ENGINEERING DYNAMICS COMPANY

EDCRASH

HVE Human Vehicle Environment

Markdown Edition — revised to describe the current version of the software

Contents

1. EDCRASH — Collision Reconstruction
2. Chapter 1 — EDCRASH Program Description
3. Chapter 2 — EDCRASH Program Input
4. Chapter 3 — EDCRASH Program Output
5. Chapter 4 — Calculation Method
6. Chapter 5 — EDCRASH Tutorial
7. Chapter 6 — Messages
8. Chapter 7 — Technical References

EDCRASH — Collision Reconstruction

Engineering Dynamics Company Reconstruction of Accident Speeds on the Highway

Version 7 — Updated Markdown edition, based on the Sixth Edition (January 2006) printed manual and revised to match the current HVE/EDCRASH release.

EDCRASH is an analysis used to reconstruct single and two vehicle accidents. It determines the conditions of impact, including the impact speeds and delta-V of the vehicles, using information obtained from vehicle and accident site inspections. EDCRASH is compatible with both HVE-2D and HVE.

How to Use This Manual

This manual describes the EDCRASH model features and use. Input parameters and output reports are described at a high level. This manual is intended to be used in conjunction with the HVE User's Manual, which provides in-depth coverage of the human, vehicle and environment models, as well as the Event Editor and Playback Editor.

Contents

Chapter	Description
1 — Program Description	Overview, model inputs/outputs, validation, HVE-2D and HVE, basic procedure
2 — Program Input	Vehicles, environment, event set-up, calculation options, executing an event
3 — Program Output	Alpha-numeric reports (Accident History, Damage Data, Event Data, Messages, Program Data, Vehicle Data) and graphic reports (Damage Profiles, Momentum Diagrams, Site Drawing)
4 — Calculation Method	Impact phase (collinear and oblique), impact-to-rest phase, trajectory simulation, assumptions
5 — EDCRASH Tutorial	Complete worked example: intersection collision between a Ford Escort and a Nissan Sentra
6 — Messages	All Fatal, Diagnostic and Informative messages issued by EDCRASH, with recommended actions
7 — Technical References	Bibliography

Related Documentation

- Calculation Options for EDCRASH — reference for every control in the EDCRASH Calculation Options dialog (Program Options, Separation Velocity Basis, Consistency Checks, Simulation Convergence Criteria).

Notes on This Edition

This Markdown edition preserves the substance of the original printed manual. Where the printed manual has become stale relative to the current release, the text has been updated and marked with an italic

(updated: ...)

note. Key updates:

- The Calculation Options dialog now includes a fourth Program Options check box, *Include Angular Momentum Solution* (default off, currently disabled), and a fourth Separation Velocity Basis choice, *Iterate on Sideslip*, which is rejected by the current physics engine.
- Default Consistency Check thresholds (PDOF ±10 deg, Delta-V ±0.10, K.E. ±0.50, Newton's 3rd Law ±1.00) and Simulation Convergence Criteria (5 runs; rest 0.10/0.10, EOR 0.15/0.15, POC 0.15) match the current release.
- Figures and report screenshots from the original are referenced by placeholder.
- The original Chapter 8 (Index) is omitted; use full-text search across the chapter files instead.

Chapter 1 — EDCRASH Program Description

Overview

EDCRASH (Engineering Dynamics Company Reconstruction of Accident Speeds on the Highway) is an analysis used to reconstruct single and two vehicle accidents. EDCRASH is based on the Calspan Reconstruction of Accident Speeds on the Highway (CRASH) [1,2,3] and includes refinements and enhancements provided by the National Highway Traffic Safety Administration (NHTSA) [4,5,6] and Engineering Dynamics Company, LLC [7,8,9,10,11]. The program determines the conditions of impact, including the impact speeds and delta-V of the vehicles, using information obtained from vehicle and accident site inspections.

The output generated by EDCRASH depends on the amount of information supplied. The minimum information required is a description of the vehicle damage. Therefore, when accident site information is not supplied, the resulting output will be limited to an analysis of the severity of impact, including delta-V (speed change) and magnitude and principal direction of force. When accident site information is supplied, the output will also include the speed of the vehicle(s) at impact.

EDCRASH is a useful tool for investigating the circumstances of an accident. These circumstances include the effect of human, vehicle, and environmental factors on the pre-impact, impact, and post-impact events.

An extremely useful feature of EDCRASH is the ability to quickly and accurately review the results generated from different input scenarios. Termed

what if

analysis, changes can be made to an isolated variable or set of variables and the effects are displayed immediately. Only the parameters that change need to be modified; the HVE Event Editor saves all the previously entered information. For example, the sensitivity of the results to impact positions, rest positions or principal direction of force can be analyzed by merely changing the event and re-executing.

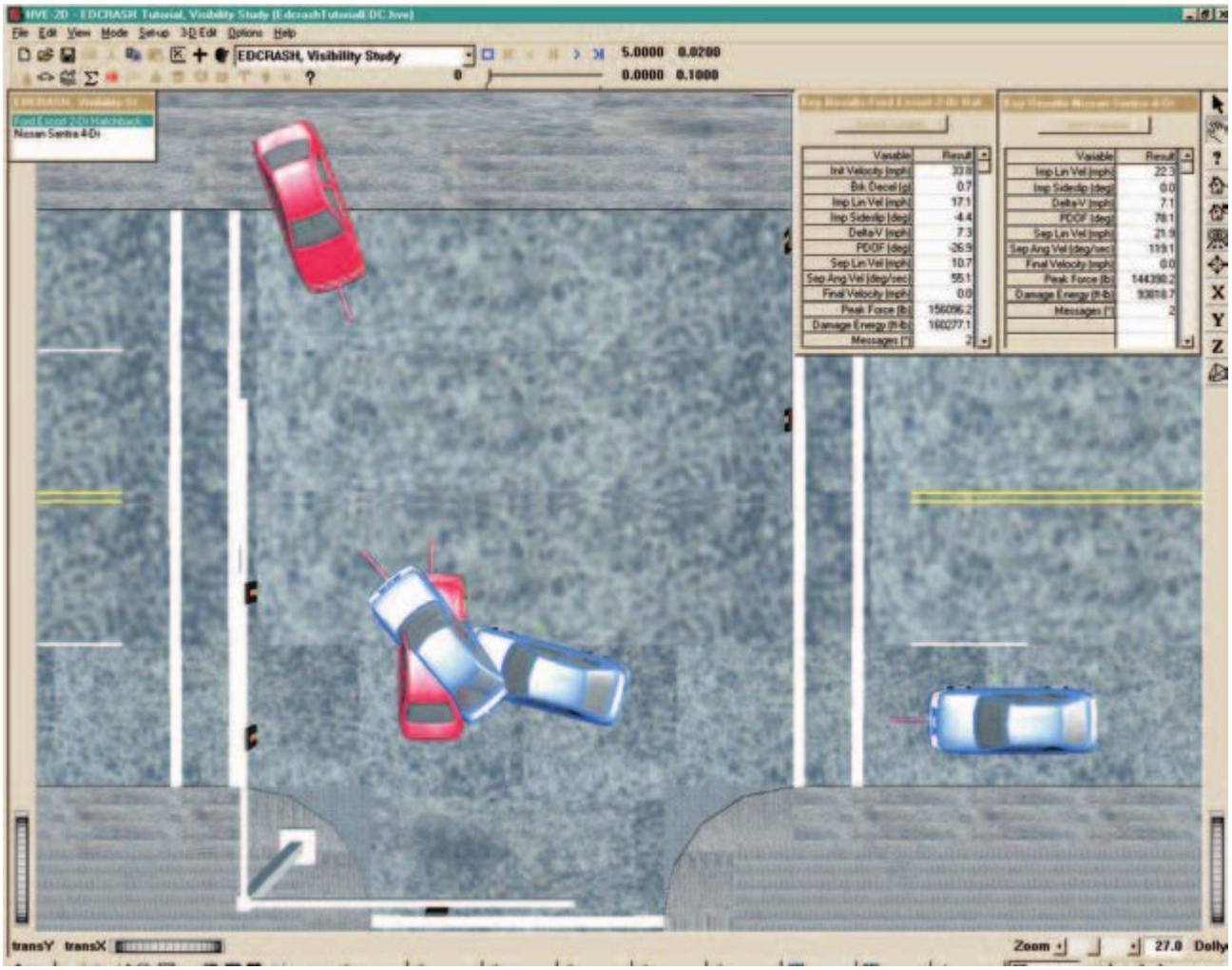


Figure 1-1: EDCRASH Event.

Model Inputs

EDCRASH inputs include either one or two vehicles and an optional environment. Event set-up parameters include optional vehicle positions (positions are optional; however, speed at impact cannot be calculated unless at least impact and rest positions are supplied), Driver Controls (Percent Wheel Lock-up) and Damage Profiles (damage profiles are optional; however, impact speed cannot be computed for collinear collisions unless damage profiles are supplied).

Model Outputs

The primary outputs from the EDCRASH analysis are impact speed and speed change (Delta-V) during the crash. The output reports produced by EDCRASH include Numeric Reports (Messages, Accident History, Vehicle Data, Damage Data and Program Data) and Graphic Reports (Site Drawing, Damage Profile and Momentum Diagrams).

Validation

The computational accuracy of the program has increased with additional refinements of the algorithms. During program development, early validation of the damage-based method of computing delta-V [11] revealed an accuracy in the range

of 12 percent (95 percent confidence level) when compared to staged collisions conducted by Calspan. More recent validation of impact speed estimates [10] revealed an accuracy in the range of −1.2 to +3.7 percent of the combined impact speed (95 percent confidence level) for oblique collisions and −7.1 to +3.2 percent of combined impact speed for collinear (damage-based) collision results. These validation studies were performed using staged collisions, wherein the data were available directly after the crash. Poor quality data can be expected to reduce the quality of the results.

For damage-based results, the linear approximation of delta-V versus crush has been shown to over-estimate delta-V for severe impacts when structural disintegration becomes a major factor. For low impact speeds the effect of the coefficient of restitution is ignored, resulting in an under-estimation of delta-V. However, for the normally experienced range of speed changes, the damage-based results are reasonable.

HVE-2D and HVE

EDCRASH is compatible with both HVE-2D and HVE. While EDCRASH has been extended and revalidated for use in the HVE environment to account for 3-D terrain, EDCRASH is essentially a 2-dimensional physics reconstruction program.

If you are using EDCRASH within the HVE environment, the Human, Vehicle, and Environment Editors will have additional features that are not available in HVE-2D. These features are described in great detail in the HVE User's Manual. While some dialogs do look different between HVE-2D and HVE, the required input for EDCRASH is found in both. Where there are differences related to the use of EDCRASH, these differences are noted in this manual.

Basic Procedure

The procedure for using EDCRASH is substantially the same as using any reconstruction or simulation model in the HVE environment. The basic procedure may be divided into three categories:

- **Data Acquisition** — Obtaining raw data from field inspections and other research
- **Data Reduction** — Converting the raw field measurements into data in the form required by the analysis
- **Data Analysis** — Analyzing (using the laws of physics) the data

Data Acquisition and Reduction

Obtaining error-free results using EDCRASH is no simple task, because results must be consistent with all of the physical laws of nature to be displayed without Fatal or Diagnostic messages. This can be frustrating because an investigator's information is frequently sketchy or estimated from several sources.

> "Any analysis produced by EDCRASH without error messages is consistent with the laws of physics (Newton's laws, the conservation of energy and the conservation of momentum) and is totally consistent with the input data which produced it."

When preparing for an EDCRASH analysis, the following procedure is recommended:

1. It is convenient (and highly recommended) to prepare data sheets to hold the required information before entering data into the computer. Separate "Site Data" and "Vehicle Data" forms work extremely well. Damage Profile Data Sheets are available from EDC by simply calling. For a Site Data form, we suggest you simply start with a large, clean sheet of paper.

2. Gather all accident site and vehicle information.
3. Transfer the accident site and vehicle information to scaled accident site and vehicle diagrams.
4. Using the scaled accident site diagram, along with a scale and protractor, measure the positions and headings at all path locations. Enter this information on the Site Data sheet.
5. Enter the pre-impact sideslip angles and coefficient(s) of friction on the Site Data sheet.
6. Using the scaled vehicle diagrams, measure the damage profile and transfer the measurements (width, depths and damage offset) to the Vehicle Data sheet.
7. Confirm the vehicle dimensional, inertial and tire properties using direct measurement if possible.

Data Analysis

Once the raw data are acquired and reduced, analyzing the data involves the following procedures:

- Use the Vehicle Editor to add one or more vehicles to the case. Edit the vehicle(s) as required to suit the needs of the current case.
- Optionally, use the Environment Editor to create a visual and physical environment.
- Use the Event Editor to set up and execute the EDCRASH reconstruction model by performing the following steps:
- Choose one or two vehicles from the list of vehicles created earlier.
- Choose the EDCRASH calculation model.
- Choose the desired Trajectory option.
- Optionally, position the vehicle(s) in the environment.
- Optionally, assign damage profiles to the vehicle(s).
- Optionally, assign driver controls (Wheel Data) for each vehicle.
- Execute the reconstruction event.
- Modify the event set-up parameters as required to eliminate any fatal errors; diagnostic messages should be reviewed to determine their effect on the results.
- Finally, use the Playback Editor to view the various reports and trajectory simulations. If desired, produce a video output of the simulation.
- Save your case!

Previous: Table of Contents · Next: Chapter 2 — EDCRASH Program Input

Chapter 2 — EDCRASH Program Input

This chapter defines the objects (vehicles and environment) and the event set-up parameters (positions, damage profiles, wheel lock-ups, and so forth) used by the EDCRASH analysis. In general, the chapter is divided into the following sections:

- **Objects** — The number of vehicles, and the specific vehicle parameters actually used by EDCRASH.
- **Events** — The various options available for setting up and executing an EDCRASH event.

Objects Overview

The objects used by the EDCRASH model are:

- **Vehicles** — One or two vehicles may be studied by EDCRASH.
- **Environment** — Like the real world, EDCRASH has exactly one environment.

> **NOTE:** The environment is used in any reconstruction or simulation model.

The following sections describe how the vehicle and environment provide the required inputs to the EDCRASH calculation model.

Vehicles

EDCRASH uses one or two vehicles created using the Vehicle Editor. Vehicles are selected from the Vehicle Database by choosing the following attributes:

- **Type** — EDCRASH supports the following vehicle types: Passenger Car, Pickup, Van, Sport-Utility, Truck, Movable Barrier and Fixed Barrier.
- **Make** — EDCRASH supports all available vehicle makes.
- **Model** — EDCRASH supports all available vehicle models, within the limits defined by number of axles and drive axles; see below.
- **Year** — EDCRASH supports all available vehicle years.
- **Body Style** — EDCRASH supports all available vehicle body styles.

Each vehicle also has the following additional user-editable parameters:

- **Driver Location** — The Driver Location is not used by EDCRASH. However, Driver Location must not be *None*; otherwise, the Driver Controls (Wheel Data) will not be available during Event mode.
- **Engine Location** — The Engine Location is not used by EDCRASH.
- **Number of Axles** — EDCRASH supports only 2-axled vehicles.
- **Drive Axle(s)** — The Drive Axle is not used by EDCRASH.

To add a vehicle to the current case, perform the following steps:

1. Choose Vehicle Mode. The Vehicle Editor is displayed.
2. Choose Add New Object. The Vehicle Information dialog is displayed.

3. Click on the Type, Make, Model, Year and Body Style option buttons to select a vehicle from the database.
4. If desired, modify the Driver Location, Engine Location, Number of Axles and Drive Axle(s) for the current vehicle.
5. Enter a name for the current vehicle. A default name is supplied for each selected vehicle. Its name is user-editable, and does not affect calculations.

> **NOTE:** Duplicate vehicle names are not allowed in the same case.

1. Click OK to add the vehicle to the current case.

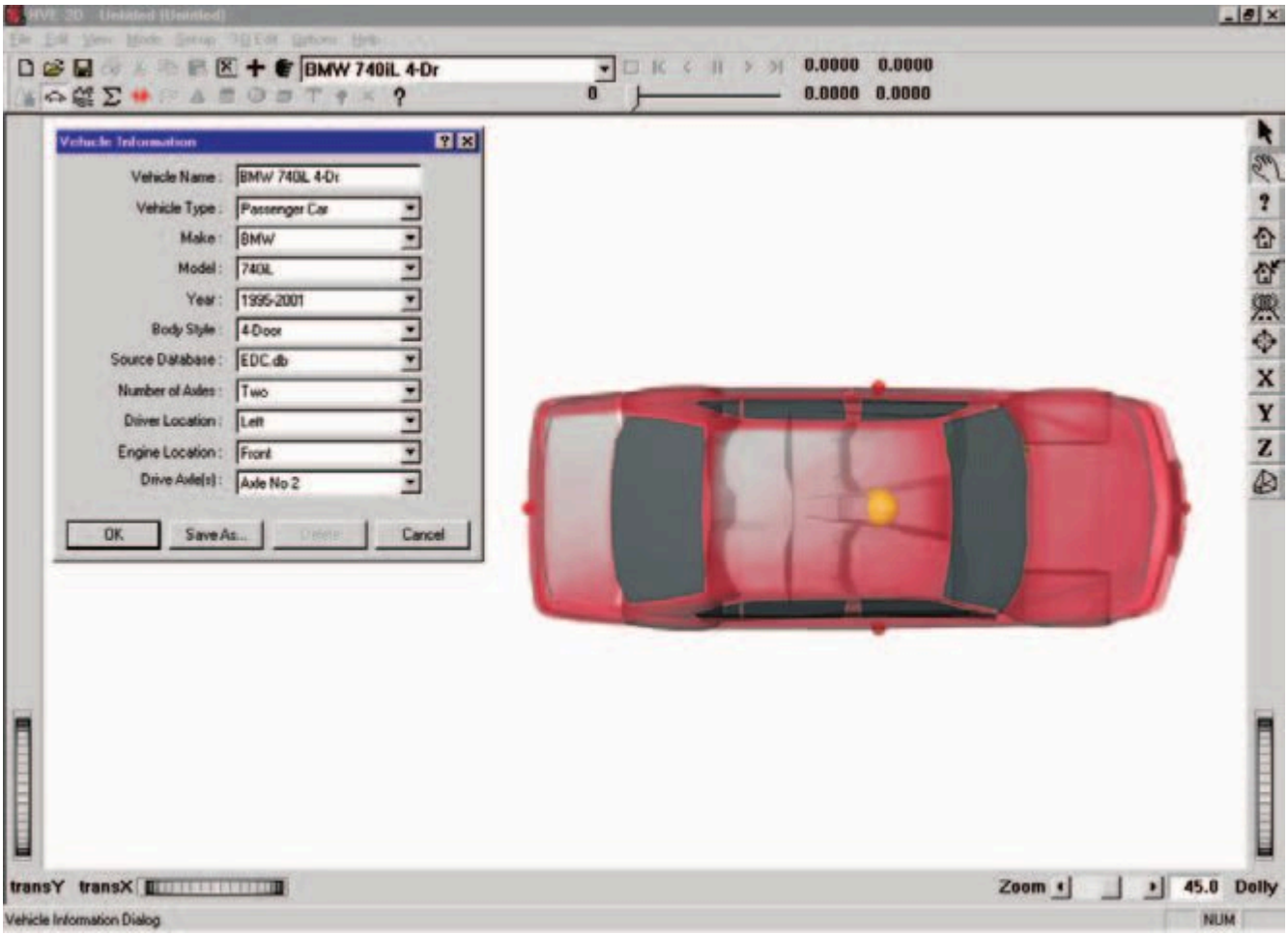


Figure 2-1: Vehicle Editor.

The following Vehicle Parameter groups are assigned using the Vehicle Editor:

- Sprung Mass
- Inertias
- Move CG
- Unsprung Mass
- Wheel Location
- Tire Data
- Suspension Data
- Brake Data

- Steering System
- Exterior
- Overall Dimensions
- Crush Stiffness Coefficients

The specific data used in each of the above parameter groups are defined in Tables 2-1 through 2-3.

Sprung Mass

Table 2-1: Vehicle Sprung Mass Parameters Used By EDCRASH

Parameter	Description
Total Weight	Total vehicle weight
Total Yaw Inertia	Total rotational inertia about the vehicle-fixed z axis
Move CG x	Relocates the CG in the vehicle-fixed x direction. This entry causes an automatic adjustment of all other vehicle dimensions to reflect the new CG location.

Inertias

EDCRASH uses the total vehicle weight (converted to mass according to the current gravitational constant; see Environment), and the total yaw rotational inertia.

Because EDCRASH does not have separate degrees of freedom for the unsprung masses, the yaw moment of inertia used by EDCRASH is the sum of the sprung mass yaw inertia plus the additional yaw inertia created by the individual wheels. See also EDCRASH Output, Vehicle Data report.

Move CG

Move CG is not directly used by EDCRASH. Its current value does not show up in the results. However, the Move CG fields may be used to quickly move the vehicle's center of gravity. The x,y,z coordinates for the wheels are updated to reflect the new CG location.

> **NOTE:** Bilateral symmetry is assumed. Moving the CG in the +y or −y direction will have no effect on the EDCRASH calculations.

Geometry File

The Geometry File is not used by EDCRASH.

Unsprung Mass

Table 2-2: Vehicle Unsprung Mass Parameters Used By EDCRASH

Parameter	Description
Wheel Location	The vehicle-fixed x,y,z wheel center coordinates
Tire Slide Friction	The slide coefficient of friction for each tire
Tire Friction Table, Test Load/Speed	The load and speed for a given set of friction results (EDCRASH uses the middle load and middle speed)
Friction In-use Factor	Multiplier for Slide Friction
Tire Cornering Stiffness	Tire lateral force per unit of tire lateral slip for small amounts of slip
Cornering Stiffness In-use Factor	Multiplier for Cornering Stiffness

Wheel Location

Although HVE-2D provides values for the vehicle-fixed x,y,z coordinates of each wheel, EDCRASH uses the following parameters: a, the distance from the CG to the front axle; b, the distance from the CG to the rear axle; and t_w, the average of the front and rear track widths.

> **NOTE:** EDCRASH uses the average x_{wheel} for the front wheels to calculate a and the average x_{wheel} for the rear wheels to calculate b. Similarly, EDCRASH uses the total distance between right-side and left-side tires to calculate track width. Bilateral symmetry is assumed. Finally, EDCRASH does not use z_{wheel} for calculations.

Tire

The tire parameters provide the following data groups:

- Physical Data
- Friction Table
- Cornering Stiffness Table
- Slip-vs-Rolloff Table

EDCRASH's use of these parameters is described below.

Physical Data

EDCRASH does not use the Tire Physical Data.

Friction Data

The Friction Data used by EDCRASH are shown in Table 2-2. EDCRASH uses the slide friction coefficient.

Because EDCRASH's tire model does not include a load or speed dependence, if friction data for more than one load or speed is supplied in the HVE Tire Data dialog, EDCRASH uses the friction coefficient for the middle load and/or speed.

> **NOTE:** If there is any doubt about which value is actually used by EDCRASH, you can check the Vehicle Data output report.

The In-use Factor, available in HVE, is a convenient way to reduce or increase the dependent friction value for a specific case.

Cornering Stiffness Data

If (and only if) the Trajectory Simulation option is selected, EDCRASH uses the Cornering Stiffness value.

Like the Friction Table, EDCRASH's tire model does not include a load or speed dependence. If more than one load or speed is supplied in the HVE Tire Data dialog, EDCRASH uses the cornering stiffness for the middle load and/or speed.

> **NOTE:** If there is any doubt about which value is actually used by EDCRASH, you can check the Vehicle Data output report.

The In-use Factor is a convenient way to reduce or increase the cornering stiffness.

> **NOTE:** If you are simulating a vehicle with a flat tire, you'll probably want to reduce the In-use Factor to about 0.1.

Slip-vs-Rolloff Table

EDCRASH does not use the Tire Slip-Rolloff data.

Suspension

EDCRASH does not use the Suspension data.

Brake

EDCRASH does not use the Brake data.

Exterior

EDCRASH uses the following Vehicle Exterior Data:

- Exterior Dimensions
- A and B Stiffness Coefficients

Table 2-3: Vehicle Exterior Parameters Used By EDCRASH

Parameter	Description
CG to Front, Right, Back and Left	The vehicle's exterior dimensions
A Stiffness Coefficient	The force per unit width required to initiate permanent deformation
B Stiffness Coefficient	The vehicle crush rate, that is, the force per unit of permanent crush depth per unit of damage width

Steering System Data

EDCRASH does not use the Steering System data.

Brake System Data

EDCRASH does not use the Brake System data.

Environment

EDCRASH uses the environment created by the HVE Environment Editor. The environment is created by defining the following groups of attributes:

- Visual Data
- Physical Data

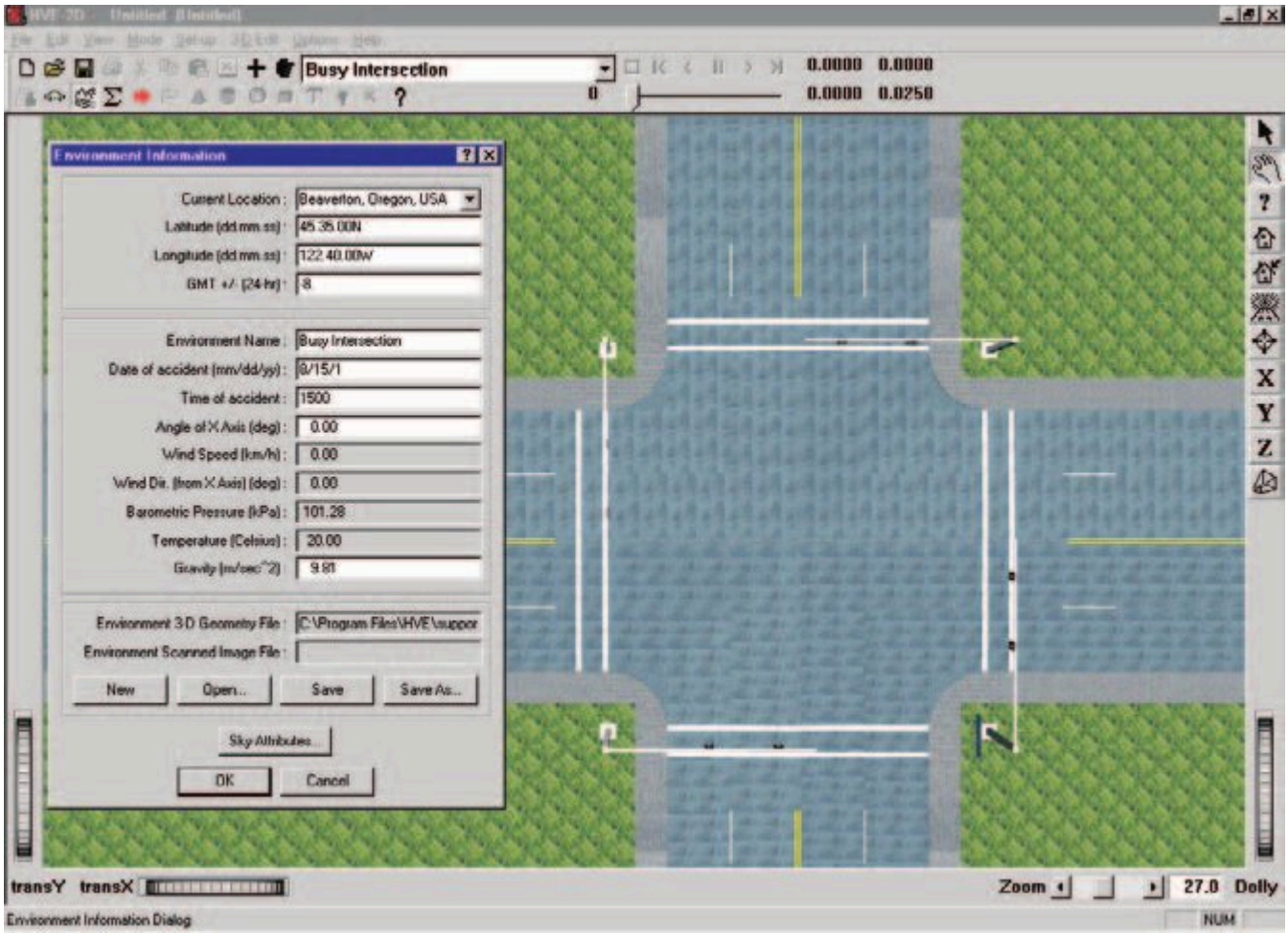


Figure 2-2: Environment Editor.

Creating an Environment

To add an environment to the current case, perform the following steps:

1. Choose Environment Mode. The Environment Editor is displayed.
2. Click Add New Object. The Environment Information dialog is displayed.
3. Click on the Location combo box to select the desired city, state and country, and associated Latitude, Longitude and GMT.
4. Enter the Time and Date for the event.
5. Enter the Angle of the X axis, Wind Speed and Direction, Barometric Pressure and Temperature for the event.
6. Enter the Gravity Constant for the event.

7. Enter an environment name. A default name is supplied for the current environment. The name is user-editable, and does not affect calculations.
8. Click OK to add the environment to the current case.

Visual Data

The following visual parameters may be edited:

- **Environment Location** — A database containing the name (City/State/Country), Latitude and Longitude and GMT for the selected location.
- **Time and Date** — The local standard time and date for the event.

The visual data are not used by the event; they are provided for studies related to visibility at the time of an event (e.g., avoidability of an accident).

> **NOTE:** The visual data (Location, Time, Date and Angle of earth-fixed X axis) affect the lighting of the event! Depending on your view (Camera Position) the scene may be shaded and difficult to see. If the time is after sundown, the view will be dark.

Physical Data

The Physical Data groups are:

- Angle of X Axis
- Wind Speed and Direction
- Atmospheric Temperature and Pressure
- Gravity Constant
- Surface Geometry

Table 2-4: Environment Parameters Used By EDCRASH

Parameter	Description
Gravitational Constant	The local acceleration of gravity
3-D Surface Geometry (Friction Factor, Elevation, Slope)	The polygon database used to create the 3-D environment

Angle of X Axis

The angle of the X axis is used to position the earth-fixed coordinate system on the surface of the earth.

> **NOTE:** The angle is specified relative to true north. If you are using a compass to determine direction at the scene of an accident, you should provide a correction factor before entering this angle.
>
> **NOTE:** The angle of the X axis affects how you visualize an EDCRASH event because it affects the location of the sun.

