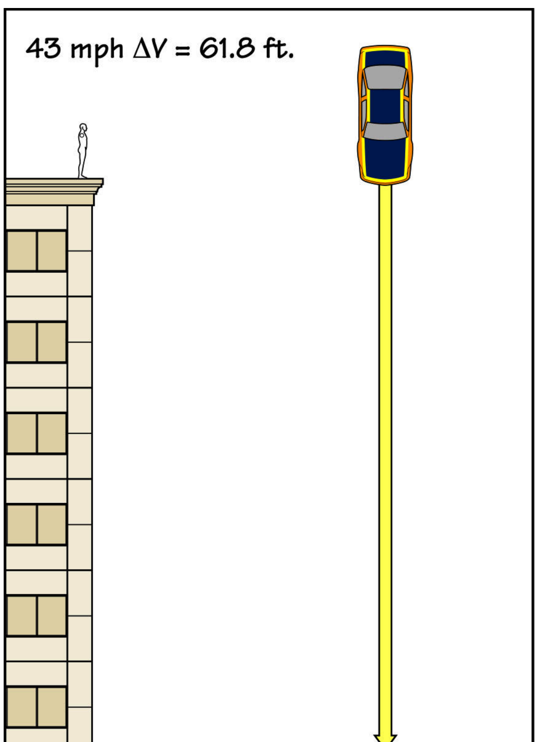


Figure 2

There is yet another aspect of the severity of this crash that must also be considered. That aspect is the acceleration level experienced during the crash. Typical passenger vehicle crashes occur over time periods of approximately one tenth of a second. The longer the time period that is allowed for a crash, the lower the acceleration required to produce the velocity change. If several seconds were available to decelerate from 43 miles per hour, the task could be accomplished without producing injury. However, several seconds would require a large distance in which to accomplish the stopping. That distance is not available in either passenger cars or racecars. Therefore in passenger cars, the velocity change occurs in approximately one tenth of a second, and filtered peak accelerations would be expected in the neighborhood of 40gs. Racecars require stiffer structures to provide greater control and handling as well as protection over a wide range of crash types. Therefore, crush distances are generally less and crash durations are generally shorter resulting in higher peak accelerations. The effective crash pulse duration in the impact of the Three Car against the wall was in the range of 70 to 80 milliseconds, likely resulting in extremely high peak accelerations. Even when the acceleration curve is filtered to assess the accelerations of biomechanical significance to the occupant, the smoothed acceleration levels were likely between 45 and 50g's in the crash of the Three Car. Unfiltered peak accelerations would be much higher. In that regard, it is important to understand the applied filter when attempting to compare these levels with those reported for other race car crashes. If less filtering is applied, peaks in this crash might be expected at levels ell above 100g's. Similar filtering needs to be applied if different data sets from different crashes are to be meaningfully compared.

Clearly occupant protection modalities were present in the Three Car which would not be practical in conventional passenger vehicles. Therefore, the driver would be expected to receive some protection benefits at crashes of significantly greater severity than those typically survived by occupants of passenger vehicles. However, the severity of the reconstructed crash of the Three Car is one which provides challenges to the protection capabilities even for racecar occupants. Even the highest acceleration levels tolerated by experimental subjects in early rocket sled experiments with elaborate experimental restraint systems have been performed with some injury in the range of approximately 45g's. Even these tests were conducted in a fashion in which significant protection was afforded to the occupant as a result of the mechanical characteristics of the equipment in which the impact was produced (Raddin, 1982). The conclusion is therefore clear that the crash of the Three Car was an extremely severe impact as a result of an unusually high component of velocity towards the wall in a relatively short, high acceleration crash pulse.

It should be noted that the severity of the impact of the Thirty-Six Car with the wall was substantially lower since the component of the Thirty-Six Car's velocity towards the wall was significantly less than that of the Three Car.

2. The direction of the crash impact accelerations was generally frontal and slightly from the right.

Assessment of vehicular crashes also requires knowledge of the direction of action for the forces on the vehicle. Examination of the crashed vehicle shows crush damage typical of a crash in which the forces on the vehicle come from the right front which would typically cause an occupant to move both forward and to the right with respect to the racecar. As the forces are applied between the wall and the vehicle, the vehicle is pushed both leftward and rearward relative to the occupant, and the occupant, in obedience to Newton's First Law, continues generally forward and rightward with respect to the vehicle. These are the directions that would have been expected had a dummy occupant been present during the Nebraska Team's full-scale crash test into the wall. However, this was not the crash direction experienced by the Three Car, since the barrier crash test did not duplicate the component of the velocity of the Three Car that was generally along a direction parallel to the wall. The down-track velocity resulted in friction losses which slowed the velocity of the vehicle along the track and parallel to the wall. This slowing of the vehicle was a part of the overall velocity change to the Three Car. The slowing of the down-track velocity resulted in forces on the Three Car which generally came from the left and slightly forward. The occupant on the basis of that component alone would have tended to move largely to the left and only slightly forward. The actual motion of the occupant of the Three Car with respect to that car was a combination of the two responses. Therefore, the component parallel to the wall tended to produce a leftward component which negated some of what would otherwise have been a larger rightward component resulting in a net motion that was more forward than would be expected on the basis of the angle of the vehicle crush line. The actual net principal direction of force resulted in motion that was generally forward and modestly to the right in a direction with respect to the car that would parallel the hour hand of a clock when the clock is reading a time between 12:40 and 12:45. In other words, this would be a direction between two thirds and three quarters of the way between the 12 o'clock position and the 1 o'clock position of the hour hand, or about 20 to 22.5 degrees to the right from straight ahead.

It should be noted that this direction would be different from that expected for the driver of the Thirty-Six Car during his wall impact. He likely tended in a direction that was both forward and more significantly rightward with respect to the vehicle.

3. There was a biodynamically significant impact to the Three Car prior to its contact with the wall.

Just prior to wall impact, the Three Car moved rapidly into the path of the Thirty-Six Car, which was located between the wall and another racecar.

Prior to the first untoward event, the speeds of the Thirty-Six Car and the Three Car were relatively similar. As a result of the pre-impact maneuvers of the Three Car, there was a loss of velocity compared to the Thirty-Six Car. In addition, the direction of the Three Car was substantially changed so that the down-track component of the velocity of the Three Car was significantly less than that of the Thirty-Six Car. These circumstances resulted in an impact between the Thirty-Six Car and the Three Car shortly before wall impact. Clear evidence of contact can be observed in the various video coverages, including motion of the left rear wheel of the Three Car in a direction strongly to the left with respect to the Three Car chassis as a result of the contact to the right rear wheel of the Three Car by the Thirty-Six Car. The overall contact resulted in the Three Car being pushed significantly to the left and somewhat forward. The velocity change associated with this contact was in the range from approximately 9 to 11 miles per hour, based on the reconstruction analysis. This velocity change, brought about during the short duration of a vehicle-to-vehicle impact, was sufficient to result in significant displacement of the driver occupant of the Three Car.

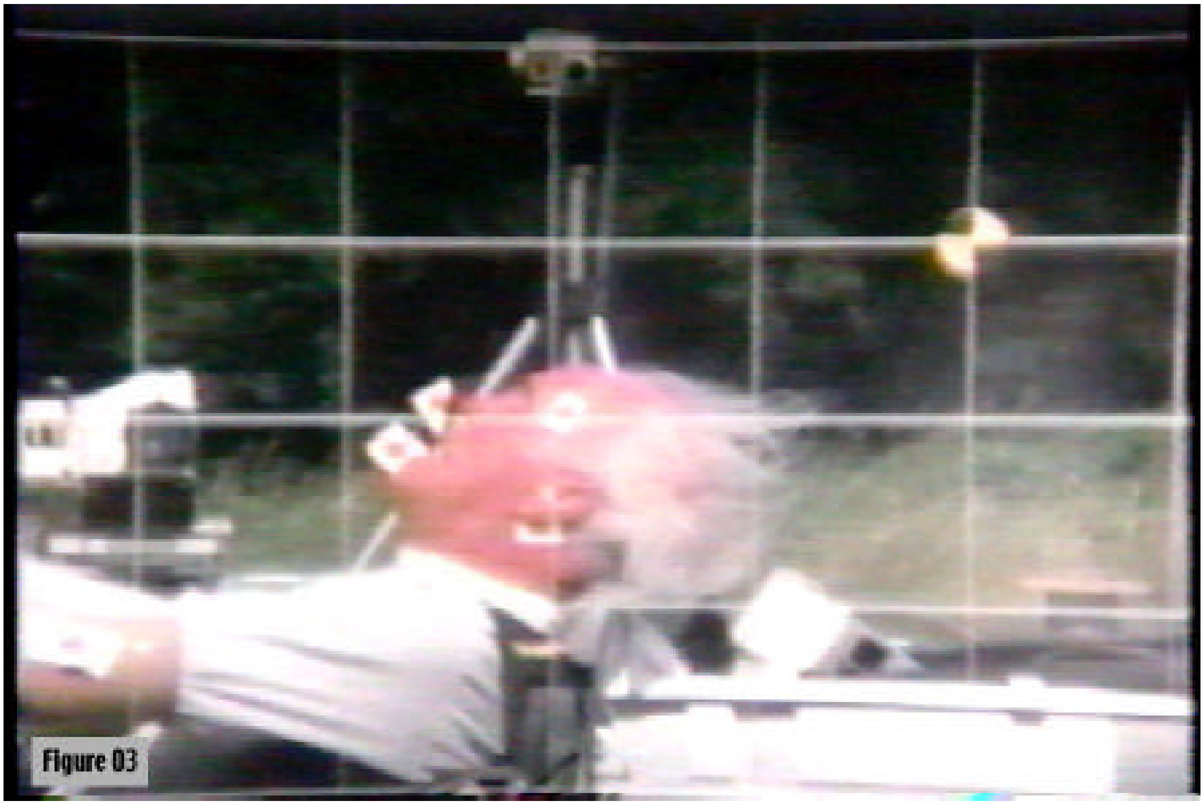
4. The time of the prior vehicle-to-vehicle impact was significantly less than one half second prior to the time of the Three Car impact with the wall.

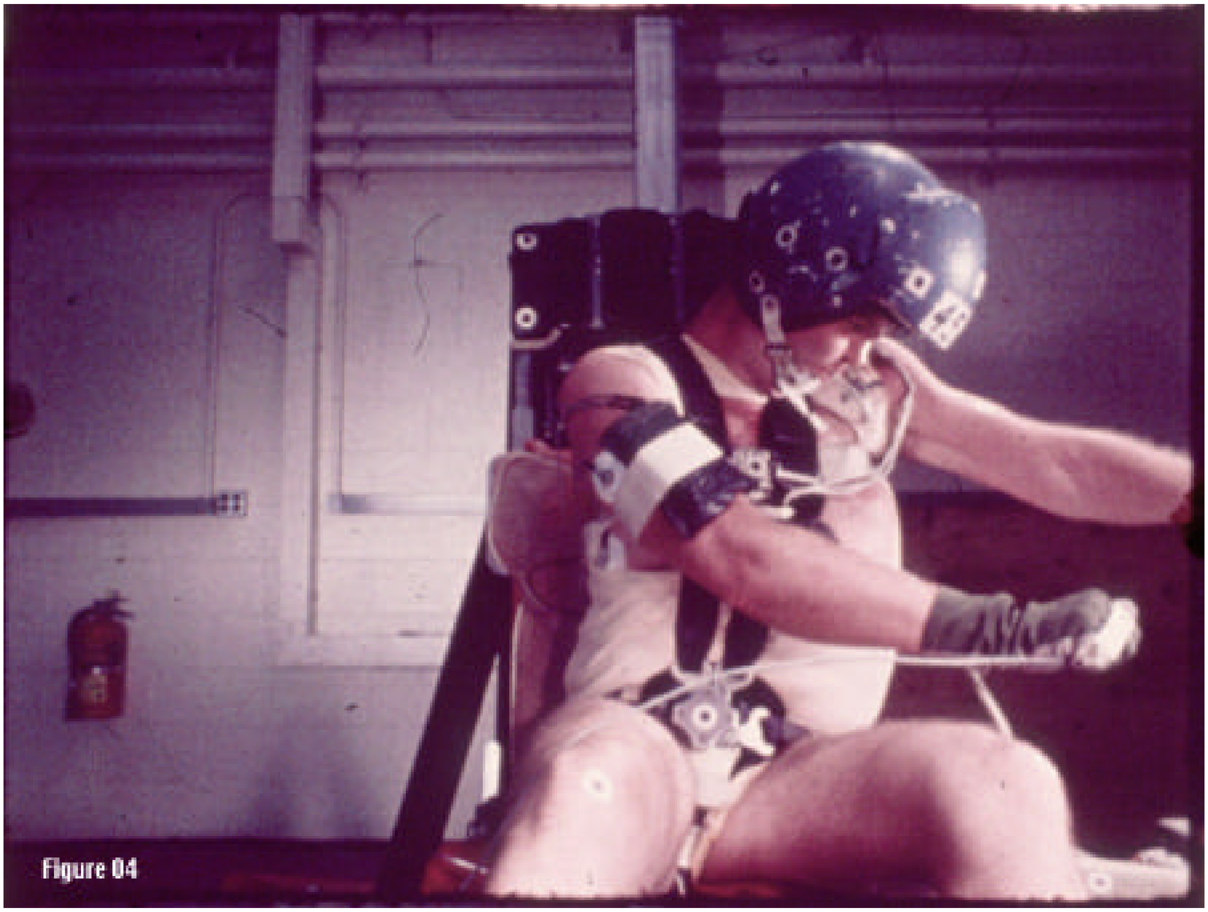
Reference to the accident reconstruction analysis, the track video coverage, and the in-car camera coverage with sound pick up from the Three Car all provide basis to conclude that the two impacts were separated by a time interval of approximately 400 milliseconds (less than twice the duration of an eyeblink), but the vehicles continued in contact during this period.

B. Occupant Kinematics

5. The occupant of the Three Car was placed in an unusual position at the time of wall impact as a result of the prior vehicle-to-vehicle impact.

Dale Earnhardt's driving position was customarily one with his head placed significantly to the left relative to the midline of his seat. Whether he moved his head from this position in the early maneuvers is not known. At the time of the impact with the Thirty-Six Car, forces were placed upon the Three Car sufficient to displace the occupant in a direction significantly to the right with parts of the occupant's body moving also somewhat rearward. Impacts conducted with human volunteers in the past have demonstrated significant response to impacts in the range of severity of that from the collision with the Thirty-Six Car. For example, Figure 3 shows the response of a volunteer human subject in a rear-end impact at 6.4 miles per hour velocity change. This is in a different direction with a much lower velocity change and a much lower acceleration level. Figure 4 shows the response of a helmeted volunteer subject in a pre-tightened, modified five-point restraint to a straight lateral impact with a significantly higher velocity change but a more similar acceleration level. The head response of the Three Car driver was likely greater than that of the volunteer in Figure 4, but with similar characteristics.





Findings in the vehicle are also consistent with this motion. Figure 5 shows a view of the driver's position in the Three Car. Figures 6 and 7 are close-up views of the upper wing of the seat which is conventionally to the right of the right upper torso and under the right arm of the seated occupant. This wing shows a scuffing of the vinyl surface in two directions with a fabric pattern imposed into the vinyl and a bunching of the vinyl in a direction to the right and somewhat rearward with respect to the seat. There is also some bending of the seat wing to the right. The scuff also shows a later forward component. The rightward scuffing and bending of the seat wing would not be expected unless the occupant was moved to the right from the Thirty-Six Car impact. The later vehicle motions should not have taken the occupant toward this structure to the extent demonstrated in the Three Car.

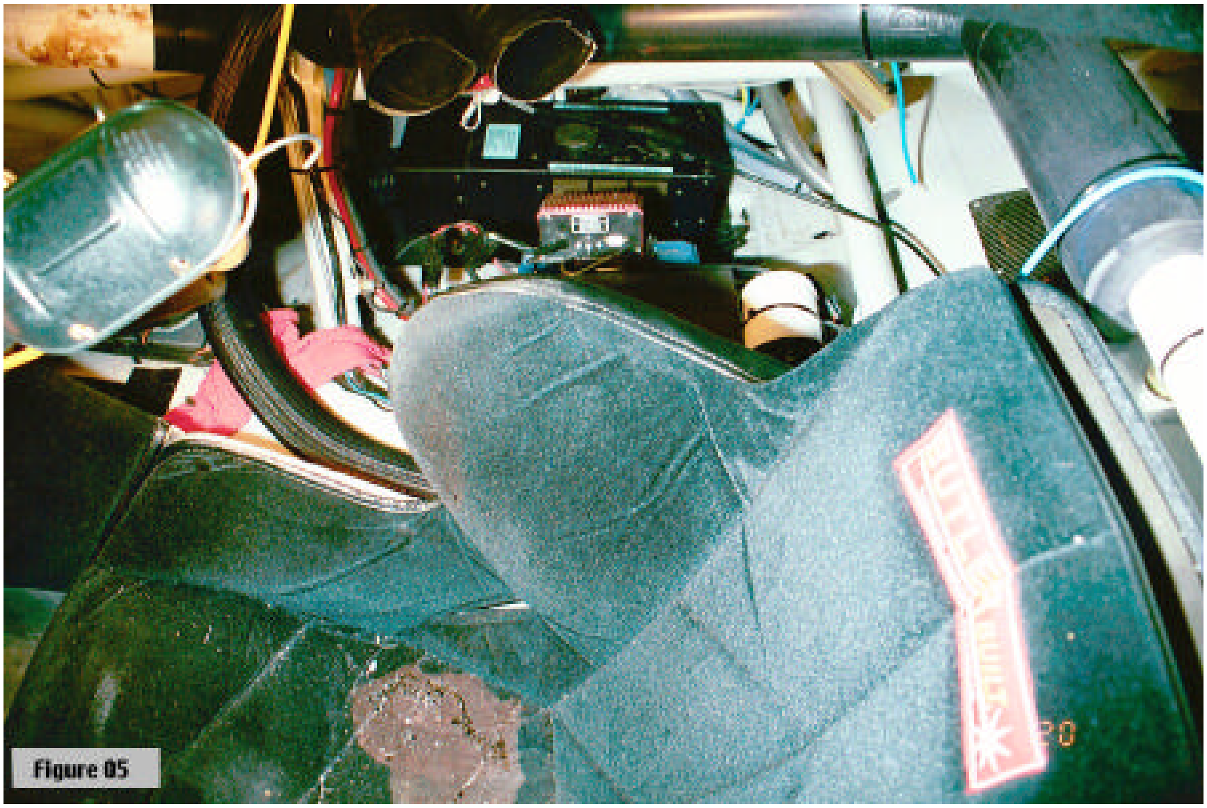
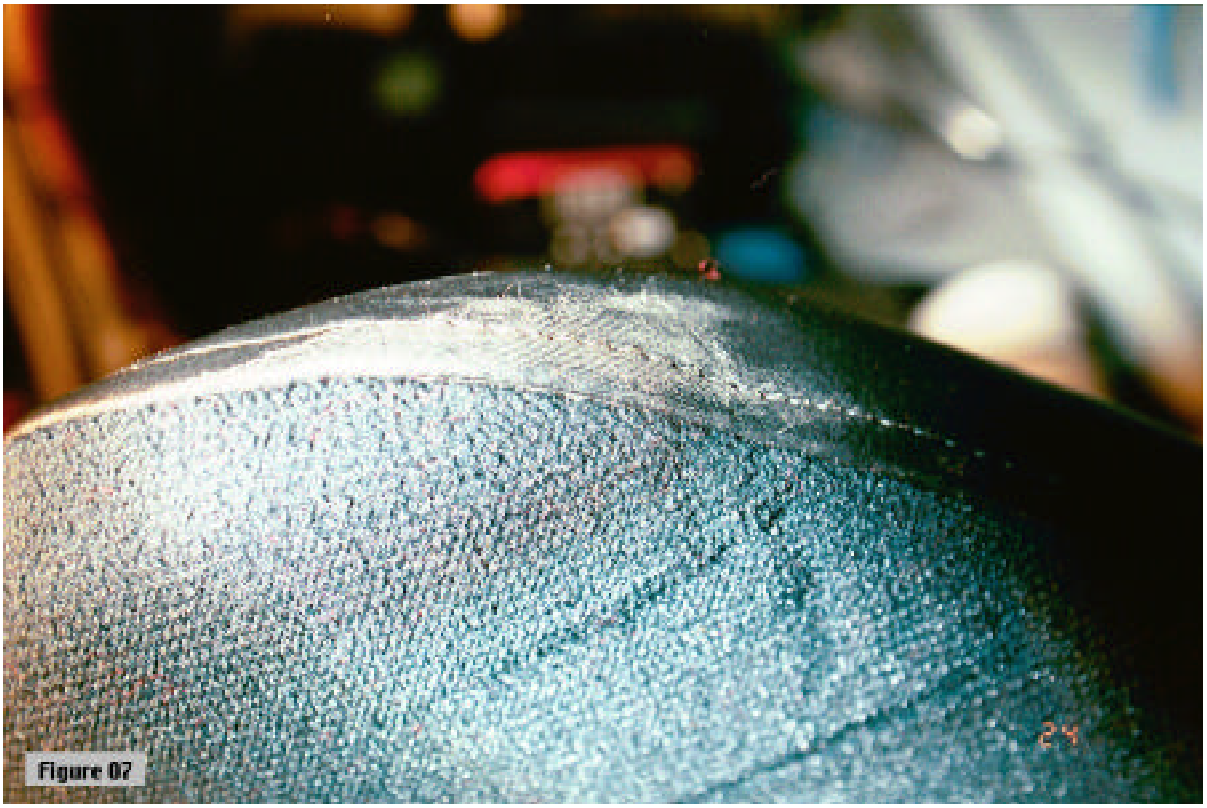


Figure 05


Figure 06



The head of the occupant was displaced to the right as a result of the Thirty-Six Car pushing the Three Car to the left and somewhat forward out from under the occupant. As the head continued its pre-impact motion, that rightward displacement was arrested by forces through the occupant's neck. However, the occupant's helmet would continue to the right and rearward in obedience to Newton's First Law, being arrested by forces through the chinstrap and friction forces against the back of the head. The resulting motion would tend to rotate the helmet up and forward with respect to the head with the helmet rotating somewhat about the chinstrap. Somewhat greater helmet rotation would be expected for Mr. Earnhardt than is shown in Figure 4 since the volunteer's helmet included a nape strap to minimize forward rotation of the helmet. The occupant of the Three Car would be expected to be in the process of this response at the time of the wall impact as a result of the short time interval between the two impacts.

By contrast, the driver of the Thirty-Six Car would respond to his impact with the Three Car in a much more forward direction and somewhat to the left. Such a response would tend to load him into his restraint system and produce forward and somewhat leftward neck flexion, constituting a potentially beneficial dynamic preload for his subsequent wall impact which was also different, both in direction and severity, from the wall impact of the Three Car.

6. Without a prior impact, the occupant's response would be expected to be generally forward and slightly to the right.

If the Thirty-Six Car impact had not occurred, the occupant's head would be expected to start from his customary position somewhat to the left with respect to the center line of the seat resulting in relatively symmetrical loads to the lap belt and shoulder harness portions of the restraint with the potential for some contact between helmet or head with steering wheel in a generally frontal fashion for a crash of this severity. Contact with the steering wheel, if it occurred, would be expected to be in a fashion such that the wheel would be loaded generally out of plane in a forward direction. That would be the preferential direction for loading to minimize head impact injury potential. The upper torso would load relatively symmetrically against the restraints since the hips would tend to start out generally centered in the seat, and the upper torso would be deviated somewhat to the left based upon the driver's customary positioning. Therefore, the hip and upper torso would transition from somewhat left, moving generally forward and slightly right, in a reasonably symmetrical load against the restraints.

7. The initial response of the occupant was forward and slightly rightward from a starting position that was substantially deviated to the right resulting in an asymmetric load and an unconventional response.

In the actual event, the occupant's body had been prepositioned significantly to the right as a result of the prior impact with the Thirty-Six Car. Therefore, the occupant's right leg moved forward and rightward from a rightward position resulting in loading against the leg guard displacing it forward and to the right as shown in Figure 8. The hips transitioned forward and slightly rightward from a position already displaced to the right leading to an asymmetric load on the lap belt. This asymmetry was likely heightened somewhat by the driver's customary habit of wrapping the crotch strap around the front of the seat rather than through the slot in the seat. This configuration is demonstrated in Figure 9 showing an exemplar vehicle and restraint. The slot would have tended to provide a centering force on the buckle which would not be present during the initial load with the crotch strap around the front of the seat. The net result would be to have an altered angle of pull on the left seat belt anchor from that which would normally be present. In addition, the severity and nature of the impact as previously described would result in a significantly higher tension being initially applied to the left belt webbing.

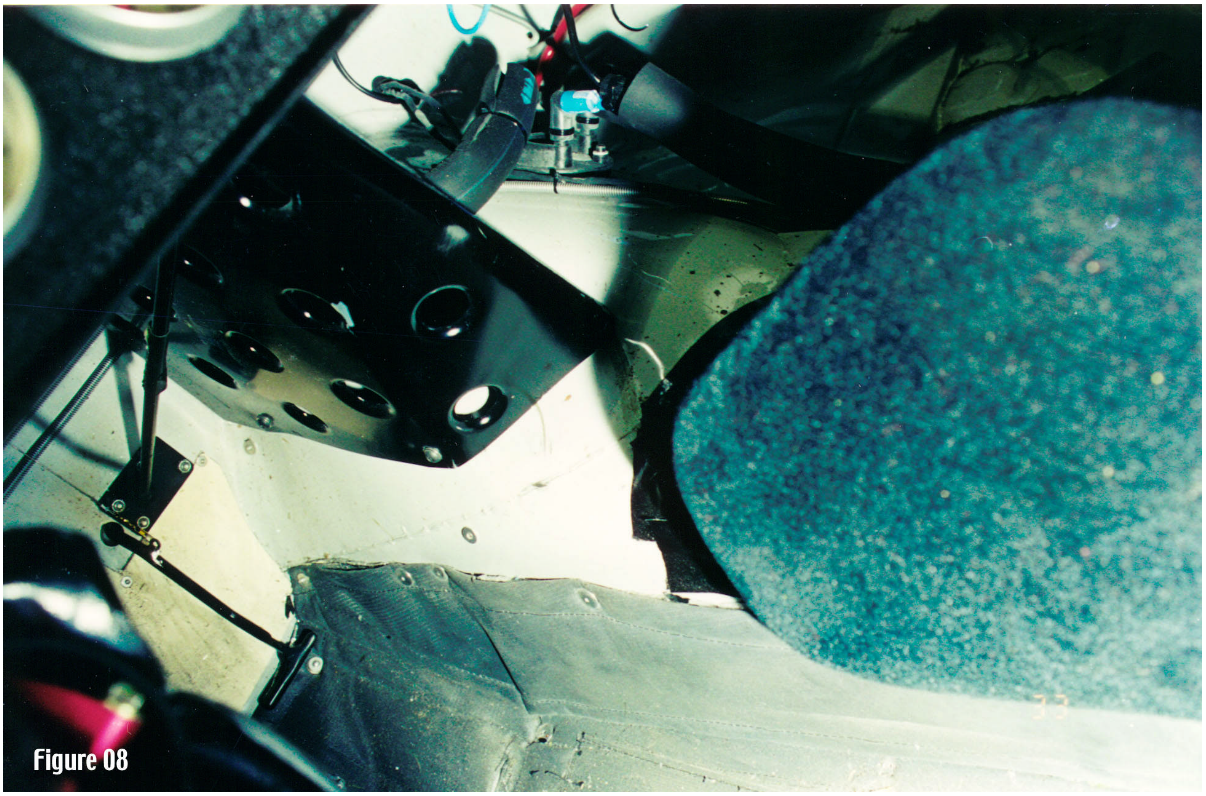


Figure 08

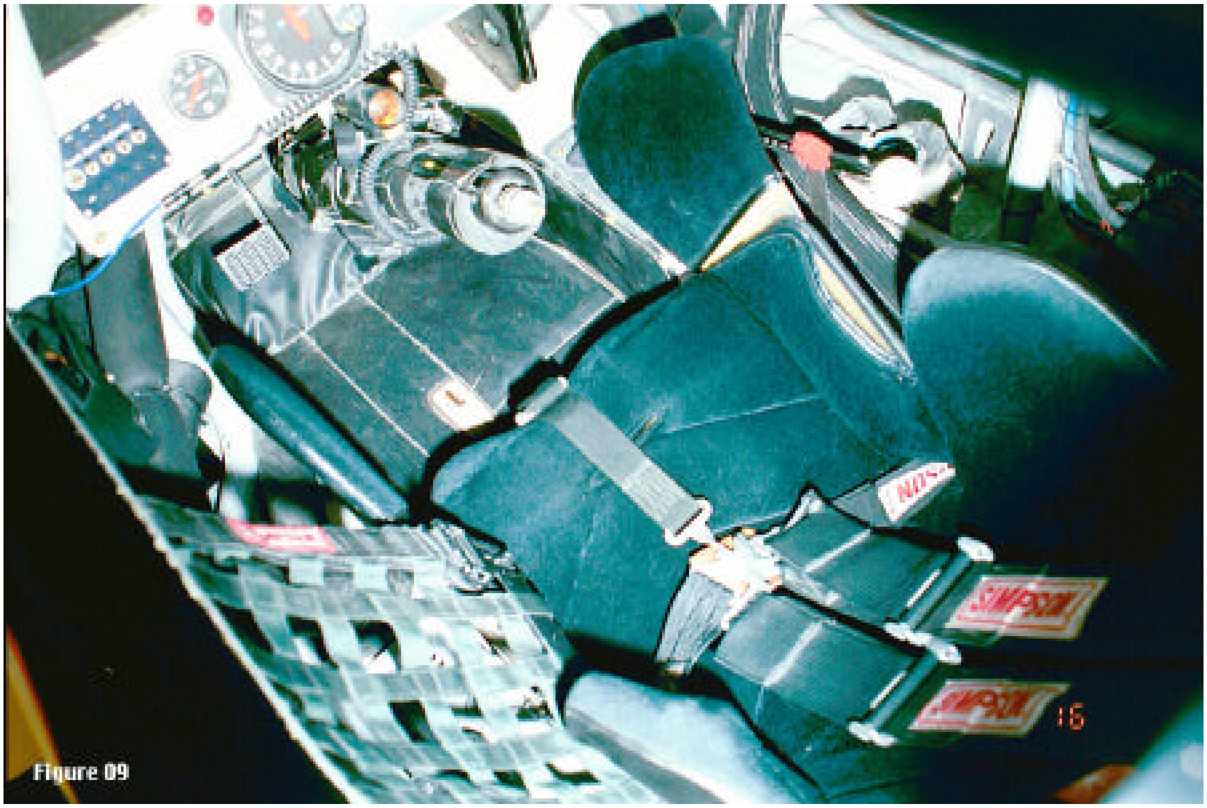


Figure 09

At the wall impact, the head began its motion forward and to the right from a position displaced significantly to the right with the helmet already rotated somewhat with respect to the head as a result of the response to the Thirty-Six Car impact. The initial forward motion of the head and helmet would not provide further relative displacement between the two because their initial motion forward and to the right with respect to the vehicle would be based upon their joint obedience to Newton's First Law. It would simply be a continuation of the pre-impact motion. However, as that motion continued, the torso would be expected to make earlier contact with the left shoulder harness resulting in a tendency to restore the upper torso to a more frontally aligned direction. Furthermore, the head would then experience a deviation from its forward and to the right travel as a result of forces mediated through the neck derived from the fact that the torso would have been substantially slowed and reoriented by the two shoulder harnesses. This would cause the head to begin to swing back to the left with the left side of the head leading. This motion of the head as a result of forces placed from the neck would now cause some further tendency to dislodge the helmet from the head. Therefore, it is likely that the head was not only somewhat left leading but that the helmet was displaced somewhat forward and to the right with respect to the head leaving portions of the left posterior part of the head to be relatively uncovered.

8. The left lap belt webbing separated under load during the impact of the Three Car with the wall.

At some point during the initial response of the occupant to the wall impact, the left lap belt webbing separated. This conclusion is based upon several lines of evidence including the following:

- Reports of the Emergency Response Team describe the lap belt buckle as being displaced from its normal, generally centered position to a position well over towards the right hip (Figure 10 shows an exemplar belt system in an exemplar vehicle depicting the normally central buckle placement);
- A photograph taken by the Medical Examiner's Office of the Three Car at Daytona shows the separated lap belt. (Figure 11);
- Observations by NASCAR officials examining the car later revealed the separated webbing with the adjustment length of webbing loose in the adjuster. The webbing attaching the adjuster to the left floor anchor was significantly displaced towards the upper corner of the adjuster;
- Physical evidence on the webbing;
- Physical evidence in other portions of the Three Car;
- Physical evidence in the form of occupant injuries.
- Other studies including fiber analysis, DNA analysis and an investigation with interviews of those in a position to observe or access the belt.

Figure 10

Figure 11

Considerable controversy has arisen regarding the issue of belt webbing separation. The issues relating to witness statements and other studies have been analyzed elsewhere. Our analysis addresses the physical evidence.

Three-inch belt webbing provides a larger area for force application during severe impacts provided that the belt remains reasonably flat against the loading surfaces both for anchors and for the occupant. In practice, this load-bearing surface area can be somewhat narrowed if the webbing folds so that the load-bearing area against the occupant is narrowed. Similarly, wide webbing can provide a larger load-bearing area against restraint system fittings such as adjusters used to tighten or loosen the webbing during use. Particularly with asymmetric loads, the webbing may undergo "dumping" within the fittings. Dumping is illustrated in Figures 12 and 13 in which it is depicted that a length of webbing on opposite sides of an adjuster may slide to opposite ends of that adjuster under significant tension since such a motion allows a parallelogramming in which the restraint can lengthen under load somewhat by the adjuster changing its angle and pulling more along a diagonal of a square or rectangle than along its sides. The lengthening occurs as a result of the diagonal being longer than the sides and the load-bearing surfaces forming a ramp. This tendency is particularly increased when the webbing is not evenly placed in the adjuster to start with or under the influence of asymmetric loads.

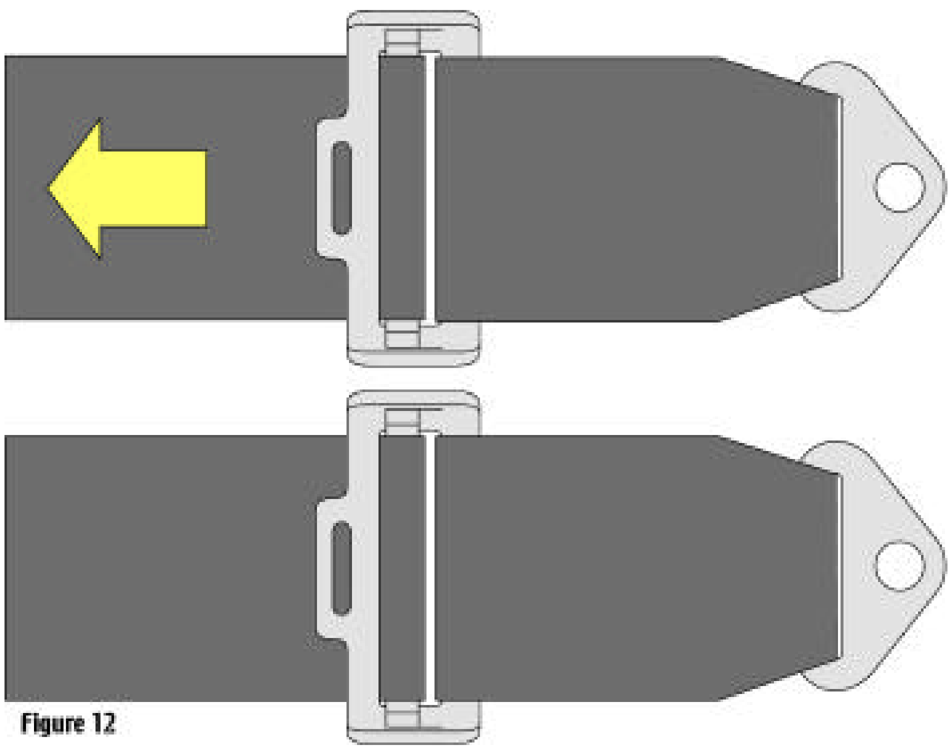


Figure 12

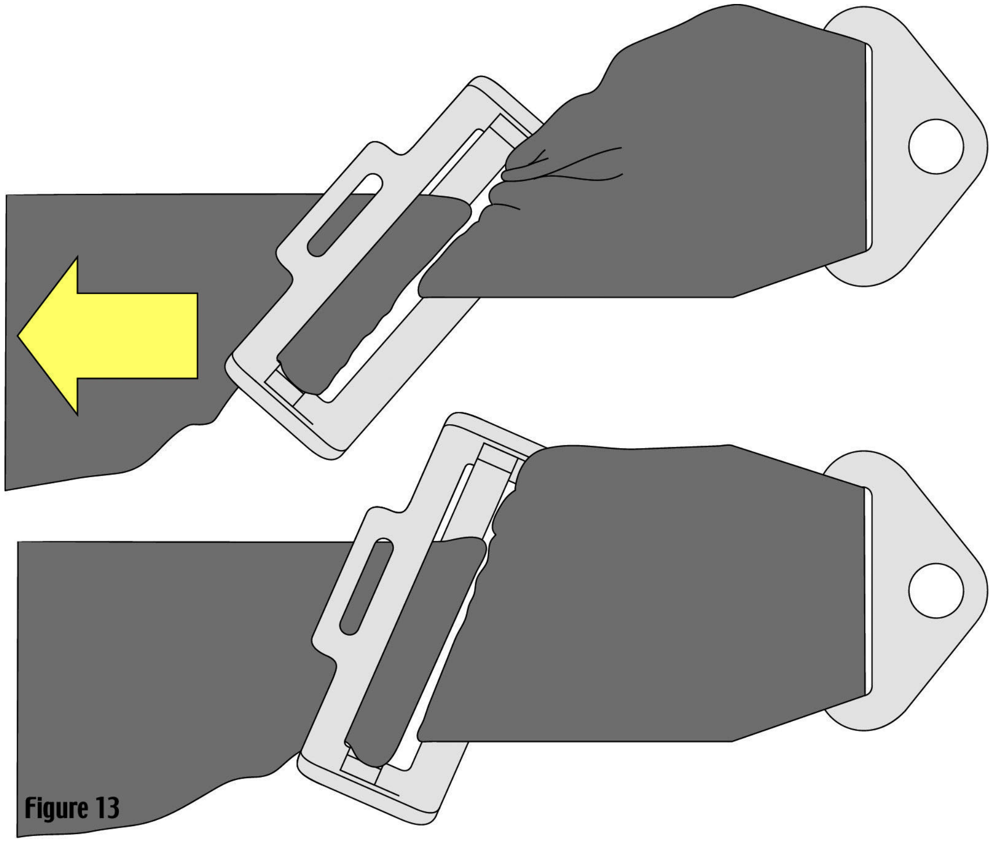


Figure 13

Figure 14 is a photograph taken by NASCAR personnel who discovered the torn webbing. Figure 15 is a photograph taken of the involved adjuster placed next to the NASCAR photograph showing the webbing dumped to one side of the adjuster. Figure 16 shows the restraint system from the Three Car with greater detail of the webbing separation shown in Figures 17 through 23.

