

HVE White Papers

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- HVE Case Studies
- Innovative tips and techniques using HVE
- Any application of HVE showcasing its capabilities (especially events involving important 3-dimensional vehicle behavior)

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Ref. #**

Description

WP-2000-1 **"Simulating Train Collisions with Highway Vehicles using EDSMAC4 and other programs"**

Lawrence Jackson, Kristin M. Bolte, Ph.D., National Transportation Safety Board

[Click here to download a !\[\]\(cf531ed27e91483460120fcc057b3901_img.jpg\) PDF version of this paper](#)

ABSTRACT:

This paper describes the successful application of the HVE system, EDSMAC4 and additional software to simulate highway-rail grade crossing crashes.

On June 3, 1998, a Union Pacific Railroad train struck a 1990 Dodge 350, 15-passenger capacity van. The train's recorder indicated that the train was going 46 mph at impact with the van. Some of the young occupants of the van indicated that the van might have stopped prior to going across the crossing. A conventional momentum analysis was attempted, but due to the lateral resistance in the tracks, and the mass differences of the vehicles, large variations in speed, ranging from 16 to 156 mph, were obtained for the van. A simulation was performed using an HVE system and the EDSMAC4 physics model. The simulation indicated that the van was traveling about 35 mph at impact and the simulation reproduced the damage to the van. Based on the successful Wagoner simulation, EDSMAC4 and supporting programs

have been used for two additional grade crossing crashes, one being completed and one recently initiated involving trains and large vehicles. The simulations provided good information and resolved some of the uncertainties surrounding the crashes.

The three simulations indicate that EDSMAC4 and supporting programs can be used to simulate highway/railroad crashes. The three crashes simulated had good train recorder data; two crashes involved impacts at the rear of the highway vehicles and the other just rearward of the center of gravity, followed by rotation of the highway vehicles. These types of crashes, with similar data, can be simulated successfully using EDSMAC4.

WP-2000-2 "The Importance of Crash Pulse Data When Analyzing Occupant Kinematics Using Simulations"

Wesley D. Grimes, Collision Engineering Associates, Inc.
F. Denny Lee, F.D. Lee

[Click here to download a !\[\]\(0f848bbd71cef6b345273b16f905912a_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Computer simulations are frequently used to analyze occupant kinematics in motor vehicle crashes, including what they collide with during the crash and the severity of these internal collisions. From study of such occupant simulations, it is then possible to infer how the actual human occupants may have been injured in a crash. When using a simulation to study how occupants react in a vehicle crash, a crash-pulse is usually required as input to the occupant simulation model. This crash-pulse is typically generated from a study of the vehicle motion and acceleration during a crash. There are several different methods for obtaining such a crash-pulse which are in common use. Each of these methods produces a different shape for the crash-pulse, even with identical velocity changes for the vehicle. The time duration, maximum acceleration, and general shape of the crash-pulse may influence the predicted motion of the occupants. In this research, the GATB (Graphical Articulated Total Body) computer simulation model is used to study basic occupant kinematics using a variety of shapes for the crash-pulse, in order to determine how the specific shape of the crash-pulse affects the predicted occupant kinematics.

WP-2000-3 "Development of HVE 3-D Surface Data through AutoCAD Land Development Desktop"

William E. Dickinson, Wolf Technical Services, Inc.

[Click here to download a !\[\]\(6059a5aa8b4ca7bb793408023d6c6e42_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Engineering Dynamics Corporation's 3-Dimensional Human, Vehicle and Environment (HVE 3-D) analysis package is an ideal tool to evaluate the dynamic response of a vehicle to various environmental conditions. Many different types of 3-Dimensional (3-D) vehicle models are readily available in the HVE 3-D vehicle library. These vehicle models can be customized to match the characteristics of the particular vehicle being evaluated. However, the second important piece of the analysis, the environment, must be recorded and developed by the user. Many different approaches to the measurement and development of a 3-D surface environment are available. These measurement techniques range from the use of state of the art total station surveying equipment to manually recording measurements of the physical geometry

using measuring wheels, measuring tapes and levels. Whatever measurement technique is utilized, the 3-D environment topography or terrain data must be developed and processed into 3-D surface data and thereafter transferred into the HVE 3-D analysis package where it will interact with the HVE 3-D vehicle model. This paper describes an approach for the development and processing of the 3-D environment's topography or terrain data from various sources using a simple spreadsheet. A comma delimited point file is developed for the 3-D surface and the files are imported into an AutoCAD Land Development Desktop (LDD), which is used to develop the various 3-D surfaces associated with the vehicle-environment analysis. Once the terrain model is developed in LDD, it can be exported as a 3-D Studio file into HVE-3D. A graphical presentation of the analysis can be created using HVE 3-D or the data can be transferred into a high order rendering program to develop the graphical presentation.

WP-2000-4 **"Dynamics and Roll Stability of a loaded Class 8 Tractor-Livestock Semi-Trailer: An EDVDS Application"**

Dan A. Fittanto, Ruhl and Associates - Forensic, Inc.
Roland L. Ruhl, Mark G. Strauss, University of Illinois at Urbana-Champaign

[Click here to download a !\[\]\(4729e517bc6a7cd81c8025b9646574fb_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Concern has been expressed for the effect of cattle movement upon the dynamic performance of the loaded Class 8 tractor-livestock trailer assembly. Loading guidelines exist for cattle that attempt to prevent injury or debilitation during transit, and literature exists on the orientation and some kinematics of loaded cattle.

