

Collision

The International Compendium for Crash Research

Includes DVD
2006 ARC-CSI Crash Conference

PDF

Principal Direction of Force

Crash Data

From 2006 ARC-CSI Conference

Untripped

Rollovers

Motorcycle

Accident Investigation



Analyzing the Collision

“2 in - 3 out”

www.collisionpublishing.com



CONTENTS

fall 2006

of interest

- 3 FROM THE EDITOR
- 5 NAPARS NEWS
- 8 ORGANIZATION NEWS
- 10 MY TURN AT THE WHEEL
- 108 CALENDAR OF EVENTS

features

- 12 PDOF: PRINCIPLE DIRECTION OF FORCE
- 20 DECELERATION RATES OF MODERN PASSENGER VEHICLES DURING STRAIGHT LINE BRAKING AND YAW EVENTS
- 30 IDENTIFICATION OF UNUSUAL TIRE MARKS AT THE SCENE OF A MOTOR VEHICLE COLLISION
- 32 **MOTORCYCLE CRASH INVESTIGATION**
- 36 SIMULATIONS 101: ANATOMY OF A SIMULATION
- 44 PICTOMETRY IN CRASH SCENE MAPPING
- 50 MAKING HISTORY: PHOTOMODELER SOFTWARE HELPS KNOTT LABORATORY REVERSE-ENGINEER THE PAST
- 56 GETTING INTO PRINT AS AN ACCIDENT RECONSTRUCTIONIST
- 62 VEHICLE DYNAMIC CHARACTERISTICS OF SUVs IN ON-ROAD, UNTRIPPED ROLLOVER ACCIDENTS
- 96 CONTRIBUTION OF A LATERALLY DISPLACED VEHICLE TO THE POST-IMPACT DECELERATION OF A HEAVY TRUCK

case study

- 40 CASE STUDY: FOLLOW-UP FROM ISSUE ONE
- 90 CASE STUDY - 2 IN 3 OUT
- 102 CASE STUDY SOLUTION - 2 IN 3



ON THE COVER

Photograph taken at the 2006 ARC-CSI Conference in Las Vegas, the "2 in 3 out" crash.
see article on page 90



from the editor

In real estate, it's all about location, location, location. It would appear that, in publishing, it's all about content, content, content. So, content has been our primary focus. The second issue of Collision is now bigger and better than the first with articles based on the 2007 ARC-CSI Conference in Las Vegas as well as articles offered by additional authors providing Collision's readers with fresh, original content not found anywhere else.

Our motto is "out with old, in with the new." We are not going to be satisfied with reprinting the same old thing; stale news releases and public records. We are going to continue to work to get new and original content to you in addition to meaningful, timely and useful testing data. Opinion pieces designed to generate discussion, test data you can actually use, topically relevant subject matter...that's what we decided Collision would be all about.



Since the first issue, we've received input from a variety of readers on a number of topics. Some have asked some really good questions, and made some comments I thought I'd share:

"Your magazine Collision is a breath of fresh air. I have been reluctant to contribute to the [other magazine] because of their nonprofessional quality. I would like to contribute to your magazine on the topic of event data recorders. I wrote my Masters thesis on the court's acceptance of event data recorder data." On this note, we would love to see the reconstruction community get more involved with Collision. If you would like us to review and article or paper for inclusion in a future issue, please email it to editor@collisionpublishing.com.

Another correspondent wrote: "...You should expand to include engineer accident reconstructionists on a wider, more diverse editorial advisory board..." Our content advisory board members are volunteers from the larger reconstruction community and we welcome others who can contribute in a meaningful way. We don't differentiate between one reconstructionist and another based on some perceived or self-serving description or a non-reconstruction specific background.

Another comment was: "Not too bad but not at a very high technical (sic) level. Since NAPARS is filled with police accident reconstructionists, you obviously have to severely limit the technical level or else those guys will get lost. I do understand why it cannot be more technical."

After I picked my jaw back up off the floor, I wondered if this individual was reading Collision or some other publication. The "technical (sic)" level of the content of Collision is aimed at Crash Reconstructionists regardless of background. We welcome the submission of a "more technical nature" if someone would care to share what that actually means. In the meantime, we find that reconstructionists of a variety of backgrounds have found Collision a valuable resource and while we're open to constructive input, it seems we're heading the right way if we've been able to generate that kind of angst in just one issue.