Figure 14

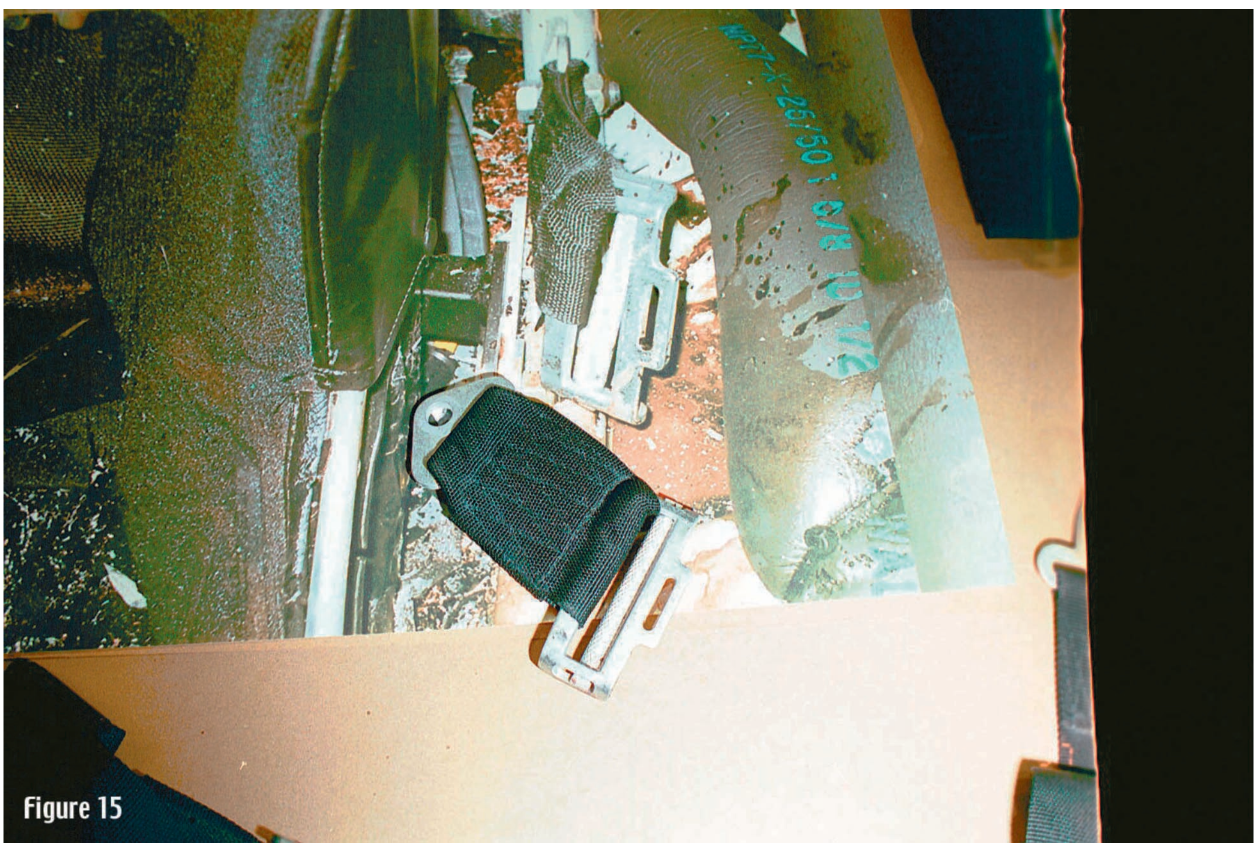


Figure 15

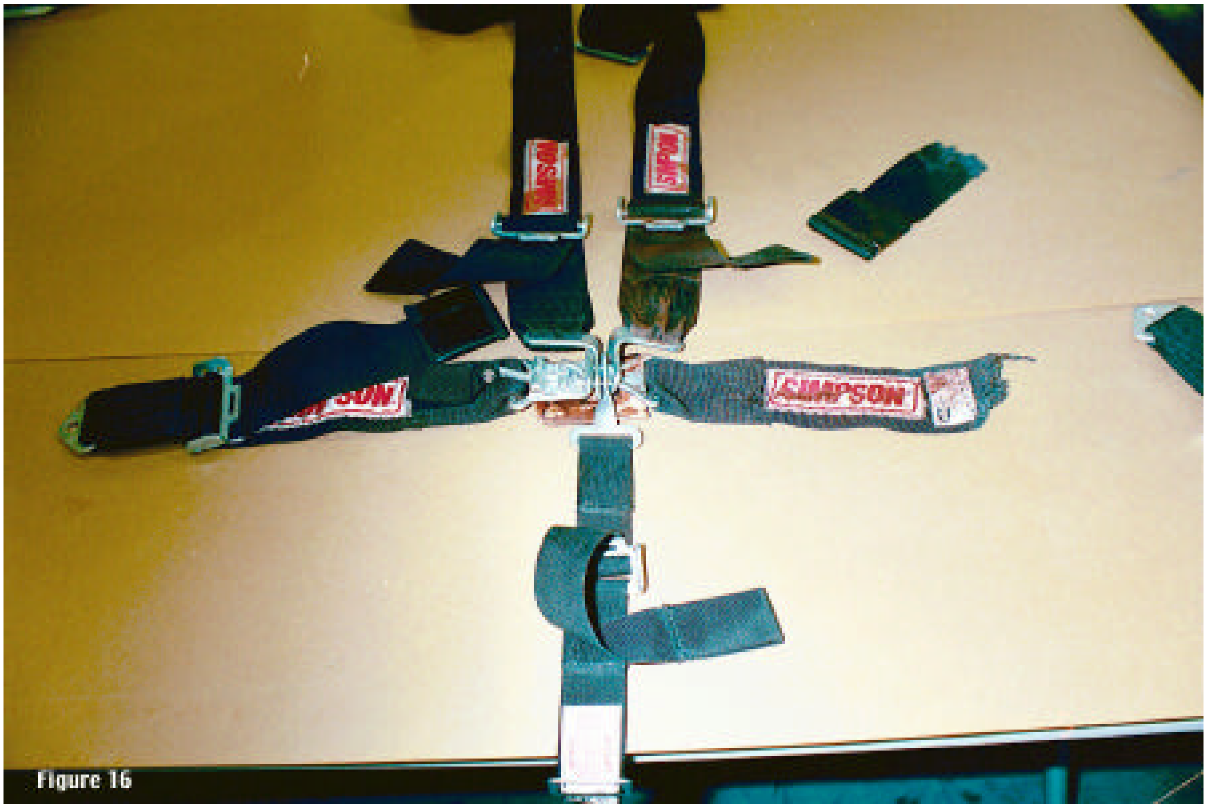


Figure 16

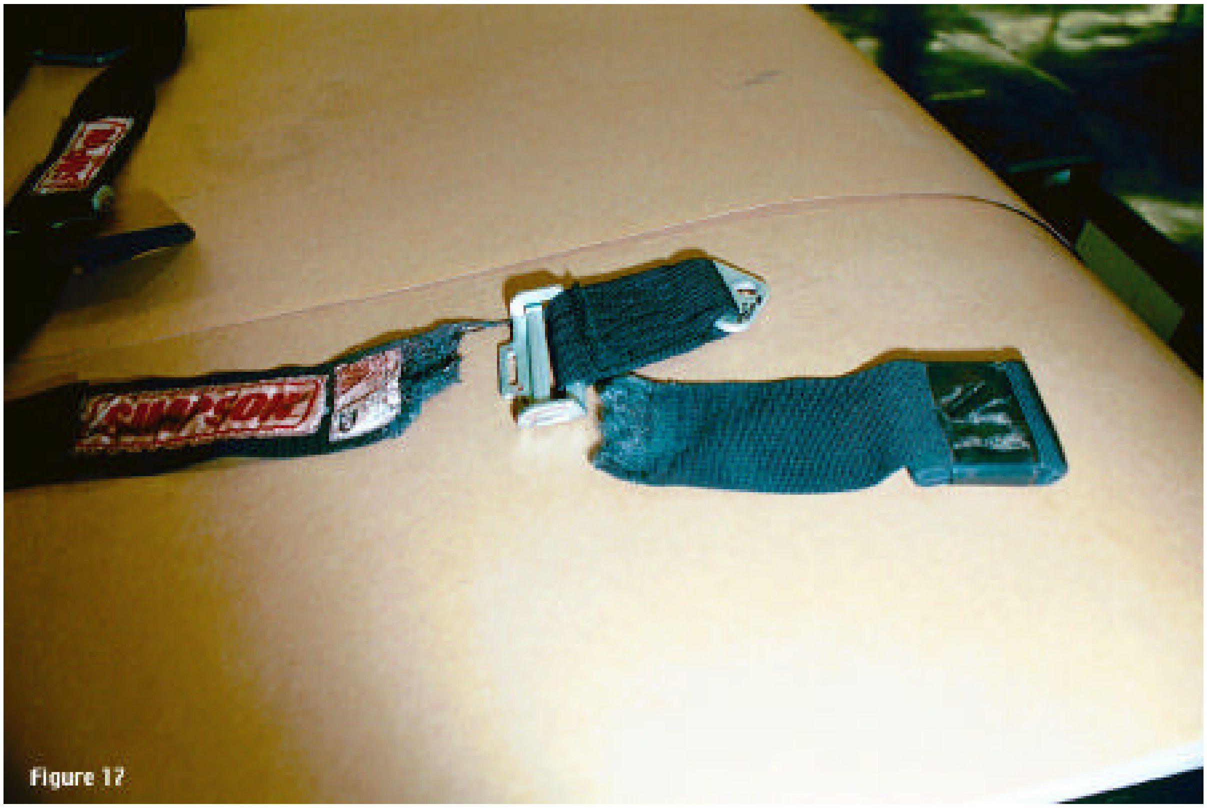


Figure 17

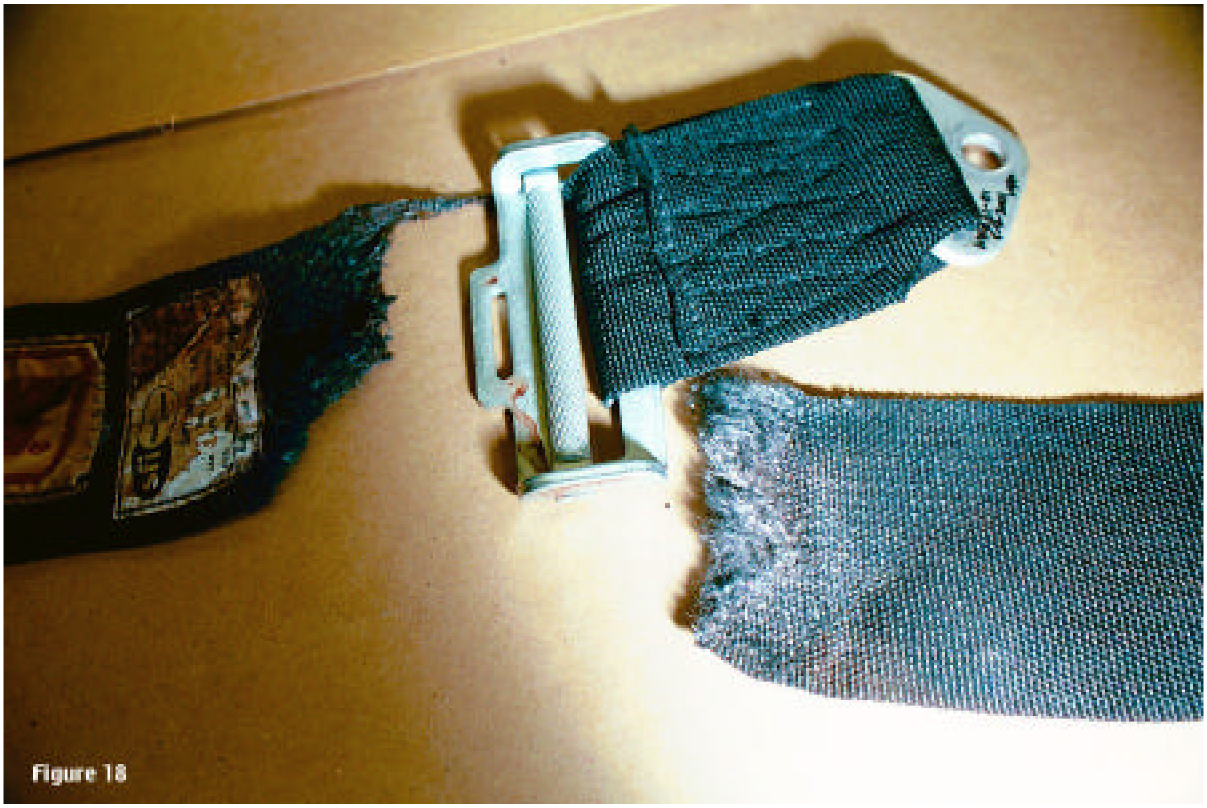


Figure 18

Figure 19

Figure 20

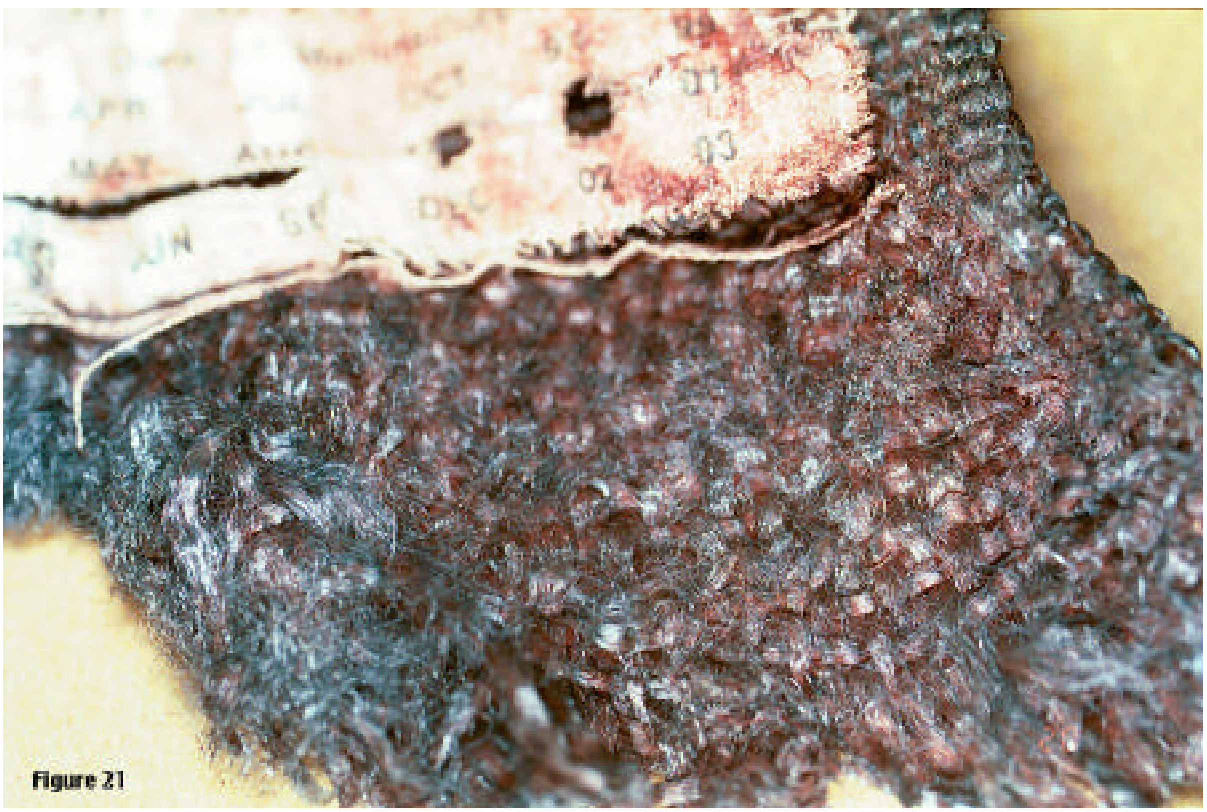


Figure 21

Figure 22

Figure 23

It can be seen in Figure 21 that the surface of the webbing shows evidence of substantial roughening as a result of moving against the checkered surface of the adjuster's lock bar under load. This figure also shows that the lap belt webbing was adjusted in a reasonably symmetrical way with the lock bar placed adjacent and generally parallel to the edge of the tag at the time it was loaded. Figure 23 demonstrates that the right side lap belt was similarly adjusted with marks from the adjuster lock bar just encroaching on a portion of the tag. The portion of the tag encroached upon indicates either an asymmetry of initial adjustment opposite to the dumping direction observed on the left side, or a slight tendency to dump in the opposite direction from that observed on the left. Since the webbing elongates to a greater extent under load than the material of the tag, tags are often torn or separated from their stitching when a belt is significantly loaded. The left lap belt tag is torn over part of its distance and separated from its stitching over the remaining distance. These physical findings along with the roughening of the webbing surface by the checkered surface of the lock bar indicates significant load having been placed on that webbing at the time that the separation occurred.

Furthermore, the separation shows separated fibers of reasonably consistent length on one edge of the separated webbing (Figure 22) and a progressively longer group of fibers as one moves to the other edge, a characteristic finding of a webbing separation that begins at the edge of the webbing where the shorter fibers of consistent length are separated. This is consistent with the tear in the portion of webbing around the lock bar occurring at the lower end of that lock bar. That is the condition that would be expected if the webbing on the lock bar side of the adjuster was dumped to the down edge of the adjuster and the webbing towards the floor anchor was dumped as observed towards the up edge of the back of the adjuster. Separation, therefore, occurred at the lower edge of the adjuster in the region near the edge of the adjuster frame and the end of the lock bar. As the separation proceeded across the webbing, the last portions of webbing pulled further through the frame of the adjuster leading to longer wisps of fibers at the edge of the webbing where the separation ended. This also pulled a diagonal portion of the free end (adjustment tab) through the adjuster leaving a characteristic diagonal mark placed there during the separation process. Figures 24 and 25 show details of the metal frame and lockbar at the front of the lower edge. A protrusion (raised area), was consistently present in all the corners of the slots for the adjusters on both sides (Figure 26).

Figure 24

Figure 25

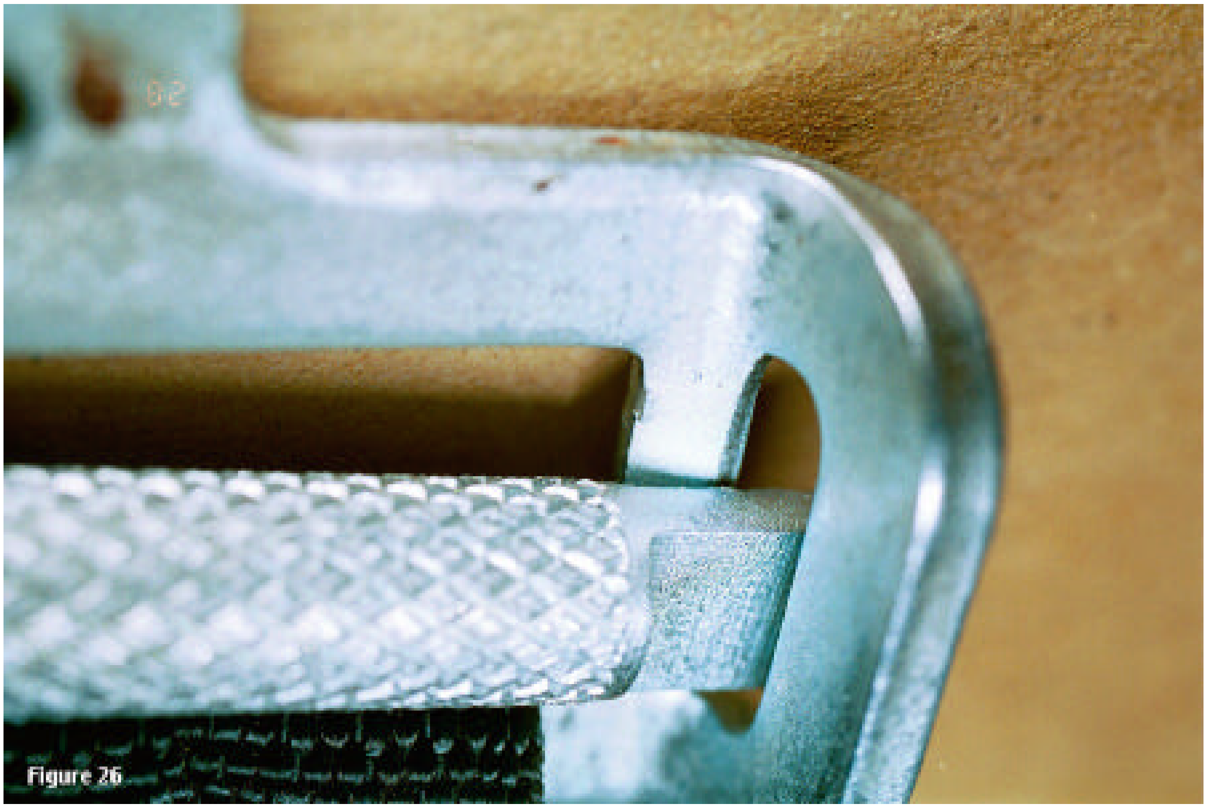


Figure 26

The available data related to the webbing consistently supports the conclusion that the belt separated under load as a result of dumping with the separation initiating on the lower edge of the adjuster at a point at the lower end of the lock bar and the adjuster frame. The findings would not be present if an unloaded webbing was cut. However, additional physical evidence on the seat provides further confirmation. Figures 27 through 29 show two areas of abraded and/or melted fibers on the surface of the seat cover to the right side of the seat bottom surface. The abrasions in the larger, more aft area are directed forward and to the right. Similar findings are not observed on the left side of the seat surface. These findings are consistent with and provide evidence for the conclusion that the occupant moved for a considerable distance against the seat bottom surface during impact with loading directed preferentially to the right side of the seat bottom.


Figure 27

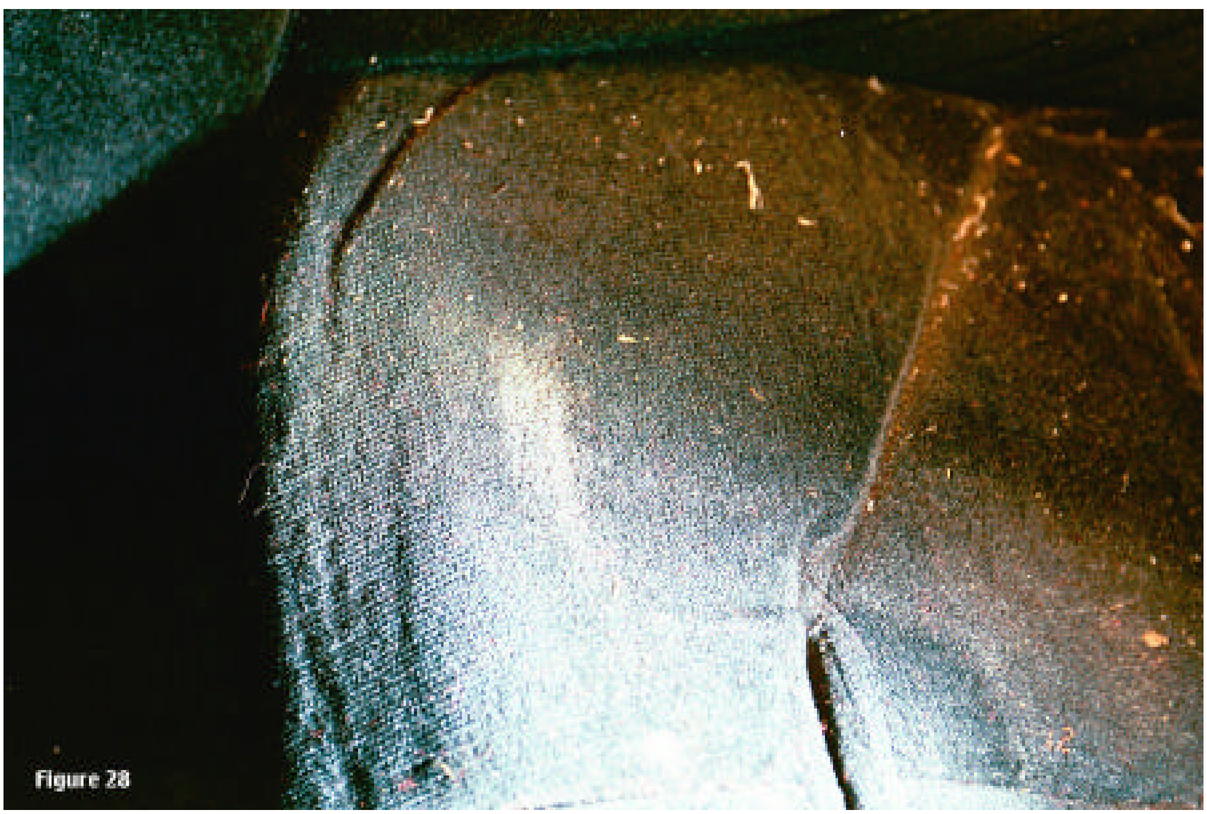


Figure 28

Observations at autopsy on the driver of the Three Car also demonstrated evidence of soft tissue injury consistent with lap belt contact in the region of the left side of the lap belt distribution. This is in the form of a 10 by 2-centimeter area of superficial abrasion which is transversely oriented. The abrasion is in the distribution expected for contact evidence between the occupant and the lap belt while loading the lap belt in a generally forward and rightward response but having started from a position deviated to the right and somewhat rotated in a clockwise direction as viewed from above with respect to the seat. There is, however, no matching symmetrical area of abrasion on the right. Instead, there is a 22 by 5-centimeter area of abrasion that proceeds from the region of the right hip in a downward angle roughly paralleling the inguinal ligament as indicated on the autopsy diagram (Figure 30). This is not a soft tissue injury finding that would be expected for an intact lap belt in the collision of the Three Car. Instead, it would indicate early contact with the intact left lap belt and then, following separation, subsequent contact after moving forward and to the right with the angled soft tissue injury consistent with force applied through the loop formed by the crotch strap and right lap belt after the occupant had moved considerably further forward and to the right than would have been the case had the left lap belt not separated.

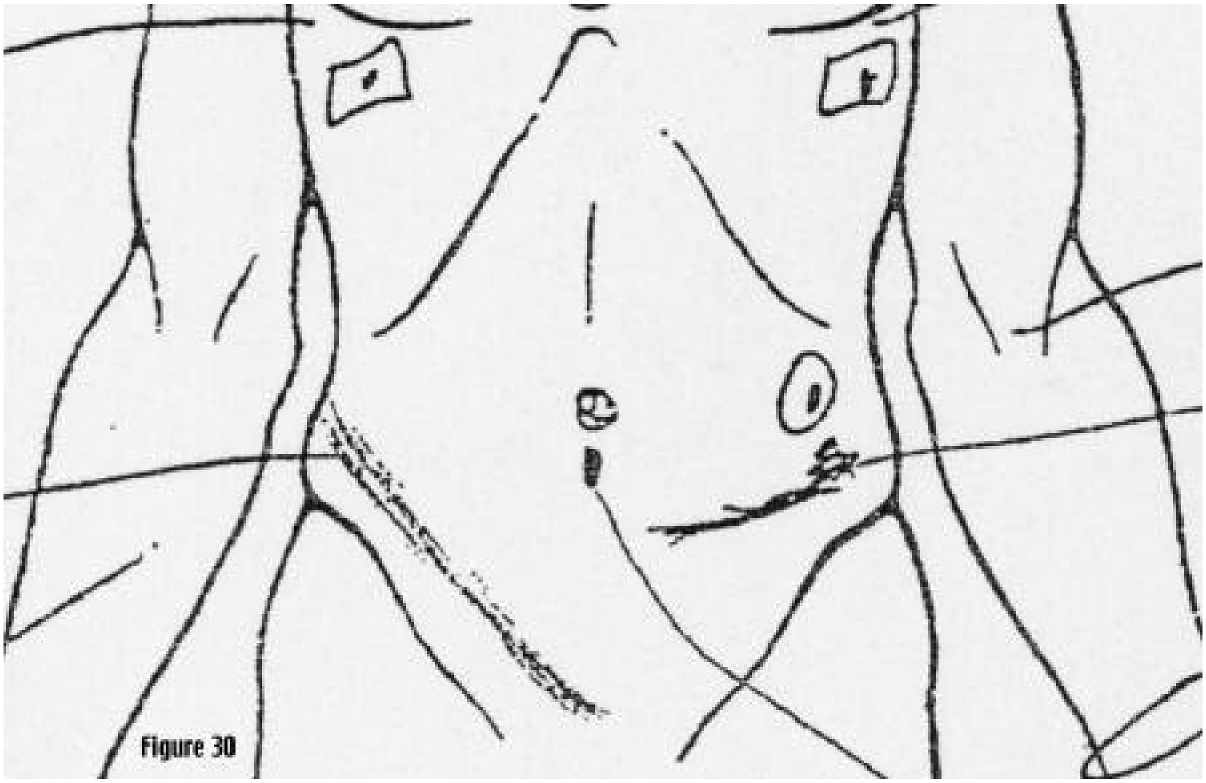


Figure 30

The physical evidence on the restraint system, the physical evidence in the Three Car, and the physical evidence in the form of injuries on the occupant together provide a clear and objective basis to conclude that the left lap belt separated under load during the impact with the wall. It was not cut after the crash. It is clear from the accident reconstruction analysis that insufficient energy existed to expect the belt separation to have occurred at the time of the impact with the Thirty-Six Car. Instead, the wall impact provides the only reasonable candidate for the energy needed to do the work of separating the belt.

The cause of the dumping is not clear. Webbing misadjustment by the driver, however, does not appear to be a factor. Physical evidence on the webbing shows that the lock bar was applied evenly across the webbing and not placed at a significant angle. Nor is there any basis for suspecting misalignment in this direction of the webbing in the right adjuster. The right belt showed evidence of loading with a slight misalignment in the opposite sense from the way that the left belt dumped, either from a slight opposite prepositioning or a slight dump the other way.

Dumping and belt separation can occur on the basis of a number of other factors. These include asymmetries in the direction of pull during an impact event, characteristics of the adjuster, routing of the webbing, and simply severity of the load. In light of the complexity of the occupant kinematics in this accident, it is not possible to determine the extent to which any one of these factors contributed to the dumping and separation of the belt in this case. There had not been a belt separation issue previously identified in NASCAR events in which similar belts, fittings, and routings have been used. The present experience however, should heighten attention to the area of restraints and provide impetus for the development of approaches to minimize the likelihood of reoccurrence.

9. The timing of the separation during the wall impact cannot be precisely defined.

Data do not exist to allow an assessment of the precise timing of the loss of load carrying integrity of the lap belt webbing. Sufficient data exist to conclude that the webbing was intact at the time the load initiated and that the webbing carried significant load during the early portion of the impact before separating prior to the end of the occupant's response. However, there is no objective means to reach a conclusion about the precise point in the impact when the separation occurred. This circumstance complicates any attempt to apportion the role of belt separation in comparison to other factors in the crash outcome.

10. The later kinematic response of the occupant following belt separation was to move substantially further forward and substantially further to the right in response to the wall impact.

The initial occupant response has been described under Finding Number 7. Following webbing separation, the lower torso was allowed to move considerably further forward and to the right. This resulted from the lack of restraining force applied to the left lap belt and the occupant's continued motion forward and to the right until arrested by forces through the crotch strap, right lap belt and shoulder harnesses. As implemented by the driver of the Three Car, the crotch strap was not routed through the slot provided for the crotch strap in the forward portion of the seat bottom. Instead, the driver chose to route the crotch strap around the front of the seat (Figure 9). This resulted in a decreased downward pull from the crotch strap on the restraint buckle and, in this crash, a greater travel of the buckle area forward and to the right once the left lap webbing separated.

The intended function of a crotch strap is to provide a downward tether to counter the upward pull of the shoulder harnesses on the front portion of the lap belt and to prevent rotation of the pelvis under the lap belt and the lap belt riding up above the pelvis and into the abdomen as the occupant moves forward. Downward tethering of the buckle keeps the lap belt on the pelvis and resists upward motion of the belt. Routing of the crotch strap in a more forward direction raises the angle of pull and allows greater upward motion of the belt prior to and after webbing separation. It is possible, therefore, that the forward routing of the crotch strap may have allowed some greater asymmetry in the angle of pull from the lap belt prior to separation. That routing certainly allowed greater forward and rightward excursion following separation.

Not only did this separation allow further forward and rightward motion of the lower torso and pelvis, but it also allowed further forward and rightward motion of the upper torso and head. This occurred because the lower anchors for the torso belts were located at the lap belt buckle. When that buckle is allowed to come forward and to the right, the lower attachments for the shoulder harness also move substantially forward and to the right giving more space within the shoulder harness for the torso to move forward and right allowing, in turn, further forward excursion of the head. Since the head began its motion already deviated to the right from the collision with the Thirty-Six Car, forces from the shoulder harness still caused the head to swing back around more to the left as the helmet and remaining portions of the body continued moving forward and somewhat to the right. This redirection of the head's motion back around to the left as a result of tethering by the shoulder harnesses occurs in a fashion similar to a tether ball starting to wrap around a pole.

Depending upon the precise timing of left lap belt separation, the forward and rightward excursion of the occupant's body and the swinging around of the head with the left side of the head initially leading could have pursued a variety of trajectories having the described general characteristics in common.

The torso would be expected to load the left shoulder harness first at wall impact as a result of the displacement and rotation of the occupant from the Thirty-Six Car impact. This would cause a tendency to reorient the torso as viewed from above back in a counterclockwise direction at wall impact, squaring it up somewhat with later and ultimately higher loads expected in the right shoulder harness as the motion forward and to the right proceeds. Even before belt separation, other potential contact points would include contacts of the left side of the torso and the left upper extremity with the steering wheel. The left side of the helmet or head would have the potential to contact the right upper portion of the steering wheel as a result of the head swinging back from its originally right deviated position. The contact would be expected to occur in a more radial direction on the wheel where the wheel rim is stiffer. Forward deflection of the wheel would require force in the range up to 200-350 pounds over several inches, based on force-deflection tests. Radial deflection requires 1300 pounds or more even for deflections less than one inch. Following left lap belt separation, the excursion would be increased allowing contact to occur further back on the left side of the head.

After maximum excursion during the wall contact, the continued motion of the vehicle in a generally left-side-leading fashion down the track would be slowed by friction forces against the track leading to a rebound of the occupant rearward and to a greater extent back towards the left with respect to the vehicle. The restraint webbing allows significant elongation under load during impact but does not store all that energy elastically; instead it retains some permanent elongation lessening the total rebound tendency. There is, however, some elastic component so that rebound will still occur, but that rebound should be at significantly lower velocities than the initial forward motion. On rebound, the occupant would be expected to have some contact, typically of the back of the torso and the back of the helmet with portions of the left rear of the seat and potentially with some other portions of the afterward and leftward vehicle structure. This would be expected to be at a lower velocity and would be expected to have the helmet intervening. However, if forward rotation of the helmet was still present, the potential for direct contact to the posterior portion of the head on rebound could still be present. Rebound from a further forward excursion could allow the development of greater contact velocities with aft structure.

11. Injuries sustained by Mr. Earnhardt included:

- **Hemorrhage/Contusion measuring 8 by 5.5 centimeters on the left side of the occipital scalp with some similar findings on the right;**
- **A few areas of scattered contusion over the right side of the scalp and vertex;**
- **Ring fracture to the base of the skull which involved the occipital bone, mastoid portions of the temporal bone, chiasmatic groove, greater wings of the sphenoid bone, and the area behind the dorsum sellae (greater separation of the ring is present anteriorly);**
- **Epidural and subarachnoid hemorrhage;**
- **Flattening of gyri and narrowing of sulci in the posterior occipital and temporal lobes;**
- **Superficial abrasion over the right side of the chin measuring 2.5 by 1.0 centimeters;**
- **Superficial abrasion over the left clavicular head measuring 1.5 by 0. 6 centimeters;**
- **Transverse fracture of the sternum at the third sternebra;**
- **Fractures of ribs two through eight anteriorly with scant hemorrhage;**
- **Lateral fracture of left ninth rib;**
- **Hemoaspiration pattern and congestion in lungs;**
- **Diffuse contusion over mid abdomen measuring 2.0 by 4.5 centimeters;**
- **Superficial abrasion measuring 10 by 2 centimeters in a transverse pattern over the left hip region;**
- **Superficial abrasion measuring 22 by 5 centimeters over the right hip region and extending down and medially paralleling the inguinal ligament;**
- **Superficial abrasions to the extremities; and**
- **Fracture-dislocation of left ankle.**

Some of these injuries were diagrammed by the medical examiner (Figure 31). As previously mentioned, this injury pattern is not consistent with those expected for a wall impact such as that sustained by the Three Car in the absence of the prior impact from the Thirty-Six Car and the separation under load of the left lap belt. Injuries for a more typically positioned and restrained occupant would be expected to involve a more significant shoulder harness contusion to the right clavicular area and more symmetrical soft tissue injury evidence in a typical lap belt distribution. Additional expected injuries would depend upon the chosen tradeoff for restraint harness stiffness. With stiff harnesses at these levels of severity, significant injuries might be expected to the bony thorax, lungs, aorta, and liver. Injuries to the posterior cervical musculature, ligaments, and/or posterior elements of the cervical vertebral bodies would also be likely, particularly with the added neck-supported weight of the helmet. However, the restraint webbing in the Three Car was significantly more stretchable as well as having a wider load-bearing area than conventional passenger car restraints. Furthermore, the webbing does not store all the energy and return it on rebound, since it retains a significant degree of "set" in its extended position. Finally, Mr. Earnhardt attached his torso harnesses near the floor after routing them around the structural support aft of his shoulders. This allowed for greater forward displacement because of the greater length of webbing available to stretch. These characteristics could provide significant benefit in certain crash types through an increased stopping distance and a larger load-bearing area for the torso. Amplification of the velocity change is also lowered by decreasing the rebound. Therefore the stresses of the torso and neck are significantly reduced with the observed torso and neck injuries of a generally lower level of severity than might be expected. However, this benefit does not come without cost. Greater excursions provide risk in the form of structural contacts in a wide range of crash types. Because of the more frontal nature of the wall impact, the increased torso excursion occurring at this level of severity would be expected to result in some steering wheel contact by the torso and the front portion of the head or face, particularly for an occupant who customarily drives with his head displaced to the left. The more typical racecar wall impacts would result in principal directions of force coming from further to the right resulting in head excursions that would more commonly fall to the right of the steering wheel.

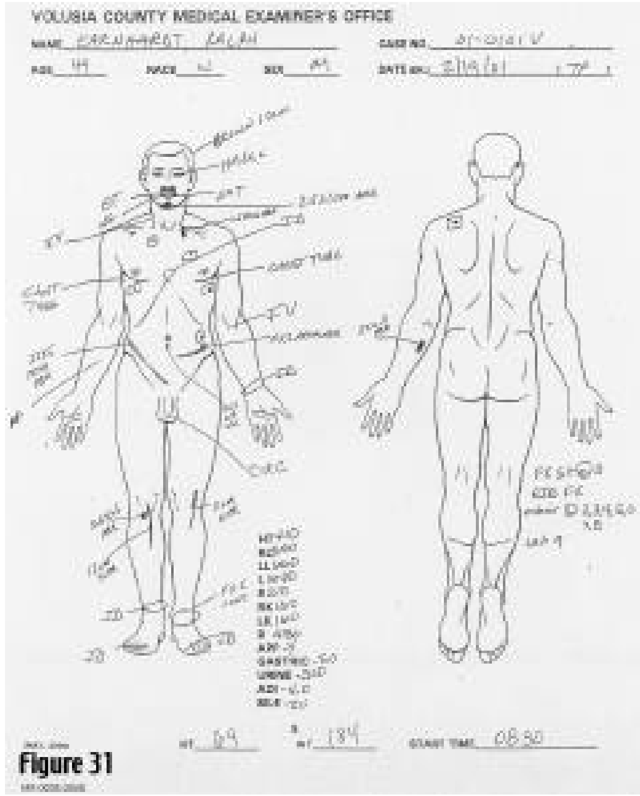


Figure 31

The deviations of the actual injuries from the expected injuries are consistent with the occupant having been prepositioned by the impact from the Thirty-Six Car and the separation of the left lap belt while using restraint webbing with a significant degree of relatively inelastic webbing elongation.

12. The cause of death was related to the ring fracture in the base of the skull.

The cause of death finding by the medical examiner was blunt force injuries of the head. Specific blunt force injuries were listed as the ring fracture of the base of the skull, the abrasion to the right side of the chin and the contusions to the left and right occipital scalp.

No specific injuries were observed in the neck. The thoracic injuries alone appeared unlikely to be sufficient to be a producing cause of death. Therefore, understanding the cause of death requires an understanding of the cause of the head injuries.

13. Injuries to the torso and extremities are consistent with those of an occupant prepositioned by the Thirty-Six Car impact and experiencing a webbing separation under load at the left lap belt adjuster.

The Thirty-Six Car impact produced a rightward and somewhat rearward response of the Three Car occupant with respect to the vehicle. This response was likely more severe for the chosen harness routings than would be expected for more typical routings. As a result, at wall impact the initial shoulder harness load was experienced in the left shoulder harness resulting in a counterclockwise tendency of the torso as viewed from above with subsequent higher loads present in the right shoulder harness. At lap belt separation, there would be movement of the occupant along the shoulder harnesses until the velocity of the occupant and the vehicle were equalized as a result of forces through the harness loop now anchored at the four points of crotch strap, right lap, and the two shoulder harnesses.

During the overall response, the occupant stretched the harnesses and developed contact between the left torso and the left lower portion of the steering wheel rim (Figure 32). The left upper extremity may also have been involved in this contact. The torso contact with the steering wheel provided a potentially beneficial alternative load path to assist in the deceleration of the occupant via load paths other than those involving the restraint systems.

Figure 32

The potential candidates for causation of the rib and sternal fractures include:

- Restraint system contact,

- Steering wheel contact, and
- Resuscitative activities following the crash.

Sternal fractures not uncommonly occur in severe frontal impacts at the location where a cross-chest, single-strap torso restraint crosses the sternum. No such crossing is likely to have been experienced in the crash of the Three Car. Therefore, direct stress placed upon the sternum is relatively unlikely unless through the steering wheel. However, sternal fractures as well as rib fractures are a recognized complication occurring with cardiopulmonary resuscitation. The relative contributions of the three potential causation sources cannot be objectively separated out on the basis of the available data, but the relative lack of bleeding at the broken ends of the ribs argues towards a post-mortem or resuscitative conclusion.

The steering wheel rim deformation is in a complex pattern with a portion of the rim pulled back towards the occupant approximately 2 inches (Figures 33 and 34) and other parts pushed forward by up to about 5 inches (Figure 35). The pulled back part is in the right upper quadrant and the pushed forward part is in the left lower quadrant referenced to a neutral wheel position for this asymmetric, three-spoke wheel. The wheel cannot be assumed to be in a neutral position at the time of deformation, nor does the deformation pattern provide indication of the driver steering input at the wall contact since asymmetric forces on the right front tire may spin the steering wheel prior to occupant-wheel contact. The pulled back portion of the wheel rim could derive from hand-to-wheel or other occupant forces during occupant motion in response to the car impacts and/or from rotation of the rim plane as other portions of the wheel are pushed forward by occupant contact.

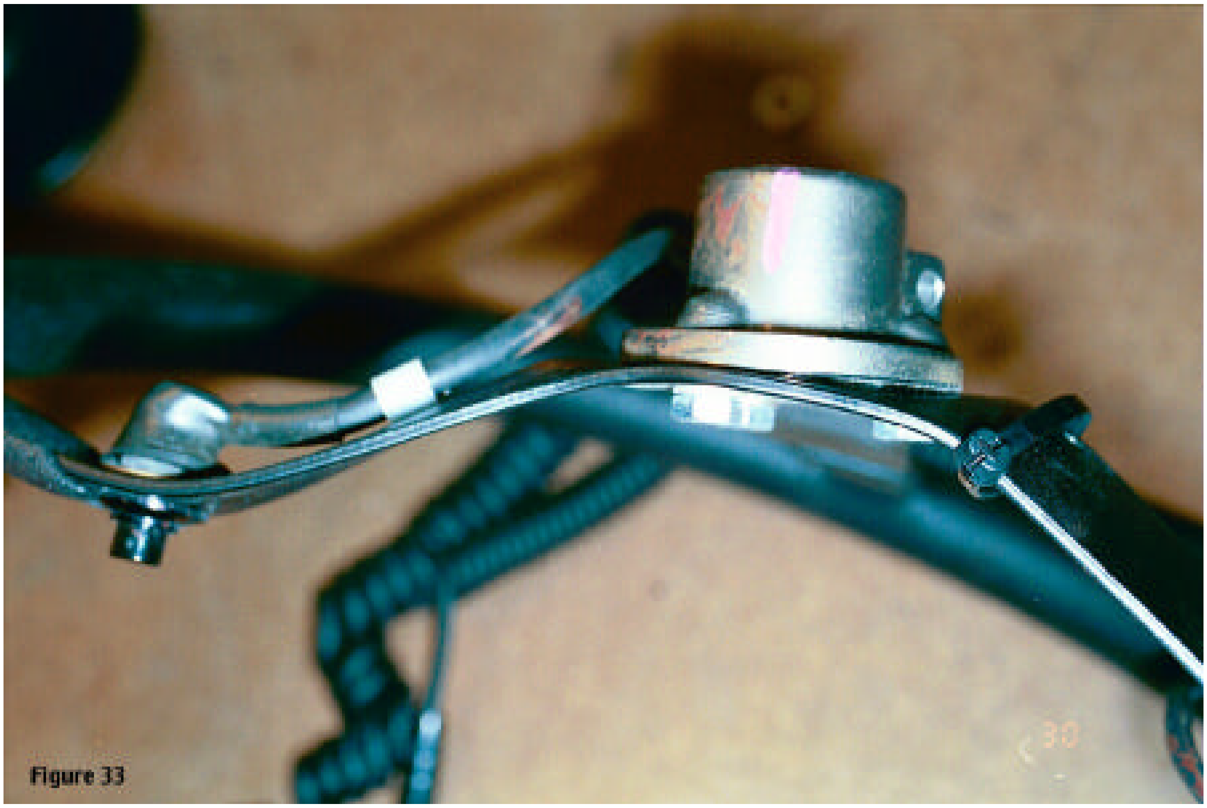


Figure 33


Figure 34

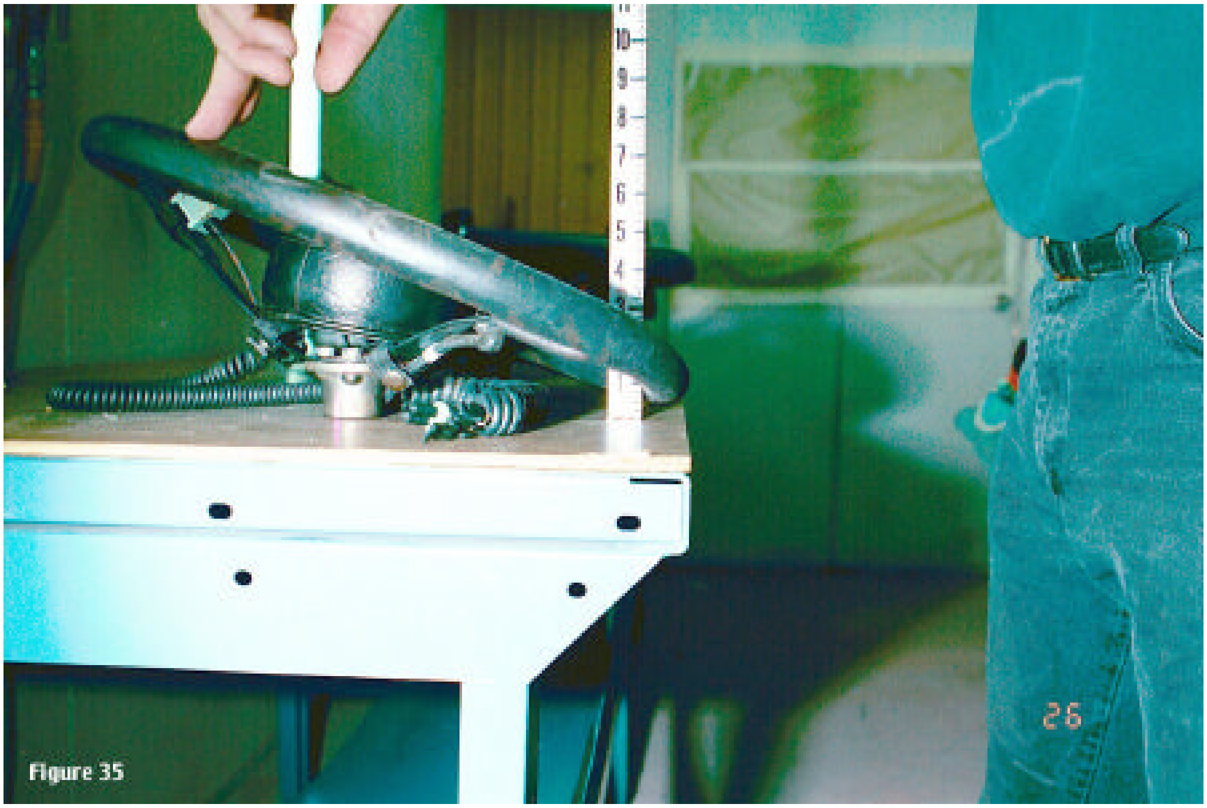


Figure 35

There is contact evidence at various points on the rim with impressions in the rim edge and scuffing particularly in the left upper quadrant (Figure 36). There is some material in some of the impressions (Figure 37) as well as in other areas of the rim facing the occupant (Figures 38 and 39). The occupant made contact with the wheel in more than one area.


Figure 36


Figure 37

Figure 38

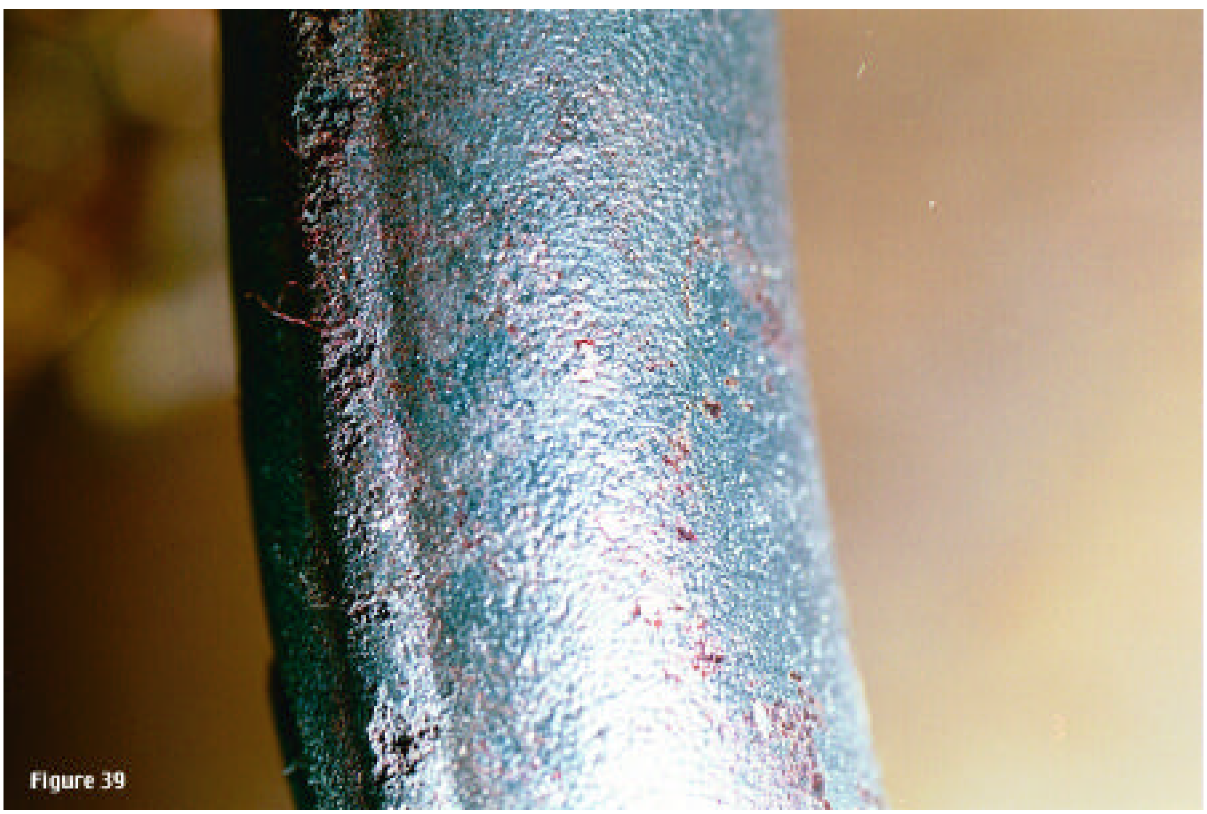


Figure 39

With regard to extremity injuries, Figure 8 depicts the leg brace located forward and to the right of the right lower leg. This is deviated forward and to the right consistent with having been contacted by the right lower leg providing some increased stopping distance for the leg. This deformation, in conjunction with the forward and rightward response of the occupant and the prior positioning, likely provided some protection for the right lower extremity. The left leg, however, was likely in a somewhat leading position as a result of the prepositioning rotation and left lap belt separation with loading applied through pedals and/or floorboard to produce the fracture dislocation in the left lower extremity. A black scuff was found on the toe pan forward of the pedals and to the left of the steering column (Figure 40).