Wind Speed and Direction

EDCRASH does not use the Wind Speed and Direction.

Atmospheric Temperature and Pressure

EDCRASH does not use the atmospheric temperature and pressure.

Gravitational Constant

The gravitational constant converts mass to force. An object's mass and rotational inertias are properties that are the same throughout the universe; however, the weight of an object is dependent on the local gravitational constant.

Surface Geometry

If the Trajectory Simulation option is used, EDCRASH uses the geometry to calculate the friction multiplier for the current X,Y position of each tire during the simulation.

In HVE, it is also used to calculate the elevation and slope.

> **NOTE:** Geometry is used only if a trajectory simulation is requested. The traditional, energy-based analysis does not use the surface geometry.

Event

EDCRASH uses the Event Editor to create, set up and execute an event. Each of these topics is described below.

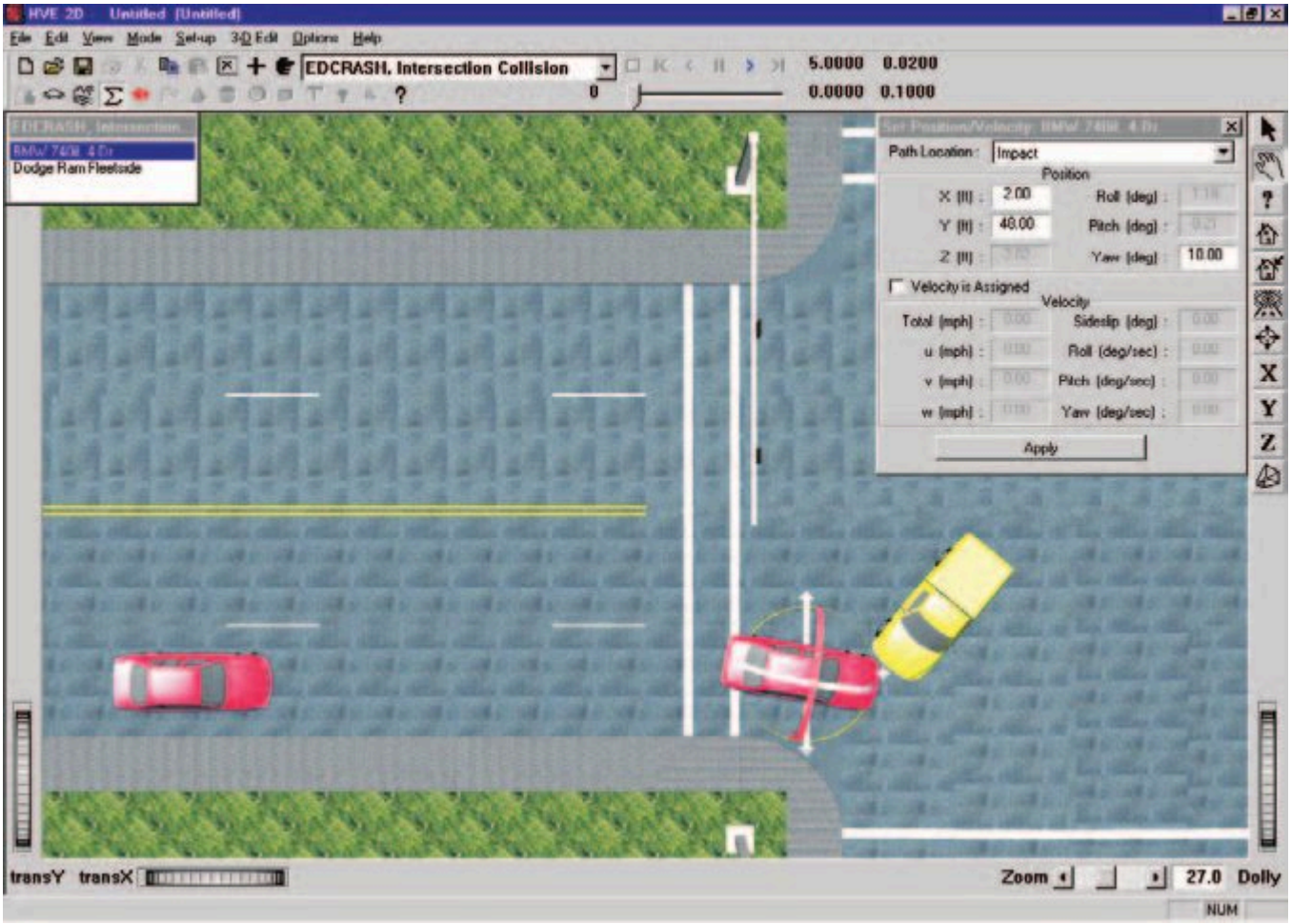


Figure 2-3: Event Editor, setting up and executing an EDCRASH Event.

Creating an Event

An EDCRASH event is created using the Event Information dialog.

To create an EDCRASH event:

1. Choose Event Mode. The Event Editor is displayed.
2. Choose Add New Object. The Event Information dialog is displayed.
3. Select one or two vehicles from the Active Vehicles list.
4. Select the calculation model, EDCRASH, from the Calculation Model options list.
5. Enter an event name. A default name is supplied for the selected event. The name is user-editable, and does not affect calculations.

> **NOTE:** Duplicate event names are not allowed in the same case.

1. Click OK to create the EDCRASH event.

> **NOTE:** If you choose a vehicle that is not compatible with EDCRASH, a message will be displayed describing the problem. You will not be allowed to proceed until EDCRASH-compatible objects are selected.

Setting Up an EDCRASH Event

EDCRASH uses the following event set-up options:

- Position/Velocity
- Driver Controls
- Damage Profiles

Table 2-5: Event Set-up Parameters Used By EDCRASH

Parameter	Description
Vehicle Position: Begin Braking, Impact, Point-on-curve, End-of-rotation, Final/Rest	The earth-fixed X,Y coordinates and heading angles of each vehicle for each of the selected positions
Driver Controls, Wheel Data	Pre-impact Drag Factor, Rotation/Lateral Skidding Flag, % Wheel Lock-up, Steer Angle*
Damage Profile	CDC, PDOF, x,y Impulse Coordinates, Damage Width, up to 10 crush depths, damage Midpoint Offset, A and B Stiffness Coefficients for each crush zone

* Steer Angle applies only if the Trajectory Simulation option was selected.

Position/Velocity

Each vehicle is positioned relative to the earth-fixed coordinate system by supplying the X,Y,Z coordinates of its CG, and roll (ϕ), pitch (θ) and yaw (ψ) angles about the vehicle x, y and z axes, respectively (Table 2-5).

> **NOTE:** In EDCRASH, +230 degrees is not the same as −130 degrees because the relative magnitude between two angles implies the rotation direction! For example, if the impact heading angle is 180 degrees and the rest heading angle is 230 degrees, the change in heading angle between impact and rest is +50 degrees clockwise; if the rest heading angle is −130 degrees, the change in heading angle is −310 degrees and the direction of rotation is counter-clockwise. Refer to the HVE or HVE-2D User's Manual for more information.
>
> **NOTE:** In HVE-2D, Z is equal to the CG height above ground, and roll and pitch are equal to 0.0.
>
> **NOTE:** In HVE, Z, roll and pitch are supplied automatically using AutoPosition.

EDCRASH uses the following positions:

- **Begin Braking** — The X,Y coordinates and heading angle of the vehicle when the brakes are applied before impact.
- **Impact** — The X,Y coordinates and heading angle of the vehicle at impact.

> **NOTE:** The positions of two vehicles at impact should overlap such that they share the same impulse center.

- **Point-on-curve (POC)** — The X,Y coordinate on a curved path between impact and end-of-rotation or rest.

> **NOTE:** Only the X,Y coordinate is required; the heading angle is not used.

- **End-of-rotation (EOR)** — The X,Y coordinate and heading angle that specify where the vehicle's motion changed from rotating/lateral skidding to pure rollout.
- **Final/Rest** — The X,Y coordinates and heading angle of the vehicle at its rest position. A velocity may also be entered. This value is used as the final velocity at the end of the path.

Positions are not required. However, if an estimate of impact speed is desired, Impact and Rest positions must be supplied. Begin Braking, End-of-rotation and Point-on-curve positions are optional.

Driver Controls

EDCRASH uses the Driver Controls, Wheel Data option. The Wheel Data dialog allows the user to enter the following parameters:

Pre-impact Wheel Lock-up — The total combined wheel lock-up (percent of available friction used by all wheels) by the vehicle during its travel from the user-entered Begin Braking position to the Impact position.

Typical values for non-braking rolling resistance for passenger car tires are provided for reference in Table 2-6 [11]. These values should be entered in the Driver Controls – Brakes dialog using the Percent Available Friction option. Representative values for locked-wheel (slide) friction coefficients for passenger car tires on a variety of surfaces are also provided, in Table 2-7 [10]. While the table is very complete, EDC makes no claim as to the accuracy of the data. The user is urged to perform thorough research in order to supply EDCRASH with the best possible data.

Rot/Lat Skidding — A checkbox. Choose this option if the vehicle's sideslip angle was changing during the post-impact phase.

> **NOTE:** If Rot/Lat Skidding is selected, EDCRASH uses the modified Marquard analysis to account for vehicle spinning.

% Lock-up — The percent of available longitudinal friction used by each tire. The entered value is assumed constant during the entire post-impact phase.

> **NOTE:** Enter only the longitudinal component! If the vehicle is sliding laterally, EDCRASH will determine that condition and account for it. If you also account for the lateral sliding, it will be accounted for twice!

Steer Angles — The constant steer angle at each tire.

Table 2-6: Rolling Resistance Braking Inputs for Pavement [11]

Tire/Wheel Condition	% Available Friction
Normal Inflation	0.010 / μ
Partial Inflation	0.013 / μ
Damaged	0.0 to 1.0
Engine Braking — High Gear	0.150 / μ to 0.200 / μ
Engine Braking — Low Gear	0.200 / μ to 0.400 / μ

Table 2-7: Tire-Ground Friction Coefficients on Various Surfaces [10]

Surface	Dry <30 mph	Dry >30 mph	Wet <30 mph	Wet >30 mph
Portland Cement				
— New, Sharp	0.80–1.20	0.70–1.00	0.50–0.80	0.40–0.75
— Traveled	0.60–0.80	0.60–0.75	0.45–0.70	0.45–0.65
— Polished	0.55–0.75	0.50–0.65	0.45–0.65	0.45–0.60
Asphalt or Tar				
— New, Sharp	0.80–1.20	0.65–1.00	0.50–0.80	0.45–0.75
— Traveled	0.60–0.80	0.55–0.70	0.50–0.80	0.45–0.75
— Polished	0.55–0.75	0.45–0.65	0.45–0.65	0.40–0.60
— Excess Tar	0.50–0.60	0.35–0.60	0.30–0.60	0.25–0.55
Gravel				
— Packed, Oiled	0.55–0.85	0.50–0.80	0.40–0.80	0.40–0.60
— Loose	0.40–0.70	0.40–0.70	0.45–0.75	0.45–0.75
Cinders				
— Packed	0.50–0.70	0.50–0.70	0.65–0.75	0.65–0.75
Rock				
— Crushed	0.55–0.75	0.55–0.75	0.55–0.75	0.55–0.75
Ice				
— Smooth	0.10–0.25	0.07–0.20	0.05–0.10	0.05–0.10
Snow				
— Packed	0.30–0.55	0.35–0.55	0.30–0.60	0.30–0.60
— Loose	0.10–0.25	0.10–0.20	0.30–0.60	0.30–0.60

Damage Profile

EDCRASH uses the CDC to assign an initial damage profile (Damage Width, Crush Depths, Midpoint Offset). The Collision Deformation Classification (CDC) is a seven-character code which describes the vehicle damage. The characters in the CDC identify the Principal Direction of Force (PDOF) in clock direction, the impacted surface (front, right, back, or left), the shape of the damage profile, and the extent of maximum penetration. If a more accurate direction than the clock direction is known, the PDOF may be entered in degrees after the CDC. Detailed explanations of the parameters making up the CDC definitions are found in the HVE-2D User's Manual, Appendix V.

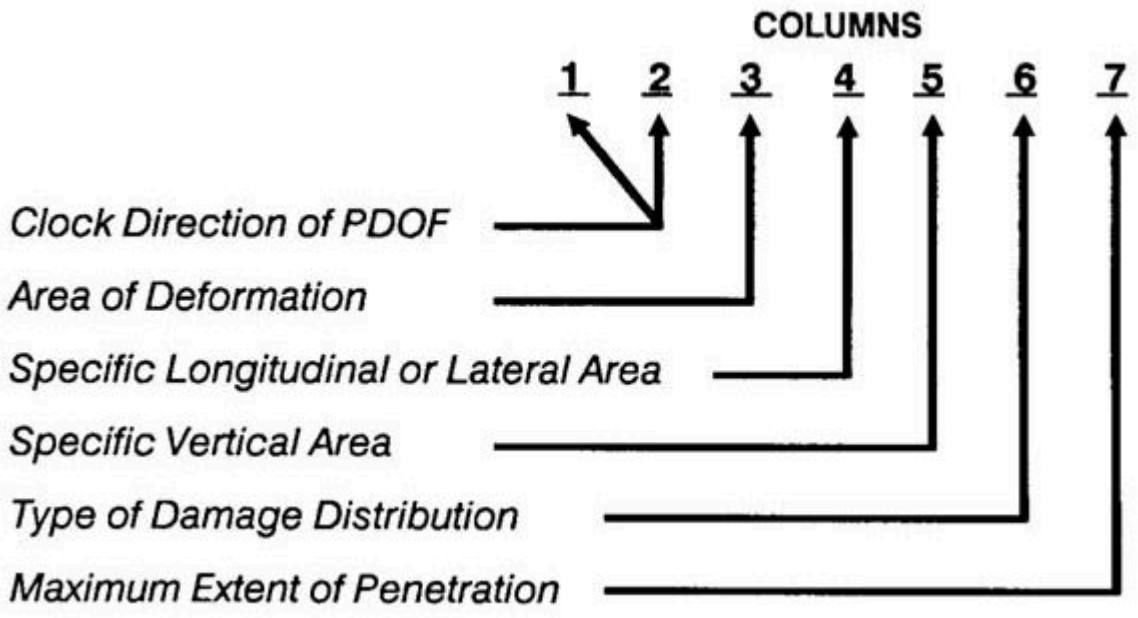


Figure 2-4: Definition of each column within the seven-character CDC code.

After entering the CDC, the damage profile may be edited by over-riding the default width, crush depths and damage offset. In addition, up to 10 crush depths may be entered, and up to 9 sets of A and B stiffness coefficients may be supplied. To delete the damage profile, enter

None

in the CDC field.

> **NOTE:** The Damage Profile dialog displays barrier results (Delta-V, damage energy and force) for the current vehicle. Please note these results do not apply to a 2-vehicle collision!

Use Newton's 3rd Law — Clicking on this checkbox causes EDCRASH to calculate the PDOF for the selected vehicle based on the vehicles' impact heading angles and the PDOF for the other vehicle. This is a convenient way to assign the PDOF for one vehicle.

> **NOTE:** You cannot use this checkbox for both vehicles.

Payload

The Payload Data are not used by EDCRASH. Payload inertias may be added to the vehicle inertias and the CG may be moved longitudinally using the Move CG dialog.

> **NOTE:** Lateral and vertical relocation of the CG are not supported by EDCRASH.

Simulation Controls

If the Trajectory Simulation option is selected, EDCRASH uses the Vehicle Trajectory integration timestep and the maximum simulation time parameters in the Simulation Controls dialog (see Options Menu, Simulation Controls).

Table 2-8: Simulation Control Parameters Used By EDCRASH

Parameter	Description
Vehicle Trajectory Integration Timestep	The integration timestep used by the numerical integration routine
Output Interval	The timestep used to send output results back to HVE
Maximum Simulation Time	The maximum simulation time determines how long the simulation is allowed to run before normal termination
Min Linear Velocity	The linear velocity used to terminate the run (if the linear and angular velocities for both vehicles are simultaneously less than these termination velocities, the run terminates)
Min Angular Velocity	The angular velocity used to terminate the run (see above)

Calculation Options

EDCRASH has the following calculation options:

- Program Options
- Separation Velocity Basis
- Consistency Checks
- Simulation Convergence Criteria

These options control the basic execution of an EDCRASH event. The current EDCRASH calculation options are displayed in the EDCRASH Program Data output report (refer to the following chapter). Each of these options is described below. For a complete description of every control in the dialog, see Calculation Options for EDCRASH.

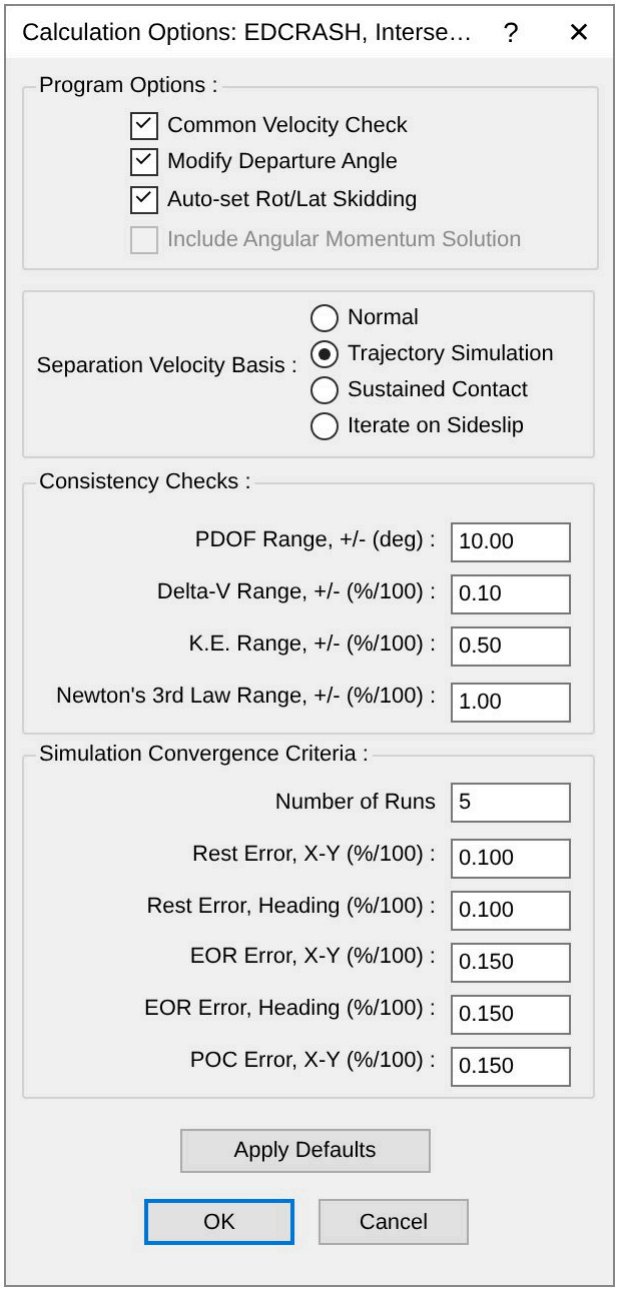


Figure 2-5: EDCRASH Event Calculation Options dialog.

Program Options

During execution of an EDCRASH event, certain features may be turned on or off. These features are:

- **Common Velocity Check** (default = TRUE) — The EDCRASH damage procedure assumes the vehicles' impulse centers reach a common earth-fixed velocity at the end of the collision phase. The Common Velocity Check compares the separation velocities for both vehicles to determine if this condition is satisfied. EDCRASH produces a warning or error message if the condition is not satisfied (see Chapter 6, Messages, for more information).

> **NOTE:** The Common Velocity Check is performed during a normal CRASH3 run.

- **Modify Departure Angle** (default = TRUE) — If a point on curve is not entered, but a vehicle's post-impact phase has an angular separation velocity and a change in heading angle between separation and end of rotation (or rest), EDCRASH modifies the departure angle using an empirical relationship [3].

> **NOTE:** Modify Departure Angle is performed during a normal CRASH3 run.

- **Auto-set Rot/Lat Skidding** (default = TRUE) — The Event Wheel Data dialog includes a check box, labeled Rot/Lat Skidding. That check box is used by EDCRASH to invoke the modified Marquard analysis [3, 15] for vehicles spinning after impact. Enabling this option causes EDCRASH to automatically assign the status for that program option. When enabled, EDCRASH sets the Rot/Lat Skidding flag to TRUE under the following circumstances: (a) the change in heading angle requires a tighter turn radius than the vehicle is capable of (as defined by its wheel base and maximum steer angle), or (b) the departure sideslip angle exceeds 10 degrees.

> **NOTE:** The Auto-set Rot/Lat Skidding feature is not included in CRASH3.

- **Include Angular Momentum Solution** (default = FALSE) — When checked, EDCRASH includes a conservation of angular momentum solution in addition to the standard linear momentum solution. *(updated: this fourth check box appears in the current Calculation Options dialog but is disabled (grayed out) and cannot be changed.)*

If all of the above options are turned off, EDCRASH performs a simplistic analysis comparable to what is traditionally done on a hand-held calculator.

Separation Velocity Basis

EDCRASH has the following user-selectable trajectory model options:

- **Normal** — Choosing Normal causes EDCRASH to perform its standard, energy-based calculations to provide an estimate for separation forward, lateral and angular velocities and departure angle.
- **Trajectory Simulation** — Choosing Trajectory Simulation causes EDCRASH to perform its standard, energy-based calculations (same as choosing Normal, above), and then use these separation velocities and departure angles as the initial conditions for a trajectory simulation. *(updated: this option does not support vehicles with dual tires — a dual tire at any wheel position is rejected with a fatal error at event initialization. The other three choices are unaffected.)*
- **Sustained Contact** — Choosing Sustained Contact causes EDCRASH to use a weighted drag factor based on the wheel lock-ups and weights of the individual vehicles.
- **Iterate on Sideslip** — *(updated: the current dialog offers a fourth radio button, Iterate on Sideslip, which requests an iterative solution on vehicle sideslip angle. This option is not supported by the current EDCRASH physics engine; selecting it causes the event to terminate with an error.)*

> **NOTE:** You cannot choose both Sustained Contact and Trajectory Simulation because the EDCRASH Trajectory Simulation does not account for the inter-vehicle contact force during the post-impact phase.

Consistency Checks

EDCRASH performs a series of internal consistency checks to confirm that various individual pieces of data are consistent with each other. When results are found to be inconsistent, as determined by these user-editable ranges,

messages are produced and displayed in the Messages Output Report (refer to Chapter 6, Messages). The following internal consistency checks are performed:

- **PDOF Range** (default = ±10 deg) — If the collision type is oblique and the user also enters damage data for both vehicles, EDCRASH can compare the PDOFs computed by the momentum analysis with the values entered by the user. If the difference between the momentum-based and user-entered values exceeds the PDOF Range, a message is displayed in the Messages Output Report.
- **Delta-V Range** (default = ±10%, entered as 0.10) — If the collision type is oblique and the user also enters damage data for both vehicles, EDCRASH can compare the delta-Vs computed by the momentum analysis with the results computed by the damage analysis. If the difference between the momentum-based and damage-based results exceeds the Delta-V Range, a message is displayed in the Messages Output Report.
- **K.E. Range** (default = ±50%, entered as 0.50) — If the collision type is oblique and the user also enters damage data for both vehicles, EDCRASH can compare the kinetic energy loss computed using the momentum-based impact speeds with the kinetic energy loss computed using the damage-based impact speeds. This difference is also directly compared with the damage energy calculated from the damage analysis. If the difference in kinetic energy from the momentum-based or damage-based impact speeds differs from the damage energy computed from the damage analysis by more than the K.E. Range, a message is displayed in the Messages Output Report.
- **Newton's 3rd Law Range** (default = ±100%, entered as 1.00) — If damage data are entered for two vehicles in a collision, EDCRASH can compare the peak forces computed independently for each vehicle. If the difference in peak forces exceeds the Newton's 3rd Law Range, a message is displayed in the Messages Output Report.

> **NOTE:** For barriers, the collision force is not calculated independently; the force on the barrier is set equal to the force on the deformable vehicle.

Simulation Convergence Criteria

If the Separation Velocity Basis was selected as Trajectory Simulation (see above), a series of tests are performed comparing the simulated path with the actual path (i.e., the path defined by the user-entered path positions). EDCRASH then reports the difference between the simulated path and actual path by calculating the distance between the individual simulated and actual path positions. The difference is reported as an error for each path position entered by the user (i.e., point on curve, end of rotation and rest). If one or more errors exceeds the allowable value(s), the separation velocities are adjusted and the simulation is re-executed.

For the simulation to successfully converge, each error must be less than that specified in the Simulation Convergence Criteria. When the difference between the simulated and actual paths is acceptable for all positions, the trajectory simulation is said to have converged. The simulation will be re-executed (up to 5 runs by default) in an effort to achieve convergence. If, after the specified number of runs, the simulation has not converged, the separation conditions that produced the smallest total error are used by EDCRASH.

The default convergence tolerances are: Rest Error X-Y = 0.10, Rest Error Heading = 0.10, EOR Error X-Y = 0.15, EOR Error Heading = 0.15, POC Error X-Y = 0.15 (all as fraction, %/100). See Calculation Options for EDCRASH for details.

The Program Data report displays all the calculation options used for the current EDCRASH event (see also Chapter 3). The results for the trajectory simulation, if selected, are also displayed in the Program Data Output Report.

Executing an Event

To execute an EDCRASH event, use the Event Controller, a component of the Event Editor.



Figure 2-6: Event Controller, used for starting and stopping event execution.

The Event Controller's buttons have the following functions:

- **Reset** — Reinitialize the calculation model for re-execution
- **Rewind to Start** — Return to the start of the simulation
- **Reverse** — Play the simulation backwards
- **Pause** — Pause the simulation
- **Play** — Execute the EDCRASH event or play the simulation forwards
- **Advance to End** — Advance to the end of the simulation

Because EDCRASH is a reconstruction program (as opposed to a simulation program), it performs a single set of calculations and terminates. Therefore, the only buttons meaningful to EDCRASH are the Play and Reset buttons. Pressing Play causes the EDCRASH calculations to be performed, then the program automatically terminates. Pressing Play again will cause the calculations to be repeated. Pressing Reset causes the event output (next chapter) to be erased; it does not affect the event input.

> **NOTE:** EDCRASH is fundamentally a reconstruction program, not a simulation program. Thus, pressing Play executes the calculations, but since there is no time-dependent simulation to display, nothing appears to happen. However, if you watch your Key Results windows, you will see the effects of execution.
>
> **NOTE:** You will probably find it very useful to execute an EDCRASH run, make changes to the event set-up options (see previous section), and re-execute the event. You will very quickly discover the event-related parameters to which the analysis is sensitive.
>
> **NOTE:** If the Trajectory Simulation option is selected, the simulation is performed, but not visualized.
>
> **NOTE:** Remember to use the Options Menu to choose useful options, such as Key Results, Axes and Velocity Vectors.

Previous: Chapter 1 — Program Description · Next: Chapter 3 — EDCRASH Program Output

Chapter 3 — EDCRASH Program Output

This chapter defines the outputs available from an EDCRASH event. The reports produced by EDCRASH are available in the Playback Editor.

Output Overview

EDCRASH produces two types of output reports:

- **Alpha-Numeric Reports** — Reports containing text and numeric information, such as vehicle dimensional parameters
- **Graphic Reports** — Reports containing static visual information, such as momentum diagrams and damage profiles

> **NOTE:** Each of these reports may be printed on the system printer. To print a report, click on the menu bar of the desired output report (the menu bar will change colors indicating that it is selected), then either choose Print from the Files menu or click on the Print icon in the toolbar. Refer to the User's Manual for further details.

To view any of these reports, perform the following steps:

1. Choose Playback Mode. The Playback Editor is displayed.
2. Choose Add New Object. The Report Window Information dialog is displayed, showing a list of all the current events in the case.
3. Select an EDCRASH event from the list. Once an event is selected, the Report Type list is displayed, containing all the available reports for the selected event.
4. Select the desired report in the Report Type list. To open several reports at once, select more than one (*Select All* selects every report); each opens in its own Report Window.
5. If desired, edit the Name. A default name is supplied for the report window. The name is user-editable, and does not affect calculations.

> **NOTE:** Duplicate Report Window names are not allowed. Because the name is truncated to 30 characters, you should ensure that two truncated names are not the same.

1. Click OK to display the report.

Alpha-Numeric Reports

EDCRASH produces the following alpha-numeric reports:

- **Accident History** — A table of initial and final positions and velocities computed by EDCRASH; also includes restitution information
- **Damage Data** — A table of damage-based results produced by EDCRASH
- **Event Data** — A table of all the user-entered scene data used by EDCRASH
- **Messages** — A list of messages produced by the current run

- **Program Data** — A table containing program control information for the current run
- **Vehicle Data** — A series of tables containing the vehicle data used by EDCRASH

Accident History

The Accident History Report displays a table of initial and final positions and velocities for the vehicle.