It all got me to thinking, wait until they see THIS issue! That takes us back to content, with this issue of Collision you'll find not a CD but a DVD with some 2+ gigabytes of content including 70 crash video clips, over 1,000 digital photos, Vericom data, Stalker data, IST data, CDR data and PowerPoint presentations from the 2007 ARC-CSI Conference. You won't find THAT anywhere else but Collision!

A handwritten signature in blue ink that reads "S. B. Baker".

Scott B. Baker

Managing Editor

www.collisionpublishing.com

DVD Included



With this issue of Collision, you will find a DVD with more than 2 gigabytes of content including 70 crash video clips, over 1,000 digital photos, Vericom data, Stalker data, IST crash data, CDR System retrieved data and PowerPoint presentations from the 2006 ARC-CSI Crash Conference. The autorun DVD includes a menu screen that will load when you insert the DVD in your computer's DVD drive. Please note this is a DATA DVD and not a video DVD. It will only work on a DVD ROM drive.

Collision Staff

Scott Baker Publisher, Managing Editor
 editor@collisionpublishing.com
 Sean Haight Editor
 Tonya Baker Advertising Account Manager

Content Advisory Committee

W. R. Rusty Haight Collision Safety Institute
 Brad Muir Collision Safety Institute
 John Meserve President, NAPARS
 Tom Szabo Biomechanical Research & Testing
 Judson Welcher Biomechanical Research & Testing

All rights reserved, © 2006 Collision Publishing LLC. The opinions and conclusions expressed in this publication and attached data disk in articles attributed to specific authors are the opinions and conclusions of the authors noted and not necessarily the editorial staff or reviewers of those documents. Really, facts belong to everybody, any other opinions to us. The distinction is yours to draw...otherwise, the opinions expressed herein are not necessarily those of any employer, not necessarily ours and probably not necessary. Dissenting opinions, discussion or conclusions which may express an adverse position to those expressed herein by specifically cited authors can be addressed in writing by sending an email to the editor at editor@collisionpublishing.com or sending a "regular mail" letter to us at 118 Lake Street South Suite G, Kirkland, WA 98033. By sending an email to any or our email or snail mail addresses listed in this publication you are agreeing that: (1) we are by definition, "the intended recipient" (2) all information in the email is ours to do with as we see fit and make such financial profit, political mileage, or good joke as it lends itself to. (3) This overrides any disclaimer or statement of confidentiality that may be included on your original message. The entire physical universe, including this publication and attached data disk, may one day collapse back into an infinitesimally small space. Should another universe subsequently re-emerge, the existence of this publication and data disk in that universe cannot be guaranteed.

ARC-CSI Crash Conference CDs

Past ARC-CSI Crash Conference CDs are available for purchase at www.CrashConferences.com



Advertising Rates & Information

All advertisement are 4-color and professionally printed using a digital press.

FORMAT	SIZE	PRICE/Issue
Full Page	8.5 x 11 in.	\$ 700
1/2 Page	8.5 x 5 in.	\$ 450
1/3 Page	2.5 x 11 in.	\$ 450
Back Cover	8.5 x 11 in.	\$1,500
Inside Back Cover	8.5 x 11 in.	\$1,200
Inside Front Cover	8.5 x 11 in.	\$1,200
2-Page Spread	17 x 11 in.	\$1,200


DIGITAL AD REQUIREMENTS:

Digital data is required for all ad submissions. Preferred format is EPS and PDF. Files should be press optimized, converted to CMYK, and have all fonts embedded. Publisher shall have no obligation or liability to Advertiser of any kind (including, without limitation, the obligation to offer Advertiser makegoods or any other form of compensation) if an as is supplied to Publisher by Advertiser in any format other than PDF. We will also accept AI, PSD, TIFF, and DOC file types. Please be sure to include a copy of all fonts used in your art work. Publisher will not supply a faxed or soft proof for Advertiser-supplied files. Advertiser is solely responsible for preflighting and proofing all advertisements prior to submission to Publisher. If Publisher detects an error before going to press, Publisher will make a reasonable effort to contact Advertiser to give Advertiser an opportunity to correct and resubmit Advertiser's file before publication.

Accepted Media: Files may be submitted on a CD-ROM or FTP'd to the publishers FTP site. The FTP service requires a User Name and Password. Please contact Collision Publishing to get the log in information.