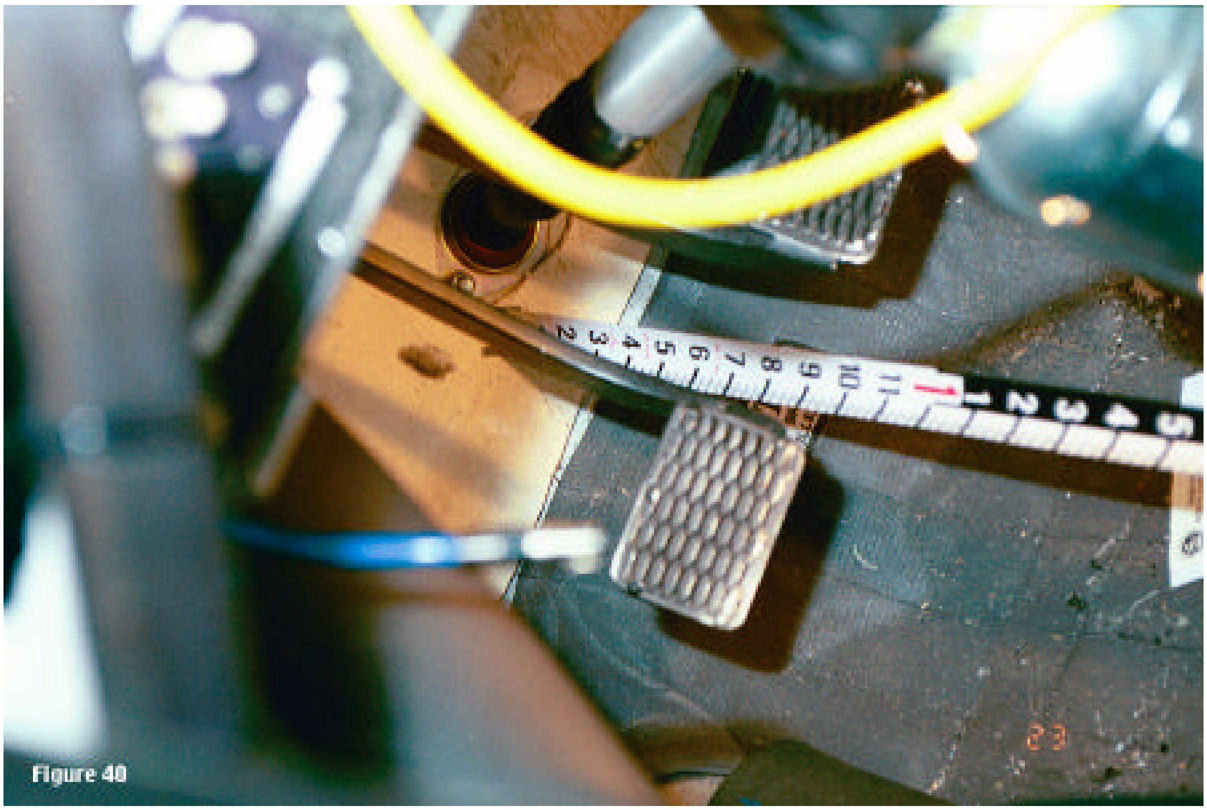


Figure 40

14. The probable cause of the head injuries was direct impact to the region of the occipital scalp.

A basilar skull fracture is a fracture involving the floor of the skull. A ring fracture has fracture lines that travel in an approximately circular manner around the foramen magnum which is the large opening in the bottom of the skull traversed by the neural tissue constituting the spinal cord. The ring fracture's circular course may be very irregular, but there is a connected path all the way around in a complete ring fracture.

Ring fractures have been described since the 1800's. A variety of authors have described a range of mechanisms by which they may occur. Examples are noted in Moritz (1954), Voigt and Skold (1974), Krantz and Lowenhielm (1986), Huelke *et. al*. (1988) and McElhaney *et. al*. (1995). Typically, the mechanisms have been deduced from studying the accident event and/or associated injuries observed in circumstances where a ring fracture has been observed at autopsy. A general consensus appears in the technical literature that ring fractures with similar characteristics can occur in more than one way. It is therefore necessary to carefully assess the injury circumstances as well as the associated injury evidence to achieve a reasonable assessment of causation.

Basilar skull fractures, including ring fractures, are caused when stress is transmitted to the floor of the skull sufficient to produce strain in those structures beyond recoverable limits. Ring fractures in particular occur when the floor of the skull is exposed to compression, tension, or torsion (Krantz and Lowenhielm, 1986). Impact to the head as a basis for ring fracture may also occur in a variety of ways. Basilar fractures, including ring fractures, have been described on the basis of blows to the head through the frontal, temporal, parietal, and occipital bones as well as the mandible (Moritz, 1954). The common characteristic seems to be that the blow must produce at the base of the skull a torsional stress, tension stress, compression stress, or some combination of torsion with one of the other two.

Uncommonly, the stresses may derive from inertial sources, without proximate blunt impact to the head, particularly in compression or tension loading. For example, neck stretch could conceivably occur in a high-speed frontal crash, particularly for a helmeted occupant, sufficient to produce tension loading to the floor of the skull beyond fracture limits. On the other hand, neck compression could occur in a fall from a great height with landing in an orientation such that the head continues down with considerable force on the stopped cervical spine. More commonly, however, basilar skull fractures, including ring fractures, are produced in a setting of blunt impact to the head usually with some torsion component (Voigt and Skold, 1974).

When the injury occurs with neck stretch or compression, without proximate head impact, findings associated with the severity of the impacts to the torso that result in the neck stretch or compression would be expected, because the torso must be accelerated very rapidly, separately from the head, to generate the required force through the neck to the head. More moderate torso impacts, and many very severe ones, typically produce neck whipping without basilar fracture. Associated findings are also often observed in the neck that occur with the dramatic tension stress. For example, with neck tension sufficient to produce basilar skull fracture by itself in a frontal collision, one would expect to see such injuries as :

- Severe thoracic injury in a context in which the thorax was rapidly stopped while the head continued forward;

- Hemorrhage in the posterior neck;
- Posterior cervical ligament tearing;
- Posterior element fracturing such as separation of a spinous process;
- Subdural hemorrhage.

Finally, one would not expect to see evidence at autopsy of direct head impact.

In Mr. Earnhardt's case, a very different picture is presented. The thoracic injuries are relatively mild in a setting in which the torso underwent a relatively more gradual deceleration allowed through stretching of torso restraints and deformation of the steering wheel rim. Evidence of typical neck stretch findings or subdural hemorrhage was not observed. Notably, evidence of proximate, blunt head impact actually was observed in the form of an 8 by 5.5 centimeter (3.15 by 2.17 inch) area of hemorrhage/contusion observable on the inside of the scalp where it is applied to the outside of the left posterior skull. Similar findings were noted on the right but were not directly measured. The pathologist conducting the autopsy concluded that Mr. Earnhardt's death resulted from blunt force injuries of the head. The autopsy data is therefore more consistent with a ring fracture derived from head impact rather than simply from the less common inertially derived neck "whipping" phenomenon.

The circumstances of the Earnhardt accident provide basis for significant neck tension to have been present, particularly during the wall impact phase. This tension may well have played some role in the character of the fracture. Clearly, during the forward and rightward excursion of the head with its subsequent leftward rotation and straightening, there would necessarily have been significant tension forces placed on the floor of the skull. However, the lack of expected associated findings and the modest evidence of dramatic forces producing sudden stopping of the torso do not provide the expected picture of the dramatic tension loads necessary to produce basilar skull fracture on the basis of tension alone.

We conclude that the ring fracture most likely occurred as a result of impact to the occipital scalp probably in conjunction with and/or in a manner to produce tension and torsion stress components to the base of the skull. This conclusion is based upon the following:

- The conclusion of the pathologist that death was caused by blunt force injuries of the head;
- The analysis of the autopsy findings including contusion to the occipital scalp;
- The accident reconstruction analysis of the wall impact defining timing and direction;
- The accident reconstruction analysis of the collision between the Three Car and the Thirty-Six Car defining severity, timing, and direction;

- The occupant kinematic analysis of the collision between the Three Car and the Thirty-Six Car and of the subsequent collision with the wall concluding that the left side of the head was generally leading at wall impact as a result of rightward pre-positioning;
- The kinematic analysis of helmet motion in both impacts concluding that the helmet tended to rotate and translate forward, rightward and upward with respect to the head during critical phases of the impact sequence;
- The analysis of physical findings in the vehicle and on the restraint system establishing critical aspects of occupant motion and contacts;
- The analysis of the left lap belt separation and its effects on occupant motion at wall impact and on rebound;
- The analysis of occupant injury patterns in conjunction with the above;
- The published data in the scientific literature establishing clear precedent for posterior and lateral proximate head impact, particularly in conjunction with added tension in the neck, to produce ring fracture of the base of the skull having the characteristics described in the autopsy report (Voigt and Skold, 1974, p. 499);
- The biomechanical analysis of the potential head impacts in the accident sequence;
- The lack of correspondence, in several of the bases above, with patterns that would be expected were alternative causation theories to be correct.

An attempt was made to assess the potential for head contact through the helmet. The CT scans of the crash-involved helmet were reviewed and compared to scans of exemplar helmets. No clear evidence of compression of the impact-attenuating liner was observed in these scans. A representative example of one of the cuts from the scans is shown in Figure 41.

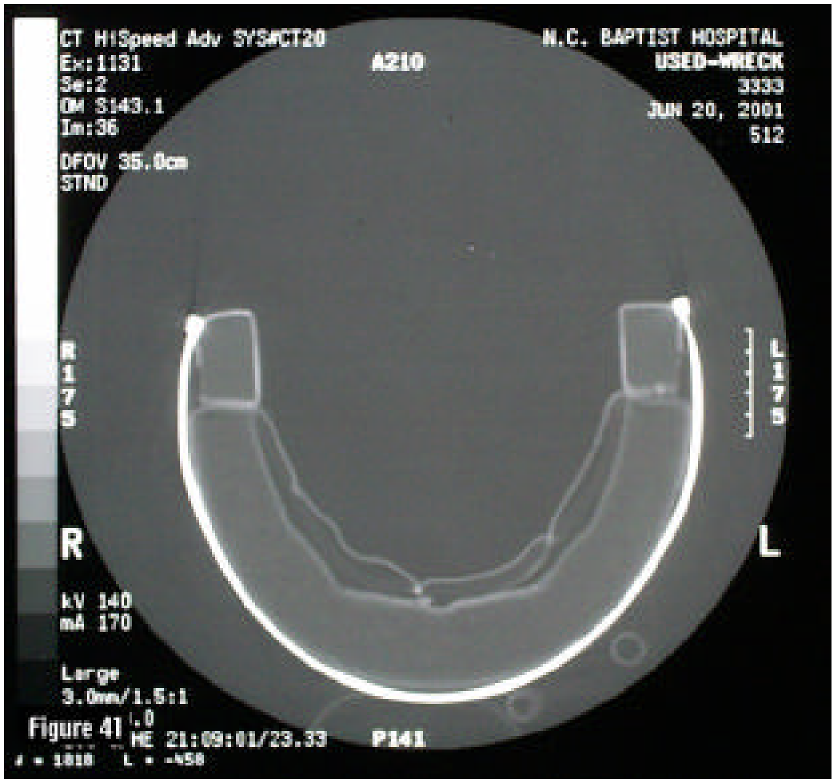


Figure 41

The crash–involved helmet was physically examined. The helmet is a non-full-face helmet which was used with goggles worn separately. The helmet had a partial fixed visor and a chinstrap but no nape strap. The goggles were reportedly found separately on the floor but have not been examined. Examination showed that there was no evidence of an impact to the back of the helmet. Specifically, the area of the helmet that normally overlies the area of contusion did not demonstrate contact evidence. Instead, there was evidence consistent with helmet displacement in the area of the chinstrap, which demonstrated areas of abrasion, folding and material deposition, and in the area of the left front edge which demonstated an imprint which matched the spring joint from the microphone boom when the microphone is rotated upward. This rotation of the boom would be expected with forward rotation of the helmet since the boom would be stopped by body contact as the helmet continued to rotate forward.

The visor attachments were damaged and a superficial 3 inch scuff was noted in the forward left portion which proceeded leftward and slightly upward. This would be consistent with superficial helmet contact to the far rightward structure during the impact with the Thirty-Six car. An additional visor attachment appears to have come off in conjunction with the separation of the plastic visor screws.

Direct impact to the exposed head against structure is more likely as an explanation for the occipital contusions than contact through an edge of the helmet outside the area protected by the impact-attenuating liner.

There are two principal opportunities for contact to occur between the head and structure. The first is contact with the wheel rim during the relatively high energy forward and rightward motion of the left-side-leading head as the head swings to the left as a result of forces mediated from the neck attached to the relatively slowed torso. This motion could allow contact of the left posterior portion of the head in the region of the steering wheel with a significant component directed radically instead of perpendicular to the plane of the wheel. Since the wheel rim is stiffer in the radial direction, this contact could induce rapid stopping of head velocities within the range necessary to create a basilar skull fracture and the left occipital findings. With forward rotation of the helmet around the chinstrap, the contused portion of the head could have been exposed to direct contact with the wheel. Such a contact would have occurred at a time of significant neck tension which could have added to the ability of the steering wheel contact both to create the basilar skull fracture and to produce the more significant separation of the fracture edges in its forward extent. Additional tension could derive from disengagement of the helmeted head from the wheel at the initiation of rebound. In this scenario, the abrasion on the right side of the chin would have been created by the chinstrap as it prevented the forward rotation of the helmet from carrying the helmet off the head.

The other principal possibility for posterior head contact occurs during the rebound phase. As the torso rebounds away from the stretched harness, tension forces in the neck are created which pull the head both rearward and somewhat leftward. The head and torso move progressively more to the left with the passage of time. This derives from the fact that the vehicle is continuing to decelerate, reducing its down-track velocity as a result of sliding friction forces of tires moving in a generally sideward direction down the track with the Three Car continuing in contact with the Thirty-Six Car. The slowing forces from track friction would produce a deceleration of the vehicle while the occupant would continue to move down-track in compliance with Newton's First Law. After the wall impact was completed, this would be the principal displacing force on the occupant. Therefore, the head rebound trajectory should start rearward and to the left and curve further to the left with respect to the vehicle. The conclusion of the rebound would likely occur towards the left rear portion of the driver's station, potentially leading to posterior head contact with some portions of the vehicle structure. The rebound contact velocity would be increased since the head had to travel a greater distance before contact since rebound began from further forward after the left lap belt separated. Again, the contact could occur directly with the posterior portion of the head if the helmet remained in a forward and rightward rotated position. In this scenario as well, the chin abrasion would come from the chinstrap.

In either scenario, forces from the chin strap in combination with the more modest secondary rebound from the aft structure and subsequent motion and contacts as the vehicle slid to rest would tend to restore the helmet to a more normal position as it was reportedly found.

Other opinions have been expressed regarding the mechanism of Mr. Earnhardt's head injury. A report issued on 10 April 2001 by Dr. Barry Myers concludes that the injury resulted from a combination of two mechanisms. The first was a "whip" mechanism as the head continued forward and was constrained by forces through the neck. The other mechanism invoked by Dr. Myers was impact with the steering wheel under the chin. These were the mechanisms investigated in McElhaney et. al. (1999) in which Dr. Myers participated. While Dr. Myers' analysis was informed by a brief opportunity to examine the autopsy photographs, his report was issued without other information such as a quantitative and objective accident reconstruction, an opportunity to inspect the vehicle, an assessment of the prior impact from the Thirty-Six Car, and an opportunity to see the helmet. Our present analysis did not include among its bases any direct access to the autopsy photographs but did have access to a number of the other sources of information for an injury causation analysis as listed above and an opportunity to consider them.

The present analysis finds lesser evidence for a simple "whip" phenomenon for the reasons previously enumerated, some of which were not apparent at the time of the earlier assessment. Similarly, the assessment of contact under the chin against the steering wheel does not fit well with the present kinematic analysis. It would be expected that, following the Thirty-Six Car impact, the forward and rightward motion of the head at wall impact would be with the left side of the head leading. The chin abrasion is noted to be on the right side of the chin. The initial movement of the head forward and to the right would not produce a trajectory of the right side of the chin onto the steering wheel. The chin abrasion is both small and superficial. There is evidence in the medical literature that basilar skull fractures can be produced through mandibular contact with relatively scant findings in the way of submental abrasions or mandibular damage. However, there is no basis to invoke mandibular contact on the basis of a chin abrasion when there are alternate explanations for that abrasion, when the abrasion does not fit with the kinematic trajectory to the steering wheel, and when there is other, more substantial evidence of head impact to a part of the head where such ring fractures have been found to be produced.

The production of ring fractures is not sufficiently understood that one can examine the fracture characteristics alone and deduce the point of application of the applied stress. Instead, the applied stresses have typically been assessed using associated signs of their application and the injury circumstances. In Mr. Earnhardt's accident, the area of soft tissue trauma to the occipital region of the head is more likely related to the production of that ring fracture than mechanisms that appear inconsistent both with the kinematic response and the associated injury patterns.

Either the forward response or rebound scenario in the Earnhardt accident provides a reason to expect contact in the posterior aspect of the head below the edge of the displaced helmet. The literature reviewed, examples of which are noted in the bibliography, provides evident basis for the occurrence of basilar skull fractures including ring fractures as a result of a wide variety of contacts including contacts to the side or rear of the head. Such contact evidence was the most prominent sign of direct trauma to the head of Mr. Earnhardt. The impact produced stresses in the skull which probably caused the fracture to initiate at some point remote from the contact and then propagate toward that contact, eventually closing the ring. Left occipital contact could have occurred during significant neck tension, particularly in the steering wheel contact scenario, and could have provided the necessary stress to initiate the ring fracture. Therefore, there does not appear to be convincing basis to exclude the occipital trauma as a potential cause of the fatal injury to Mr. Earnhardt. In fact, based upon the analysis of the associated injuries and the kinematic response to both impacts, trauma to this area by one of the two scenarios outlined above appears to be a more likely explanation for the injury than either an isolated "whip" or a "whip" with submental impact theory as advanced in the earlier preliminary analysis.

On 20 July 2001, a sled impact was carried out by Autoliv in Auburn Hills, Michigan, under the supervision of BRC with crash pulse data from the Nebraska Team and with additional assistance from NASCAR. The purpose was to observe the general characteristics of the kinematic response of a rightward displaced occupant to an impact similar to that of the Three Car with the wall. A sled test buck was constructed using a racecar frame, seat, restraints, and steering wheel and column. A fiftieth percentile Hybrid III Anthropomorphic Test Device (ATD) was utilized. A fiftieth percentile ATD has a base weight of 172.3 pounds and a 34.8-inch sitting height. This device was modified to increase the weight based upon reports of Mr. Earnhardt's weight with equipment. At the time of the test, the actual weight of the ATD was 202 pounds, with weight proportionately added to the ATD in the various body segments. A 2.0-inch spacer was placed between the pelvis and lumbar spine and a 0.81-inch spacer was placed at the base of the neck to increase the seating height of the ATD.

The ATD was placed within the seat and restrained with an exemplar restraint system routed in the fashion in accordance with Mr. Earnhardt's custom. An exemplar helmet was placed upon the ATD's head and appeared to provide a reasonably tight fit. It was fastened with the chinstrap over a neck insert and a string was tied around the left side projection of the helmet above the chinstrap attachment. The string was used to anchor the dummy in a position similar to that shown in Figure 4 with some helmet displacement but limited by the relative lack of flexibility, particularly in the torso but also in the neck of the ATD. This positioning was designed to approximate the pre-positioning of the Three Car occupant caused by the collision with the Thirty-Six Car. The pre-positioning was necessary because a sled test cannot replicate the type of dual impact accident that occurred in this case. The string was set up to be cut by sled motion without adding additional tension. The pre-impact test setup is demonstrated in Figure 42. The left lap belt adjuster was prepositioned with some asymmetry, particularly for the webbing passing through the adjuster frame closest to the floor mount, and all belts were made snug.


Figure 42

An impact was produced on the buck using a Bendix HYGE with a target velocity change and acceleration pulse shape and size which was generally duplicative of the filtered crash pulse derived from the analysis performed by the Nebraska team. The actual values produced in the test were very close for the sled velocity change but the peak acceleration came in somewhat low in the region of 44.5 g's instead of 48 and with an effective crash pulse that was approximately 90 milliseconds instead of near 80 milliseconds. At the lower acceleration pulse severity of the sled test and with the ATD occupant, the lap webbing did not separate. However, even with the restraint system intact, sufficient forward motion occurred to produce contact of the left lower torso and left arm of the dummy with the steering wheel producing significant deformation of the steering wheel as well as some dynamic deflection of the column generally to the right with a displacement on the order of 3 inches. The column deflection was greater than would have been expected in the Three Car.

The resulting kinematics involved generally forward and rightward motion with the head swinging around and making contact on the left posterior inferior portion of the helmet against the steering wheel rim. The steering wheel rim in the region of helmet/head contact was moving toward the ATD head at the time of contact as a result of earlier contact of the ATD torso to the lower part of the wheel rim resulting in rotation of the rim plane.

The ATD rebounded rearward and somewhat to the left making helmet contact with structure to the left and aft of a neutral head position in the seat. The helmet was displaced up and forward during rebound and rotated further forward at aft contact. It should be noted that the rebound portion of the sled test in particular did not simulate the conditions of the Three Car impact. For the sled, track friction produced a deceleration which resulted in a significant addition to the rearward component of the dummy's rebound. In the actual crash of the Three Car, the forward impact was followed by a principally lateral velocity change due to tire friction as previously described. Therefore, it would be expected that the occupant of the Three Car would tend to react substantially more to the left and rearward than would have been the case with the ATD in the sled demonstration.

The sled demonstration could not duplicate the crash events because of the unknowable factors, but it provided a helpful means of visualizing the general characteristics of the kinematic response assessed in this analysis. With the left lap belt remaining intact, and the test steering column being displaced too much to the right, contact of the ATD with the steering wheel was low on the helmet. Had the left lap belt separated, the ATD would be expected to move significantly further forward and to the right yielding a range of scenarios in which contact with the steering wheel rim could occur in the left posterior region of the head below the area covered by the forward-rotated helmet. Figures 43 and 44 present a sequence of still frames taken during the sled demonstration from cameras above and on the right taken. It should be noted that the purpose of the test was to demonstrate a kinematic scenario. There was no way to duplicate the separation point during the impact for the left lap belt since that point will never be known. Therefore, no attempt could be made to duplicate the characteristics or severity of the actual head impact in the Earnhardt collision. Neither could the initial conditions be sufficiently defined to ensure that the rightward motion in response to the Thirty-Six Car impact was appropriately duplicated by the pre-impact positioning of the ATD in the sled demonstration. Therefore, no attempt was made to measure quantitative head accelerations or other ATD responses. Rather, the test was to observe general characteristics of the kinematic response and served that function in demonstrating some characteristics of that response under the conditions of a very late separation of the left lap belt webbing during the actual crash.

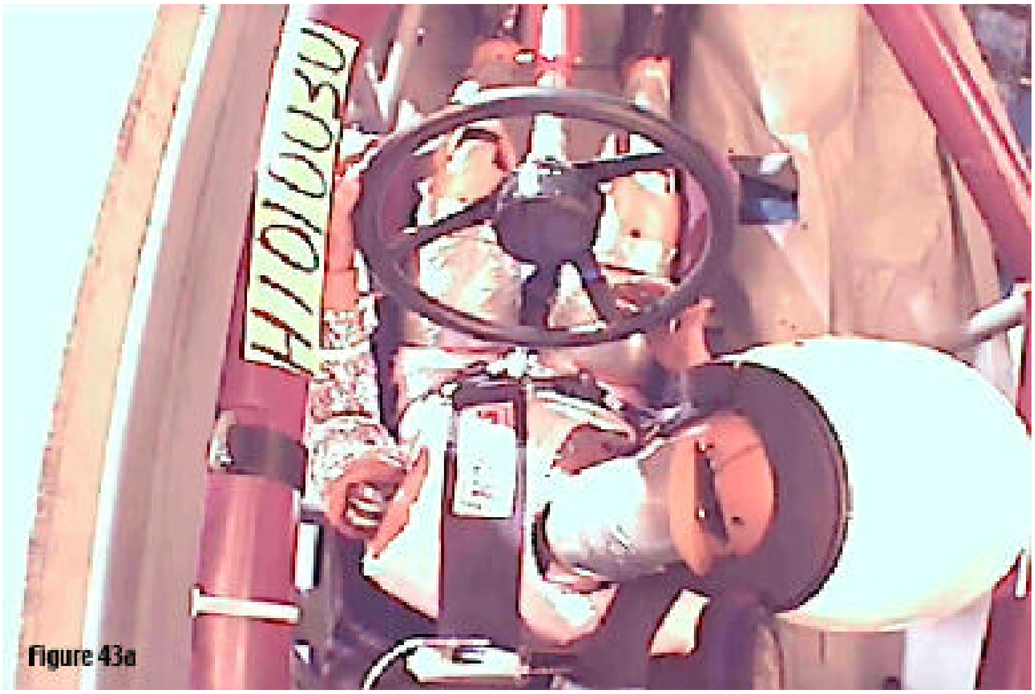


Figure 43a

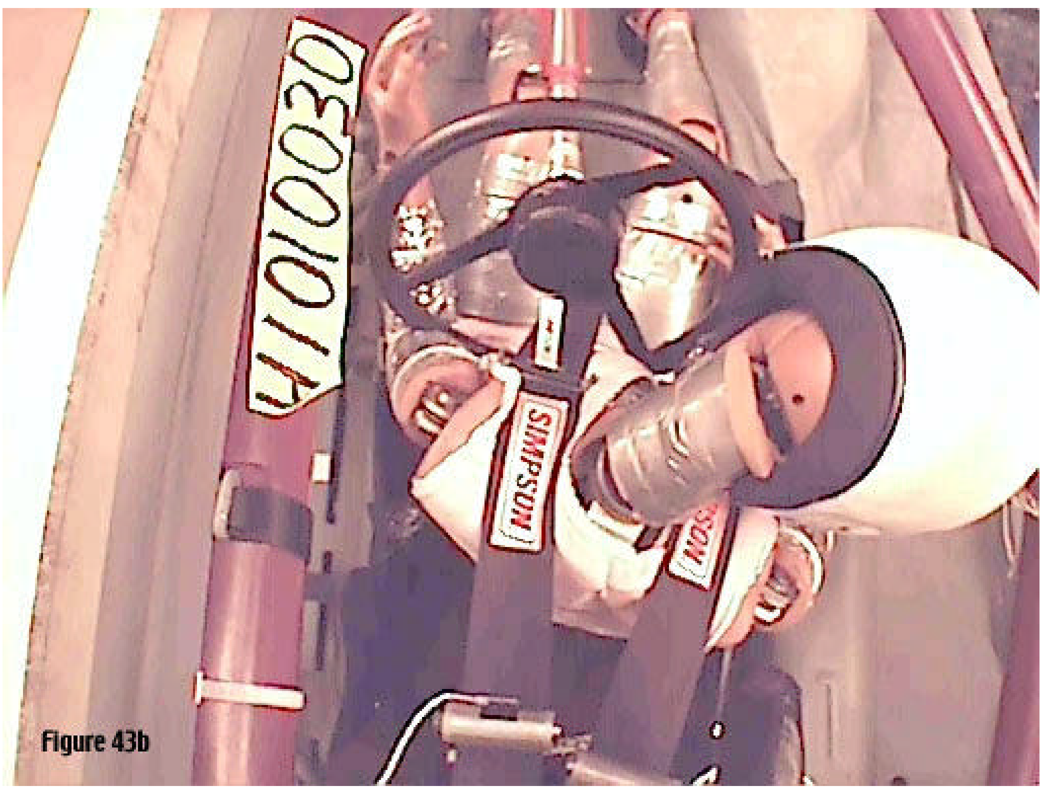


Figure 43b

Figure 43c

Figure 43d

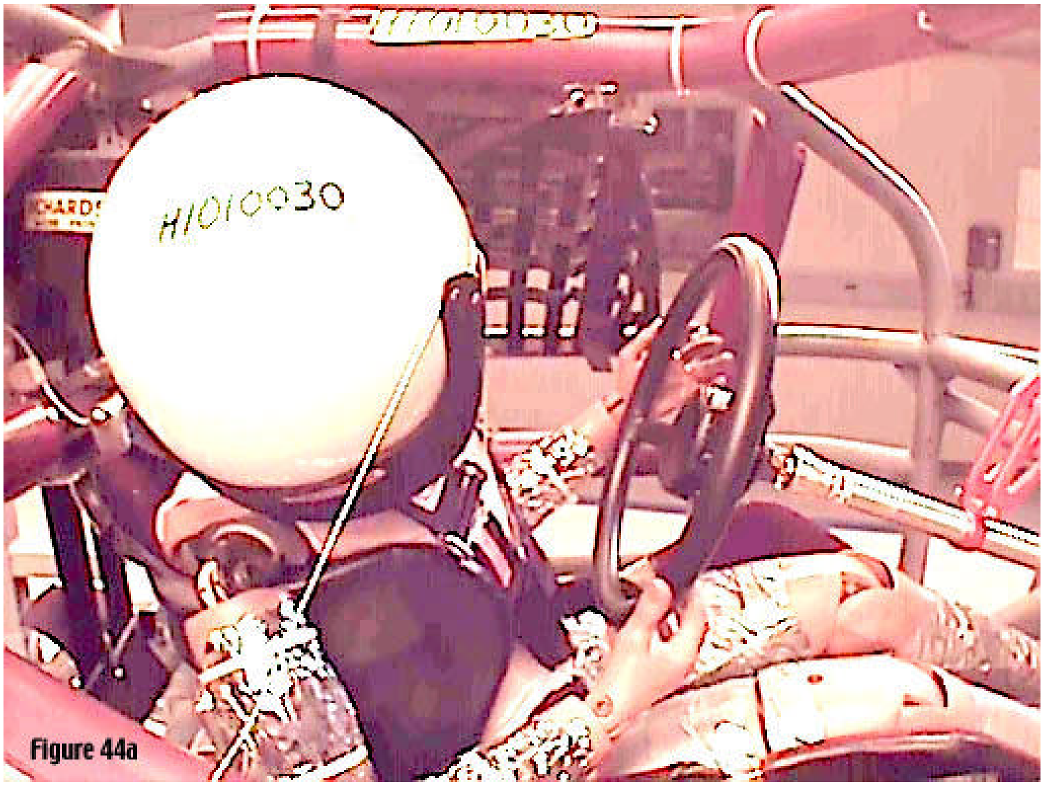


Figure 44a

Figure 44b

Figure 44c

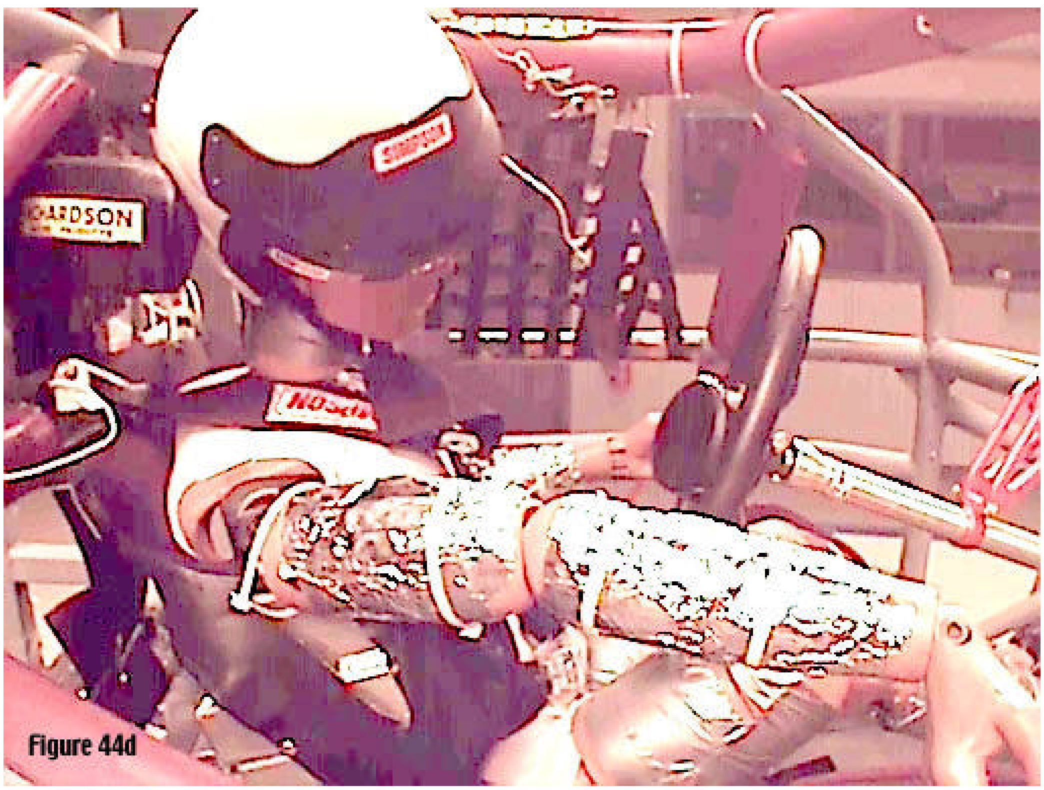


Figure 44d

IV. Summary and Conclusion

The Earnhardt crash has been described by some as "not looking that bad". However, analysis demonstrates it to have been an extremely severe crash in terms of its velocity change, its peak acceleration, and its significantly more frontal principal direction of force. The crash was preceded by a biodynamically significant impact between the Thirty-Six Car and the Three Car which resulted in a rightward prepositioning of Mr. Earnhardt in the last fraction of a second prior to wall impact. As a result of the wall impact, Mr. Earnhardt moved generally forward and to the right from his rightward deviated position with the left side of his head leading and his head tending to swing back towards the left. During this response, the left lap belt webbing separated under load allowing a greater forward and rightward excursion and more significant contact with the steering wheel from the left part of Mr. Earnhardt's upper body and potentially the left posterior portion of his head. During rebound, Mr. Earnhardt's body moved rearward with respect to the vehicle and curved more and more to the left. Contact with the posterior portion of his head could also have occurred in this phase with aft structures rather than against the steering wheel. Mr. Earnhardt's death likely resulted from an impact to the occipital scalp in the presence of neck tension producing a fatal ring fracture.

Three unusual events acting together were responsible for the tragic outcome of this crash. The first and most significant is the severity and direction of the impact against the wall. The component of velocity acting towards the wall and the relatively frontal nature of the resulting impact produced an unusually severe and unfortunately directed crash event. The second factor was the prior collision with the Thirty-Six Car at a time so close to the unusually severe wall impact that the occupant was dislodged from a normal position just prior to the wall crash. This motion also produced forward displacement of the helmet with respect to the head, leaving portions of the posterior head somewhat exposed. The occupant motion in response to both impacts was likely affected by the choice of restraint system routing. The third event was the separation under load of the left lap belt webbing in the adjuster as a result of dumping. The timing of that separation cannot be determined but it was clearly such that significant load was carried by the restraint prior to the separation and significantly greater response forward and to the right of the occupant occurred following the separation. The near simultaneous occurrence of these three unusual events resulted in the death of Mr. Earnhardt probably as a result of direct head contact.

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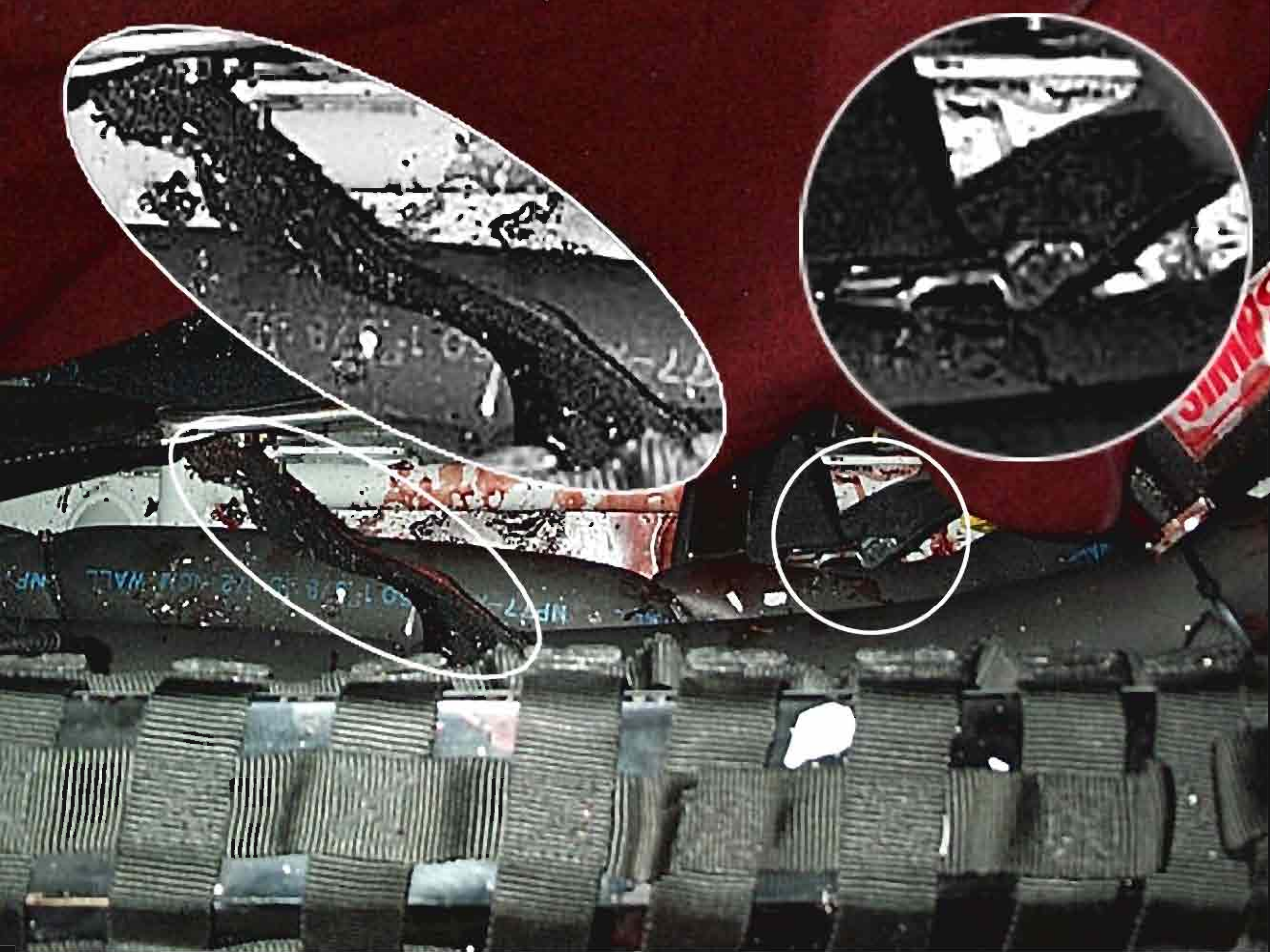
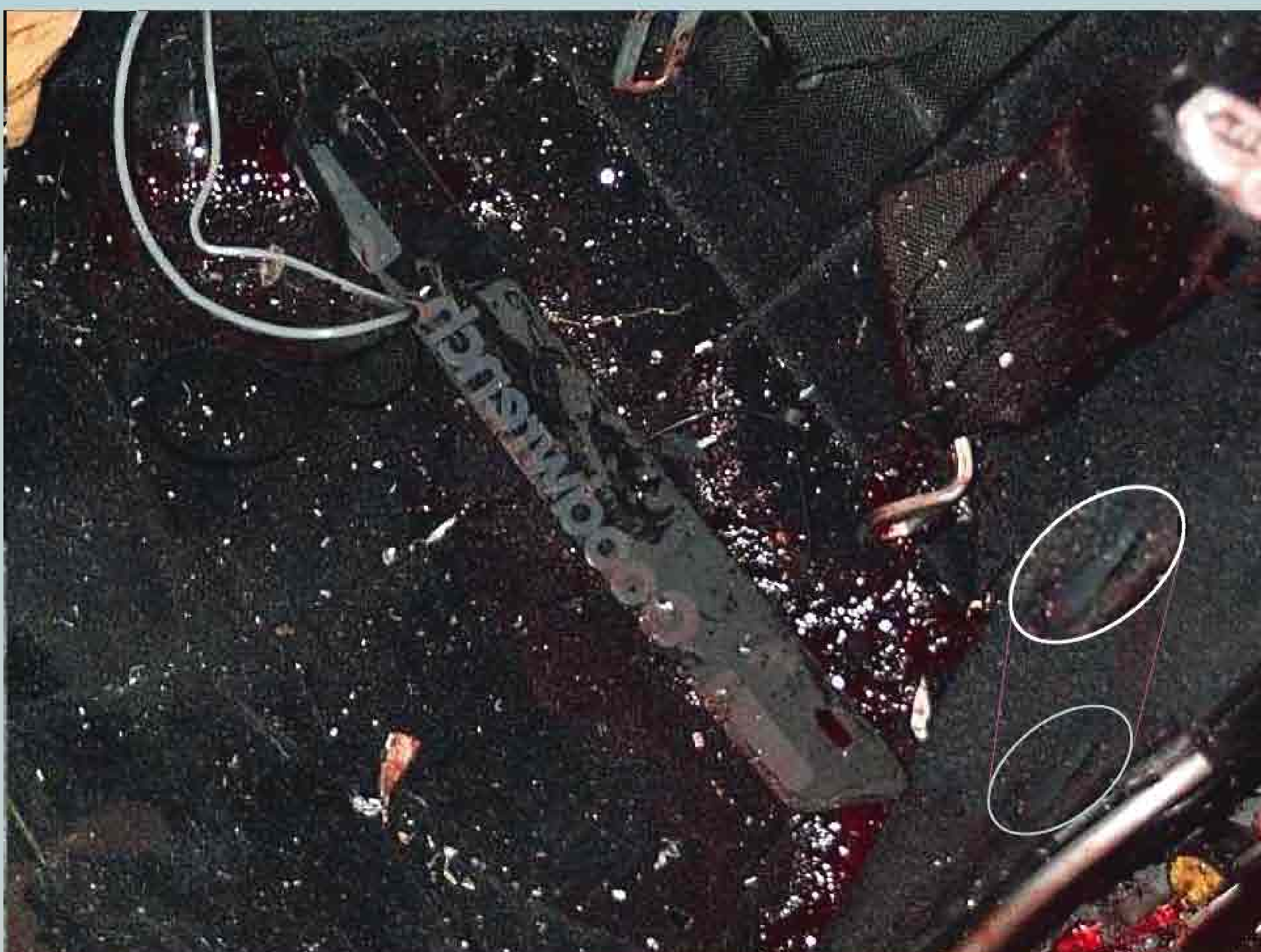
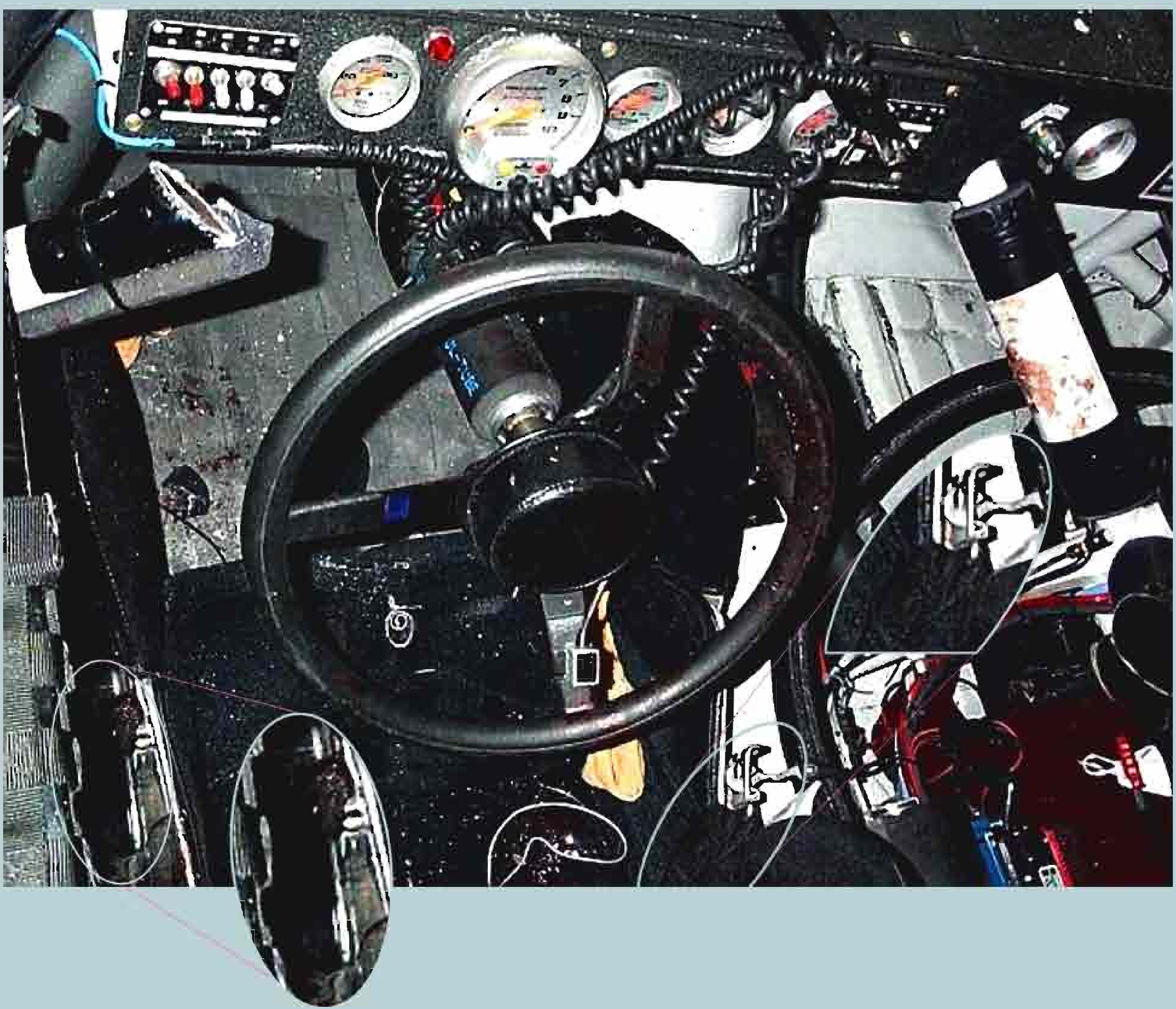
Tab 3



Tab 4



Tab 5



Tab 6

Tab 7

Barry S. Myers, M.D., Ph.D.
Biomedical and Mechanical
Engineering Consultant
5207 Pine Cone Lane
Durham, NC
27705

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DUKE UNIVERSITY
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DURHAM NC, 27708
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April 9, 2001

Mr. Dale Earnhardt Crash Analysis

The purpose of this report is to explain the cause of death of Mr. Dale Earnhardt, with particular attention to the role of facial contact, inertial head loading (the whip mechanism), and impact near the top of the head.