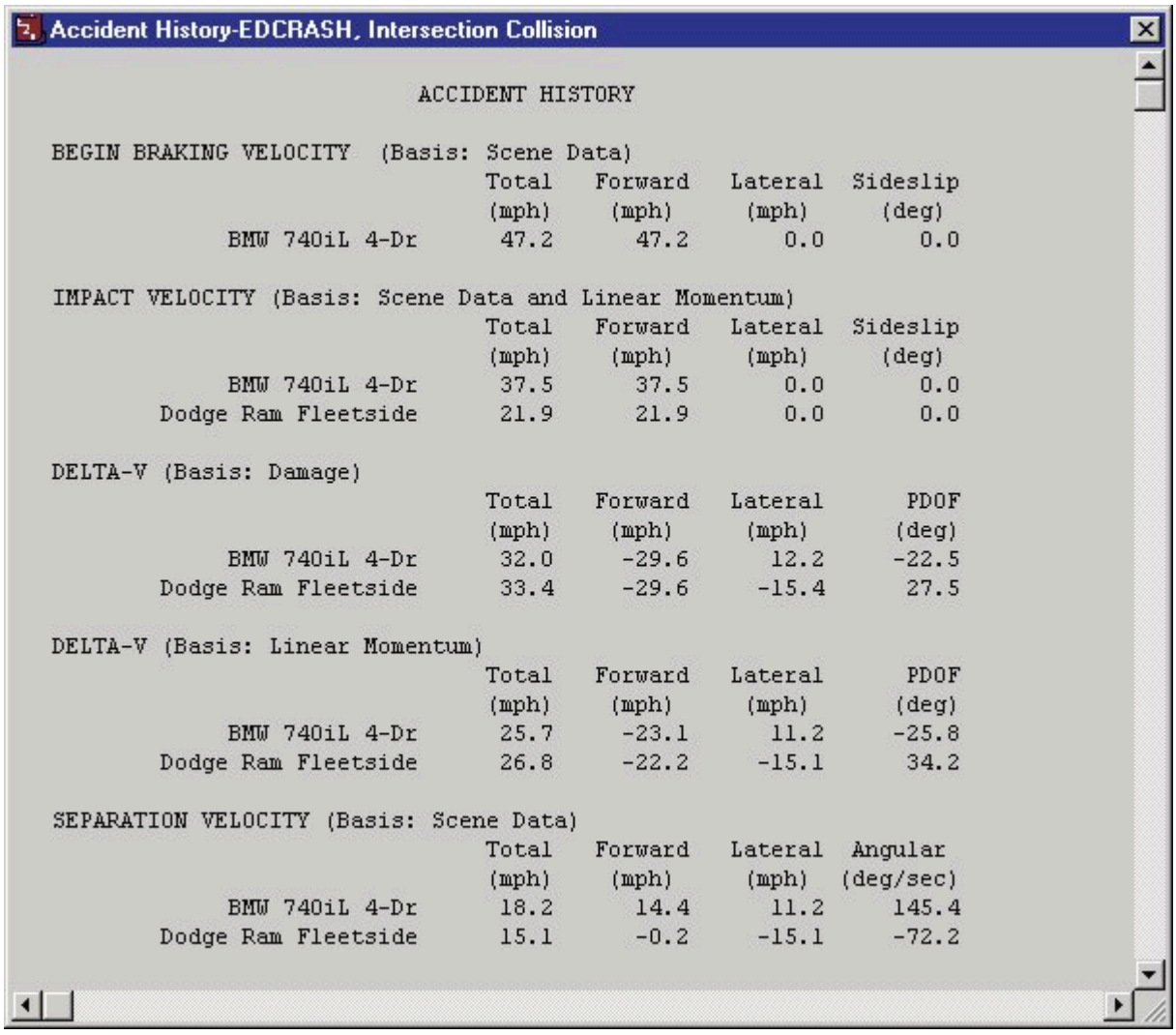


Figure 3-1: Typical Accident History Output Report produced by EDCRASH.

- **Begin Braking** — Total velocity, forward and lateral velocity components, and sideslip angle for each vehicle for which a begin braking position was given.
- **Impact** — Total velocity, forward and lateral velocity components, and sideslip angle for each vehicle at impact.

> **NOTE:** The total velocity is the vector sum of the forward and lateral components, i.e.: $\vec{V} = \vec{V}_{fwd} + \vec{V}_{lat}$
>
> **NOTE:** A sideslip angle greater than +90 degrees or less than −90 degrees implies the vehicle is moving backwards (i.e., the forward velocity component is negative) at impact.

Next to "Impact Velocity" is the basis for results. It specifies which delta-V calculation method (damage or linear momentum) was used in the computation of impact speed. For collinear impact, the results will be based on impact-to-

rest phase calculations (trajectory) and vehicle damage. Otherwise, the results will be based on trajectory and the conservation of linear momentum.

- **Delta-V** — The change in velocity and forward and lateral components of velocity change for each vehicle due to the collision. Also, Principal Direction of Force, PDOF.

If the collision was collinear, only the damage-based delta-V will be displayed. If the collision was oblique, a delta-V computed from scene data (i.e., linear momentum) will be displayed in addition to the damage-based delta-V.

> **NOTE:** If a fatal error occurred, impact speed will not be reported; the calculated results will be limited to the damage-based delta-V.

When the momentum solution is used, two important means of helping to ensure valid results are available (see also Warning Messages):

- the delta-V computed by momentum should be approximately equal to (within ±10% of) the delta-V computed by damage
- the value of the momentum-based PDOF should be approximately equal to (within ±10% of) the damage-based PDOF

- **Separation Velocity** — Total velocity, forward and lateral velocity components, and sideslip angle for each vehicle at separation.

> **NOTE:** Separation velocity is only computed when scene data are entered (see Calculation Method).

- **Relative Velocity** — The closing velocity of the vehicles at impact and the coefficient of restitution.

By definition, the relative velocity is computed in a direction defined by the line between the vehicle CGs. The coefficient of restitution should be positive (a negative value results in a warning message; see Warning Messages).

Damage Data

The Damage Data Report includes the following information:

- **CDC** — User-entered Collision Deformation Classification for each vehicle.
- **PDOF** — User-entered Principal Direction of Force for each vehicle. This is the direction in which the peak collision force (see below) acts.
- **Damage Width** — User-entered Damage Width for each vehicle.
- **Crush Depths** — User-entered Crush Depths for up to nine crush zones on each vehicle.
- **Damage Midpoint Offset** — User-entered distance from the vehicle CG to the middle of the damage region for each vehicle.
- **Damage Energy** — The calculated damage energy for each vehicle.

The energy dissipated by damage is based on the damage data (damage profile and crush stiffness coefficients) and not on the conservation of energy. A check for agreement with the conservation of energy is performed. If the results are not consistent, a warning message is issued (see Messages). This is also an important means of helping to ensure valid results.

- **Peak Collision Force** — The calculated peak collision force for each vehicle. The peak collision force acts through the impulse center in the direction of the PDOF.
- **Moment Arm of PDOF** — Perpendicular distance from the vehicle CG to the peak collision force.

> **NOTE:** A positive moment arm produces clockwise rotation; a negative moment arm produces counter-clockwise rotation. These directions should normally be consistent with the user-entered rotation directions. Otherwise a warning message will be issued (see Warning Messages).

- **Impulse Center** — The vehicle-fixed x,y coordinates for the center of impulse for each vehicle.

The impulse center is calculated from the summation of forces and moments acting on the vehicle. The peak collision force acts through the impulse center in the direction of the PDOF.

> **NOTE:** For a homogeneous vehicle (i.e., equal stiffness coefficients in all crush zones), the impulse center is the same as the damage centroid.

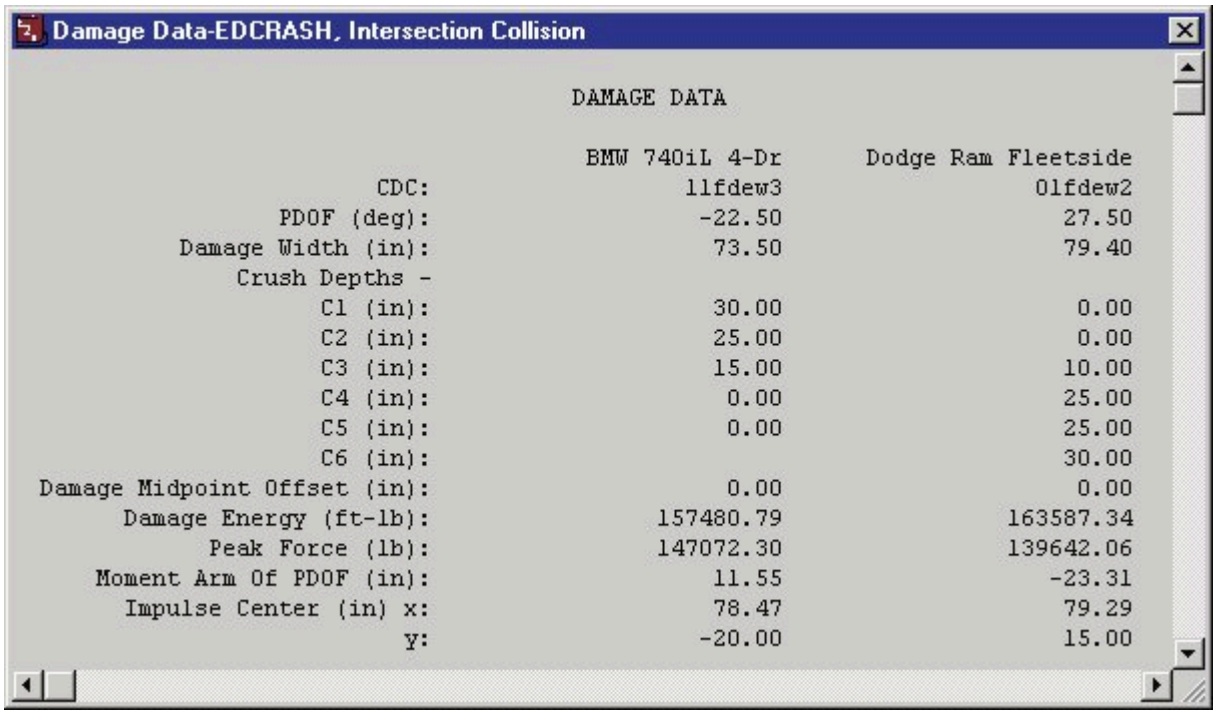


Figure 3-2: Typical Damage Data Output Report produced by EDCRASH.

Event Data

The Event Data Report includes the following scene information for each vehicle if scene data were entered:

- **Impact Information** — The user-entered impact position and orientation for each vehicle. Also includes angular velocity and sideslip angle at impact.

> **NOTE:** The angular rotation rate at impact will always be zero.
>
> **NOTE:** For collinear collisions, the pre-impact sideslip angle may be modified by EDCRASH to be consistent with the user-entered PDOFs and calculated separation velocities. If the modified sideslip angles are inconsistent with other information, you should carefully review, and perhaps modify, the PDOFs and/or departure angles.

- **Separation Information** — The separation position and orientation for each vehicle. Also includes departure angle and separation linear and angular velocities at separation.

> **NOTE:** The separation positions and headings are identical to the impact positions and headings — the result of assuming a quasi-instantaneous impact.

Separation linear and angular velocities are displayed in the vehicle-fixed coordinate system (the forward and lateral velocity components are relative to the vehicle heading). The separation angle of the velocity vector (or departure angle) is relative to the earth-fixed coordinate system and is the angle used by the momentum analysis to establish the momentum-based delta-V.

The separation velocities are the results of the impact-to-rest phase computations (see Calculation Method). If no rotational or lateral skidding was specified, the angular velocity will be zero and the linear velocity will be based on simple energy relationships. Otherwise, special calculations will be performed which account for simultaneous linear and angular velocity. If a trajectory simulation has been performed, the linear and angular velocities may be modified if the simulation did not converge on the first run.

- **Point-on-curve (POC) Information** — The user-entered X,Y POC position for each vehicle (if entered).
- **End-of-rotation (EOR) Information** — The user-entered X,Y EOR position and orientation for each vehicle (if entered).
- **Final/Rest Information** — The user-entered final/rest position and orientation for each vehicle. Also includes final velocity.

Event Data-EDCRASH, Intersection Collision

SCENE INFORMATION

	BMW 740iL 4-Dr	Dodge Ram Fleetside
Begin Braking, X (ft):	-62.41	
Begin Braking, Y (ft):	48.94	
Begin Braking, Heading (deg):	0.00	
Impact, X (ft):	2.00	15.29
Impact, Y (ft):	48.00	41.90
Impact, Heading (deg):	10.00	130.00
Impact Ang Vel (deg/sec):	0.00	0.00
Impact Sideslip Angle (deg):	0.00	0.00
Separation, X (ft):	2.00	15.29
Separation, Y (ft):	48.00	41.90
Separation, Heading (deg):	10.00	130.00
Separation Angle (deg):	47.84	39.07
Separation, Vtotal (mph):	18.19	15.08
Separation, Fwd Vel (mph):	14.36	-0.24
Separation, Lat Vel (mph):	11.16	-15.08
Separation, Ang Vel (deg/sec):	145.39	-72.18
Final/Rest, X (ft):	13.01	39.05
Final/Rest, Y (ft):	64.96	54.95
Final/Rest, Heading (deg):	135.00	15.00
Final/Rest, Vtotal (mph):	0.00	0.00
Rot/Lat Skid:	Yes	Yes
Impact-to-rest Rotation (deg):	125.00	-115.00
Rotation Direction:	Clockwise	Counter-clockwise

Figure 3-3: Typical Event Data Output Report produced by EDCRASH.

Messages

The Messages Report lists all Fatal, Warning and Note messages produced by the current run. For a complete listing of messages issued by EDCRASH, see Chapter 6.

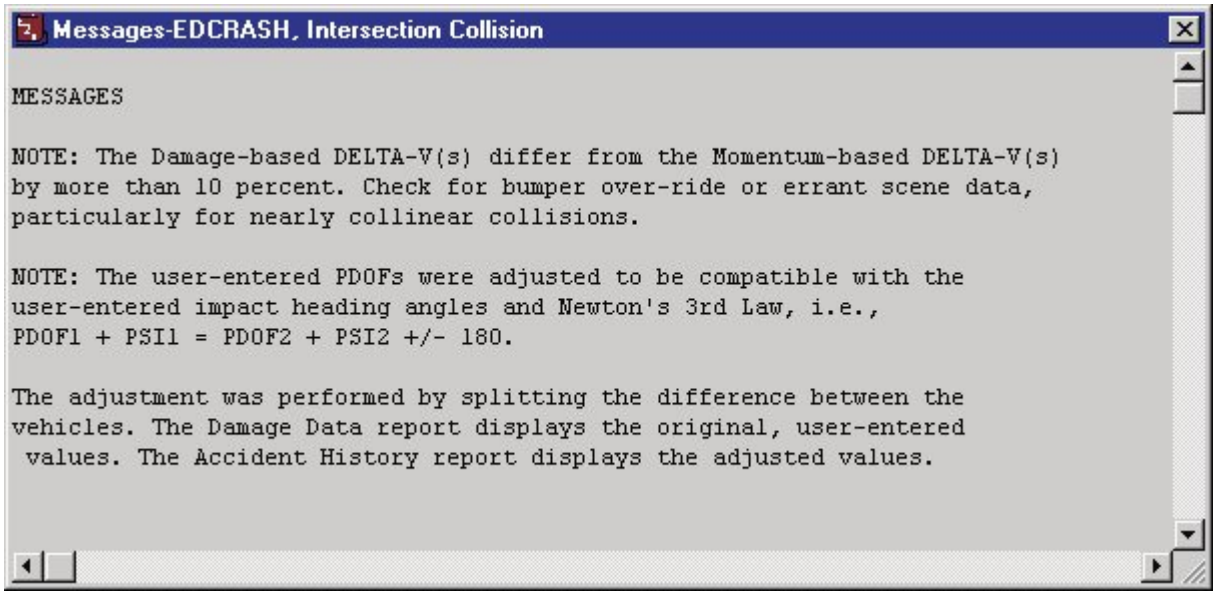


Figure 3-4: Typical Messages Output Report produced by EDCRASH.

Program Data

The Program Data Report displays general program control information for the current run, including:

- **EDCRASH Version Number** — The version of the EDCRASH calculation model used for the run.
- **Program Options** — The status (Yes/No) of the Common Velocity Check, Modify Departure Angle, Auto-set Rot/Lat Skid and Include Angular Momentum options, and the selected Separation Velocity Basis (e.g., Normal).
- **Consistency Checks** — The current PDOF Range (deg), Delta-V Range, K.E. Range and Newton's 3rd Law Range values.
- **Trajectory Simulation Results** — If Trajectory Simulation was selected as the Separation Velocity Basis, the convergence results for the simulation are also displayed.

The Program Data report is a useful record of exactly which calculation options (see Chapter 2 and Calculation Options for EDCRASH) were in effect for the current event.

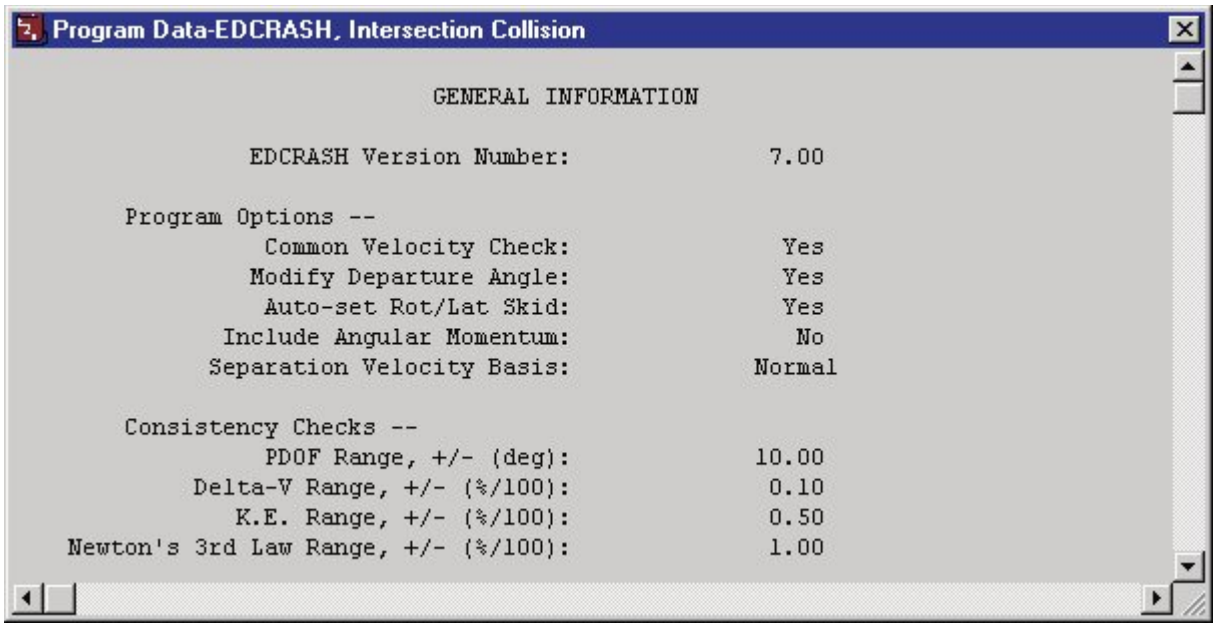


Figure 3-5: Typical Program Data Output Report produced by EDCRASH.

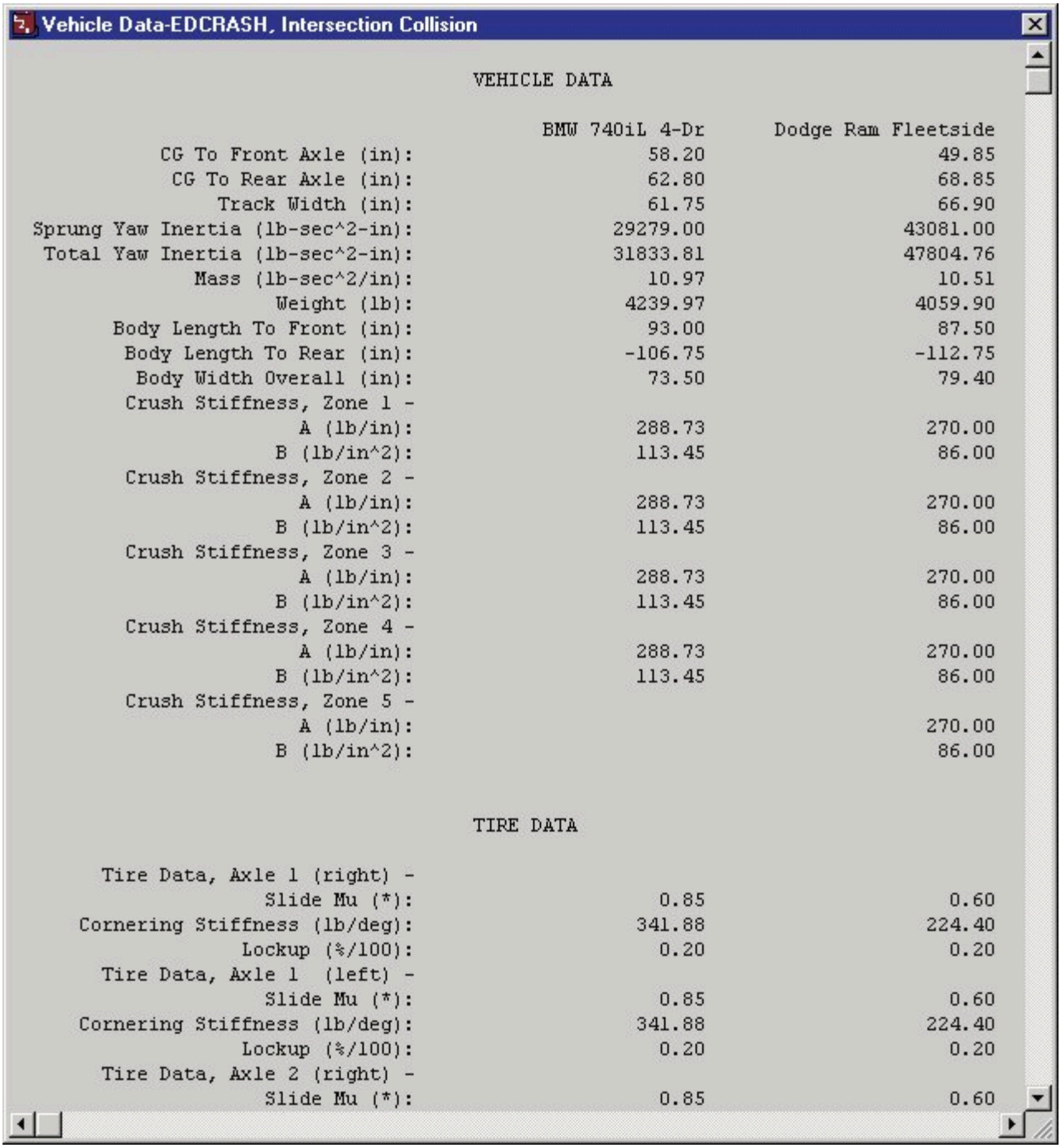
Vehicle Data

The Vehicle Data Report includes the following information:

- **Dimensional, Inertial and Crush Stiffness Properties** — The vehicle dimensional, inertial and crush stiffness parameters that were used by EDCRASH in the current event.

> **NOTE:** The Yaw Inertia value displayed in the Vehicle Data report includes the additional rotational inertia created by the unsprung masses (wheels and axles); thus the value printed is greater than the one displayed in the Vehicle Editor's Inertias dialog.

- **Tire Data** — The tire parameters, cornering stiffness and percent wheel lock-ups used by EDCRASH in the current event.


Vehicle Data-EDCRASH, Intersection Collision

VEHICLE DATA

	BMW 740iL 4-Dr	Dodge Ram Fleetside
CG To Front Axle (in):	58.20	49.85
CG To Rear Axle (in):	62.80	68.85
Track Width (in):	61.75	66.90
Sprung Yaw Inertia (lb-sec^2-in):	29279.00	43081.00
Total Yaw Inertia (lb-sec^2-in):	31833.81	47804.76
Mass (lb-sec^2/in):	10.97	10.51
Weight (lb):	4239.97	4059.90
Body Length To Front (in):	93.00	87.50
Body Length To Rear (in):	-106.75	-112.75
Body Width Overall (in):	73.50	79.40
Crush Stiffness, Zone 1 -		
A (lb/in):	288.73	270.00
B (lb/in^2):	113.45	86.00
Crush Stiffness, Zone 2 -		
A (lb/in):	288.73	270.00
B (lb/in^2):	113.45	86.00
Crush Stiffness, Zone 3 -		
A (lb/in):	288.73	270.00
B (lb/in^2):	113.45	86.00
Crush Stiffness, Zone 4 -		
A (lb/in):	288.73	270.00
B (lb/in^2):	113.45	86.00
Crush Stiffness, Zone 5 -		
A (lb/in):		270.00
B (lb/in^2):		86.00

TIRE DATA

Tire Data, Axle 1 (right) -		
Slide Mu (*):	0.85	0.60
Cornering Stiffness (lb/deg):	341.88	224.40
Lockup (%/100):	0.20	0.20
Tire Data, Axle 1 (left) -		
Slide Mu (*):	0.85	0.60
Cornering Stiffness (lb/deg):	341.88	224.40
Lockup (%/100):	0.20	0.20
Tire Data, Axle 2 (right) -		
Slide Mu (*):	0.85	0.60

Figure 3-6: A portion of a typical Vehicle Data output report produced by EDCRASH.

Graphic Reports

EDCRASH produces the following Graphic reports:

- **Damage Profiles** — A plan view of the vehicles showing their damage profiles (damage width, depth and midpoint offset).
- **Momentum Diagrams (Scene and Damage)** — A vector diagram showing the pre-impact and post-impact momentum vectors for each vehicle. The scene-based diagram uses impact velocity calculated from the momentum-based delta-V; the damage-based diagram uses the impact velocity calculated from the damage-based delta-V.

- **Site Drawing** — A static perspective view of the accident site showing the vehicles at their user-entered positions.

Damage Profiles

The Damage Profile Graphic Report includes the following information:

- **Plan View** — Vehicle outline and damage profile shown in plan view. The vehicles are drawn to scale (the scale is determined such that the vehicle(s) fit into the allotted space). The damage profile shows the width, crush depths, damage midpoint offset, PDOF, and center of impulse.

The Damage Profiles are very useful for confirming the damage data were entered properly (see Warning Messages). This is extremely helpful in debugging.

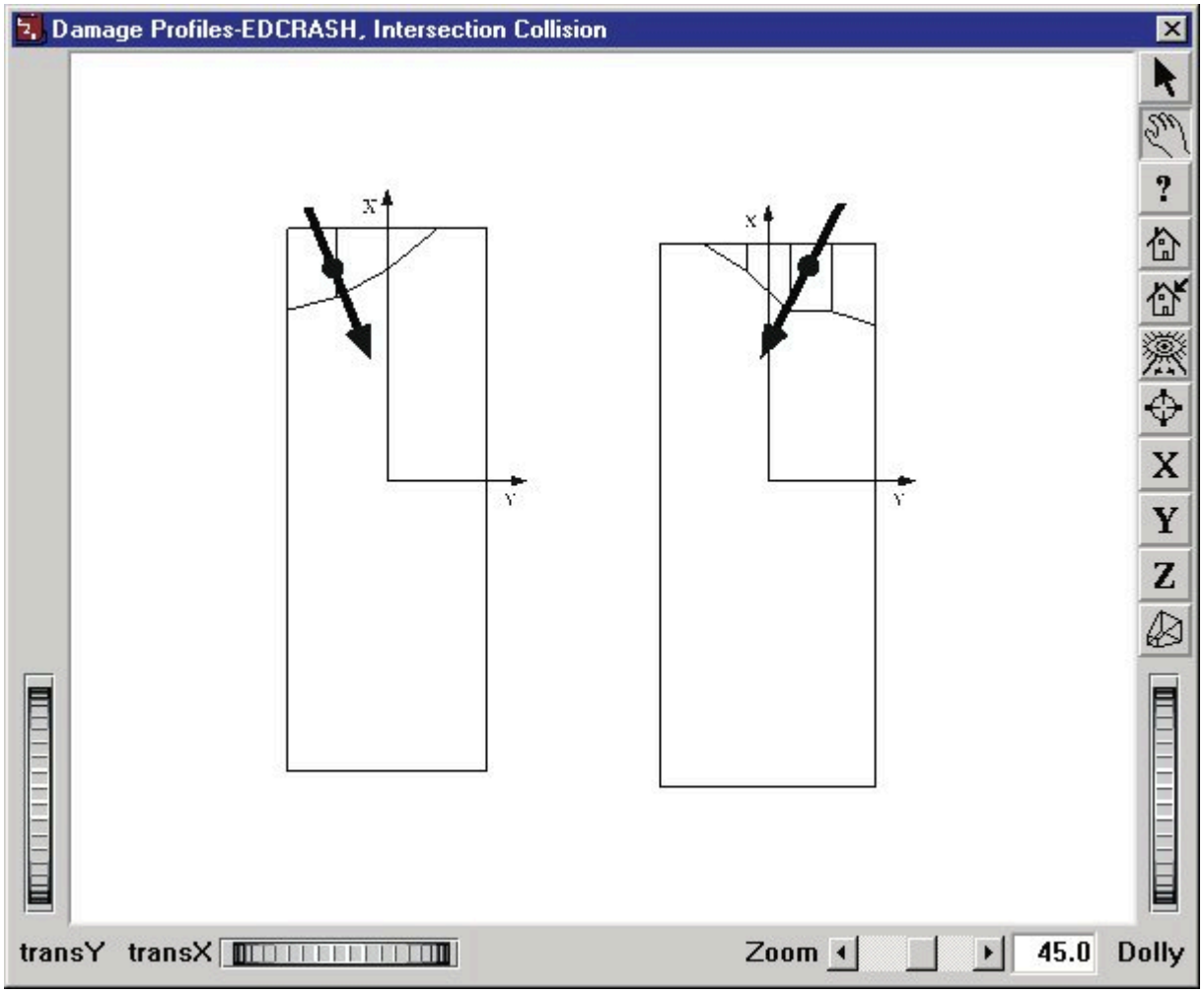


Figure 3-7: Typical Damage Profiles output report produced by EDCRASH.

Momentum Diagram

The Momentum Diagram Report includes the following information:

- **Pre-impact and Post-impact Momentum Vectors** — Vectors displayed to scale (the scale is determined by HVE to allow the vectors to fill the viewer) representing each vehicle's momentum (mass × velocity) at the instant before and after the collision.
- **Impulse Vector** — A vector showing the earth-fixed direction of the impulse vector, labeled with an "I".

- **Total Momentum** — A vector showing the total system momentum (before and after impact; they are, of course, the same).