For complete and up-to-date information regarding advertising in Collision, please refer to our web site:
www.collisionpublishing.com/advertising.html

Collision Publishing LLC
 118 Lake Street South
 Suite G
 Kirkland, WA 98033
 Toll Free: 800-346-9571
 Email: editor@collisionpublishing.com
 Web: www.collisionpublishing.com



Advertise on the ARC Network

Advertise on the #1 web site for accident reconstruction and traffic accident investigation - The ARC Network. For complete information visit:

www.accidentreconstruction.com/advertising

Motorcycle Crash Investigation Performance Testing & Review of Previous Studies



BY GARY LEWIS

ABSTRACT:
In the analysis of motor vehicle collisions, involving passenger cars and/or light trucks, the determination of a deceleration rate is relatively simple to determine. Vehicles with conventional braking systems usually “lock up the tires” in pre-impact skids and the tires are often locked by vehicle damage post-collision. The percentage of the vehicle’s weight remains fairly constant during the pre and post-impact phases of the collision. Vehicles with ABS systems perform rather uniformly during “skidding” or hard braking maneuvers, and usually react predictably and similar to vehicles with conventional braking systems post-impact, assuming the vehicles are uncontrolled post-impact.

However, motorcycles have unique braking systems. There are two separate brake controls on the vast majority of motorcycles, and sometimes different types of brakes on each wheel. Some motorcycles have integrated braking systems and a few models have ABS systems. Previous studies have shown that it is difficult for the motorcycle operator to efficiently control two independent brakes during hard braking maneuvers. Add to that the reduced fine motor skills during stressful situations, such as impact avoidance, and it is even more difficult to effectively utilize the brakes on a motorcycle. Limited rider training in the proper use of motorcycle brakes further reduces the effectiveness of the vehicle/rider braking capability.

The author attempted to determine the most significant factors involved in the determination of the deceleration rate to be assigned to the motorcycle in pre-impact braking.

INTRODUCTION:
There have been significant advances in the design of passenger car and light truck braking systems. ABS systems are becoming more the norm than the exception. Motorcycle braking systems have been improved in the area of friction capability, but the overall braking system has remained relatively the same since the vehicle’s original design – a hand lever controls the front brake and a foot pedal controls the rear brake. In integrated systems there is some pressure applied to the front brake during activation of the rear brake and in some there is rear brake application during front lever actuation.

Motorcycle operator training is limited. Most motorcycle training courses are conducted at low speeds, usually under 35 mph, and at isolated locations, free from other traffic. The riders are taught how to control the vehicle’s clutch, throttle, and gear shift to start from a stopped position, and to accelerate from a stopped position. They perform low speed turns through a marked course. There is training in proper clutch and brake control to bring the vehicle to a safe stop during normal operating conditions. Few motorcycle operators receive any additional training before taking their vehicles on the road.

During the investigation of motor vehicle collisions, the investigator commonly attempts to quantify speed (energy) losses of the involved vehicles. For passenger cars and light trucks, the determination of an acceleration rate (positive or negative) is typically easier to determine than that of a motorcycle.

Vehicle Dynamic Characteristics of SUVs in On-Road, Untripped Rollover Accidents



Lawrence Wilson
Wilson Consulting

Daniel Godrick
Ian S. Jones & Associates

Shaun Kildare
Ian S. Jones & Associates

ABSTRACT
Rollover testing has typically been conducted with vehicles equipped with outriggers. The outriggers serve two primary purposes: to insure the safety of the test driver and to prevent irreparable damage to the test vehicle. However, outrigger contact usually occurs shortly after two-wheel lift, subsequently affecting the vehicle's pre-roll trajectory.

Within the last ten years, state-of-the-art technology has allowed for remote control operation of vehicles subject to rollover. However, remote control operation of vehicles subjected to on-road untripped rollovers at highway speeds is costly endeavor. Therefore, very little test data exists, particularly at the point of roll, for vehicles that have experienced steering-induced on-road, untripped rollover.

The purpose of this paper is to present vehicle dynamics data for Sport Utility Vehicles (SUVs) that have been involved in real world, on-road, untripped rollover accidents. This paper compiles and analyzes 34 SUV rollover accidents. The accidents were reconstructed with the pre-roll vehicle motion simulated using the Vehicle Dynamic Analysis Non-Linear (VDANL) computer program. The vehicle dynamic characteristics that were analyzed include: vehicle speed, roll angle, roll rate, yaw angle, yaw rate, lateral acceleration, and sideslip angle. These characteristics were analyzed at two distinct points: two-wheel lift and four-wheel lift. Steer inputs, numbers of rolls, and rollover distances are also presented.