BACKGROUND

Mr. Earnhardt sustained a number of injuries as a result of his collision. Mr. Earnhardt's fatal injury was the basilar skull fracture described in the autopsy report. A basilar skull fracture is any fracture of the skull in which the fracture originates in or propagates to the base (lower portions) of the skull. There are several types of basilar skull fractures including ring fractures in which the fracture forms a complete or incomplete ring around the foramen magnum (the hole through which the spinal cord passes). Ring fractures are also a diverse group of fractures, and arise from many widely differing mechanisms. These include: impact to the chin, jaw, and face; impact to the head anteriorly, posteriorly, or laterally; impact near the top of the head; and inertial head loading in which the spine and neck muscles are called upon to stop the moving head. In preparing this report, I considered and evaluated each of the possible mechanisms.

THE CRASH DYNAMICS

Understanding the injury mechanism requires understanding and reconstructing the crash. Mr. Earnhardt's car initially yawed counterclockwise when viewed from above and traveled down (toward the center of) the track. A right steer corrected this trajectory, however, the vehicle yawed clockwise and began climbing up the track. As a result, while most of the velocity of the car was directed along the track, a significant component of velocity was directed toward the wall. Prior to impacting the wall, Mr. Earnhardt's car contacted another vehicle which increased its clockwise yaw angle relative to its direction of travel. As a result, the impact with the wall was equivalent to a passenger–side angled barrier impact. As a result of the collision, Mr. Earnhardt's velocity toward the wall was arrested and a component of his velocity along the track was also arrested. This gave rise to a ΔV (change in velocity) with a PDOF (direction) which is predominately frontal and from the right. Because there was no significant additional rotation of the vehicle after the crash, the ΔV of the occupant is very similar to the ΔV of the vehicle. Mathematical analysis and observation of the impact with the wall demonstrates that this was a very severe crash. By contrast, many people have commented that the crash did not 'appear' to be severe. The reason for this common misconception is that the frontal crash occurs in only one tenth of a second. As such, the crash is over in 'a blink of an eye', and the ΔV occurs over a very short time producing very large accelerations. Frontal crashes which are angled to the right side of the vehicle are especially dangerous for the head and the neck of the driver.

OCCUPANT DYNAMICS

In accordance with Newton's laws and as a result of the crash, Mr. Earnhardt moved forward and slightly toward the right in the vehicle. This motion was opposed by his restraint system, the steering wheel, and the other components of the vehicle interior with which he interacted (e.g. the instrument panel with his knee, etc.). Initially, his head traveled along this nearly straight line. As his chest and pelvis were stopped by the restraint system, his head began to follow a circular arc forward and down. Large inertial forces developed as the neck was stopping the forward motion of both the head and the helmet. This is the basis of the whip mechanism which occurs in right side angled frontal collisions. In crashes like Mr. Earnhardt's, these inertial forces alone can be large enough to produce ring fractures of the skull base.

As the circular arcing motion continued, Mr. Earnhardt struck the steering wheel submentally (on the underside of his chin). This caused significant deformation of the wheel rim and a spoke and resulted in the impression/abrasion described in the autopsy report. While an abrasion in and of itself might be associated with small or large forces, this particular abrasion was the result of a very significant impact involving large forces. Moreover, these forces were directed posterosuperiorly (upward and backward). These impact forces alone can be large enough to produce ring fractures of the skull base.

NONCONTRIBUTING MECHANISMS

Other mechanisms of ring fractures include impacts to the top of the head and impacts to the back of the head. Both of these have been suggested as possible injury mechanisms in this case. The fracture pattern is not consistent with either of these mechanisms, however. Impacts to the top of the head produce ring fractures because the head is compressed between the impact surface and the neck. These ring fractures commonly have associated neck injuries and show evidence of compression in the fracture surfaces. No neck injuries were present and the fractures showed clear evidence of tension. As such, the mechanism of an impact to the top of the head did not cause Mr. Earnhardt's injury. Of note, I have not examined the helmet which would provide additional support for this conclusion. However, I do not believe this is necessary in light of the other compelling findings. Regarding the impact to the back of the head, both the fracture pattern and the associated injuries are not consistent with the type of ring fracture which Mr. Earnhardt suffered. Specifically, the anterior diastasis (opening at the front) with comparative posterior fracture stability, and the absence of externally mediated posterior bruising, show that an impact to the back of the head was not the cause Mr. Earnhardt's ring fracture.

HELMET EFFECTS AND RESTRAINT EFFECTS

It has been suggested that a full face helmet might have been an important aid in preventing the injuries in this crash. This is incorrect. If Mr. Earnhardt had worn a full face helmet, he would still have experienced the same tragic outcome. There are several reasons for this. Addition of a full face helmet does not effect the inertial (whip) mechanism. In the chin impact mechanism, the impact was submental and as such directed forces posterosuperiorly (upward and backward). Addition of the full face helmet would not significantly alter how that force was transmitted through the maxilla and mandibular condyles (face and jaw). Moreover, it would not have significantly changed the ride-down distance and therefore the deceleration of the head during the phase in which the steering wheel impact and deformation occurred. In contrast, a full face shield provides benefit in protecting the jaw and face from direct trauma. It also can work in conjunction with other systems to control the head. Thus, while not ameliorating Mr. Earnhardt's injury, a full face shield is of potential benefit to other drivers.

Review of the vehicle photographs shows that the left (outboard) lap belt webbing is separated and appears torn. For the purposes of this analysis, I am assuming that the belt was torn as a result of crash forces as opposed to being cut following the crash (i.e. assuming a worst case scenario). Physical evidence clearly shows that the restraint system, including the left outboard lap belt, carried large forces during the crash sequence. This evidence includes the rib and sternal fractures as well as the seat belt abrasions including an abrasion over the left iliac crest and left lower quadrant. The fact that Mr. Earnhardt's head rotated and was struck from below also shows that his upper torso was restrained. This upper torso restraint is also supported by the absence of steering wheel deformation characteristic of chest impact, and by the absence of steering wheel mediate chest trauma. As such, the restraint system functioned to slow Mr. Earnhardt's body. This includes the outboard lap belt for some significant portion of the crash. If the outboard lap belt had remained intact throughout the crash, Mr. Earnhardt's head would still likely have experienced similar inertial forces and similar contact forces with the steering wheel. As such, the restraint failure does not appear to have played a role in Mr. Earnhardt's fatal injury. That said, an important part of occupant protection, including preventing head injury, is having an appropriately tuned restraint system that gives both occupant ride-down and strongly couples the occupant to the vehicle during the crash-pulse. As such, while lap belt failure did not contribute to this injury, the restraint system should be appropriately studied as part of an ongoing safety effort.

RELATIVE IMPORTANCE OF THE MECHANISMS

Understanding the relative contributions of the inertial mechanism and the submental impact mechanism to the creation of Mr. Earnhardt's ring fracture is challenging. Both forms of loading can cause the injury. Moreover, the chin impact occurred during the inertial loading, so the two mechanisms occurred concurrently. Under many conditions, contact of the face with the wheel actually serves a protective role for the head and neck.

This protection occurs because the steering wheel deforms, absorbs energy over time, and helps the neck stop the head. Working in conjunction with facial protection this method of protection can be very effective. Unfortunately, that was not the case in Mr. Earnhardt's crash because the impact came to the underside of his chin. The features revealed at autopsy suggest that the chin impact did cause, or at the very least enhanced, his injury. That said, absent the chin impact, crashes of this kind can give rise to forces which are more than large enough to produce this injury, as revealed by study of similar crash tests using instrumented crash test devices (dummies). In other words, if Mr. Earnhardt did not hit his chin, he still could have suffered the same fatal injury in this crash.

SOLUTIONS

Better understanding of the relative contributions of these two mechanisms to Mr. Earnhardt's fatal injuries could be achieved through extensive biomechanical testing. Such testing would need to be repeated until very accurate occupant kinematics were recreated. Such efforts are not required, however, as the reduction in injury risk from either the inertial or chin impact mechanisms occurs through improved control of the head during a crash. Achieving good control of the head in a crash is the result of design efforts which include seat and vehicle geometry, belt design, and head-helmet-suspension-retention system use. Many people have asked whether the use of a HANS device would have prevented this injury. Such a device offers the potential to help control the head and prevent injuries, as do the other elements of the design. Without detailed sled and crash test data however, I cannot evaluate its role in this particular crash. Clearly, further study is merited of methods to control the head while still allowing adequate driver mobility for the unique demands of NASCAR racing.

Sincerely,

Barry Myers, M.D., Ph.D.
Associate Professor, Department of Biomedical Engineering
Associate Professor, Division of Orthopaedic Surgery
Assistant Professor, Department of Biological Anthropology and Anatomy

Tab 8

James E. Rocap, III
Baker Botts, LLP.
The Warner
1299 Pennsylvania Avenue, NW
Washington, DC 20004-2400

RE: Dale Earnhart accident investigation

Dear Mr. Rocap:

This report describes my examination of items of evidence relating to the investigation of the death of Dale Earnhart. The first section is a narrative describing events from our arrival at Conover, North Carolina, until I turned over the DNA samples to Cellmark Diagnostics; the second is a discussion of my visual observations of the items that I examined; the third is a detailed description of where and how each sample for DNA analysis was collected; and the final section is a discussion of the testing for human blood that I conducted. I have illustrated my report with photographs as appropriate.

Narrative:

I accompanied you on Tuesday, May 8, 2001, to the NASCAR Tech Center, located at 2025 Evans Street, Conover, North Carolina 28613, for the purpose of examining Dale Earnhart's racing seat belts and his racing car (Goodwrench #3). The seat belts were retrieved from safety deposit box 109 in the Bank of Granite in Newton, North Carolina. The seat belts were taken from the safety deposit box by Gary Nelson at approximately 10 am and placed in my custody. The seat belts were in an unsealed red and white United Parcel Service (UPS) envelope. Also present when the seat belts were taken from the safety deposit box were James Rocap and Robert Clayton Auton. The seat belts were then taken to the NASCAR Tech Center for examination. All examinations of the seat belts were conducted in a conference room at the NASCAR Tech Center. At no time were the seat belts out of my care, custody and control; when it became necessary for me to leave the conference room, I locked the door of the conference room and retained the key on my person. No other persons remained in the room during my absence. An inventory of the contents of the UPS envelope revealed intact right and left shoulder belts, an intact right lap belt and a left lap belt in two parts (see Figure 1). After completion of the inventory and a preliminary visual examination of the seat belts, the Earnhart racing car (which NASCAR informed me had been in the accident) was visually examined for orientation purposes in a locked service bay in another part of the NASCAR Tech Center. I then returned to the conference room where I conducted a visual examination of the seat belts and photographically documented the condition of the seat belts. Swabbings and scrapings for DNA analysis were taken from four apparently bloodstained areas on two of the belts. Presumptive tests for the presence of blood were performed on the same four areas and swabbings were taken from each and tested for the presence of human hemoglobin. At the request of Gary Nelson, I next examined and photographed the steering wheel from the Earnhart racing car. At the end of my examinations a crotch seat belt that was in the Earnhart car at the time I examined it was removed by Gary Nelson and added to the seat belt assembly by him. After my examinations of the seat belts were completed, I marked all the seat belts and the UPS envelope for identification; I placed all the seat belts in the UPS envelope, which I then sealed with packaging tape. I initialed across the tape seal. I then turned the envelope over to Robert Clayton Auton, in whose possession it remained until it was returned in my presence to the safety deposit box in the Bank of Granite in Newton, North Carolina, at approximately 4:17 pm. Upon completion of my examination of the seat belts, I photographed the Earnhart racing car and took DNA samples from two areas inside of it. Presumptive tests for the presence of blood were performed on the same two areas, and swabbings were taken from each and tested for the presence of human hemoglobin.

As described below, the swabbings and scrapings (samples) taken for DNA testing were packaged and placed in a locked evidence container for our return to Washington, DC. On May 9, 2001, I carried and delivered the samples intended for DNA testing to Cellmark Diagnostics, 20271 Goldenrod Lane, Germantown, Maryland.

Visual examinations:

A visual examination of the seat belts revealed the presence of numerous red-brown stains, which had the color and other visual characteristics of bloodstains. For the purposes of this discussion, the components of the left lap belt will be designated as follows:

lap belt (A): the portion of the belt with attached buckle;

lap belt (B): the portion of the belt with a taped end; and

lap belt (C): the portion of the belt with tensioner and anchor.

The separated ends of lap belt (A) and lap belt (B) are shown in Figure 2. As may be seen in Figure 2, torn fibers at the end of lap belt (A) are matted with dried blood, while the corresponding end of lap belt (B) are not matted. This is consistent with the left lap belt being separated before the blood was deposited on it. Pooling of blood was noted in at least two locations on the outer surface (i.e. the surface which would face away from the body when the belt was worn normally) of lap belt (A)(see Figures 3 and 4). This pooling is consistent with lap belt (A) lying horizontally while the blood pooled and dried. The back of the leather pad at the buckle end of lap belt (A) was also found to be bloodstained. As may be seen in Figure 5, the blood on the back (i.e. the surface which would face toward the body when the belt was worn normally) of the leather pad has flowed downward and then laterally; there are also two small areas where blood has been smeared prior to drying. This pattern of bloodstaining is consistent with blood being initially deposited on back of the leather pad while it was oriented vertically (e.g. while the seat belt was attached to the buckle mechanism). Subsequently the blood was smeared laterally and flowed toward the right edge of the leather pad. The smearing of the blood could have resulted from the unlatching of the buckle assembly. The surface of lap belt (B) has a triangular abraded area (Figure 2). A small number of dark particles were noted lodged in the grooves of the tensioner on lap belt (C). The abraded surface of lap belt (B) and the dark particles on the tensioner of lap belt (C) are consistent with lap belt (B) being pulled through the tensioner on lap belt (C).

Samples taken for DNA profiling:

Both swabbings and scrapings were taken for subsequent DNA analysis by Cellmark Diagnostics. All swabbings were obtained using sterile cotton swabs (Fisher Scientific) moistened with sterile deionized water. The swabs were allowed to airdry and then were wrapped in autoclaved aluminum foil packets, which were labeled with my case number (WFR01-01), the date, my initials and the exhibit designation. The following areas were sampled by swabbing:

Q1: matted fibers on the separated edge of the left lap belt (A), approximately in the middle of the width of the belt.

Q2: apparent pooled, dried blood on left lap belt (A).

Q3: apparent pooled, dried blood from leather pad on left lap belt (A).

Q4: surface of metal buckle on right lap belt.

Q5: top of roll cage bar at bottom of left side of drivers seat.

Q6: drivers seat on bottom edge lefthand slot used for lap belt.

Scrapings were also taken from areas Q1-Q5. Each scraping was made with a fresh sterile scalpel blade on to a clean sheet of weighing paper (Fisher Scientific). Each piece of weighing paper was carefully folded, sealed with clear tape and marked for identification. The areas sampled are shown in Figures 2-4 and 6-8.

The swabbings and scrapings were placed in a locked evidence container and were in my care, custody and control until I personally delivered them on May 9, 2001, to Katherine Columbo at Cellmark Diagnostics, 20271 Goldenrod Lane, Germantown, Maryland.

Tests for the presence of human blood:

Immediately after collecting swabbings and scrapings from Q1 through Q6 for DNA analysis, I performed presumptive tests for blood on rubbings from the same areas. The rubbings were made on clean filter paper and tested for the peroxidase activity of hemoglobin using the tetramethylbenzidine and reduced phenolphthalein tests. All test results were positive. These results strongly indicate the presence of blood.

I then performed confirmatory tests for the presence of human hemoglobin. Samples of suspected dried blood were swabbed from areas Q1-Q6 and tested for the presence of human hemoglobin using *OneStep* ABAcard HemaTrace cards (Abacus Diagnostics). All tests were positive.

Based on these test results, it is my opinion that the red-brown stains in areas Q1-Q6 are human blood.

A copy of my *curriculum vitae* is attached.

Yours truly,

Walter F. Rowe

Walter F. Rowe, Ph.D.
Professor
The George Washington University
Washington, DC 20052

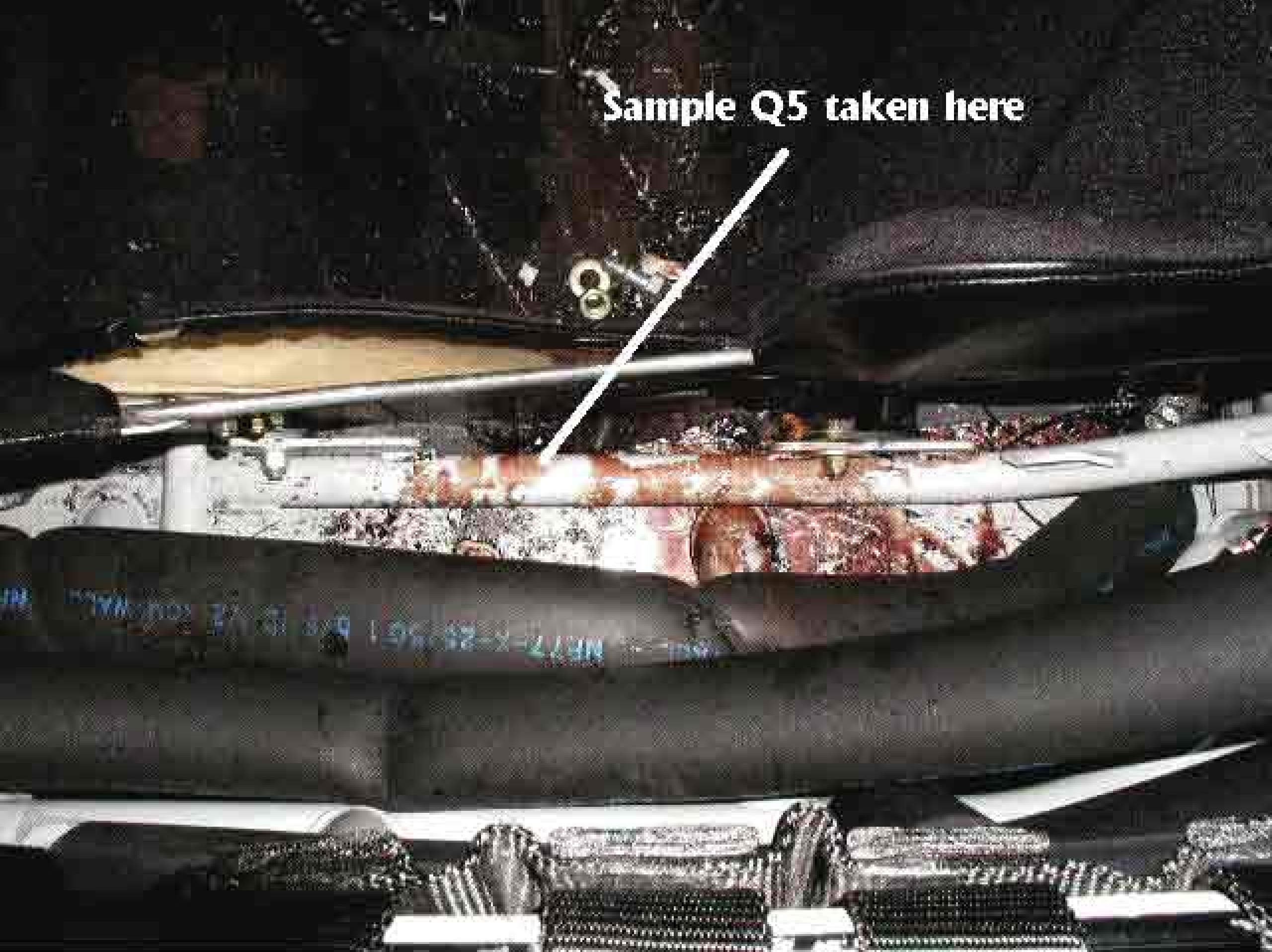
Tab 9


C·Thru®
Sample Q1 taken here


C·Thru
Sample Q2 taken here


C·Thru
Sample Q3 taken here


Sample Q4 taken here
C·Thru


Sample Q5 taken here


Sample Q6 taken here

Tab 10

CELLMARK
DIAGNOSTICS

20271 Goldenrod Lane · Germantown, Maryland 20876
Telephone: (301) 428-4980 (800) USA-LABS
Administration Fax: (301) 428-4877
Laboratory Fax: (301) 428-7946
www.cellmarklabs.com

REPORT OF LABORATORY EXAMINATION

May 31, 2001

Mr. James E. Rocap, III
Baker Botts L.L.P.
The Warner
1299 Pennsylvania Avenue, N.W.
Washington, D.C. 20004-2400

Re: Cellmark Case No. F011267

EXHIBITS:

Items of evidence were received for analysis on May 9, 2001. Polymerase chain reaction (PCR) testing was performed on the items listed below:

Item #	Description
Q1	Swab in foil wrap labelled "...Q1..."
Q2	Swab in foil wrap labelled "...Q2..."
Q3	Swab in foil wrap labelled "...Q3..."
Q4	Swab in foil wrap labelled "...Q4..."
Q5	Swab in foil wrap labelled "...Q5..."
Q6	Swab in foil wrap labelled "...Q6..."
Q1	Scrapings in glassine fold labelled "Q1"
Q2	Scrapings in glassine fold labelled "...Q2"
Q3	Scrapings in glassine fold labelled "...Q3"
Q4	Scrapings in glassine fold labelled "...Q4"
Q5	Scrapings in glassine fold labelled "...Q5"

RESULTS:

DNA extracts isolated from the items listed above were tested using the AmpF*l*STR Profiler Plus™ and the AmpF*l*STR COfiler™ PCR Amplification Kits. The short tandem repeat (STR) loci tested and the types obtained for each sample are listed in the attached tables.

CONCLUSIONS:

Swabs labelled Q1, Q2, Q3, Q4, Q5, and Q6; and scrapings labelled Q1, Q2, Q3, Q4, and Q5:

The DNA obtained from the swabs labelled Q1, Q2, Q3, Q4, Q5, and Q6, and the scrapings labelled Q1, Q2, Q3, Q4, and Q5 is from a male. The DNA profiles from these samples are consistent with having originated from the same source.

Using Recommendation 4.1 from the 1996 National Research Council report[1], the approximate frequencies in the Caucasian, African American, and Hispanic populations of the DNA profile obtained from the swabs labelled Q1, Q2, Q3, Q4, Q5, and Q6, and the scrapings labelled Q1, Q2, Q3, Q4, and Q5 are as follows:

Database	Frequency
Caucasian	1 in 5.6 X 10^{15} unrelated individuals
African American	1 in 27 X 10^{15} unrelated individuals
Hispanic	1 in 36 X 10^{15} unrelated individuals

EVIDENCE DISPOSITION:

In the absence of specific instructions, evidence will be returned to the submitting agency by Federal Express or other appropriate carrier.

Kathryn Colombo
Kathryn Colombo
DNA Analyst III

Robin Cotton
Robin W. Cotton, Ph.D.
Laboratory Director

If expert witnesses are needed for depositions or court testimony, please notify us by telephone at 301-515-6155 at least four weeks in advance.

[1] The National Research Council Committee on DNA Forensic Science (1996) The Evaluation of Forensic DNA Evidence. National Academy Press, Washington, D.C. (see p. 122, using $\theta = 0.03$).

Results for Cellmark Case No.: F011267
Date: 31-May-01
Table No.: 1
Page No.: 3

ALLELES DETECTED - PROFILER PLUS

Case	Sample	D3S1358	vWA	FGA	AMEL	D8S1179	D21S11	D18S51	D5S818	D13S317	D7S820
F011267 01 P	swab (Q1)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 02 P	swab (Q2)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 03 P	swab (Q3)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 04 P	swab (Q4)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 05 P	swab (Q5)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 06 P	swab (Q6)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 07 P	scrapings (Q1)	15,17	17	22,23	X,Y	1,16	30	12,16	13	11	8,9
F011267 08 Pr	scrapings (Q2)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 09 Pr	scrapings (Q3)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 10 P	scrapings (Q4)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9
F011267 11 P	scrapings (Q5)	15,17	17	22,23	X,Y	11,16	30	12,16	13	11	8,9

In addition to the profiles obtained from the items referenced in this report, weak results were observed. These results may be due to the presence of DNA from more than one individual or to technical artifacts, and therefore were not interpreted.

Results for Cellmark Case No.: F011267
Date: 31-May-01
Table No.: 2
Page No.: 4

ALLELES DETECTED - COfiler

Case	Sample	D3S1358	D16S539	AMEL	TH01	TPOX	CSF1PO	D7S820
F011267 01 C	swab (Q1)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 02 C	swab (Q2)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 03 C	swab (Q3)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 04 Cr	swab (Q4)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 05 C	swab (Q5)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 06 Cr	swab (Q6)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 07 C	scrapings (Q1)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 08 C	scrapings (Q2)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 09 Cr	scrapings (Q3)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 10 C	scrapings (Q4)	15,17	11,12	X,Y	6,7	8,11	12	8,9
F011267 11 Cr	scrapings (Q5)	15,17	11,12	X,Y	6,7	8,11	12	8,9

In addition to the profiles obtained from the items referenced in this report, weak results were observed. These results may be due to the presence of DNA from more than one individual or to technical artifacts, and therefore were not interpreted.

Tab 11

OFFICE OF THE MEDICAL EXAMINER
FLORIDA, DISTRICTS 7 & 24
VOLUSIA & SEMINOLE COUNTIES
1360 INDIAN LAKE ROAD, DAYTONA BEACH, FL 32124-1001
(904) 258-4060

NAME EARNHARDT, RALPH DALE **ME #** 01-0101V

AGE 49 **DOB** APRIL 29, 1951 **RACE** W **SEX** M **COUNTY** VOLUSIA

DATE DEATH (FOUND) FEBRUARY 18, 2001 **DATE OF EXAM** FEBRUARY 19, 2001 **TIME** 0830 HRS.

GROSS ANATOMIC DIAGNOSES

FINDINGS: I. Blunt force injuries.
- A. Head and neck.
  - 1. Ring fracture of base of skull.
    - a. Fractures include the occipital bone, fractures of bilateral temporal bones, fractures of the body of the sphenoid bone behind the dorsum sella and through the chiasmatic groove, and through the greater wings of the sphenoid bone (with preservation of the hypophysial fossa).
    - b. Associated subarachnoid and epidural hemorrhage.
    - c. Mild edema of the posterior occipital lobes and posterior temporal lobes bilaterally.
  - 2. Abrasion, right side of chin.
  - 3. Contusion of left and right sides of occipital scalp.
- B. Torso.
  - 1. Rib fractures.
    - a. Left ribs 2 through 8 fractured anteriorly.
    - b. Left rib 9 fractured laterally.
  - 2. Fracture of 3rd sternebra.
  - 3. Superficial abrasions.
- C. Extremities.
  - 1. Fracture of left ankle (with fracture of distal fibula).
  - 2. Superficial abrasions.

II. Cholelithiasis.

FINAL DIAGNOSIS

CAUSE OF DEATH: Blunt Force Injuries of the Head.

DUE TO: Motor Vehicle Accident.

MANNER OF DEATH: Accident.

SPECIAL STUDIES: (See last page of report.)

XC: State Attorney's Office
Daytona Beach Police Department

Thomas R Parsons MD DATE 3/23/01

ASSOCIATE MEDICAL EXAMINER/Thomas R. Parsons, M.D.

NAME EARNHARDT, RALPH DALE ME # 01-0101V

REPORT OF AUTOPSY

EXTERNAL EXAMINATION

Received is the unembalmed, symmetrically developed, adequately nourished and hydrated, body of an adult white male appearing approximately his reported age of 49 years. The length is 69 inches. The weight is 184 pounds. The body is cool to the touch and has been previously refrigerated. Rigor mortis is fully developed in the muscles of the jaw and extremities. Dorsal livor mortis is spared in areas exposed to pressure, and blanches upon firm pressure. The cranium is symmetrically developed, with brown scalp hair measuring up to 10 cm in length. There is no palpable crepitus over the bridge of the nose. The eyebrows are intact. There is no congestion or petechial hemorrhages within the palpebral or bulbar conjunctivae. The irides are blue. The pupils are round, equal, central and measure 3 mm. The nasal septum is intact and in the approximate midline. Over the upper lip is a well groomed, brown hair mustache. The remaining cheeks, chin, and neck are clean-shaven. The external ears are unremarkable, with no foreign material in the external auditory canals. There is abundant blood in the external auditory canals bilaterally. Dentition is natural and in a good state of repair. There are no oral buccal mucosal injuries. The neck is symmetrically developed, without unusual masses palpable. The trachea is palpated in the midline. The chest is symmetrically developed. The abdomen is soft and without palpable masses or organomegaly. The external genitalia are those of a circumcised adult male with bilaterally descended testes palpable within the scrotum. The anus and perineal region are grossly unremarkable. The lower extremities are symmetrically developed and are without an absence of digits. Attached to the left great toe is a cardboard identification tag which is inscribed with the decedent's identifying information, including the name "Ralph Earnhardt". Encircling the right ankle is a hospital identification bracelet which is inscribed with the name "John Pacific Doe". Attached to the right great toe by a piece of string is a hospital identification disk which has the same name on it. The left ankle has a displaced fracture with contusion, described further subsequently (see EVIDENCE OF INJURY). A white plastic identification bracelet encircles the left wrist with the name "Dale Earnhardt" on it. The upper extremities are symmetrically developed and are without an absence of digits. The fingernails are of medium length, without underlying dirt, debris, hair, or tissue. There are no absent fingernails. There is no tearing of the fingernails on the left hand. There is no acute tearing of the fingernails on the right hand. A yellow metal ring encircles the left fourth finger.

EVIDENCE OF THERAPY: A nasogastric tube is present in the naris. An endotracheal tube emanates from the right corner of the mouth. An intravenous catheter is secured in the right side of the neck by black suture material. Chest tubes are secured in the chest bilaterally by black suture material. These are inserted cutaneously at approximately the level of the nipples, just anterior to the midaxillary line. An intravenous catheter is secured in the left antecubital fossa. Numerous self-adhesive EKG pads are present over the anterior chest bilaterally, over the left lateral abdomen, and left posterior shoulder. Three needle puncture marks are present over the flexor aspect of the right forearm and antecubital fossa. There are numerous needle puncture marks in the right subclavian area and on the left side of the neck. No other evidence of therapeutic intervention is seen on the surface of the body.

SCARS AND IDENTIFYING MARKS: A nearly vertically oriented, 11 cm scar is present over the left knee, lateral to the patella. A nearly vertically oriented, well healed, curvilinear scar is present over the right knee and measures 12 cm in

REPORT OF AUTOPSY

length. A 3 cm, vertically oriented, well healed, curvilinear scar is present over the distal head of the biceps on the lateral aspect of the left upper arm. There are no other convincing scars, tattoos, or identifying marks observed on the surface of the body.

EVIDENCE OF INJURY: Over the right side of the chin is a 2.5 x 1.0 cm, superficial abrasion. Over the left sternoclavicular joint is a 1.5 x 0.6 cm, superficial abrasion. Over the left hip region is a nearly transversely oriented, 10 x 2 cm area of superficial abrasion. Over the right hip region is a 22 x 5 cm area of faint superficial abrasions. Over the mid abdomen is an area of diffuse purple-red contusion which measures 2.0 x 4.5 cm. Just inferior to the umbilicus in the midline is a 0.5 x 0.4 cm laceration.

Over the inferior right patella is a 0.6 x 0.5 cm, superficial abrasion. Surrounding the palpable dislocation of the left ankle is a purple-blue area of contusion which extends from the medial malleolus inferiorly to the sole of the foot, and from the heel anteriorly to the head of the metatarsals. This continues to the approximate midline. There is palpable fracture of the distal left fibula included in this dislocation and fracture of the left ankle. Over the medial head of the left gastrocnemius is a faint purple contusion measuring 6.5 x 3.5 cm. Over the posterior proximal left forearm is a 2.0 x 0.8 cm, superficial abrasion.

No other evidence of acute injury is seen externally.

INTERNAL EXAMINATION

Through the usual Y-shaped incision, 4.0 cm of yellow subcutaneous adipose tissue and soft, red-brown musculature are revealed. There is generalized congestion of the subcutaneous tissues and musculature. The peritoneal cavity is free of excess fluid. The ends of the chest tubes are present within the pleural cavities bilaterally through the 5th intercostal spaces. The omentum and viscera are normally disposed. The appendix vermiformis is intact and grossly unremarkable. The right and left pleural cavities have the associated chest tube incisions, without other defects of the pleurae. The remaining pleurae are smooth, glistening, and purple-gray to red-brown with areas of dependent congestion. The pericardial sac is intact and contains a scant amount of pale yellow, clear fluid. The pericardial sac is otherwise unremarkable. The mediastinum is grossly unremarkable. The sternum is transversely fractured at the 3rd sternebra. Left ribs 2 through 8 are fractured anteriorly, with scant hemorrhage surrounding the fractured ends. Left rib 9 is fractured laterally, in approximately the mid axillary line. There are no fractures of the right ribs. There are no unusual odors.

CARDIOVASCULAR SYSTEM: The aorta is of normal course and caliber. There is focal atheromatous streaking with minimal calcification distally. There are no aneurysms identified. The great vessels have their usual anatomical relationships. The pulmonary arteries appear patent and free of thromboemboli. The pulmonary veins are grossly unremarkable. The vena cava is grossly unremarkable. The heart weighs 410 grams. The epicardial surface is smooth, glistening, and red-brown with a moderate amount of yellow subepicardial fat. The coronary ostia are patent and give rise to a normally distributed coronary arterial system which is right dominant. The coronary arteries are thin,

REPORT OF AUTOPSY

elastic, and have focal atheromatous streaking, without significant stenosis. Serial sections through the myocardium are firm and red-brown, with no areas of softening or fibrosis. The cardiac valves and chambers have their usual anatomical relationships. The valve leaflets are thin and delicate, without vegetations. Sections through the area of the conduction system are grossly unremarkable.

RESPIRATORY TRACT: The trachea contains an appropriately placed endotracheal tube. A small amount of blood is present over the mucosal surfaces. The mucosal surfaces of the trachea and main stem bronchi are otherwise grossly unremarkable. The right lung weighs 590 grams. The left lung weighs 660 grams. The lungs are moderately collapsed, with a pattern of hemoaspiration beneath the pleural surfaces. The pleural surfaces are otherwise smooth, glistening, and pink-tan to red-brown. Serial sections are pink-tan to red-brown, with areas of dependent congestion and mild hemoaspiration. Mass lesions are not identified. Purulent exudates are not apparent. Emphysematous changes are inconspicuous.

GASTROINTESTINAL TRACT: The esophagus is of normal course and caliber. The surface of the esophagus is grossly unremarkable. The esophagus is free of foreign material. A nasogastric tube is curled above the level of the epiglottis and did not enter into the stomach. The mucosal surface of the esophagus is grossly unremarkable. The serosal surface of the stomach is grossly unremarkable. The stomach contains 50 cc of bloody fluid, a portion of which is retained. No food or medications are identified. The mucosal surface of the stomach is grossly unremarkable. The serosal surface of the small bowel is grossly unremarkable. The small bowel contains a moderate amount of liquid, yellow-green material. Medications are not appreciated. The mucosal surface of the small bowel is grossly unremarkable. The serosal surface of the colon is grossly unremarkable. The colon contains a moderate amount of pasty, greenish brown fecal material. The mucosal surface of the colon is grossly unremarkable.

HEPATOBILIARY TRACT: The liver weighs 1640 grams. The smooth, glistening, red-brown capsular surface is intact. Serial sections are firm and red-brown, with preservation of the normal hepatic lobular architecture. Steatosis is not apparent. Fibrosis is inconspicuous. Mass lesions are not identified. The gallbladder is intact and contains 20 cc of dark green, liquid bile, a portion of which is retained. There are a few, less than 1.0 cm, black-green gallstones. The biliary tract appears free of obstruction.

HEMATOPOIETIC SYSTEM: The spleen weighs 210 grams. The slate gray connective tissue capsule is intact and slightly wrinkled. Serial sections are soft to gelatinous and red-brown. There are no mass lesions. The lymph nodes and bone marrow are grossly unremarkable.

ENDOCRINE SYSTEM: The right and similar left adrenal glands are of normal size, shape and position. On cut section, the cortices are yellow and the medullae are soft and gray. There are no hemorrhages or mass lesions. The pancreas is of normal size, shape and position. The surface of the pancreas is grossly unremarkable. Serial sections demonstrate preservation of the normal pancreatic lobular architecture. There are no calcifications or hemorrhages. The thyroid gland is of normal size, shape and position. The serosal surface and cut sections are grossly unremarkable. The pituitary is of normal size, shape and position.

REPORT OF AUTOPSY

GENITOURINARY TRACT: The right and left kidneys weigh 160 grams each. The capsules strip with ease to reveal smooth, dark red-brown cortical surfaces punctuated by occasional fetal lobulations. There are no cortical cysts. On cut section, the cortices and medullae are well demarcated in their respective zones. There are no mass lesions. The renal pyramids are grossly unremarkable. The caliceal systems are grossly unremarkable. Stones are not identified. The ureters are of uniform course and caliber. The serosal surface of the urinary bladder is grossly unremarkable. The bladder contains 300 cc of pale yellow, clear urine, a portion of which is retained. The mucosal surface of the urinary bladder is grossly unremarkable. The prostate gland is of normal size, shape, and position to palpation.

HEAD: Reflecting the scalp demonstrates an 8.0 x 5.5 cm area of hemorrhage on the left side of the occipital scalp. There is a second, similar area of hemorrhage on the right side. These overlie the area of ring fracture, which extends through the temporal bones and occipital bone. There is hemorrhage beneath the temporalis muscles bilaterally in the area of the fracture. A few other areas of scattered hemorrhage are present over the right side of the scalp and over the vertex. Reflecting the bony calvarium demonstrates epidural and subarachnoid hemorrhage. There is no significant subdural hemorrhage. Subarachnoid hemorrhage is accentuated in the areas surrounding the fracture and at the base of the brain and cerebellar hemispheres. A small area of subarachnoid hemorrhage is located on the left side of the pontomedullary junction. Epidural hemorrhage is present in the areas surrounding the fracture sites. Discolorations of the bony calvarium are not apparent. The superior sagittal sinus and all venous dural sinuses appear patent and free of thromboemboli. The brain in the fresh state weighs 1450 grams. From the vertex, the cerebral hemispheres are symmetrical, without significant atrophy. There is flattening of the gyral surfaces and narrowing of the sulci in the posterior occipital and temporal lobes. Anteriorly, there is no evidence of edema. The leptomeninges over the surface of the brain and around the base of the brain are thin and delicate, with the previously described subarachnoid hemorrhage. Purulent exudates are not appreciated. There is no evidence of herniation of the hippocampal unci or cerebellar tonsils. The circle of Willis has its usual anatomical relationships. There are no atheromas or aneurysms present. Serial coronal sections of the cerebral hemispheres demonstrate no gross abnormality of the gray or white matter. Mass lesions are not identified. Serial sagittal sections of the cerebellum demonstrate preservation of the normal cerebellar architecture. There is no gross abnormality of the gray or white matter. Serial transverse sections of the brainstem and midbrain demonstrate preservation of the normal architecture. There is no gross abnormality of the gray or white matter. Mass lesions are not identified. Stripping the dura from the base of the skull demonstrates a ring fracture which extends through the occipital bone, through the temporal bones, with fracture of the mastoid portions of the temporal bones bilaterally, and with fractures behind the dorsum sella and through the chiasmatic groove and through the greater wings of the sphenoid bone, with preservation of the hypophysial fossa. This ring fracture includes wide separation of the ring anteriorly (through the sphenoid bone and the temporal bones) and with no separation of the fracture through the internal occipital protuberance of the occipital bone. Although the fracture is seen on both the internal and external tables of the occipital bone in this area, there is no separation of the fractured calvarial plates as there is on the remaining portion of the ring fracture. Examination of the superior cervical spinal canal, upon flexion, extension and rotation of the head, demonstrates no fractures or subluxations.

REPORT OF AUTOPSY

NECK: The hyoid bone and thyroid cartilage are intact. There are no abnormal collections of extravasated blood over the surface of the hyoid bone or thyroid cartilage. Laminar dissection of the strap muscles of the neck demonstrates no abnormal collections of extravasated blood, except in association with the therapeutic devices and intravenous catheters of the right side of the neck. The cricoid cartilage is intact and grossly unremarkable. The larynx and hypopharynx are free of foreign material. The mucosal surfaces of the larynx are grossly unremarkable. The epiglottis and vocal cords are grossly unremarkable. Posterior dissection of the neck demonstrates no injury to the vertebral arteries or to the ligaments of the posterior cervical spine.

MICROSCOPIC EXAMINATION

HEART: A representative section of left ventricular myocardium demonstrates no pathologic processes.

LIVER: A random section of liver demonstrates unremarkable hepatic lobular architecture. No viral, reactive or inflammatory changes are appreciated.

OFFICE OF THE MEDICAL EXAMINER
DISTRICTS 7 & 24

NAME EARNHARDT, RALPH DALE ME # 01-0101V

SPECIAL STUDIES

TOXICOLOGY (Performed by Wuesthoff Reference Laboratories.)

