ENGINEERING DYNAMICS COMPANY

EDSMAC4

HVE Human Vehicle Environment

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

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EDSMAC4 — Multi-Vehicle Collision Simulator

Engineering Dynamics Company Simulation Model of Automobile Collisions, 4th Revision — Version 6

Updated Markdown edition, converted from the Sixth Edition manual (January 2006) and brought up to date with the current version of the EDSMAC4 program and the HVE user interface.

How to Use This Manual

This manual is the user's manual for the EDSMAC4 simulation model. It describes the model's features and use. Input parameters and output reports are described at a high level. It is intended to be used in conjunction with the HVE-2D or 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. For specific model definitions, the user is referred to the User's Manual.

EDSMAC4 is compatible with both HVE-2D and HVE. If you are using EDSMAC4 within the HVE environment, the Human, Vehicle and Environment Editors will have additional features not available in HVE-2D. While some dialogs look different, the required input for EDSMAC4 is found in both. Where there are differences related to the use of EDSMAC4, these differences are noted in this manual.

If You Have Questions

Engineering Dynamics Company, LLC provides technical assistance for supported users. When you call, have available: your User ID number, your System Hardware Profile report, HVE-2D or HVE Version Information (Help System), and EDSMAC4 Version Information (EDSMAC4 Program Data report).

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The original manual's Chapter 8 (Index) is omitted; use text search in this Markdown edition instead.

Related pages:

- EDSMAC4 Calculation Options — dialog-by-dialog reference for the EDSMAC4 Calculation Options dialog.

Chapter 1 — EDSMAC4 Program Description

Overview

EDSMAC4 (Engineering Dynamics Company Simulation Model of Automobile Collisions, 4th Revision) is a simulation analysis of single- or multiple-vehicle crashes. It is based on the program called SMAC [1,2,3,4,5], developed at Calspan for NHTSA, and includes several major extensions and enhancements developed by Engineering Dynamics Company, LLC [6,7]. EDSMAC4 uses a set of assumed or estimated initial conditions, including positions, velocities and driver controls, provided by the user for each vehicle. EDSMAC4 then predicts the outcome of a crash by simulating the vehicle trajectories and damage profiles.

The output generated by EDSMAC4 is a time history of the vehicle kinematics (position, velocity, and acceleration), kinetics (summation of tire and collision forces and moments acting at the CG), and tire skidmarks for the duration of the crash sequence. The program also computes the resulting damage profiles, the Collision Deformation Classifications, or CDC (see reference 8; also refer to your EDCRASH Physics manual, Program Inputs), Principal Direction of Force, or PDOF (again, see reference 8), delta-V (a measure of crash severity) and peak acceleration for each damage range. EDSMAC4 also produces a collision pulse (acceleration vs time history) useful for occupant simulations, such as EDHIS.

Accident investigators can use EDSMAC4 to determine how the crash may have occurred. By repeated adjustments of the initial conditions and driver braking (or acceleration) and steering inputs, the user will converge on the data that best match the known accident site evidence (usually rest positions, skidmarks, and vehicle damage).

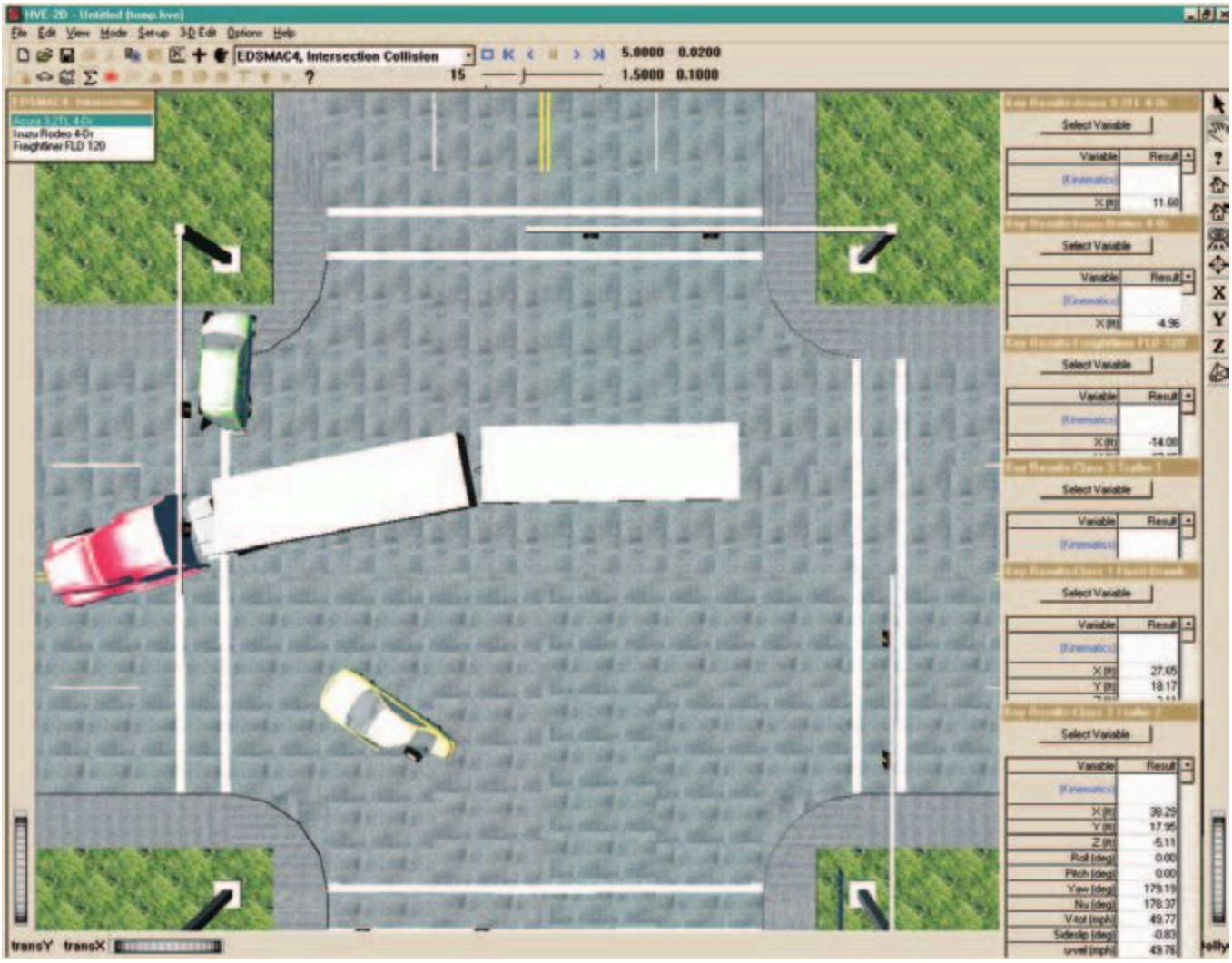


Figure 1-1: Typical EDSMAC4 Event, showing a complex intersection event involving several vehicles, with Key Results windows along the right edge of the 3-D viewer.

In addition to vehicle-to-vehicle collisions, EDSMAC4 may also be used for many types of barrier collisions, including pole impacts. Specific procedures are provided in Chapter 2.

Users of EDCRASH will find it convenient to first analyze the accident using EDCRASH to estimate the impact speeds, then use these speeds as the initial conditions for the EDSMAC4 program. The resulting confirming analysis is both very complete and very powerful.

Accident researchers can use EDSMAC4 to simulate an actual staged collision test. This can be done before the test in order to predict or anticipate the results and help during test preparations. Test parameters may be adjusted based on EDSMAC4 results to help ensure the test is successful. After the test, the researcher can note the differences between the actual and simulated collision and modify the EDSMAC4 input in order to obtain a better match.

An extremely useful feature of EDSMAC4 is the ability to quickly and easily review the results associated with different input scenarios. Termed

what if

analysis, changes can be made to an isolated variable or set of variables in order to identify their effect on the outcome. Only the inputs that change need to be modified; the program saves all the previously entered information. For example,

the sensitivity of the results to initial velocity, or post-impact driver control, can be studied by merely changing those parameters.

Another useful feature of the program is the ability to display the results in 3-D viewers. These trajectory simulations display the vehicles at user-specified time intervals during the sequence. Using the Playback Editor, it is simple and easy to create a digital movie file.

Model Inputs

EDSMAC4 inputs include one or more vehicles, and an optional environment with terrain geometry. Event set-up parameters include vehicle initial positions and velocities and driver controls (steering, brakes and throttle).

Model Outputs

EDSMAC4 output reports include Accident History, Damage Data, Driver Data, Environment Data, Event Data, Messages, Program Data, Vehicle Data, Variable Output, Trajectory Simulations and Damage Profile Simulations. The acceleration vs time history provides a collision pulse available for use in any HVE-compatible occupant impact simulator.

Validation

EDSMAC4 was validated first by direct comparison with earlier versions of EDSMAC to ensure the basic model was intact after porting the original codes to the C programming language and making the model HVE-compatible. Additional validation was performed comparing EDSMAC4 results to other models, as well as direct comparison with controlled collision experiments [23].

HVE-2D and HVE

EDSMAC4 is compatible with both HVE-2D and HVE. While EDSMAC4 has been extended and revalidated for use in the HVE environment to account for 3-D terrain, EDSMAC4 is essentially a 2-dimensional physics simulation program.

If you are using EDSMAC4 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 EDSMAC4 is found in both. Where there are differences related to the use of EDSMAC4, these differences are noted in this manual.

Basic Procedure

The procedure for using EDSMAC4 is substantially the same as using any simulator in the HVE-2D or HVE environment:

1. Use the Vehicle Editor to add one or more vehicles to the case.
2. Optionally, use the Environment Editor to create a visual and physical environment.
3. Use the Event Editor to set up and execute the EDSMAC4 simulation model by performing the following steps:
4. Choose one or more vehicles from the list of vehicles created earlier.
5. Choose the EDSMAC4 calculation model.

6. Position the vehicle(s) in the environment, and assign velocities.
7. Assign driver controls (Steering, Braking, Throttle) to each vehicle.
8. Execute the simulation event, comparing the simulation results with actual or measured results.
9. Modify the inputs as required to achieve the desired match between the simulation and the actual event.

Finally, use the Playback Editor to view the various reports and trajectory simulations. If desired, include the event along with other events in the Playback Window and produce a digital movie of the simulation.

Next: Chapter 2 — EDSMAC4 Program Input

Chapter 2 — EDSMAC4 Program Input

This chapter defines the objects (vehicles and environment) and the event set-up parameters (positions, driver controls, and so forth) used by the EDSMAC4 analysis. In general, the chapter is divided into the following sections:

- **Objects** — The number of vehicles, and the specific vehicle parameters actually used by EDSMAC4.
- **Events** — The various options available for setting up and executing an EDSMAC4 event.

Objects Overview

The objects used by the EDSMAC4 model are:

- **Vehicles** — One or more vehicles may be studied by EDSMAC4. The maximum number of vehicles in a single EDSMAC4 event is 20.
- **Environment** — Like the real world, EDSMAC4 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 EDSMAC4 calculation model.

Vehicles

EDSMAC4 uses one or more vehicles created using the Vehicle Editor. Vehicles are selected from the Vehicle Database by choosing the following attributes:

- **Type** — EDSMAC4 supports the following vehicle types: Passenger Car, Pickup, Sport-Utility, Van, Truck, Trailer, Dolly, Fixed Barrier and Movable Barrier.
- **Make** — EDSMAC4 supports all available vehicle makes.
- **Model** — EDSMAC4 supports all available vehicle models, within the limits defined by number of axles and drive axles; see below.
- **Year** — EDSMAC4 supports all available vehicle years.
- **Body Style** — EDSMAC4 supports all available vehicle body styles (except Class 2 Hinged Drawbar Dolly).

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

- **Driver Location** — The Driver Location is not used by EDSMAC4. However, if you would like the vehicle to have any steerable axles, Driver Location must not be None.
- **Engine Location** — The Engine Location is not used by EDSMAC4. However, if you would like the Throttle Table to be available during Event mode, Engine Location must not be None.
- **Number of Axles** — EDSMAC4 supports 1-, 2- or 3-axled vehicles.
- **Drive Axle(s)** — The Drive Axle is used by EDSMAC4 to determine which wheels to include in the Throttle Table during Event mode.

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.