Considerable literature exists on the effect of liquid slosh in tankers and swinging beef carcasses suspended from hooks in refrigerated van trailers on the dynamic response and roll stability of those vehicles. However, no research is reported on the case of a loaded livestock trailer, although it is analogized (incorrectly) to the above. The research that is outlined herein focuses specifically on loaded Class 8 tractors and livestock semi-trailers.

The authors have engaged in an extensive program involving the five following components:

1. Extensive full scale testing of loaded livestock trailers in accepted test protocols including:
 - a. Tilt table tests (SAE J2180)
 - b. U-turn maneuvers (SAE J2181)
 - c. 200 ft. radius turns (SAE J2181)
 - d. Slalom maneuver (ISO 7401)
 - e. Highway Evasive maneuver (ISO 3888)
2. Driving on public roads at highway speeds
3. Simulation of the tractor-trailer using EDVDS (Engineering Dynamics Vehicle Dynamics Simulator) to perform the driving maneuvers in the computer environment.
4. Comparison to quasi-static analysis using a static roll model (SRM).
5. Analysis of videotape of cattle during test maneuvers.

Results of this research verify the stability of Class 8 livestock trailers and validate the use of EDVDS as tool for analysis.

WP-2000-5 **"Using Motion Layers to Analyze Pre-Accident Event Timelines"**

Patrick M. Fay, Fay Engineering Corporation

[Click here to download a !\[\]\(2bdfe261b986065ee0ac76460d6528c9_img.jpg\) PDF version of this paper](#)

ABSTRACT:

This paper presents a technique for using HVE's Playback Editor to analyze automobile accidents where one of two conditions exists. The first is when an analysis of the pre-accident timing or visibility is necessary. For example, a vehicle may momentarily hinder visibility as it passes between two others that then collide. The second is when the boundaries of two vehicles overlap during some portion of the event, but do not come in contact. For example, a car may pass beneath some portion of a semi-trailer without making contact. The technique involves superimposing two vehicles in the same scene and manipulating their positions relative to each other by changing a time delay.

WP-2000-6 **"Building Vehicles for HVE"**

J. Travis Garvey, Engineering Dynamics Corporation

[Click here to download a !\[\]\(ec9132f1d27c8919987d92907322654d_img.jpg\) PDF version of this paper](#)

ABSTRACT:

The accuracy of any vehicle simulation software depends upon the accuracy of the data used to create the vehicles. It is therefore essential to follow a consistent, documented process in gathering and entering data used for the mathematical dynamics model and visual representation. The vehicle data file consists of all the data that makes up the dynamic model, where as, the geometry file is the visual representation of the vehicle. This paper presents an overview of the entire process of creating a vehicle to be used in the HVE vehicle database. An in depth review of the information that resides in the vehicle data file is given. The collection of physical data from the desired vehicle is discussed. In addition, the objectives and process for digitizing a vehicle for HVE are explained. Finally the process of orienting the vehicle geometry file to the coincided with the vehicle data file is discussed.

WP-2001-1 **"Vehicle Trajectory Following Steering Disconnect Investigated by Application of HVE-VSM Steering DOF Capability"**

William Blythe, William Blythe, Inc.

[Click here to download a !\[\]\(fe3aebe81acea8d45108cd2768939da7_img.jpg\) PDF version of this paper](#)

ABSTRACT:

A single vehicle run-off-the-road accident occurred on a major highway in Sonora State, Mexico. It was daylight and the road was dry. The accident initially was attributed to tire failure, but subsequent investigation indicated no tire damage.

Approximately one year after the accident the driver of the Dodge pickup, a citizen of the US living in Southern California, received a recall notice from the manufacturer indicating a possible steering column separation problem.

A lawsuit was filed against the manufacturer, claiming the loss of control was due to steering column separation. The car had been destroyed in Mexico before the lawsuit was filed.

The Defense claimed that the path followed by the car was inconsistent with steering column separation and only could have been achieved with steering input. Therefore, the loss of control was due to inattentive driving and inappropriate steer input by the driver.

The recently-introduced steer degree of freedom (DOF) capability of VSM was used to investigate the claims of both the plaintiff and the defense.

WP-2001-2 "Collection of Field Data and Special Effects to Enhance HVE Simulations of Large Commercial Vehicle Collisions"

Lawrence Jackson, P.E., Kristin M. Bolte, Ph.D., Shane Lack
National Transportation Safety Board

[Click here to download a !\[\]\(0aff635c4179ba9e710b00f4b01d3b20_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Many of the highway crash investigations undertaken by the National Transportation Safety Board involve collisions of several large vehicles, large vehicle rollovers, or other highly dynamic and complex scenarios. The collision simulations were enhanced with detailed scene and vehicle documentation. A variety of tools were used in an effort to best replicate the physical evidence at the scene and the crush characteristics of the vehicles within the HVE system. The purpose of this paper was to detail the large commercial vehicle crashes simulated using HVE and associated "special effects" in an effort to address safety issues.

WP-2001-3 "Creating Three Dimensional Environments from As-Built Plans"

Kenneth S. Baker and James P. Sneddon, Northwestern University Center for Public Safety

[Click here to download a !\[\]\(47734e4656765d20df4fdbd5b7aff048_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Creating three dimensional environments requires significantly more point data than an orthographic two dimensional diagram. Ideally, this point data is acquired through a total station survey of the site. Circumstances occur when a survey is not possible. The roadway improvements may have changed since the date of the accident, or regulatory and safety issues prevent you from performing a survey.