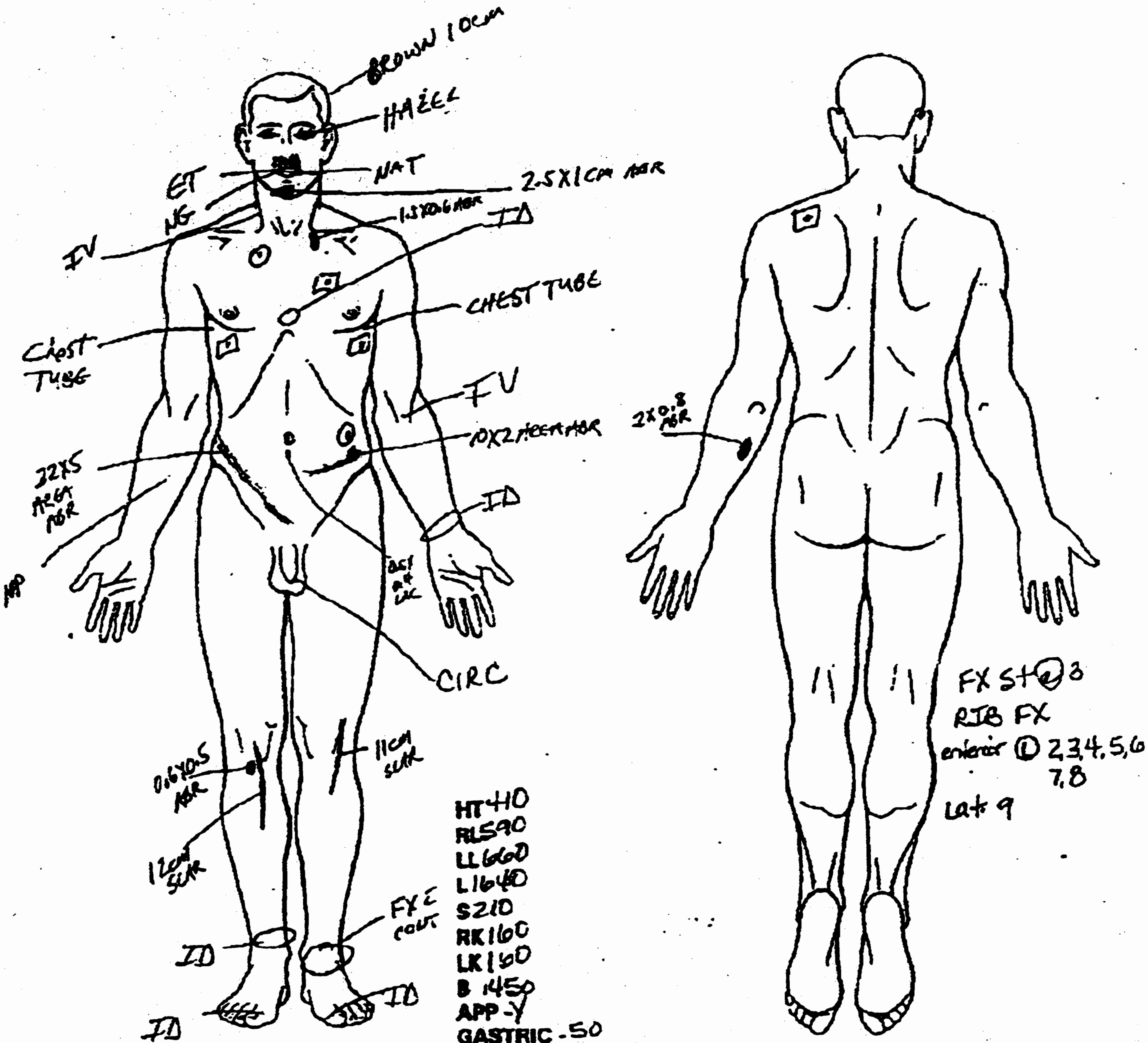
BLOOD	
ETHANOL	None Detected
GC/MS	Caffeine
IMMUNOASSAY SCR	
CANNABINOIDS	Negative
COCAINE METAB	Negative
OPIATES	Negative
BENZO	Negative
BARBITURATE	Negative
SALICYLATE	Negative
URINE	
TLC	Cimetidine, Quinine/Quinidine, Caffeine
HPLC	Cimetidine, Cimetidine Metabolite, Quinine/Quinidine, Quinine/Quinidine Metabolite
IMMUNOASSAY SCR	
CANNABINOIDS	Negative
COCAINE METAB	Negative
OPIATES	Negative
BENZO	Negative
PROPOXYPHENE	Negative
METHADONE	Negative
PCP	Negative
METHAQUAL	Negative
BARBITURATE	Negative
AMPH/METH	Negative
MISC SCREEN	
QUINIDINE SCREEN	Negative
SALICYLATE SCR	Negative
GHB	
GHB	None Detected
VITREOUS	
ELECTROLYTE PAN	
UREA NITROGEN	14 MG/DL
CREATININE	0.4 MG/DL
SODIUM	144 MMOL/L
POTASSIUM	7.7 MMOL/L
CHLORIDE	124 MMOL/L
GLUCOSE	11 MG/DL

Tab 12

VOLUSIA COUNTY MEDICAL EXAMINER'S OFFICE

NAME EARNHARDT, RALPH CASE NO. 01-0101 V

AGE 49 RACE W SEX M DATE (DR.) 2/19/01 (JP)



HT 410
RL 590
LL 660
L 1640
S 210
RK 160
LK 160
B 1450
APP -Y
GASTRIC -50
URINE -300
ADI -4.0
BILE -20

(MAY, 2000) HT 69 WT 184 START TIME 0830

ME-0036-0500

Tab 13

FLORIDA OFFENSE/INCIDENT REPORT – SUPPLEMENTAL/CONTINUATION

AGENCY ORI NUMBER	AGENCY NAME	AGENCY REPORT NUMBER
FL0640100	DAYTONA BEACH POLICE DEPARTMENT	010201594
VICTIM(S) NAME:	**INCIDENT HEADER**	**ORIGINAL REPORT DATE:**
Earnhardt, Ralph Dale	Police Information	18 Feb 2001

NARRATIVE:

On 29 May 2001, NASCAR officials Mike Helton, Gary Nelson, and Capt. Galloway made available the Simpson racing harness system removed from Mr. Earnhardt's vehicle involved in the crash of 18 February 2001. Access was also provided to inspect Mr. Earnhardt's vehicle as stored by NASCAR since the crash event.

The Simpson harness, inside a UPS envelope, had been in the custody of NASCAR, with a documented chain of custody and access. Examining the package revealed the package was sealed, and initialed. Upon opening the UPS envelope, the entire Simpson restraint system was rendered available for inspection. When placing the individual belts into the configuration of installation in a vehicle, it was readily observed the left lap belt was in two separate pieces. Closer examination with a magnifying glass (3X and 5X magnification) revealed the belt fibers torn, with some exposed fiber ends in a "ball" as if melted. There was no indication appearing consistent with a cut from an edged instrument, and no abrasions were observable in the areas adjacent to the break in the belt ends. The location of the break in the belt was consistent with the location of the restraint-adjusting bar.

A demonstration by NASCAR President Mike Helton was performed at this time. Using the same model of Simpson belt, Mr. Helton cut the belt material using a pocket knife and the cut ends examined. The cut belt did not have any similarity to the belt ends that was involved in the crash.

At this same time, NASCAR provided access to Mr. Earnhardt's second Car 3 (back-up vehicle), with the same interior scheme as the vehicle involved in the crash. The same Simpson restraint system was installed, and the seat location was identical to the crash vehicle. I immediately observed the left lap belt adjustment bar outside of the seat (between the seat and car interior).

This detective then inspected the actual Earnhardt Car 3 involved in the crash of 18 February 2001. Examination of the seat, interior and anchor bolts revealed no abnormalities. Inspection of the steering wheel indicated a "bend" on the right diameter of the wheel; two impression marks similar to and consistent with the harness metal clasps were located on the bottom of the steering wheel. Undercarriage examination provided no suspicious areas of damage that could be detected.

Photographs of the harness and restraint system, back-up vehicle and restraint system, and the actual crash vehicle were taken by this detective supervisor utilizing a Canon A-1 35mm SLR w/normal (50mm/1.8) lens. A Vivitar Automatic Electronic flash was used as a lighting source. All photographs were taken at 1/60 second exposure, f 8 aperture, on KODAK Gold 200 ASA speed color print film. Developed negatives were forwarded to CST Youngman for index/storage.

CASE STATUS: Continued

CASE CLEARANCE: [ ] ARREST [ ]EXCEPTION [ ] UNFOUNDED **CASE STATUS:** [ ] PENDED/INACTIVE [X] CONTINUED [ ]CLOSED

REPORTING OFFICER:	DATE:	OFFICER ASSIGNED:	REVIEWED BY:	DATE:
Det. Sgt. S. W. Szabo	31 May 01	Szabo, S. W.	Russell J. Cormican	06-08-01

SW Szabo

Tab 14

MYRON T. SCHOLBERG
FORENSIC CONSULTANT

July 16, 2001

Mr. James E. Rocap, III
Attorney At Law
Baker Botts, LLP
1299 Pennsylvania Avenue, NW
Washington, D.C. 20004-2400

REFERENCE: Results of Earnhardt Accident Seat Belt Examination

ITEM RECEIVED: On July 11, 2001, evidence was personally received from D.C.Page who presented a sealed plastic "DHL" bag. The top of the bag was sealed with tape and marked with initials. Mr. Page and I removed the tape from the bag which contained seven pieces of a seat belt harness system.

EXAMINATION REQUESTED: The examination requested was of the lower belt to determine if any cuts and/or tears existed. An examination was conducted on two separate end portions of the lower belt which were subsequently marked by my initials.

The examinations were conducted using a comparison microscope and a medium power microscope which enables the examiner to view the ends of each fiber.

RESULTS: Microscopic examination of the fiber ends of the two separated portions of the lower belt revelaed fibers that were torn. No fibers were observed with ends that were cut with a sharp instrument.

My conclusions are based on over 18 years experience with the Federal Bureau of Investigation as a Special Agent Laboratory Examiner and tthe Unit Chiefof the Microscopic Analysis Unit where I conducted and supervised thousands of similar fiber examinations. Subsequently, I have conducted numerous hair and fiber examinations for the Commonwealth of Virginia.

DISPOSITION OF EVIDENCE: After the examination, the evidence was turned over to Mr. Page who sealed the seat belts in the same plastic bag, sealed it with tape and initialed the seal.

Myron T. Scholberg

MYRON T. SCHOLBERG

Tab 15

ROBERT A. MENDELSOHN, M.D., P.C.

6121 Executive Boulevard
Rockville, Maryland 20852
301-770-3134
FAX: 301-770-6914
TAX ID: 52-17493-42

August 16, 2001

James V. Benedict, M.D.
James H. Raddin, Jr. M.D.
Biodynamic Research Corporation
9901 1H 10 West, Suite 1000
San Antonio, Texas 78230

Re: Earnhardt Study

Dear Drs. Benedict and Raddin:

This will confirm my thoughts with respect to your analysis and conclusions as to the February 18, 2001 accident involving Dale Earnhardt at Daytona International Speedway.

In my view, your analysis is thorough, objective and scientifically-based, and, based on the information that has been provided to me, I agree with your conclusions.

Sincerely,

Robert A. Mendelsohn, M.D.

MEDICAL-LEGAL CONSULTANTS, INC.

6361 NANCY RIDGE DRIVE
SAN DIEGO, CALIFORNIA 92121
Telephone (858) 457-9711
Facsimile (858) 457-9775

ALAN M. NAHUM, M.D., F.A.C.S.
MARK A. GOMEZ, Ph.D.
JOSHUA S. GOLDEN, M.D.

www.expertwitness-biomech.com
drnahum@expertwitness-biomech.com
drgomez@expertwitness-biomech.com

August 15, 2001

James V. Benedict, M.D.
James H. Raddin, Jr., M.D.
Biodynamic Research Corporation
9901 IH 10 West, Suite 1000
San Antonio, TX 78230

Re: Earnhardt Study

Dear Drs. Benedict and Raddin:

Thank you for the opportunity to review the analysis and conclusions you have reached with respect to the accident involving Dale Earnhardt at Daytona International Speedway on February 18, 2001.

I find your analysis to be very thorough, objective and scientifically-based. Based on the information provided to me and our discussions, I concur in the conclusions that you have reached.

Sincerely,
Alan M. Nahum

Alan M. Nahum, M.D.

Tab 16

CURRICULUM VITAE

DEAN L. SICKING, Ph.D., P.E.

PROFESSIONAL INTERESTS

Protective Highway Structures
Vehicle Dynamics
Computer Simulation of Vehicle Dynamics
Highway Safety Warrants

EDUCATION

Texas A&M University, College Station, Texas:

Doctor of Philosophy - Civil Engineering, December 1992
Master of Science - Civil Engineering, May 1987
Bachelor of Science - Mechanical Engineering, May 1980, Summa Cum Laude

EXPERIENCE

2001-	Director, Midwest Roadside Safety Facility Professor, Civil Engineering, University of Nebraska-Lincoln
1997-2001	Director, Midwest Roadside Safety Facility Associate Professor, Civil Engineering, University of Nebraska-Lincoln
1992-1997	Director, Midwest Roadside Safety Facility Assistant Professor, Civil Engineering, University of Nebraska-Lincoln
1989-1992	Associate Research Engineer, Texas Transportation Institute
1985-1989	Assistant Research Engineer, Texas Transportation Institute
1981-1988	Lecturer, Civil Engineering Department, Texas A&M University
1980-1985	Engineering Research Associate, Texas Transportation Institute

PROFESSIONAL LICENSES

Registered Professional Engineer:

Texas - Mechanical Engineering, 1985, No. 57617
Arizona - Civil Engineering, 1990, No. 24602
Nebraska - Civil Engineering, 1993, No. 7659

AWARDS

1999 Best Paper Award, Presented by Roadside Safety Features Committee of the Transportation Research Bo

1998 Dean's Special Recognition For Exemplary Performance, Presented by Dean of Engineering for Outstanding Success of Freshman Engineering Design Project.

1997 FHWA Region 7 Safety Award, MwRSF and the Mid-States Regional Pooled Fund Program received award for Research Leading the Advancement of Roadside Safety.

1997 Parents Certificate of Recognition for Contributions to Students, Presented to Faculty that "Made a Significant Difference" in a student's education.

1996 Nominated for Federal Highway Administration Safety Award, the Midwest Roadside Safety Facili

1995 Best Paper Award, Presented by Roadside Safety Features Committee of the Transportation Research Bo

1994 Best Paper Award, Presented by Roadside Safety Features Committee of the Transportation Research Bo

1992 Federal Highway Administration Safety Award, Presented to the Texas Department of Transportat

1986 Fred Burggraf Award, National Academy of Science, Transportation Research Board, for Paper entitl

1980 C. M. Simmang Award, Outstanding Achievement in Thermal Science, Texas A&M University,

Member Pi Tau Sigma - National Mechanical Engineering Honor Society.
Member Tau Beta Pi - National Engineering Honor Society.
Member Phi Kappa Phi- National Honor Society.

RESEARCH EXPERIENCE

Dr. Sicking was brought to UNL as Director of a fledgling research program, the Midwest Roadside Safety Facility, and was assigned the task of bringing the organization into national preeminence. Under Dr. Sicking's direction, the Midwest Roadside Safety Facility (MwRSF) has become recognized both nationally and internationally as a leader in the development of safer roadside safety features. Many new roadside safety features have been developed under this program that have become standard designs in states across the country. During this process Dr. Sicking developed a small three-state, mid-west pooled fund program into a major source of funding for roadside safety research. The program now includes 11 states ranging from Montana to Connecticut. In 1994, Dr. Sicking was asked to lead an effort to win the FHWA Region 7 Transportation Center. In this role, he assembled a consortium of five universities and was lead author of the proposal that successfully captured funding for the Federal Region 7 Transportation Center and created the Mid-America Transportation Center. Dr. Sicking has also been a leader in the development of new safety features for private companies. As shown below, Dr. Sicking has been awarded 16 U.S. patents for roadside safety features. Based on these patents, 11 new roadside safety products are currently being marketed nationally with three of these sold globally. Almost every new guardrail terminal installed this year on the National Highway System is covered by one or more of Dr. Sicking's patents.

PATENTS

1. U.S. Patent No. 6060827, July 17, 2001
   Title: *Light Truck Guardrail System*
   Inventors: D. L. Sicking, J.D. Reid, R.K. Faller, B.G. Pfiefer, B.T. Rosson, and J.R. Rohde

2. U.S. Patent No. 6254063 July 3, 2001
   Title: *Energy Absorbing Breakaway Steel Guardrail Post*
   Inventors: J.R. Rohde, J.D. Reid and D.L. Sicking

3. U.S. Patent No. 6244571, June 12, 2001
   Title: *Controlled Kinking Breakaway Cable Terminal*
   Inventors: J.D. Reid, J.R. Rohde, and D.L. Sicking

4. U.S. Patent No. 6,109,597, August 29, 2000
   Title: *Anchor Cable Release Mechanism for a Guardrail System*
   Inventors: D.L. Sicking, J.D. Reid and J.R. Rohde
   Licensed to Road Systems Incorporated, Big Spring, Texas
   Approved by 44 States as component of SKT-350 and FLEAT-350 Terminals.

5. U.S. Patent No. 6,022,003, February 8, 2000
   Title: *Guardrail Cutting Terminal*
   Inventors: D.L. Sicking, J.D. Reid and J.R. Rohde
   Licensed to Interstate Steel Incorporated, Big Spring, Texas
   Approved by 22 states as BEST Guardrail Terminal

6. U.S. Patent No. 5,988,598, November 23, 1999
   Title: *Breakaway Steel Guardrail Post*
   Inventors: D.L. Sicking, J.D. Reid, and J.R. Rohde
   Licensed to Road Systems Incorporated, Big Spring, Texas
   Approved for use in guardrail terminals by 19 states.

7. U.S. Patent No. 5,931,448, August 3, 1999
   Title: *Reverse Twist Turned-Down Terminal for Road Guardrail Systems*
   Inventors: D.L. Sicking, J.D. Reid, and G.W. Paulsen

8. U.S. Patent No. 5,924,680, July 20, 1999
   Title: *Foundation Sleeve for A Guardrail System*
   Inventors: D.L. Sicking, J.D. Reid, and J.R. Rohde
   Licensed to Road Systems Incorporated, Big Spring, Texas
   Approved by 33 states as acceptable component for SKT-350 and FLEAT -350 Terminals

9. U.S. Patent No. 5,775,675, July 7, 1998
   Title: *Sequential Kinking Guardrail Terminal*
   Inventors: D.L. Sicking, J.D. Reid, and J.R. Rohde
   Licensed to Road Systems Incorporated, Big Spring, Texas
   Approved by 44 states as SKT-350 and FLEAT-350 Terminals

10. U.S. Patent No. 5,547,309, August 20, 1996
    Title: *Thrie-Beam Terminal With Breakaway Post Cable Release*
    Inventors: K.K. Mak, R.P. Bligh, D.L. Sicking, and H.E. Ross, Jr.
    Licensed to Trinity Industries, Dallas, Texas

11. U.S. Patent No. 5,503,495, April 2, 1996
    Title: *Thrie-Beam Terminal With Breakaway Post*
    Inventors: K.K. Mak, R.P. Bligh, D.L. Sicking, and H.E. Ross, Jr.
    Licensed to Trinity Industries, Dallas, Texas

12. U.S. Patent No. 5,407,298, April 18, 1995
    Title: *Slotted Rail Terminal*
    Inventors: D.L. Sicking, R.P. Bligh, K.K. Mak, and H.E. Ross, Jr.
    Licensed to Trinity Industries, Dallas, Texas
    Approved by 45 states as ET-2000 Guardrail Terminal.

13. U.S. Patent No. 5,391,016, February 21, 1995
    Title: *Metal Beam Rail Terminal*
    Inventors: D.L. Ivey, C.E. Buth, K.K. Mak, and D.L. Sicking
    Licensed to Trinity Industries, Dallas, Texas
    Approved by 3 states as WyBET guardrail terminal.

14. U.S. Patent No. 5,078,366, January 7, 1992
    Title: *Guardrail Extruder Terminal*
    Inventors: Sicking, D.L., A. Qureshy, H.E. Ross, Jr., and C.E. Buth
    Licensed to Trinity Industries, Dallas, Texas
    Approved by 45 states as ET-2000 Guardrail Terminal.

15. U.S. Patent No. 4,928,928, May 29, 1990
    Canadian Patent 1,306,130, November 18, 1992
    European Patent EP398923B1, April 13,1994
    Title: *Guardrail Extruder Terminal*
    Inventors: Buth, C.E., H.E. Ross, Jr., A. Qureshy, and D.L. Sicking
    Licensed to Trinity Industries, Dallas, Texas
    Approved by 45 states as ET-2000 Guardrail Terminal.

16. U.S. Patent No. 4,815,565, March 28, 1989
    Title: *Low Maintenance Crash Cushion End Treatment*
    Inventors: D.L. Sicking and H.E. Ross Jr.
    Licensed to Energy Absorption Systems Incorporated, Chicago, Illinois
    Approved by 37 states as QuadGuard - LM.

PATENTS PENDING (Under Review by Examiner)

1. U.S. Patent Application Filed May 7, 1999
   Title: *Crash Attenuation System*
   Inventors: J. D. Reid, J.R. Rohde, and D.L. Sicking

FUNDED RESEARCH PROJECTS

Funding levels include only extramural funding without any university match or in-kind contributions.

2000 **Identification of Vehicular Impact Conditions Associated with Serious Ran-Off-Road Crashes** $500,000
National Cooperative Highway Research Program
PI:'s D.L. Sicking, K.K. Mak

2000 **Development of an Energy Absorbing Cushion Wall - Phase 2** $253,454
Indy Racing League, LLC
P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid

1999-2000 **Midwest States Pooled Fund Crash Test Program - Year 10** $445,000
Transportation Departments: Nebraska, Iowa, Kansas
Minnesota, Missouri, Ohio, South Dakota, Wisconsin, and Connecticut
P.I.'s: D.L. Sicking, J.R. Rohde and J.D. Reid

2000 **Development of an Energy Absorbing Cushion Wall** $267,616
Indy Racing League, LLC
P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid

1999	**Safety Evaluation of Michigan's Type B and Type T Guardrail Systems** Michigan Department of Transportation P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde, and J.Holloway	$123,444
1999	**Development and Testing of Indianapolis Crash Barrier** Indy Racing League, LLC P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid	$97,970
1999	**Design and Compliance Testing of Missouri's Bridge Rail to W-Beam Transition** Missouri Department of Transportation P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde, J. Holloway and J.D. Reid	$42,579
1998-99	**Midwest States Pooled Fund Crash Test Program - Year 9** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.R. Rohde and J.D. Reid	$430,618
1998-99	**Safety Evaluation of South Dakota's Cable Guardrail to W-Beam Transition** South Dakota Department of Transportation P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid	$92,329
1997-98	**Midwest States Regional Pooled Funds Program - Year 8** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.D. Reid and J.R. Rohde	$488,519
1997-98	**Development of a New Guardrail System for the Milford Proving Ground Circular Test Track** General Motors Corporation P.I.'s: J.D. Reid, R.K. Faller and D.L. Sicking	$95,379
1997-98	**Midstates Pooled Fund Program - Year 7** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.D. Reid, B.T. Rosson and J.R. Rohde	$388,667
1996-98	**Bridge Rail to Guardrail Transition** Nebraska Department of Roads P.I.'s: J.D. Reid and D.L. Sicking	$40,282

1996-98 **Development of a BEST Terminal to Comply with NCHRP Report 350 Criteria** $332,213
Interstate Steel Corporation and Mid-America Transportation Center
P.I.'s: J.R. Rohde and D.L. Sicking

1996-97 **Midwest States Regional Pooled Fund Program - Year 6** $345,099
Transportation Departments: Nebraska (lead state), Iowa, Kansas, Minnesota, Missouri, South Dakota, and Wisconsin
P.I.'s: D.L. Sicking, B.T. Rosson and J.D. Reid

1995-97 **Development of a New Vehicle Guardrail System** $358,982
Buffalo Specialty Products, Inc.
P.I.'s: D.L. Sicking, J.D. Reid and B.T. Rosson

1995-97 **Guidelines for the Selection, Installation, and Maintenance of Highway Safety Features** $500,000
National Cooperative Highway Research Program
P.I.'s: C.E. Buth and D.L. Sicking

1995-96 **Mid-America Transportation Center** $1,000,000
U.S. Department of Transportation
P.I.'s: P.T. McCoy and D.L. Sicking

1995 **Evaluation of the Effect of Wood Quality on the Performance of W-Beam Guardrail Systems** $79,136
Nebraska Department of Roads
P.I.'s: J.R. Rohde, J.D. Reid and D.L. Sicking

1995-96 **Dual Support Breakaway Sign Design and Simulation** $20,829
Federal Highway Administration
P.I.'s: J.D. Reid and D.L. Sicking

1995-96 **Mid-State Pooled Fund Program** $276,975
Transportation Departments: Nebraska (lead state), Iowa, Kansas, Minnesota, Missouri, South Dakota, and Wisconsin
P.I.'s: D.L. Sicking and B.T. Rosson

1994-95 **Supercomputing at UNL** $100,000
University of Nebraska Foundation
P.I.'s: J.D. Reid and D.L. Sicking

1994-96 **Mid-State Pooled Fund Program** $308,611
Transportation Departments: Nebraska (lead state), Iowa, Kansas, Missouri
P.I.'s: D.L. Sicking and B.T. Rosson

1994 **Dynamic Testing of Impact Attenuators with Prow Covers** $13,784
Port Authority of NY and NJ.
P.I.: D.L. Sicking

1994 **Guardrail Runout Lengths** $38,109
Nebraska Department of Roads
P.I.: D.L. Sicking

1994 **Clear Zone Widths** $30,167
Nebraska Department of Roads
P.I.: D.L. Sicking

1993 **Lighted Guidance Tube Hazard Assessment** $8,398
3M Corporation
P.I.'s: B.T. Rosson and D.L. Sicking

1993 **Development of an Energy Absorbing Barrier System** $15,422
Ultra Barrier Corporation
P.I.'s: D.L. Sicking and R.K. Faller

1993-94 **Mid-States Pooled Fund Program** $253,415
Transportation Departments: Nebraska (lead state), Kansas, Missouri P.I.'

1993 **W-Beam Guardrail End Treatment Evaluation** $117,252
Interstate Steel Corporation
P.I.: D.L. Sicking

1992 **Improved Procedures for the Cost-Effectiveness Evaluation of Roadside Safety Features** $200,000
National Cooperative Highway Research Program
P.I.'s: K.K Mak and D.L. Sicking

1992 **Expert Panel for FHWA Interactive Highway Design Model** $6,388
Federal Highway Administration
P.I.: D.L. Sicking

1989	**Evaluation of Performance Level Selection Criteria for Bridge Railings**. National Cooperative Highway Research Program P.I.'s: K.K. Mak, D.L. Sicking	$200,000
1989	**Bridge Approach Rail Evaluation** Arizona Department of Transportation P.I.'s: D.L. Sicking, R.P. Bligh	$139,531
1988	**Development of Guardrail to Bridge Rail Transition**. Texas Department of Transportation P.I.'s: H.E. Ross D.L. Sicking	$75,000
1988	**Development of Low Maintenance Rubber Crash Cushion** Texas Department of Transportation P.I.'s: H.E. Ross, Jr., D.L. Sicking	$150,000
1987	**Rollover Caused by Concrete Safety Shaped Barriers** Federal Highway Administration P.I.'s: K.K. Mak, D.L. Sicking	$288,000
1987	**Optimization of Texas' Strong Post W-beam Guardrail** Texas Department of Transportation P.I.'s: H.E. Ross, Jr., D.L. Sicking	$95,000
1986	**Safety Analysis at Ford's Arizona Proving Grounds** Ford Motor Company P.I.'s: H.E. Ross, Jr., D.L. Sicking	$28,000
1985	**Full-Scale Crash Tests of TTI's Low Maintenance Crash Cushion with GREAT System Hardware** Energy Absorption Systems Inc. P.I.'s: D.L. Sicking, H.E. Ross, Jr.	$22,000
1984	**Evaluation of Franklin Steel Eze-Erect Sign System with Modified Spacer-Retainer Strap** Franklin Steel Company P.I.'s: H.E. Ross, Jr., D.L. Sicking	$12,000

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2. Faller, R.K., Sicking, D.L., Polivka, K.A., Rohde, J.R., and Bielenberg, R.W., "A Long-Span Guardrail System for Culvert Applications," Transportation Research Record 1720, Transportation Research Board, Washington, D.C., January 2001.

3. Sicking, D.L., J.R. Rohde, and J.R. Reid, "Design and Development of Steel Breakaway Posts", Transportation Research Record 1720, Transportation Research Board, Washington, D.C., January 2001.

4. D.L. Sicking, J.D. Reid and J.R. Rohde, "Development of a Flared Energy Absorbing Terminal for W-Beam Guardrail," Transportation Research Record 1690, TRB, National Research Council, Washington, D.C., November 1999, pp. 8-16.

5. J.D. Reid and D.L. Sicking, "Design and Simulation of a Sequential Kinking Guardrail Terminal," International Journal of Impact Engineering, Vol. 21, No. 9, 1998, pp. 761-772.

6. Mak, K.K, D.L. Sicking, and K.J. Zimmerman, "Roadside Safety Analysis Program," Transportation Research Record 1647, Transportation Research Board, Washington D.C., November, 1998.

7. Sicking, D.L., J.D. Reid, and J.R. Rohde, "Development of the SKT-350 Guardrail Terminal," Submitted to Transportation Research Record 1647, Transportation Research Board, Washington D.C., November, 1998.

8. Pfiefer, B.J., and D.L. Sicking, "NCRHP Report 350 Compliance Testing of the Beam-Eating Steel Terminal System," Submitted to Transportation Research Record 1647, Transportation Research Board, Washington D.C., November 1998.

9. Reid, J.D., D.L. Sicking, and R.P. Bligh, "Critical Impact Point for Longitudinal Barriers," Journal of Transportation Engineering, American Society of Civil Engineers, Vol 124, No. 1, January-February 1998. pp 65-72.

10. Wolford, D., and D.L. Sicking, "Guardrail Need: Embankments and Culverts," Transportation Research Record 1599 Transportation Research Board, Washington D.C., December, 1997.

11. Reid, J.D., D.L. Sicking, R.K. Faller, and B.G. Pfeifer, "Development of a New Guardrail System," Transportation Research Record 1599, Transportation Research Board, Washington D.C., December 1997.

12. Wolford, D. and D.L. Sicking, "Guardrail Runout Lengths Revisited," Transportation Research Record 1528, Transportation Research Board, November 1996.

13. Faller, R.F., K. Soyland, and D.L. Sicking, "Approach Guardrail Transition for Single Slope Barriers," Transportation Research Record 1528, Transportation Research Board, November 1996.

14. Holloway, J.C., D.L. Sicking, and R.K. Faller, "Reduced Height Performance Level 2 Bridge Rail," Transportation Research Record 1528, Transportation Research Board, November 1996.

15. Pfeiffer, B.G., and D.L. Sicking, "Development of a Metal Cutting Guardrail Terminal," Transportation Research Record 1528, Transportation Research Board, November 1996.

16. Reid, J.D., D.L. Sicking, and G. Paulsen, "Design and Analysis of Approach Terminal Sections Using Simulation," Journal of Transportation Engineering, American Society of Civil Engineers, Volume 122, No. 5, 1996.

17. Mak, K. K., R. P. Bligh, H. E. Ross, Jr., and D.L. Sicking, "Slotted Rail Guardrail Terminal," Transportation Research Record 1500, Transportation Research Board, November, 1995.

18. Mak, K. K. and D. L. Sicking, "Analysis of Bridge Rail Accidents", Transportation Research Record 1468, Transportation Research Board, January 1995.

19. Sicking, D. L., K. K. Mak, and W. Wilson, "Box Beam Guardrail End Terminal," Transportation Research Record 1468, Transportation Research Board, January 1995.

20. Faller, R. F., B. T. Rosson, M. A. Ritter, and D. L. Sicking "Design and Evaluation of Two Low-Volume Bridge Railings," Transportation Research Record, Sixth International Conference on Low Volume Roads, Volume II, National Academy Press, Washington, D.C. 1995.

21. Reid, J. D. and D. L. Sicking, "Design Concepts for Collapsing Turned Down Guardrail," Society of Automotive Engineers, Paper No. 951086, April 1995.

22. Schapery, R. A. and D. L. Sicking, "On Nonlinear Constitutive Equations for Elastic and Viscoelastic Composites with Growing Damage," Proceedings of the 7th International Conference on Mechanical Behavior of Materials, May 28-June 2, 1995, The Hague.

23. Mak, K.K. and D.L. Sicking, "Rollover Caused by Concrete Safety Shaped Barrier," Transportation Research Record 1258, Transportation Research Board, 1992.

24. Roschke, P.N., D.L. Sicking, and M. F. Thompson, "Selection of Rubber Materials and Shapes for Energy-Absorbing Elements," Journal of Materials in Civil Engineering, Vol. 2, No. 4, ASCE, 1990.

25. Sicking, D.L., P.N. Roschke, and H.E. Ross, Jr., "Low-Maintenance Rubber Crash Cushion," Journal of Transportation, Vol. 116 No. 3, ASCE, 1990.

26. Ivey, D.L., H.E. Ross, Jr., D. L. Sicking, and C.C. MacAdam, "Truck Losses of Control Produced by Pavement Edge and Shoulder Conditions," Surface Characteristics of Roadways: International Research and Technologies, ASTM STP 1031, 1990.

27. Sicking, D.L., A.B. Qureshy, and H.E. Ross, Jr., "Development of Guardrail Extruder Terminal," Transportation Research Record 1233, Transportation Research Board, 1990.

28. Sicking, D.L., A.B. Qureshy, and H.E. Ross, Jr., "Development of Slotted-Rail Terminal Break-Away Cable Terminal," Transportation Research Record 1233, Transportation Research Board, 1990.

29. Bligh, R.P. and D.L. Sicking, "Applications of Barrier VII in the Design of Flexible Barriers," Transportation Research Record 1233, Transportation Research Board, 1990.

30. Bligh, R.P., D.L. Sicking, and H.E. Ross, Jr., "Development of a Strong Beam Guardrail to Bridge Rail Transition," Transportation Research Record 1198, Transportation Research Board, 1988.

31. Sicking, D.L., and H.E. Ross, Jr., "Structural Optimization of Strong Post W-Beam Guardrail," Transportation Research Record 1133, Transportation Research Board, l987.

32. Sicking, D.L. and H.E. Ross, Jr., "Benefit/Cost Analysis of Roadside Safety Alternatives," Transportation Research Record l065, 1986.

33. Sicking, D.L., and H.E. Ross, Jr., "A Low-Maintenance End Treatment for Concrete Barriers," Transportation Research Record l065, Transportation Research Board, 1986.

34. Mak, K.K., Sicking, D.L., and H.E. Ross, Jr., "Real World Impact Conditions for Ran-Off-the-Road Accidents," Transportation Research Record l065, Transportation Research Board, 1986.

35. Ivey, D.L., and D.L. Sicking, "The Influence of Pavement Edge and Shoulder Characteristics on Vehicle Handling and Stability," Transportation Research Record l084, Transportation Research Board, 1986.

36. Sicking, D.L., "Guidelines for Positive Barrier Use in Construction Zones," Transportation Research Record l035, Transportation Research Board, l985.

37. Ross, H.E. Jr., and D.L. Sicking, "Guidelines for Placement of Longitudinal Barriers on Slopes," Transportation Research Record 970, Transportation Research Board, l984.

38. Sicking, D.L., H.E. Ross, Jr., T.J. Hirsch, and D.L. Ivey, "A Portable Traffic Barrier for Work Zones," Transportation Research Record 942, Transportation Research Board, l983.

39. Sicking, D.L., and H.E. Ross, Jr. "A Crash Cushion for Narrow Objects," Transportation Research Record 942, Transportation Research Board, 1983.

40. Ross, H.E., Jr., Sicking, D.L., et al., "Safety Treatment of Roadside Drainage Structures," Transportation Research Record No. 868, Transportation Research Board, with H. E. Ross, et al., l982.

Accepted for Publication - Publication Pending

41. Faller, R.K., Sicking, D.L., Polivka, K.A., Rohde, J.R., and Bielenberg, R.W., "A Long-Span Guardrail System for Culvert Applications," Paper No. 00-0598, Accepted for publication, Transportation Research Board, Washington, D.C., January 2000.

42. Sicking, D.L., J.R. Rohde, and J.R. Reid, "Design and Development of Steel Breakaway Posts", Accepted for publication, Transportation Research Board, Washington, D.C., January 2000.

Refereed Publications Under Review

1. Polivka, K.A., Sicking, D.L., Faller, R.K., and Rohde, J.R., "A W-Beam Guardrail Adjacent to a Slope," Submitted for presentation and publication, 80th Annual Meeting of the Transportation Research Board, Washington, D.C., January 7-11, 2001.

REFEREED CONFERENCE PAPERS

1. J.D. Reid, R.K. Faller and D.L. Sicking, "High Speed Crash Barrier Investigation Using Simulation," *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems - 2000*, ASME, November 2000.

2. J.D. Reid and D.L. Sicking, "Design of the SKT-350 Using LS-DYNA3D," *TRB Paper 980352*, Transportation Research Board 77th Annual Mtg, January 1998.

3. Sicking, D.L. and K.K. Mak, "Severity Estimates for Ran-Off-Road Accidents," Transportation Research Board 76th Annual Meeting, January 12-16, 1997.

4. J.D. Reid and D.L. Sicking, "Design Concepts for a Collapsing Turned-Down Guardrail," *IX International Conference on Vehicle Structural Mechanics and CAE*, SAE P-290, 1995, pp. 61-68.

INVITED CONFERENCE PROCEEDINGS

1. Sicking, D.L and K.K. Mak, "Improving Roadside Safety by Computer Simulation," in Transportation in the New Millenium, Transportation Research Board, Washington, D.C. January 2000.

2. Sicking, D. L., "Applications of Simulation in Design and Analysis of Roadside Safety Features," Transportation Research Circular No. 435, January 1995. Transportation Research Board, National Research Council.

3. Sicking, D.L., "Energy Dissipation Characteristics of Rubber Cylinders," Proceedings, Ninth Conference on Engineering Mechanics, Engineering Mechanics Division of the American Society of Civil Engineers, May. l992, pp. 139-142.

4. "Update of NCHRP Report 230, Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," Transportation Research Circular 374, July 1991, Author of Part 2, Section C.

5. Ross, H.E. Jr. and D.L. Sicking, "Selection of Performance Levels for Longitudinal Barriers," Proceedings, American Society of Civil Engineers Specialty Conference on Effectiveness of Highway Safety Improvements, Mar. l986, pp. 23l-24l.

6. Sicking, D.L., and H.E. Ross, Jr., "Evaluation of Safety Alternatives by Benefit/Cost Analysis," Proceedings, American Society of Civil Engineers Specialty Conference on Effectiveness of Highway Safety Improvements, Mar. l986, pp. l59-l7l.

OTHER PUBLICATIONS

1. Sicking, D.L. and H.E. Ross, Jr., "Low Maintenance End Treatment for Concrete Barriers," Public Works, May l987, pp. 80-8l.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORTS

1. Ross, H. E., Jr., Krammes, R. A., Sicking, D. L., Tyer, K. D., and Perera, H. S., "Traffic Barriers and Control Treatments for Restricted Work Zones," National Cooperative Highway Research Program Report 358, Transportation Research Board, Washington D.C., 1994.

2. Ross, H.E. Jr., D.L. Sicking, R.A. Zimmer, and J. Michie, "Recommended Procedures for the Safety Performance Evaluation of Highway Features," National Cooperative Highway Research Program Report 350, Transportation Research Board, Washington D.C., 1993, 132 pp.

3. Ross, H.E. Jr., H.S. Perera, D.L. Sicking, and R.P. Bligh, "Roadside Safety Design for Small Vehicles," National Cooperative Highway Research Program, Report 318, Transportation Research Board, 1989, 70 pp.

RESEARCH REPORTS

1. Polivak, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Holloway, J.C., and Keller, E.A., *Development of a W-BEam Guardrail System for Use on a 2:1 Slope*, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-99-00, Project No. SPR-3(017)-Years 9 & 10, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, August 9, 2000.

2. *Development of a Short Radius Guardrail System for Intersecting Roadways*, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-100-00, Project No. SPR-3(017)-Year 8, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, July 26, 2000.

3. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., *Crash Tests of Work Zone Traffic Control Devices - Phase V*, Final Report to Dicke Tool Company, Transportation Research Report No. TRP-03-96-00, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, July 18, 2000.

4. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., *Safety Performance Evaluation of Missouri's Self-Driving Temporary Sign Stands*, Draft Report to the Missouri Department of Transportation, Transportation Research Report No. TRP-03-97-00, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, July 17, 2000.

5. Bielenberg, B.W., Reid, J.D., Faller, R.K., Rohde, J.R., Sicking, D.L., Keller, E.A., Holloway, J.C., and Supencheck, L., "Phase III Development of a Bullnose Guardrail System for Median Applications", Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-95-00, Project No. SPR-3(017)-Years 7 and 8, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, June 1, 2000.

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General Electric Company, Transportation Research Report No. TRP-03-93-00, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, May 19, 2000.

7. Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., and Holloway, J.C., "Crash Testing of Missouri's W-Beam to Thrie Beam Transition Element," Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-94-00, Project No. SPR-3(017)-Year 9, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, April 11, 2000.

8. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., "Crash Tests of Work Zone Traffic Control Devices - Phase IV," Final Report to Dicke Tool Company, Transportation Research Report No. TRP-03-92-99, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, March 21, 2000.

9. Polivka, K.A., Faller, R.K., Reid, J.D., Sicking, D.L., Rohde, J.R., Keller, E.A., and Holloway, J.C., "Development of an Approach Guardrail Transition Attached to a Thrie Beam and Channel Bridge Railing," Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-91-99, Project No. SPR-3(017)-Year 6, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, March 21, 2000.

10. Polivka, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Reid, J.D., and Holloway, J.C., "Guardrail and Guardrail Terminals Installed Over Curbs," Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-83-99, Project No. SPR-3(017)-Year 8, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, March 21, 2000.

11. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., "Crash Tests of Work Zone Traffic Control Devices - Phase V," Draft Report to Dicke Tool Company, Transportation Research Report No. TRP-03-96-00, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, March 17, 2000.

12. Wolford, D.F., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., "Review of Safety Standards for the Midwest States Regional Pooled Fund Program Part V: Bridge Rails and Permanent Barriers," MwRSF Internal Draft Only - Not Submitted, Prepared for the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-67.5-00, Project No. SPR-3(017), Midwest Roadside Safety Facility, University of Nebraska-Lincoln, February 4, 2000.

13. Polivka, K.A., Sicking, D.L., Rohde, J.R., Faller, R.K., and Holloway, J.C., "Crash Testing of Michigan's Type B (W-Beam) Guardrail System," Final Report to the Michigan Department of Transportation, Transportation Research Report No. TRP-03-90-99, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, November 10, 1999.

14. Bielenberg, B.W., Faller, R.K., Holloway, J.C., Rohde, J.R., Pfeifer, B.G., Wolford, D.L., and Sicking, D.L., "Review of Safety Standards for the Midwest States Regional Pooled Fund Program Part III: Temporary Barriers," MwRSF Internal Draft Only - Not Submitted, Prepared for the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-67.3-99, Project No. SPR-3(017), Midwest Roadside Safety Facility, University of Nebraska-Lincoln, October 1999.

15. Bielenberg, B.W., Faller, R.K., Holloway, J.C., Rohde, J.R., Pfeifer, B.G., Wolford, D.L., and Sicking, D.L., "Review of Safety Standards for the Midwest States Regional Pooled Fund Program Part II: Bullnose and Short-Radius Guardrail," MwRSF Internal Draft Only - Not Submitted, Prepared for the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-67.2-99, Project No. SPR-3(017), Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 1999.

16. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., "Crash Testing of MDI's Portable Work Zone Signs - 1999 - Phase I," Final Report to Marketing Displays International, Transportation Research Report No. TRP-03-89-99, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 16, 1999.

17. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., "Evaluation of Temporary Sign Stands and Flag Systems - Phase I," Final Report to Lang Products International, Transportation Research Report No. TRP-03-82-99, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 1, 1999.

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62. Mak, K. K. and Sicking, D. L.,"Development of Roadside Safety Data Collection Plan," Final Report, FHWA Contract No. DTFH61-90-C-00040, Texas Transportation Institute, Texas A&M University System, February 1993.

63. Mak, K. K. and Sicking, D. L., "Evaluation of AASHTO Guide Specifications for Bridge Railings," Final Report on NCHRP Project 22-8, Texas Transportation Institute, Texas A&M University, College Station, Texas, January, 1993.

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65. Mak, K. K. and Sicking, D. L.,"Development of End Terminal for Box Beam Guardrail," Report on Project 7174, Texas Transportation Institute, Texas A&M University, July, 1991.

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72. Ross, H. E., Jr., H.S. Perera, Sicking, D. L., and R.P. Bligh, "Roadside Safety Design for Small Vehicles," Final Report (two volumes), NCHRP Project 22-6, Texas Transportation Institute, Texas A&M University, Apr. 1988.

73. Ivey, D.L., H.E. Ross, Jr., D.L. Sicking, and C.C. MacAdam. "Tractor Semi-Trailer Stability in Traversing Pavement Edges," Policy Development Report 9429-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, March 1988.

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81. H.E. Ross, Jr. and D.L. Sicking, "Guidelines for Use of Temporary Barriers in Work Zones," Research Report 4l5l-l, Final Report, Vol. I., Contract DOT-F H-ll-9688, Texas Transportation Institute, Texas A&M University, July 1983.

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83. P.R. Hall, D.L. Sicking, and H.E. Ross, Jr., "High-Speed Crash Test of Multiple Support Sign with U-Posts and V-Loc Base," Research Report 4872-l, Texas Transportation Institute, Texas A&M University, July 1983.

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86. H.E. Ross, Jr. and D.L. Sicking, "Guidelines for Placement of Longitudinal Barriers on Slopes," Research Report 3659-l, Texas A&M Research Foundation, Texas A&M University, Dec. l982.

87. H.E. Ross, Jr., D.L. Sicking, et al., "Tests of Longitudinal Barriers on Slopes," Research Report 3659-2, Texas A&M Research Foundation, Texas A&M University, Dec. l982.

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89. Sicking, D.L., H. E. Ross and Fred C. Benson, "A Crash Cushion for Narrow Objects," Research Report No. 2296-lF, Texas Transportation Institute, Texas A&M University, Sept. l982.

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92. Ross, H.E., Jr., R. G. Robertson, and D.L. Sicking, "Static Load Tests of Franklin Steel Signposts," Research Report No. 4277-l, Texas Transportation Institute, Texas A&M University, Dec. l98l.

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FORMAL PRESENTATIONS

1. “Build It, Crash It, and Walk Away,” Presented at the Nebraska Cooperative Research Conference,” Sponsored by the Nebraska Department of Roads, Lincoln, NE, October 12, 2000

2. “Safety Treatment of Narrow Medians,” Presented at Issues in Roadside Safety, Sponsored by the Transportation Research Board, Woods Hole, Massachusetts, August 20-23, 2000.