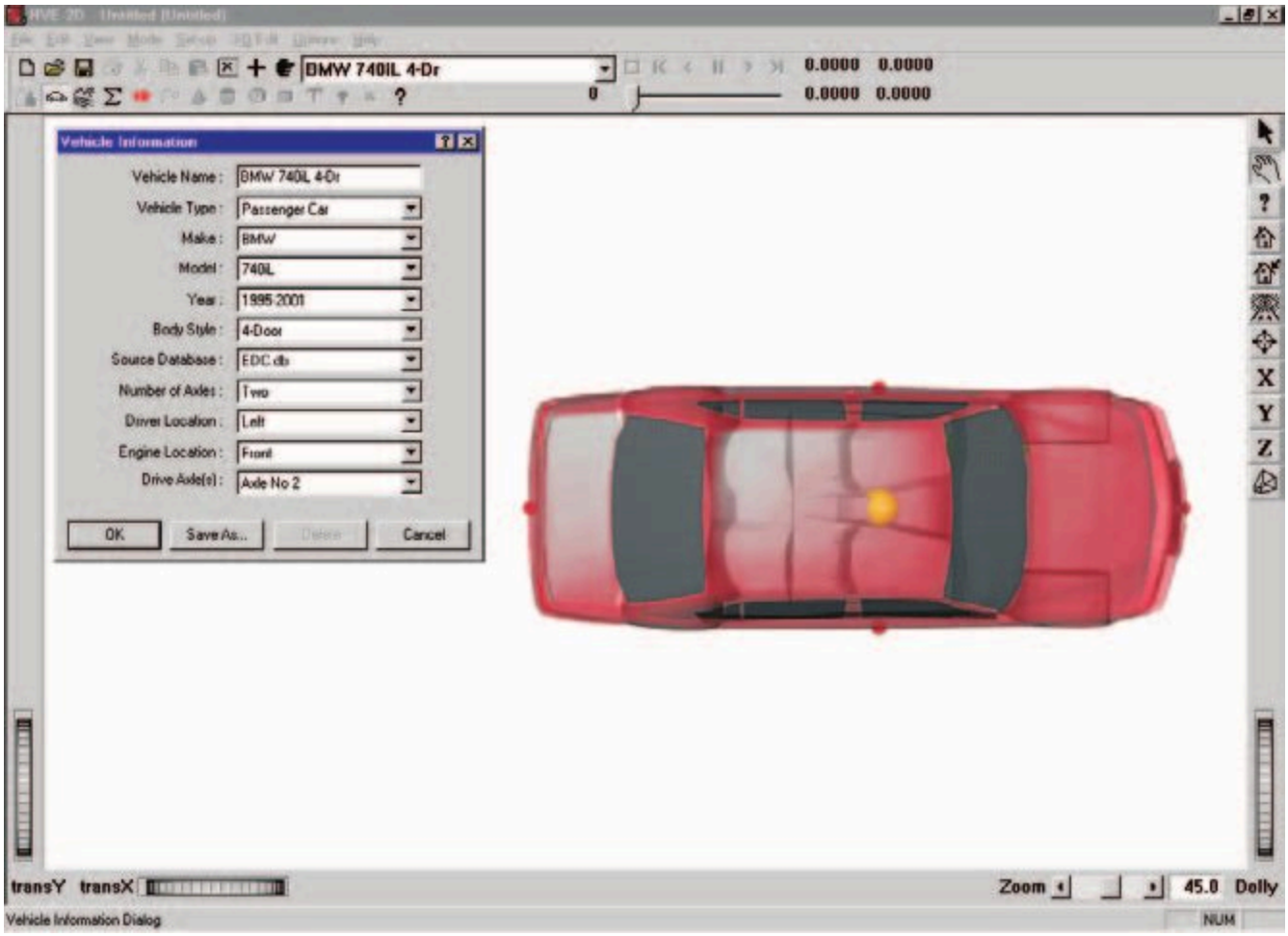


Figure 2-1: Vehicle Editor.

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

- Sprung Mass — Inertias, Move CG, Inter-vehicle Connections
- Unsprung Mass — Wheel Location, Tire Data, Suspension Data
- Exterior — Overall Dimensions, Stiffness Coefficients
- Steering System

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 EDSMAC4

Parameter	Description
Total Weight	Total vehicle weight
Total Yaw Inertia	Rotational inertia about the vehicle-fixed z axis
Move CG x,z	Relocates the CG in the vehicle-fixed x and z directions. This entry causes an automatic adjustment of all other vehicle dimensions to reflect the new CG location.
Inter-vehicle Connections (x, y, z, Max Articulation Angle)	Vehicle-fixed x,y,z connection coordinates; Maximum Articulation Angle (rear connection)

Inertias

EDSMAC4 uses the total vehicle weight (converted to mass according to the current gravitational constant; see Environment), and the total yaw rotational inertia.

Move CG

Move CG is not used directly by EDSMAC4. 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 and z coordinates for the wheels are updated to reflect the new CG location.

> **NOTE:** Bilateral symmetry is assumed. In HVE, moving the CG in the +y or −y direction will have no effect on the EDSMAC4 calculations.

Geometry File

The Geometry File is not used by EDSMAC4 for physics calculations (it is used for visualization, tessellation in the Vehicle Mesh dialog, and — in the current version — optionally for initializing the collision perimeter; see the **Use Vehicle Geometry for Rho Vector Init** calculation option). *(updated: the current EDSMAC4 can derive initial RHO vector lengths from the vehicle body mesh when this option is checked; see EDSMAC4 Calculation Options.)*

Inter-vehicle Connections

EDSMAC4 uses the x,y,z Connection Locations when articulated vehicles are simulated. The Maximum Articulation Angle is also used.

The Connection y coordinate is user-editable only in HVE.

> **NOTE:** Every trailer will have a pre-defined front connection. However, not every tow vehicle has a pre-defined rear connection. Use the Vehicle Editor to confirm the vehicle has a connection.
>
> **NOTE:** Be sure both vehicles have the proper connections (Hitch/Ball or King Pin/Fifth Wheel).
>
> **NOTE:** The connection elevation above ground must be the same for the tow vehicle and the trailer. Otherwise, the vehicle will accelerate or decelerate on level ground (the 2-D equations of motion have no way of knowing how to handle non-normal tire forces). *(updated: the current version can automatically reconcile mismatched hitch heights at event initialization via the **Inter-Vehicle Connection** calculation option — the hitch z-coordinates are adjusted, not the vehicle positions; see EDSMAC4 Calculation Options.)*

Unsprung Mass

Table 2-2: Vehicle Unsprung Mass Parameters Used By EDSMAC4

Parameter	Description
Wheel Location	The vehicle-fixed x,y,z wheel center coordinates
Dual Tire	Flag indicating wheel position has dual tires
Tire Radius	Tire radius in unloaded condition (editable in HVE)
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 (EDSMAC4 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 lateral slip
Cornering Stiffness In-use Factor	Multiplier for Cornering Stiffness

Wheel Location

Unlike previous SMAC models, EDSMAC4 uses the values for the vehicle-fixed x,y,z coordinates of each wheel. This allows the researcher to study the effects of wheels displaced by damage (see Event, this chapter).

Within HVE-2D, wheel x and y coordinates may be changed. Bilateral symmetry is enforced. Within HVE, wheel x,y,z coordinates may be changed independently for each wheel.

Tire

Single or dual tires may be supplied at each wheel position. The HVE-2D tire parameters provide the following data groups (additional parameters are available in HVE, but they are not used by EDSMAC4):

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

EDSMAC4's use of these parameters is described below.

Physical Data

EDSMAC4 uses the unloaded tire radius at each wheel to establish the vehicle's static CG elevation. In HVE, tire unloaded radius is user-editable.

Friction Table

EDSMAC4 uses the slide friction coefficient.

EDSMAC4's tire model does not incorporate load dependence. If friction data for more than one load are supplied, EDSMAC4 uses the friction coefficient for the middle load.

> **NOTE:** If there is any doubt about which value is actually used by EDSMAC4, you can check the Vehicle Data output report.

EDSMAC4's tire model has the capability to include speed dependence. If friction data are entered for more than one speed, EDSMAC4 calculates a speed dependence factor (see Chapter 4 — Calculation Method).

Friction In-use Factor, available in HVE, is a convenient way to reduce or increase the slide friction value during the entire run for a specific tire.

> **NOTE:** During an event, the actual tire-terrain friction used during the current timestep is the product of the slide friction coefficient, the in-use factor and the terrain friction multiplier for the polygon beneath the tire. Mathematically,

$$\mu_{Tire-terrain} = \mu_{Slide} \times InUseFactor \times Mult_{Polygon}$$

Cornering Stiffness Table

EDSMAC4 uses the Cornering Stiffness value.

EDSMAC4 does not use the HVE Fy vs Slip Angle table, but instead uses the cornering stiffness parameter directly. If cornering stiffness data for more than one load and/or speed are supplied, EDSMAC4 uses the cornering stiffness for the middle load and/or speed.

> **NOTE:** If there is any question about which value is actually used by EDSMAC4, you can check the Vehicle Data output report.

Cornering stiffness In-use Factor, available in HVE, is a convenient way to reduce or increase the cornering stiffness value during the entire run for a specific tire.

(The original manual said "slide friction value" here; the factor applies to 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

EDSMAC4 does not use the Slip-Rolloff data.

Suspension

The HVE-2D Suspension Model provides the following data:

- Inter-tandem Load Transfer

EDSMAC4 supports all suspension types, including those with tandem axles. However, the suspension at each wheel is not modeled, per se. Rather, roll couple distribution is used.

Table 2-3: Vehicle Suspension and Steering Parameters Used By EDSMAC4

Parameter	Description
Inter-tandem Axle Load Transfer	Rear-to-front inter-axle load transfer due to braking of tandem axles
Steering Gear Ratio	Ratio of the angle at the steering wheel to the angle at the wheel

Inter-tandem Axle Load Transfer

If three axles are supplied for the vehicle, the vehicle is assumed to have tandem rear axles. In this case, a longitudinal load transfer due to braking may be simulated by supplying an Inter-tandem Load Transfer Coefficient.

Studies have shown the value of −0.38 to be representative of typical four-spring suspension systems [4]. The negative sign indicates load transfer from the front to the rear axle.

The value for walking beam suspensions with 100% torque rod effectiveness is 0.0 [14]. For non-perfect torque rods with effectiveness less than 100%, the load transfer is:

$$(\frac{AAA}{R})(\frac{100 - T_e}{100})$$

where:

- AAA = inter-tandem dimension
- R = tire radius
- T_e = torque rod efficiency

Brake

EDSMAC4 does not use the (vehicle) Brake data.

Exterior

EDSMAC4 uses the following Vehicle Exterior Data:

- Exterior Dimensions
- A and B Stiffness Coefficients

Table 2-4: Vehicle Exterior Parameters Used By EDSMAC4

Parameter	Description
CG to Front, Right, Back and Left	The vehicle's exterior dimensions
A Stiffness Coefficient	The initial deflection constant for each side. This coefficient represents the force per unit of damage width required to initiate damage.
B Stiffness Coefficient	The linear spring rate for each side of the crushed surface. This coefficient represents the force required per inch of crush depth per inch of damage width.

> **NOTE:** Unlike EDSMAC, EDSMAC4 uses individual stiffness values for the front, sides and back. Note also the use of A and B stiffness coefficients, rather than K_L, is unique to EDSMAC4.

Steering System Data

EDSMAC4 uses the Steering System to determine which axles are steerable. Only steerable wheels are displayed in the Driver Controls, Steer Table. In addition, if the Steer Table, At Driver option is used, the steering gear ratio parameter is used to compute the steer angle at each steerable tire.

*(updated: in the current version the Steering System data are also used by the optional dynamic steer degree of freedom — see the **Steer DOF** calculation option in EDSMAC4 Calculation Options. When Steer DOF is Normal, Append or AutoStart, steer angles are computed from the torques acting on the steering system rather than taken directly from the steer tables.)*

Brake System Data

EDSMAC4 does not use the Brake System data.

Environment

EDSMAC4 uses the environment created by the Environment Editor. The environment is created by defining the following groups of attributes:

- Visual Data
- Physical Data

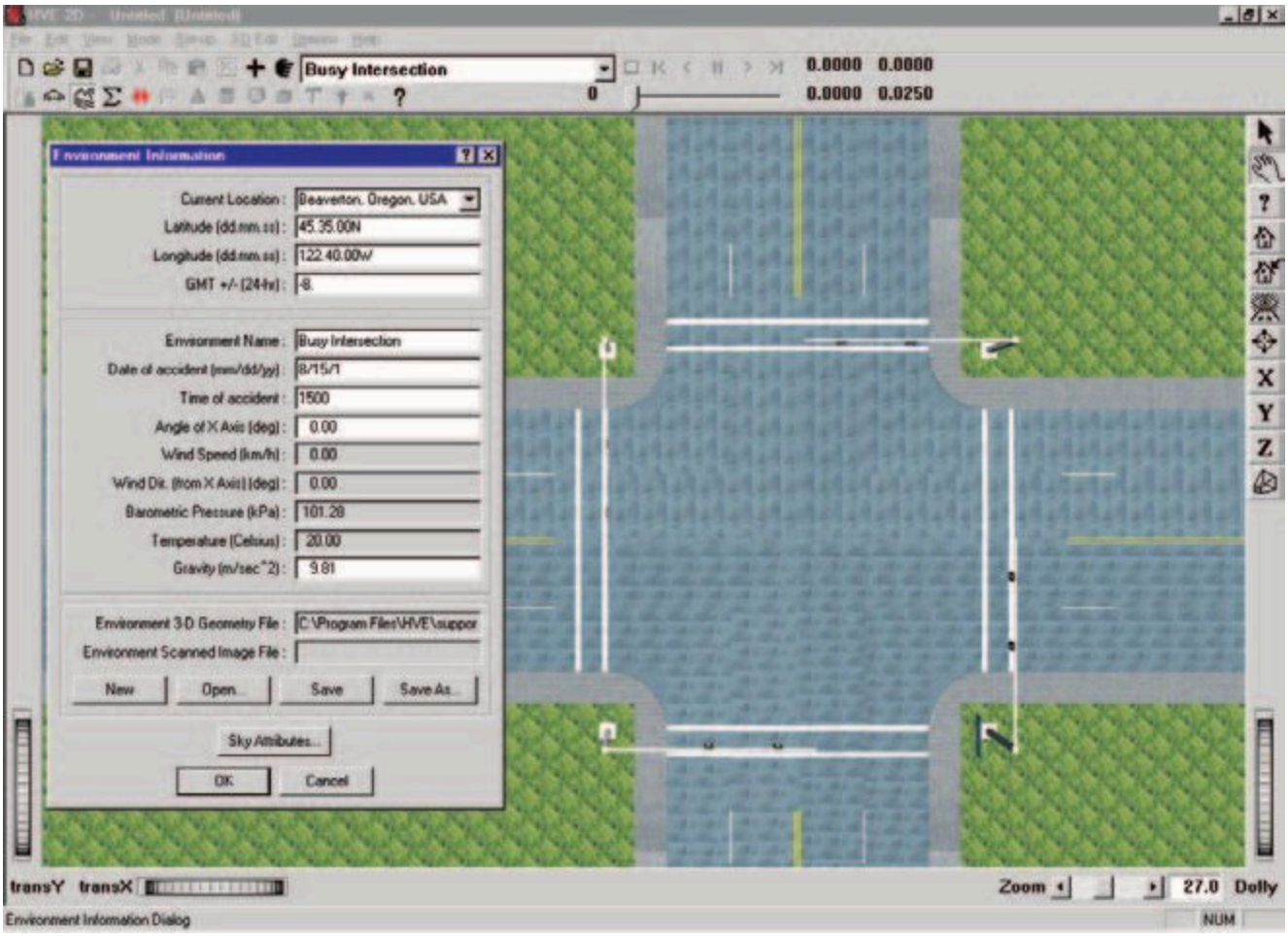


Figure 2-2: Environment Editor.