Construction plans exist for the majority of paved streets and highways in the United States. Changes made during construction are often recorded on a set of revised plans called As-Built plans. Three dimensional environments can be generated from these plans in lieu of a site survey.

Third party software such as AutoCAD is necessary to create the environment, which can then be imported into HVE. The user constructs a "virtual" roadway in a computer environment. The process is similar to what occurs when the actual roadway is built. First the roadway is staked, then cut to grade, and finally the surfaces are poured.

The path of the roadway is established by a survey line or centerline. This centerline provides the spine from which the roadway can be constructed. Initially, the centerline is plotted using only horizontal data. After which adjustments for grade and vertical curves are made.

Typical cross sections define the roadway crown, curb and gutter, and super-elevation. There may be multiple cross sections, which apply to various locations along the centerline. Cross sections are placed along the centerline at points where changes occur in the centerline's traverse.

Using the centerline and cross sections as a skeleton, entities are drawn to establish roadway edges, curbs and gutters. Intersecting roadways, drives and alleys are added. Finally, surfaces are constructed between the centerline and roadway edge or curb and gutter. Roadside features and pavement markings are added before the environment is exported.

WP-2001-4 **"Extracting Tire Model Parameters From Test Data"**

Wesley D. Grimes and Eric Hunter, Collision Engineering Associates, Inc.

[Click here to download a !\[\]\(5a132f13505a6571904d622757b7a8f0_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Computer models used to study crashes require data describing the vehicles. Data such as weight, length, wheelbase, tire locations, crush stiffness, tire parameters, etc. all require some source of information. Usually the tire parameters are difficult to obtain and analysts will routinely use default or "typical" values. Engineering Dynamics Corp. (EDC), with support from many in the field of crash reconstruction, conducted a tire test series in 1999 to obtain tire data that will be used in studying motor vehicle performance. The computer simulations in use today require some type of tire data coefficients or lookup tables that must be extracted from the raw collected data. This paper presents a basic overview of the tire test data and presents a technique for extracting the required tire parameters for use in computer simulation modeling.

WP-2002-1 **"Yaw Stability of Single Versus Tandem Axle Tractors"**

Dan A. Fittanto, Ruhl Forensic, Inc.

[Click here to download a !\[\]\(35dc653d59570f8f891c312eeece91a2_img.jpg\) PDF version of this paper](#)

ABSTRACT:

Yaw instability was studied for five tractor-semitrailer configurations using EDVDS and SIMON in the HVE 4.10 operating system. Steady-state analyses were performed on the vehicle configurations by implementing a series of trapezoidal steer inputs, roll angles, articulation angle and forward velocity were recorded. Steer angles were incrementally increased until the vehicle experienced yaw divergence, rollover or steer tire saturation.

The five vehicle configurations were:

1. 3-axle tractor with loaded 53-foot semitrailer, nominal GVW of 80,000 lbs
2. 3-axle tractor with partially loaded 53-foot semitrailer, nominal GVW of 67,000 lbs
3. 2-axle tractor with partially loaded 53-foot semitrailer, nominal GVW of 65,000 lbs
4. 2-axle tractor with same trailer as 3 and 4 above, with slider position moved forward
5. 2-axle tractor with fully loaded 27-foot semitrailer, nominal GVW of 45,000 lbs

Handling diagrams were prepared for each vehicle configuration using the data obtained from EDVDS and SIMON. The five vehicle configurations were compared to each other using EDVDS data and again using SIMON data. Relative stability of each configuration was compared.

The results for each individual configuration as reported by EDVDS and SIMON were also compared.

SIMON and EDVDS revealed similar trends among the vehicle configurations. EDVDS and SIMON demonstrated rather different responses within the sensitivity of the handling diagrams. The vehicles modeled in SIMON tended to be more neutral steer than those modeled in EDVDS. That is, 2-axle tractor configurations exhibited more oversteer in EDVDS than in SIMON and 3-axle tractor configurations tended to exhibit more understeer in EDVDS than in SIMON.

A unique characteristic of the vehicle response was observed in the SIMON runs. Between approximately .07 and .12 g's, a spike in the yaw rate was observed in all five runs.

WP-2002-2 **"Introduction to Creating HVE Environments with Rhinoceros"**

James P. Sneddon, Northwestern University Center for Public Safety

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ABSTRACT:

Since HVE®'s introduction, users have employed third party software to create environments for import. Numerous computer aided drafting and 3-D modeling programs are available, and the user's choice is influenced by many factors. Some of the more significant factors concerning HVE users are:

- Surface tools
- Seams between surfaces
- Surface normals
- File compatibility

Modeling an HVE environment requires three dimensional point data that is typically acquired from a site survey. HVE's Environment Editor was intended to import surfaces constructed from this data, using either computer aided drafting or 3-D modeling software. Creating surfaces that accurately match the point data is largely dependant upon the software's surface tools. Similarly, ensuring "watertight" seams between adjacent surfaces is a function of the software's capability.

Additionally, the direction of surface normals is critical to HVE calculation models. Surface normal directions are established by the CAD or 3-D modeling software. The method by which normals are oriented vary among programs and file formats, and have caused problems for HVE users. Finally, the

software must be able to export a file format supported by HVE. If not, a translator must be available, or another piece of software purchased solely for this purpose.

This white paper provides an introduction to using Rhinoceros® (a.k.a. Rhino) as it applies to these issues.