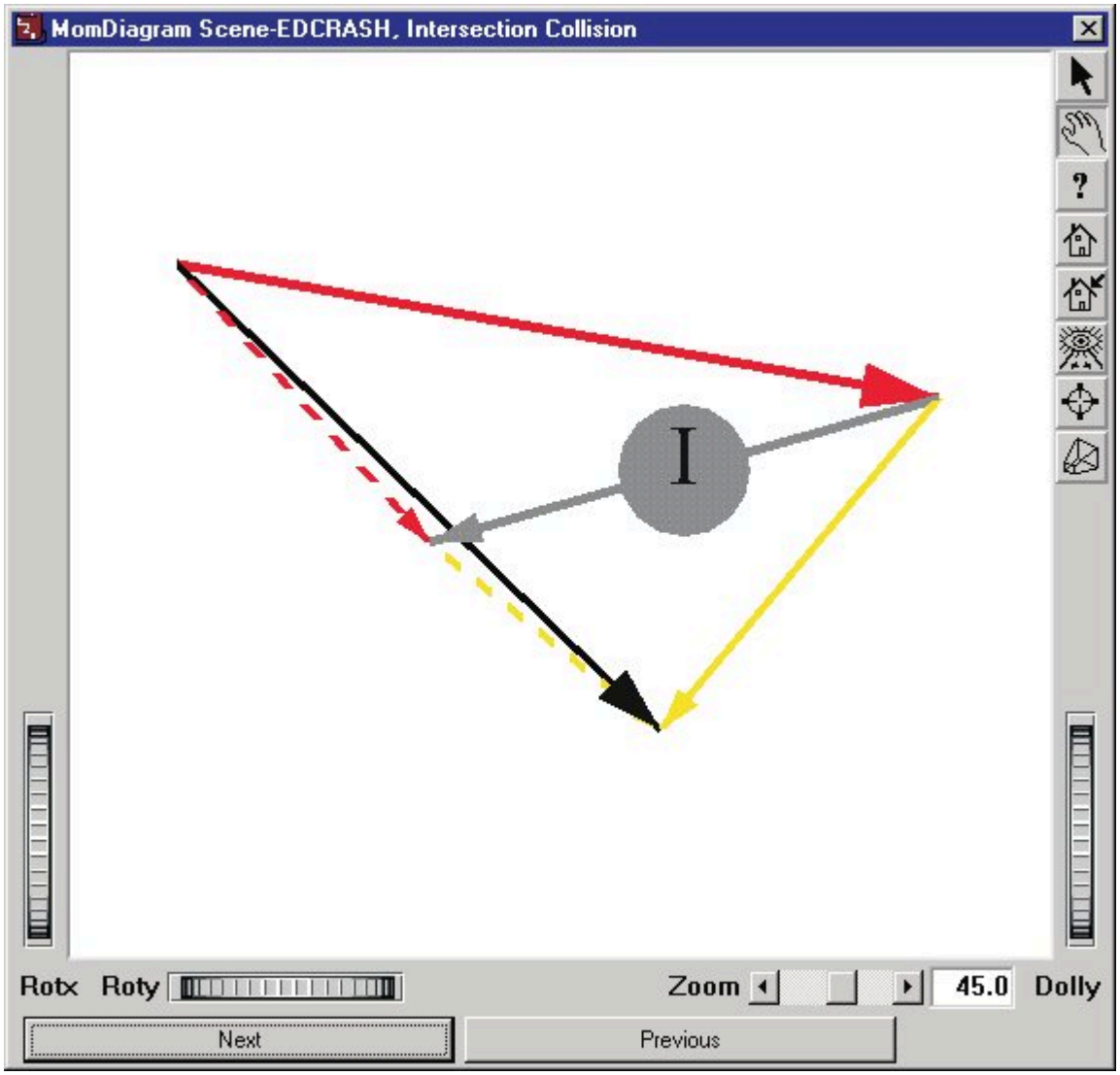


Figure 3-8: Typical Momentum Diagram output report produced by EDCRASH.

Site Drawing

The Site Drawing Graphic Report includes the following information:

- **Crash Site Environment** — A user-selectable view (plan or perspective) of the environment where the crash occurred.
- **Vehicle Positions** — The vehicles are displayed at each position supplied for the event.

The Site Drawing is very useful for confirming that the scene data were entered properly (see Warning Messages).

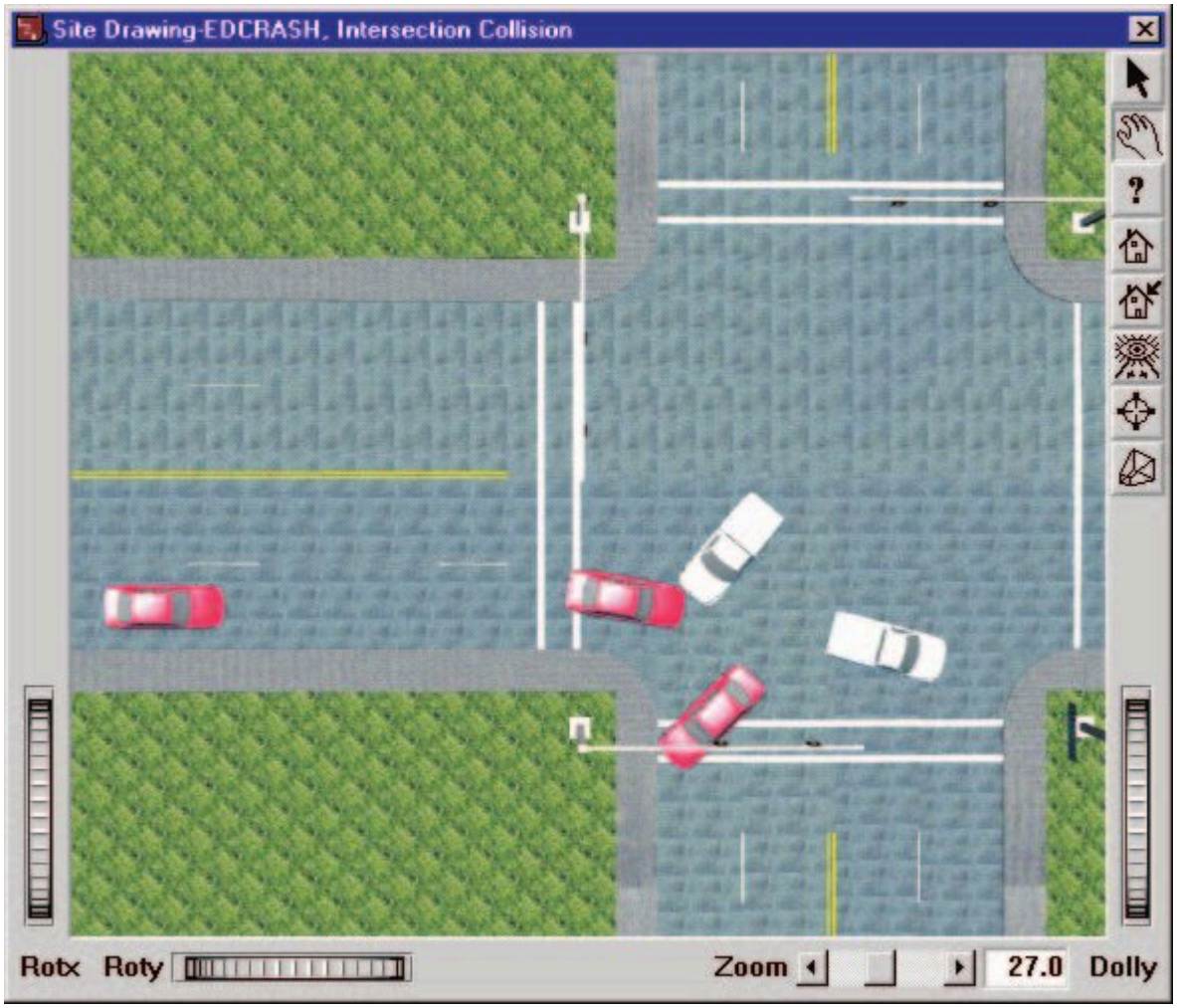


Figure 3-9: Typical Site Drawing output report produced by EDCRASH.

Previous: Chapter 2 — Program Input · Next: Chapter 4 — Calculation Method

Chapter 4 — Calculation Method

Basis for Analysis

The analytical techniques used by EDCRASH to calculate the results are the same as previous CRASH programs, which are well documented. For this reason, the following discussion speaks only to the general analytical approach. For a detailed description of the procedures and algorithms, the interested reader is referred to the EDCRASH Training Manual [15] and EDCRASH Source Code [9]. The applications and limitations of CRASH are also described in the technical literature [19]. Several other references are listed in the References section at the end of this manual.

All three accident phases are analyzed by EDCRASH. These are the pre-impact phase, impact phase and the impact-to-rest phase. The general methods used to analyze each phase are described below.

Impact Phase

This phase of analysis includes all of the dynamics associated with inter-vehicle contact. The major criterion is the delta-V (velocity change), that is, the reduction (or increase) in vehicle velocity directly attributable to the force of impact. The approach used depends directly upon the angle of impact (specifically, the included angle between the pre-impact velocity vectors).

If the included angle between the pre-impact velocity vectors is equal to or less than 10 degrees, the impact is termed *collinear* and the damage-based solution is used. The impact is also treated as *collinear* when the velocity vectors are within 10 degrees of being anti-parallel (i.e., the included angle is greater than or equal to 170 degrees) — a nearly head-on configuration — and whenever either vehicle is a fixed barrier. In all other cases the impact is termed *oblique* and the linear momentum solution is used.

> **NOTE:** When scene data are not entered, the damage-based solution is used, regardless of the angle of impact, and the results available are limited to the delta-V; impact velocity cannot be computed.

Collinear Impact

The solution for collinear impacts is a semi-empirical analysis which compares the damage produced during the subject impact with damage produced during impacts of known (measured) delta-V. The delta-V (and impact force) are assumed to be linearly proportional to crush depth. Stated another way, this is simply Hooke's Law applied to vehicles.

The damage-based analysis is not based on the conservation of energy. The fact that the damage-based analysis is not dependent on the conservation of energy is very important: it allows for an independent check on the validity of the results (see Messages). Rather, the solution is based on Newton's second law, $F = ma$.

Empirical coefficients determine the spring rate of the vehicle exterior. The spring rate, k, and deformation, δ, are multiplied to yield the summation of external forces on each vehicle mass, m. Based on Newton's second law, the equations for both vehicles are (assuming tire forces are negligible):

$$\Sigma F_1 = k_1 \delta_1 = m_1 a_1$$

and

$$\Sigma F_2 = k_2 \delta_2 = m_2 a_2$$

Because $\Sigma F_1 = \Sigma F_2$, the above equations can be combined into the following differential equation:

$$\frac{m_1 m_2}{m_1 + m_2} \ddot{\delta} + \frac{k_1 k_2}{k_1 + k_2} \delta = 0$$

The problem has been reduced to a single mass system with two springs in series. The solution to this differential equation is

$$\delta = A\sin(\omega t) + B\cos(\omega t)$$

$$\dot{\delta} = \omega A\cos(\omega t) - \omega B\sin(\omega t)$$

where

$$\omega = \sqrt{\frac{k_1 k_2 / (k_1 + k_2)}{m_1 m_2 / (m_1 + m_2)}}$$

This is a boundary value problem with the following initial conditions. At $t = 0$:

$$\delta = 0$$

$$\dot{\delta} = \dot{\delta}_1 - \dot{\delta}_2 = V_{Closing}$$

The first condition states that at the instant of initial contact there is zero deformation, while the second condition states that the rate of initial deformation is equal to the closing velocity.

By expressing the energy stored in each spring as $E = k\delta^2 / 2$, the equation for the system impulse, I, can be written as:

$$\vec{I} = \sqrt{2(E_1 + E_2)\frac{m_1 m_2}{m_1 + m_2}}$$

Once we have the system impulse, it is a simple matter to compute the delta-V for each vehicle:

$$\Delta\vec{V}_1 = \frac{\vec{I}}{m_1}$$

and

$$\Delta\vec{V}_2 = \frac{\vec{I}}{m_2}$$

The spring rate, k, is defined by two empirical coefficients, A and B. These coefficients are derived from barrier crash tests. The A coefficient defines the force per inch of damage width necessary to initiate damage (i.e., if the force is less than A, no damage will occur). The B coefficient defines the spring rate; it determines how much force is required per inch of crush depth per inch of damage width. Default A and B coefficients are assigned when you choose a vehicle. Note the stiffness values are different for front, rear and side impacts. The third character of the CDC determines which coefficients are used. The default coefficients may be changed during Event mode.

Damage-based results are generally improved when the default coefficients are replaced by actual A and B coefficients derived from a crash test. Reference 25 contains A and B coefficients from crash tests for approximately 1500 vehicles.

Computing the damage energy from the crush measurements

The crush profile is entered as a set of equally spaced crush depths $C_1 \ldots C_{n+1}$ measured across a damage width W, dividing the damage into n zones. Within a zone the force per unit of damage width rises linearly with crush depth as

$A + B\,C$, so the crush force and the energy absorbed are

$$F = \frac{W}{n} \sum_{i=1}^{n} [A_i + \frac{B_i}{2}(C_i + C_{i+1})]$$

$$E = \frac{W}{n} \sum_{i=1}^{n} [\frac{A_i(C_i + C_{i+1})}{2} + \frac{B_i}{6}(C_i^2 + C_i\,C_{i+1} + C_{i+1}^2) + G_i]$$

where

$$G = \frac{A^2}{2B}$$

is the energy absorbed in reaching the damage threshold — the energy that went into the structure without producing measurable residual crush. Because the coefficients are carried separately for each zone, the damaged surface need not have uniform stiffness.

The energy obtained here, after the magnification for non-perpendicular crush described below, is the quantity E_1 or E_2 used in the impulse equation above; the force is the Magnitude of Principal Force reported for the vehicle.

(updated: earlier editions described the spring model and the impulse equation but never stated how the A and B coefficients and the measured crush depths produce the damage energy.)

Two modifications are incorporated into the above analysis to make it generally applicable to motor vehicle collisions. For the case of non-perpendicular crush, the energy stored in the spring ($k\delta^2$ / 2) is increased by the value of $1 + \tan^2(\alpha)$, where α is the angle between the PDOF and a line perpendicular to the surface (see Figure 4-1). This *energy magnification factor* accounts for the increased distance, C', through which the crush force acts when compared with the measured crush, C. The factor is not allowed to increase beyond a value of 2.0 (note the tangent increases to infinity as the angle approaches 90 degrees), so the cap takes effect at α = 45 degrees and the factor is 2.0 for every PDOF beyond that.

The magnitude of principal force is corrected for the same non-perpendicular geometry, by dividing it by $|\cos\alpha|$.

(updated: earlier editions gave the energy magnification factor but did not state the angle at which the cap takes effect, and did not describe the corresponding correction applied to the force.)

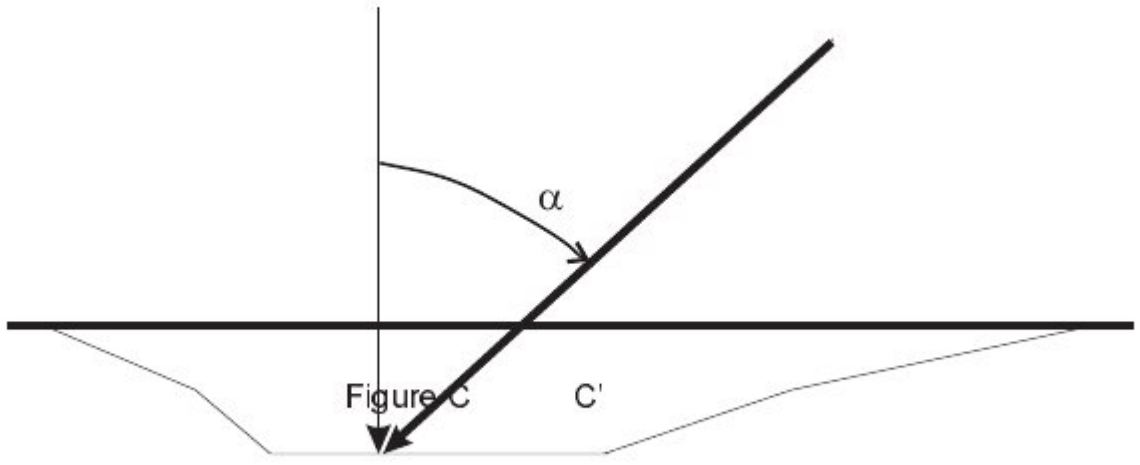


Figure 4-1: Energy Magnification Factor.

The second modification factor is called the *mass reduction factor*, γ,

$$\gamma = \frac{r_{gy}^2}{r_{gy}^2 + h^2}$$

where r_{gy} is the vehicle's radius of gyration and h is the moment (torque) arm caused by the impulse acting in the direction of the PDOF about the center of gravity. The vehicle mass is multiplied by the mass reduction factor in the impulse equation (described earlier) to account for the fraction of the total damage energy which is used to create the angular kinetic energy at separation.

The mass reduction factor is equal to 1.0 for central impact (i.e., an impact in which the PDOF acts through the vehicle's CG). It is always less than 1 for non-central impacts. As a consequence of this fact, a non-central impact always results in a lower delta-V than a central impact for the same damage profile and PDOF.

The damage-based analysis described above is always performed. It provides more than just the delta-V. The additional information includes the energy absorbed by impact and the Magnitude of Principal Force. The user should note that, even if the impact velocity is based on the delta-V computed by the momentum solution, the results for impact energy and force are still based on the damage data.

Oblique Impact

The momentum solution of oblique impacts is well documented in the literature. The law of Conservation of Linear Momentum simply requires the pre-impact system momentum to be equal to the post-impact system momentum,

$$m_1 \vec{V}_{1,Impact} + m_2 \vec{V}_{2,Impact} = m_1 \vec{V}_{1,Separation} + m_2 \vec{V}_{2,Separation}$$

where:

- m_1 = mass of vehicle 1
- m_2 = mass of vehicle 2
- $\vec{V}_1$ = velocity of vehicle 1 at impact and separation
- $\vec{V}_2$ = velocity of vehicle 2 at impact and separation

Impact-To-Rest Phase

EDCRASH allows the user to analyze accidents with many types of post-impact vehicle trajectories. This is a valuable feature because most vehicles do not travel along a simple, straight-line path from impact to rest. Rather, the typical vehicle rotates and may travel a somewhat curved path during its post-impact trajectory. An accurate analysis of the impact-to-rest phase is essential. Together with the velocity change, it determines the impact velocity.

Straight-line Rollout (without rotation)

The simplest post-impact trajectory is one defined by a straight line between the impact and rest positions, wherein the vehicle is redirected by impact but does not spin out, or rotate, during the actual impact-to-rest phase. In this case, the separation velocity is determined by the energy dissipated by the vehicle during its movement between impact and rest positions. For this case, the traditional formula applies,

$$V_{Separation} = \sqrt{2\,g\,f\,S}$$

where:

- $V_{Separation}$ = total separation linear velocity (in/sec)
- g = acceleration of gravity (in/sec²)
- f = deceleration or drag factor (G-units)
- S = path length (in)

Rotating/Lateral Skidding

For the case where the vehicle spins and/or slides sideways (laterally), additional factors must be considered. For example, consider the fact that while the vehicle's motion is in the same direction as its heading, the tires might be rolling — with the associated resistance to motion. But after the vehicle has rotated 90 degrees, the tires are sliding sideways — with the resistance associated with locked-wheel braking.

The above observation is extremely significant in the final outcome because the vehicle is not slowing (decelerating) at a constant rate and the traditional energy formula no longer applies. Rather than the one-line formula associated with straight-line deceleration, the solution requires five to ten pages of analytical development. The procedure was initially described by Marquard and refined by McHenry [1,2,16]. The basis of the analysis is the simple concept that a vehicle which both slides and rotates a given amount prior to coming to rest must have sufficient time to do both, and that the two phenomena do not occur simultaneously, but rather occur in two somewhat distinct phases.

Only in the case of rotating/lateral skidding can a vehicle have a non-zero separation angular velocity.

Rollout

It is not unusual for a vehicle at separation to undergo a rotating/lateral skidding phase followed by a short distance of pure rollout, during which no rotating or lateral skidding occurs. This is the case when a spinning vehicle slows and its tires catch, aligning itself with its direction of (linear) motion. If this occurs, the vehicle may simply roll a few more feet. In this case, the point where the end of rotation (EOR) occurs must be documented, and the skidding and rollout phases are analyzed separately.

Curved Path (with or without rotation)

It is also common for a vehicle to travel a curved path between impact and rest positions. Two features of this condition are significant: the path length is longer, and the separation angle is different. Both conditions can play a major role in the results. The increase in path length results in greater energy dissipation (higher separation velocity), while the change in departure angle affects the direction of the post-impact velocity vector.

> **NOTE:** The effect of path curvature on the angle of the separation velocity vector can be particularly important for the momentum analysis.

Trajectory Simulation Analysis

The above procedures describe how EDCRASH calculates linear and angular separation velocities. These velocities can be supplied as the initial conditions for a simulation analysis (which, by definition, will compute the rest conditions). If the initial conditions (separation velocities and departure angle) are correct, the simulated vehicle path should begin from the impact position, cross through the user-entered point on curve and end of rotation (if entered), and stop at the user-entered rest position.

At the user's request (see Input, Calculation Options), the trajectory simulation will perform this confirming analysis. The analysis is a simplified 3-degree-of-freedom simulation which models the forces and resulting motion of the vehicle throughout the separation-to-rest phase. The simulation assumes all forces are applied to the vehicle as shear forces generated at the tire-road interface (i.e., aerodynamic forces are neglected). Cornering stiffness tire data are used in these calculations. Since wheel spin degrees of freedom are neglected, the simulation requires that the braking force at each wheel be constant throughout the impact-to-rest phase. Steer angles are allowed, but must be held constant.

> **NOTE:** The trajectory simulation does not support vehicles with dual tires. A dual tire at any wheel position is rejected at event initialization with a fatal error and the event will not run. The restriction applies **only** to this Separation Velocity Basis — the same vehicle runs normally under Normal or Sustained Contact, where no tire forces are integrated.

The simulation is performed up to five times for each vehicle (the maximum number of runs is user-editable; see Calculation Options, Simulation Convergence Criteria). After each run, the simulated path is compared to the user-entered point on curve, end of rotation, and rest positions. **Five** error values are computed — the position *and* heading errors at rest, the position *and* heading errors at the end of rotation, and the position error at the point on curve — and each is tested against its own separate tolerance (see Calculation Options for EDCRASH). If any one of the five exceeds its tolerance, the simulation has failed to converge (i.e., the simulated path is not suitably close to the actual path). The initial velocities and separation angle are then modified in a manner intended to improve the results (i.e., to reduce the previous errors), and another simulation is attempted. After the allowed number of attempts, if the errors are not acceptably small the simulation is terminated.

EDCRASH will use the velocities which produced the smallest total weighted error sum during the simulation (if the simulation converged, the velocities which produced convergence are used). The convergence criteria associated with each path location are displayed in the Program Data output report.

The trajectory simulation can affect your results in two important ways. First, it might alter the separation velocities. Second, it might alter the separation angle. Combined, these alterations can have a significant influence on the results. Always compare your results with and without using the trajectory simulation option. Be suspicious whenever the results differ by a substantial amount [10].

Assumptions

In order to provide a useful analysis without becoming burdensome and overly complex, EDCRASH makes several simplifying assumptions. If the user is to use EDCRASH properly, it is important that these assumptions and their consequences be understood. In some cases, data which violate these assumptions will cause a fatal error, along with a message indicating the reason for the error. In other cases, the error is not with the data but with the use of the program under conditions which violate the assumptions inherent to the computations. EDCRASH will issue results which may not be valid for the circumstances of the accident.

Before using EDCRASH, be sure your accident is within the scope of the program analysis defined by the following assumptions:

3 Degrees Of Freedom

EDCRASH assumes the accident occurred on a flat, horizontal surface. Effects of the suspension are neglected, as are load transfers due to deceleration. If the vehicle drives into a ditch or over a cliff, the results are questionable.

Simplified Post-impact Trajectory

Although a significantly complex analysis of the impact-to-rest phase is performed, which can even include a simulation of the predicted response, EDCRASH still assumes the vehicle is not under the control of its driver. The specified steering and braking conditions must be constant throughout the impact-to-rest phase of the accident. The results are questionable if the driver applied the accelerator or steered back and forth.

Linear Exterior Crush Stiffness

The damage analysis assumes there is a linear relationship between crush and the force which caused it.

Because of improvements in the algorithm, EDCRASH does not require the vehicle's exterior to be homogeneous. However, the analysis does not allow for variation in vertical crush depth. Therefore, crush depth involving override damage must be associated with the proper stiffness values.

Common Velocity Assumption

For the damage-based analysis, EDCRASH assumes the earth-fixed velocities of the vehicles' shared damage centroid reach a common velocity. Therefore, accidents such as sideswipes cannot be handled.

This assumption is required by the boundary conditions which provide the solution to the differential equation describing the impact (see Calculation Method — Collinear Impact).

The common velocity check is a procedure which compares the separation conditions (see Warning Messages).

> **NOTE:** In a damage-only analysis, the common velocity check cannot be performed (there are no scene data). Therefore, it is up to the user to ensure (via some other means) a common velocity was achieved during impact.

Location of the Impulse Center

The default location for the impulse is defined by the point in the damage profile where the summation of forces and moments is equal to zero (i.e., the forces in each crush zone are balanced).

> **NOTE:** The balance point is found by weighting each crush zone by the share of the total crush force it carries. Where the crush is uniform and the stiffness homogeneous, every zone carries the same force and the result is simply the centroid of the damage area.

The impulse center may be relocated using the Event Editor, Damage Profile dialog.

Instantaneous Impact

The impact actually occurs over a finite time interval, usually lasting slightly over 1/10 of a second. The heading angles and instantaneous force between the vehicles change during this time interval. EDCRASH assumes the separation heading angles are the same as the impact heading angles. Since the direction of the force between the vehicles is changing, EDCRASH replaces this changing direction of force with a single Principal Direction of Force (PDOF), which is actually the direction of the impulse.

Negligible Tire Forces During Impact

During impact, there are two forces acting on the vehicles. These are the impulsive force between the vehicles and tire forces acting separately on each vehicle. Like all momentum solutions, EDCRASH assumes the tire forces are insignificant compared to the impulsive force. This is a good assumption with three possible exceptions: minor impacts, sideswipes and impacts involving large trucks. The reason for the exceptions is that the forces acting at the tires can approach the magnitude of the impulsive force.

Fiala Tire Model

A trajectory simulation requires the calculation of longitudinal and lateral forces at each tire. EDCRASH uses the Fiala [17] tire model which computes the lateral force from cornering stiffness (a measured tire property), the vertical tire force and the current tire slip angle. This model assumes the cornering stiffness does not change with changes in vertical load. The application of the Fiala model to a wheel rolling on its rim has not been documented.

Previous: Chapter 3 — Program Output · Next: Chapter 5 — EDCRASH Tutorial

Chapter 5 — EDCRASH Tutorial

This tutorial illustrates a very common use of EDCRASH, that is, to estimate the vehicle impact velocities from accident scene and vehicle damage measurements. This tutorial is continued in the EDSMAC(4) Tutorial, wherein the initial vehicle velocities are used to simulate the crash. You may wish to review that tutorial after finishing this one.

Like all EDCRASH events, the procedure involves the following basic steps:

- Create the vehicle(s)
- Create the environment
- Execute the EDCRASH event
- Review the EDCRASH output reports

This basic procedure is described in detail in this tutorial.

> **NOTE:** It is assumed that HVE-2D or HVE is up and running, and that the user is familiar with its basic features, such as using dialogs and viewers, as well as the Editors. The purpose of this tutorial is to illustrate those features while setting up and executing an EDCRASH event.

Getting Started

As in other tutorials, before we get started, let's set the user options so we're all starting on the same page.

> **NOTE:** In HVE-2D, all options simply affect the appearance in a viewer during Event or Playback mode. However, in HVE, AutoPosition affects the data used in the analysis. For example, if AutoPosition is On, the vehicle position conforms to the local surface; otherwise, the position is set by the Position/Velocity dialog. Obviously, the resulting difference in initial conditions could substantially change the event.
>
> **NOTE:** Some of the following options are "toggles" that switch between two different modes. Make sure these options are set correctly.

To set the initial user options, choose the following from the Options Menu:

- ON: Show Key Results
- OFF: Show Axes
- OFF: Show Contacts
- OFF: Show Velocity Vectors
- ON: Show Skidmarks
- OFF: Show Targets
- ON: AutoPosition
- Units equals S.I.

> **NOTE:** As we'll see when we create our environment, our EDCRASH Tutorial studies a crash that took place in Australia; thus we require metric units.

- Render Options:
- Show Humans as Actual
- Show Vehicles as Actual
- Phong Render Method
- Complexity equals Object
- Render Quality equals 5
- Texture Quality equals 1
- Anti-aliasing equals 1

The remaining options will automatically initialize to their default conditions. We're now ready to proceed with the tutorial.

Creating the Vehicles

Let's add the vehicles to our case. The first vehicle is a white, 1996 Ford Escort 2-Door Hatchback; the second vehicle is a dark red 1995 Nissan Sentra 4-Door Sedan. Let's add the first vehicle:

1. If the Vehicle Editor is not the current editor, choose Vehicle Mode. The Vehicle Editor is displayed.
2. Click Add New Object. The Vehicle Information dialog is displayed. The Vehicle Information dialog allows the user to select the basic vehicle attributes according to Type, Make, Model, Year and Body Style.

> **NOTE:** The Vehicle Information dialog also allows you to edit the Driver Location, Engine Location, Number of Axles and Drive Axle(s). These options are already assigned for each vehicle and need not be edited in our tutorial.