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. Edit the Time and Date for the event.
5. Edit the Angle of the X Axis, Wind Speed and Direction, Barometric Pressure and Temperature for the event.
6. Edit the Gravity Constant for the event.
7. Edit the 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, 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 2-5: Environment Parameters used by EDSMAC4

Parameter	Description
Gravitational Constant	The local acceleration of gravity
3-D Surface Geometry (Friction Factor, Elevation, Slope)	The polygon database used to create the 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 local correction factor before entering this angle.
>
> **NOTE:** The angle of the X axis affects how you visualize an EDSMAC4 event because it affects the location of the sun.

Wind Speed and Direction

EDSMAC4 does not use the Wind Speed or Direction.

Atmospheric Temperature and Pressure

EDSMAC4 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.

> **NOTE:** All user-entered weights are divided by this gravitational constant and stored as mass.

3-D Surface Geometry

The Surface Geometry is used by the tire model in EDSMAC4 to calculate the friction multiplier for the current X,Y position of each tire. In HVE, it is also used to calculate the elevation and slope.

If the elevation changes result in a vehicle roll or pitch angle that exceeds the allowable angle, the simulation will terminate and report an "Excessive Roll or Pitch Angle" error condition. This message is issued by HVE/LibHve (during surface-geometry evaluation), not by EDSMAC4 itself, so it does not appear in the EDSMAC4 message catalog in Chapter 6 — Messages.

*(updated: the current version can also use water polygons in the terrain, together with the **Hydroplane Model** calculation option, to model reduced tire friction due to hydroplaning; see EDSMAC4 Calculation Options.)*

Event

EDSMAC4 uses the Event Editor to create, set up and execute an event. Each of these topics is described below.

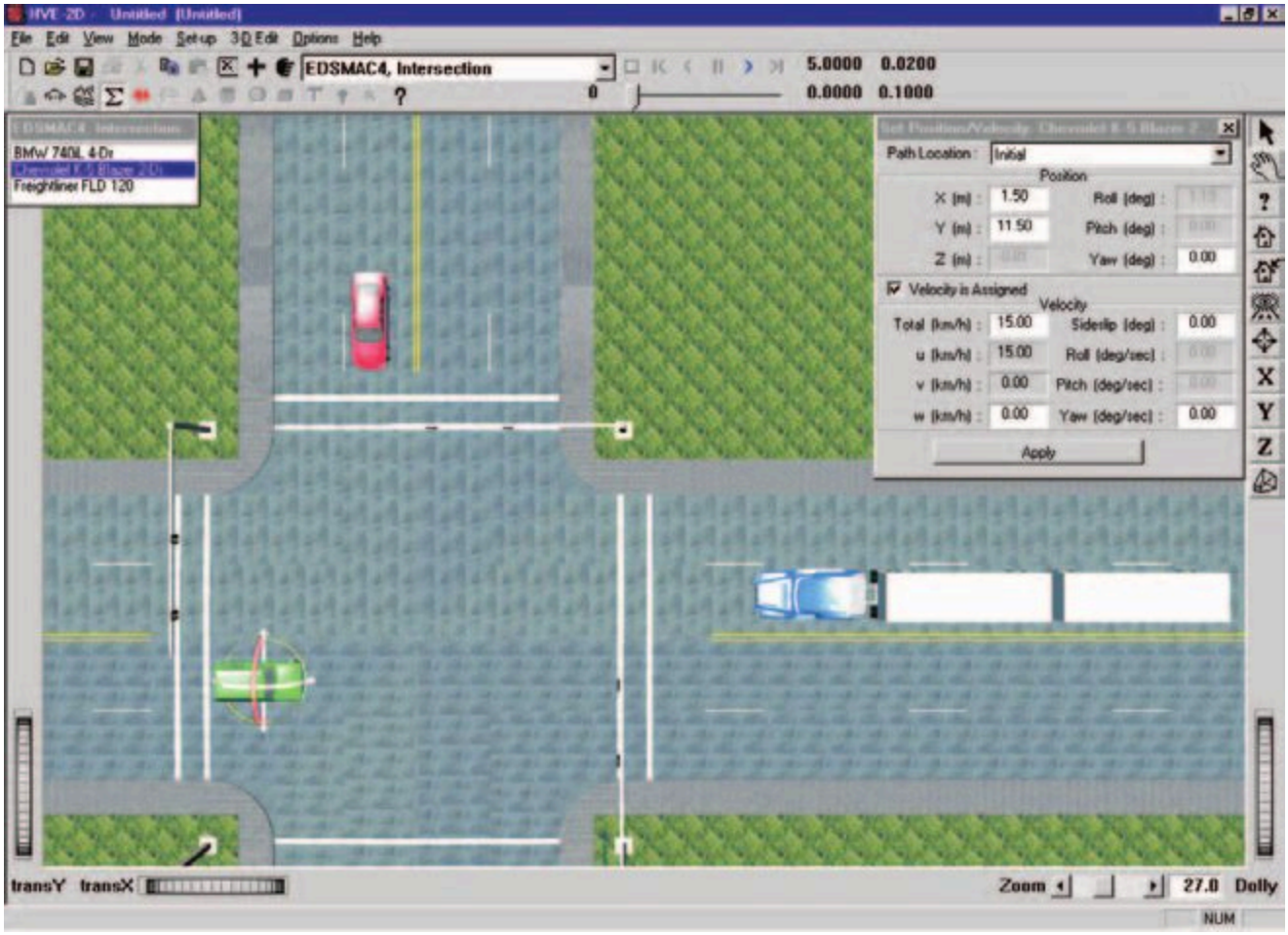


Figure 2-3: Event Editor, setting up and executing an EDSMAC4 event.

Creating An Event

An EDSMAC4 event is created using the Event Information dialog. To create an EDSMAC4 event:

1. Choose Event Mode. The Event Editor is displayed.
2. Click Add New Object. The Event Information dialog is displayed.
3. Select one or more vehicles from the Active Vehicles list.
4. Select the calculation model, EDSMAC4, 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 EDSMAC4 event.

> **NOTE:** If you choose a vehicle that is not compatible with EDSMAC4, such as a single-axle hinged drawbar dolly, a message will be displayed describing the problem. You will not be allowed to proceed until EDSMAC4-compatible objects are selected.

Setting Up an Event

EDSMAC4 uses the following event set-up options:

- Position/Velocity
- Driver Controls
- Vehicle Mesh
- Wheel (Tire Blow-out and Wheel Displacement)
- Accelerometers

Table 2-6: Event Set-up Parameters used by EDSMAC4

Parameter	Description
Vehicle Initial Position	The earth-fixed X,Y coordinates and yaw angle of each vehicle at the start of the simulation
Vehicle Initial Velocity	The forward and lateral linear velocities, and the yaw angular velocity, at the start of the run
Driver Controls, Steer Table	Steer Table Option; Steering Wheel Angle vs Time or Tire Steer Angle vs Time
Driver Controls, Brake Table	Brake Table Option; Wheel Force vs Time or Percent Available Friction vs Time
Driver Controls, Throttle Table	Throttle Table Option; Wheel Force vs Time or Percent Available Friction vs Time
Vehicle Mesh	Maximum Side Length (Tessellation), Inter-vehicle Friction
Wheels, Tire Blowout	Start time, duration, stiffness factor, and rolling resistance factor; available for each tire
Wheels, Displacement	Start time, duration, change in x,y,z coordinates, change in camber; available for each tire
Accelerometers	The x,y coordinates of up to 5 accelerometers

Position/Velocity

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

> **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 by HVE using AutoPosition.

The vehicle velocities are supplied in the form of a total velocity and sideslip angle.

> **NOTE:** The vehicle-fixed u (forward) and v (side) velocity components are calculated according to the user-entered total velocity and sideslip angle. Vertical velocity is set to zero.

EDSMAC4 uses the following positions and velocities:

- **Initial Position** — The X,Y coordinates and heading angle of the vehicle at the start of the simulation. Only the initial position is used by EDSMAC4.

> **NOTE:** Other positions may be supplied as target positions, used to assess how closely the simulated path matches the actual path during a run. Refer to the User's Manual, Options Menu, for more information about Target positions.

- **Initial Velocity** — The total velocity and sideslip angle of the vehicle(s) at the start of the simulation.

> **NOTE:** Initial positions and velocities must be entered for each single or tow vehicle in an EDSMAC4 event.

Driver Controls

EDSMAC4 uses the following Driver Controls:

- **Steering** — A table of steering inputs as a function of time. The At Driver and At Axle options are supported.
- **Braking** — A table of braking inputs as a function of time. The Wheel Force and Percent Available Friction options are supported.
- **Throttle** — A table of throttle inputs as a function of time. The Wheel Force and Percent Available Friction options are supported.
- **HVE Driver** — The HVE Driver Model is a closed-loop driver control model that uses driver control attributes to attempt to follow a user-specified path. The path is constructed of Path/Location positions set up by the user. This model is described in detail in Reference [25].

Brake

Typical values for non-braking rolling resistance for passenger car tires are provided below for reference in Table 2-7 [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 2-8 [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 EDSMAC4 with the best possible data.

Table 2-7: 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 2-8: 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

EDSMAC4 does not use the (user-entered) Damage Profile data.

> **NOTE:** EDSMAC4 produces a simulated damage profile.

Vehicle Mesh

The Vehicle Mesh dialog allows the user to do the following:

- Tessellate the vehicle geometry file (mesh)
- Select a pair of vehicles and edit their inter-vehicle friction properties

The **Tessellation** option allows the user to add additional detail to the 3-D Geometry File (also referred to as a mesh). The option is enabled by clicking on the Tessellate check box. The user then enters a value for the maximum length of a side for any triangle in the mesh. Each triangle is then evaluated, and any side longer than the specified value is cut in half until the resulting triangle has no sides longer than the specified value. The process of creating new and smaller triangles is called tessellation. This process is useful for vehicle meshes having extremely large triangles, especially for Generic Vehicles.

The **Inter-vehicle** option allows the user to choose the value for the coefficient of sliding friction (default 0.55) between the exteriors of the selected pair of objects. *(updated: the original manual associated this coefficient with the **Minimum Velocity for Friction** calculation option; the two quantities were transposed. The inter-vehicle sliding friction coefficient is now set per vehicle pair here in the Vehicle Mesh dialog and is no longer part of the Calculation Options dialog.)*

Payload

The Payload Data are not used by EDSMAC4. Payload inertias may be added to the vehicle inertias and the CG may be moved longitudinally and/or vertically using the Move CG dialog.

> **NOTE:** Lateral relocation of the CG is not supported by EDSMAC4.

Collision Pulse

The Collision Pulse data are not used by EDSMAC4.

> **NOTE:** EDSMAC4 produces a collision pulse (time history of longitudinal, lateral and angular velocities) that may be used by other HVE-compatible physics models (i.e., EDHIS and GATB occupant simulation models).

Wheels

EDSMAC4 supports the Tire Blowout Model and Wheel Displacement option. These options allow the user to study event-related phenomena at each wheel.

- **Tire Blowout** — The start time, deflation duration, deflated stiffness factor, and deflated rolling resistance factor for a blown tire.
- **Wheel Displacement** — The start time, displacement duration, change in x,y,z coordinates (z is available only in HVE) of the wheel center, and change in camber due to a wheel displacement.

> **NOTE:** This option is particularly useful for collisions in which a wheel was struck and displaced during impact.
>
> **NOTE:** The Tire Blowout and Wheel Displacement options can be used concurrently.

Accelerometers

EDSMAC4 allows the user to place virtual accelerometers in the vehicle at up to five vehicle-fixed locations. These accelerometers can be used to track the total acceleration and acceleration components at various locations within the vehicle (e.g., specific seat locations). The accelerometer outputs are included in the Variable Output, Accelerometer group (see Chapter 3, Variable Output).

Simulation Controls

EDSMAC4 uses the Vehicle Collision, Separation and Trajectory integration timesteps and the maximum simulation time parameters in the Simulation Controls dialog (see Options Menu, Simulation Controls).

The output time interval is the interval at which output results (positions, velocities, accelerations, forces) are reported back to HVE-2D or HVE. This has a direct effect on the tabular results available in the Playback Editor Variable Output table (see Chapter 3 — Output, Variable Output).

Table 2-9: Simulation Control Parameters used by EDSMAC4

Parameter	Description
Vehicle Collision Integration Timestep	The integration timestep used during the collision phase
Vehicle Separation Integration Timestep	The integration timestep used for the first 100 timesteps of the simulation (or until collision occurs); also used for the first 100 timesteps after the end of the collision phase
Vehicle Trajectory Integration Timestep	The integration timestep used before and after the collision phase (after 100 timesteps without collision, as described above)
Output Interval	The timestep used to send output results back to HVE-2D or HVE
Maximum Simulation Time	Maximum length of the run
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 (if the linear and angular velocities for both vehicles are simultaneously less than these termination velocities, the run terminates)

> **NOTE:** For analyses of gross vehicle motion, damage, and rest position, an output interval of 0.10 sec is generally sufficiently small.
>
> **NOTE:** For analyses of vehicle accelerations or collision pulses, smaller output intervals are recommended.
>
> **NOTE:** The output time interval should be an even multiple of the vehicle trajectory integration timestep. For example, if the integration timestep is 0.02, the output interval might be 5 × 0.02, or 0.10.