To reduce the occurrence of rollover and the high injury severity associated with these accidents, a better understanding of the vehicle dynamics that lead to rollover important design tools. Furthermore, the data presented in this paper provide valuable information for reconstructing rollover accidents.

INTRODUCTION
A rollover is defined as an event in which the vehicle rotates at least 90 degrees about its longitudinal axis and its tires are no longer in contact with the ground. [1] Rollovers account for 3% of all vehicle accidents involving passenger cars and 8% of all accidents involving SUVs. [2] Although these frequencies are relatively low when compared to all types of vehicle accidents, rollovers are associated with high fatality rates. FARS data for 1991-2000 calendar years show that rollovers accounted for 75% of all fatalities involving SUVs and 42% of all fatalities involving passenger cars. [3]

Typical rollover testing has been conducted with vehicles equipped with outriggers. The outriggers serve two primary purposes: to insure the safety of the test driver and to prevent irreparable damage to the test vehicle. However, outrigger contact usually occurs shortly after two-wheel lift, subsequently affecting the vehicle's pre-roll trajectory and thus preventing observation of the vehicle dynamic characteristics at point of roll. The point of roll is defined as the point at which there are no longer any vertical tire forces on any of the vehicle's tires. Within the last ten years, state-of-the-art technology has allowed for remote control operation of vehicles subject to rollover, including braking, accelerating, and steering. However, remote control operation of vehicles subjected to on-road untripped rollovers is a difficult and costly endeavor. Furthermore, most tests that induce rollovers are conducted at speeds no more than 50 miles per hour (mph). Therefore, very little test data exists at the point of roll for vehicles that have experienced steering induced on-road, untripped rollovers, particularly at highway speeds.

The database presented in this paper is a compilation of 34 real world SUV rollovers. These cases were investigated and reconstructed for the purposes of litigation. The original data base which has been updated and augmented for this research has



2006 ARC-CSI CRASH CONFERENCE



Analyzing the Collision

a case study

by C. Gregory Russell, Rusty Haight & Brad Muir



EDITORIAL STUFF FIRST

Let's get this out of the way up front: yes, we pre-cut the target car so it would split in half. So what? Let's keep this in perspective: this case study is about momentum ... particle momentum ... tracking masses moving in specific directions at specific speeds ... vectors. We are not applying any sort of energy analysis ... no crush damage in this analysis. Maybe, if we had some idea of specifically what impact (pun intended) the pre-test "dotted line" had on the stiffness of the target car in this example, if we could quantify the change we made in the structural integrity of the target car, we might entertain that as a separate intellectual exercise, but that was not the plan here so before we get sidetracked with inane permutations, too mindless to consider, let's stay on track: this is a momentum exercise; complete, simple, independent of energy¹.



BACKGROUND

On June 5th, 2006 during the ARC-CSI Conference in Las Vegas, a crash test was conducted using a 2000 Chevrolet Malibu as the designated bullet vehicle and a 1991 Geo Metro at the target vehicle. It was the Geo that, prior to the test, was pre-cut to ensure that during the crash the Geo would separate into two pieces; two pieces of known dimensions.

Since this was crash test - it was planned and conducted - there are facts about the crash that an investigator who would be working this crash after the fact would not have normally

known with the same degree of certainty as we have here (that's why crash tests make good case problems!). In order to attempt to make this analysis as realistic as possible, let's approach it as if this crash had occurred on a public road, with the analysis, when possible, based solely on the scene evidence. There were facts known about the movement of the vehicles post collision that will be ignored in this case problem, since they would not have been known to a investigator working the collision in "the real world," but that's the only meaningful difference here.