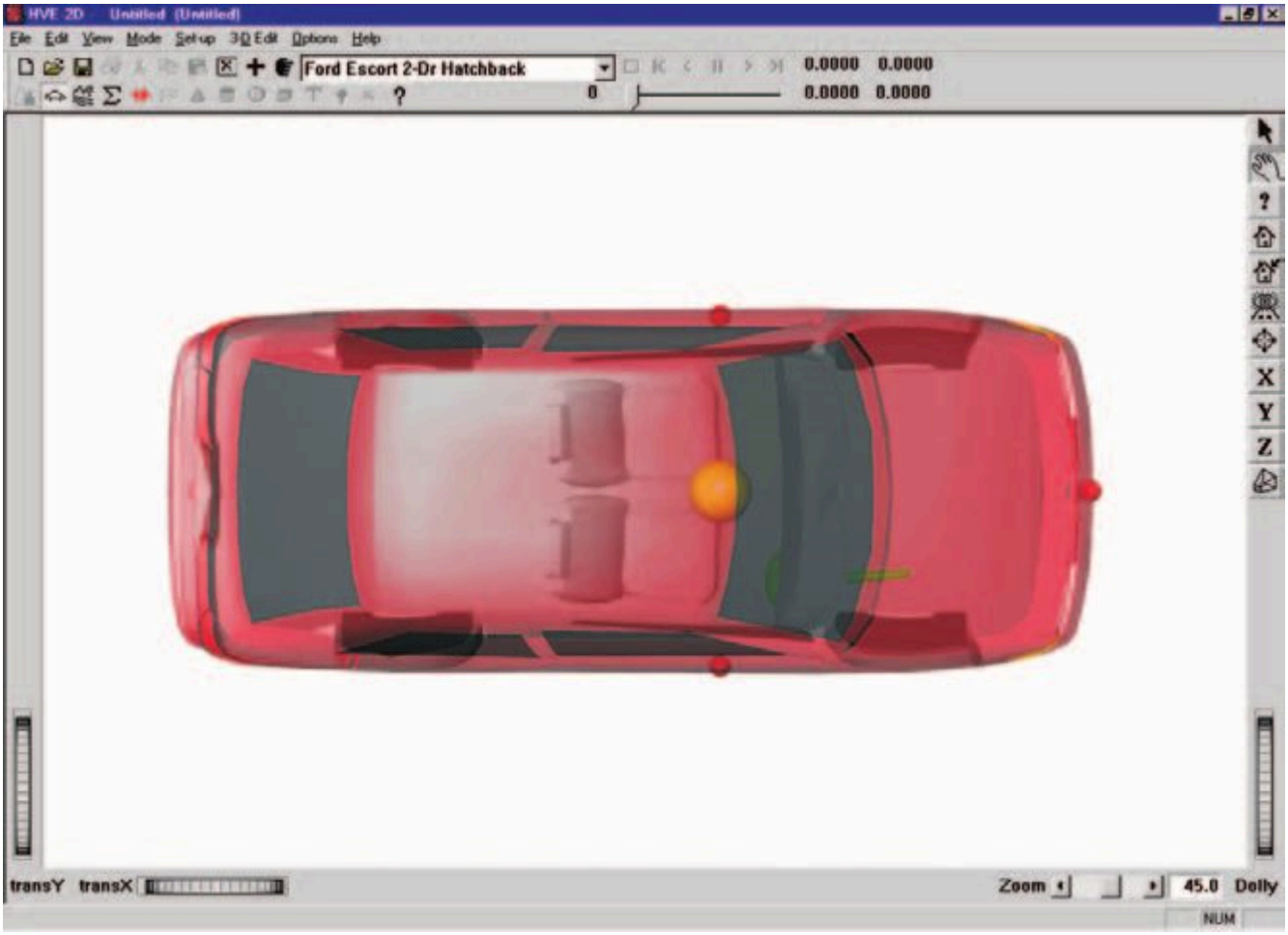
1. Using the option buttons, click each button to choose the following vehicle from the database:
2. Type = Passenger Car
3. Make = Ford
4. Model = Escort
5. Year = 1991–1996
6. Body Style = 2-Door Hatchback
7. Source Database = Tutorial.db
8. Driver Location = Right
9. Click OK to add Ford Escort to the Active Vehicles list.

Next, let's add the Nissan Sentra:

1. Click Add New Object to show the Vehicle Information dialog.
2. Using the option buttons, click each button to choose the following vehicle from the database:
3. Type = Passenger Car
4. Make = Nissan
5. Model = Sentra
6. Year = 1995–1999
7. Body Style = 4-Door

8. Source Database = Tutorial.db
9. Driver Location = Right
10. Click OK to add Nissan Sentra to the Active Vehicles list.

We now have the vehicles required for our study.



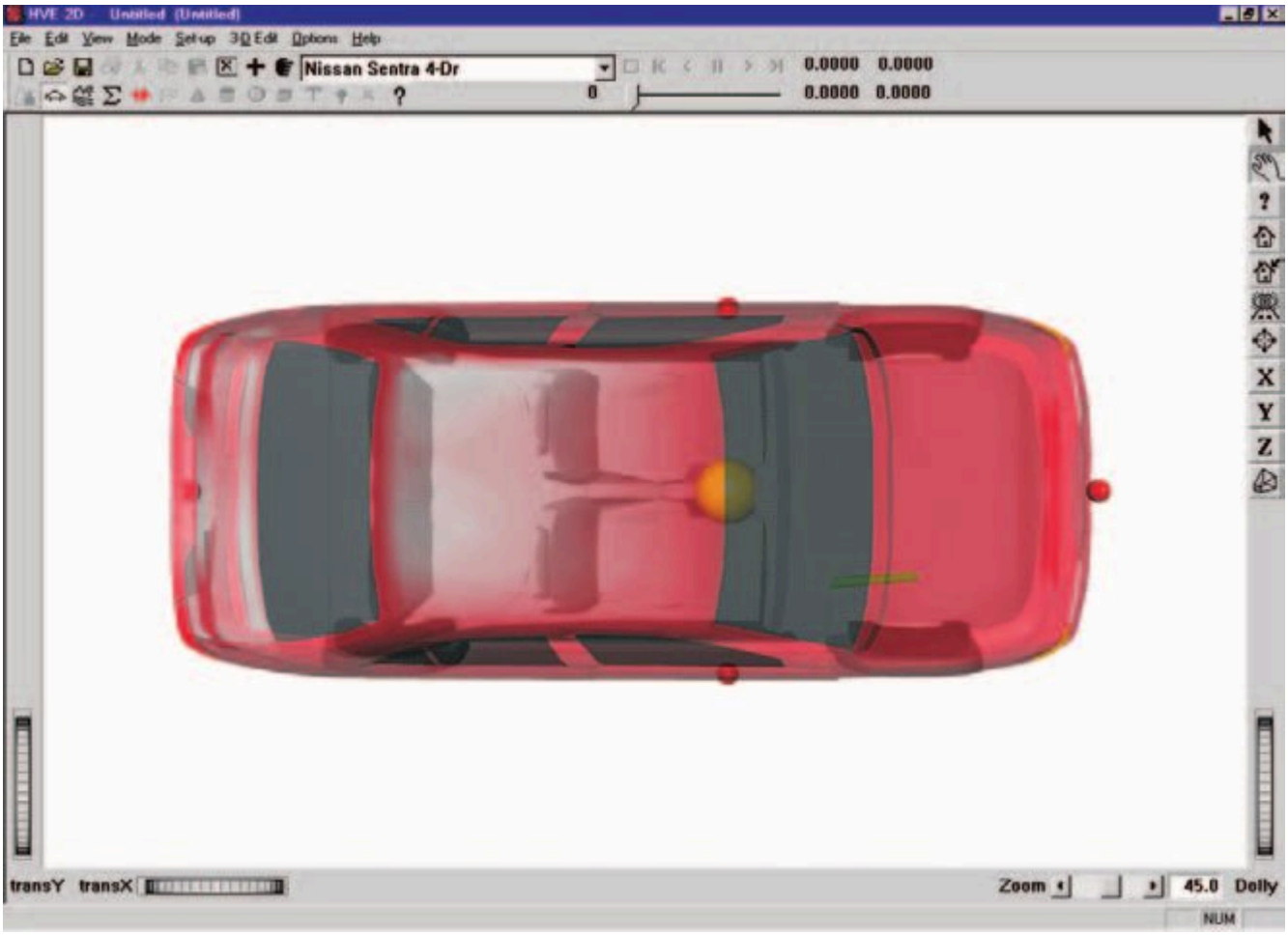


Figure 5-1: Ford Escort (above) and Nissan Sentra (below).

Editing the Vehicles

Next, we'll edit the vehicles to change their color and weight. In addition, we'll change the stiffness of the Nissan Sentra, using values derived from our initial reconstruction analysis.

Start by changing the color of the Ford Escort:

1. Click on Ford Escort in the Active Vehicles list, making it the current vehicle. The Ford Escort is now displayed in the Vehicle Editor.
2. Click on the CG and choose Color. The Vehicle Color dialog is displayed, showing the vehicle's current color (the small black square, or *hot spot*, in the color wheel) and intensity (the arrow in the intensity slider). Click on the hot spot and drag it to the center of the blue area. To lighten the vehicle, click on the intensity slider and drag it to the far right end.

> **NOTE:** The color chip on the left shows the current color.

1. When the color is to your liking, close the dialog by clicking the close button on the upper right corner of the dialog.

> **NOTE:** The vehicle's apparent color may be slightly misleading because the vehicle is translucent when displayed in the Vehicle Editor. The actual color will be used whenever the vehicle is displayed during Event and Playback mode.

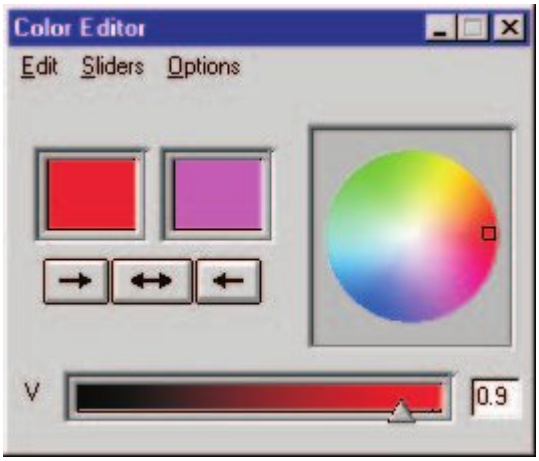


Figure 5-2: Vehicle Color dialog, used for assigning the vehicle color.

Next, let's change the Escort's weight. Perform the following steps:

1. Click on the CG and choose Inertias. The Inertias dialog is displayed, and we're ready to change the vehicle's weight.

> **NOTE:** The vehicle's roll, pitch and yaw moments of inertia are also displayed in the Inertias dialog; however, only the yaw inertia is used by the 3-DOF EDCRASH calculations.

1. In the Total Weight text field, replace the existing weight, 10279 Newtons, with the measured value, 11032 Newtons.

> **NOTE:** The weight is entered as a force (Newtons). Mass units (kg) are calculated and displayed.
>
> **NOTE:** The dialog might display 10279.761, or a similar number, because the weight is actually divided by the current gravity constant and stored as mass. Extra precision results when the mass is multiplied by the current gravity constant and redisplayed.

1. If not already selected, click the checkbox for Auto Update Inertia When Weight Changes.
2. Press OK to accept the weight value and update the Total Yaw Inertia of the vehicle.

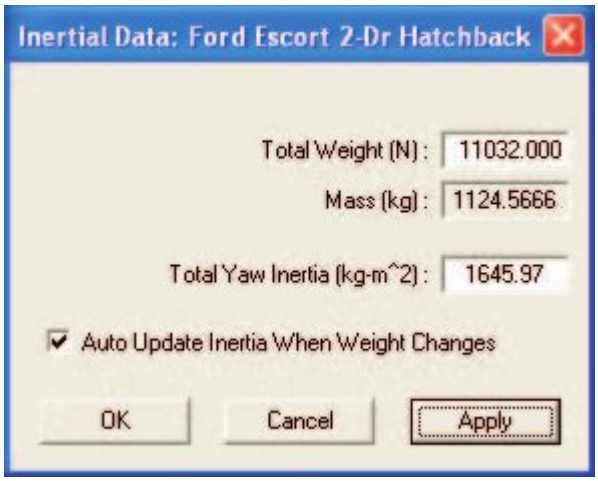


Figure 5-3: Vehicle Inertias dialog.

The Ford Escort is now ready for use in our tutorial. Using the viewer thumb wheels or mouse, zoom in or out on the vehicle or translate the vehicle in the viewer X or Y directions.

Now, let's change the color, weight and stiffness of the Nissan Sentra:

1. Click on Nissan Sentra in the Active Vehicles list, making it the current vehicle. The Nissan Sentra is now displayed in the Vehicle Editor.
2. Click on the CG and choose Color. The Vehicle Color dialog is displayed. The vehicle's color is fine, but we need to darken it. To darken the vehicle, click on the intensity slider and drag it to the middle of the range.
3. When the color is to your liking, close the dialog by clicking the close button on the upper right corner of the dialog.

Next, let's change the Nissan's weight:

1. Click on the CG and choose Inertias. The Inertias dialog is displayed.
2. In the Total Weight text field, replace the existing weight, 10858 Newtons, with the measured value, 11282 Newtons.

> **NOTE:** Again, the value displayed in the dialog may contain extra precision, for the reasons explained earlier.

1. If not already selected, click the checkbox for Auto Update Inertia When Weight Changes.
2. Press OK to accept the weight value and update the Total Yaw Inertia of the vehicle.

Finally, let's change the stiffness on the right side of the vehicle. An SAE moving barrier crash test (SAE J972) revealed the A and B stiffness coefficients for the side of the vehicle were 245 N/cm and 50 N/cm², respectively. Let's enter the new values:

1. Click on the right side surface icon (red sphere). The CG to Right Side dialog is displayed.
2. Click Stiffness. The Stiffness Coefficients dialog for the right side surface is displayed.

> **NOTE:** The Vehicle Editor assumes the stiffness is uniform across the right side of the vehicle. If desired, we can add hard spots using the Damage Profile dialog during Event mode.

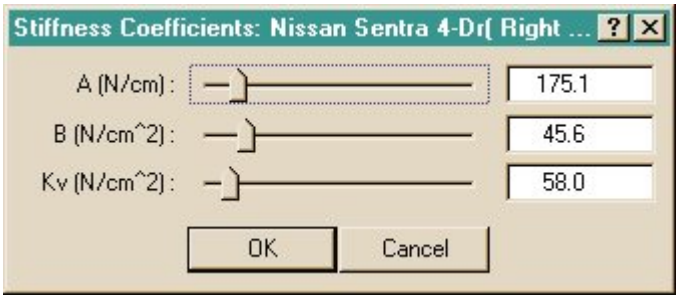


Figure 5-4: Vehicle Stiffness dialog, used for editing the current A, B and Kv stiffness coefficients for the current surface. EDCRASH allows different stiffness values for the front, back and sides. By default, the stiffness is uniform on any side; hard spots may be assigned using the Event Editor.

To edit the current A and B stiffness coefficients:

1. Replace the current value in the A field with the calculated value, 245 N/cm. Then enter a new value for B, 50 N/cm².
2. Click OK to update the stiffness coefficients.
3. Click OK again to remove the CG to Right Side dialog.

The Nissan Sentra is now ready for use in our tutorial. Using the viewer thumb wheels, pan, zoom and look at the vehicle. Note that, in HVE, the thumb wheels rotate the vehicle about the viewer axes, not the vehicle axes.

Now we have both vehicles ready for our study.

Saving the Case

Now that we've created vehicles for our case, let's save the case file.

1. Click on the File menu and choose Save. The Save-as File Selection dialog is displayed.

> **NOTE:** The Save-as dialog is displayed because the case has not been saved previously, so we need to enter a filename.

1. Place the mouse cursor in the Case Title text field and enter *EDCRASH Tutorial, Visibility Study*.

> **NOTE:** The Case Title is displayed as a heading on all printed output reports.

1. Place the mouse cursor in the Filename text field and enter *EdcrashTutorial*.
2. Click SAVE. The current case data are saved in the /supportFiles/case subdirectory.

> **NOTE:** Saving the file occasionally is a highly recommended practice.

Creating the Environment

Now, let's add the environment:

1. Choose Environment Mode. The Environment Editor is displayed.
2. Click on Add New Object. The Environment Information dialog is displayed.

3. Using the Location Database combo box, choose Sydney, NSW, Australia. The latitude (35.53.00S), longitude (151.10.00E) and GMT, hours from the prime meridian (+10) are displayed for the selected location.

> **NOTE:** If Sydney were not included in your Location Database, you could add it simply by typing in the new location name, latitude, longitude and GMT.

1. Enter a name for the accident site, *Blind Intersection*.
2. Edit the date and time of the incident we are studying, 7/23/99 and 1330, respectively.
3. Edit the angle from true north to the earth-fixed X axis in our environment, −10 degrees.

> **NOTE:** The Latitude, Longitude, GMT, Date/Time and angle from true north are used to position the sun in the scene. This is, of course, important because the sun is the primary light source for the scene.

1. To add the environment geometry file to our case, click on Open. The Environment Geometry File Selection dialog is displayed.
2. Click on the Files of Type option list and choose HVE Geometry Files (*.h3d). A list of environment geometry files using the .h3d file format is displayed in a list box.
3. Double-click on EdcrashEdsmacTutorial_2D.h3d to choose the environment file and remove the dialog.

> **NOTE:** HVE users should select the environment file named EdcrashEdsmacTutorial.h3d.

1. Press OK.

The selected environment is added to our case and displayed in the Environment Viewer. Use the viewer thumb wheels to view the scene.

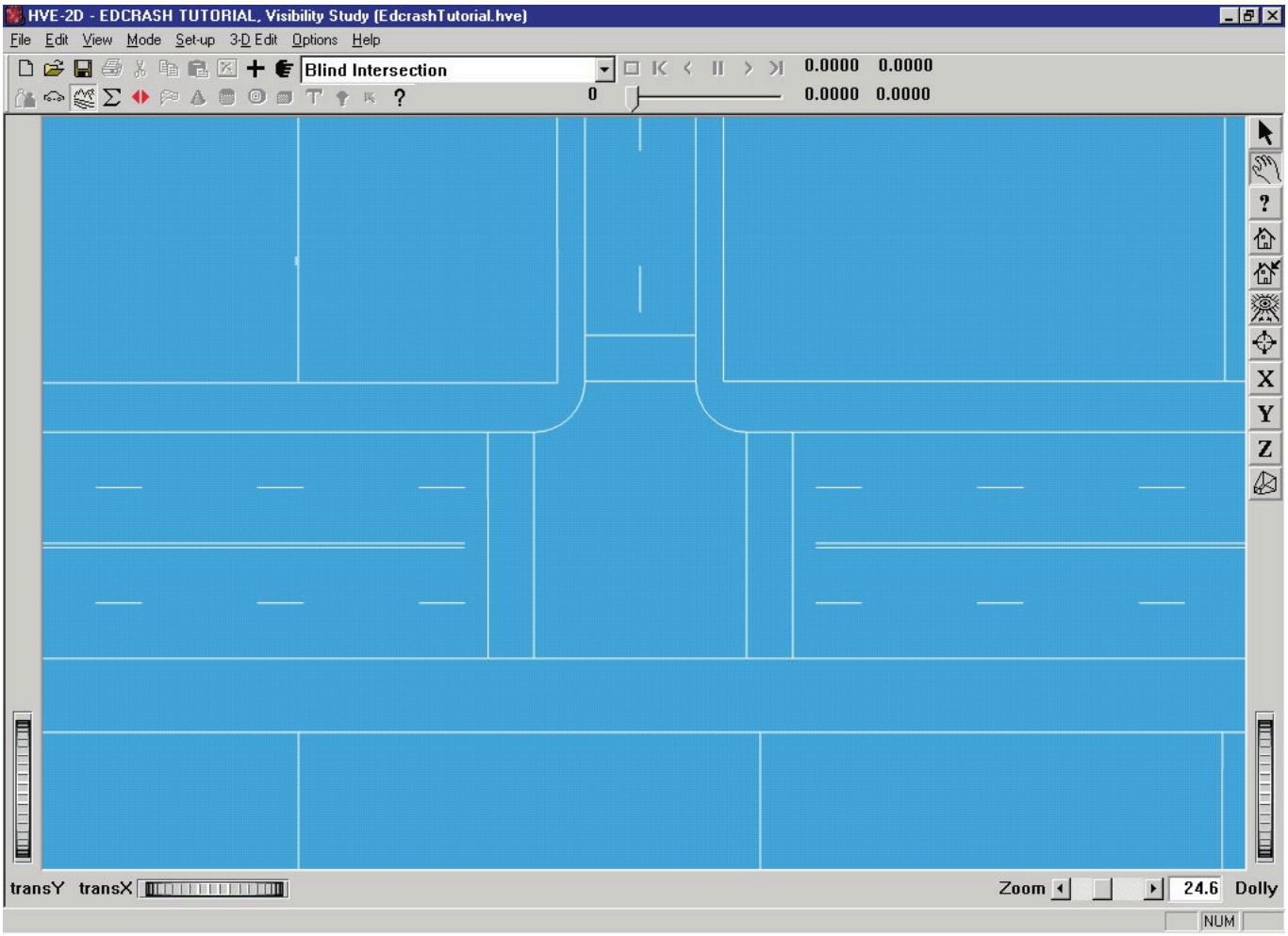


Figure 5-5: Appearance of the 2-D environment geometry used for the EDCRASH tutorial.

Creating the Event

As mentioned at the outset, this EDCRASH tutorial describes a common application of EDCRASH, that is, to determine pre-impact vehicle velocities. This can be accomplished only when scene data (vehicle positions at impact and rest) are known. Fortunately, we have that data, owing to a splendid at-scene investigation. In addition, vehicle damage profiles are available from vehicle inspections.

To create the event, perform the following steps:

1. Choose Event Mode. The Event Editor is displayed.
2. Click on Add New Object. The Event Information dialog is displayed.
3. Select Ford Escort and Nissan Sentra from the Active Vehicles list. The vehicles are added to the Event Humans and Vehicles list.
4. Select EDCRASH from the Calculation Method options list.
5. Enter a name for the event, *Visibility Study*.

> **NOTE:** The name of the calculation method will automatically be appended to the event name, thus the complete event name will become "EDCRASH, Visibility Study."

1. Press OK to display the Event Editor.

Now we're ready to set up the event. Event set-up for EDCRASH involves the following three steps:

- **Position the Vehicles** — The minimum required vehicle positions are Impact and Rest. Vehicle positions at Begin Braking, Point-on-curve (POC) and End-of-rotation (EOR) are optional positions that may be assigned for each vehicle.

> **NOTE:** If Impact and Rest positions are not assigned for both vehicles, impact speeds cannot be computed — it is physically impossible!

- **Assign Wheel Data** — Wheel data (% Wheel Lock-up, Steer Angle and Pre-impact Wheel Lock-up) are required whenever scene data are supplied.
- **Assign Damage Profiles** — Vehicle damage profiles (damage Width, Depth and Offset) are optional for oblique collisions, but required for collinear collisions, where the momentum analysis is too sensitive to the scene data to be reliable.

> **NOTE:** Even though damage profiles are not required for oblique collisions, they provide an excellent confirming analysis.

Positioning the Ford Escort



Figure 5-6: Positioning the Ford Escort using the Event Editor.

Let's set up the Ford Escort. It skidded for a short distance before impact. Let's start by entering its Begin Braking position:

1. Select Ford Escort from the Event Humans & Vehicles list.
2. Click Set-up from the menu bar and choose Position/Velocity. The Impact position for the Escort is displayed at the earth-fixed origin.
3. Click on the Position/Velocity dialog's Path Location option list and choose Begin Braking. The Escort Begin Braking position is displayed at the earth-fixed origin.
4. Click on the vehicle's X-Y manipulator, wait for it to turn bright yellow (indicating it has been selected), and drag it to its begin braking position, X = 18.0 m, Y = 15.0 m. In the Yaw field of the Position/Velocity dialog, replace the existing value with the correct heading angle for the start of braking, 180 degrees.

> **NOTE:** To select the X-Y manipulator, the viewer must be in Pick mode, as indicated by the highlighted arrow in the upper right corner of the viewer.
>
> **NOTE:** If necessary, adjust the viewer by panning and dollying back (using the viewer controls) until you can see the entire intersection.
>
> **NOTE:** Be sure to keep the mouse button depressed while you drag the manipulators.
>
> **NOTE:** If you can't position the vehicle at the exact coordinates, you can simply enter the coordinates in the dialog (remember to press \<Enter> after entering the data; otherwise the new values will not be used!).

Now let's position the Escort at its impact position:

1. Click on the Position/Velocity dialog's Path Location option list and choose Impact. The Escort impact position is displayed at the earth-fixed origin.
2. Click on the vehicle's X-Y manipulator, wait for it to turn bright yellow, and drag it to its impact position, X = 6.0 m, Y = 13.75 m. In the Yaw field of the Position/Velocity dialog, replace the existing value with the impact heading angle, 195.0 degrees.

Now, enter the sideslip angle at impact:

1. Click the Velocity Is Assigned check box to allow velocity entries.
2. Enter the impact sideslip angle, −4.35 degrees.

> **NOTE:** Although you could enter an impact velocity, EDCRASH would not use it; after all, it is EDCRASH's role to calculate impact speed!

Next, let's position the Escort at its rest position:

1. Click on the Path Location option list and choose Final/Rest. The Escort is displayed at the earth-fixed origin.
2. Click on the vehicle's X-Y manipulator, wait for it to turn bright yellow, and drag it to its rest position, X = 3.5 m, Y = 12.75 m. In the Yaw field of the Position/Velocity dialog, replace the existing value with the rest heading angle, 230 degrees.



Figure 5-7: View of the scene after the Ford Escort has been positioned at its Begin Braking, Impact and Rest positions.

> **NOTE:** In HVE and HVE-2D, +230 degrees is not the same as −130 degrees because the relative magnitude between two angles implies the rotation direction! For example, if the impact heading angle is 180 degrees and the rest heading angle is 230 degrees, the change in heading angle between impact and rest is +50 degrees clockwise; if the rest heading angle is −130 degrees, the change in heading angle is −310 degrees and the direction of rotation is counter-clockwise.
>
> **NOTE:** If you can't position the vehicle at the exact coordinates, simply enter them in the dialog (in fact, it's often easier to directly enter the coordinates using the dialog).

Driver Controls for the Ford Escort

Next, let's enter the driver controls for the Ford Escort:

1. Choose Set-up from the menu bar, select Driver Controls. The Driver Controls dialog is displayed.
2. The Wheel Data page is displayed for the Ford Escort.

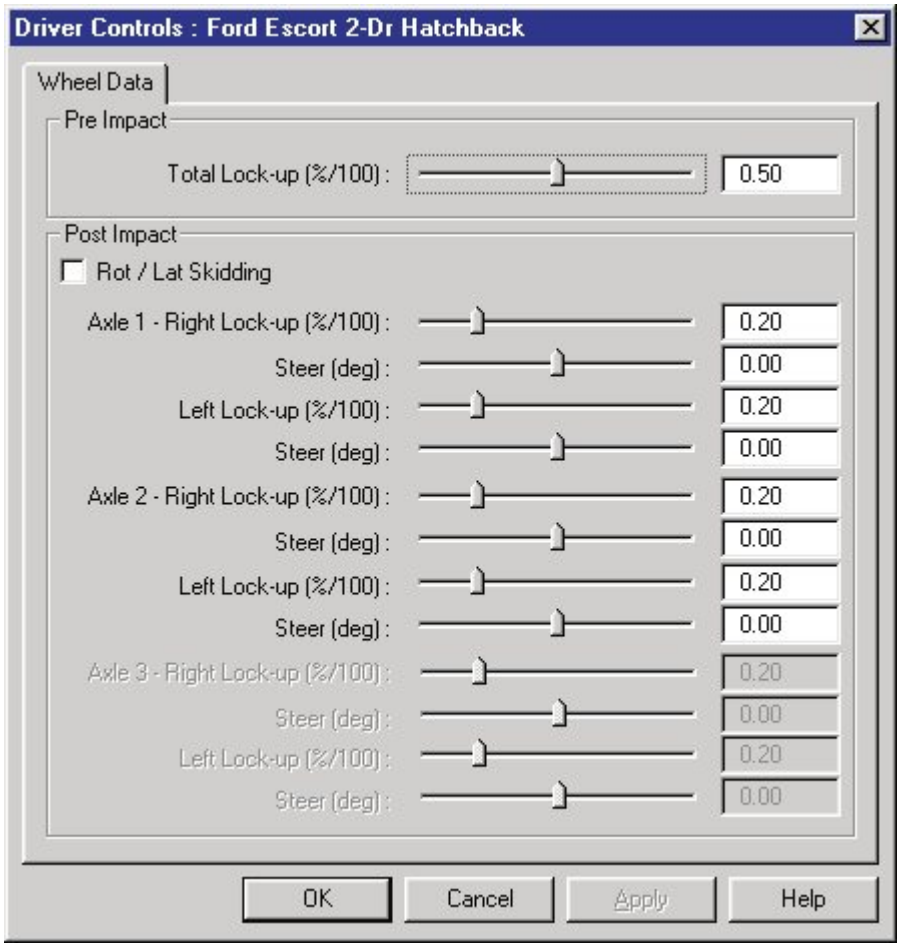


Figure 5-8: Wheel Data dialog for the Ford Escort.

According to our vehicle inspection, both front wheels were locked after impact by damage, while the rear wheels were free turning. Let's enter the appropriate values, first for the front wheels:

1. Place the cursor in the Post Impact Percent Lock-up field for the right front wheel and enter 1.0. Enter the same value, 1.0, for the left front wheel.

Now the rear wheels:

1. Place the cursor in the Percent Lock-up field for the right rear wheel and enter 0.01 (0.01 / μ_{slide}). Enter the same value, 0.01, for the left rear wheel.

Table 5-1: Typical Wheel Lock-up Values [20]

Wheel Condition	Typical Range
No Damage, Free-rolling	0.01 / μ_{slide} to 0.02 / μ_{slide}
No Damage, Drive Wheel	0.10 / μ_{slide} to 0.15 / μ_{slide}
Damage	0.0 to 1.0

> **NOTE:** For undamaged wheels, be sure to divide by the slide coefficient of friction, μ_{slide}, before entering the value for each wheel.

Next, let's enter the Percent Lock-up during pre-impact braking. Because the tires left skidmarks, we'll assume 100 percent braking:

1. Place the text cursor in the Pre-impact Total Wheel Lock-up field and enter 1.0.

Finally, noting the vehicle rotated and skidded after impact, let's select that EDCRASH option:

1. Click on the Rot/Lat Skid check box.
2. Press OK to accept the wheel data.

The wheel data have now been assigned for the Ford Escort.

Damage Profile for the Ford Escort

Let's conclude event set-up for the Escort by supplying a damage profile:

1. Choose Set-up from the menu bar, select Damage Profiles. The Damage Profile dialog is displayed for the Ford Escort.

The Damage Profile dialog initially contains

None

, waiting for us to assign a CDC (Collision Deformation Classification; see HVE User's Manual):

1. Replace *None* in the CDC field with **11FDEW3** and click Apply. The default damage profile is displayed according to the CDC.

Because we actually measured the damage profile during our vehicle inspection, let's enter the measured width, depth and offset:

1. The default damage width, 169.42 cm, and offset, 0.00 cm, are acceptable.

We measured seven crush depths, so we have six crush zones:

1. Click on the Damage Profile Zones option list and change the default value from 3 to 6.
2. Enter the seven crush depths, beginning on the left end of the damage profile, according to Table 5-2.

> **NOTE:** Remember to press Apply after entering the crush depth values.

Table 5-2: Crush depths for the front of the Ford Escort 2-Dr Hatchback

Crush Depth No.	Crush Depth (cm)
1	75.0
2	60.0
3	50.0
4	45.0
5	40.0
6	40.0
7	45.0

> **NOTE:** Front and rear crush depths are entered left-to-right.