Calculation Options

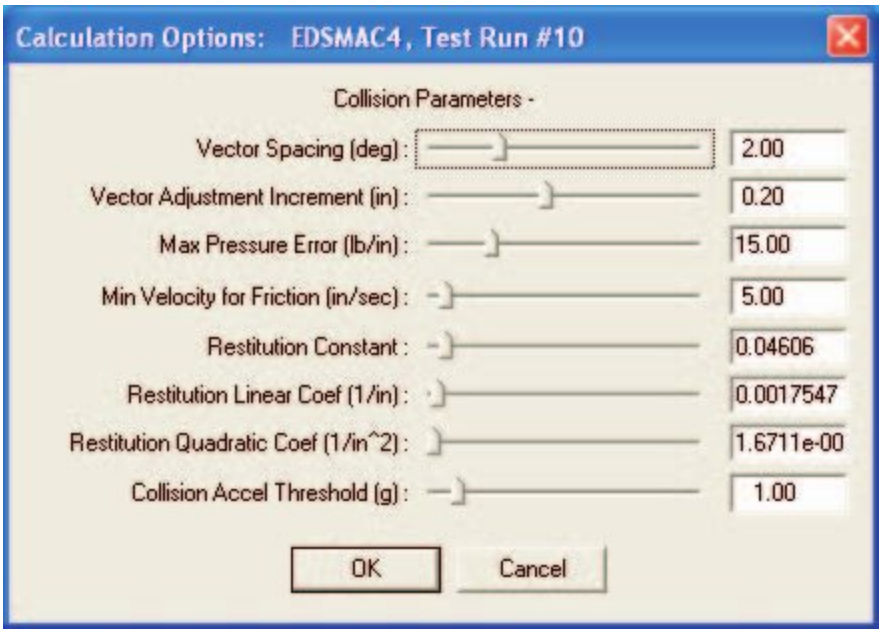


Figure 2-4: EDSMAC4 Event Calculation Options, available from the Options menu.

EDSMAC4 has the following calculation option parameters. For the complete dialog reference (defaults and all current options), see **EDSMAC4 Calculation Options**.

- **Vector Spacing** — This angle determines the angular interval between RHO vectors (see Calculation Method). *(updated: the current program default is 2 degrees; the original manual recommended 1 degree.)*
- **Vector Adjustment Increment** — This increment determines the incremental adjustment for each RHO vector as the collision routine seeks to establish force equilibrium between vehicles. Default 0.20 in.
- **Vector Force Tolerance** — This value is the allowable difference in the force exerted by corresponding RHO vectors for each vehicle. A small value is obviously preferable. In general, it should not exceed 50 lb/in (about 100 N/cm). Default 15 lb/in.
- **Minimum Velocity for Friction** — This value represents the minimum relative surface velocity at which the full inter-vehicle friction is achieved. Default 5 in/sec. *(updated: the original manual described this option as setting the inter-vehicle friction coefficient; the two quantities were transposed. This option sets the minimum velocity only — the inter-vehicle friction coefficient is now set per vehicle pair in the Vehicle Mesh dialog.)*
- **Restitution Coefficients** — These three values, C_0, C_1 and C_2, are the constant, linear and quadratic terms used for the parametric restitution model used in EDSMAC4. Defaults 0.04606, 0.0017547 1/in and 0.000016711 1/in².
- **Use Vehicle Geometry for Rho Vector Init** *(new)* — Initializes the RHO (crush perimeter) vectors from the vehicle's actual body mesh geometry rather than the idealized rectangle.
- **Steer DOF** *(new)* — Off / Normal / Append / AutoStart; enables the dynamic steer degree of freedom.
- **Inter-Vehicle Connection** *(new)* — Selects how mismatched hitch heights between connected vehicles are reconciled at event initialization (hitch z-coordinates are adjusted, not vehicle positions).
- **Connection Model** *(new)* — Selects how connection (hitch) constraint stiffness and damping are derived: Use Both Vehicles (derives them from the *lighter* vehicle's weight), Use Heavier Vehicle (default), or Use Tow Veh Properties.
- **Hydroplane Model** *(new)* — Off or NASA; applies the NASA hydroplaning model at tires travelling over water polygons.

- **Accident History Basis** *(new)* — Impact Force (default) or Acceleration; the criterion used to bound each collision phase in the Accident History report. With the Acceleration basis, the **Threshold (g)** value (default 1 g) is the total acceleration either vehicle must exceed — in addition to the vehicles' perimeters overlapping — for the collision phase to begin, and below which both vehicles must fall for it to end. See Chapter 4 — Impact and Separation Times.
- **Damage Data Format** *(new)* — Traditional or Collision Data (default), plus the Include Free Space setting. This selects not only the layout of the Damage Data report but the calculation behind it: the PDOF, delta-V and peak acceleration are determined by two different methods and will not agree exactly. See Chapter 4 — Collision Severity Results.

Get Surface Information

Both HVE-2D and HVE use a surface-information search to determine on which environment polygon each tire is riding. This search looks below the X,Y coordinates of each tire contact patch, and uses a user-selectable method to determine the friction and other characteristics of the surface beneath.

The default search method is From Previous Polygon, Sorted (friction zones and water polygons are checked first, then the search spreads outward from the previous polygon). Refer to the User's Manual — and the Terrain Search Options section of the Calculation Options reference — for further information about how the Get Surface Information options work.

(updated: the original manual named the plain "From Previous Polygon" method as the default.)

Executing An Event

To execute an EDSMAC4 event, use the Event Controller, a component of the Event Editor. 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 event or play the simulation forwards
- **Advance to End** — Advance to the end of the simulation



Figure 2-5: Event Controller, used for starting and stopping event execution. The Event Controller can also be used for replaying previously executed events, both forward and backward.

> **NOTE:** If you make changes to any of the vehicle or environment parameters or event set-up options (see previous sections), those changes will have no effect unless you press Reset before pressing Play.
>
> **NOTE:** Remember to use the Options Menu to choose useful options, such as Key Results, Axes, Velocity Vectors and Skidmarks.

Barrier Collisions

The original SMAC collision algorithm was not designed to accommodate barrier collisions (barrier being defined as an infinitely rigid object that absorbs no energy when struck). The reason is clear upon close inspection of the collision algorithm: it requires that both colliding objects be deformable (see references 3, 4, 6 and 7 for a detailed description of the original SMAC collision algorithm).

The collision algorithm developed for EDSMAC4 has been improved significantly. These changes, along with other improvements, allow EDSMAC4 to be used for many barrier and pole impacts. For a complete description of the new algorithm, see reference 21.

> **NOTE:** The use of smaller than normal integration timesteps is sometimes required for impacts with small objects, such as poles. Otherwise, the pole may be completely engulfed by the vehicle before a collision is detected, resulting in a fatal error during the collision phase.
>
> **NOTE:** Barriers with large aspect ratios (long and skinny) can be problematic, especially if impacted near the ends where there are fewer RHO vectors (see Chapter 4 — Calculation Method). To avoid this, make your barriers square and contact them in the center. You can apply a realistic geometry file so that they "look right."

Previous: Chapter 1 — Program Description — Next: Chapter 3 — EDSMAC4 Program Output

Chapter 3 — EDSMAC4 Program Output

This chapter defines the outputs available from an EDSMAC4 event. The reports produced by EDSMAC4 are available in the Playback Editor.

Output Overview

EDSMAC4 produces three types of output reports:

- **Alpha-Numeric Reports** — Reports containing text and numeric information, such as vehicle dimensional parameters
- **Variable Output Tables** — Reports containing tabular simulation results as a function of time
- **Trajectory Simulations** — Viewers containing dynamic, 3-D visual simulations

> **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 EDSMAC4 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

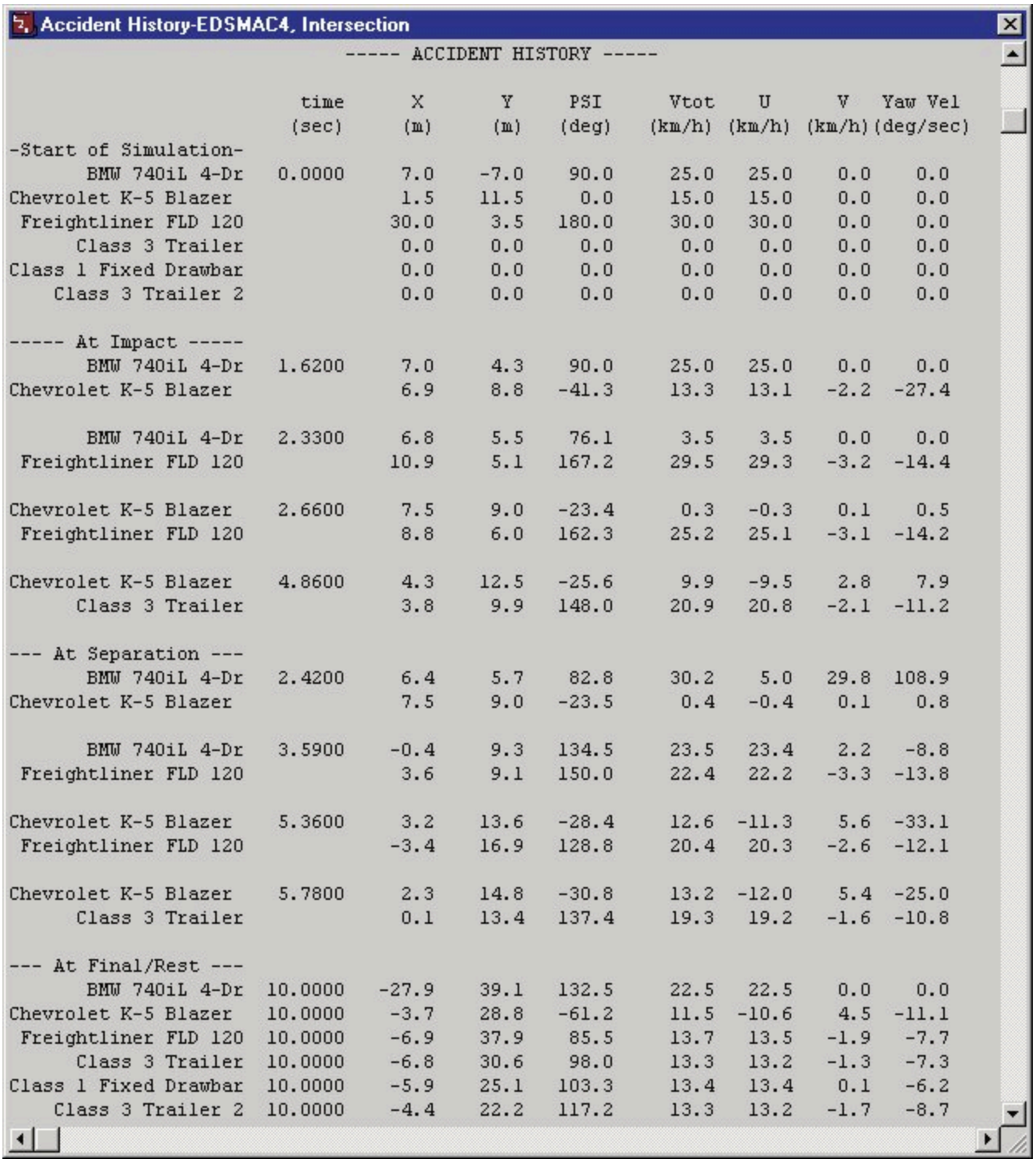
EDSMAC4 produces the following alpha-numeric reports:

- **Accident History** — A table of initial, impact, separation and final positions and velocities for each vehicle in the current event
- **Damage Data** — Tables describing the damage sustained by each vehicle: the collision pulses with their start and end times, peak acceleration, peak force, delta-V and PDOF, and the resulting CDC and crush measurements. The layout depends on the Damage Data Format calculation option (see below)

- **Driver Data** — Individual Driver Control tables for steering, braking and throttle used by each vehicle in the current event
- **Environment Data** — Information describing the environment data used by the current EDSMAC4 event
- **Event Data** — A table containing event-related parameters for the current event
- **Messages** — A list of messages produced by the current event
- **Program Data** — A table containing program control information for the current event
- **Vehicle Data** — A series of tables containing the vehicle data used by the current EDSMAC4 event

Accident History

The Accident History Report displays a table of initial, impact, separation and final positions and velocities for each vehicle.