WP-2002-3 **"Predicting and Analyzing Vehicle Dynamics in a Train-Passenger Vehicle Collision Using EDSMAC"**

James S. Sobek and William E. Dickinson, Wolf Technical Services, Inc.

[Click here to download a !\[\]\(6605b201d6f14d9b3bcb8ab5f274d107_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

This paper describes the successful application of EDSMAC to "pre-construct" a staged car/train collision. The paper compares the real-world results of that April 1996 collision with the EDSMAC predictions and with a recent re-analysis of the collision using the HVE system and the current EDSMAC4 program.

Wolf Technical Services, Inc. (WOLF), Indiana Rail Road, WRTV Channel 6, Teen Challenge and Operation Lifesaver worked together to stage a grade crossing collision involving a 1984 Cadillac deVille and an EMD GP-16 locomotive. The purpose of the event was to produce a news program geared to educate the public on the dangers of railroad grade crossings. To ensure that the filming was completed in a safe manner, WOLF was asked to design the collision configuration. WOLF personnel used the EDVAP EDSMAC vehicle dynamics program to determine how to place the car on the grade crossing and to predict the dynamics of the collision once the train struck the car. The vehicle C.G. (center of gravity) position was established at the site. The car post-impact path and rest position were "right on track" and were predicted within inches, showing the accuracy of the EDSMAC program in both reconstruction and pre-construction. Crash dummies and video cameras were in the car. Channel 6 and WOLF provided video coverage from a variety of other viewpoints. Excerpts from that coverage will be shown . . .

As a demonstration of the ability to use HVE for the same purpose, we used the same general techniques in EDSMAC4 to reanalyze the collision.

WP-2003-1 **"Downhill Commercial Vehicle Simulations - Part A (Tractor/Semi-trailer Brake Fade)"**

Lawrence Jackson, PE, MS and Kristin Poland, PhD, National Transportation Safety Board

[Click here to download a !\[\]\(d8ab143e904bfa3467271eec5af75a9b_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

The purpose of this paper is to present a simulation of a large, commercial vehicle during a mountainous descent using the SIMON physics program contained in the Human Vehicle Environment (HVE) system. This paper discusses the simulation of a brake fade for a fully loaded tractor/semi-trailer in Mountainburg, Arkansas as it negotiated a long, mountainous descent. The simulation required SIMON to apply aerodynamic forces on the vehicle and to simulate the forces due to braking. The Mountainburg

tractor/semi-trailer was built in 1989 reflecting older commercial vehicle technologies that are still on the road. The brakes were not adjusted properly as discovered through post-accident inspection.

SIMON has several unique features that were needed to refine the simulation. The aerodynamic drag was used to slow the vehicle as it descended the mountain and to calibrate the drag in gear. Brake Designer was needed to account for the hot brake linings and to simulate brake fade.

WP-2003-2 "Downhill Commercial Vehicle Simulations - Part B (Intercity Bus Equipped with an Engine Data Recorder)"

Lawrence Jackson, PE, MS, and Kristin Poland, PhD, National Transportation Safety Board

[Click here to download a !\[\]\(71ceb62b681518c82e95d615e7265d66_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

The purpose of this paper is to present a simulation of a large, commercial intercity-bus during a mountainous descent using the SIMON physics program contained in the Human Vehicle Environment (HVE) system. This paper discusses the simulation of a run-off-the-road intercity bus accident in Canon City, Colorado. The accident involved a commercial vehicle braking on a long, mountainous descent. The simulation required SIMON to estimate the aerodynamic forces on the vehicle, to simulate the forces due to braking on a slippery surface during cornering and to simulate the loss of lateral control. The Canon City intercity bus was built in 1999, reflecting current commercial vehicle technologies including a DDEC IV engine recorder, ABS, and a transmission retarder.

SIMON has several unique features that were needed to refine the simulations. The aerodynamic drag was used to slow these vehicles as they descended the mountain and to calibrate the drag in and out of gear. In the Canon City simulation, the robust tire and suspension models were needed during the two loss-of-control events and also when brakes and the retarder were applied, especially during cornering.

WP-2003-3 "Reconstruction of Real World Side Impact Vehicle Collisions Using HVE - A Case Series of Pediatric Pelvic Fracture"

Rajiv A. Menon, Yoganand S. Ghati, Shresta B. Marigowda and Kristy Abrogast
The Children's Hospital of Philadelphia

Flaura K. Winston, University of Pennsylvania

[Click here to download a !\[\]\(ac7494f141109b59d18bf9c3aeb84d93_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

This paper describes the application of HVE software to reconstruction of a series of side impact automobile crashes resulting in pelvic fracture to pediatric case occupants. This paper compares crash dynamics, injury mechanisms and occupant kinematics from on-site crash investigations, with reconstruction of these cases using HVE.

In-depth investigations of eight near side impacts crashes involving children (8-15 years old) with pelvic fractures were conducted. Vehicle dynamics and vehicle damage were reconstructed using the

EDSMAC4 program. The acceleration pulse generated from the EDSMAC4 program was then input into the GATB module to predict the child occupant kinematics in these crashes. The results confirmed the vehicle dynamics and damage pattern as measured in the crash investigations. The HVE reconstructions of occupant kinematics suggested that initial orientation and subsequent rotation of the pelvis during the intrusion influenced the likelihood of injury.