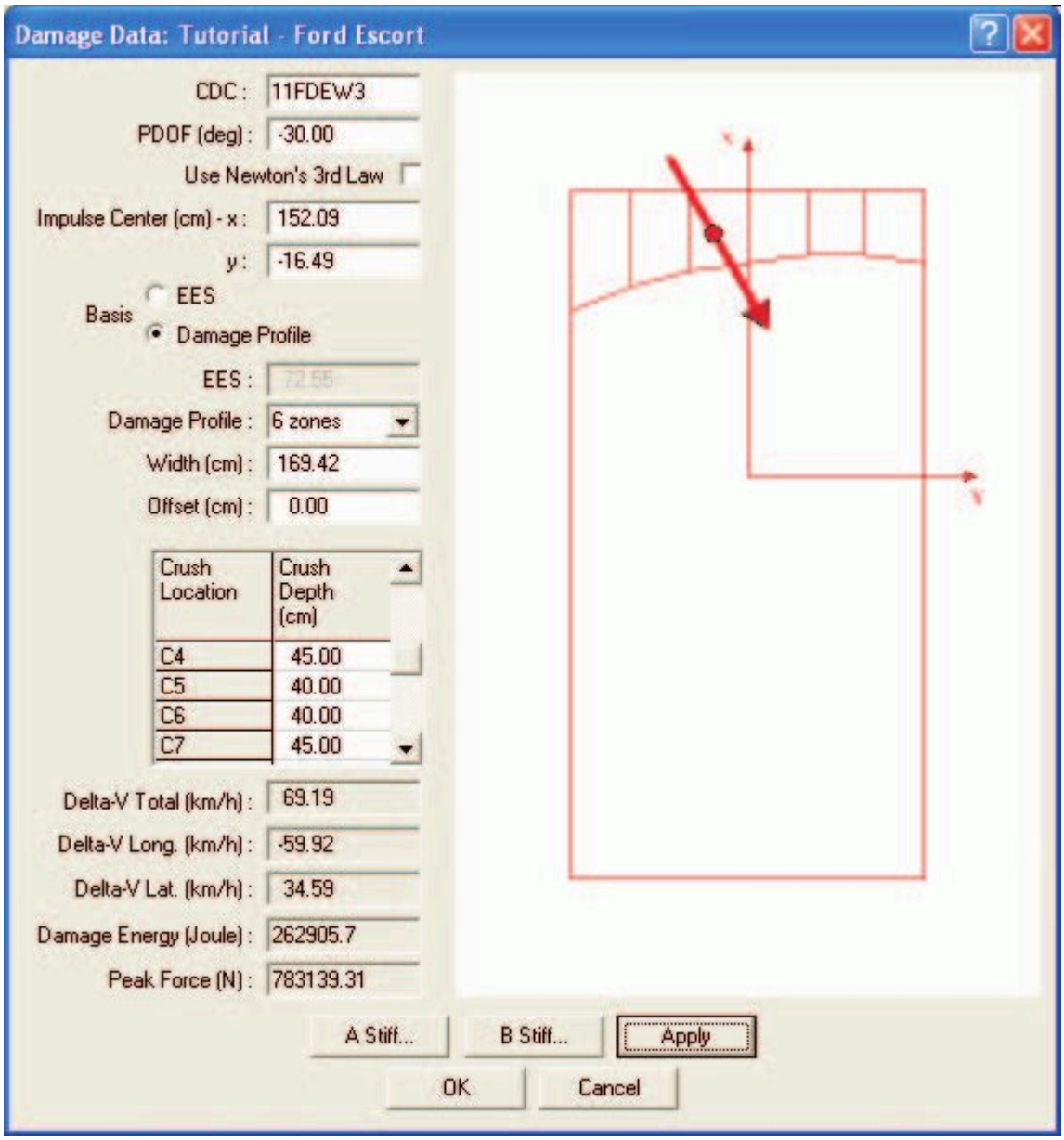


Figure 5-9: Damage Profile dialog for the Ford Escort.

1. Press OK to accept the assigned damage profile data.

Event set-up for the Ford Escort is now complete.

Setting Up the Nissan Sentra

Let's set up the Nissan Sentra. We'll start by assigning its impact and rest positions:

1. Select Nissan Sentra from the Event Editor's Event Humans and Vehicles list.
2. Click Set-up from the menu bar and choose Position/Velocity. The Impact position for the Sentra is displayed at the earth-fixed origin.

3. Click on the vehicle's X-Y manipulator, wait for it to turn bright yellow, and drag it to its impact position, X = 3.5 m, Y = 13.0 m. In the Yaw field of the Position/Velocity dialog, replace the existing value with the heading angle, −90 degrees.

> **NOTE:** Be sure to keep the mouse button depressed while you drag the manipulators. You may wish to enter the values directly in the Position/Velocity dialog.

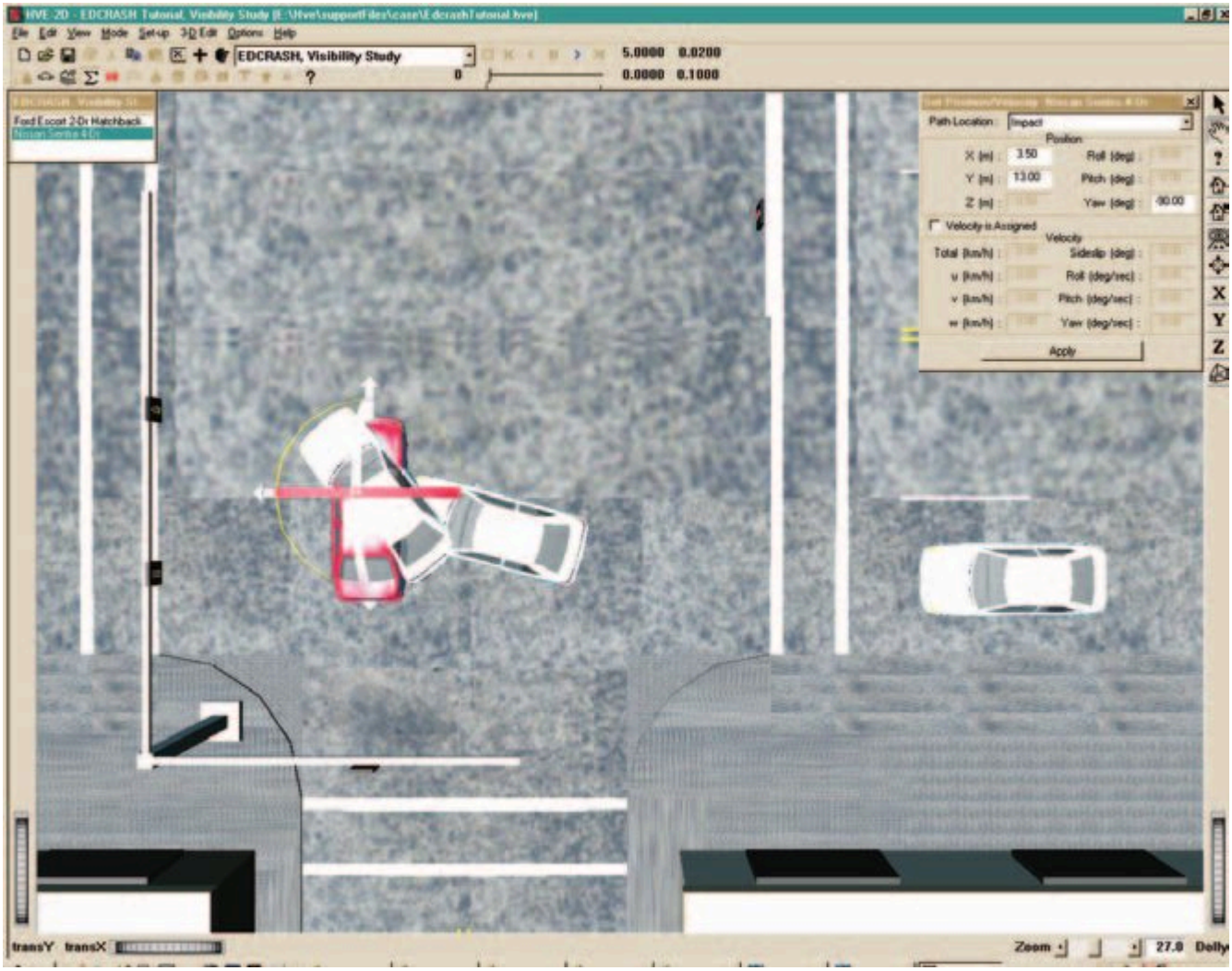


Figure 5-10: Positioning the Nissan Sentra using the Event Editor. Note the Ford Escort's rest position visually obstructs the positioning of the Nissan Sentra; this visual obstruction does not affect calculations.

Next, let's position the Nissan at its rest position:

1. Click on the Position/Velocity dialog's Path Location option list and choose Final/Rest. The Sentra's rest position is displayed at the earth-fixed origin.
2. Click on the vehicle's X-Y manipulator, wait for it to turn bright yellow, and drag it to its rest position, X = 0.5 m, Y = 2.25 m. In the Yaw field of the Position/Velocity dialog, replace the existing value with the rest heading angle, 70 degrees.

> **NOTE:** In HVE and HVE-2D, +70 degrees is not the same as −290 degrees because the relative magnitude between two angles implies the rotation direction!

The Nissan's positions are now established. Let's enter the driver controls. In this case, there are no driver inputs, per se. However, after impact the vehicle coasts to rest, so we need to enter rolling resistances:

1. Choose Set-up from the menu bar and select Driver Controls. The Wheel Data dialog is displayed.

According to our vehicle inspection, all the wheels were free turning (i.e., not locked by damage). Let's enter the appropriate values, first for the front wheels:

1. Accept the default values for Percent Lock-up for Axle 1, Right Side and Left Side, 0.20 (0.15 / μ_{slide}).

Now the rear wheels:

1. In the Percent Lock-up field for Axle 2, Right Side, enter 0.01 (0.01 / μ_{slide}). Enter the same value, 0.01, for the left rear wheel.

> **NOTE:** The Nissan is a front wheel drive vehicle, hence the larger front wheel lock-up values; see Table 5-1.

Finally, noting the vehicle rotated and skidded after impact, let's select that EDCRASH option:

1. Click on the Rot/Lat Skid check box.
2. Press OK to accept the wheel data for the Nissan Sentra.

The wheel data have now been assigned for the Nissan Sentra.

Damage Profile for the Nissan Sentra

Let's conclude event set-up for the Nissan Sentra by supplying a damage profile:

1. Choose Set-up from the menu bar, select Damage Profiles. The Damage Profile dialog is displayed for the Nissan Sentra.
2. Replace *None* in the CDC field with **02RPEW3** and click Apply. The default damage profile is displayed according to the CDC.

Because we actually measured the damage profile during our vehicle inspection, let's enter the measured width, depth and offset:

1. Enter the right side damage width, 220 cm, and offset, −40 cm.

We measured five crush depths along the right side of the Nissan, so we have four crush zones:

1. Click on the Damage Profile Zones option list and change the default value from 3 to 4.
2. Enter the five crush depths along the right side, according to Table 5-3 (remember to press Apply after entering all of the values).

Table 5-3: Crush depths for the right side of the Nissan Sentra 4-Dr

Crush Depth No.	Crush Depth (cm)
1	20.0
2	30.0
3	50.0
4	45.0
5	10.0

> **NOTE:** Side crush depths are entered rear-to-front.

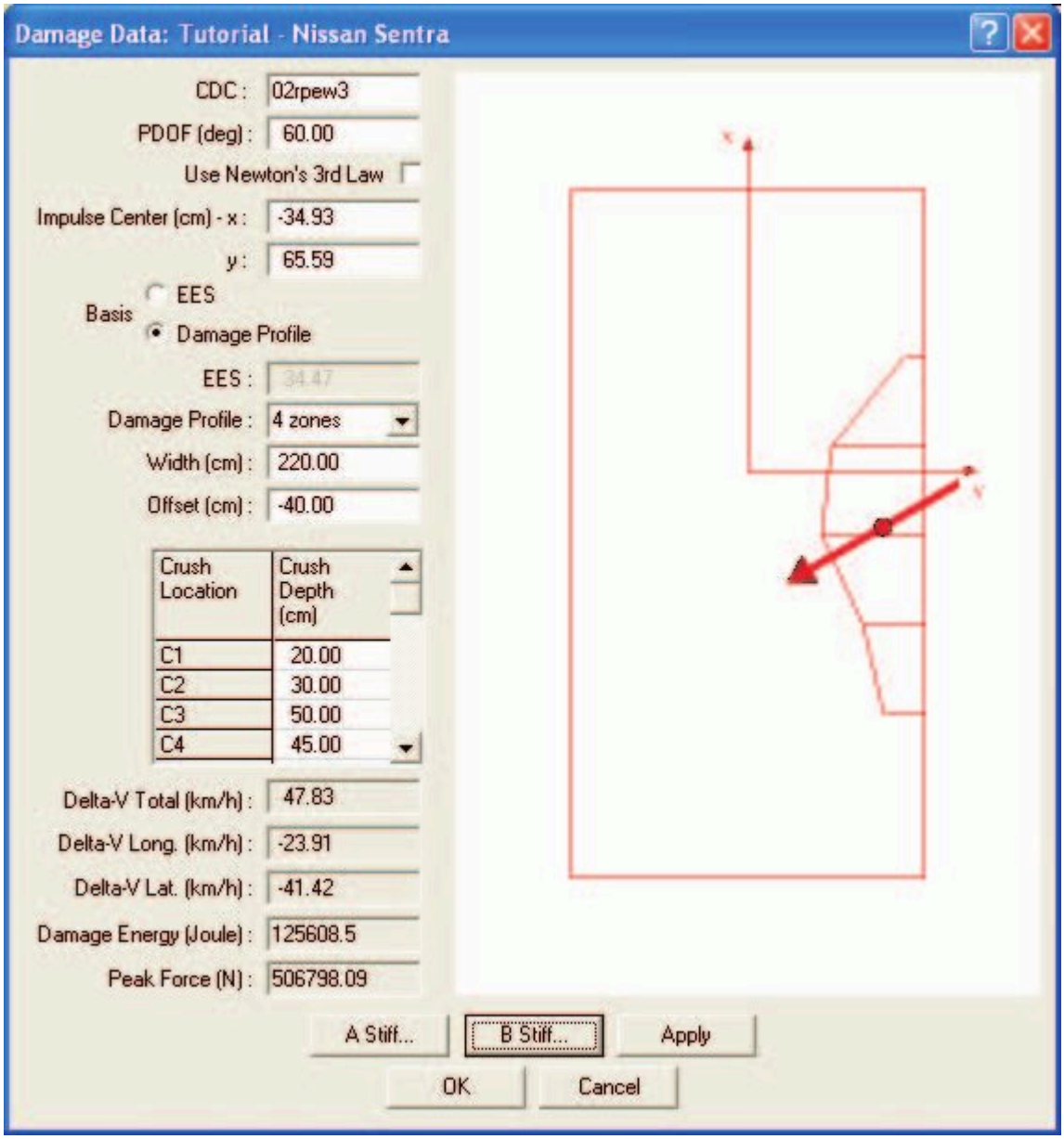


Figure 5-11: Damage Profile dialog for the Nissan Sentra.

Note the reported force is 506,798 Newtons. Further, note the force reported for the Ford Escort is 783,139 Newtons. According to Newton's 3rd Law, the forces on both vehicles should be equal.

> **NOTE:** It is quite common for the initially computed forces to be different when side impact is involved because a vehicle's side stiffness varies according to where it was impacted; the wheels are much stiffer than other locations.

The best way to solve this problem is to adjust the stiffness coefficients to equalize the forces. If the damage profile has uniform stiffness, we can quickly estimate the amount of the adjustment by noting the current ratio of the calculated collision forces:

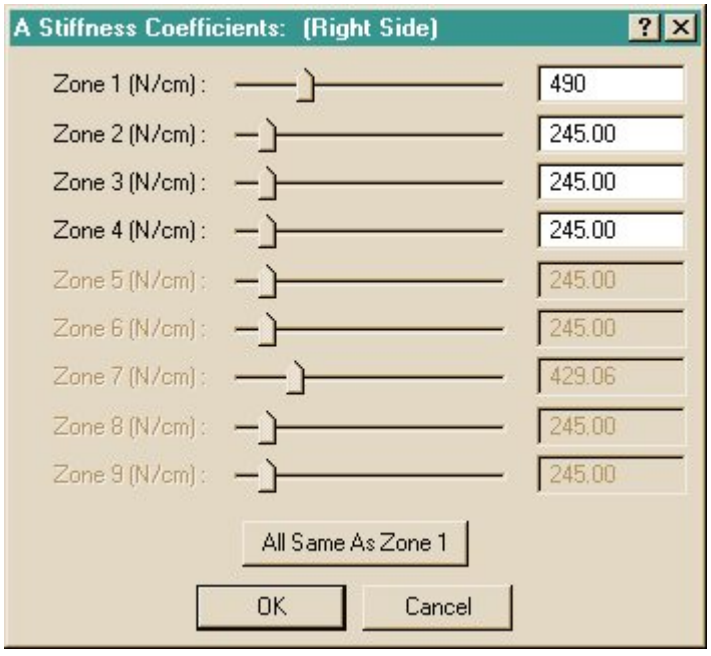
$$\text{force ratio} = \frac{F_{Escort}}{F_{Sentra}} = \frac{783,139}{506,798} = 1.55$$

But the side of the Nissan does not have a uniform stiffness, and a large portion of the impact force was applied at the right rear wheel. Therefore, we cannot directly use the above method. Let's adjust the stiffness by increasing the A and B coefficients for zone 1, the zone that includes the right rear wheel, using trial and error.

> **NOTE:** The A and B stiffness coefficients are related; when adjusting the stiffness coefficients, always multiply A and B by the same factor!

Let's try a factor of 2.0:

1. Click A Stiffness. The A Stiffness Coefficients dialog is displayed with the default value, 245 N/cm. The adjusted value for our first attempt is 490 (245 × 2).
2. Enter 490.0 for Zone 1.
3. Press OK to accept the new value.



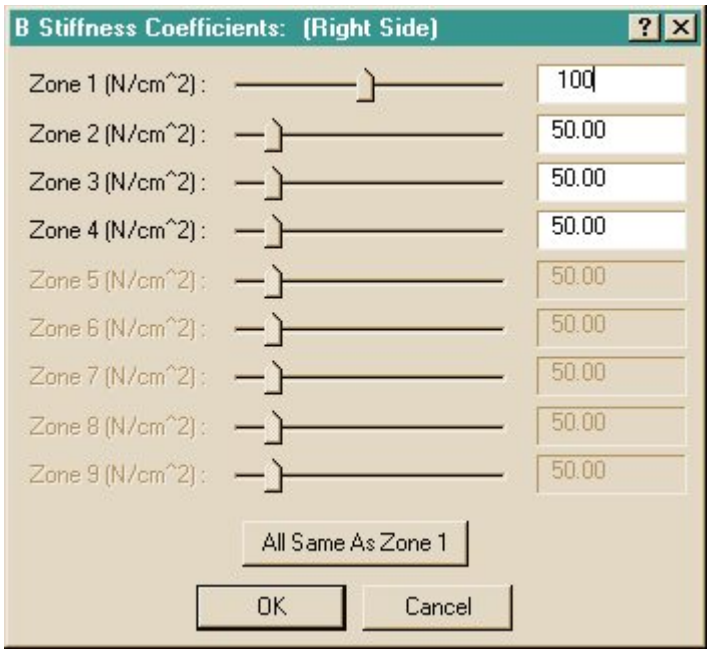


Figure 5-12: A Stiffness and B Stiffness coefficients dialogs.

Now, let's adjust the B value:

1. Click B Stiffness. The B Stiffness Coefficients dialog is displayed with the default value, 50 N/cm². The adjusted value for our first attempt is 100.0 (50 × 2).
2. Enter 100.0 for Zone 1.
3. Press OK to accept the new value.

Now, note the current peak force displayed in the Damage Profile dialog. The value is quite a bit too low (again, we want it to equal the value of 783,139 Newtons for the Ford Escort). Try a factor of 5:

1. Click A Stiffness to display the A Stiffness Coefficients dialog, and enter 1225 (245 × 5). Press OK to remove the dialog.
2. Click B Stiffness to display the B Stiffness Coefficients dialog, and enter 250 (50 × 5). Press OK to remove the dialog.

Now the force for the Nissan is quite a bit greater than the force on the Ford. Repeat the process using a factor of 4:

1. Click A Stiffness to display the A Stiffness Coefficients dialog, and enter 980 (245 × 4). Press OK to remove the dialog.
2. Click B Stiffness to display the B Stiffness Coefficients dialog, and enter 200 (50 × 4). Press OK to remove the dialog.

The resulting force on the Nissan is 791,634 Newtons, closely matching the force on the Ford Escort.

1. Press OK to accept the assigned damage profile.

Checking the PDOFs

It is always a good idea to make sure that the entered impact positions and PDOFs conform to Newton's 3rd Law. According to Newton's 3rd Law, the vehicles' PDOFs must be equal and opposite. When we apply this constraint to our

data, we find the following condition must be satisfied:

$$PDOF_1 + \psi_1 = PDOF_2 + \psi_2 \pm 180$$

where ψ = heading angle. Solving for $PDOF_2$, we have:

$$PDOF_2 = PDOF_1 + \psi_1 - \psi_2 \pm 180 = -30 + 195 - (-90) \pm 180 = 75 \text{ deg}$$

But we assigned a CDC of 02RPEW3, which has a default PDOF of 60 degrees. Our calculation above shows that to satisfy Newton's 3rd Law, we must change the PDOF to 75 degrees. In this event, the PDOFs are not opposite. Therefore, we will edit the PDOF:

1. In the PDOF field, replace 60 with 75.
2. Click Apply to accept the change.

> **NOTE:** If you click on Use Newton's 3rd Law, EDCRASH will make this calculation for you automatically!

Due to the effect of the energy magnification factor, the above change to the PDOF will change the peak force calculated for the Nissan Sentra. The peak force is now 709,760 N for the Nissan Sentra. By comparing this force with the peak force on the Ford Escort, 783,139 N, we find the difference is acceptable, so we are finished setting up the event.

1. Press OK to accept the assigned damage profile.

Executing the Event

Before we execute the event, let's set up the Key Results windows:

1. If Key Results windows are not displayed, choose Show Key Results from the Options menu.
2. Drag the Key Results windows to a convenient location, where they do not block the view but still allow access to the viewer thumb wheel controls (in case we want to change the view).

Now we're ready to execute the event. Take a moment to set the view using the viewer controls or Set Camera dialog. Now, let's execute the EDCRASH event.

1. Using the Event Controller, press Play to execute the event.

Although nothing appears to happen (i.e., the vehicles don't move), the event has been executed. Unlike simulation calculations, which are repetitive, reconstruction calculations are executed only once, and thus happen very quickly.

> **NOTE:** You may confirm that execution has occurred by checking the results in your Key Results windows.

We have now completed the event.

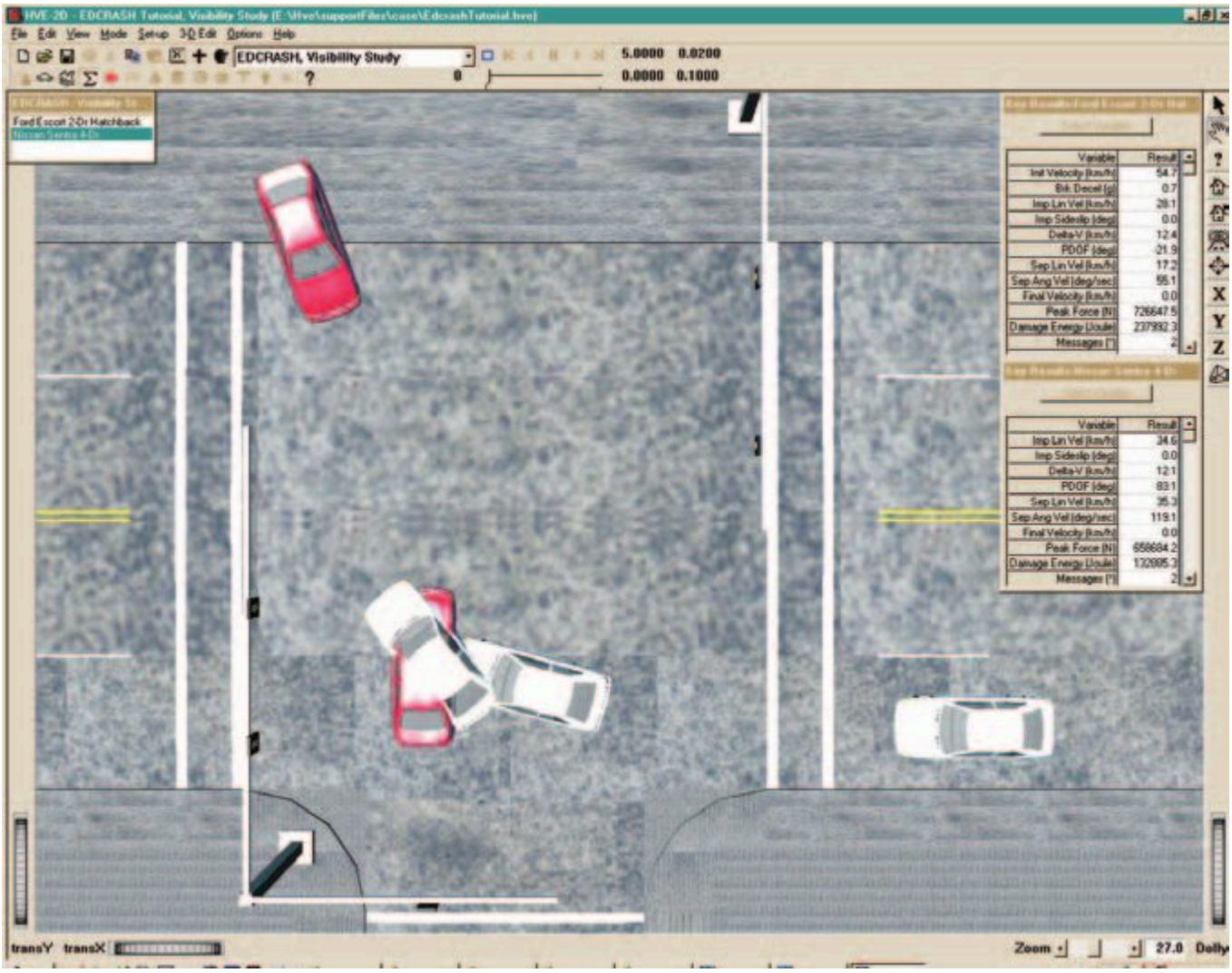


Figure 5-13: EDCRASH Tutorial event after execution. The Key Results windows show the pre-impact speeds, delta-Vs, and other key information from the analysis.

Viewing Results

Now that we have produced our EDCRASH results, let's take a detailed look at them. The Playback Editor is used for reviewing and printing reports for each event in the current case, as well as for producing video output.

EDCRASH produces the following reports:

- **Accident History** — A table of user-entered positions and their respective (calculated) velocities
- **Damage Data** — A table of damage profile coordinates, CDC, PDOF and Delta-V for each vehicle
- **Damage Profiles** — A plan view of the vehicles showing their damage profiles (damage width, depth and midpoint offset)
- **Event Data** — A table of scene data (positions, orientations and velocities)
- **Messages** — A list of messages produced by the current run
- **Momentum Diagrams (Scene and Damage)** — A vector diagram showing the pre-impact and post-impact momentum vectors for each vehicle. The scene-based diagram uses impact velocity calculated from the momentum-

based delta-V; the damage-based diagram uses the impact velocity calculated from the damage-based delta-V.

- **Program Data** — A table containing program control information
- **Site Drawing** — A static perspective view of the accident site showing the vehicles at their user-entered positions
- **Vehicle Data** — A series of tables containing the vehicle data used by EDCRASH

To view the output reports, we need to be in Playback mode:

1. Choose Playback Mode. The Playback Editor is displayed.

Report Windows

The reports listed above are displayed by selecting Report Windows. Each Report Window contains an individual report.

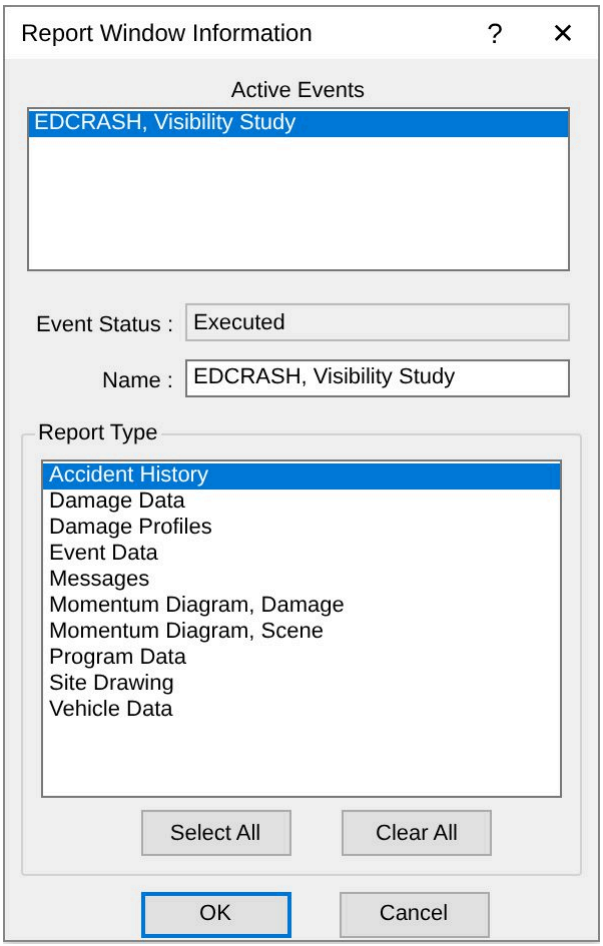


Figure 5-14: Report Window Information dialog, showing the name of the event(s) in the current case.

To view the reports produced by the EDCRASH, Visibility Study event, perform the following steps:

1. Click Add New Object. The Report Window Information dialog is displayed and includes a list of the active events (EDCRASH, Visibility Study is the only event in this tutorial). The Report Window Information dialog also includes the user-editable Report Window Name text field and the Report Type list.
2. Select EDCRASH, Visibility Study from the Active Events list.
3. In the Report Type list, select one or more of the available reports. *Select All* selects every report; each selected report opens in its own Report Window.