Accident History-EDSMAC4, Intersection

----- ACCIDENT HISTORY -----

	time (sec)	X (m)	Y (m)	PSI (deg)	Vtot (km/h)	U (km/h)	V (km/h)	Yaw Vel (deg/sec)
-Start of Simulation-								
BMW 740iL 4-Dr	0.0000	7.0	-7.0	90.0	25.0	25.0	0.0	0.0
Chevrolet K-5 Blazer		1.5	11.5	0.0	15.0	15.0	0.0	0.0
Freightliner FLD 120		30.0	3.5	180.0	30.0	30.0	0.0	0.0
Class 3 Trailer		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Class 1 Fixed Drawbar		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Class 3 Trailer 2		0.0	0.0	0.0	0.0	0.0	0.0	0.0
----- At Impact -----								
BMW 740iL 4-Dr	1.6200	7.0	4.3	90.0	25.0	25.0	0.0	0.0
Chevrolet K-5 Blazer		6.9	8.8	-41.3	13.3	13.1	-2.2	-27.4
BMW 740iL 4-Dr	2.3300	6.8	5.5	76.1	3.5	3.5	0.0	0.0
Freightliner FLD 120		10.9	5.1	167.2	29.5	29.3	-3.2	-14.4
Chevrolet K-5 Blazer	2.6600	7.5	9.0	-23.4	0.3	-0.3	0.1	0.5
Freightliner FLD 120		8.8	6.0	162.3	25.2	25.1	-3.1	-14.2
Chevrolet K-5 Blazer	4.8600	4.3	12.5	-25.6	9.9	-9.5	2.8	7.9
Class 3 Trailer		3.8	9.9	148.0	20.9	20.8	-2.1	-11.2
--- At Separation ---								
BMW 740iL 4-Dr	2.4200	6.4	5.7	82.8	30.2	5.0	29.8	108.9
Chevrolet K-5 Blazer		7.5	9.0	-23.5	0.4	-0.4	0.1	0.8
BMW 740iL 4-Dr	3.5900	-0.4	9.3	134.5	23.5	23.4	2.2	-8.8
Freightliner FLD 120		3.6	9.1	150.0	22.4	22.2	-3.3	-13.8
Chevrolet K-5 Blazer	5.3600	3.2	13.6	-28.4	12.6	-11.3	5.6	-33.1
Freightliner FLD 120		-3.4	16.9	128.8	20.4	20.3	-2.6	-12.1
Chevrolet K-5 Blazer	5.7800	2.3	14.8	-30.8	13.2	-12.0	5.4	-25.0
Class 3 Trailer		0.1	13.4	137.4	19.3	19.2	-1.6	-10.8
--- At Final/Rest ---								
BMW 740iL 4-Dr	10.0000	-27.9	39.1	132.5	22.5	22.5	0.0	0.0
Chevrolet K-5 Blazer	10.0000	-3.7	28.8	-61.2	11.5	-10.6	4.5	-11.1
Freightliner FLD 120	10.0000	-6.9	37.9	85.5	13.7	13.5	-1.9	-7.7
Class 3 Trailer	10.0000	-6.8	30.6	98.0	13.3	13.2	-1.3	-7.3
Class 1 Fixed Drawbar	10.0000	-5.9	25.1	103.3	13.4	13.4	0.1	-6.2
Class 3 Trailer 2	10.0000	-4.4	22.2	117.2	13.3	13.2	-1.7	-8.7

Figure 3-1: Typical Accident History Output Report issued by EDSMAC4.

*(updated: the criterion used to detect the beginning and end of each collision phase reported here is selectable via the **Accident History Basis** calculation option — Impact Force (default) or Acceleration with a threshold in g; see EDSMAC4 Calculation Options and, for how the impact and separation times are found, Chapter 4 — Impact and Separation Times.)*

> **NOTE:** Impact and separation are tracked for each *pair* of vehicles, so an event involving three or more vehicles produces one impact and one separation entry for each colliding pair. The impact conditions are those of the pair's **first** contact and are not updated by subsequent contacts between the same pair.

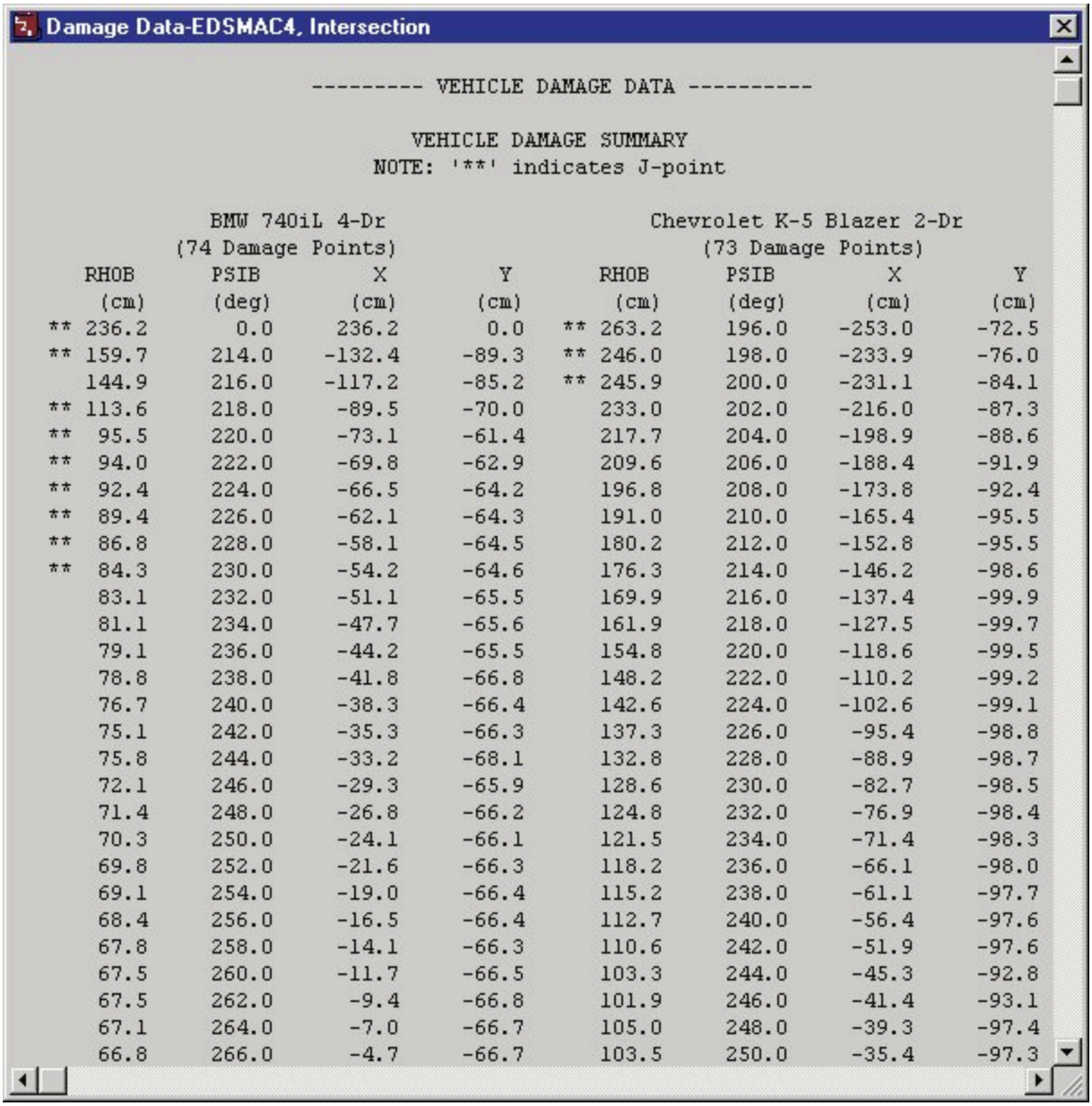
Damage Data

The Damage Data Report includes the following information:

- **Vehicle Damage Summary** — A table containing the collision ("RHO") vector information in two forms: RHO vector length and angle, and RHO vector x,y endpoint coordinates.

> **NOTE:** This table is used to define the damage profile.

- **Vehicle Damage Ranges** — A table containing the starting and ending points for each damage range, along with its CDC, PDOF, total delta-V and peak acceleration.



Damage Data-EDSMAC4, Intersection

--------- VEHICLE DAMAGE DATA ----------

VEHICLE DAMAGE SUMMARY
NOTE: '**' indicates J-point

	BMW 740iL 4-Dr (74 Damage Points)				Chevrolet K-5 Blazer 2-Dr (73 Damage Points)			
	RHOB (cm)	PSIB (deg)	X (cm)	Y (cm)	RHOB (cm)	PSIB (deg)	X (cm)	Y (cm)
**	236.2	0.0	236.2	0.0	263.2	196.0	-253.0	-72.5
**	159.7	214.0	-132.4	-89.3	246.0	198.0	-233.9	-76.0
	144.9	216.0	-117.2	-85.2	245.9	200.0	-231.1	-84.1
**	113.6	218.0	-89.5	-70.0	233.0	202.0	-216.0	-87.3
**	95.5	220.0	-73.1	-61.4	217.7	204.0	-198.9	-88.6
**	94.0	222.0	-69.8	-62.9	209.6	206.0	-188.4	-91.9
**	92.4	224.0	-66.5	-64.2	196.8	208.0	-173.8	-92.4
**	89.4	226.0	-62.1	-64.3	191.0	210.0	-165.4	-95.5
**	86.8	228.0	-58.1	-64.5	180.2	212.0	-152.8	-95.5
**	84.3	230.0	-54.2	-64.6	176.3	214.0	-146.2	-98.6
	83.1	232.0	-51.1	-65.5	169.9	216.0	-137.4	-99.9
	81.1	234.0	-47.7	-65.6	161.9	218.0	-127.5	-99.7
	79.1	236.0	-44.2	-65.5	154.8	220.0	-118.6	-99.5
	78.8	238.0	-41.8	-66.8	148.2	222.0	-110.2	-99.2
	76.7	240.0	-38.3	-66.4	142.6	224.0	-102.6	-99.1
	75.1	242.0	-35.3	-66.3	137.3	226.0	-95.4	-98.8
	75.8	244.0	-33.2	-68.1	132.8	228.0	-88.9	-98.7
	72.1	246.0	-29.3	-65.9	128.6	230.0	-82.7	-98.5
	71.4	248.0	-26.8	-66.2	124.8	232.0	-76.9	-98.4
	70.3	250.0	-24.1	-66.1	121.5	234.0	-71.4	-98.3
	69.8	252.0	-21.6	-66.3	118.2	236.0	-66.1	-98.0
	69.1	254.0	-19.0	-66.4	115.2	238.0	-61.1	-97.7
	68.4	256.0	-16.5	-66.4	112.7	240.0	-56.4	-97.6
	67.8	258.0	-14.1	-66.3	110.6	242.0	-51.9	-97.6
	67.5	260.0	-11.7	-66.5	103.3	244.0	-45.3	-92.8
	67.5	262.0	-9.4	-66.8	101.9	246.0	-41.4	-93.1
	67.1	264.0	-7.0	-66.7	105.0	248.0	-39.3	-97.4
	66.8	266.0	-4.7	-66.7	103.5	250.0	-35.4	-97.3

Figure 3-2: Typical Damage Data Output Report issued by EDSMAC4.

*(updated: the report layout is selectable via the **Damage Data Format** calculation option — Traditional or Collision Data (default); see EDSMAC4 Calculation Options. The description above is the Traditional layout. With the default Collision Data layout the report instead*

contains:

- *a **Collision Summary** table listing, for each collision pulse, the vehicle or environment struck, the start and end times and duration of the pulse, the peak acceleration, the peak collision force, the delta-V and the PDOF (for what counts as one pulse, and why intermittent contact is not split into several, see Chapter 4 — How a pulse is delimited);*
- *a **Damage Profile** table giving the CDC, damage width and offset, and maximum crush for each pulse;*
- *a **Crush** table giving the crush depths across the damaged surface.*

The two layouts are produced by entirely separate calculations and do not give identical numbers. See Chapter 4 — Collision Severity Results for how the PDOF, delta-V and peak acceleration are determined under each.)

Driver Data

The Driver Data report displays a table of user-entered driver control tables for steering, braking and throttle for each vehicle in the event.

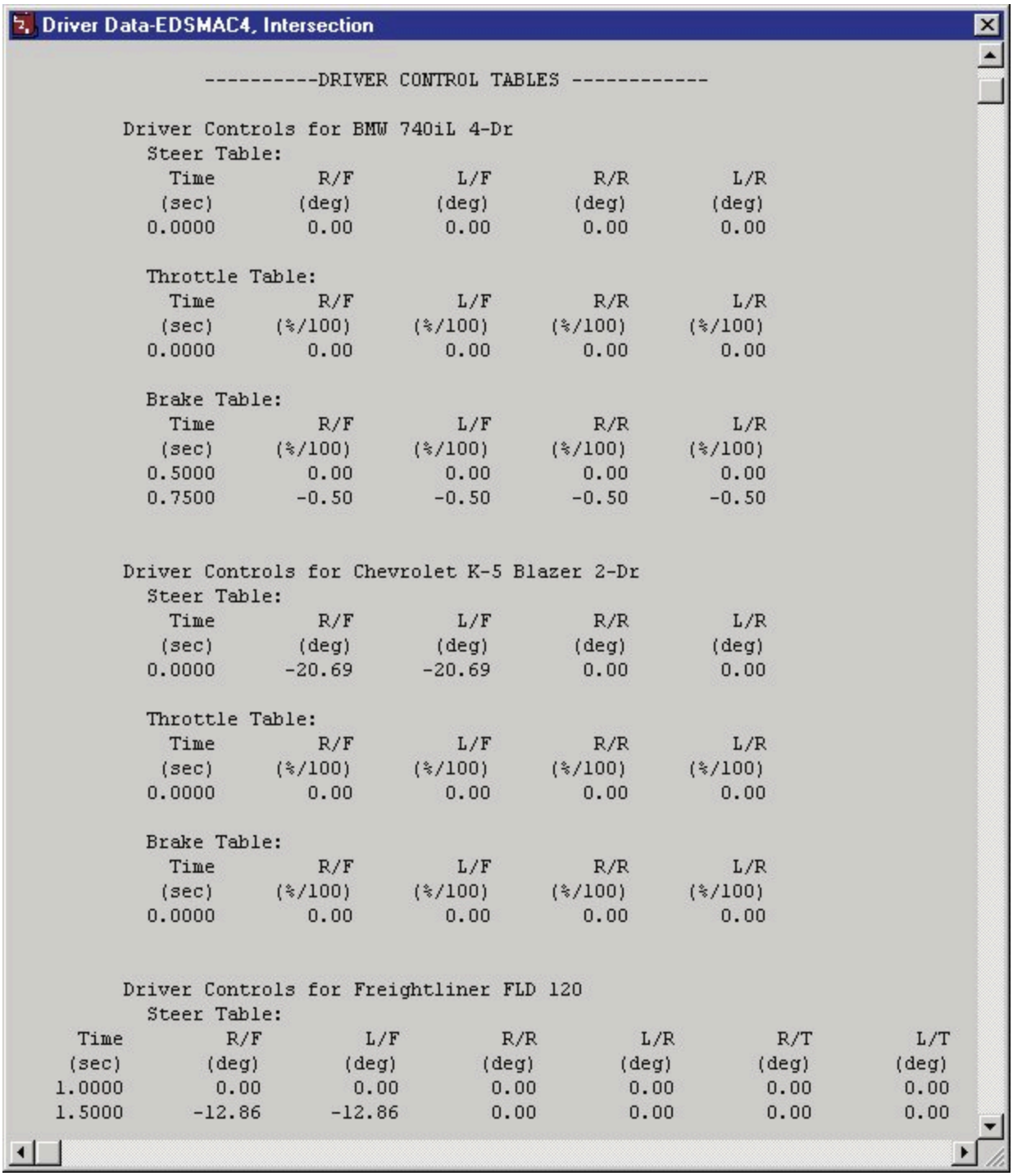


Figure 3-3: Typical Driver Data Output Report issued by EDSMAC4.