WP-2003-4 "Investigating the Use of Simulation Model Non-linear (SIMON) for the 'Virtual Testing' of Road Humps"

Iwan Parry BSc (Hons) MIHT, Fabian Marsh BEng, and Nicola Cripps
Transport Research Laboratory (TRL Limited), United Kingdom

[Click here to download a !\[\]\(6e934896f25e6ce1b0dbb50c23abc197_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

This paper presents the results of a study which involved the measurement of various vehicles response to being driven over various types of road hump at a range of speeds. As part of this project, computer simulation runs were conducted using SIMON to investigate the use of this program for the 'virtual testing' of future road hump designs.

This paper compares the results of physical tests and 'virtual tests' for five different vehicle types traveling over four different designs of road hump, with each vehicle being tested at speeds of up to 40 mph. Vehicle types include a passenger car with independent suspension, a taxi and a minibus, both with solid axle suspensions, and a bus and ambulance with airbag suspensions. The methods by which input parameters were measured for each vehicle are described.

Results are presented for COG vertical acceleration, wheel vertical displacement and pitch angle/rate. These show good consistency between physical and test data. It was found that sensitivity tests of key variables allowed a 'best fit' between the simulation and physical test results to be developed. The paper comments on issues arising from the use of measured vehicle parameters, and the sensitivity tests that were undertaken to generate a 'best fit' between virtual and physical tests.

WP-2003-5 "Constructing Detailed Road Surfaces for Vehicle Dynamics Simulation Using 3D Laser Scanning Techniques"

Iwan Parry BSc (Hons) MIHT and Fabian Marsh BEng
Transport Research Laboratory (TRL Limited), United Kingdom

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ABSTRACT:

The Investigations and Risk Management Group of TRL Limited has been researching and developing applications for 3D laser scanning technology in traffic accident investigation and reconstruction, crime scene preservation, and transport related infrastructure investigations. One such application of this technology is the detailed measurement of road surface, verge and/or kerb line geometry.

Laser scan data has been used to generate detailed road surface models, in the form of a dense three dimensional mesh, for vehicle dynamics simulations where the precise geometry of the road surface is important to the simulation, or where detailed road geometric information is difficult, or impractical, to measure using other means.

The paper describes the methods used to generate detailed road surface models from laser scan data. Examples are provided in which road surface models have been created from data captured in heavily trafficked road environments, and in which laser scan data has been used to construct a complex 3D surface for a vehicle dynamics simulation.

The use of laser scanning systems at incident sites will invariably involve the measurement of areas surrounding the road such as topography, buildings, vegetation, etc. This information can be used to enhance visualisations by allowing detailed models of the environment surrounding the road to be constructed.

WP-2004-1 **"Human Performance - Can Visual Phenomena Be Recreated in HVE?"**

Lawrence E. Jackson, P.E., M.S., ACTAR, and Kristin M. Poland, Ph.D., and Paula Sind-Prunier, Ph.D.
National Transportation Safety Board

[Click here to download a !\[\]\(9ea682cef02bbbdc0191f78cdae1d433_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

On Saturday, October 13, 2001, at about 2:00 pm, a 22-year-old male was driving a 2000 Thomas 78-passenger school bus westbound on Nebraska State Route 6 at about 40 mph, and was approaching a bridge. The roadway was under construction. Witness statements and Safety Board observations on-scene indicated that the school bus driver might have perceived that one of the three oncoming vehicles veered into his lane thus causing him to steer rapidly to the right to avoid a collision.

A simulation was developed to replicate the school bus motion and also that of the oncoming traffic. This simulation resulted in the observation of several visual phenomena, which may have contributed to the accident. The purpose of this paper is to present a simulation of a school bus negotiating a narrow, curvy roadway in a construction zone with oncoming traffic and to detail visual phenomenon contributing to the accident.

WP-2004-2 **"Creating an HVE Vehicle Geometry from Orthographic Diagrams"**

James P. Sneddon, Baker Sneddon Consulting

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ABSTRACT:

The vehicle geometry file provides a graphic visualization of a vehicle and damage profile in HVE simulations. Many users prefer specific vehicle geometries over generic for use in video exhibits. An increased need for specific vehicle geometries occurred with the release of the DYMESH option in SIMON. Unlike EDSMAC4, the vehicle geometry is an integral part of the collision simulation in DYMESH.

Currently, there are over 150 vehicle geometry files included with the HVE system software, and additional models are added with each release. Most users will periodically require a vehicle that is not included in the database. If a generic vehicle geometry will not suffice, the user can order the vehicle from EDC, purchase the vehicle geometry from a third party, or build the vehicle geometry file using 3D modeling software.

Building a vehicle geometry requires three dimensional point data. This data is best acquired by using a digitizing arm, survey instrument or photogrammetry. However, some vehicle configurations can be built from orthographic diagrams. This whitepaper will provide an introduction to this method.

WP-2004-3 **"Comparison between EDVSM and SIMON: Automobile Handling Characteristics "**

Daniel A. Fittanto, M.S.M.E., P.E. and Adam Senalik, M.S.G.E., P.E.
Ruhl Forensic, Inc.

[Click here to download a !\[\]\(65669ef2a9341eca7c5ba6092e766555_img.jpg\) PDF Version of this paper](#)

ABSTRACT:

Steady-state directional control was studied for several passenger cars and two sport utility vehicles using EDVSM and SIMON in the HVE 4.4 operating system. Constant velocity, variable steer tests were performed and relevant data recorded and analyzed.