At this point, the trained investigators and attentive readers will realize that the crash data from the June 5 ARC-CSI Conference in Las Vegas is right here before you, in your hands at this very moment: it's on the DVD which is part of this issue of Collision. So,



Contribution of a Laterally Displaced Vehicle to Post-Impact Deceleration of a Heavy Truck

Wade Bartlett, PE
Mechanical Forensics
Engineering Services, LLC

Bill Wright
Florida Reconstruction

David Brill
Collision Analysis &
Investigations

ABSTRACT
It is not uncommon for a slow-moving passenger vehicle (PV) to be struck in the side by a commercial motor vehicle (CMV). When this occurs, the PV often remains engaged with the CMV to their final rest position. Evaluating an appropriate post-impact drag factor requires assessing the frictional contribution of both vehicles. Two crash tests were conducted in which a stationary PV was struck by a CMV traveling at approximately 40 mph (64 kph) in order to assess the overall post-impact drag factor. It was found that the combined units slowed at a rate higher than the CMV alone, but lower than the skidding value of the passenger vehicle alone, and commensurate with the mass-ratio of the two vehicles involved. Standard crash analysis techniques were found to accurately predict the CMV's pre-crash speed.

INTRODUCTION
Two collisions were staged in which a heavy commercial motor vehicle (CMV) impacted a stationary passenger car on one side. The first test (Crash #1) involved a bobtail International cabover truck-tractor striking a Chevrolet Lumina, while the second test (Crash #2) involved a GMC conventional truck-tractor pulling a lightly loaded flat-bed trailer which struck a Chevrolet S-10 Blazer. For both tests, the CMV operator initiated an emergency stop immediately prior to the impact.

The roadway coefficient of friction at the test area was determined by conducting locked-wheel skid tests with three passenger vehicles. Test skids were also conducted using both CMVs to determine their emergency-stop deceleration rates. Neither CMV was equipped with an anti-lock brake system (ABS), consequently, most of the wheels locked during an emergency stop.

Additionally, the CMV deceleration rates were estimated using the technique promulgated by Heusser [1992], based on vehicle parameters and measured brake adjustments.

The overall post-impact deceleration rate was evaluated based on both VC3000 and Stalker data, and compared to a standard weight-ratio-based momentum analysis.

TEST AREA AND ENVIRONMENTAL FACTORS:
The test area was a concrete apron at Cecil Field in Jacksonville, Florida. Skid tests were conducted approximately one week prior to the crash test, which occurred on April 25, 2006, as part of IPTM's 2006 Special Problems seminar. For all tests and crashes, the weather was warm and dry.

PASSENGER VEHICLE SKID TESTS
Locked wheel emergency-stop skid tests were conducted between 35 and 43 miles per hour (57 and 69 kph) using three vehicles: a 1999 Chevrolet Astro van bearing the vehicle identification number (VIN) 1GNDM19W0XB171453, a 2006 Hyundai Sonata 4-door sedan bearing VIN 5NPEU-46FX6H091142, and a 2006 Chevrolet Cobalt 4-door sedan bearing VIN 1G1AL55F467759992. The Astro's rear wheels could not be reliably locked by the service brake, so tests conducted with only the service brake pedal were discarded. The reported value was the result of simultaneous application of the service brake pedal and the emergency brake pedal, which resulted in four-wheel lockup, and a slightly higher braking rate.

The average skidding acceleration of each vehicle was evaluated using a Vericom VC3000 accelerometer and a Stalker ATS radar unit. The acceleration recorded by the VC3000 was averaged between the point where acceleration reached -0.2 g's and the point where the vehicle was stopped. The Stalker data was evaluated as the change in speed divided by the change in time, starting from the point where the calculated acceleration rate approached -0.2 g's to the point where the radar unit ceased recording the vehicle's speed, which was typically at 3 to 5 mph. Consistent with other research (Bartlett et al, 2006), the average acceleration recorded during the five locked-wheel skid tests as measured by the two techniques were essentially the same, and are shown in Table 1.

PDOF

Principle Direction of Force

C. Gregory Russell

Calculating the Principle Direction of Force “pdof” relative to a vehicle involved in a collision, is important for a number of reasons. Not the least of these is demonstrating that the analysis has complied with Newton’s Three Laws of Motion while providing for a basis of an occupant motion or kinematics study.

Arguably the most commonly used formula used to calculate the pdof is the following:

$$pdof = \sin^{-1} \left(\frac{v' \times \sin \Delta \theta}{\Delta v} \right)$$

Where:

v' = the vehicle’s post impact velocity

Delta Theta = the change in direction between the vehicle’s approach and departure angles.

Delta v = the change in velocity the vehicle experienced as a result of the collision.