3. “Practical Safety Treatments for Fixed Objects in Narrow Medians,” Presented at the Western Association of State Highway and Transportation Officials, Rapid City, South Dakota, June 18-21, 2000.

4. “Recent Developments in Roadside Safety,” Presented at the AASHTO Subcommittee on Design Annual Meeting, Rapid City, South Dakota, June 20-23, 2000.

5. “Impact Performance of Work Zone Signs and Traffic Control Devices,” Smart Work Zone Conference, Sponsored by the Mid-America Transportation Center, Omaha, Nebraska, January 24-25, 2000.

6. “Development of a Breakaway Steel Guardrail Post,” Transportation Research Board 79th Annual Meeting, January 10-13, 2000

7. “Meeting NCHRP Report 350 Impact Performance Guidelines,” Presented at the Federal Highway Administration Region 1 Safety Conference, Hartford, Connecticut, March 14-15, 1999.

8. “Development of Flared Energy Absorbing Terminal,” Transportation Research Board 78th Annual Meeting, January 12-15, 1999

9. “Development of Sequential Kinking Terminal,” Transportation Research Board 77th Annual Meeting, January 11-15, 1998.

10. “Development of BEST-350,” Transportation Research Board 77th Annual Meeting, January 11-15, 1998.

11. “Problems Created by NCHRP Report 350 Safety Standards,” Ohio Transportation Conference, Columbus, Ohio, November 21, 1997.

12. “Alternative Techniques for Evaluating Roadside Safety Devices,” Presented at Roadside Safety Testing Issues, Sponsored by the Transportation Research Board, Woods Hole, Massachusetts, July 26-28, 1997.

13. “Severity Estimates for Ran-Off-Road Accidents,” Transportation Research Board 76th Annual Meeting, January 12-16, 1997.

14. “Guardrail Performance with Light Trucks,” 78th Annual Kansas Transportation Engineering Conference, April 11-12, 1996.

15. “Guardrail Performance With Light Trucks,” Annual Maintenance Conference sponsored by Nebraska Department of Roads, Kearney, Nebraska, April 10, 1996.

16. “Nebraska’s New Guardrail Terminals,” Annual Maintenance Conference sponsored by Nebraska Department of Roads, Kearney, Nebraska, April 10, 1996.

17. "Roadside Barriers, How They Function and Why They Sometimes Fail," Great Lakes Highway Hardware Workshop, Sponsored by Federal Highway Administration, Madison, Wisconsin, March 25-27, 1996.

18. "Computer Simulation of Roadside Safety Features," Great Lakes Highway Hardware Workshop, Sponsored by Federal Highway Administration, Madison, Wisconsin, March 25-27, 1996.

19. "Wood Guardrail Post Specifications, Why Current Standards are Inappropriate," Great Lakes Highway Hardware Workshop, Sponsored by Federal Highway Administration, Madison, Wisconsin, March 25-27, 1996.

20. "Recent and Future Research at Midwest Roadside Safety Facility," Great Lakes Highway Hardware Workshop, Sponsored by Federal Highway Administration, Madison, Wisconsin, March 25-27, 1996.

21. "Guardrail for Light Trucks," Project Engineers Conference, Sponsored by the Nebraska Department of Roads, Columbus, Nebraska, March 10, 1996.

22. “Guardrail Runout Lengths Revisited,” Transportation Research Board 75th Annual Meeting, January 7-11, 1996.

23. “Approach Guardrail Transition for Single Slope Barriers,” Transportation Research Board 75th Annual Meeting, January 7-11, 1996.

24. “Reduced Height Performance Level 2 Bridge Rail,” Transportation Research Board 75th Annual Meeting, January 7-11, 1996.

25. “Development of a Metal Cutting Guardrail Terminal,” Transportation Research Board 75th Annual Meeting, January 7-11, 1996.

26. “A Procedure for Developing and Validating Safety Hardware Impact Severities,” Presented to the Severity Indices Task Force, August 10, 1995, Irvine, California.

27. "Guardrail Terminals - A Changing Landscape", Presented at the AASHTO Subcommittee on Design, Annual Meeting, Branson, Missouri, June 21-23, 1995.

28. "Fundamentals of Guardrail Performance," Midwest Highway Hardware Workshop, Lincoln, NE, March 13 & 14, 1995.

29. "Development of the BEST Guardrail Terminal," Midwest Highway Hardware Workshop, Lincoln, NE, March 13 & 14, 1995.

30. "Warrants for Multiple Performance Level Safety Hardware," Midwest Highway Hardware Workshop, Lincoln, NE, March 13 & 14, 1995.

31. "Applications of Simulation in Design and Analysis of Roadside Safety Features," Presented at Roadside Safety Issues, Sponsored by the Transportation Research Board, Woods Hole, Massachusetts, August 11-13, 1994.

32. “Box-Beam Guardrail Terminal” presented at the 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 11, 1994.

33. "Full Scale Crash Testing of Guardrails and Bridge Rails," presented at the 14th Annual Concrete Paving Workshop, Nebraska Chapter of America Concrete Pavement Association, February 4, 1993.

34. "Energy Dissipation Characteristics of Rubber Cylinders," presented at the Ninth Conference on Engineering Mechanics, Engineering Mechanics Division of the American Society of Civil Engineers, May. 1992, pp. 139-142.

35. "Pavement Edges and Automobile Stability," presented at the 1991 Torts Litigation Seminar, Philadelphia, Pennsylvania, August 1991.

36. "Development of Guardrail Extruder Terminal," presented at the 68th Annual Transportation Research Board Meeting, Washington, D.C., Jan 1989.

37. "Feasibility of Incorporating Rubber Attenuation Elements in Conventional Crash Cushions," presented at the 62nd Annual Highway and Transportation Short Course, Texas A&M University, October 1988.

38. "Rollover Caused by Concrete Safety Shaped Barriers," presented at the 62nd Annual Highway and Transportation Short Course, Texas A&M University, October 1988.

39. "Development of a Strong Beam Guardrail to Bridge Rail Transition," presented at the 67th Annual Transportation Research Board Meeting, Washington, D.C., January 1988.

40. "A New End Treatment for Guardfence," presented at the 61st Annual Highway and Transportation Short Course, Texas A&M University, October 1987.

41. "Performance of Roadside Safety Features for Mini-Cars," presented at the 61st Annual Highway and Transportation Short Course, Texas A&M University, October 1987.

42. "Structural Optimization of Strong Post W-Beam Guardrail," presented at the 66th Annual Transportation Research Board Meeting, Washington, D.C., January l987.

43. "A Low-Maintenance End Treatment for Concrete Barriers," presented at the 60th Annual Highway and Transportation Short Course, Texas A&M University, October 1986.

44. "Evaluation of Safety Alternatives by Benefit/Cost Analysis," presented at a Specialty Conference on "Effectiveness of Highway Safety Improvements" sponsored by the American Society of Civil Engineers, Nashville, Tennessee, March 24-26, 1986.

45. "A Low-Maintenance End Treatment for Concrete Barriers," presented at the 65th Annual Transportation Research Board Meeting, Washington, D.C., January 1986.

46. "Benefit/Cost Analysis of Highway Safety Alternatives," presented at 1985 American Society of Civil Engineering Spring Convention, Denver, Colorado, May 1985.

47. "Guidelines for Positive Barrier Use in Construction Zones," presented at the 64th Annual Transportation Research Board Meeting, Washington, D.C., January 1985.

48. "A Portable Traffic Barrier for Work Zones," presented at 62nd Annual Transportation Research Board Meeting, Washington, D.C., January 1983.

49. "A Crash Cushion for Narrow Objects," presented at 62nd Annual Transportation Research Board Meeting, Washington, D.C., January 1983.

CONFERENCES ORGANIZED

Midwest Highway Hardware Workshop, Sponsored by Federal Highway Administration-Region 7 in Cooperation with the Midwest Roadside Safety Facility and the Center for Infrastructure Research, Lincoln, Nebraska, March 9-10, 1998.

Great Lakes Highway Hardware Workshop, Sponsored jointly by the Wisconsin DOT and Federal Highway Administration, Madison, Wisconsin, March 24-25, 1996.

Midwest Highway Hardware Workshop, Sponsored by Federal Highway Administration-Region 7 in Cooperation with the Midwest Roadside Safety Facility and the Center for Infrastructure Research, Lincoln, Nebraska, March 14-15, 1995.

Computer Simulation of Impact with Roadside Safety Features, Conference Session presented at 74^{th} Annual Transportation Research Board Meeting, Washington, D.C., January 22, 1995.

PROFESSIONAL COMMITTEE ASSIGNMENTS:

Chairman, Transportation Research Board, Subcommittee A2A04(1), "Computational Mechanics Subcommittee," 1994-present.

Member, Transportation Research Board, Committee A2A04, "Committee on Roadside Safety Features," 1992-present.
Member, AAHSTO Task Force on NCHRP Report 350, 1998.

Member, Transportation Research Board, Committee A3B12, "Committee on Motor Vehicle Technology," 1986-1994.

Member, Transportation Research Board, Subcommittee A2A04(1), "Subcommittee on Computer Simulation," 1986-present.

Member, National Cooperative Highway Research Program, Project Panel 22-14, "Update of Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," 1996-present.

Member, National Cooperative Highway Research Program, Project Panel 17-11, "Recovery-Area Distance Relationships for Highway Roadsides," 1996-present.

Member, National Cooperative Highway Research Program, Project Panel 20-5, "Synthesis of Guardrail Systems," 1994.

CONTINUING EDUCATION

One of Dr. Sicking's major activities at UNL is to provide ongoing technical support for states that support the Mid-States Pooled Fund Program. This support generally takes the form of answering technical questions from state DOT's that encounter difficult roadside safety problems. Providing this ongoing technical counseling comprises almost 20% of Dr. Sicking's time. Most of this technical support is provided to the following State DOT contacts.

Pat McDaniel
Missouri Department of Transportation
105 West Capital Avenue, PO Box 270
Jefferson City MO 65102
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Iowa Department of Transportation
800 Lincoln Way
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1980 West Broad Street
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Connecticut DOT
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Wisconsin DOT, Division of Highways
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608-267-7943
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David Huft
Research Engineer
South Dakota DOT, Office of Research
700 East Broadway
Pierre SD 57501
605-773-3358
dave.huft@state.sd.us

SHORT COURSES PRESENTED

Roadside Design for Safety - 12 Hours, Presented to Missouri Department of Transportation August 14-15, 1996.

NDOR's New Safety Standards - 28 Hours of instruction, Presented to 120 engineers from Nebraska Department of Roads and local consultants.

Applications of Computer Simulation in Roadside Safety Design," workshop presented at the Institute National de Recherche Sur Les, Transports et Leur Securite (INRETS), Lyon, France, October 1989.

GRADUATE STUDENTS

Graduate Students Supported by Dr. Sicking's Research Funding

Kevin Reiser, Master of Science - Civil Engineering Expected Graduation May 2002, Topic: "Finite Element Analysis of Guardrail Terminal Systems,"

Jason Herr, Master of Science - Civil Engineering, Expected Graduation, May 2001, Topic: "Design of Guardrail Systems Installed in Rock."

Ken Addink, Master of Science - Civil Engineering, Expected Graduation, May 2001, Topic: "Strength of Wooden Guardrail Posts."

Karla Polivka - Master of Science - Mechanical Engineering, Expected Graduation, May 2001, Topic: "Design and Analysis of Portable Work Zone Signs Using Finite Element Analysis."

Sridhar Ravikoti, Master of Science - Mechanical Engineering, Expected Graduation, May 2001, Topic: "Impact Analysis of Cable Guardrail Systems."

Jason Heinz, Master of Science - Civil Engineering, Expected Graduation, May 2001, Topic: "Effective Moment of Inertia Analysis of Elasto-Plastic Behavior."

Matthew Goeller, Master of Science - Civil Engineering, May 2000, "Soil Behavior During a Guardrail Post Impact."

Brian Coon, Master of Science - Civil Engineering, December 1999. Thesis "Dynamic Impact Testing and Simulation of Guardrail Posts Embedded in Soil"

Robert W. Bielenberg, Master of Science - Mechanical Engineering, Thesis: Finite Element Simulation of a Bullnose Median Barrier System, August, 1999.

Dan Wolford, Master of Science - Civil Engineering, May 1997. Thesis topic: "Methods for Selecting Guardrail Length of Need." (Chair of Graduate Committee.)

Richard Smith, Master of Science - Civil Engineering, August 1997, "Quantification of Guardrail Post Soil Interaction."

SICKING, Dean L.

Karl Zimmerman, Master of Science - Civil Engineering, December 1996. Thesis topic: "Cost-
Effectiveness Analysis Procedures." (Chair of Graduate Committee.)

Gene W. Paulsen, Master of Science - Mechanical Engineering, May, 1996, Thesis: "Design and Testing of a Dual Support Breakaway Sign Using Nonlinear Finite Element Analysis."

Mark G. Bierman, Master of Science - Civil Engineering, December, 1995, Thesis: "Behavior of Guardrail Posts Under Lateral Impact Loads."

Thomas V. Strauss, Master of Science - Civil Engineering, December 1995, "A Ground Water
Sampling and Grouting System for the Cone Penetrometer"

Bavneet Singh Brar, Master of Science - Mechanical Engineering, Thesis: Component Testing and
Simulation of Guardrail End Terminal, August 1995.

Ashraf F. Taha, Master of Science - Civil Engineering, August 1994, "The Effect of Using Fly Ash
as a Partial Replacement for Cement in Precast/Prestressed Concrete", Supported on other projects

James C. Holloway, Jr., Master of Science - Civil Engineering, December 1993; Thesis: "Safety
Performance Evaluation of Vehicular Impacts on Mountable Curbs." (Co-Chair of Graduate Committee with Dr. Barry Rosson.)

James K. Luedke, Master of Science - Civil Engineering, December, 1993, Thesis: "Development of Equivalent Dynamic Forcing Functions of Vehicle Impacts on Bridge Rails."

Ronald K. Faller, Doctor of Philosophy, May 1998. Thesis topic: "Elasto-Plastic Beam Bending
Under Monotonic and Alternating Yield Conditions." (Applied to the design of bridge rails for
wooden bridges.)

Brian G. Pfeiffer, Doctor of Philosophy, Graduated May 1997. Thesis topic: "Energy Dissipation by Shearing Steel Plates." (Chair of Graduate Committee).

Service as Graduate Committee Member w/o Providing Support

Bruce J. Keeler, Master of Science - Civil Engineering, December, 1995, Thesis: "Experimental Investigation of Flush End-Plate Connections in Steel Frames."

Stephen D. Kathol, Master of Science - Civil Engineering, December, 1994, Thesis: "Performance of a Steel Girder Bridge."

Yerrapalli Shekar, Master of Science - Civil Engineering, August, 1993, Thesis: "Performance of Concrete Slab Bridges."

Paul Balthazer Brungardt, Jr., Master of Science - Civil Engineering, December 1992, Thesis: "Design and Detailing of Transverse Reinforcement in High Strength Reinforced Concrete Columns Subjected to Seismic Loading."

Yaron Yakel, Doctor of Philosophy, Expected Graduation, May 2001, "Design Procedures for High
Performance Steel Bridges."

TEACHING EXPERIENCE

Introduction to Civil Engineering (CE 112)
Fall 1997. Undergraduate survey of Civil Engineering.
Mechanics of Materials Laboratory (CE 370)
Spring 1996, 1997, and 1998. Undergraduate laboratory on mechanics of materials.

Introduction to Structural Analysis (CE 341)
Fall 1997; Fall 1998. Undergraduate structural analysis class.
Reinforced Concrete Design (CE 440)
Fall 1998. Undergraduate class on design of reinforced concrete structures.
Steel Design (CE 444)
Fall 1995. Undergraduate class on design of steel structures.
Issues in Civil Engineering (CE 490)
Fall 1999, Fall 2000. Undergraduate course on engineering practice taught via interactive television.
Structural Dynamics (CE 842)
Spring 2000. Graduate course on dynamic analysis of structures taught via interactive television.
Transportation Safety (CE 867)
Spring 1993; Spring 1995; Fall 1996; Fall 1999. Graduate class in transportation safety taught via interactive television.
Behavior of Structural Materials (CE 944)

Fall 1993. Graduate class in mechanics of structural materials.

Advanced Structural Engineering (CE 946)
Fall 1994. Graduate class in advanced structural analysis taught via interactive television.
Seminar in Civil Engineering (CE 989)
Spring 1994, Spring 1998. Graduate seminar.

Courses Developed

Mechanics of Materials Laboratory, Civil Engineering 370 - This class was designed to demonstrate the concepts of stress and strain in the laboratory for axial, torsional, shear and flexural loadings. The labs were also designed to demonstrate the deformation of materials and failure mechanisms. Experiments include uniaxial tension testing of metals, polymers, and composites; torsional testing of steel; flexural testing of steel, aluminum, and wood; compressive strength testing of concrete; tensile strength testing of concrete using split cylinder testing; elastic and inelastic buckling of columns; and lateral torsional buckling of steel beams. Students were asked to write detailed lab reports and do some outside reading to answer specific questions for each report.

Transportation Safety, Civil Engineering 867 - This course was designed to provide students with a detailed understanding of highway design for safety. Topics included development and design of roadside safety features, warranting for roadside safety features, roadway and roadside geometric design for safety, accident monitoring systems, accident mitigation techniques, and benefit/cost analysis of safety improvement projects.

Behavior of Structural Materials, Civil Engineering 944 - This graduate class was developed at the request of the structures division faculty. The course was designed to cover a broad spectrum of advanced materials, including steels, nonferrous metals, high strength concrete, high performance ceramics, polymers, and composites. The new course was designed to be an overview of the basic behavior of these materials as wells as advanced methods for material characterization. The course covered material structure, deformation, failure criteria, fracture, plasticity, as well as laminated plate theory for composites. The broad spectrum approach to this class was intended to attract students who needed a better understanding of advanced materials and analysis techniques, but did not have the time to take an in-depth course on each subject.

Tab 17

JOHN D. REID
August 2001

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Mechanical Engineering Department
University of Nebraska-Lincoln
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PROFESSIONAL INTERESTS

Roadside Safety
Automotive Crashworthiness
Impact Engineering
Nonlinear Finite Element Analysis

EDUCATION

Michigan State University

1990 Ph.D. in Mechanical Engineering, Dynamic Physical System Simulation
1983 M.S.M.E., Modeling and Analysis of Dynamic Systems
1981 B.S.M.E. with High Honors

EXPERIENCE

Associate Professor, July 1999 to present
Assistant Professor, August 1993 thru June 1999
Dept. of Mechanical Engineering, University of Nebraska-Lincoln

- P.I. for 16 funded proposals, co-P.I. for 13 funded proposals, research funding $4,632,938 (Funding amount does not include any UNL match.)
- 44 technical papers, 24 of which are refereed Journal papers (2 of which are still in review)
- Director of a FHWA Center of Excellence in DYNA3D Analysis

Senior Project Engineer, June 1990 to August 1993
Safety and Crashworthiness Systems, General Motors Corporation, Warren, MI

- Frontal crashworthiness Lead Engineer for the 1997 Park Avenue.
- Developed modeling techniques for predicting the crashworthiness of vehicle structures. Worked on the first application within General Motors to combine finite element and lumped parameter modeling techniques for structural crashworthiness simulation.

Instructor, July 1986 to June 1990
Dept. of Mechanical Engineering, GMI Engineering & Management Institute, Flint, MI

- Taught courses in Systems Analysis, Dynamics, CAD, and Computer Graphics
- Fifth year thesis advisor (approximately 4 or 5 students per year).

Systems Engineer, July 1981 to June 1986
General Motors Corporation (three different divisions), Warren, MI

- Researched and developed computer aided engineering applications.
- Supervised twelve programmers developing computer aided design applications.

FUNDED RESEARCH

Listed amounts do not include any UNL match.

2001-03	**Center of Excellence in DYNA3D Analysis** Federal Highway Administration P.I.: J.D. Reid	$100,000
2000-01	**Development of an Energy Absorbing Cushion Wall - Phase 2** Indy Racing League, LLC P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid	$253,454
2000-01	**Midwest States Pooled Fund Crash Test Program - Year 11** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.R. Rohde and J.D. Reid	$445,000
2000	**Development of an Energy Absorbing Cushion Wall** Indy Racing League, LLC P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid	$242,968
1999-01	**Wood, Soil & Concrete Material Models for Roadside Safety Simulation** Aptek, Inc P.I.'s: J.D. Reid and J.R. Rohde	$165,000
1999-00	**Midwest States Pooled Fund Crash Test Program - Year 10** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.R. Rohde and J.D. Reid	$400,000
1999	**Development and Testing of Indianapolis Crash Barrier** Indy Racing League, LLC P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid	$97,970
1999	**Design and Compliance Testing of Missouri's Bridge Rail to W-Beam Transition** Missouri Department of Transportation P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde, J. Holloway and J.D. Reid	$42,579
1998-99	**Midwest States Pooled Fund Crash Test Program - Year 9** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.R. Rohde and J.D. Reid	$430,618
1998-99	**Crash Testing of South Dakota's Cable Guardrail to W-Beam Transition** South Dakota Department of Transportation P.I.'s: R.K. Faller, D.L. Sicking, J.R. Rohde and J.D. Reid	$92,330
1998-99	**DYNA3D Center of Excellence** Federal Highway Administration P.I.: J.D. Reid	$100,000
1998-99	**Midwest States Regional Pooled Funds Program - Year 8** $488,519 Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.D. Reid and J.R. Rohde	

1997-99	**Side Impact: Finalizing the Test Procedures and Preliminary Countermeasures** Subcontract from the University of Iowa on a Federal Highway Administration Project (total $413,505) P.I.: J.D. Reid	$68,290
1997-98	**Dynamic Impact Testing of Guardrail Posts** Federal Highway Administration P.I.: J.D. Reid	$48,876
1997-98	**Development of a New Guardrail System for the Milford Proving Ground Circular Test Track** General Motors Corporation P.I.'s: J.D. Reid, R.K. Faller and D.L. Sicking	$90,379
1997-98	**Midstates Pooled Fund Program - Year 7** Transportation Departments: Nebraska, Iowa, Kansas Minnesota, Missouri, Ohio, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, J.D. Reid, B.T. Rosson and J.R. Rohde	$388,667
1997	**Dynamic Post-Soil Interaction Modeling** Federal Highway Administration P.I.: J.D. Reid	$7,000
1996-98	**Side Impact Simulation of a Dual Support Breakaway Sign** Federal Highway Administration P.I.: J.D. Reid	$21,207
1996-98	**Bridge Rail to Guardrail Transition** Nebraska Department of Roads P.I.: J.D. Reid and D.L. Sicking	$40,282
1996-97	**Midwest States Regional Pooled Fund Program - Year 6** Transportation Departments: Nebraska (lead state), Iowa, Kansas, Minnesota, Missouri, South Dakota, and Wisconsin P.I.'s: D.L. Sicking, B.T. Rosson and J.D. Reid	$345,099
1996	**Temperature Effects on the Performance of Guardrail Systems** NRI Engineering Research Center Grants P.I.'s: J.D. Reid and J.R. Rohde	$20,000
1995-97	**Development of a New Vehicle Guardrail System** Buffalo Specialty Products, Inc. P.I.'s: D.L. Sicking, J.D. Reid and B.T. Rosson	$358,982
1995-96	**Design of Breakaway Mounts for Cluster Box Units** United States Postal Service P.I.'s: J.D. Reid and R.K. Faller	$44,188
1995	**Axial Buckling of Thin-Walled Structures** Alcoa Foundation P.I.: J.D. Reid	$7,500
1995	**Evaluation of the Effect of Wood Quality on the Performance of W-Beam Guardrail Systems** Nebraska Department of Roads P.I.'s: J.R. Rohde, J.D. Reid and D.L. Sicking	$79,136

1995-96 **Dual Support Breakaway Sign Design and Simulation** $20,829
Federal Highway Administration
P.I.'s: J.D. Reid and D.L. Sicking

1994-95 **Supercomputing at UNL** $100,000
University of Nebraska Foundation
P.I.'s: J.D. Reid and D.L. Sicking

1994-95 **Advanced Crashworthiness Simulation Technology** $1,990
UNL Research Council
P.I.: J.D. Reid

1994 **Manufacturing Variances on the Crashworthiness of Structures** $7,500
General Motors Corporation, Cadillac/Luxury Car Division
P.I.: J.D. Reid

Research projects funded that I was not on the original proposal but subsequently became project leader.

1995 **Development of a Non-Proprietary Crashworthy End Treatment for Steel Plate Guard Fence** $52,585
Kansas Department of Transportation

1994-95 **Performance Evaluation of a Dual Support Highway Sign with Ground Mounted Wide-Flange Posts, Multi-Direction Slip Bases, and Attached Hinge Plates** $31,642
Missouri Highway and Transportation Department

1994 **Concept Development of a Retrofit for the Turned-Down Approach Terminal Section** $40,348
Nebraska Department of Roads

HONORS AND AWARDS

2001 Ralph R. Teetor Educational Award, Society of Automotive Engineers, March 6, 2001.

1999 Best Paper Award for "Development of Flared Energy-Absorbing Terminal for W-beam Guardrails," by D.L. Sicking, J.D. Reid and J.R. Rohde, awarded by the Roadside Safety Features Committee A2A04 of the Transportation Research Board, January 2000.

College of Engineering & Technology Faculty Research Award, UNL, May 1, 1998.

Graduate College Faculty Fellow, UNL, September 24, 1997.

Department of Mechanical Engineering Faculty Research Award, UNL, April 19, 1997.

1996 Best Paper Award for "Nonlinear Finite Element Analysis of a Dual Support Breakaway Sign," by G.W. Paulsen and J.D. Reid, awarded by the Roadside Safety Features Committee A2A04 of the Transportation Research Board, January 1997.

The FHWA Region 7 Administrator's Safety Award was presented to the Midwest Roadside Safety Facility, of which, I am an active researcher, December 12, 1996.

Awarded travel expenses by Livermore Software Technology Corporation to attend the *Fourth International LS-DYNA3D Conference*, Minneapolis, MN, September 1996.

Elected Honorary Member of Pi Tau Sigma, November 17, 1995.

One of my computer simulation figures was selected for the cover of *Directory of Applications Software for Cray Research Supercomputers*, April 1995.

"Order of the Golden Shaft" by the students of Pi Tau Sigma, April 16, 1994.

GM Lighting Awards for outstanding contributions - Sept. 1990 and Oct. 1991.

Best Graduate Student in Mechanical Engineering at Michigan State, June 1990.

PATENTS

U.S. Patent No. 6,260,827, July 17, 2001
Title: *Guardrail System*
Inventors: D.L. Sicking, J.D. Reid, R.K. Faller, B.G. Pfeifer, B.T. Rosson and J.R. Rohde

U.S. Patent No. 6,254,063, July 3, 2001
Title: *Energy Absorbing Breakaway Steel Guardrail Post*
Inventors: J.R. Rohde, J.D. Reid and D.L. Sicking

U.S. Patent No. 6,244,571, June 12, 2001
Title: *Controlled Buckling Breakaway Cable Terminal*
Inventors: J.D. Reid, J.R. Rohde and D.L. Sicking

U.S. Patent No. 6,109,597, August 29, 2000
Title: *Anchor Cable Release Mechanism for a Guardrail System*
Inventors: D.L. Sicking, J.D. Reid and J.R. Rohde

U.S. Patent No. 5,988,598, November 23, 1999
Title: *Breakaway Steel Guardrail Post*
Inventors: D.L. Sicking, J.D. Reid and J.R. Rohde

U.S. Patent No. 5,931,448, August 3, 1999
Title: *Reversed Twist Turned-Down Terminal for Road Guardrail Systems*
Inventors: D.L. Sicking, J.D. Reid and G.W. Paulsen.

U.S. Patent No. 5,924,680, July 20, 1999
Title: *Foundation Sleeve for a Guardrail System*
Inventors: D.L. Sicking, J.D. Reid and J.R. Rohde

Patent Application filed May 7, 1999 (still in review)
Title: *Crash Attenuation System*
Inventors: J.D. Reid, J.R. Rohde and D.L. Sicking

U.S. Patent No. 5,855,443, January 5, 1999
Title: *Breakaway Connection System for Roadside Use*
Inventors: R.K. Faller, J.D. Reid, E.W. Paulsen and K.L. Krenk

U.S. Patent No. 5,775,675, July 7, 1998
Title: *Sequential Kinking Guardrail Terminal System*
Inventors: D.L. Sicking, J.D. Reid and J.R. Rohde

U.S. Patent No. 5,339,242, August 16, 1994
Title: *Method and Apparatus for Vehicle Crash Discrimination Based on Oscillation and Energy Content*
Inventors: J.D. Reid and J. Jensen

REFEREED JOURNAL PAPERS

1. J.D. Reid, J.R. Rohde and D.L. Sicking, "Box-Beam Burster Energy Absorbing Single-Sided Crash Cushion," *Transportation Research Record*, TRB, National Research Council, Washington, D.C., submitted July 27, 2001.

2. J.D. Reid and D. Marzougui, "An Improved Truck Model for Roadside Safety Simulation: Part I - Structural Modeling," *Transportation Research Record*, TRB, National Research Council, Washington, D.C., submitted July 25, 2001.

3. J.D. Reid, B.W. Bielenberg and B.A. Coon, "Indenting, Buckling and Piercing of Aluminum Beverage Cans," *Finite Elements in Analysis and Design*, Vol. 37, 2001, pp.131-144.

4. J.D. Reid, J.R. Rohde and D.L. Sicking, "A Box-Beam Bursting Energy Absorbing Terminal," *ASCE Journal of Transportation Engineering*, submitted March 1, 2001, accepted for publication June 21, 2001.

5. B.W. Bielenberg, J.D. Reid and R.K. Faller, "NCHRP Report No. 350 Compliance Testing of a Bullnose Median Barrier System," *Transportation Research Record*, TRB, National Research Council, Washington, D.C., submitted July 24, 2000, accepted for publication February 26, 2001.

6. J.D. Reid, "Designing for the Critical Impact Point on a New Bullnose Guardrail System," *International Journal of Crashworthiness*, Vol. 5, No. 2, 2000, pp. 141-152.

7. D.L. Sicking, J.R. Rohde and J.D. Reid, "Design and Development of Steel Breakaway Posts," *Transportation Research Record 1720*, TRB, National Research Council, Washington, D.C., November 2000, pp. 59-66.

8. D.L. Sicking, J.D. Reid and J.R. Rohde, "Development of a Flared Energy Absorbing Terminal for W-Beam Guardrail," *Transportation Research Record 1690*, TRB, National Research Council, Washington, D.C., November 1999, pp. 8-16.

9. J.D. Reid and B.W. Bielenberg, "Using LS-DYNA Simulation To Solve a Design Problem: Bullnose Guardrail Example," *Transportation Research Record 1690*, TRB, National Research Council, Washington, D.C., November 1999, pp. 95-102.

10. J.D. Reid, "A New Breakaway Mailbox Designed Using Nonlinear Finite Element Analysis," *Finite Elements in Analysis and Design*, Vol. 32, 1999, pp. 37-49.

11. J.D. Reid and D.L. Sicking, "Design and Simulation of a Sequential Kinking Guardrail Terminal," *International Journal of*

Impact Engineering, Vol. 21, No. 9, 1998, pp. 761-772.

12. D.L. Sicking, J.D. Reid and J.R. Rohde, "Development of a Sequential Kinking Terminal for W-Beam Guardrails," *Transportation Research Record 1647*, TRB, National Research Council, Washington, D.C., November 1998, pp. 89-96.

13. R.K. Faller, J.D. Reid and J.R. Rohde, "Approach Guardrail Transition for Concrete Safety Shape Barriers," *Transportation Research Record 1647*, TRB, National Research Council, Washington, D.C., November 1998, pp. 111-121.

14. J.D. Reid, "Tracking the Energy in an Energy Absorbing Guardrail Terminal," *International Journal of Crashworthiness*, Vol. 3, No. 2, 1998, pp. 135-146.

15. J.D. Reid, "Admissible Modeling Errors or Modeling Simplifications," *Finite Elements in Analysis and Design*, Vol. 29, 1998, pp. 49-63.

16. J.D. Reid, D.L. Sicking and R. Bligh, "Critical Impact Point for Longitudinal Barriers," *ASCE Journal of Transportation Engineering*, Vol. 124, No. 1, Jan./Feb.1998, pp. 65-72.

17. J.D. Reid and G.W. Paulsen, "Design and Simulation of Large Breakaway Signs," *ASCE Journal of Transportation Engineering*, Vol. 124, No. 1, Jan./Feb.1998, pp. 59-64.

18. J.D. Reid, D.L. Sicking, R.K. Faller and B.G. Pfeifer, "Development of a New Guardrail System," *Transportation Research Record 1599*, TRB, National Research Council, Washington, D.C., September 1997, pp. 72-80.

19. J.D. Reid, "Crashworthiness of Automotive Steel Midrails: Thickness and Material Sensitivity," *Thin-Walled Structures*, Vol. 26, No. 2, 1996, pp. 83-103.

20. J.D. Reid, D.L. Sicking and G.W. Paulsen, "Design and Analysis of Approach Terminal Sections Using Simulation," *ASCE Journal of Transportation Engineering*, Vol. 122, No. 5, Sep./Oct. 1996, pp. 399-405.

21. J.D. Reid, "Dual-Support Breakaway Sign with Modified Fuse Plate and Multidirection Slip Base," *Transportation Research Record 1528*, TRB, National Research Council, Washington, D.C., September 1996, pp. 61-68.

22. G.W. Paulsen and J.D. Reid, "Nonlinear Finite Element Analysis of a Dual Support Breakaway Sign," *Transportation Research Record 1528*, TRB, National Research Council, Washington, D.C., September 1996, pp. 146-154.

23. J.D. Reid, "Towards the Understanding of Material Property Influence on Automotive Crash Structures," *Thin-Walled Structures*, Vol. 24, No. 4, 1996, pp. 285-313.

24. J.D. Reid, "Visualizing Cross Section Forces," *Computers & Graphics*, Vol. 19, No. 3, 1995, pp. 475-480.

25. J.D. Reid and R.C. Rosenberg, "Object Oriented Bond-Graph/Block-Diagram Modeling," *Bond Graphs For Engineers*, IMACS Transaction Special Volume, 1992.

26. R.C. Rosenberg, J. Whitesell and J.D. Reid, "Extendible Software for Dynamic Systems," *SIMULATION*, Vol. 58, No. 3, 1992, pp. 175-184.

REFEREED CONFERENCE PAPERS

27. B.W. Bielenberg and J.D. Reid, "Concept Development of a Tie-Down Temporary Concrete Barrier System," *Proceedings of the 2001 ASME Design Automation Conference*, Special Session on Design for Crash Safety, American Society of Mechanical Engineering, Sept 2001.

28. B.A. Coon, J.D. Reid, J.R. Rohde and J. Herr, "A New Shear Strength Testing Device for NCHRP Report 350 Strong Soil," *TRB Paper 01-0412*, Transportation Research Board 80th Annual Mtg, January 2001.

29. J.D. Reid, R.K. Faller and D.L. Sicking, "High Speed Crash Barrier Investigation Using Simulation," *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems - 2000*, ASME, AMD-Vol. 246, November 2000, pp. 111-127.

30. J.D. Reid, "Transition from a Frontal Impact to a Redirection Impact on a New Bullnose Guardrail System Design," *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems - 1999*, ASME, AMD-Vol. 237, November 1999, pp. 303-317.

31. J.D. Reid and D.L. Sicking, "Design of the SKT-350 Using LS-DYNA3D," *TRB Paper 980352*, Transportation Research Board 77th Annual Mtg, January 1998.

32. J.D. Reid, "Steel Post Simulation for the Buffalo Guardrail System," *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems - 1997*, ASME, AMD-Vol. 225, November 1997, pp. 147-164.

33. J.D. Reid, R.K. Faller and G.W. Paulsen, "A New Breakaway Concept for Neighborhood Delivery & Collection Box Units," *TRB Paper 970119*, Transportation Research Board 76th Annual Mtg, January 1997.

34. J.R. Rohde and J.D. Reid, "Evaluation of the Performance Criteria for Wood Posts in Strong-Post W-Beam Guardrail," *TRB Paper 971206*, Transportation Research Board 76th Annual Mtg, January 1997.

35. J.D. Reid, W.N. Weins, R.E. Ekstrom, G. Paulsen and D.S. McConnell, "Side Impact Assessment Using Drop Testing," *SAE Paper 961012*, SAE International Congress & Exposition, February 1996.

36. J.D. Reid and D.L. Sicking, "Design Concepts for a Collapsing Turned-Down Guardrail," *IX International Conference on Vehicle Structural Mechanics and CAE*, SAE P-290, 1995, pp. 61-68.

37. J.D. Reid and M.Y. Sheh, "Load Path Analysis in Vehicle

Crashworthiness," *Crashworthiness and Occupant Protection in Transportation Systems*, ASME, AMD-Vol. 169, November 1993, pp. 97-104.

38. M.Y. Sheh, J.D. Reid, S.M. Lesh and W. Cheva, "Vehicle Crashworthiness Analysis Using Numerical Methods and Experiments," *Eighth International Conference on Vehicle Structural Mechanics and CAE*, SAE P-258, 1992, pp. 119-128.

39. J.D. Reid, R.C. Rosenberg and J. Whitesell, "Some Pros and Cons of Object Oriented Programming for Physical System Simulation," *IMACS '91 Conference Proceedings*, Dublin, Ireland, 1991, pp. 1096-1098.

40. R.C. Rosenberg and J.D. Reid, "An Approach to the Computer Aided Design of Planar Mechanical Systems Using Bond Graphs," *Computers in Engineering, 1984*, ASME, New York, 1984, pp. 736-741.

OTHER PAPER PUBLICATIONS

41. R.W. Bielenberg, S.H. Magner and J.D. Reid, "Sidewall Indentation and Buckling of Deformed Aluminum Beverage Cans," *Sixth International LS-DYNA Users Conference*, Dearborn, MI, April 2000, pp. 10-27 to 10-40.

42. B.A. Coon, P. Anugonda and J.D. Reid, "Piercing of Aluminum Beverage Cans," *Sixth International LS-DYNA Users Conference*, Dearborn, MI, April 2000, pp. 10-41 to 10-50.

43. J.D. Reid, M.W. Hargrave and D. Rekenthaler Jr., "It's a Jungle Out There: Using the Bullnose Guardrail to Protect the Elephant Traps," *Public Roads*, Vol. 62, No. 4, Jan/Feb 1999, pp. 13-17.

44. J.D. Reid, "Side Impact Simulation: A Fixed Rigid Pole and A Breakaway Sign," *Fifth International LS-DYNA Users Conference*, Southfield, MI, September 1998 (invited).

45. J.D. Reid, "Recent Progress in Roadside Safety Simulation," *Fourth International LS-DYNA3D Conference*, Minneapolis, MN, September 1996, pp. 195-212 (invited).

46. J.D. Reid, "Simulation of Four Roadside Safety Applications," *FHWA Vehicle Crash Analysis*, Conference Proceedings, FHWA Publication No. FHWA-RD-96-212, April 1997, pp. 95-111.

47. J.D. Reid and K.J. Bonello, "Manufacturing Influence on Thin-Walled Column Collapse," *2nd International LS-DYNA3D Conference*, San Francisco, CA, September 20-21, 1994.

48. J. Whitesell and J.D. Reid, "Computational Mechanics Solvers Based on Object-Oriented Design Principles," *1990 Winter Simulation Conference Proceedings*, December 1990.

BOOKS/BOUND VOLUMES

J.D. Reid, *LS-DYNA Examples Manual*, Livermore Software Technology Corporation, February 1998, 292 pages.

J.D. Reid, P. Fyhrie, H. Mahmood and M. El-Bkaily, Editors, *Crashworthiness and Occupant Protection in Transportation Systems - 1995*, ASME, AMD-Vol. 210, 1995.

J.D. Reid and K.H. Yang, Editors, *Crashworthiness and Occupant Protection in Transportation Systems - 1993*, ASME, AMD-Vol. 169, 1993.

J.D. Reid, *Dynamic Physical System Simulation and Object Oriented Programming*, Dissertation, Michigan State University, 1990.

J.D. Reid, *Computer-Aided Design of Planar Mechanical Systems*, Thesis, Michigan State University, 1983.

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF) RESEARCH REPORTS

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., and Holloway, J.C., *Crash Testing of Missouri's W-Beam to Thrie Beam Transition Element*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-94-00, Project No. SPR-3(017)-Year 9, MwRSF - UNL, September 12, 2000.

Bielenberg, B.W., Reid, J.D., Faller, R.K., Rohde, J.R., Sicking, D.L., Keller, E.A., and Holloway, J.C., *Concept Development of a Short Radius Guardrail System for Intersecting Roadways*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-100-00, Project No. SPR-3(017)-Year 8, MwRSF - UNL, September 12, 2000.

Reid, J.D., Faller, R.K., and Bielenberg, B.W., *Validation Efforts on APTEK's New Wood Material Model Using LS-DYNA*, Report to APTEK, Inc., Report No. TRP-03-102-00, MwRSF - UNL, August 31, 2000.

Bielenberg, B.W., Reid, J.D., Faller, R.K., Rohde, J.R., Sicking, D.L., Keller, E.A., Holloway, J.C., and Supencheck, L., *Phase III Development of a Bullnose Guardrail System for Median Applications*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-95-00, Project No. SPR-3(017)-Years 7 and 8, MwRSF - UNL, June 1, 2000.

Polivka, K.A., Faller, R.K., Reid, J.D., Sicking, D.L., Rohde, J.R., Keller, E.A., and Holloway, J.C., *Development of an Approach Guardrail Transition Attached to a Thrie Beam and Channel Bridge Railing*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-91-99, Project No. SPR-3(017)-Year 6, MwRSF - UNL, March 21, 2000.

Polivka, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Reid, J.D., and Holloway, J.C., *Guardrail and Guardrail Terminals Installed Over Curbs*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-83-99, Project No. SPR-3(017)-Year 8, MwRSF - UNL, March 21, 2000.

Coon, B.A., Reid, J.D., and Rohde, J.R., *Dynamic Impact Testing of Guardrail Posts Embedded in Soil*, Final Report to the Federal Highway Administration, Transportation Research Report No. TRP-03-77-98, MwRSF - UNL, July 21, 1999.

Bielenberg, B.W., Reid, J.D., Faller, R.K., Rohde, J.R., Sicking, D.L., Keller, E.A., and Holloway, J.C., *Phase II Development of a Bullnose Guardrail System for Median Applications*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-78-98, Project No. SPR-3(017)-Years 7 and 8, MwRSF - UNL, December 18, 1998.

Faller, R.K., Sicking, D.L., Rohde, J.R., Holloway, J.C., Keller, E.A., and Reid, J.D., *Crash Testing of South Dakota's Cable Guardrail to W-Beam Transition*, South Dakota Report No. SD98-16, Final Report to the South Dakota Department of Transportation, Report No. TRP-03-80-98, Project No. SPR-3(017), MwRSF - UNL, December 4, 1998.

Bielenberg, B.W., Faller, R.K., Reid, J.D., Rohde, J.R., Sicking, D.L., and Keller, E.A., *Concept Development of a Bullnose Guardrail System for Median Applications*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-73-98, MwRSF - UNL, May 1998.

Pfeifer, B.G., Faller, R.K., and Reid, J.D., *NCHRP Report 350 Evaluation of the Nebraska Thrie Beam Transition*, Final Report to the Nebraska Department of Roads, Report No. TRP-03-70-98, MwRSF - UNL, May 1998.

Faller, R.K., Reid, J.D., Rohde, J.R., Sicking, D.L., and Keller, E.A., *Two Approach Guardrail Transitions for Concrete Safety Shape Barriers*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-69-98, MwRSF - UNL, May 1998.

Vogel, J.C., Faller, R.K., Reid, J.D., and Sicking, D.L., *A Review of Breakaway Supports for Small Signs and Mailbox Installations*, Final Report to the Midwest State's Regional Pooled Fund Program, Report No. TRP-03-68-98, MwRSF - UNL, February 1998.

Pfeifer, B.G., Reid, J.D., and Brar, B.S., *Development of an Effective Flared Guardrail Terminal*, Final Report to the Kansas Department of Transportation, Report No. TRP-03-56-96, MwRSF - UNL, June 1997.

Rohde, J.R., Reid, J.D., and Sicking, D.L., *Evaluation of the Effect of Wood Quality on W-beam Guardrail Performance*, Final Report to the Nebraska Department of Roads, Report No. TRP-03-60-96, MwRSF - UNL, November 1995.

G.W. Paulsen, R.K. Faller and J.D. Reid, *Design and Testing of a Breakaway Base for a Cluster Box Unit and a Neighborhood Delivery & Collection Unit*, Final Report to the United States Postal Service, Report No. TRP-03-55-96, MwRSF - UNL, April 1996.

J.C. Holloway and J.D. Reid, *Performance Evaluation of a Dual Support Sign with Ground Mounted Pipe Posts and Multi-Directional Slip Bases*, Final Report to the Missouri Highway and

Transportation Department, Report No. TRP-03-50-95, MwRSF - UNL, September 1995.

G.W. Paulsen, B.G. Pfeifer, J.C. Holloway and J.D. Reid, *Design and Testing of a Dual Support Breakaway Sign*, Final Report to the Missouri Highway and Transportation Department, Report No. TRP-03-48-95, MwRSF - UNL, September 1995.

G.W. Paulsen, J.D. Reid, R.K. Faller and D.L. Sicking, *Concept Design and Analysis of Nebraska Turned-Down Approach Terminal Sections*, Final Report to the Nebraska Department of Roads, Report No. TRP-03-45-95, MwRSF - UNL, January 1995.