The modeled vehicles are taken directly from the HVE Vehicle Database. These vehicles represented various class categories. Two vehicles were modified by selecting different tires from within the HVE Tire Database. The modeled vehicle configurations were as follows:

1. 1990-1995 Chevrolet Corvette
2. 1996-2000 Honda Civic
3. 1996-2000 Honda Civic modified with low-profile tires
4. 1995-2001 Ford Explorer
5. 2002 Pontiac Grand Am
6. 1991-1997 Chevrolet Impala SS
7. 1991-1997 Chevrolet Impala SS modified with 70-series tires
8. 1992-1999 Chevrolet Suburban K1500

Steering diagrams and/or handling diagrams were generated from the results of these simulated tests and the understeer characteristics were analyzed. Relative comparisons were made between vehicles both in EDVSM and SIMON. Similarities and differences between EDVSM and SIMON responses for each vehicle were also observed and discussed.

Vehicles exhibited intuitive and expected relative understeer characteristics within both EDVSM and SIMON. For each vehicle, the SIMON-modeled vehicle exhibited a greater level of understeer than the EDVSM-modeled vehicle. Aerodynamic forces were found to only slightly influence the vehicle responses in SIMON.

WP-2004-4 **"Computerised simulation of car and 4WD impacts into alternative median barrier profiles using the DyMESH collision algorithm within the HVE simulation environment"**

Grant Johnston and Iwan Parry, TRL Limited

Clint Bradley, Grant Johnston Consulting Engineers Pty Limited

Please contact the [author](#) for further information regarding this paper

ABSTRACT:

This paper presents a cost effective alternative to repetitive finite element modelling of vehicle to barrier impacts using Engineering Dynamics Corporation's HVE 3D Simulation system. Whilst it is not claimed this system is suitable for full NCHRP compliance testing it was found to provide a cost effective and fast alternative for preliminary testing of alternative barrier profiles. A pre-beta release of the DyMesh Collision Algorithm was used to simulate a series of vehicle to barrier impacts for a blackspot location in Sydney, Australia. An alternative barrier profile had to be considered due to road width limitations preventing the footprint of a standard "New Jersey" profile barrier.

WP-2005-1 **"HVE Data Inputs Based on Testing for a Wet Pavement Accident Involving an Intercity Bus and an SUV"**

Lawrence E. Jackson, PE, MS, ACTAR, David Rayburn, Dan Walsh, PE, Jennifer Russert, National Transportation Safety Board
David Gents, George A. Tapia, Vincent M. Paolini General Dynamics Tire Research Facility

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ABSTRACT:

This paper will discuss the technique used to simulate a wet pavement accident. It will discuss the weather data, the environment data and the surface friction inputs and the bus tire friction inputs used for an HVE SIMON loss-of-control simulation on wet pavement. By knowing the rain intensity, texture, drainage path length and cross slope of the pavement, it could be determined that the surface was flooded. The surface was documented with an ASTM skid trailer using a treaded and a smooth tire. This data showed that for smooth tires the friction changed both longitudinally every 0.1-mile and laterally between wheel paths, which created a split coefficient of friction. Five of the accident bus's 8 tires were tested at the General Dynamics Tire Research Facility (TIRF), on a smooth surface selected to match the accident site, for cornering and longitudinal friction at different speeds, and with different water depths. The surface used on the TIRF was validated with the ASTM ribbed and smooth tires. The results of these tire tests are presented. Finally, the data inputs for the surface friction factors and the tire in-use factors will be discussed.

WP-2005-2 **"Heavy Truck Brake Designer Validation Testing"**

Thomas H. Vadnais, P.E., Vadnais, Wood & Rivers, Atlanta, GA
Wesley D. Grimes, P.E., Collision Engineering Associates, Mesa, AZ

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ABSTRACT:

In late August 2004, a week-long series of well-documented heavy truck braking tests was conducted at Transportation Research Center (TRC) in East Liberty, OH. Using the same tractor and flatbed semi-trailer, tests were performed with and without ABS, on wet and dry surfaces, loaded and unloaded, and at both 30 and 60 mph. Additional tests were done with the semi-trailer's ABS disabled, with only the tractor's ABS system cross-wired, with some of the tractor and trailer brakes out of adjustment, and with the bobtail tractor alone. Both the tractor and semi-trailer were documented to allow creation of an accurate HVE vehicle model, including all brake components. For this initial paper, SIMON runs, using the Brake Designer, were made of several actual test runs to validate the software against the actual test data. These were compared to similar simulations using generic vehicles. For this paper, only loaded, non-ABS, 60 mph tests were modeled, with all brakes in adjustment, and some out of adjustment.

WP-2005-3 **"SIMON and EDVDS Validation Study: Steady State and Transient Handling"**

Daniel A. Fittanto, M.S.M.E., P.E. and Adam Senalik, M.S.G.E., P.E.
Ruhl Forensic, Inc.

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ABSTRACT:

This research compares the responses of vehicle modeled in SIMON and EDVDS in the HVE simulation operating system against instrumented responses of a 3-axle tractor, 2-axle semi-trailer combination. The instrumented tests were previously described in SAE 2001-01-0139 and SAE 2003-01-1324. The vehicle inertial parameters were measured by UMTRI (University of Michigan Transportation Research Institute). The tire data was provided by Smithers Scientific Services, Inc. and UMTRI. The series of tests discussed herein compares the modeled and instrumented vehicle responses during quasi-steady state and transient handling maneuvers. The time response of the following variables is compared graphically:

1. Tractor lateral acceleration
2. Tractor yaw rate
3. Trailer lateral acceleration

SIMON and EDVDS simulated responses are found to reasonably follow the trends of the instrumented vehicle. SIMON is found to more closely simulate the truck dynamics of the experimental vehicle than EDVDS. SIMON responses correlated well to the experimental values in both step steer transient phases and steady state phases in all tests except for the steady state phase of the Step Steer at 20 m/sec.