Environment Data

The Environment Data report displays the physical and visual information describing the environment. This information is displayed in two sections:

- **General Environment Data** — Physical parameters describing the environment (Temperature and Pressure are not used in the EDSMAC4 calculations).
- **3-D Environment Terrain Data** — Geometric parameters describing the terrain.

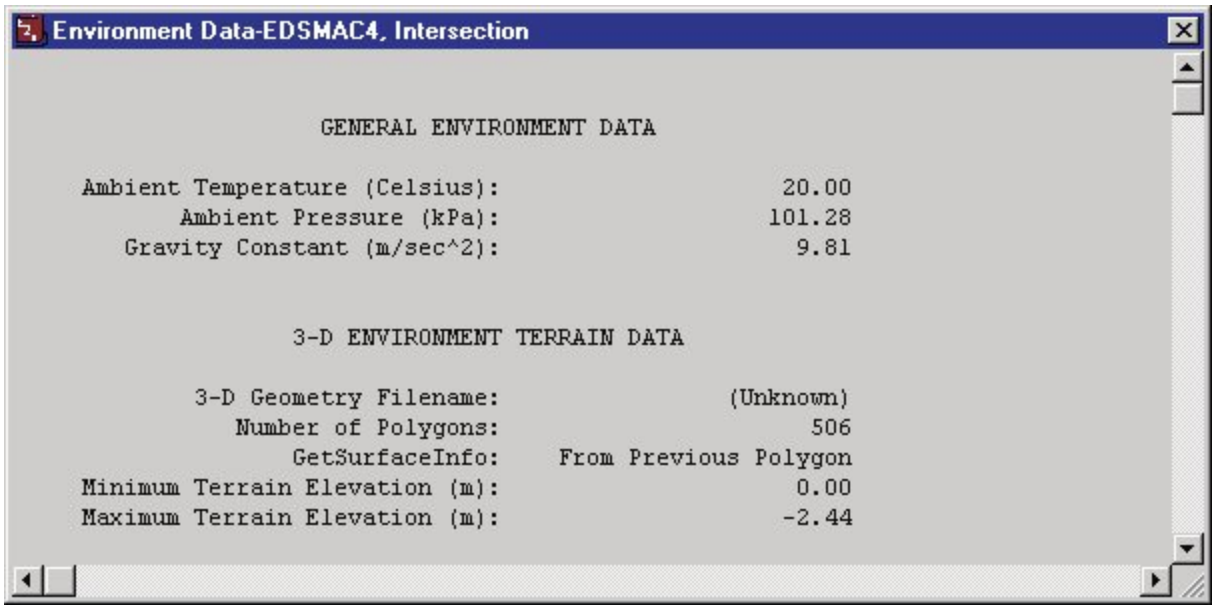


Figure 3-4: Typical Environment Data Output Report issued by EDSMAC4.

> **NOTE:** A detailed description of the terrain vertex information is not practical owing to its potentially large size (a terrain is often composed of several thousand vertices). However, it is possible to view the terrain information (friction multiplier, slope, elevation, and so forth) beneath each tire at each timestep during the simulation by selecting the tire terrain outputs in the Variable Output, Tires output group (see Variable Output later in this chapter).

Event Data

The Event Data report displays event-specific information for each vehicle:

- **Accelerometer Data** — Vehicle-fixed coordinates for up to five accelerometers (the acceleration vs. time history for each accelerometer is found in Variable Output, described later in this chapter).
- **Wheel Displacement Data** — User-defined time and displacement parameters for each displaced wheel location.
- **Tire Blow-out** — User-defined time and tire blow-out parameters for each blown tire.

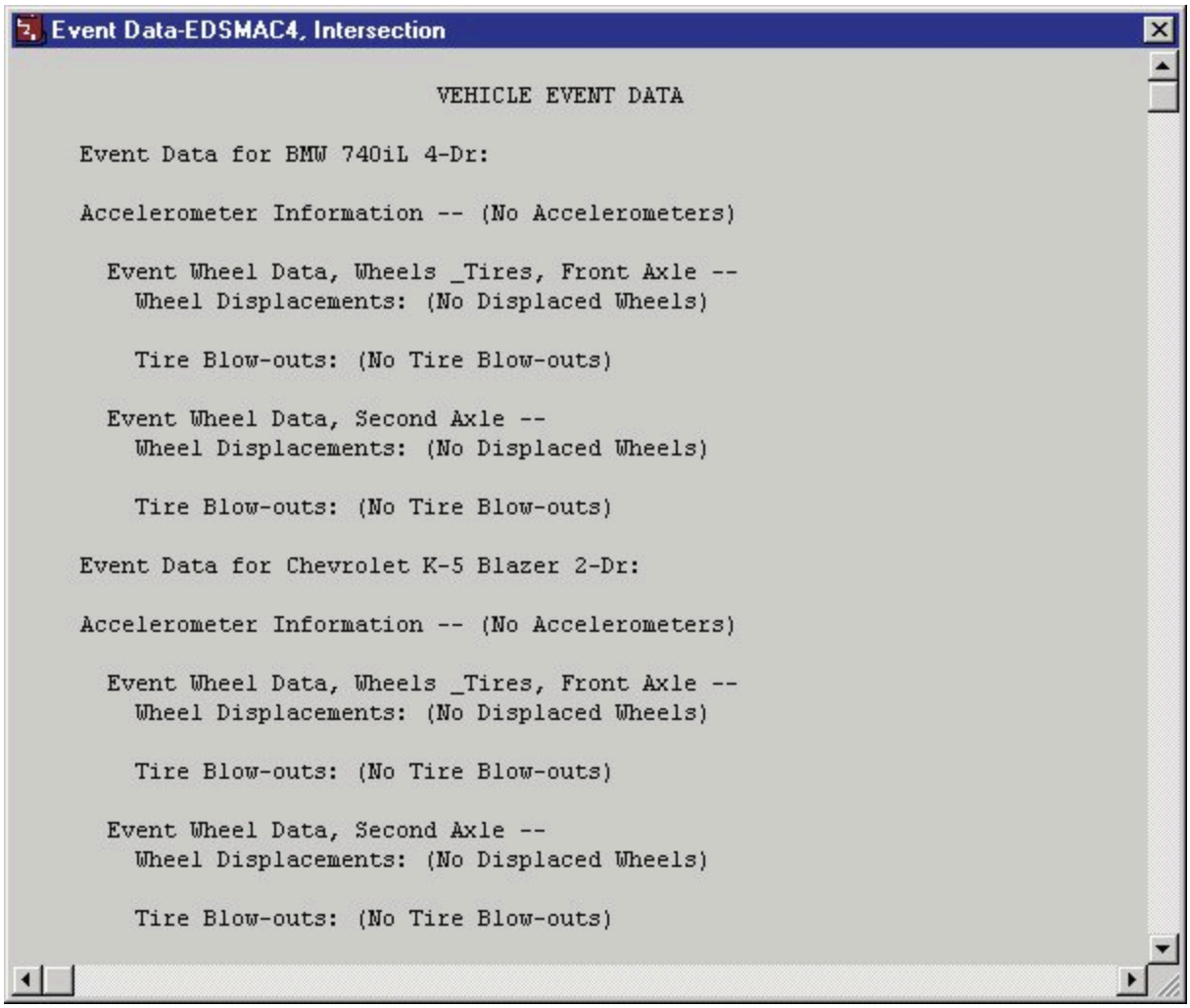


Figure 3-5: Typical Event Data Output Report issued by EDSMAC4.

Messages

The Messages report lists the messages produced during execution of the current event. For a complete listing of messages issued by EDSMAC4, see Chapter 6.

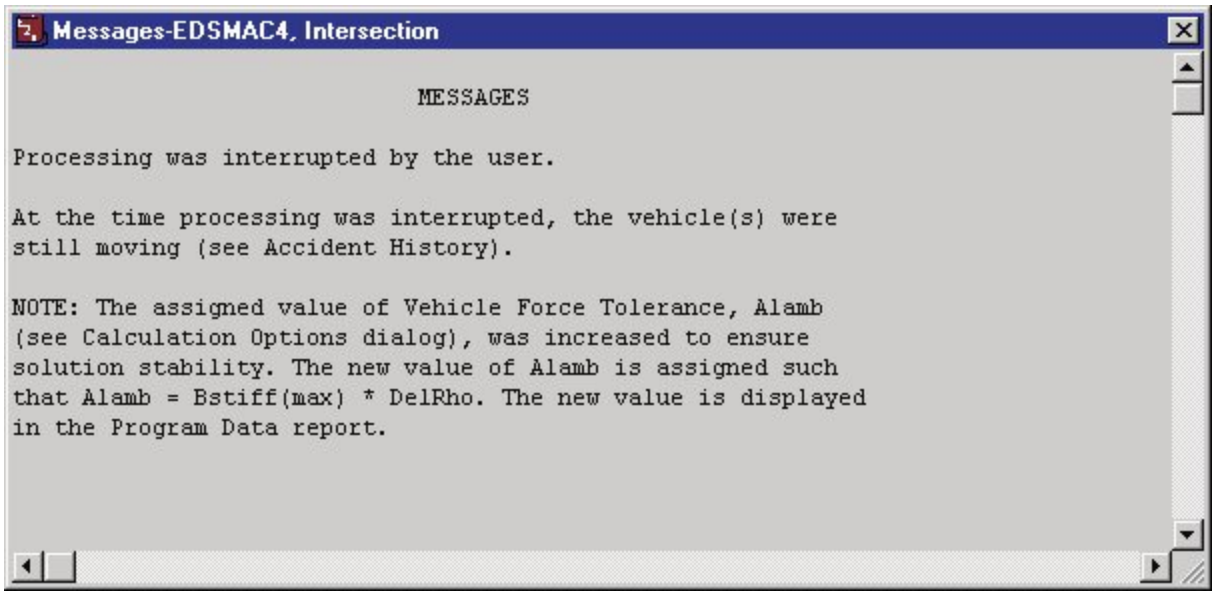
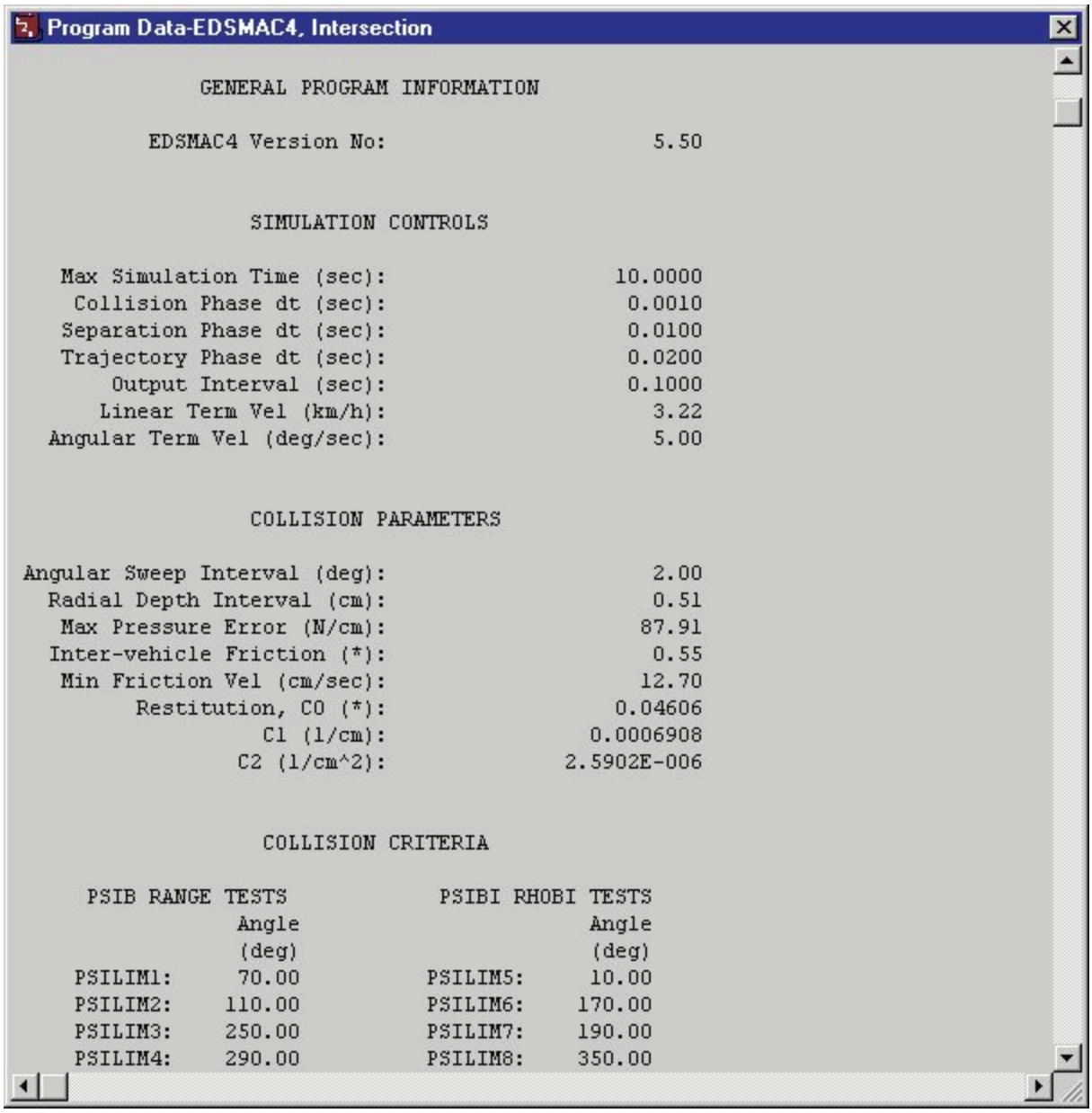


Figure 3-6: Typical Messages Output Report issued by EDSMAC4.