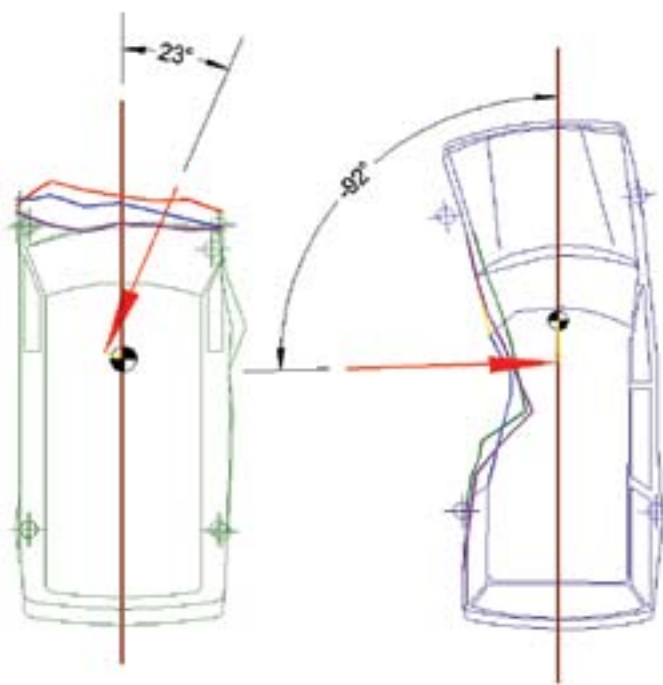
PRINCIPLE DIRECTION OF FORCE:

In the confines of collision reconstruction, the pdof is used to describe the direction of the force that was applied to the vehicle during the collision. The pdof is measured relative to the direction the center mass was traveling on impact, typically along the longitudinal axis of the vehicle for which the pdof is being determined. When using this convention, the longitudinal axis (running front-to-rear) is such that an angle of 0° is at the front of the vehicle while the angle of 180° is to the rear. When the pdof angle is expressed as a positive number it identifies a pdof that intersects the longitudinal axis from the right, while a pdof expressed as a negative number identifies an angle intersecting the longitudinal axis from the left. However, it is important to note, without additional analysis, there is no significance whether the angle returned by the pdof equation is either positive or negative.

The pdof is used, from a purely mathematical or physics based perspective to demonstrate that the reconstruction-

ist has met the test of Newton’s Third Law of Motion. That is, the force applied to each of the vehicles was equal and specifically opposite when the vehicles are positioned along their respective approach headings at the point of maximum engagement.

From an occupant motion perspective, the pdof is used to analyze the kinematics or motion of occupants in a vehicle during the collision as a result the collision forces. Relative to the vehicle, the occupants in a car will appear to move in a line opposite to the force applied, or toward the pdof. For example, a force applied to the right front quarter of a vehicle will result in the appearance of the occupants moving inside the car, to the right front. Therefore, an unrestrained right front passenger might be expected to make contact with the right “A” pillar while an unrestrained driver might be expected to move toward the review mirror mounted on the windshield.



Discussion Forum
Expert Directory
Industry News
Research
Vehicle Specs DB
Crush Stiffness DB



Event Calendar
AR Newsletter
Book Store
Education
Library of Papers
Member Discounts

The ARC Network is the largest research & resource organization for accident reconstruction & traffic accident investigation. We also host the industries largest online expert directory.

Join now and also receive a FREE copy of Jeff Muttart's **DRIVE3** software program from REC-TEC a \$250 value!

JOIN TODAY
MEMBERSHIPS START AT JUST \$69 PER YEAR

CONFERENCES



ARC Network members receive a \$50 discount to all ARC Network hosted Conferences.

www.CrashConferences.com

CDR SYSTEM



Purchase a Vetronix CDR System through the ARC Network and receive a FREE CDR certification course and ARC Network Membership!

www.cdr-system.com

PUBLICATION



Join the ARC Network as a Police Department or Platinum level member and receive a FREE subscription!

www.CollisionPublishing.com

WWW.ACCIDENTRECONSTRUCTION.COM

TOLL FREE: (866) 223-4984



JANUARY 29-31, 2007 HOUSTON, TEXAS

The 2nd Annual International Crash Data Retrieval User's Conference is a comprehensive conference to publish CDR System related information. The conference will address legal issues, legislation, user applications, current and future developments and applications. Well known presenters will offer insight into crash data and using the Vetronix Crash Data Retrieval System through peer reviewed papers, data compendium and presentations.

REGISTER ONLINE AT:

WWW.CRASHCONFERENCES.COM

OR CALL: (866) 223-4984