4. Press OK to display the report.

The selected report will be displayed in a resizable window. The reports produced for the EDCRASH, Visibility Study event are described below. Each is viewed by the same four steps above, choosing the appropriate report from the Selected Output list.

Accident History

The EDCRASH Accident History report is the primary output from EDCRASH. This report summarizes the key results for each vehicle, including impact velocity, delta-V for each available calculation method (Damage and Linear Momentum), separation velocity and relative velocity at impact.

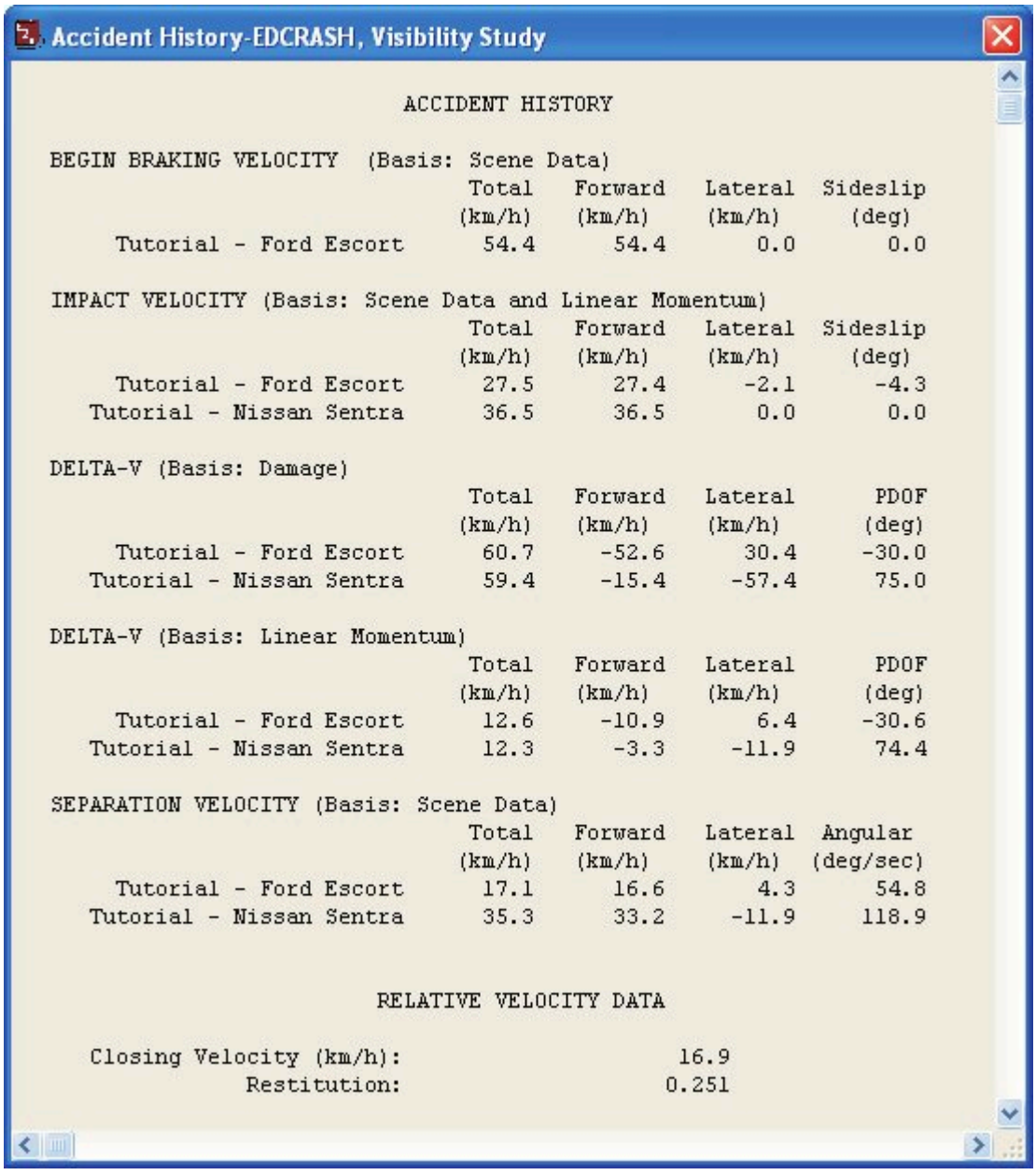


Figure 5-15: Accident History Report for EDCRASH, Visibility Study event.

Damage Data

The Damage Data report provides the user-entered damage profile and other event-related damage data for the current EDCRASH event.

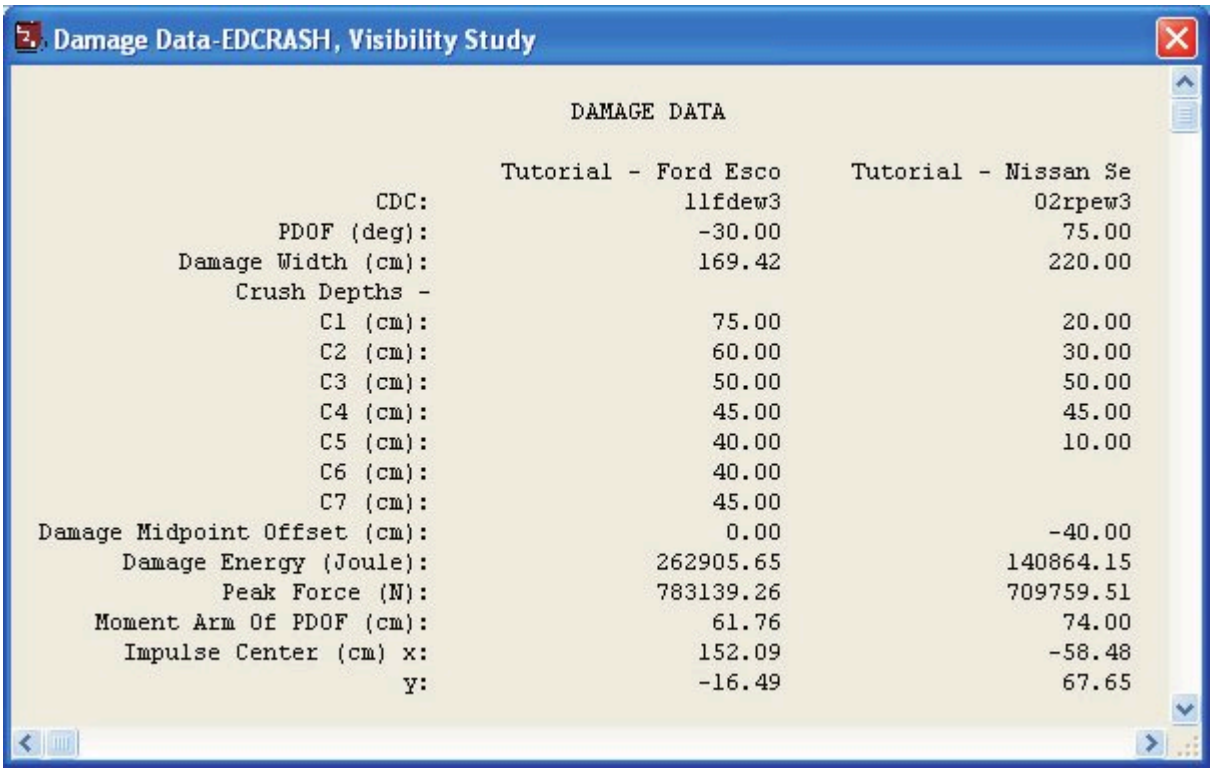


Figure 5-16: Damage Data Report for EDCRASH, Visibility Study event.

Damage Profiles

The Damage Profiles report provides a visual representation of the user-entered damage profile and PDOF for the current EDCRASH event.

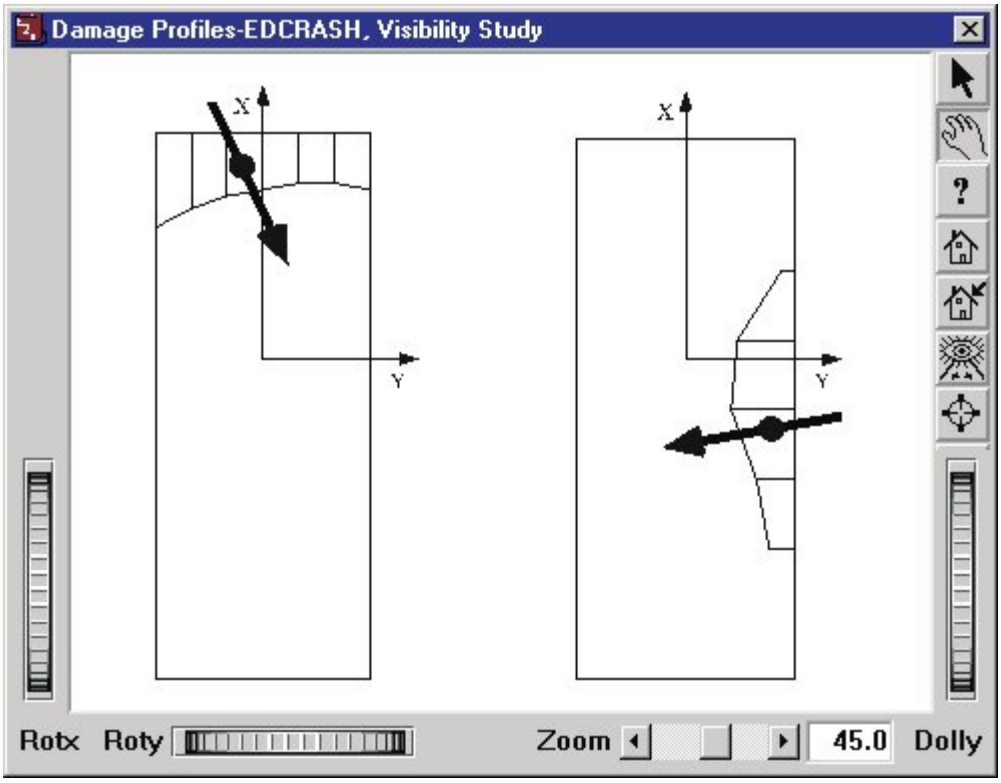


Figure 5-17: Damage Profiles Report for EDCRASH, Visibility Study event.

Event Data

The EDCRASH Event Data report includes all the scene data used for the current EDCRASH event. This scene data also provides the total amount and direction of rotation (clockwise vs counter-clockwise).

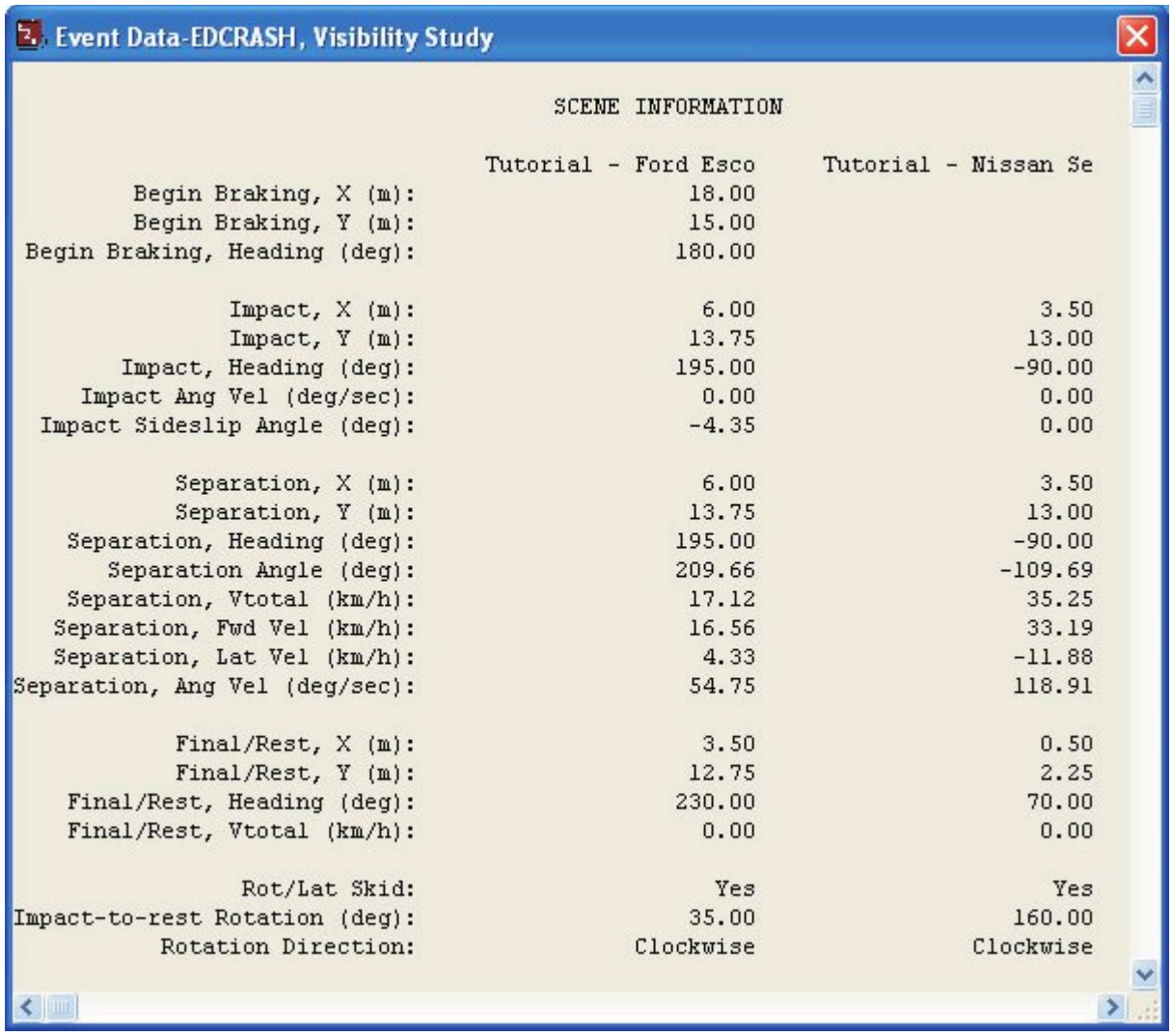


Figure 5-18: Event Data Report for EDCRASH, Visibility Study event.

Messages

The Messages report produced by EDCRASH is one of its most important reports. While simulation programs typically produce very few messages, a reconstruction program has the opportunity to evaluate the consistency of the user-entered scene and damage measurements. Careful review of these messages may show inconsistencies; correcting these inconsistencies may lead to improved results.

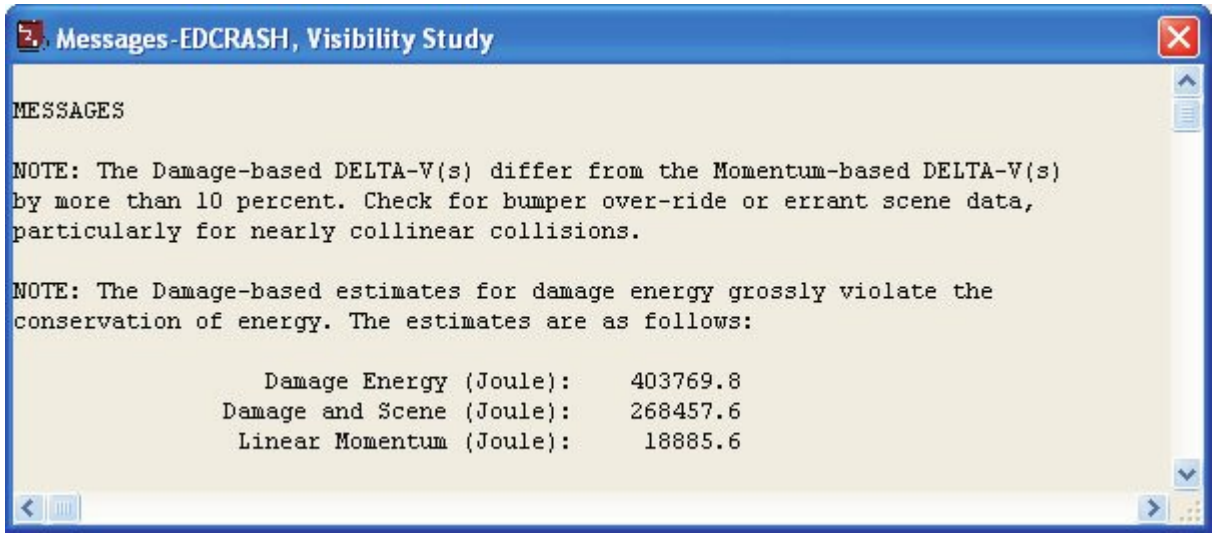


Figure 5-19: Messages Report for EDCRASH, Visibility Study event.

Momentum Diagrams

To view the Momentum Diagram, Scene Data, report, choose Momentum Diagram, Scene from the Report Type list.

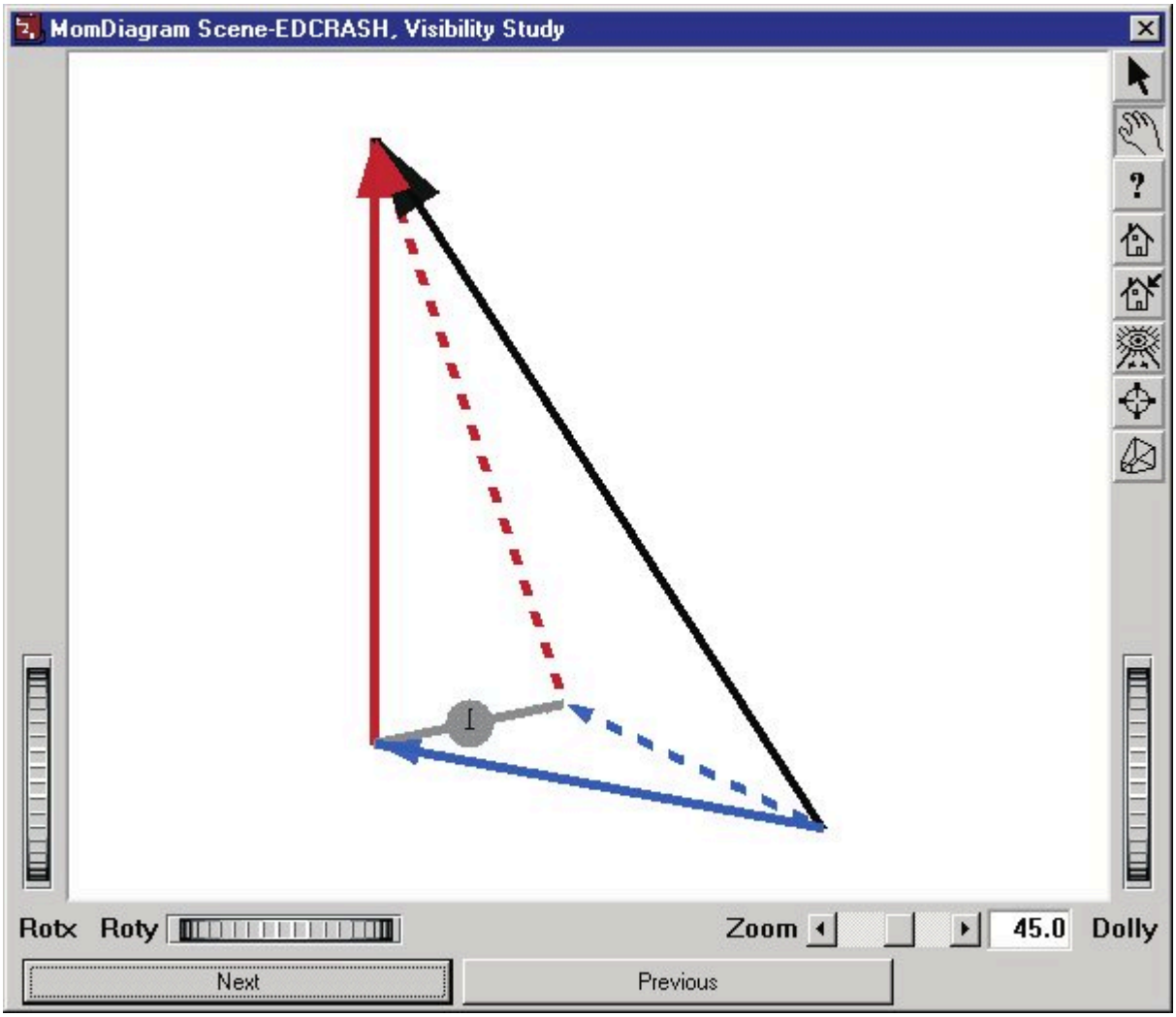


Figure 5-20: Momentum Diagram Report for EDCRASH, Visibility Study event.

Program Data

The EDCRASH Program Data report lists the physics program, in this case EDCRASH, and physics program version number. It also contains parameters used when the Trajectory Simulation option is selected and consistency checks within EDCRASH.

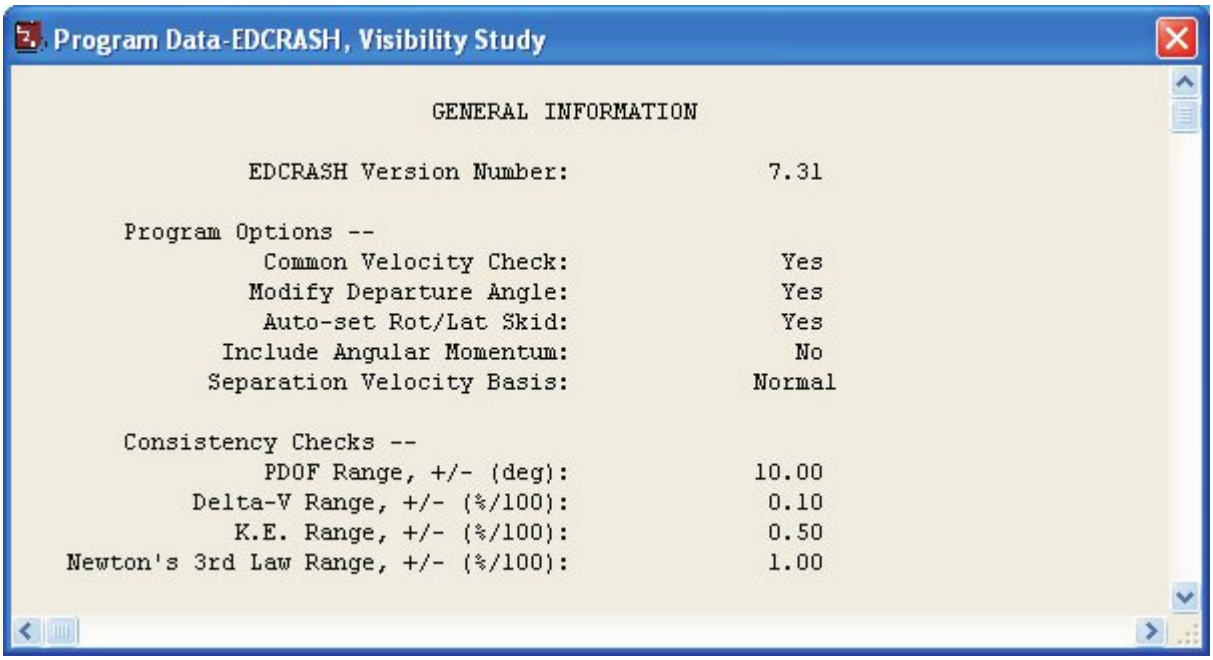


Figure 5-21: Program Data Report for EDCRASH, Visibility Study event.

Site Drawing

The Site Drawing is a static display of the event with the vehicles at their user-entered path positions (Begin Braking, Impact, Point-on-curve, End-of-rotation and Rest).

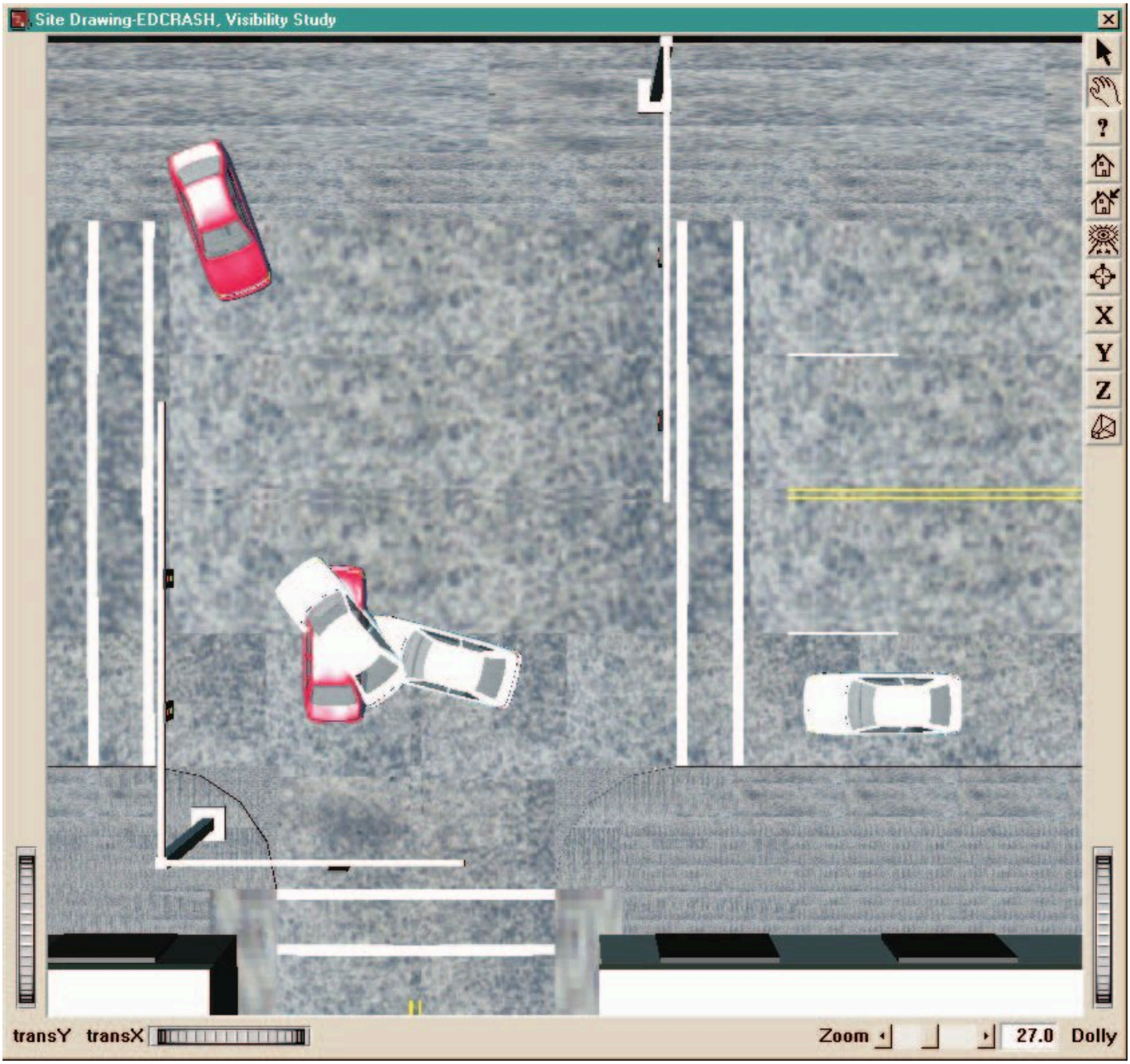


Figure 5-22: Site Drawing Report for EDCRASH, Visibility Study event showing both vehicles at each user-entered position.

Vehicle Data

The Vehicle Data report provides the physical data used by EDCRASH, including dimensions, inertias, tire properties, wheel lock-ups and stiffness coefficients.

Vehicle Data-EDCRASH, Visibility Study

VEHICLE DATA

	Tutorial - Ford Esco	Tutorial - Nissan Se
CG To Front Axle (cm):	93.22	91.69
CG To Rear Axle (cm):	156.72	162.31
Track Width (cm):	143.51	144.93
Sprung Yaw Inertia (kg-m^2):	1611.98	1922.12
Total Yaw Inertia (kg-m^2):	1763.82	2033.94
Mass (kg):	1124.04	1149.52
Weight (N):	11032.04	11282.05
Body Length To Front (cm):	178.56	173.99
Body Length To Rear (cm):	-252.09	-252.73
Body Width Overall (cm):	169.42	171.44
Crush Stiffness, Zone 1 -		
A (N/cm):	515.63	980.00
B (N/cm^2):	70.93	200.00
Crush Stiffness, Zone 2 -		
A (N/cm):	515.63	245.00
B (N/cm^2):	70.93	50.00
Crush Stiffness, Zone 3 -		
A (N/cm):	515.63	245.00
B (N/cm^2):	70.93	50.00
Crush Stiffness, Zone 4 -		
A (N/cm):	515.63	245.00
B (N/cm^2):	70.93	50.00
Crush Stiffness, Zone 5 -		
A (N/cm):	515.63	
B (N/cm^2):	70.93	
Crush Stiffness, Zone 6 -		
A (N/cm):	515.63	
B (N/cm^2):	70.93	

TIRE DATA

Tire Data, Axle 1 (right) -		
Slide Mu (*):	0.72	0.74
Cornering Stiffness (N/deg):	765.10	504.01
Lockup (%/100):	1.00	0.20
Tire Data, Axle 1 (left) -		
Slide Mu (*):	0.72	0.74
Cornering Stiffness (N/deg):	765.10	504.01
Lockup (%/100):	1.00	0.20
Tire Data, Axle 2 (right) -		
Slide Mu (*):	0.72	0.74
Cornering Stiffness (N/deg):	765.10	504.01
Lockup (%/100):	0.01	0.01
Tire Data, Axle 2 (left) -		

Figure 5-23: Vehicle Data Report for EDCRASH, Visibility Study event.

> **NOTE:** The Vehicle Data and several other reports contain more information than fits into the default window size. Use the scroll bars or resize the dialog to view the entire report.

Printing

The final step is to print the above reports. Printing reports is simple. All you do is choose a report and print it. For example:

1. Click on the dialog header of the Accident History – EDCRASH, Visibility Study report. Your selection is highlighted and the Accident History window pops to the top of the display (if it isn't there already), indicating it is the current window.
2. Click on the File menu and choose Print. The Print dialog is displayed, allowing the user to select from several available print options.

> **NOTE:** Alternatively, you can click on the print icon in the upper menu bar.