Program Data

The Program Data Report includes the following information:

- **Simulation Controls** — Integration parameters used for the current event.
- **Collision Parameters** — Parameters used within the collision model.
- **Collision Criteria** — Parameters used to determine which side (front, back, right or left) a RHO vector intersects; used to determine the RHO vector's initial length.



Program Data-EDSMAC4, Intersection

GENERAL PROGRAM INFORMATION

EDSMAC4 Version No: 5.50

SIMULATION CONTROLS

Max Simulation Time (sec):	10.0000
Collision Phase dt (sec):	0.0010
Separation Phase dt (sec):	0.0100
Trajectory Phase dt (sec):	0.0200
Output Interval (sec):	0.1000
Linear Term Vel (km/h):	3.22
Angular Term Vel (deg/sec):	5.00

COLLISION PARAMETERS

Angular Sweep Interval (deg):	2.00
Radial Depth Interval (cm):	0.51
Max Pressure Error (N/cm):	87.91
Inter-vehicle Friction (*):	0.55
Min Friction Vel (cm/sec):	12.70
Restitution, C0 (*):	0.04606
C1 (1/cm):	0.0006908
C2 (1/cm^2):	2.5902E-006

COLLISION CRITERIA

PSIB RANGE TESTS	Angle (deg)	PSIBI RHOBI TESTS	Angle (deg)
PSILIM1:	70.00	PSILIM5:	10.00
PSILIM2:	110.00	PSILIM6:	170.00
PSILIM3:	250.00	PSILIM7:	190.00
PSILIM4:	290.00	PSILIM8:	350.00

Figure 3-7: Typical Program Data Output Report issued by EDSMAC4.

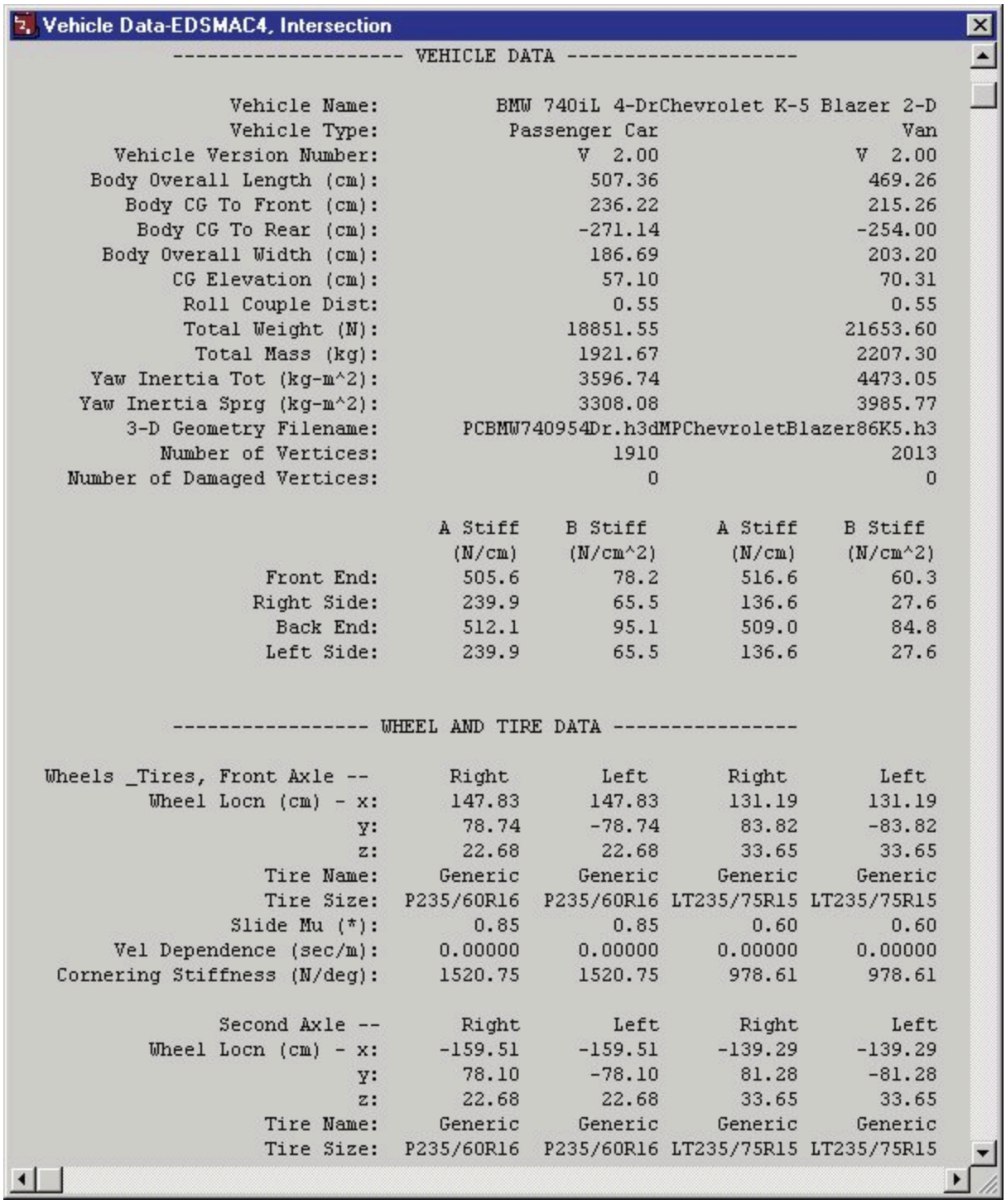
Vehicle Data

The Vehicle Data Report includes the following information:

- **Vehicle Dimensional and Inertial Properties** — The dimensional and inertial parameters used by each vehicle in the current event.

> **NOTE:** The yaw inertia displayed in the Vehicle Data report includes the inertial contributions of the unsprung masses. These masses are added to the sprung mass yaw inertia to calculate the total yaw inertia used by EDSMAC4.

- **Tire Properties** — The tire parameters used by each vehicle in the current event.



Vehicle Data-EDSMAC4, Intersection

---------- VEHICLE DATA ----------

Vehicle Name:	BMW 740iL 4-Dr	Chevrolet K-5 Blazer 2-D		
Vehicle Type:	Passenger Car		Van	
Vehicle Version Number:	V 2.00		V 2.00	
Body Overall Length (cm):	507.36		469.26	
Body CG To Front (cm):	236.22		215.26	
Body CG To Rear (cm):	-271.14		-254.00	
Body Overall Width (cm):	186.69		203.20	
CG Elevation (cm):	57.10		70.31	
Roll Couple Dist:	0.55		0.55	
Total Weight (N):	18851.55		21653.60	
Total Mass (kg):	1921.67		2207.30	
Yaw Inertia Tot (kg-m^2):	3596.74		4473.05	
Yaw Inertia Sprg (kg-m^2):	3308.08		3985.77	
3-D Geometry Filename:	PCBMW740954Dr.h3d	MPChevroletBlazer86K5.h3		
Number of Vertices:	1910		2013	
Number of Damaged Vertices:	0		0	

	A Stiff (N/cm)	B Stiff (N/cm^2)	A Stiff (N/cm)	B Stiff (N/cm^2)
Front End:	505.6	78.2	516.6	60.3
Right Side:	239.9	65.5	136.6	27.6
Back End:	512.1	95.1	509.0	84.8
Left Side:	239.9	65.5	136.6	27.6

---------- WHEEL AND TIRE DATA ----------

Wheels _Tires, Front Axle --	Right	Left	Right	Left
Wheel Locn (cm) - x:	147.83	147.83	131.19	131.19
y:	78.74	-78.74	83.82	-83.82
z:	22.68	22.68	33.65	33.65
Tire Name:	Generic	Generic	Generic	Generic
Tire Size:	P235/60R16	P235/60R16	LT235/75R15	LT235/75R15
Slide Mu (*):	0.85	0.85	0.60	0.60
Vel Dependence (sec/m):	0.00000	0.00000	0.00000	0.00000
Cornering Stiffness (N/deg):	1520.75	1520.75	978.61	978.61
Second Axle --	Right	Left	Right	Left
Wheel Locn (cm) - x:	-159.51	-159.51	-139.29	-139.29
y:	78.10	-78.10	81.28	-81.28
z:	22.68	22.68	33.65	33.65
Tire Name:	Generic	Generic	Generic	Generic
Tire Size:	P235/60R16	P235/60R16	LT235/75R15	LT235/75R15

Figure 3-8: Typical Vehicle Data Output Report issued by EDSMAC4.

Graphic Reports

EDSMAC4 produces no Graphic Output Reports.

> **NOTE:** Graphs of simulation results vs time may be produced using the Variable Output window (see next section).

Variable Output Table

EDSMAC4 produces a Variable Output table containing the time-based simulation results. The Variable Output groups produced by EDSMAC4 are as follows:

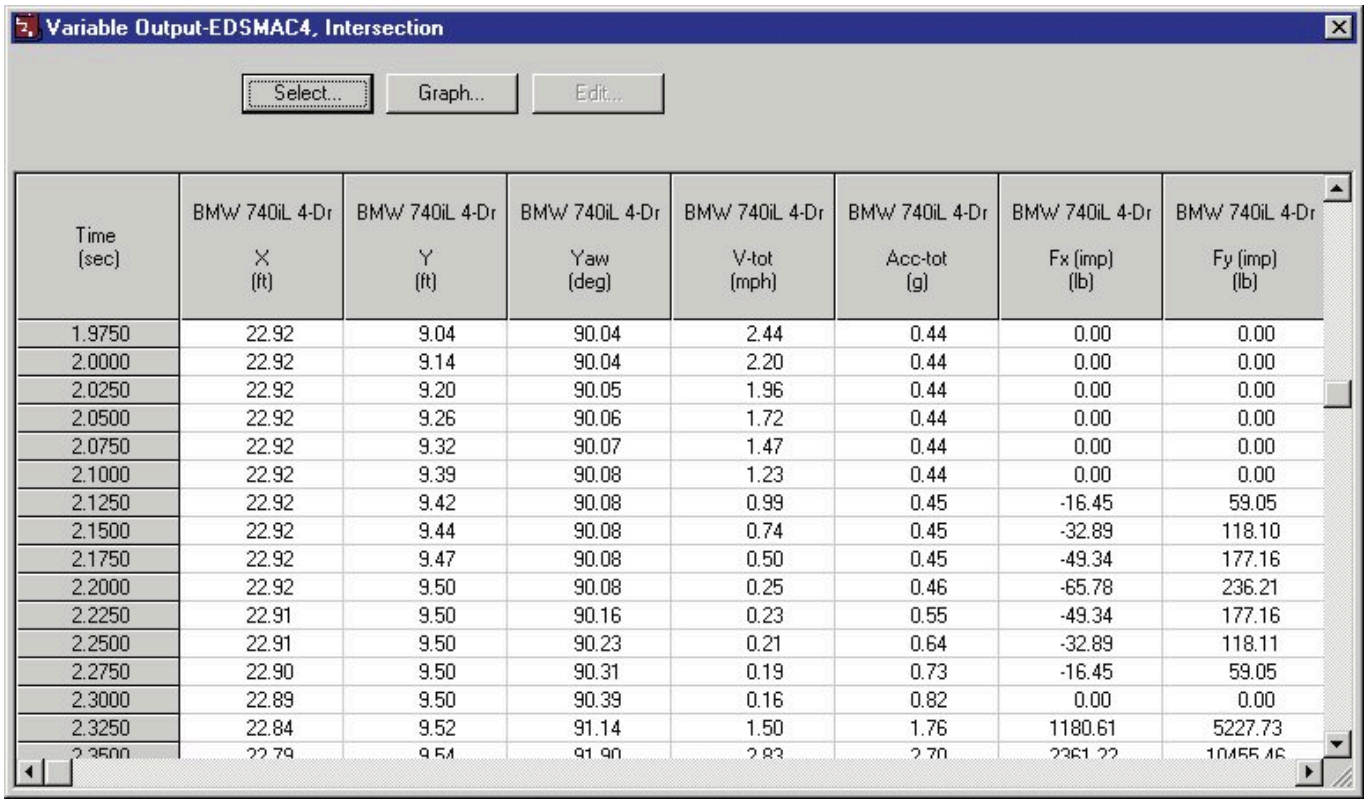
Vehicle Output Groups

- **Kinematics** — Position, velocity and acceleration for each vehicle
- **Kinetics** — Summation of collision forces and moments acting at the CG of each vehicle
- **Accelerometers** — Linear acceleration at each user-specified accelerometer location for each vehicle
- **Tire** — The tire output parameters existing at the tire contact patch (compare with Wheel output, below)
- **Wheel** — The wheel output parameters existing at the wheel's hub; information about the position of each wheel (compare with Tire output, above)
- **Connections** — Trailer articulation angle and connection forces for each articulated vehicle
- **Driver** — Current levels of driver inputs (steering, braking and throttle)