WP-2005-4 **"Simulation of a Side Impact and Vehicle Rollover Using EDVSM and EDSMAC4 within HVE"**

James E. Flynn, Stephen Harper, Howard Underwood, Robert Buckert and Phillip Parks
J2 Engineering, Inc.

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ABSTRACT:

EDVSM and EDSMAC4 were used to determine impact speeds, vehicle changes in velocity and vehicle rollover mechanics during the analysis of a side impact collision. On the date of the incident, a 1997 Ford Crown Victoria was parked facing westerly on the northerly shoulder of the No. 2 westbound lane of a four lane, east-west directed roadway. The driver of the Crown Victoria initiated a U-turning maneuver from the shoulder with the reported intent of crossing the center earthen median and proceeding easterly within the eastbound lanes of the roadway. As the Crown Victoria crossed into the No. 1 westbound lane, it was collided with at the left front fender and left front wheel by a westbound 1991 Chevrolet S-10 Blazer. Subsequent to the collision, the Crown Victoria was propelled in a westerly direction while rotating clockwise to its point of rest. The Crown Victoria came to rest facing southerly on the line striping separating the No. 1 and No. 2 westbound lanes. The collision deflected the Blazer in a southwesterly direction after which it exited the No. 1 lane and traveled onto the earthen median where it rolled over and came to rest on its top while facing northerly. The right front occupant of the Blazer was ejected and sustained a severe brain injury during the rollover process. The use of EDVSM and EDSMAC4 allowed for successful modeling of both pre and post impact vehicle dynamics. Tire marks produced by the model were found to match those imported from the post-collision scene survey. Vehicle crush, including that resulting from secondary vehicle to vehicle contact, matched damages documented during the inspections of the vehicles. The rollover simulation was found to correlate well with the vehicle rollover damages and the Blazer's documented final orientation and point of rest.

WP-2005-5 **"Investigating the Sensitivity of Vehicle Response to Inter-Vehicle Friction Values for Broadside Collisions utilizing HVE (EDSMAC4 Algorithm)"**

Jubal D Hamernik, Ph.D., Douglas M. Schuler, MS, Brendan C. Rudack, David E. Wittekind and Brian P. Tholl
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ABSTRACT:

In this research, Engineering Dynamics Corporation's Human Vehicle Environment (HVE) software was utilized to model a series of broadside impacts where the inter-vehicle friction coefficient, relative vehicle mass ratio, and contact alignment were allowed to vary. The sensitivity of these parameters was examined by comparing the relative final rest positions, as predicted by EDSMAC4, when each parameter was individually varied. The research consisted of utilizing two identical vehicle models for all simulations where only the weight of the bullet vehicle weight was modified. All simulations are based on a stationary target vehicle, where a bullet vehicle traveling at 40-mph contacts the stationary vehicle at a 90-degree configuration. Results obtained from the target vehicle during simulation are presented for delta-V, change in heading, post-contact travel distance, CDC, and PDOF are presented and compared. The findings of this research are useful to aid HVE EDSMAC4 users in their understanding and application of inter-vehicle friction coefficients when simulating an array of broadside collisions.

WP-2005-6 **"Simulation of Tire Interaction with Curbs and Irregular Terrain"**

Terry D. Day, Engineering Dynamics Corporation

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ABSTRACT:

The reconstruction of vehicular loss of control often involves a path that includes irregular terrain, such as pavement edges, curbs and soft soils. Depending on the angle of impact and soil characteristics, these irregularities can significantly influence the vehicle's trajectory. To draw proper conclusions regarding accident causation requires an understanding of how such irregularities may have affected the trajectory or contributed to the loss of control. This paper describes a new tire-terrain model that includes the capability of simulating tire interaction with irregular terrain. In addition to simulating non-homogeneous pressure distributions at the contact patch, the model also simulates the forces and moments produced by tire sidewall interaction with pavement edges, curbs and soft soils. This paper presents the details of the modeling approach. Examples are provided illustrating the use of these models, including tire interaction with a curb, pavement edge and soft soil. The new model is compared with the existing point contact tire model.

WP-2006-1 **"Presentation of HVE Validation Studies"**

Eric Deyerl, P.E.
Quan, Smith & Associates

Fawzi P. Bayan, P.E., Anthony D. Cornetto, III, P.E. and Jonathan Anderson
SEA, Ltd.

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ABSTRACT:

HVE users are regularly required to provide explanation as to how the various HVE simulation programs operate and how they have been validated. This paper presents a method by which HVE validation studies may be visually depicted so that a viewer may gain a rapid understanding of what the HVE programs do and the methods by which they have been validated.

In this method, EDSMAC4 validation simulations are used to create movie files with viewpoints and effective frame rates similar to those of the cameras used to document full-scale dynamic vehicle tests. The viewer is provided with a visual comparison of the motion of the simulated vehicles played adjacent to the films of the full-scale crash tests. It is contended that this technique provides a more concise and understandable explanation of the program's operation and validation than would a verbal description alone.