1. Press OK. The Accident History output report is printed on the system printer.

That's all there is to it! You can print any other report using the same two steps described above.

> **NOTE:** The Print dialog provides several options. Refer to your Windows or printer manual for more information.
>
> **NOTE:** For several reports it may be best to print in landscape rather than portrait mode.
>
> **NOTE:** The font size of both the printed reports and screen display may be edited by clicking on the Options menu and choosing Preferences. Use the Font Size option list to change the size.

Previous: Chapter 4 — Calculation Method · Next: Chapter 6 — Messages

Chapter 6 — Messages

Messages may be issued by the operating system, HVE-2D or HVE, or by EDCRASH. Some of the more common operating system messages are described in the Appendix. A more thorough discussion of operating system messages may be found in the operating system manual. Messages produced by HVE-2D or HVE are described in the User's Manual, Appendix II.

Errors issued by EDCRASH appear in the EDCRASH output and may be one of three types:

- **Fatal Messages (Level 1)** — These messages halt execution and are caused by the program's inability to continue the calculation procedure based on intermediate results which are inconsistent or incompatible with basic program assumptions.
- **Diagnostic Messages (Level 2)** — These messages do not halt execution, but are the result of the internal consistency checks performed by the program and suggest inconsistencies in the results of which the user should be aware. These inconsistencies may be the result of bad or suspicious data.
- **Informative Messages (Level 3)** — These messages do not halt execution, and provide information about execution not affecting accuracy, but suggestive of something the user may want to review to ensure data were as intended.

All messages issued by EDCRASH are listed below. Each message includes a description or nature of the cause, the level of the message (Informative, Diagnostic or Fatal), and the recommended action to eliminate the problem. If you receive an error message not listed below, first check to see if it is an HVE-2D or operating system message by referring to the HVE-2D Appendix or your computer's operating system manual. If the message is not listed in either place, please contact EDC immediately with the offending error message and the case file that caused the error.

COMMON VELOCITY WARNING

> *An adjustment of vehicle separation velocities was performed in order to be consistent with the assumption that the contact interface reached a common velocity. The adjustment did not exceed 10 percent.*

(Level 2 — Diagnostic)

The separation velocity of each vehicle is computed independently, based totally on user-entered data. The damage-based calculations require the velocity at the damage centroids for each vehicle to be equal (the CG velocities may not be equal). If the user-entered data results in a small discrepancy (up to 10%), the separation velocities are adjusted and the above message is issued.

No response by the user is necessary. However, refer to the information below (COMMON VELOCITY ERROR) for data affecting this message.

COMMON VELOCITY ERROR

> *** COMMON VELOCITY ERROR ***
> *The vehicle contact interface failed to reach a common velocity, based on user-supplied data for impact-to-rest path length and rolling resistance. Impact Speed calculations were not performed.*

(Level 1 — Fatal)

The earth-fixed velocity at the damage centroid is computed for each vehicle separately, based on user-entered scene data and the PDOF. If this velocity differs between vehicles by more than allowed (typically 10 percent), an adjustment of the separation conditions is performed (see Common Velocity Warning, above). For collinear collisions, if, after this adjustment, the velocities at the damage centroid still differ by more than 10 percent, the common velocity assumption cannot be satisfied and EDCRASH aborts.

What To Do:

1. Check first to see that all accident site path data (impact, rest, EOR and POC) were entered correctly. Make sure that you entered the heading angles correctly. Then see if the damage data (damage profiles and PDOFs) were entered correctly. Use the Graphics.
2. Scrutinize the path data. Is it possible the impact positions and headings or the rest positions and headings were not what you thought? Were there pre-impact sideslip angles? Was there an EOR that you did not enter? Was the POC valid? Are you sure about the rotation direction? Scrutinize your path data.
3. Scrutinize the Wheel Data. Check the tire/road friction. Were the wheels really locked? Free rolling? In between? (If so, how did you arrive at your entries?) Scrutinize your Wheel Data.
4. Scrutinize the PDOFs. Is it possible they were greater (or less) than the values you entered? Try entering a range of possible values, checking the effect on your results. Scrutinize your PDOFs.
5. Finally, make sure the collision was not a sideswipe collision, which violates the common velocity assumption (see Assumptions).

Newton's Third Law Warning

> *WARNING: Damage-based estimates for Magnitude of Principal Force grossly violate Newton's Third Law of motion. Review the output to determine required corrections to Damage Data and adjust as necessary. The Magnitudes of Principal Force should be approximately equal.*

(Level 3 — Informative)

An analysis of the vehicle damage data is performed using CDC-generated data or user-entered damage dimensions. This analysis results in the damage-based Delta-V, the energy absorbed by damage and the magnitude of the principal force. This fact serves as an excellent check on the validity of the damage-based results. If the results are reasonable, then the independently-calculated forces should be approximately equal as well. If these forces differ by more than allowed (typically 100 percent), the above message is displayed.

What To Do:

1. Check to see if the damage data (damage profiles and PDOFs) were entered correctly. Use the Graphics.

2. Scrutinize the Damage Data. Check the damage dimensions (width, crush depths, and damage offset) to be sure they were accurately measured. Remember to include induced damage, especially for narrow impact widths (less than 16 inches). Scrutinize your Damage Data.
3. Scrutinize the PDOFs. If scene data were entered, you may be able to compare the PDOF with the angle of the impulse (see PDOF Compatibility warning message). Remember: as the PDOF angle decreases (becomes less perpendicular) to the damaged surface, the Magnitude of Principal Force increases. Scrutinize your PDOFs (see Energy Magnification Factor).
4. Scrutinize the Crush Stiffness Coefficients. Default data are assigned according to the selected vehicle, but may be changed by the user. The Crush Stiffness coefficients are the result of test data [22]. Higher coefficients increase the Magnitude of Principal Force; the coefficients may be higher than assigned by the Stiffness Category if the damage region was primarily in a stiff region, such as a wheel or frame area. Lower coefficients decrease the Magnitude of Principal Force; the coefficients may be lower than assigned by the Stiffness Category if the damage region was primarily in a soft region, such as a fender or grill (above the bumper) area.

SPINOUT ERROR

> *** SPINOUT ERROR DETECTED ***
>
> *The position and heading entered for the end of rotation or rest of the vehicle, and/or the specified direction of rotation are not compatible with the submitted rolling resistances and the total path length from separation to rest. User should carefully review this physical evidence for adjustment and rerun.*
>
> - Relative error figure =
> - Wheel lock-up =
> - Sep. to EOR path length =
> - Sep. to EOR heading change =
> - EOR to rest path length =

(Level 1 — Fatal)

A negative (−) relative error figure indicates the vehicle had insufficient separation velocity to reach the specified rest position given the rolling resistance; a positive (+) figure indicates the vehicle translated an insufficient distance for the specified rotation from separation to rest.

This message will only result if the rotating/lateral skidding option was selected (see Program Input, Setting Up an Event; Wheel Data). This option calculates the separation velocities using the empirical method developed by McHenry (see references 2, 15 and 16). If the results of the empirical calculations conflict with the laws of motion, the above message is issued and EDCRASH aborts.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Use the Graphics.
2. Use the Relative Error Figure. Compare the value shown in the present run with the next run to see if your adjustments had a positive effect. If the relative error figure is negative, the vehicle had insufficient velocity at separation to reach the rest position given the EOR-to-rest path length; an adjustment in the correct direction will

make this figure closer to zero. If the relative error figure is positive, the separation-to-EOR path length is probably too short to allow the indicated heading change to take place.

3. Scrutinize the Path Data. Is it possible the impact positions and headings or the rest positions and headings were not what you think they were? Were there pre-impact sideslip angles? Was there an EOR that you did not enter? Was the EOR entered accurately? Was the POC valid? Are you sure about the direction of rotation? Scrutinize your Path Data.
4. Scrutinize the Wheel Data. Check the tire/road friction. Were the wheels really locked? Free rolling? In between? (If so, how did you arrive at your entries?) Scrutinize your Wheel Data.

Separation Velocity Warning

> *WARNING: The separation velocity of the striking vehicle is greater than the separation velocity of the struck vehicle along a line between the vehicle CGs.*

(Level 3 — Informative)

This condition implies the striking vehicle is driving through the struck vehicle after the impact! This is obviously not possible within the assumptions of the program (especially that the vehicle does not break into two pieces!).

The coefficient of restitution should be positive. Check this value. The value will increase (i.e., become positive) by reducing the separation velocity of the striking vehicle or increasing the separation velocity of the struck vehicle.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Use the Graphics.
2. Scrutinize the path data. Even though the graphics shows the data were entered properly, is it possible that any of the path data are off by a few feet? Try modifying these parameters to identify how they affect the coefficient of restitution.
3. Scrutinize the rolling resistances and friction coefficients. Are the percent lock-ups assigned correctly? Have you assigned a higher coefficient of friction for the striking vehicle? Try modifying these parameters to identify how they affect the coefficient of restitution (it should be a small positive number).

Point-on-Curve Warning

> *WARNING: User-entered Point-on-Curve was discarded because the position was practically on a straight line between impact and rest or it was too far away from other path coordinates to make sense. If the post-impact path was curved and your Point-on-Curve was rejected, the results may be erroneous. Check your data.*

(Level 2 — Diagnostic)

EDCRASH checks the validity of a point on curve if one is entered. Two conditions are possible which will cause it to be rejected: if the point on curve is on a straight line, or if the point on curve is outside of the smallest possible circle connecting the impact and rest (or EOR) positions. In the former case, there is no problem; the message serves only to remind the user why the point on curve is not displayed in the output listing. In the latter case, the results may be

substantially affected. This is particularly true if the separation angle determined by the circular arc defined by the point on curve is substantially different from the separation angle determined by the straight line between impact and rest (or EOR) positions.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Use the Graphics.
2. Scrutinize the POC. Check to see if the POC is on a straight line between impact and rest positions (this should not occur if you are using a site drawing as a tool for analysis). If the point is not on a straight line, check the possible range of points on curve using a compass to draw the smallest circle connecting the impact and rest (or EOR) positions. The point on curve must lie within the circle. Scrutinize your POC.

PDOF Adjustment Warning

> *WARNING: User-entered Principal Directions of Force have been adjusted to be 180 degrees apart.*

(Level 3 — Informative)

This message serves only as a reminder that the PDOFs were adjusted. No response by the user is necessary. However, if the adjusted values are not correct, use the Damage Profile dialog to re-enter either or both vehicles' PDOFs.

Sideslip Angle Adjustment Warning

> *WARNING: User-entered sideslip angle BETA was adjusted for compatibility with components of separation velocity and specified Principal Direction of Force. If adjusted value of BETA is not consistent with available physical evidence, basis of PDOF should be reviewed for possible adjustment and rerun.*

(Level 3 — Informative)

The user-entered pre-impact sideslip angle BETA may result in lateral separation velocities not compatible with the PDOFs. To remedy this anomaly, the sideslip angle is adjusted. This message only occurs for collinear collisions when the user enters an impact sideslip angle.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Use the Graphics.
2. Scrutinize the sideslip angles. Do you have a firm basis for your estimates? Are they entered correctly (according to the vehicle-fixed coordinate system)? Are the signs correct? Scrutinize your sideslip angles.
3. Scrutinize the PDOFs. Make changes and observe the results. The PDOFs of both vehicles must be perfectly compatible with the sideslip angles and separation velocity components. Scrutinize your PDOFs.

Sustained Contact Note

> *NOTE: Sustained contact solution form.*

(Level 3 — Informative)

The above message is displayed to remind the user that this option was selected. Certain analyses which normally follow, such as the trajectory simulation, are not allowed with this option. No response by the user is necessary; this is simply a reminder.

Barrier Collision Note

> *NOTE: Barrier Collision Analysis — Common Velocity Check not performed.*

(Level 3 — Informative)

The above message is displayed as a reminder to the user that when the collision involves a barrier, the common velocity check is not performed.

Rotation Direction Warning

> *WARNING: The direction of angular velocity change from SCENE DATA for vehicle is not compatible with moment arm of principal force from user-entered PDOF. Review damage data if results are questionable. Most likely, this requires either a change in the rotation direction or the PDOF.*

(Level 3 — Informative)

The user assigns the direction of rotation by entering heading angles for each path position. If the heading angle increases as the vehicle travels along its path, a positive rotation is indicated; if the angle decreases, a negative rotation is indicated; otherwise there is no rotation. EDCRASH does not allow for the condition whereby either vehicle is spinning prior to impact. Thus, any post-impact spinning must be due to the force of impact. The moment (torque) exerted on the vehicle as a result of the impact force must be consistent with the user-entered direction of rotation.

What To Do:

1. Check to see if the damage data (damage profiles and PDOFs) were entered correctly. Use the Graphics. Carefully note the distance from the PDOF vector to the CG (the actual moment arm distance is displayed in the Damage Data output report; see Chapter 3, Program Output) and determine if the force would tend to cause clockwise or counterclockwise rotation about the CG.
2. Scrutinize the crush stiffness coefficients. Determine if a hard spot, such as a wheel, exists that may have caused the principal force not to go through the damage centroid as normally modeled. (Note that the principal force is assumed to go through the damage centroid.) If this was not the case, you can override this assumption by supplying different crush stiffness coefficients for each crush zone, or by moving the impulse center (see Chapter 2, Program Input, Setting Up an Event; see also the User's Manual, Vehicle Damage).

PDOF Compatibility Warning

> *WARNING: The user-entered PDOFs are not consistent with the angles computed by the momentum analysis. Check the Accident History report. The user-entered PDOFs should be approximately equal to the values computed using Linear Momentum (scene data).*

(Level 3 — Informative)

The impact phase is always analyzed using the damage data. If the collision was oblique, the impact phase is also analyzed using linear momentum. Therefore, the angle of the impulse is computed. This provides an excellent opportunity to confirm (or refute) the user's estimate for PDOFs. If the user's PDOFs differ from the PDOFs computed by the momentum analysis by more than about 10 degrees (user-editable; see Calculation Options), the above message is issued.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Then see if the damage data (damage profiles and PDOFs) were entered correctly. Use the Graphics.
2. Scrutinize the Path Data. Is it possible the impact positions and headings or the rest positions and headings were not what you think they were? Were there pre-impact sideslip angles? Was there an EOR that you did not enter? Was the POC valid? Are you sure about the direction of rotation? The angle calculated by the momentum analysis is only as good as the scene data. Scrutinize your Path Data.
3. Scrutinize the angle between the pre-impact velocity vectors. If they are just slightly more than 10 degrees from being parallel, the results calculated by the momentum analysis may be extremely sensitive to small changes in scene data; in particular, the impact heading and sideslip angles, and point on curve. If your results are afflicted with this problem, it will be obvious by observing the angle of the impulse (refer to the values of PDOF displayed in the Accident History output report). These angles will be vastly different from your estimate of the PDOFs. Impact speeds based on these angles will probably be preposterous. The major purpose of this error message is to provide the reason why. Scrutinize the angle between the pre-impact velocity vectors.
4. Make the right decision. If you have great confidence in your scene data and the momentum-based values of the PDOF seem reasonable, change the PDOF of each vehicle to be equal to the calculated PDOFs. Otherwise, do not change the PDOFs. Instead, locate and change the errant scene data. Make the right decision.

Delta-V Compatibility Note

> *NOTE: The Damage-based Delta-V(s) differ from the Momentum-based Delta-V(s). Check for bumper over-ride or errant scene data, particularly for nearly collinear collisions.*

(Level 2 — Diagnostic)

The delta-V is always analyzed using the damage data. If the collision was oblique, the delta-V is also analyzed using linear momentum. This provides an excellent opportunity to confirm (or refute) the delta-V(s). If the momentum- and damage-based delta-Vs differ by more than about 10 percent (user-editable; see Calculation Options), the above message is issued.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Then see if the damage data (damage profiles and PDOFs) were entered correctly. Use the Graphics.
2. Scrutinize the momentum-based delta-V(s). The delta-V calculated by the momentum analysis is only as good as the scene data. Scrutinize your delta-V(s).
3. Scrutinize the Path Data. Is it possible the impact positions and headings or the rest positions and headings were not what you think they were? Were there pre-impact sideslip angles? Was there an EOR that you did not enter? Was the POC valid? Are you sure about the direction of rotation? Scrutinize your Path Data.
4. Scrutinize the angle between the pre-impact velocity vectors (see the PDOF compatibility check above). If they are just slightly more than 10 degrees from being parallel, the results calculated by the momentum analysis may be extremely sensitive to small changes in scene data; in particular, the impact heading and sideslip angles. If your results are afflicted with this problem, it will be obvious by observing the angle of the impulse (refer to the calculated values for PDOF displayed in the Accident History). These angles will be vastly different from your estimate of the PDOFs, also displayed in the Accident History. Impact speeds based on these angles will probably be preposterous because the reported impact speeds will be based on the errant momentum analysis. The major purpose of this error message is to provide the reason why. Scrutinize the angle between the pre-impact velocity vectors.

Coefficient of Restitution Warnings

> *WARNING: The coefficient of restitution is negative. This implies the striking vehicle traveled through the struck vehicle during impact.*

(Level 3 — Informative)

> *WARNING: The coefficient of restitution is greater than 1.0. This implies the crash created energy. The normal range is ~0 to 0.25, perhaps slightly greater for low-speed impacts.*

(Level 3 — Informative)

The classic definition of coefficient of restitution, r, is the ratio of the rebound velocity to the approach velocity. In the case of vehicle collisions, we define the coefficient of restitution as the ratio of the difference in vehicle separation velocities to the difference in impact velocities,

$$r = \frac{-(v_1 - v_2)_{sep}}{(v_1 - v_2)_{imp}}$$

For most collisions, the value should lie in the range $0.0 < r < 0.25$, although for some low-speed impacts the value may be higher due to springback of energy-absorbing bumper systems.

A value of $r < 0.0$ is only possible if the vehicles pass through each other. For example, consider an axial rear-end collision that involves a moving vehicle striking the rear of a stationary vehicle. Consider the possibility that, following impact, the striking vehicle has a larger (forward) separation velocity than the struck vehicle. If you can visualize this, you will quickly see this is not possible — unless the striking vehicle actually goes through the struck vehicle. This condition is revealed by a negative restitution coefficient.

Of course, it is also possible that the struck vehicle's separation velocity is much higher than the striking vehicle's. This implies the vehicles are bouncing off of each other like super balls. This is clearly not possible in vehicle collisions. In

the extreme case, in fact, the system energy would actually be higher after impact than before impact. This condition is revealed by a coefficient of restitution greater than 1.0.

What To Do:

1. Inspection of the equation above reveals that its denominator can never be negative (a negative denominator would imply the vehicles never collided). Thus, if r is less than 0.0, the problem must lie in the numerator. Note the numerator includes only the separation velocities. These velocities are calculated from scene data (path length, tire-road friction) and wheel lock-ups. So, focus on the scene data and the wheel lock-ups.
2. The classic coefficient of restitution is derived from particle kinematics in which the colliding objects have a point mass and zero size. This is not true for vehicles, which are basically large rectangles. Thus, the equation cited earlier uses the components of the impact and separation velocities along a line drawn between the vehicle centers of gravity at their impact positions. These velocity components change as the vehicle impact positions are moved relative to each other. Therefore, confirm the relative impact positions.

(updated: the current release also issues an intermediate "restitution too high" warning when the computed restitution exceeds the normally expected range without exceeding 1.0, and a "negative approach velocity" message when the impact geometry implies the vehicles were separating at impact. The guidance above applies to these variants as well.)

Closing Velocity Error

> *ERROR: The closing velocity is less than zero, indicating a calculation error has occurred. Two vehicles cannot collide if their closing velocity is less than zero.*

(Level 1 — Fatal)

This is the error-level form of the "negative approach velocity" condition referenced above. The closing (approach) velocity is the component of the difference in impact velocities along the line between the vehicle centers of gravity; it must be positive for the vehicles to have collided. If the impact geometry derived from the entered data implies the vehicles were separating (a negative closing velocity), EDCRASH cannot compute an impact speed and issues this message.

What To Do:

1. Re-examine the impact positions, heading angles, and PDOFs. A negative closing velocity usually indicates one of these is inconsistent with the intended collision geometry.

Conservation of Energy Warning

> *WARNING: The Damage-based estimates for damage energy grossly violate the conservation of energy.*

(Level 2 — Diagnostic)

The energy dissipated by damage is computed when damage data are entered. If no scene data were entered, the damage analysis is the only way to compute damage energy. However, if scene data were entered, the impact and separation

velocities of each vehicle are computed. The loss in kinetic energy which occurs between impact and separation should be equal to the damage energy.

This compatibility check can be performed whether the impact phase was based on Damage or Linear Momentum. If the variation between estimates exceeds the allowable limit (typically 50 percent) the above message is issued.

What To Do:

1. Check first to see that all accident site Path Data (impact, rest, EOR and POC) were entered correctly. Then see if the damage data (damage profiles and PDOFs) were entered correctly. Use the Graphics.
2. Scrutinize the Damage Data. Check the damage dimensions (width, crush depths, and damage offset) to be sure they were accurately measured. Remember to include induced damage, especially for narrow impact widths (less than 16 inches). Scrutinize your Damage Data.
3. Scrutinize the PDOFs. For oblique collisions, you can compare the PDOFs with the angles of the impulse (see PDOF Compatibility warning message). Remember: as the PDOF angle decreases (becomes less perpendicular) to the damaged surface, the energy dissipated by damage increases. Scrutinize your PDOFs.
4. Scrutinize the Crush Stiffness coefficients. Default coefficients are assigned when the vehicle is selected, but can be changed by the user during Event mode. The best coefficients are obtained from crash test data [25]. Higher coefficients increase the Energy Dissipated by Damage; the coefficients may be higher than assigned by the Stiffness Category if the damage region was primarily in a stiff region, such as a wheel or frame area. Lower coefficients decrease the Energy Dissipated by Damage; the coefficients may be lower than assigned by the Stiffness Category if the damage region was primarily in a soft region, such as a fender or grill (above the bumper) area. Scrutinize the Crush Stiffness Coefficients.

Angular Momentum PDOF Note

> *NOTE: The user-entered PDOFs are not consistent with the angles computed by the angular momentum analysis. Check the Accident History report. The user-entered PDOFs should be approximately equal to the values computed using Angular Momentum (scene data).*

(Level 3 — Informative)

This message is the angular-momentum counterpart of the PDOF Compatibility Warning (above). When the collision is oblique and the PDOF does not act through the vehicle's center of gravity, the angle of the impulse can also be computed from an angular momentum analysis, providing an additional check on the user's estimate for PDOFs. If the user's PDOFs differ from the angular-momentum-derived values by more than the allowed range, the above message is issued.

> **NOTE:** The Angular Momentum solution has not been implemented in this release of EDCRASH; this message will not occur. *(updated: this remains true in the current version — the current version does not issue this message, and the Include Angular Momentum Solution check box in the Calculation Options dialog is disabled.)*

Angular Momentum Delta-V Note

> *NOTE: The Damage-based Delta-V(s) differ from the Angular Momentum-based Delta-V(s) by more than 10 percent. Check for bumper over-ride or errant scene data, particularly for nearly collinear collisions.*

(Level 2 — Diagnostic)

The delta-V is always analyzed using the damage data. If the collision was oblique and the PDOF does not act through the vehicle's center of gravity, the delta-V is also analyzed using angular momentum. This provides an excellent opportunity to confirm (or refute) the delta-V(s). If the momentum- and damage-based delta-Vs differ by more than 10 percent, the above message is issued.

> **NOTE:** The Angular Momentum solution has not been implemented in this release of EDCRASH; this message will not occur. *(updated: this remains true in the current version — the Include Angular Momentum Solution check box in the Calculation Options dialog is disabled.)*

Collinear Collision Needs Damage Error

> *** ERROR ***
> *Impact Velocity and Delta-V were not computed because the collision type was collinear and damage profiles were not assigned. Collinear collisions require that damage profiles be assigned so that a damage-based Delta-V may be calculated for each vehicle.*

(Level 1 — Fatal)

For oblique collisions, EDCRASH requires that the user enter only scene data for the calculation of impact speed and delta-V. Damage profiles, if entered, are used as an internal consistency check. However, collinear collisions require that damage data be entered for both vehicles in order to perform the calculation of impact speed and delta-V. If damage data are not entered for collinear collisions, the above message is issued.

What To Do:

1. Confirm the collision type. The collision type is defined by the relative directions of the velocity vectors at impact.

> **NOTE:** The definition is based on the direction of the velocity vectors — not the heading vectors!

If the angle between the velocity vectors at impact is equal to or less than 10 degrees and you did not enter damage data, simply supply damage profiles for both vehicles (rigid barriers are an exception; they do not require damage profiles because they do not absorb energy).

Both PDOFs Requested Error

> *** ERROR ***
> *The user requested EDCRASH to calculate the PDOFs for both vehicles. It is only possible to calculate the PDOF for one vehicle given the PDOF of the other. It is not possible to calculate the PDOFs for both vehicles.*

(Level 1 — Fatal)

The Damage Profile dialog includes an option, called Use Newton's 3rd Law, that will tell EDCRASH to calculate the PDOF of one vehicle based on the impact heading angles and the user-entered PDOF for the other vehicle. If the user asks EDCRASH to calculate the PDOF for both vehicles (i.e., the user chooses the Use Newton's 3rd Law option for both vehicles), this message will be issued.

What To Do:

1. Choose the Damage Profiles dialog for one of the vehicles and deselect the Use Newton's 3rd Law option.

When deselecting the Use Newton's 3rd Law option, which vehicle should you choose? Choose the vehicle for which you have the most confidence in your estimated PDOF entry. EDCRASH will then calculate the PDOF for the other vehicle based on your estimated PDOF.

Automatic PDOF Note

> *NOTE: The PDOF for the vehicle was automatically calculated by EDCRASH to be consistent with Newton's 3rd Law based on the user-entered impact heading angles and the PDOF of the other vehicle.*

(Level 3 — Informative)

The Damage Profile dialog includes an option, called Use Newton's 3rd Law, that will tell EDCRASH to calculate the PDOF of one vehicle based on the impact heading angles and the user-entered PDOF for the other vehicle. This message simply documents that this option was selected. No action by the user is necessary.

PDOF Split-Adjustment Note

> *NOTE: The user-entered PDOFs were adjusted to be compatible with the user-entered impact heading angles and Newton's 3rd Law, i.e., PDOF1 + PSI1 = PDOF2 + PSI2 +/− 180. The adjustment was performed by splitting the difference between the vehicles. The Damage Data report displays the original, user-entered values. The Accident History report displays the adjusted values.*

(Level 3 — Informative)

If damage profiles are entered for both vehicles, PDOFs are assigned by the user as well. These PDOFs must be compatible with Newton's 3rd Law (that is, they must be in opposite directions with respect to the earth-fixed coordinate system).

If the error does not exceed the PDOF Range consistency-check value (default ±10 degrees, user-editable; see Calculation Options), EDCRASH will automatically adjust the user-entered PDOFs, adding (or subtracting) half the difference to the assigned PDOF for each vehicle. If the error exceeds the PDOF Range, the event is terminated instead (see PDOF Incompatibility Error, below).

What To Do:

1. No action by the user is necessary. However, if you do not wish to have EDCRASH perform this adjustment, you have two options: the simplest is to use the AutoCalc PDOF option for one of the vehicles (choose the one you have

the least confidence in); the other option is to re-enter valid PDOFs (i.e., those that satisfy the equation PDOF1 + PSI1 = PDOF2 + PSI2 ± 180).

PDOF Incompatibility Error

> *** ERROR ***
> *The event was terminated because the user-entered PDOFs and impact heading angles were not compatible with Newton's 3rd Law, i.e., PDOF1 + PSI1 = PDOF2 + PSI2 +/− 180.*

(Level 1 — Fatal)

If damage profiles are entered for both vehicles, PDOFs are assigned by the user as well. These PDOFs must be compatible with Newton's 3rd Law (that is, they must be in opposite directions with respect to the earth-fixed coordinate system). This message was issued and must be corrected because the error exceeds the allowed range.

What To Do:

1. Re-enter valid PDOFs (i.e., those that satisfy the equation PDOF1 + PSI1 = PDOF2 + PSI2 ± 180).
2. If desired, use the AutoCalc PDOF option to automatically assign the PDOF for one of the vehicles.

Missing Damage Data Note

> *NOTE: Damage data were not entered for one of the vehicles. Any damage energy absorbed by that vehicle is not included in the Damage-Based solution. This may lead to errant damage-based results and related compatibility checks between Damage- and Momentum-based results.*

(Level 2 — Diagnostic)

If damage profiles are assigned, damage-based delta-Vs will be computed for each vehicle. The calculation of damage-based delta-V is based on the system energy, that is, the sum of the damage energies for each vehicle. If a damage profile is entered for only one vehicle, the damage-based delta-Vs will still be computed, but they will probably under-estimate the true delta-Vs because a portion of the system energy is missing from the calculation. The exception is if one of the vehicles is a rigid barrier (because rigid barriers absorb no energy); in this case, EDCRASH will not issue this message.

What To Do:

1. Confirm that damage profiles are entered for both vehicles.

Trajectory Simulation Time-out Note

> *NOTE: The Trajectory Simulation for Vehicle 'n' failed to converge because the vehicle timed out. Increase the Maximum Simulation Time (see Simulation Controls dialog).*

(Level 2 — Diagnostic)

If the Trajectory Simulation option is chosen (see EDCRASH Calculation Options), the vehicle paths are simulated using a basic trajectory simulation analysis. By default, the maximum simulation time is 5.0 seconds. If the vehicle is still moving when the maximum simulation time is reached, this message is issued. The resulting path error calculated for the rest position is probably larger than it would be if the vehicle had been allowed to continue uninterrupted to its natural rest position.

What To Do:

1. The solution is to simply increase the Maximum Simulation Time using the Simulation Controls dialog and rerun the EDCRASH event.

Iterate on Sideslip Error

(updated: added — not in the original manual)

If the Separation Velocity Basis in the Calculation Options dialog is set to

Iterate on Sideslip

, the event terminates with a "tire model not supported" error before any calculations are performed, because the iterative sideslip solution is not supported by the current EDCRASH physics engine.

What To Do:

1. Open the EDCRASH Calculation Options dialog and choose *Normal*, *Trajectory Simulation* or *Sustained Contact* as the Separation Velocity Basis, then re-execute the event.

Previous: Chapter 5 — EDCRASH Tutorial · Next: Chapter 7 — Technical References

Chapter 7 — Technical References

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Previous: Chapter 6 — Messages · Back to Table of Contents