GENERAL MOTORS RESEARCH REPORTS

Internal General Motors reports reviewed by GM engineers. Due to the proprietary nature of the work, external publications were not approved.

J.D. Reid, "Powertrain Influence on a 30 MPH Frontal Barrier Test," CLCD-VS&D Report 4485, General Motors Safety Center, June 10, 1993.

J.D. Reid, "Removal of the Lateral Rail for the '97 Park Avenue," CLCD-VS&D Report 4484, General Motors Safety Center, June 10, 1993.

J.D. Reid, "Lumped Parameter Modeling for the '97 Park Avenue," CLCD-VS&D Report 4483, General Motors Safety Center, June 10, 1993.

R. Mau and J.D. Reid, "Front Midrail Reinforcement Methods," CLCD-VS&D Report 4482, General Motors Safety Center, June 9, 1993.

J.D. Reid, "1992 Honda Accord Barrier Test," GME93000010, General Motors Safety Center, February 5, 1993.

J.D. Reid, "Verifying Model Accuracy and Increased Understanding Using Load Path Analysis," CPER-484, General Motors Safety and Crashworthiness Systems, November 12, 1992.

J.D. Reid, "Load Path Analysis Techniques," CPER-482, General Motors Safety and Crashworthiness Systems, November 6, 1992.

J.D. Reid, "DYNA3D: Observed Difficulties in Contact Types 10, 11 and 12," CPER-459, General Motors Safety and Crashworthiness Systems, April 30, 1992.

M.Y. Sheh and J.D. Reid, "Vehicle Crashworthiness Using FEM, LPM, and Experiments," CPER-444, General Motors Safety and Crashworthiness Systems, January 28, 1992.

J.D. Reid, "LPM Animation Using DYNA3D and INSTANT," CPER-437, General Motors Safety and Crashworthiness Systems, January 9, 1992.

J.D. Reid, "Lumped Parameter Modeling Revisited: Further Understanding of the Methodology," CPER-431, General Motors Safety and Crashworthiness Systems, November 4, 1991.

J.D. Reid, "30 MPH Frontal Barrier of a 91'C-Car with No Engine/Bumper/Hood," CPER-427, General Motors Safety and Crashworthiness Systems, October 10, 1991.

J.D. Reid, "Hybrid Modeling of a Front End Vehicle Structure," CPER-416, General Motors Safety and Crashworthiness Systems, May 29, 1991.

J.D. Reid, "Detecting High Speed Pole Impacts," CPER-357, General Motors Safety and Crashworthiness Systems, December 7, 1990.

SCHOLARLY PRESENTATIONS

"Box-Beam Terminal," *Transportation Research Board 80th Annual Meeting*, Washington D.C., January 10, 2001.

"High Speed Crash Barrier Investigation Using Simulation," *Symposium on Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems*, ASME International Congress, Orlando, FL, November 7, 2000.

"Sidewall Indentation and Buckling of Deformed Aluminum Beverage Cans," *Sixth International LS-DYNA Users Conference*, Dearborn, MI, April 10, 2000.

"Piercing of Aluminum Beverage Cans," *Sixth International LS-DYNA Users Conference*, Dearborn, MI, April 10, 2000.

"Bullnose Project Update," *Transportation Research Board 79th Annual Meeting*, Washington D.C., January 11, 2000.

"Transition from a Frontal Impact to a Redirection Impact on a New Bullnose Guardrail System Design," *Symposium on Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems*, ASME Winter Annual Meeting, Nashville, TN, November 1999.

"Aluminum Can Simulation at UNL," Alcoa Technical Center, PA, September 2, 1999.

"Bullnose Simulation - From Frontal to Redirection Impact," *TRB A2A04 - Subcommittee on Computational Mechanics*, Estes Park, CO, August 1, 1999.

"Bullnose Redirection: Modeling Areas of Concern," *FHWA DYNA3D Summer Workshop*, University of Nebraska-Lincoln, June 24, 1999.

"Using LS-DYNA Simulation To Solve a Design Problem: Bullnose Guardrail Example," *Transportation Research Board 78th Annual Meeting*, Washington D.C., January 11, 1999.

"Roadside Safety Advancements Due to Simulation," UNL Mechanical Engineering Seminar, Lincoln, NE, December 11, 1998.

"Side Impact Simulation: A Fixed Rigid Pole and a Breakaway Sign," *5th International LS-DYNA Users Conference*, Southfield, MI, September 22, 1998.

"NCHRP 350 Bullnose," *FHWA University Research Program Meeting*, George Washington University, Ashburn, VA, July 1, 1998.

"Design of the SKT-350 Using LS-DYNA3D," *Transportation Research Board 77th Annual Meeting*, Washington D.C., January 13, 1998.

"Steel Post Simulation for the Buffalo Guardrail System," *Symposium on Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems*, ASME Winter Annual Meeting, Dallas, TX, November 1997.
"Mesh Refinement: A Designer's Perspective," *TRB A2A04 Committee Summer Meeting*, Woods Hole, MA, July 27, 1997.

"Correlating Crash Tests with Finite Element Analysis," *TRB A2A04 Computer Subcommittee Meeting*, Washington D.C., January 16, 1997.

"Development of a New Guardrail System," *Transportation Research Board 76th Annual Meeting*, Washington D.C., January 16, 1997.

"A New Breakaway Concept for Neighborhood Delivery and Collection Box Units," *Transportation Research Board 76th Annual Meeting*, Washington D.C., January 15, 1997.

"Recent Progress in Roadside Safety Simulation," *Fourth International LS-DYNA3D Conference*, Minneapolis, MN, September 5, 1996.

"Simulation of Four Roadside Safety Applications," *FHWA Vehicle Crash Analysis Conference*, McLean, VA, July 8, 1996.

"Research at the Midwest Roadside Safety Facility," *AASHTO - AGC - ARTBA Task Force No. 13 Meeting*, San Antonio, TX, March 29, 1996.

"Nonlinear Finite Element Analysis of a Dual Support Breakaway Sign," *Transportation Research Board 75th Annual Meeting*, Washington D.C., January 10, 1996.

"Development of a Modified Tension Fuse Plate for Dual Support Breakaway Signs," *Transportation Research Board 75th Annual Meeting*, Washington D.C., January 8, 1996.

"Progress in Roadside Safety Research at UNL's Midwest Roadside Safety Facility," *AASHTO - AGC - ARTBA Task Force No. 13 Meeting*, Charleston, S.C., April 7, 1995.

"Side Impact Assessment Using Drop Testing," *IX International Conference on Vehicle Structural Mechanics and CAE*, Troy, MI, April 4, 1995.

"Design Concepts for a Collapsing Turned-Down Guardrail," *IX International Conference on Vehicle Structural Mechanics and CAE*, Troy, MI, April 4, 1995.

"Roadside Safety: Guardrail Design and Simulation," Pi Tau Sigma Spring Social, Lincoln, NE, March 7, 1995.

"Re-evaluation of Turned-Down Guardrail Terminals," Formal Presentation, *Transportation Research Board 74th Annual Meeting*, Washington D.C., January 22, 1995.

"Vehicle Crashworthiness Simulation," Lawrence Livermore National Laboratory, Livermore, CA, September 22, 1994.

"Manufacturing Influence on Thin-Walled Column Collapse," *2nd International LS-DYNA3D Conference*, San Francisco, CA, September 20, 1994.

"Parameter Studies for Thin-Walled Column Crush," Cadillac/Luxury Car Division of General Motors, July 28, 1994.

"Engineering at General Motors: Design and Analysis," ASME Student Chapter, Lincoln, NE, March 18, 1994.

"Load Path Analysis in Vehicle Crashworthiness," *Symposium on Crashworthiness and Occupant Protection in Transportation Systems*, ASME Winter Annual Meeting, New Orleans, La, November 1993.

"Safety and Crashworthiness at General Motors," Lawrence Livermore National Laboratory, Livermore, CA, July 1992.

"Vehicle Crashworthiness Analysis Using Numerical Methods and Experiments," *Eighth International Conference on Vehicle Structural Mechanics and CAE Conference*, Traverse City, MI, June 1992.

"An Approach to the Computer Aided Design of Planar Mechanical Systems Using Bond Graphs," *ASME Computers in Engineering Conference*, Las Vegas, Nevada, July 1984.

TEACHING ACTIVITIES

Courses Taught at University of Nebraska

August 1993 - present

- ME 343 - Elements of Machine Design
- ME 350 - Intro To Dynamics and Control of Eng Systems
- ME 447 - Design II (supervised a few projects)
- ME 455/855 - Vehicle Dynamics
- ME 950 - Impact Engineering

Short Courses Taught

LS-DYNA Training & Workshop

March & June 2000	LSTC, Livermore, CA
October 1999	General Motors Corporation, Roseville, MI
January & June 1999	LSTC, Livermore, CA

April 1998	General Motors Corporation, Roseville, MI
March & August 1998	LSTC, Livermore, CA
March & June 1997	LSTC, Livermore, CA
November 1996	General Motors Corporation, Troy, MI
March & June 1996	LSTC, Livermore, CA
July 1995	Wichita State University, Wichita, KS
March & July 1995	LSTC, Livermore, CA

Courses Taught at GMI Engineering & Management Institute

July 1986 - June 1990

- ME 102 - Engineering Graphics - Computer Aided Design
- ME 301 - Dynamics
- ME 402 - Systems Analysis
- ME 444 - Computer Graphics Systems

Course Development

ME 950 - Impact Engineering: New course. This graduate level only class studies design and analysis of structures that undergo impact. Nonlinear, large-deformation finite element analysis of structures with applications in vehicle crashworthiness, roadside safety design, sheet metal forming, and projectile impacts.

ME 455/855 - Vehicle Dynamics: New course. This senior/graduate level course studies the basic mechanics governing vehicle dynamic performance. Analytical methods in vehicle dynamics. Laboratory work consists of performing various vehicle dynamic tests on actual vehicles. A capstone of the course is a major design project. A typical term project is the design and build of an SAE mini-baja vehicle. Dr. W. Weins has contributed significantly on the development of the labs associated with the course.

ME 350 - Introduction to Dynamics and Control. Changed books, developed course notes, and implemented a little more emphasis on computer simulation using a new software package.

ME 343 - Elements of Machine Design: This course was previously ME 443, a senior level class. As a junior level class the course was modified to include a little more basic theory, finite element analysis and statistical considerations in design.

Developed a short course titled *LS-DYNA Introductory Training and Workshop*. This 4 day course teaches the basic operations of LS-DYNA, a leading explicit nonlinear, large-deformation FEA software. The course was developed for Livermore Software Tech Corp.

Undergraduate Student Advising

2000: Advisor for 35 students
1999: Advisor for 30 students
1998: Advisor for 26 students
1997: Advisor for 29 students
1996: Advisor for 32 students
1995: Advisor for 31 students
1994: Advisor for 28 students

Student Recommendations/Reference Letters

Requests by former students and colleagues to provide recommendation/reference letters.

- 2000 - 4 letters
- 1999 - 5 letters
- 1998 - 3 letters
- 1997 - 7 letters
- 1996 - 7 letters
- 1995 - 8 letters
- 1994 - 6 letters

Graduate Student Activities

Graduate College Faculty Fellow, September 24, 1997
Graduate College Faculty Member, February 1994.
Graduate Student Advising

Ph.D. Students

Brian A. Coon (Spring 2000 to present)

Brian G. Pfeifer, Dissertation: *Development and Simulation of an Energy Absorbing Guardrail Terminal*, May 1997, Co-Advisor with Dean Sicking, Civil Engineering

M.S. Students

Ritesh Fating (Spring 2001 to present) - Thesis Option

David Belter (Fall 1997 to present) - Thesis Option

Karla Polivka, Thesis: *Crash Testing and Analysis of Work Zone Sign Supports*, April 2001.

Sridhar Ravikoti, Thesis: *Finite Element Simulation of Indy Racetracks HDPE Crash Barriers*, January 2001.

Bob W. Bielenberg, Thesis: *Finite Element Simulation of a Bullnose Median Barrier System*, July 1999.

Gene W. Paulsen, Thesis: *Design and testing of a Dual Support Breakaway Sign Using Nonlinear Finite Element Analysis*, April 1996.

Bavneet Singh Brar, Thesis: *Component Testing and Simulation of Guardrail End Terminal*, August 1995.

Graduate committees served on:

M.S.

Arthur Hieronymus, Oral Exam April 27, 2000.
Matthew Goeller (C.E.), Oral Exam April 21, 2000.
Phanidhar Anugonda (E.M.), Oral Exam March 24, 2000
Brian A. Coon (C.E.), Oral Exam December 9, 1999.
Jeffrey M. Koss, Oral Exam December 1, 1999.
Scott Peterson, Oral Exam September 10, 1999.
Brent Wilson, Oral Exam April 23, 1999.
Lin Yang, Oral Exam February 2, 1999.
Vishal G. Sharma, Oral Exam January 27, 1999.
Ken C. Halvorsen, Oral Exam December 9, 1998.

Frank C. Pruitt, Oral Exam July 30, 1998.
Amol S. Kshatriya, Oral Exam July 14, 1997.
Scott H. Magner, Oral Exam April 30, 1997.
James Schelert, Oral Exam April 22, 1996.
Udayabhaskara Ramesh Salagram, Oral Exam February 10, 1995.
Anand Mahabaleshwar, Oral Exam April 12, 1994.
Ming-Feng Jean, Oral Exam August 4, 1994.

Foreign Student Exchange Program

Dr. W. Weins and myself are the lead UNL faculty advisors on this project. The objective of the project is to encourage Mechanical Engineering students to study abroad during their academic careers. Over 100 students were sent abroad during this program and was considered one of the most successful FIPSE programs ever. Many UNL students participated in this program.

Title: **E.C./U.S. Student Mobility in Automotive Engineering**
Awarded: $175,000 (for U.S. Schools)
Sponsor: Department of Education - FIPSE Duration: July 1996 to June 2000
P.I.'s: David J. Doherty (GMI Engineering & Management Institute, Michigan) and Heidelore Schroder (Fachhochschule fur Technik und Wirtschaft Berlin, Germany)
Other Univ: UNL, Marshall University (West Virginia), Ecole Nationale d'Ingenieurs de Belfort (France), Universidad de Zaragoza (Spain), Hogeschool van Arnhem en Nijemgen (Netherlands), Chalmers University (Sweden), University of Newcastle (England)

Self-Improvement

Workshops, discussions and seminars attended which were sponsored by UNL's Teaching and Learning Center (TLC):

Conversation with an Artist: Teaching for Diversity, Jeff Raz - Actor and Playwright, April 3, 2000.

Conversation with an Artist: Teaching for Diversity, Dadisi Sanyika - Musician and Community Organizer, March 27, 2000.

Promoting Deep Learning Workshop, Dr. James Eison, Director of the Center for Teaching Enhancement, University of South Florida, March 9, 2000.

Grading and Learning - Policies, Practices, Pitfalls - Part II, UNL-TLC, Nov. 9, 1999.

Grading and Learning - Policies, Practices, Pitfalls - Part I, UNL-TLC, October 12, 1999.

Developing a Teaching Portfolio, UNL-TLC, January 28, 1998.

How to Become an OSCAR Winning Teacher, T. Grasha, Session Leader, UNL-TLC, October 31, 1997.

The Students' Perspective: Teaching Strategies That Make A Difference, C. Martin, Facilitator, UNL-TLC, November 19, 1996.

A Conversation with the Chancellor About Teaching, J. Moeser, Chancellor, UNL-TLC, October 31, 1996.

The Teaching Portfolio & the Beginning Teacher, H. Moore, Chair and Professor of Sociology, UNL-TLC, September 30, 1996.

Along the Path Toward Effective Peer Review of Teaching, D. Bernstein, C. Mignon, P. Starr and M. Thornton, UNL-TLC, March 12, 1996.

Using the World Wide Web to Promote Teaching and Learning, A. Steckelberg, D. Fowler, M. Grady and B. Krumm, UNL-TLC, February 6, 1996.

Conversation with the new Dean of Arts and Sciences about Teaching, B. Foster, UNL-TLC, February 28, 1995.

Integrating Oral Communication in Your Class, W. Seiler, R. Pardy and J. Scheer, Comprehensive Education Program Workshop, UNL-TLC, November 28, 1994

Tips on Testing and Grading, J. Impara, D. Lee and E. Petrakis, UNL-TLC, November 9, 1994.

Balancing Teaching, Research and Service, D. Kizzier, T. Gutkin, J. Rankin and S. Treves, UNL-TLC, October 11, 1994.

Presenting and Explaining, B. Erickson - Univ. of Rhode Island, UNL-TLC, Oct. 6, 1994.

High-Tech Classroom Demonstration, S. Dunbar, T. Shores and M. Thornton, Mathematics and Statistics, UNL-TLC, April 12, 1994.

Documenting Effective Teaching for Promotion and Tenure, J. Bernthal, D. Bernstein, R. Bonnstetter, H. Moore and J. Ritchie, UNL-TLC, February 21, 1994.

Using Active Learning to Teach Reasoning Skills, Dr. C. Bonwell, St. Louis College of Pharmacy, UNL-TLC, November 18, 1993.

Assertiveness: How To Take Charge in a Nice Way, UNL-TLC, November 9, 1993.

Effective Teaching Strategies: A Workshop for New Faculty, D. Wright, M. Wilhite, M. Brooks and J. Lunde, UNL-TLC, August 31, 1993.

SERVICE ACTIVITIES

Committee Service

College

Member of Library and Publications Committee (1993 - 1997)

Ad hoc Supercomputer Committee

- In 1995 a Cray J90 Supercomputer was installed for the College of Engineering & Technology. This computational intensive computer was a direct result of a year and a half of work on my part. Starting with a U. Nebraska Foundation Grant of $100,000 (obtained by J.D. Reid and D.L. Sicking), I combined this grant with $300,000 from the College (obtained through Dean S. Liberty) and spearheaded a special computer committee to secure the Supercomputer. This computer was an order of magnitude more powerful than any computer on campus previously available to the engineering faculty as a whole.

Department

Chair of Graduate Committee (2000 - present)

Seminar Coordinator (1999 - 2000)

Chair of the Scholarship and Honors Committee (1998 - 1999)

Library Liaison (1993 - 1997)

Member of the Graduate Committee (1997 - present)

Member of the Computer Committee (1993 - present)

Member of the Scholarship and Honors Committee (1994 - 1998)

Member of the Faculty Search Committee (1995-1996, 1997-1998)

Professional Societies

Society of Automotive Engineers (since 1980)

American Society of Mechanical Engineers (since 1981)

American Society for Engineering Education (since 1993)

EIT, State of Michigan

Member of the Transportation Committee, AMD, ASME (since 1993)

Member of TRB A2A04 (1) - Subcommittee on Computational Mechanics (since 1995)

Co-Chair of Structural Crashworthiness - I Session for the symposium titled *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems*, Orlando, FL, November 2000.

Co-Chair of Session I for the symposium titled *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems*, Nashville, TN, November 1999.

Chair of Session III for the symposium titled *Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems*, Dallas, TX, November 1997.

Chair of Session 6 for the *Fourth International LS-DYNA3D*

Conference, Minneapolis, MN, September 1996.

Member of the National Cooperative Highway Research Program (NCHRP) Project Panel G17-13 (1995-1997). This program functions under the National Academies of Sciences and Engineering. The objective of Project 17-13 was to develop a *Strategic Plan for Improving Roadside Safety*. In 1997 Research Results Digest 220 was published as a result of this effort.

Active participant on a committee formed by the Federal Highway Administration (FHWA) to help determine future direction of the use of computer simulation in roadside safety (1996). This has resulted in a cooperation between the FHWA and TRB A2A04 subcommittee on computer simulation.

Organizer of the IV Symposium on Crashworthiness and Occupant Protection in Transportation Systems, 1995 ASME Congress, with Dr. P. Blenman-Fyhrie from General Motors. This symposium consisted of 5 sessions and 28 papers. I was also a chair for one of the sessions at the symposium.

Organizer of the ASME 1993 Symposium on Crashworthiness and Occupant Protection in Transportation Systems, with Dr. K.H. Yang from Wayne State University. This symposium consisted of 5 sessions and 27 papers. I was also a chair for one of the sessions at the symposium.

Professional Review

Review papers for:
- Applied Mechanics Division of ASME
- Dynamic Systems and Control Division of ASME
- Finite Elements in Analysis and Design (International Journal)
- Journal of Bridge Engineering (ASCE)
- Journal of Transportation Engineering (ASCE)
- Society of Automotive Engineers
- Structural Engineering and Mechanics (International Journal)
- Thin-Walled Structures Journal
- Transportation Research Record - National Research Council

Review books for McGraw-Hill

Research Grant Proposal Review:
- The Natural Sciences and Engineering Research Council of Canada (NSERC)

Other

SAE Student Organization - catalyst for getting the student organization active again by developing an SAE Mini-Baja vehicle in the Vehicle Dynamics course taught Spring 1995. A new mini-baja was designed and built in Vehicle Dynamics class during Fall 1998. This new and improved vehicle was used by the

SAE group to compete in the annual SAE competition.

Gave presentations and demonstrations to the *Bright Lights Engineering Day Camp* program (1997 and 1998).

Developed the *Computational Design Lab* consisting of four Unix workstations and three personal computers (1998).

Tab 18

BRC
BIODYNAMIC RESEARCH CORPORATION

JAMES V. BENEDICT, PHD, MD

CURRICULUM VITAE

EDUCATION

M.D.	University of Texas Health Science Center at San Antonio, San Antonio, Texas.	1976
Ph.D.	Mechanical Engineering, Tulane University, New Orleans, Louisiana.	1969
M.S.	Mechanical Engineering, Tulane University, New Orleans, Louisiana.	1966
B.S.	Mechanical Engineering, with Honors, Tulane University, New Orleans, Louisiana.	1963

POST GRADUATE MEDICAL STUDIES

Post Graduate Studies	Bexar County Hospital District OB-GYN, San Antonio, Texas.	1977-1978
Internship	Bexar County Hospital District OB-GYN, San Antonio, Texas.	1976-1977

PROFESSIONAL EXPERIENCE

Director and Principal Consultant — 1986-Pres
Biodynamic Research Corporation
San Antonio, Texas

Physician — 1979-1998
Highland Medical Center
San Antonio, Texas

Physician — 1978-1981
Wilson County Professional Association
Floresville, Texas

Engineer and Manager 1969-1973
Technology, Inc.
San Antonio, Texas

PROFESSIONAL REGISTRATIONS

National Board of Medical Examiners License #175559 1977
Texas State Board of Medical Examiners License #E6228 1976
Louisiana State Board of Professional Engineers
License #12323 1970
Certificate #T884 1965

PROFESSIONAL AFFILIATIONS

American Academy of Family Physicians
American College of Occupational & Environmental Medicine
American Medical Association
Bexar County Medical Society
Texas Medical Association
Texas Academy of Family Physicians
Society of Automotive Engineers
Association for the Advancement of Automotive Medicine
Society of the Sigma Xi
Tau Beta Pi

COMMITTEES AND CLINICAL APPOINTMENTS

Association for the Advancement of Automotive
Medicine (AAAM), President October 2000-December 2001
Association for the Advancement of Automotive
Medicine (AAAM), President-Elect October 1999-December 2000
Association for the Advancement of Automotive
Medicine (AAAM), Representative
National Conference on Medical Indications for Air Bag
Disconnection, The George Washington University Medical Center,
Washington, D.C. July 16-18, 1997
Association for the Advancement of Automotive
Medicine (AAAM), Representative
The 17th Meeting of the Motor Vehicle Research Safety Advisory
Committee, NHTSA, Washington, D.C. May 26, 1999
Association for the Advancement of Automotive
Medicine (AAAM) Endowment Fund 1990-present

Association for the Advancement of Automotive Medicine (AAAM) Board of Directors	1991-1993
Technical Resource Committee, National Operating Committee on Standards for Athletic Equipment, Kansas City, Missouri	1986-1990
Immediate Past Chief-of-Staff, Southeast Baptist Hospital	1985
Joint Conference Committee, Baptist Medical Center	1985
Medical Executive Board, Baptist Medical Center	1985
Utilization Review, Southeast Baptist Hospital	1985
Chief-of-Staff, Southeast Baptist Hospital	1984-1985
Internal Medicine Audit Policy Committee, Baptist Medical Center	1984
Joint Conference Committee, Baptist Medical Center	1984
Medical Executive Board, Baptist Medical Center	1984
Nominating Committee, Southeast Baptist Hospital	1984
Special Care Committee System, Southeast Baptist Hospital	1984
OB-GYN Audit Policy Committee, Baptist Medical Center	1983
Pharmacy Committee, Southeast Baptist Hospital	1983
Utilization Review Committee, Southeast Baptist Hospital	1983
Planning and Development Committee, Baptist Memorial Hospital System	1982
Chief of Family Practice, Southeast Baptist Hospital	1981-1982
Special Care Committee, Baptist Medical Center	1980-1982
Internal Medicine Audit Policy Committee, Baptist Medical Center	1979-1982
Acting School Physician, Poth Independent School District	1980-1981
OB-GYN Audit Policy Committee, Baptist Medical Center	1980-1981
Acting Director, Wilson County Health Dept.	1979-1981
Clinical Supervisor, Clinical Practice Program University of Texas School of Nursing at San Antonio, University of Texas Health Service Center at San Antonio	1979-1981
Primary Care Preceptor, Physician Assistant Program University of Texas Health Service Center at Dallas	1979-1981
Medical Director Family Planning Program, Community Council of South Central Texas	1978-1981

INDUSTRIAL MEDICINE EXPERIENCE

Alamo Clay Products	Green Valley Nursery	Safety-Kleen
Alamo Lumber	Harris Systems Int.	Sandstone Materials
Barber Ford	Highway Department	Seward Construction
Chevron Resources	Holmes Foods	Sheriff Department
City of Floresville	Holt Company	South Texas Construction
Conoco Industries	Liberto's Specialty	Tandy Company

Dairy Rich	Midas Company	Tex-Hens
Decker Meat Packaging	Morris Lumber	Texas Rehabilitation
Dickey Clay	Nelson & Sons	Three T. Company
Dixilyn Field	Penrod Drilling	T. Moy & Sons
Floresville Electric	Preson Dairy	Wiatrek Meat
Gann Peanut		Wiatrek Welding

HONORS AND AWARDS

Fellow, Association for the Advancement of Automotive Medicine (AAAM)	1998
American Medical Association Physician Recognition Award	1992,1995,1998
Physician of the Year - Four Seasons Nursing Home	1985
Southern Medical Association Grant for Head Injury Research	1975
The Society of the Sigma Xi	1970
Harold A. Levey Alumni Award for Excellence in Engineering	1969
Public Health Service Traineeship	1967-1969
National Science Foundation Fellowship	1966-1967
National Institutes of Health Assistanceship	1964-1965
NASA Fellowship	1963
Hamilton Watch Award for Interest in the Humanities and Social Sciences	1963
James M. Robert Leadership Award	1963
Leon H. Scherch Memorial Award for Excellence in Engineering	1963
Louisiana Engineering Society Award for Highest Scholastic Average in Graduating Class	1963
American Society for Testing Materials Excellence Award	1962
Omicron Delta Kappa National Honorary Leadership Society	1962
Tau Beta Pi, National Engineering Honor Society	1961
Tulane University Activity Key Recipient for Outstanding Achievements in Extracurricular Activities	1961
Who's Who Among Students in American Colleges and Universities	1961

PUBLICATIONS

Benedict, J.V.; The Stress-Strain Relationship of Human Cadaveric Plantaris Tendon. Honors Thesis, Tulane University, 1963.

Walker, L.B., Jr.; Harris, E.H.; Benedict, J.V.; "Stress-Strain Relationship in Human Cadaveric Tendon". Proc. 16th Annual Conference Engineer, Medical and Biological Vol. VI, 1963.

Walker, L.B. Jr.; Harris, E.H.; Benedict, J.V.; "Stress-Strain Relationship in Human Cadaveric Plantaris Tendon; A Preliminary Study", Med. Electro, Bio. Engineer., 2:31-38, 1963.

Walker, L.B. Jr.; Harris, E.H.; Bass, B.R.; Benedict, J.V.; "Tensile Strength and Stress-Strain Studies of Cadaveric Human Tendons". Eighth International Congress of Anatomists. Weisbaden, August 8-13, 1965.

Benedict, J.V.; Stress-Strain Relationship of Embalmed Human Tendon. Masters Thesis, Tulane University, 1966.

Benedict, J.V.; Harris, E.H.; Walker, L.B. Jr.; "Stress-Strain Relationship of Unembalmed Human Tendon". Proc. of the Annual Conference of Eng. in Med. and Biol., Vol. VIII, 1966.

Benedict, J.V.; Walker, L.B. Jr.; Harris, E.H.; "Stress-Strain Characteristics and Tensile Strength of Unembalmed Human Tendon". J. Biomechanic, 1:53-63, 1968.

Benedict, J.V.; An Analysis of an Impact Loaded, Fluid Filled Thin Spherical Shell as a Mathematical Model for an Investigation of the Cavitation Theory of Brain Damage. Ph.D. Dissertation, Tulane University, 1969.

Benedict, J.V.; Lin, C.L.; Stevens, C.C.; "Study to Design a Univac Programming System for the Automated Analysis of Exercise Wectrocardiograms". Final Report, Contract N00600-69-C-1006. Naval Aerospace Medical Institute, 1970.

Moffatt, C.A.; Benedict, J.V.; "The Investigation of Vertebral Injury Sustained During Aircrew Ejection". Annual Report, Contract NAS 2-5062. Ames Research Center, 1970.

Benedict, J.V.; Harris, E.H.; Von Rosenbert, D.U.; "An Analytical Investigation of the Cavitation Hypothesis of Brain Damage". J. Basic Engineering-Transactions of the ASME, Vol. 92, Series D, No. 3, September 1970, PP. 597-603, 1970.

Lin, C.J.; Benedict, J.V.; Moffatt, C.A.; "Smoothing and Baseline Straightening of Exercise Electrocardiograms of Digital Filtering"; Proceedings of the Annual Conference on Engineering in Medicine and Biology, Vol. 12, p 47, 1970.

Benedict, J.V.; "Use of a Mathematical Model for the Evaluation of Head Injury Criteria". Symposium on Biodynamic Models and Their Application. AMRL-TR071-29 pp 123-139, 1974.

Miller, D.M.; Ward, B.; Benedict, J.V.; Nickel, J.A.; "Bedrest and Its Effects Upon Human Tolerance to Specific Accelerative Force"; Contract NAS 9-11314, 1970.

Miller, D.M.; Ward, B.; Benedict, J.V.; Nickel, J.A.; "Study of Physiological Tolerance to Centrifugation"; Final Report. Contract NAS 9-11314, 1971.

Benedict, J.V.; Lin, C.J.; "Analytical Investigation of the General Motors Severity Index"; ASME Paper No. 71-WA/BHF-6, 1970.

Benedict, J.V.; "Mathematical Model for Predicting Human Vertebral Fracture"; NASA Tech. Brief ARC-0691, 1970.

Raddin, James H. Jr., M.D.; Ziegler, James, M.S.E.; Benedict, James V., Ph.D., M.D.; Smith, Harry, Ph.D., M.D.; An Active Neck Protection System for Crewmembers of High Performance Aircraft, Final Report for Research Conducted under U.S.A.F. Small Business Innovation Research Contract #F41622-89-C-1024. Submitted for Publication as U.S.A.F. School of Aerospace Medicine Technical Report, February 1990; publication June 1990.

Raddin, James H. Jr., M.D.; Ziegler, James, M.S.E.; Benedict, James V., Ph.D., M.D.; Smith, Harry, Ph.D., M.D.; Concept Feasibility Analysis for a Large Radius Track-Centrifuge, Final Report for Research Conducted under U.S.A.F. Small Business Innovation Research Contract #F1622-89-C-1025. Submitted for Publication as U.S.A.F. School of Aerospace Medicine Technical Report, February 1990, publication June 1990.

Howard, Richard P., M.D., M.S.; Benedict, James V., Ph.D., M.D.; Raddin, James H., Jr., M.D. S.M.; Smith, Harry L., Ph.D., M.D.; "Assessing Neck Extension-Flexion as a Basis for Temporomandibular Joint Dysfunction," Journal of Oral and Maxillofacial Surgery, 49:1210-1213, 1991.

Raddin, James H. Jr., M.D.; Scott, William R., Ph.D.; Bomar, John B. Jr., Ph.D.; Smith, Harry, Ph.D., M.D.; Benedict, James V., Ph.D., M.D.; McConnell, Whitman E., M.D.; Perret, Patricia K.; Guzman, Herbert M.; Adapting the ADAM Manikin Technology for Injury Probability Assessment, Final Report for Period July 1991 to February 1992, prepared for Armstrong Laboratory, Human Systems Division, Crew Systems Directorate, United States Air Force, Brooks AFB, Texas.

McConnell, Whitman E.; Howard, Richard P.; Guzman, Herbert M.; Bomar, John B.; Raddin, James H., Jr.; Benedict, James V.; Smith, Harry L.; Hatsell, Charles P.; "Analysis of Human Test Subject Kinematic Responses to Low Velocity Rear End Impacts"; SAE Technical Paper #930889, March 1993.

Scott, M.W.; McConnell, W.E.; Guzman, H.M.; Howard, R.P.; Bomar, J.B.; Smith, H.L.; Benedict, J.V.; Raddin, J.H., Jr.; Hatsell, C.P.; "Comparison of Human and ATD Head Kinematics During Low-speed Rearend Impacts"; Presentation to Society of Automotive Engineers, Inc., 1993 SAE International Congress & Exposition, Detroit, MI, SAE Paper #930094, March 1993.

McConnell, W.E.; Benedict, J.V.; "Automobile Rollover Injury". Proceedings of the 26th International Symposium on Automotive Technology and Automation (ISATA), Dedicated Conference on Road and Vehicle Safety, Aachen, Germany; September 1993. Croydon, England, Automotive Automation Limited, 165-170, 1993.

Scott, M.W.; Labra, J.J.; Guzman, H.; Benedict, J.V.; Smith, H; Ziegler, J.; "Injury Analysis of Impacts Between a Cage-type Propeller Guard and a Submerged Head". J. SAFE, 24:12-28; 1994.

McConnell, W.E.; Howard, R.P.; Van Poppel, J.; Krause, R.; Guzman, H.M.; Bomar, J.B.; Raddin, J.H.; Benedict, J.V.; and Hatsell, C.P.; "Human Head and Neck Kinematics After Low Velocity Rear-End Impacts -Understanding 'Whiplash'." Presentation by Dr. McConnell to Society of Automotive Engineers, Inc., 39th Annual Stapp Car Crash Conference Proceedings, Coronado, CA, November 1995.

Labra, J.J., Benedict, J.V. "Computers, Mathematical Modeling and Flying Elephants", ABA Tort and Insurance Practice Committee News, Summer 1997.

Scott, W.R.; Lloyd, W. C., Benedict, J.V., Meredith, R. "Ocular Injuries due to Projectile Impacts"; Presentation to Association for the Advancement of Automotive Medicine Annual Conference, Chicago, Illinois. October 1-4, 2000.

PRESENTATIONS AND INVITED LECTURES

"A Theoretical Investigation of the Cavitation Hypothesis of Closed Head Injury"; National Institute of Neurological Diseases and Strokes, National Institutes of Health, Bethesda, Maryland; 1969.

"Mathematical Modeling for Studying Head Injury"; Institute of Electrical and Electronic Engineers, Group on Engineering in Medicine and Biology, San Antonio, Texas; 1969.

"Use of Mathematical Model for the Evaluation of Head Injury Criteria"; Biodynamics Symposium, National Research Council National Science Foundation, Dayton, Ohio; 1970.

"Engineering Approach to Injuries to the Spine"; Engineering Seminar, Trinity University, San Antonio, Texas; 1971.

"An Analytical Investigation of the General Motors Severity Index"; American Society of Mechanical Engineers, Washington, D.C.; 1971.

"Mathematical Models for the Evaluation of Head Injury Criteria"; Tulane University, New Orleans, Louisiana; 1970.

"Mathematical Modeling Applied to Impact Trauma"; Bioengineering Seminar, Tulane University, New Orleans, Louisiana; 1970.

"The Biomechanics of Impact Trauma"; Bioengineering Seminar, University of Texas Medical School at San Antonio, Texas; 1972.

"The Physical Basis of Contre Coup and Investigative Study"; Tenth Annual Meeting, Society of University Neurosurgeons, San Antonio, Texas; 1974.

"An Analytical Approach to the Problem of Contre Coup Head Injury"; Twenty-Seventh Annual Meeting, Southern Neurosurgical Society, Inc., San Antonio, Texas; 1975.

"Biomechanics of Head and Spine Trauma — Part I"; Invited Lecturer, International Harvester Corporation, Chicago, Illinois; 1983.

"Biomechanics of Head and Spine Trauma — Part II"; Invited Lecturer, International Harvester Corporation, Chicago, Illinois; 1985.

"Biomechanics of Impact Trauma"; Invited Lecturer, New Seabury Seminar Program, New Seabury on Cape Cod, Massachusetts; 1985.

"The Role of Biomechanics in the Determination of Injury Causation"; Invited Lecturer, American Bar Association, Annual Torts Seminar, San Antonio, Texas; February, 1987.

"Biomechanics and Injury Evaluation of Restraint System Effectiveness"; Invited Lecturer, General Motors, Detroit, Michigan; December 1987.

"Principles and Concepts of Restraint System Biomechanics"; Invited Lecturer, United Services Automobile Association, San Antonio, Texas; June, 1988.

"Biomechanics of Injury Causation"; United Services Automobile Association, San Antonio, Texas; 1988.

"Reducing Injuries Sustained in Automobile Crashes"; United Services Automobile Association, San Antonio, Texas; 1988.

"Injury Causation in the Automotive Environment"; Honda Motor Co., Ft. Lauderdale, Florida; 1989.

"Rear Restraint Seat Belts"; General Motors Corporation, San Antonio, Texas; 1989.

"Crash Performance Standards and the Biomechanics of Impact: What are the Relationships?", "Brain, Skull and Face", and "Pelvis and Extremities"; Invited Faculty. Association for the Advancement of Automotive Medicine, San Antonio, Texas; 1989.

"Injury Causation Analysis"; State Farm Insurance, Seattle, Washington, and Bloomington, Illinois; 1989.

"The Biomechanics and Injury Causation in the Underwater Environment"; Boat Safety Advisory Council, Coer d'Alene, Idaho; 1989.

"Cervical Spine in the Rollover Environment"; Invited Lecturer, Snell & Wilmer, Phoenix, Arizona; January 1990.

"Analysis of Soft Tissue Injuries of the Cervical Spine; Challenge of the Cervical Spine"; San Antonio, Texas; April 25-29, 1990.

"Biomechanics and Injury Causation"; Invited Lecturer, Royal Insurance Group, Charlotte, North Carolina; October 1990.

"Principles of Biomechanics and Injury Causation"; Invited Lecturer, Nissan Motor Co./Tokyo Fire and Marine, Torrance, California. April 1991.

"Biomechanics of Head and Spinal Trauma"; Faculty Member, 5th Annual Trauma Conference, Las Cruces, New Mexico. June 7-9, 1991.

"Biomechanics and Injury Causation in the Truck Environment"; Invited Lecturer, American Law Firm Association, Atlanta, Georgia. January 28-30, 1992.

"An Introduction to Biomechanics, Occupant Kinematics and Crash Severity Assessment"; Invited Lecturer, Association for the Advancement of Automotive Medicine, TSA, McLean, Virginia. May 10, 1992.

"Injury Research"; Invited Lecturer, Vehicle Rollovers TOPTEC; Society of Automotive Engineers, Scottsdale, Arizona. September 20-23, 1992.

"Traffic Injury: Are we Prepared for the Next Millennium?" Invited Lecturer, Association for the Advancement of Automotive Medicine, New Mexico State Highway and Transportation Department, Santa Fe, New Mexico. December 2-4, 1992.

"Rollover Research on Injury Mechanisms"; Invited Lecturer, Vehicle Rollovers TOPTEC: An Update of the Current Issues; Society of Automotive Engineers, Dearborn, Michigan. August 1993.

"Low Velocity Impact Investigation"; Invited Lecturer, National Insurance Crime Bureau Western Regional Office, Glendora, California. August 8-9, 1996.

"Early Assessment of Injury Potential from Low Velocity Impacts/Collisions"; Invited Lecturer, International Association of Special Investigation Units 1996 Annual Seminar, Tucson, Arizona. September 8-12, 1996.

"Low Velocity Impact Investigation"; Invited Lecturer, National Insurance Crime Bureau Advanced Special Investigations Academy, Tempe, Arizona. December 4-5, 1996.

"Injuries Associated with Airbag Deployment"; Invited Lecturer, American Bar Association Emerging Issues in Motor Vehicle Product Liability Litigation, Phoenix, Arizona. March 20-21, 1997.

"Low Impact/Soft Tissue Claims - Biomechanical Investigation"; Invited Lecturer, The 1997 Claims Conference Property Loss Research Bureau & Liability Insurance Research Bureau, Atlanta, Georgia. April 6-9, 1997.

"Auditory and Visual System Injury Potential with Airbag Deployment"; Presentation to Society of Automotive Engineers Airbag Design and Performance TOPTEC, Costa Mesa, CA. August 14-15, 1997.

"Mechanism of Low Back Injury and Reconstruction"; Invited Lecturer, 8th International Conference on Lumbar Fusion and Stabilization, Sponsored by The University of Texas Medical Branch at Galveston; San Antonio, TX, September 30-October 4, 1997.

"The Effect of Air Bag Deployments on Restrained Occupant Belt Loads and Biomechanical Forces"; Invited Lecturer, American Bar Association Emerging Issues in Motor Vehicle Product Liability Litigation, Phoenix, Arizona. April 2-3, 1998.

"Pediatric Biomechanics"; Invited Rapporteur, Association for the Advancement of Automotive Medicine 42nd Annual Conference, Charlottesville, VA. October 4-7, 1998

"Frontal Air Bag Deployment and the Out of Position Child"; Association for the Advancement of Automotive Medicine Advanced Air Bag Technology in Frontal and Side Impacts, July 27-28, 2000, Southfield, MI.

ACADEMIC DUTIES

Adjunct Faculty Appointment, Department of Health Care Administration, Trinity University, San Antonio	1978
Adjunct Associate Professor of Bioengineering, University of Texas Medical School at San Antonio	1972

Tab 19

BRC
BIODYNAMIC RESEARCH CORPORATION

JAMES H. RADDIN, JR., MD, SM

CURRICULUM VITAE

EDUCATION AND CERTIFICATIONS

S.M.	Management (Alfred P. Sloan Fellow), MIT Sloan School of Management, Cambridge, Massachusetts.	1983
M.D.	University of New Mexico School of Medicine (PG-1 in General Surgery at USAF Medical Center, Keesler AFB, Mississippi, 1977).	1975
S.B.	Aeronautics and Astronautics, Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts.	1967

POST GRADUATE MEDICAL STUDIES

Post Graduate Studies	Board Certified in Aerospace Medicine USAF School of Aerospace Medicine, Brooks AFB, Texas.	1985

PROFESSIONAL EXPERIENCE

Director and Principal Consultant Biodynamic Research Corporation San Antonio, Texas	1988-Pres.
Vice Commander USAF School of Aerospace Medicine Brooks AFB, Texas.	1985-1988
Assistant Deputy Commander for Research, Development, and Acquisition Aerospace Medical Division (now Human Systems Division) Brooks AFB, Texas.	1984-1985
MIT Sloan Fellow and Aerospace Medicine Resident	1982-1984
Chief Aeromedical Advisor Life Support Systems Program Office Aeronautical Systems Division, Wright-Patterson AFB, Ohio.	1980-1982

BIODYNAMIC RESEARCH CORPORATION
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San Antonio, Texas 78230
(210) 691-0281

Principal Investigator, AF Aerospace Medical Research Laboratory Wright-Patterson AFB, Ohio.	1977-1980
Medical Student and General Surgery Intern.	1972-1977
Test Engineer Central Inertial Guidance Test Facility, Holloman AFB, New Mexico.	1968-1972
Graduate Research Assistant MIT Instrumentation Laboratory (now Charles Stark Draper Laboratory) Cambridge, Massachusetts.	1967-1968

PROFESSIONAL REGISTRATIONS

Consultant in Aerospace Medicine to the Surgeon General, USAF	1987-1988
Licensed by the State of Ohio, License #40980	1977-Pres

PROFESSIONAL AFFILIATIONS

Aerospace Medical Association	1977-Pres
Air Force Association	1977-Pres
Air Standardization Coordinating Committee's Working Party 61	1980-1985
Society of Automotive Engineers (SAE)	1989-Pres
Association for the Advancement of Automotive Medicine (AAAM)	1991-Pres

HONORS AND AWARDS

Sigma Gamma Tau National Aeronautical Engineering Honorary Society	1966
Distinguished Military Graduate, MIT	1967
Air Force Systems Command Award for Technical Achievement	1971
Alpha Omega Alpha National Medical Honorary Society	1974
Distinguished Graduate, Primary Course in Aerospace Medicine	1976
Air Force Systems Command Flight Surgeon of the Year	1977
Air Force Commendation Medal	1972; 1981
Air Force Meritorious Service Medal	1980; 1982
The Legion of Merit	1988
John Paul Stapp Award from the Aerospace Medical Association	2000

PUBLICATIONS AND PRESENTATIONS

THESES:

Raddin, James H. Jr.; Discretionary Funds in Research and Development: A Case Study in Military Biotechnology Management, Master's Thesis, Massachusetts Institute of Technology Sloan School of Management, Cambridge, Massachusetts, May, 1983.

TEXTBOOKS:

Brinkley, James W. and J.H. Raddin, Jr.; "Biodynamics: Transitory Acceleration" in Fundamentals of Aerospace Medicine, Roy L. DeHart, Editor, Lea and Febiger, 1985.