WP-2006-2 **"Tractor-Semitrailer Handling Analysis Using EDVDS and EDVTS"**

Daniel A. Fittanto, M.S., P.E. and Louis V. Inendino, M.S., P.E.
Ruhl Forensic, Inc.

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ABSTRACT:

A 2005 HVE Forum Whitepaper compared simulated responses in SIMON and EDVDS against instrumented responses for a tractor-semitrailer combination. The instrumented tests involved a three-axle tractor with an unloaded two-axle trailer in a series of handling maneuvers.

In this research the same series of tests are simulated using EDVTS. Simulated results are compared to experimental results and previously reported EDVDS results. The time response of the following variables is compared graphically:

1. Tractor lateral acceleration
2. Tractor yaw rate

The initial EDVTS results are found to more closely correlate with EDVDS than with SIMON from the past series of tests.

For EDVDS and EDVTS, the steering gain (steering gear ratio) was varied, without changing the shape of the steering profile or changing vehicle parameters to determine if simulated vehicle responses similar to the experimental tests could be found. Simulated results for trailer lateral acceleration were also compared with experimental results for EDVDS.

Modifications were then made to the tire data as used by EDVTS and EDVDS to more closely approximate the lateral tire forces that would have occurred during full-scale tire testing. The maneuvers were rerun in EDVTS and good agreement was found with the experimental data without modification to the steering gear ratio. EDVDS results were improved.

Several observations regarding the lateral and yaw responses of the three HVE tractor-semitrailer simulation programs, SIMON, EDVDS and EDVTS are discussed.

WP-2008-1 **"Application of HVE SIMON to the Analysis of Lateral Wind Loadings on High-sided Vehicles"**

William Blythe, P.E., Ph.D.
William Blythe, Inc.

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ABSTRACT:

The SIMON simulation model, part of the HVE simulation environment, automatically calculates longitudinal wind forces as a function of vehicle speed and user-specified drag coefficients. Lateral wind

loads are not calculated at the present time, but may be constructed by the user. Modifications to the SIMON program are suggested.

Tractor-trailer rollover due to high crosswinds is a well-recognized accident type. Some highway jurisdictions limit high-profile vehicle travel under certain weather conditions in certain locations to reduce the probability of rollover or other loss of control. The research literature relating to this issue has been reviewed and reported.

WP-2008-2 **"Validation of Collision Reconstruction Opinion Utilizing EDSMAC4"**

Steven Day
California Highway Patrol

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ABSTRACT:

This paper describes the use of old and new technologies to validate a collision reconstruction opinion regarding the relation of undocumented tire friction marks to a fatal collision.

The collision occurred on a rural two lane mountainous roadway in which an Acura NSX crossed into the opposing traffic lane, from behind a pickup truck, and struck a Volkswagen Beetle head-on. Responding California Highway Patrol (CHP) officers documented specific items of physical evidence utilizing a station line, but discounted four distinct curvilinear tire friction marks present at the collision scene they believed were not associated with the fatal collision. Photographs of the scene were taken, but were limited in their coverage. Approximately 22 months following the collision, a CHP MAIT (Multi-disciplinary Accident Investigation Team) investigation was initiated to confirm or eliminate the tire friction marks as part of the fatal collision as well as determine vehicle speeds at and prior to impact if possible.

Photogrammetry reconstruction methodologies were used in conjunction with a traditional site survey and a 3-D laser scan of the collision site to re-establish the tire friction marks in question in relation to the roadway. The data from the photogrammetry reconstruction, site survey, and site scan were imported into AutoCAD where a traditional collision reconstruction was completed.

To validate the opinions of the traditional collision reconstruction, a three dimensional environment and the tire marks were imported into HVE and an EDSMAC4 event was created in an attempt to reconstruct the collision event. The EDSMAC4 event provided additional confirmation that the tire marks in question were indeed related to the collision event and deposited by the errant vehicle while in a steering induced yaw. An additional EDSMAC4 event, created per the errant driver's statement, refuted his claim that the yaw marks were created by an emergency brake only application due to a mechanical failure of the vehicle's braking system.

Eric Deyerl
Dial Engineering

Louis Cheng
Applied BioMechanics

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ABSTRACT:

The use of computer simulation to analyze motorcycle into-vehicle collisions is examined and presented. The software program EDSMAC4 within the HVE-2D suite, developed for the simulation of vehicle-to-vehicle collisions, is extended in this study to the analysis of collisions between motorcycles and other vehicles. Simulation results are compared to the results of the series of full-scale staged collisions between motorcycles and passenger vehicles previously published in SAE paper 2002-01-0551, "Seventeen Motorcycle Crash Tests Into Vehicles and a Barrier" by Adamson, et. al.

The rest positions, damage ranges, and speed changes of the test vehicles in the simulations and those in the full-scale tests are presented in numerical and graphical formats. This effort achieved good to excellent correlation between the simulated and test results, thereby providing support for the use of this simulation technique for the type of motorcycle-vehicle collisions examined in this study. In the set of 10 crash tests analyzed, 10 motorcycles moving at speeds between 25 and 49 miles per hour were guided into 2 stopped passenger vehicles. The simulations of these full-scale tests calculated the rest locations of the test automobiles to within approximately 1 foot or less in 7 out of the 10 tests, the changes in the automobile headings to within 4 degrees in all 10 of the tests, the automobiles' speed changes to within 2 ½ miles per hour in 8 of the 10 tests, the motorcycle speed changes to within 3 miles per hour in 7 out of the 10 tests, and the average automobile damage depths to within 2 inches in 7 out of the 10 tests.