OTHER PUBLICATIONS:

Raddin, James H. Jr.; "A Mass-Unbalance Torquing Scheme for the SABRE Guidance System" (Classified), MIT Instrumentation Laboratory (now Charles Stark Draper Laboratory) Technical Report, Cambridge, Massachusetts, January, 1968.

Raddin, James H. Jr.; "Gyroscope Temperature Gradient Study," Working Paper MDSLG-68-6, Central Inertial Guidance Test Facility, Holloman AFB, New Mexico, June, 1968.

Raddin, James H. Jr., and R. Thede; "Slipring Resistance Stability and Its Effect in Gyroscope Testing," Working Paper MDSLG-69-2, Central Inertial Guidance Test Facility, Holloman AFB, New Mexico, January, 1969.

Raddin, James H. Jr.; "Gyroscope Thermal Gradient Test Investigation," Working Paper MDSLG-69-4, Central Inertial Guidance Test Facility, Holloman AFB, New Mexico, April, 1969.

Raddin, James H. Jr., and W. Langley; "Space Precision Attitude Reference System (SPARS) MOD 1A, Project 681D1 Test Plan," Central Inertial Guidance Test Facility, Holloman AFB, New Mexico, June, 1970.

Raddin, James H. Jr.; "Documentation of a Gyroscope Thermal Gradient Sensitivity Test." Presented by Lieutenant Raddin at the Fifth Guidance Test Symposium, Central Inertial Guidance Test Facility, Holloman AFB, New Mexico, October, 1970, and published in the proceedings (Volume 1, AFSWC-TR-19).

Raddin, James H. Jr. and R. Thede; "Space Precision Attitude Reference System (SPARS) and Precision Earth Pointing System (PEPSY) MOD 1B, Project 681D1 Test Plan," Central Inertial Guidance Test Facility, Holloman AFB, New Mexico, October, 1970.

Raddin, James H. Jr. and R. Thede; "Precision Earth Pointing System (PEPSY) Phase 1B Final Test Report, Part II: SPARS/PEPSY Laboratory Test at the Central Inertial Guidance Test Facility," Space and Missile Systems Organization (AFSC), Los Angeles AFS, California, May, 1971.

Raddin, James H. Jr.; "Laboratory Test of the Space Precision Attitude Reference System/Precision Earth Pointing System (SPARS/PEPSY)" (Classified). Presented by Captain Raddin at the Air Force Systems Command Science and Engineering Symposium, Dayton, Ohio, October, 1971, and published in the proceedings.

Raddin, James H. Jr.; "Assessment of Risk Associated with Ejection Through the Canopy." Presented by Dr. Raddin at the 50th Annual Scientific Meeting of the Aerospace Medical Association, Washington, D.C., May, 1979 and published as a preprint at the meeting.

Brinkley, James W., J.H. Raddin, Jr., and J.M. Powers; "Investigation of the Effects of Restraint Design Variations on Human Response to Impact." Presented by Mr. Brinkley at the 50th Annual Scientific meeting of the Aerospace Medical Association, Washington, D.C., May, 1979 and published as a preprint at the meeting.

Raddin, James H. Jr., L.J. Specker, and J.W. Brinkley; "Minimizing the Sequenced Delay Time for Escape from High-Speed, Low-Level Flight Profiles." Presented by Dr. Raddin at the NATO AGARD Conference on High-Speed, Low-level Flight: Aircrew Factors, Lisbon, Portugal, October, 1979, and published in the proceedings (AGARD-CP-267).

Raddin, James H. Jr., J.W. Brinkley and B.F. Hearon; "The Implications of Dynamic Preload in Human Impact Tolerance." Presented by Dr. Raddin at the 51st Annual Scientific Meeting of the Aerospace Medical Association, Anaheim, California, May, 1980, and published as a preprint at the meeting.

Hearon, Bernard F. and J.H. Raddin, Jr.; "Experience with Highly Selective Screening Techniques for Acceleration Stress Duty." Presented by Dr. Hearon at the NATO AGARD Conference on the Effect of Long-term Therapeutics, Prophylaxis and Screening Techniques on Aircrew Medical Standards, Toronto, Canada, September, 1980, and published in the proceedings (AGARD-CP-310).

Brinkley, James W., B.F. Hearon, and J.H. Raddin, Jr.; "Influence of F/FB-111 Crew Seat and Restraint Configuration Changes on Responses of Volunteers to +GZ Impact." Presented by Mr. Brinkley at the 52nd Annual Scientific Meeting of the Aerospace Medical Association, San Antonio, Texas, May, 1981, and published as a preprint at the meeting.

Hearon, Bernard F., J.W. Brinkley, and J.H. Raddin, Jr.; "The Effects of Dynamic Preload on Human Response to -GX Impact Acceleration." Presented by Dr. Hearon at the 52nd Annual Scientific Meeting of the Aerospace Medical Association, San Antonio, Texas, May, 1981, and published as a preprint at the meeting.

Brinkley, James W., J.H. Raddin, Jr., B.F. Hearon, L.A. McGowan, and J.M. Powers; Evaluation of a Proposed, Modified F/FB-111 Crew Seat and Restraint System. Technical Report AFAMRL-TR-80-52, AF Aerospace Medical Research Laboratory, November, 1981. 414 pp.

Raddin, James H. Jr.; "Improvements to Aircraft Oxygen Systems - The Intentions of the United States Air Force." Presented by Dr. Raddin at the Air Standardization Coordinating Committee Working Party 61 Oxygen Systems Symposium, Farnborough, England, November, 1981, and published in the proceedings.

Raddin, James H. Jr.; "Fluomine Chemical Absorption System: USAF Experience." Presented by Dr. Raddin at the Air Standardization Coordinating Committee Working Party 61 Oxygen Systems Symposium, Farnborough, England, November, 1981, and published in the proceedings.

Raddin, James H. Jr. and G.R. McNutt; "Improvements in Design and Performance of USAF Aircrew Masks and Helmets." Presented by Major McNutt at the Air Standardization Coordinating Committee Working Party 61 Oxygen Systems Symposium, Farnborough, England, November, 1981, and published in the proceedings.

Raddin, James H. Jr. and B. F. Hearon; "Dynamic Preload as an Impact Protection Concept." Presented by Dr. Raddin at the SAFE Silver Anniversary Symposium, Las Vegas, Nevada, December, 1981, and published in the proceedings.

Hearon Bernard F., H.A. Thomas, and J.H. Raddin, Jr.; "Mechanism of Vertebral Fracture in the F/FB-111 Ejection Experience" in Aviation, Space and Environmental Medicine, 53(5): 440-8, 1982.

Hearon, Bernard F., J.W. Brinkley, J.H. Raddin, Jr., L.A. McGowan, and J.M. Powers; Comparative Vertical Impact Testing of the F/FB-111 Crew Restraint System and a Proposed Modification. Technical Report AFAMRL-TR-82-13, AF Aerospace Medical Research Laboratory, 1982. 308 pp.

Hearon, Bernard F., J.H. Raddin, Jr., and J.W. Brinkley; "Influence of Dynamic Preload on Human Response to Transverse (-GX) Impacts." Presented by Dr. Hearon at the 53rd Annual Scientific Meeting of the Aerospace Medical Association, Bal Harbor, Florida, May, 1982, and published as a preprint at the meeting.

Hearon, Bernard F., J.H. Raddin, Jr., and J.W. Brinkley; "Evidence for the Utilization of Dynamic Preload in Impact Injury Prevention." Presented by Dr. Hearon at the NATO AGARD Conference on Impact Injury Caused by Linear Acceleration: Mechanisms, Prevention and Cost, Cologne, Federal Republic of Germany, April, 1982, and published in the proceedings (AGARD-CP-322).

Hearon, Bernard F., J.W. Brinkley, J.H. Raddin, Jr., L.A. McGowan, and J.M. Powers; Evaluation of the Influence of Upper Extremity Bracing Techniques on Human Response During Vertical Impact. Technical Report AFAMRL-TR-82-54, AF Aerospace Medical Research Laboratory, August, 1982. 221 pp.

Hearon, Bernard F., J.W. Brinkley, J.H. Raddin, Jr., and B. W. Fleming, Jr.; "Knee Ligament Injury During Lateral Impact" in Aviation, Space and Environmental Medicine, 56(1):1-9, January, 1985.

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ACADEMIC DUTIES

Assistant Clinical Professor, Community Medicine (Aerospace Medicine),
Wright State University School of Medicine,
Dayton, Ohio 1980-1983

Tab 20

IPSA
International

D.C. PAGE
SENIOR MANAGING DIRECTOR

D.C. Page is the Senior Managing Director of IPSA's Miami office and is responsible for all services in Florida, Latin America and the Caribbean.

D.C. joins IPSA from Kroll Associates, where he was a Managing Director in the company's Miami and Los Angeles offices for over ten years. After opening Kroll's Miami Latin American Regional office in 1993, D.C.'s practice focused on litigation support, complex litigation management, asset searching, business intelligence, intellectual property and security related matters. Working in Los Angeles and Miami provided D.C. the experience of managing cases in the complex international marketplace.

Prior to joining Kroll Associates, D.C. was with the United States Customs Service for more than 10 years where he was a Senior Special Agent in Washington, D.C. and San Diego. His experience in this capacity included investigating and prosecuting complex money-laundering conspiracy cases and narcotics-related special operations. In addition, he investigated trade related business frauds including counterfeit product manufacturing and importation. As the Assistant to the Commissioner of Customs, D.C. had responsibility for all enforcement matters for the service in addition to providing liaison with other government bodies such as the Treasury Department, Justice Department and the Congress.

D.C. also worked as a special investigator for the State of Wisconsin. He worked in a deep cover capacity infiltrating narcotics and organized crime criminal operations.

D.C. attended the University of Wisconsin and received his B.A. from the American University in Washington, D.C. with degrees in the Administration of Justice and Political Science. He also received the State of Wisconsin's Law Enforcement Standards Board Certification and attended the Federal Law Enforcement Training Center in Glynco, Georgia. He is a Certified Fraud Examiner.

Tab 21

CURRICULUM VITAE
WALTER FREDERICK ROWE

E-MAIL ADDRESS:	wfrowe@gwu.edu
EDUCATIONAL BACKGROUND:	Ph.D. 1976, Harvard University A.M. 1968, Harvard University B.S. 1967, Emory University (with highest honors in chemistry)
SPECIAL FIELD:	Physical Chemistry
THESIS TOPIC:	The Microwave Spectrum of Malonaldehyde
ACADEMIC DISTINCTIONS:	National Science Foundation Fellowship, 1967-1969, 1971-1973 Honor Graduate, U. S. Army Military Police School, Criminal Investigator Course Woodrow Wilson Fellowship, 1967 Graduated with highest honors in chemistry, first in graduating class, 1967 Phi Beta Kappa, 1966 Emory University Scholarship, 1963-1967
EXPERIENCE IN TEACHING AND/OR EDUCATIONAL ADMINISTRATION	1990-present: Professor of Forensic Sciences, The George Washington University 1980-1990: Associate Professor of Forensic Sciences, The George Washington University 1975-1980: Assistant Professor of Forensic Sciences, The George Washington University 1972-1974: Teaching Fellow in Chemistry, Harvard University [Recipient of award for excellence in teaching chemistry, 1974] 1966: Teaching Fellow in Chemistry, Emory University

OTHER EXPERIENCE: 1969-1971: Forensic Chemistry Specialist/Criminal Investigator, U.S. Army

PROFESSIONAL ORGANIZATIONS:
American Academy of Forensic Sciences, Criminalistic Section [Fellow]
American Chemical Society
American Association for the Advancement of Science
The Forensic Science Society
Mid-Atlantic Association of Forensic Scientists
Association of Harvard Chemists
Sigma Xi
Pan-American Biodeterioration Society

OTHER DISTINCTIONS:
Member, Editorial Board, *The Journal of Forensic Sciences*
Summer Faculty Fellowship Program, NASA Goddard Space Flight Center
Review Panel Member, National Institute of Justice, 1992-1997
Saferstein Memorial Lecturer, Barnett Institute, Northeastern University, 2000
Member, ASTM Committee E30

SPECIAL TRAINING FORENSIC SCIENCE OR CRIMINAL JUSTICE:
Resident training in forensic chemistry, U.S. Army Military Police School, Ft. Gordon, Georgia
Criminal investigation course, U.S. Army Military Police School, Ft. Gordon, Georgia.
Forensic electrophoresis workshop, Baltimore City Police Department, 1983.
ANTHROPOLOGY 186: The Physical Anthropology of Modern Man (taught by Dr. J. Lawrence Angel, Smithsonian Institution).

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"Errors in the Estimation of the Distance of Fall and Angles of Impact of Blood Drops" (with Cordelia Willis, Anna K. Piranian, John R. Donaggio, and Robert J. Barnett) *Forensic Science International* (in press).

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"DNA Testing Not Ready for Court?! A Tale of Two Surveys," *The Journal of Forensic Sciences*, 34, 803-805 (1989).

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"Examination of Alleged Pore Structure Found in Sasquatch (Big Foot) Footprints," (with D. J. Freeland), *Skeptical Inquirer*, 13, 273-276 (1989).

PRESENTATIONS AT SCIENTIFIC MEETINGS (1984 to present)

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"Is It Time to Stop Microscopic Hair Comparisons?" (with David R. Foran), paper presented at the 53rd annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 19-24, 2001.

"Investigation of the Early stages of Fungal Attack on Human Head Hair," (with Nicholas F. Marko), paper presented at the 53rd annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 19-24, 2001.

"Preliminary Report on the Examination of Human Hairs and Textile Fibers Recovered During Excavations at Harewood Cemetery Near Charles Town, West Virginia," (with Harold A. Deadman), paper presented at the 52nd annual meeting of the American Academy of Forensic Sciences, Reno, Nevada, February 23-26, 2000.

"What's in a Bullseye?" (with K. Michelle Ricketts and William A. MacCrehan), paper presented at the annual meeting of the Mid-Atlantic Association of Forensic Scientists, April

20-23, 1999, in Ocean City, Maryland.

“What’s in a Bullseye?” (with K. Michelle Ricketts and William A. MacCrehan), paper presented at the 51st annual meeting of the American Academy of Forensic Sciences, Orlando, Florida, February 15-20, 1999.

“Use of Microcon Microconcentrators to Maximize Analyses of Suspected Semen Stains,” (with Amy B. Lowery), paper presented at the 51st annual meeting of the American Academy of Forensic Sciences, Orlando, Florida, February 15-20, 1999.

“Alpha-Amylase in Perspiration,” paper presented at the 51st annual meeting of the American Academy of Forensic Sciences, Orlando, Florida, February 15-20, 1999.

“Errors in the Estimation of the Angle of Impact of Blood Droplets with Surfaces,” (with Cordelia L. Willis), paper presented at the 51st annual meeting of the American Academy of Forensic Sciences, Orlando, Florida, February 15-20, 1999.

“Collection and Analysis of Gun Shot Residue by Supercritical Fluid/ Micellar Electrokinetic Capillary Electrophoresis (SFE/MECE)”(with Richard A. Baltzersen and William A. MacCrehan), paper presented at 1998 annual meeting of the Mid-Atlantic Association of Forensic Scientists, Rockville, Maryland, May 11-15, 1998.

"Identical Twin Fingerprint Patterns: What Went Wrong in Collaborative Testing Services Latent Fingerprint Proficiency Test," paper presented at 1997 annual meeting of the Mid-Atlantic Association of Forensic Scientists, Roanoke, Virginia, April 30-May 2, 1997.

"Did the Supreme Court in *Daubert* Adopt an Obsolete Model of Science?" paper presented at 1997 annual meeting of the Mid-Atlantic Association of Forensic Scientists, Roanoke, Virginia, April 30-May 2, 1997.

"A Preliminary Study of the Use of Scanning Electron Microscopy to Compare 9-mm Glock Pistol Rounds," paper presented at the 49th annual meeting of the American Academy of Forensic Sciences, New York, New York, February 17-22, 1997.

"Fake!" paper presented at the 49th annual meeting of the American Academy of Forensic Sciences, New York, New York, February 17-22, 1997.

"Did the Supreme Court in *Daubert* Adopt an Obsolete Model of Science?" paper presented at the 49th annual meeting of the American Academy of Forensic Sciences, New York, New York, February 17-22, 1997.

"Fake!" paper presented at 1996 meeting of the Mid-Atlantic Association of Forensic Scientists, Harrisburg, Pennsylvania, May 8-10, 1996.

"Microscopic Examination of Hairs Excavated on the James Family Farm," (with James E. Starrs), paper presented at 1996 meeting of the Mid-Atlantic Association of Forensic Scientists, Harrisburg, Pennsylvania, May 8-10, 1996.

"Preliminary Study of the Use of Scanning Electron Microscopy to Compare 9-mm Glock Pistol Rounds," (with Richard S. Bendel and Paul Salvetti), paper presented at 1996 meeting of the Mid-Atlantic Association of Forensic Scientists, Harrisburg, Pennsylvania, May 8-10, 1996.

"Identification of Gunshot Residue from 'Clean-Fire™' Lead-Free Primers Utilizing Scanning Electron Microscopy," (with Paul E. Tingle, Robert L. Hunkeler, Erich P. Junger and Joseph N. Madary), paper presented at the 48th annual meeting of the American Academy of Forensic Sciences, Nashville, Tennessee, February 19-24, 1996.

"A Comparative Study of the Effectiveness of Forensic Light Sources in the Detection of Biological Stain Evidence, (with Michael S. Maloney and Donald G. Housman), paper presented at the 48th annual meeting of the American Academy of Forensic Sciences, Nashville, Tennessee, February 19-24, 1996.

"A Study of the Effectiveness of the Cyanoacrylate Ester Fuming Wand and Its application in the Crime Scene Development of Latent Fingerprints," (with Donald G. Housman and Michael S. Maloney), paper presented at the 48th annual meeting of the American Academy of Forensic Sciences, Nashville, Tennessee, February 19-24, 1996.

"A Second Look at the 'Blue Sense' -- A Critical Examination of the Police Use of Psychics," paper presented at the 48th annual meeting of the American Academy of Forensic Sciences, Nashville, Tennessee, February 19-24, 1996.

"Application of X-Ray Diffraction to the Forensic Differentiation of Electrical Tape," (with Michael Frontz) paper presented at 1995 meeting of the Mid-Atlantic Association of Forensic Scientists, Fairfax, Virginia, May 11-12, 1995.

"A Second Look at the 'Blue Sense': A Critical Examination of the Police Use of Psychics," paper presented at 1995 meeting of the Mid-Atlantic Association of Forensic Scientists, Fairfax, Virginia, 1995.

"Application of X-Ray Diffraction for the Forensic Differentiation of Electrical Tape," (with Michael Frontz) paper presented at 47th annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 13-18, 1995.

"Analysis of Smokeless Powder in Post-Blast Pipe Bomb Fragments Using Micellar Electrokinetic Capillary Electrophoresis, (with Kelly D. Smith, Bruce R. McCord, Kelly A. Hargadon and William A. MacCrehan) paper presented at 47th annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 13-18, 1995.

"The Effects of Temperature on Gunshot Residue Patterns as Determined Using a New Method for Pattern Analysis, (with Ty R. Cresap, Debra Goldman, Erich P. Junger, Robert C. Veasey and David W. Hause) paper presented at 47th annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 13-18, 1995.

"The Effects of Luminol and Coomassie Blue on DNA Typing by PCR," (with Ty R. Cresap, John L. Pecko, David James Zeliff, Virginia L. Fristoe, Molly A. Moses, Marie D. Ricciardone, James P. Ross, Rhonda Kay Roby, Deborah L. Fisher and Victor Walter Weedn) paper presented at 47th annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 13-18, 1995.

"Analysis of Fungal Tunneling in 300 Year Old Hair Samples Taken From Buried Lead Coffins," (with Heidi F. Kunert, Robert L. Hunkeler, Joseph N. Madary and Erich P. Junger) paper presented at 47th annual meeting of the American Academy of Forensic Sciences, Seattle, Washington, February 13-18, 1995.

"The Lessons of Pathological Science," (with Michael Epstein and Luigi Garlaschelli) paper presented at 21st annual meeting of the Federation of Analytical and Spectroscopy Societies, St. Louis, Missouri, October 4, 1994.

"Detection of Smokeless Powder Residue by Micellar Electrokinetic Electrophoresis," (with Kelly D. Smith, William A. McCrehan, and David Baker) paper presented at 1994 meeting of the Mid-Atlantic Association of Forensic Scientists, Virginia Beach, Virginia, May 6-8, 1994.

"Biodeterioration of Natural Fibers: Three Case Studies," paper presented at 1994 meeting of the Mid-Atlantic Association of Forensic Scientists, Virginia Beach, Virginia, May 6-8, 1994.

"Daubert: Has The Supreme Court Bitten Off More Than It Can Chew?" paper presented at 1994 meeting of the Mid-Atlantic Association of Forensic Scientists, Virginia Beach, Virginia, May 6-8, 1994.

"Perspectives on the Validity of Personal Identification Methodology in Identical Twins," (with Amy Sirignano and Michael Krakow) paper presented at 46th annual meeting of the American Academy of Forensic Sciences, San Antonio, TX, February 14-19, 1994.

"SEM Examination of Questioned Documents and Correction Ribbon," (with S.M. Castro, N.W. Galbreath, J.L. Pecko, and F.N. Hellman) paper presented at 46th annual meeting of the American Academy of Forensic Sciences, San Antonio, TX, February 14-19, 1994.

"The Comparison of the Dentition of Twins," (with Michael Krakow and Amy Sirignano) paper presented at 45th annual meeting of the American Academy of Forensic Sciences, Boston, MA, February 15-20, 1993.

"Biodeterioration of Buried Hairs and Textile Fibers," paper presented at 45th annual meeting of the American Academy of Forensic Sciences, Boston, MA, February 15-20, 1993.

"Spreadsheet Forensic Science," paper presented at 45th annual meeting of the American Academy of Forensic Sciences, Boston, MA, February 15-20, 1993.

"Mixed-Mode Analysis in the Examination of Forensic Evidence," paper presented at 31st annual meeting of the Eastern Analytical Symposium, Somerset, New Jersey, November 16-20, 1992.

"Humpty Dumpty's Day in Court," paper presented at 1992 meeting of the Mid-Atlantic Association of Forensic Scientists, Richmond, Virginia, May 7-8, 1992.

"Blood Detection by Luminol on Substrates Cleaned with Household Agents," (with Leslie M. Bryant) paper presented at 44th annual meeting of the American Academy of Forensic Sciences, New Orleans, LA, February 17-22, 1992.

"Contrast Enhancement of Cyanoacrylate-Developed Latent Fingerprints Using Biological Stains and Commercial Fabric Dyes," (with Julie B. Kempton) paper presented at 1991 meeting of the Mid-Atlantic Association of Forensic Scientists, Bethesda, Maryland, May 30-31, 1991.

"A Video Microscopy System for Training and Casework," paper presented at 42nd annual meeting of the American Academy of Forensic Sciences, Cincinnati, Ohio, February 1990.

"Examination of Footprints of Adult Caucasian Females," (with S. M. Wenner, R. E. Harvey, W. J. McChesney and B. Nakasone) paper presented at 42nd annual meeting of the American Academy of Forensic Sciences, Cincinnati, Ohio, February 1990.

"The Infrared Spectra of Buried Acetate and Rayon Fibers," (with S. M. Singer, D. M. Northrop and M. W. Tungol), paper presented at 3rd annual meeting of the Pan-American Biodeterioration Society, Washington, DC, August 1989.

"DNA Testing Not Ready For Casework?! A Tale of Two Surveys," paper presented at 1989 meeting of the Mid-Atlantic Association of Forensic Scientists, Baltimore, Maryland, May 17-19, 1989.

"A Study of Hair Degradation in Soil," (with J. A. Kundrat) 2nd annual meeting of the Pan-American Biodeterioration Society, Washington, DC, July 1988.

"Biodeterioration of Man-made Textiles in Various Soil Environments," (with S. M. Singer)

2nd annual meeting of the Pan-American Biodeterioration Society, Washington, DC, July 1988.

"Deterioration of Hair by Airborne Microorganisms: Implications for Museum Biological Collections," (with C. A. Hawks) paper presented at the 1988 meeting of the Society for the Preservation of Natural History Collections, Pittsburgh, Pennsylvania, May 30-June 3, 1988.

"Examination of Bullet Substitution Claims in the Sacco-Vanzetti Case," (with D. Miller and J. Thompson) paper presented at the 40th annual meeting of the American Academy of Forensic Sciences, Philadelphia, Pennsylvania, February 1988.

"Criminalistics in Traffic Accident Reconstruction," paper presented at the First International Congress of Legal Medicine and Forensic Sciences, Cairo, Egypt, December 1987.

"Deterioration of Hair by Airborne Micro-organisms: Implications for Museum Biological Collections," (with C. A. Hawks) paper presented at the Seventh International Biodeterioration Symposium, Cambridge, England, September 1987.

"Asbestos Monitoring in the University Environment," (with A. McLane) paper presented at the spring 1987 meeting of the Mid- Atlantic Association Forensic Scientists, Richmond, Virginia.

"Effect of the Effect of the Soil Environment on the Biodeterioration of Man-Made Textiles," (with D. M. Northrop), 1st annual meeting of the Pan-American Biodeterioration Society, Washington, DC, July 1986.

"The Biodeterioration of Hair in a Soil Environment," (with J. M. Serowik) 1st annual meeting of the Pan-American Biodeterioration Society, Washington, DC, July 1986.

"The Effects of the Soil Environment on the Morphology and Chemical Composition of Synthetic Fibers," (with D. M. Northrop) paper presented at fall 1985 meeting of the Mid-Atlantic Association of Forensic Scientists, Dover, Delaware.

"Fiber-Plastic Fusions in Traffic Accident Reconstruction," (with S. Masakowski, B. Enz and J. Cothern) paper presented at spring 1985 meeting of the Mid-Atlantic Association of Forensic Scientists, Washington, D. C.

"Textile-Plastic Fusions in Vehicular Accident Reconstruction," paper presented at 23rd annual meeting of the Eastern Analytical Symposium, New York, November 1984.

"Range-of-Fire Estimates from Regression Analysis Applied to the Spreads of Shotgun Pellet Patterns: Results of a Blind Study," paper presented at 10th Triennial Meeting of the International Association of Forensic Sciences, Oxford, England, 18-25 September 1984.

TEACHING DUTIES

ForS 103-104: Introduction to the Forensic Sciences
ForS 201: Forensic Serology I
ForS 202: Instrumental Analysis
ForS 204: Firearm and Toolmark Identification
ForS 205: Personal Identification
ForS 220: Physical Aspects of Forensic Sciences
ForS 221: Biological Aspects of Forensic Sciences
ForS 251: Moot Court
ForS 254: Selected Topics in Forensic Science: Forensic DNA Profiling
ForS 265: Drugs of Abuse
ForS 271: Forensic Serology II
ForS 273: Forensic Chemistry I
ForS 280: Forensic Chemistry II

Additional teaching:

Course in basic microscopy for personnel in New Jersey state crime laboratory system.

"Forensic Serology: A Guide for the Perplexed" invited presentation at annual meeting of National Defense Investigators Association, Baltimore, MD, October 1987.

"Blasting into the '90s" panel discussion participant, American Bar Association Criminal Justice Section, November 1990.

Guest lecturer, Winterthur Museum, Winterthur, Delaware, May 11, 1992

Guest lecturer, Medicolegal Investigation of Death, Lincoln, Nebraska, September 30-October 3, 1992. Course sponsored by Pathology Medical Services, the Lancaster County Attorney's Office and the Nebraska Medical Association.

Guest lecturer, DNA 101-Unraveling the Mystery, course presented by the American Prosecutors Research Institute, Alexandria, Virginia, November 2-4, 1995.

Guest lecturer, DNA: Witness to the Truth, course presented by the American Prosecutors Research Institute, Charleston, South Carolina, November 20-23, 1996.

Tab 22

CELLMARK
DIAGNOSTICS

20271 Goldenrod Lane · Germantown, Maryland 20876
Telephone: (301) 428-4980 (800) USA-LABS
Administration Fax: (301) 428-4877
Laboratory Fax: (301) 428-7946

COMPANY PROFILE

Cellmark Diagnostics is the recognized world leader in DNA FINGERPRINTING[SM] services. Cellmark provides DNA testing, training, contract data basing, contract research, and expert consultation, serving both prosecution and defense counsel needs. Over the past ten years, Cellmark has become the largest and most experienced private forensic DNA identity laboratory in the country, analyzing thousands of criminal and biological relationship cases from all 50 states, in addition to cases from Canada, Puerto Rico, Guam, and several South American countries. Cellmark scientists have testified in more than 750 criminal cases, and are frequently requested to provide expert consultation services in evaluating the DNA testing conducted by other laboratories. Additionally, Cellmark is a pioneer in DNA quality assurance, being the first to provide a quarterly proficiency testing program designed exclusively for DNA identity laboratories and the first private laboratory to obtain accreditation by the American Society of Crime Laboratory Directors - Laboratory Accreditation Board (ASCLD-LAB).

One of the first laboratories in the world to offer DNA identity testing, Cellmark Diagnostics opened in 1987 using the revolutionary technology developed by the geneticist Sir Alec Jeffreys at the University of Leicester in the United Kingdom. Jeffreys' probe technology includes the application of multilocus probes (MLPs) in biological relationship cases and single-locus probes (SLPs) in both criminal and biological relationship case work. MLP technology remains the most powerful discrimination tool available in resolving biological relationship cases. Cellmark is proud to be accredited by the American Association of Blood Banks (AABB) for biological relationship testing.

Cellmark has continued to play a prominent role in providing a variety of services to law enforcement agencies and government crime laboratories. The Combined DNA Index System (CODIS), which is administered by the FBI, serves all law enforcement agencies in the United States by providing a national convicted offender DNA data base. In 1992, Cellmark Diagnostics was the first company to offer data basing services to state law enforcement agencies. Cellmark's data basing clients have included the states of South Dakota, Oregon, Wyoming, New York and Nevada.

Cellmark is currently under contract to perform the STR analysis of thousands of backlogged sexual assault kits from the New York City Police Department, the Illinois State Police, and the Phoenix Police Department. These kits consist of blood standards, vaginal swabs, anal swabs, and body secretions. Cellmark is performing presumptive testing and STR analysis on the probative swabs designated by the respective agency. Cellmark has implemented a high throughput process to effectively manage and complete this analysis in the required turnaround time. Using a Laboratory Information Management System, dedicated staff, and efficient techniques, Cellmark is completing these contracts on time and within budget.

Cellmark remains a leader in the application of innovative DNA identity technology. Cellmark was the first forensic DNA laboratory to use Short Tandem Repeat (STR) PCR testing for human identification of casualties in the 1991 Persian Gulf War. In 1999, Cellmark Diagnostics began processing casework with the STR fluorescent detection system that uses the 13 CODIS loci that the FBI has designated as the standard in the forensic DNA community. This technology permits Cellmark to process cases with the most sensitive, discriminating tests available, and generate results that can be entered directly into the National DNA Indexing System (NDIS).

As a leader in its field, Cellmark was among the first companies to provide forensic DNA training to other scientists from around the world, including a training course dedicated specifically to the interpretation of RFLP DNA test results. Cellmark Diagnostics continues today to respond to invitations from regional and national forensic science and criminal justice organizations to provide instructors for workshops and training seminars. Cellmark also provides extensive consultation services for the establishment of new DNA testing laboratories, including the delivery of turnkey laboratory operations.

In recognizing its responsibility as a member of the criminal justice community, Cellmark Diagnostics voluntarily initiated the only forensic DNA laboratory program in the United States offering a national pro bono DNA identification service to indigent criminal defendants. Cellmark utilizes DNA technology to analyze relevant physical evidence in up to six pro bono cases per year.

Although many of these achievements are known only to members of the legal and scientific communities, recent highly publicized criminal cases at Cellmark have propelled the science of DNA testing in general, and Cellmark Diagnostics in particular, into public awareness. These include the O.J. Simpson case, the JonBenet Ramsey case, and the Unabomber case. Cellmark is proud to be recognized as a company known for quality, dependability, innovation, and customer satisfaction in the world of DNA identity testing.

Note: Cellmark Diagnostics, Inc. is a subsidiary of Lifecodes Corporation. Located in Stamford, Connecticut, Lifecodes is the leading manufacturer and worldwide supplier of DNA products for human identity testing and transplantation. Lifecodes and Cellmark Diagnostics are privately held and employee-owned.

Tab 23

MYRON T. SCHOLBERG
FORENSIC CONSULTANT

BIOGRAPHICAL SUMMARY

Myron T. Scholberg graduated from South Dakota State University, Brookings, South Dakota, in 1960 with a B.S. Degree in Education. He accepted employment as a High School Science Instructor at White, South Dakota and began his teaching career in the fall of 1960, teaching Biology, Chemistry and Physics. Mr. Scholberg continued his education at South Dakota State University, attending night classes and summer sessions. He received a M.Ed. Degree in 1962 and accepted the position as Superintendent of the White Independent School District, a position he held until 1964. During these two years, Mr. Scholberg supervised the activities of the staff of instructors (K-12) and handled the administrative duties necessary to successfully manage a public school system.

In 1964, Mr. Scholberg resigned his position and accepted employment as a Special Agent with the Federal Bureau of Investigation, a title he held until his retirement in March, 1985.

Mr. Scholberg's career with the FBI included field assignments as Investigator in Dallas and Amarillo, Texas and Los Angeles, California from 1964-1967.

In 1967, Mr. Scholberg was assigned to the Hair and Fiber Unit of the FBI Laboratory, Washington, D.C. Mr. Scholberg remained in the Unit for 18 years, serving as an Examiner until 1977, at which time he was promoted to Unit Chief. As Unit Chief, Mr. Scholberg administered the day-to-day activities of the Hair and Fiber Unit and supervised twenty-two Special Agent Examiners and Physical Science Technicians who were actively involved in examining items of evidence for hairs, fibers and related materials.

During Mr. Scholberg's career in the FBI Laboratory, he examined thousands of cases involving rape, murder and sexual assaults and testified in State, Local and Federal Courts in 44 States of the United States, the District of Columbia, Puerto Rico, the Virgin Islands, the Cayman Islands and Okinawa. He was also involved in instructing the FBI Introduction to Hair and Fiber Course at the FBI Academy at Quantico, Virginia. In addition, he has given numerous speeches and presentations to Law Enforcement Groups throughout the world concerning his area of expertise.

Since retiring from the FBI, Mr. Scholberg has entered the private sector in his specialty, conducting examinations and providing consultation in cases from coast to coast in the United States. He has also been employed during this time by the State of Virginia as a Forensic Scientist.

Mr. Scholberg has testified in excess of 500 times to the results of hair and fiber analysis in cases of violent crime. His career includes a variety of experiences - field investigative, administrative, forensic and teaching.

[redacted]

Tab 24

THERE TV, INC.

There TV is a film and television production company specializing in digital broadcast television graphics and effects. There TV has worked with many major advertising agencies and Fortune 500 companies, winning many industry awards in the process. Early adopters of advanced digital video and photographic techniques, There TV's team of technologists have completed many projects for technical, law enforcement, and legal clients.

Located in Chicago, IL, their digital artists utilize state-of-the-art equipment to aid authorities in assessing motion-sensitive images captured by film, video and digital photography.

Their work in the 1998 restoration and enhancement of the 1963 Abraham Zapruder Film of the Kennedy assassination has been entered into the National Archives in Washington, D.C.

Tab 25

AUTOLIV, INC.

Autoliv Inc. develops and manufactures automotive safety systems for all major automotive manufacturers in the world. Together with its joint ventures Autoliv has close to 80 facilities with almost 30,000 employees in more than 30 vehicle-producing countries. In addition, the company has eight technical centers around the world, including 19 test tracks, more than any other automotive safety supplier. Sales in 2000 amounted to US $4.1 billion and net income to US $170 million.

* * * * * *

Tab 26

ROBERT A. MENDELSOHN, MD, PC, FACS

6121 Executive Boulevard
Rockville, Maryland 20850

Phone: 301 770-3134
Fax: 301 770-6914

Born: August 14, 1926, Baltimore, Maryland

TRAINING AND CERTIFICATIONS

Graduated Georgetown University Medical School, 1949,
Magna Cum Laude
Rotating Internship, Walter Reed Army Hospital, 1949-1950
Neurosurgery Resident, Mayo Clinic, 1951-1954
Chief of Neurosurgery, Lackland Air Force Hospital, 1954-1958
Private Practice Neurosurgery, Washington, D.C. Metropolitan Area,
1958 - 1992
American Board of Neurological Surgeons, Certified May 1957
Fellow, American College of Surgeons

HOSPITAL ASSOCIATIONS

Formerly Chief of Neurosurgery:
Prince George's Hospital Center, Cheverly, Maryland
Holy Cross Hospital, Silver Spring, Maryland
Washington Adventist Hospital, Takoma Park, Maryland

MEMBERSHIPS

Congress of Neurological Surgeons
American Association of Neurologic Surgeons
Middle Atlantic Neurosurgical Society
Washington Academy of Neurosurgery (Formerly President)
Maryland Neurosurgical Society (Formerly President 1988-1991)
Association for Advancement of Automotive Medicine
(Board of Directors 1991 - 1994)
American Medical Association
Prince George's County Medical Society
Cervical Spine Research Society
Society of Automotive Engineers
American Clinical Neurophysiology Society

ROBERT A. MENDELSOHN, MD, PC, FACS

PUBLICATIONS

McCarty, C.S. and Mendelsohn, R.A.: Injury of the Cervical Vertebra with Sequelae after Fifty Years. Proceedings of the Staff Meetings of the Mayo Clinic. 29:372-375, June 30, 1954.

Dodge, H.W. and Mendelsohn, R. A.: Recent Trends in the Surgical Management of Infantile Hydrocephalus. Minnesota Medicine. 37:440-443, June, 1954.

Craig, W. McK., Dodge, H.W., DuShand, J.W. and Mendelsohn, R.A.: Sympathectomy for Hypertension in Childhood. Collected papers of the Mayo Clinic and the Mayo Foundation. 46:606-607, 1954.

Uihlein, A., Mendelsohn, R.A. and Brown, H.A.: Syndrome of the Cerebellopontine Angle: Report of Two cases. Minnesota Medicine. 37:498-500, July, 1954.

Mendelsohn, R.A., Weiner, I.H., and Keegan, J.M.: Myelographic Demonstration of Brachial Plexus Root Avulsion. A.M.A. Archives of Surgery. 75:102-107, July, 1957.

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Mendelsohn, R.A. and Mora, Federico: Spontaneous Subarachnoid Hemorrhage Due to Ependymoma of the Filum Terminale. Journal of Neurosurgery. 15:460-463, July, 1958.

Weiner, I.H., Azzato, N.M. and Mendelsohn, R.A.: Cerebral Angiography: A New Technique. Catheterization of the Common Carotid Artery via the Superficial Temporal Artery. Journal of Neurosurgery. 15:618-626, November, 1958.

Barrett, J.W. and Mendelsohn, R.A.: Post-Traumatic Porencephaly in Infancy. Journal of Neurosurgery. 23:522-527 November 23, 1965.

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Huelke, Donald F., Mendelsohn, Robert A., States, John D., and Melvin, John W.: Cervical Fracture and Fracture Dislocations: Sustained Without Head Impact. Journal of Trauma. 18:533-538, July, 1978.

Huelke, Donald F., Moffatt, Edward, Mendelsohn, Robert A., and Melvin, John W.: Cervical Fractures and Fracture Dislocations: An Overview. (790131) SAE-SP438: 9-15, February, 1979.

Huelke, D.F., Mendelsohn, R.A., States, J.D. and Melvin, J.W.: Cervical Fractures and Fracture Dislocations Sustained Without Head Impact. (790132) SAE-438: 17-24, February, 1979.

Mendelsohn, R.A.: Anatomy and Trauma of the Cervical Spinal Cord. (790133) SAE-SP438: 25-30, February, 1979.

Huelke, Donald F., O'Day, James, Lawson, Thomas E., Barhvdt, Wendy H. and Mendelsohn, Robert A.: Cervical Injuries in Automobile Crashes. University of Michigan Highway Safety Research Institute. 80-40, Special Report 1980, Sponsored by the National Highway Traffic Safety Administration, Department of Transportation.

Huelke, Donald F., O'Day, James, and Mendelsohn, Robert A.: Cervical Injuries Suffered in Automobile Crashes. Journal of Neurosurgery. 54:316-322, March, 1981.

Mendelsohn, R.A. and Huelke, D.F.: Anatomy, Injury and Biomechanics of the Cervical Spine. AM ASSN for Automotive Medicine and International Research Council on Biokinetics of Impact. Captiva Island, Florida, 123-162, May, 1986.

Bandstra, Richard A., Welkey, George M., and Mendelsohn, R.A.:
Door Latch Seatbelt Capture: Odd Restraint Failure, Unusual Injury. Accident Reconstruction Journal. 20-23. Volume 5, No. 4, July/August, 1993.

Bandstra, Richard A., Meissner, Uwe, Warner, Charles Y., Monaghan, Susan, Mendelsohn, Robert A., MacPherson, Duncan: Seat-Belt Injuries in Medical and Statistical Perspectives. 16th International Technical Conference on the Enhanced Safety of Vehicles; Windsor, Ontario, Canada, (98-S6-W-25) 1-4 June 1998.

Tab 27

CURRICULUM VITAE

Alan M. Nahum, M.D., F.A.C.S.
Medical-Legal Consultants, Inc.
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San Diego, California 92121
(858) 457-9711
(858)457-9775 FAX

EDUCATION

1949-1953	Yale University - B.A.
1953-1957	Tufts University School of Medicine - M.D.
1957-1958	New England Medical Center (Pratt Diagnostic Hospital) - Internship.
1958-1962	UCLA Center for the Health Sciences - Residency in General, Head & Neck Surgery.

PROFESSIONAL EXPERIENCE

1962-1971	UCLA Center for the Health Sciences: Associate Professor of Surgery; Co-Director, Trauma Research Group; Director, Biomechanics Research Laboratory.
1971-1986	University of California at San Diego School of Medicine: Professor of Surgery; Head, Division of Head and Neck Surgery; Co-Director, Biomechanics Research Laboratory.
1986-present	University of California at San Diego School of Medicine: Professor Emeritus of Surgery.

ORGANIZATIONAL MEMBERSHIPS

American Medical Association
California Medical Association
American College of Surgeons
Society of Automotive Engineers
California Association of Criminalists
American Academy of Forensic Sciences

PROFESSIONAL ACTIVITIES
Stapp Car Crash Committee (Rotating Chairman)
Deputy Coroner, County of Los Angeles 1964-1971
NHTSA Advisory Committee to Secretary of Transportation 1967-70

PROFESSIONAL EDUCATION DEVELOPMENT
SAE International, *Passenger Car Rollover TOPTEC: Cause & Prevention, January 22, 1999, San Diego, CA*

TRAUMA BIBLIOGRAPHY

1. Nahum, A.M. "Prevention of facial trauma in automobile accidents." California Medicine 99, 386. 1963. 2 pgs.

2. Nahum, A.M. "Later complications of mandibular fractures." Annals ORL 733, 989. 1964. 6 pgs.

3. Nahum, A.M. "Facial trauma in automobile collisions." Trans. AAOO 69, 396. 1965. 9 pgs.

4. Nahum, A. & Canty, T. "Case study investigation of human injury patterns and the relation to vehicular design." Proc. 7th Stapp Car Crash Conference, 19. 1965. 7 pgs.

5. Nahum, A.M. "Automobile injury epidemic: The failure of preventive medicine." California Medicine 103, 442. 1965. 2 pgs.

6. Nahum, A.M., Siegel, A.W., Miller, S.E. "Injury in nonfatal accidents." Proc. 8th Stapp Car Crash Conference, 1. 1966. 9 pgs.

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8. Nahum, A.M. "Early management of acute trauma: A symposium." St. Louis: C.V. Mosby Co. 1966.

9. Nahum, A.M., Siegel, A.W., Trachtenberg, S.B. "Causes of significant injuries in nonfatal traffic accidents." Proc. 10th Stapp Car Crash Conference, 182. 1966. 15 pgs.

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19. Douglass, J.M., Nahum, A.M., "Applications of experimental head injury research." Proc. 12th Stapp Car Crash Conference, 317. 1968. 21pgs.

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and nonrestrained occupants and fatal injury patterns." SAE International Auto. Engineering Congress, SAE No. 690245, 1. 1969. 17 pgs.

23. Lasky, I.I., Nahum, A.M., Siegel, A.W. "Cardiac injuries incurred by drivers in automobile accidents." J. Forensic Sciences 14, 443. 1969. 7 pgs.

24. Nahum, A.M., "Immediate care of acute blunt laryngeal trauma." J. Trauma 9, 112.

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27. Nahum, A.M., "Emergencies of the head and neck." In: Management of Medical Emergencies.

28. Nahum, A.M., "Mechanism and Prevention of Design-related Injuries in Automobile Collisions." Joint meeting of American College of Surgeons and Deutsche Gesellschaft Fur Chirurgie, Muncih. J. Burkle de la Camp, et al. (eds.) New York: Springer, 160. 1969. 8 pgs.

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30. Roberts, S.B., Ward, C.C. and Nahum, A.M., "Head Trauma: A parametric dynamic study". J. Biomechanics 2, 397. 1969. 19 pgs.

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32. Siegel, A.W. and Nahum, A.M., "Vehicle Postcollision Considerations." In: 1970 International Automobile Safety Conference Compendium. Soc. Auto. Engineers, Inc., 1222. New York. 1970. 28 pgs.

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38. Nahum, A.M. & Seigel, A.W. "The changing panorama of collision injury." S.G.O. 133, 783. 1971. 9 pgs.

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