Table 3-1: Vehicle Variable Output Data

Parameter	Description
Vehicle Kinematic Data	X,Y,Z position of CG; ϕ, θ, ψ orientation; total linear velocity, u,v,w components; sideslip angle; r angular velocity; total linear acceleration, forward, side components; $\dot{u}$, $\dot{v}$ linear components; $\dot{r}$ angular component
Vehicle Kinetic Data	ΣF_x, ΣF_y, ΣM_z (collision); ΣF_x, ΣF_y, ΣM_z (tires); ΣF_x, ΣF_y, ΣM_z (connection)
Accelerometer Data	Total linear acceleration; forward, lateral components of linear acceleration at each user-specified accelerometer location
Tire Data	X,Y,Z position of tire contact patch; slip angle; F'_x, F'_y, F'_z; skid flag
Wheel Data	x,y,z location of each wheel; F_x, F_y, F_z; steer angle (δ) at each steerable wheel
Connection Data	Articulation angle, F_x, F_y, F_z at each connection
Driver Data (*)	Steering wheel angle

(*) If Driver Control option was At Driver



Time (sec)	BMW 740iL 4-Dr X (ft)	BMW 740iL 4-Dr Y (ft)	BMW 740iL 4-Dr Yaw (deg)	BMW 740iL 4-Dr V-tot (mph)	BMW 740iL 4-Dr Acc-tot (g)	BMW 740iL 4-Dr Fx (imp) (lb)	BMW 740iL 4-Dr Fy (imp) (lb)
1.9750	22.92	9.04	90.04	2.44	0.44	0.00	0.00
2.0000	22.92	9.14	90.04	2.20	0.44	0.00	0.00
2.0250	22.92	9.20	90.05	1.96	0.44	0.00	0.00
2.0500	22.92	9.26	90.06	1.72	0.44	0.00	0.00
2.0750	22.92	9.32	90.07	1.47	0.44	0.00	0.00
2.1000	22.92	9.39	90.08	1.23	0.44	0.00	0.00
2.1250	22.92	9.42	90.08	0.99	0.45	-16.45	59.05
2.1500	22.92	9.44	90.08	0.74	0.45	-32.89	118.10
2.1750	22.92	9.47	90.08	0.50	0.45	-49.34	177.16
2.2000	22.92	9.50	90.08	0.25	0.46	-65.78	236.21
2.2250	22.91	9.50	90.16	0.23	0.55	-49.34	177.16
2.2500	22.91	9.50	90.23	0.21	0.64	-32.89	118.11
2.2750	22.90	9.50	90.31	0.19	0.73	-16.45	59.05
2.3000	22.89	9.50	90.39	0.16	0.82	0.00	0.00
2.3250	22.84	9.52	91.14	1.50	1.76	1180.61	5227.73
2.3500	22.79	9.54	91.90	2.83	2.70	2361.22	10455.46

Figure 3-9: Typical Variable Output table from EDSMAC4.

Trajectory Simulation

EDSMAC4 produces a trajectory simulation of the current event. The trajectory simulation is a 3-D visualization of the vehicle position data displayed in the Variable Output table (see previous section).

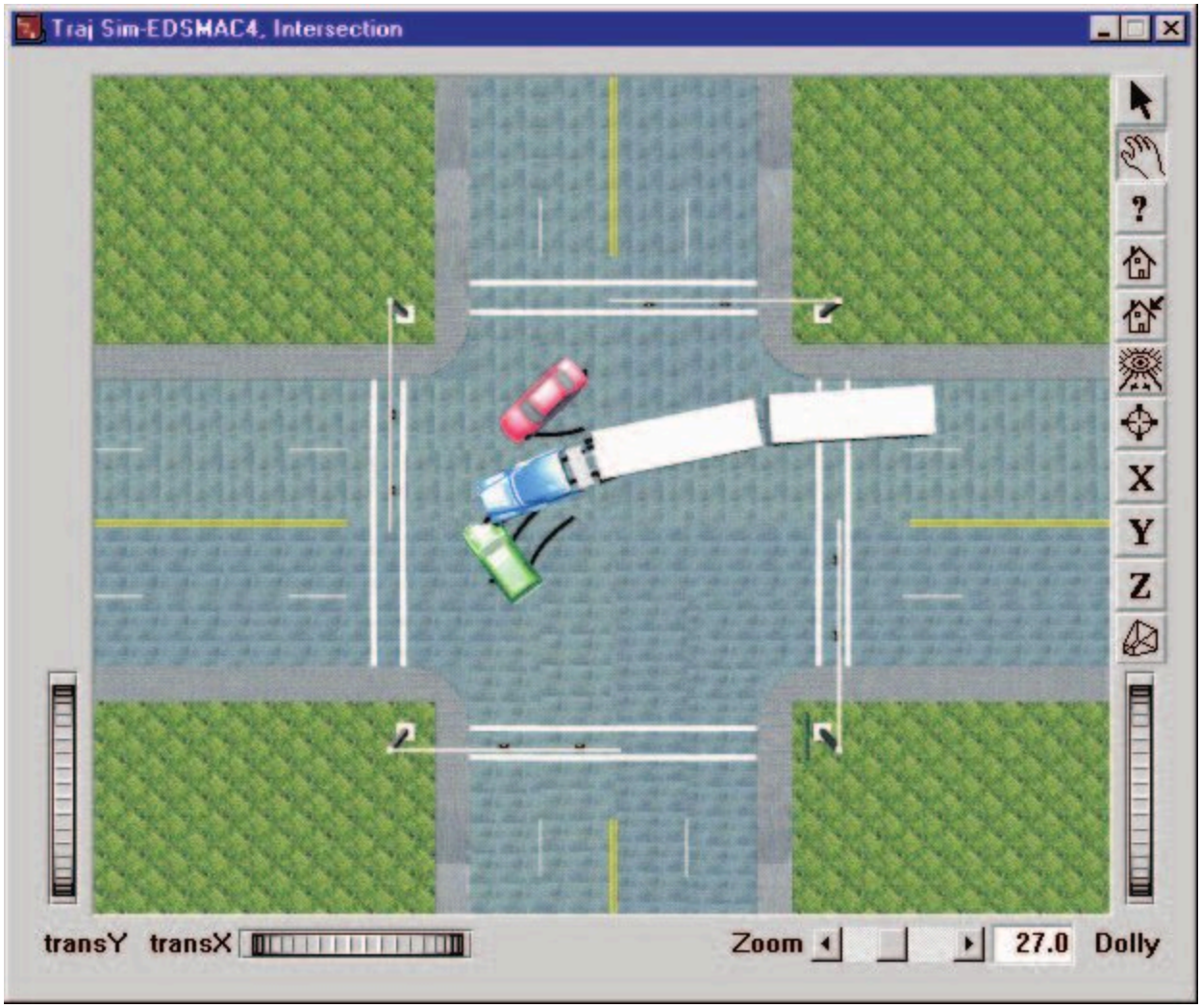


Figure 3-10: Typical EDSMAC4 Trajectory Simulation.

Displaying a Trajectory Simulation

The Trajectory Simulation is controlled using the Playback Controller. The Playback Controller's buttons have the following functions:

- **Reset** — Return to the start of the simulation
- **Rewind to Start** — Return to the start of the simulation
- **Reverse** — Play the simulation backwards
- **Pause** — Pause the simulation
- **Play** — Execute the event or play the simulation forwards
- **Advance to End** — Advance to the end of the simulation



Figure 3-11: Playback Controller, used for controlling Trajectory and Damage Profile Simulations.

Displaying a Damage Profile Simulation

EDSMAC4 produces a dynamic simulation of the vehicle damage profile. The simulated damage is displayed in the Damage Profile viewer. The vehicle is initially displayed in its original shape without damage. To display a time-history of the damage, use the Playback Controller.

> **NOTE:** A Trajectory Simulation window must be open in order to enable the Playback Controller.

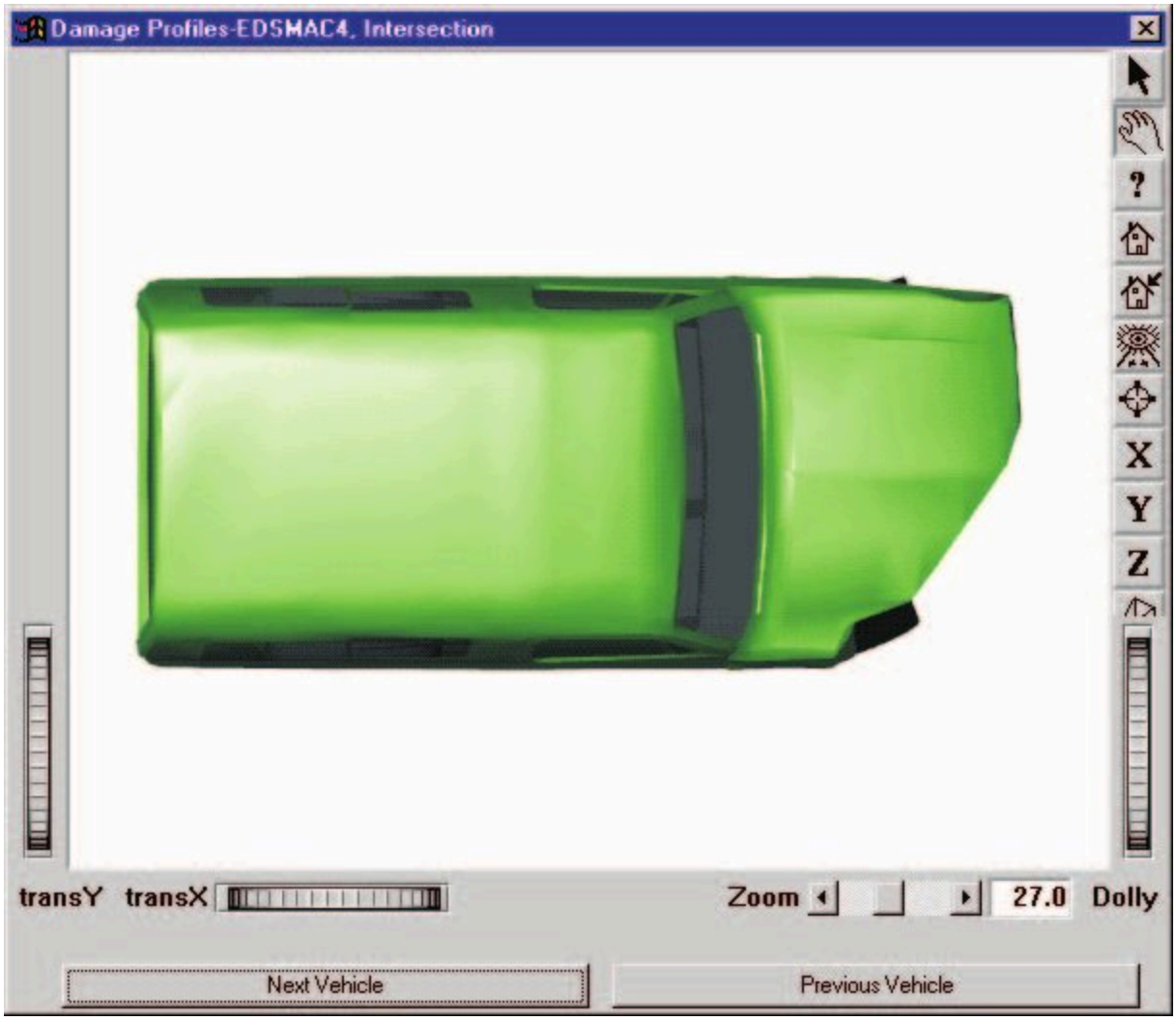


Figure 3-12: Typical EDSMAC4 Damage Profile Simulation.

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

Chapter 4 — Calculation Method

Basis for Analysis

EDSMAC4 is a dynamic analysis of a crash sequence involving one or more vehicles. The program uses a tire model to calculate forces acting on the vehicle at the tire-road interface. If contact between vehicles is detected, collision forces are also computed. Newton's laws of motion are solved at discrete, user-entered time steps for each vehicle. The resulting accelerations are integrated to update the position and velocity at the end of each time step.

The mathematical model for EDSMAC4 was extended from EDC's EDSMAC model, which, in turn, was developed from the SMAC model originally developed and validated at Calspan [1-5, 11-13]. Extensions provided by EDC are explained in references 6, 7, 22 and 23.

To use EDSMAC4 successfully, a good understanding of vehicle dynamics is extremely useful and is recommended. However, the following discussion is limited to the general analytical approach. The discussion describes the solution procedure while the vehicles are in contact during the collision phase and while they are separated (before and after impact) during the trajectory phases. For a detailed treatise on the subject of vehicle dynamics and simulation programs, the user is referred to the references listed at the end of this manual (Chapter 7) as well as those listed in the User's Manual, Appendix VI.

Equations of Motion

EDSMAC4 is a 3-degree-of-freedom analysis. Vehicle motion is calculated in the earth-fixed X and Y directions and rotation about the vertical Z axis. The vector velocity (amplitude and direction) is resolved in the vehicle-fixed coordinate system by resolving its components along the vehicle's forward (u-velocity) and lateral (v-velocity) directions. For more information, refer to SAE J670e — Vehicle Dynamics Terminology.

The required equations of motion, applicable to each vehicle, are:

$$\Sigma F_x = m(\dot{u} - vr)$$

$$\Sigma F_y = m(\dot{v} + ur)$$

$$\Sigma M_z = I_z \dot{r}$$

where:

- m = mass
- I_z = yaw moment of inertia
- u = forward velocity
- v = lateral velocity
- r = angular yaw velocity about the z axis
- ΣF_x = summation of external forces in the vehicle-fixed x-direction
- ΣF_y = summation of external forces in the vehicle-fixed y-direction
- ΣM_z = summation of external moments about the vehicle-fixed z axis

EDSMAC4 solves these equations of motion at discrete, user-entered time intervals (see Simulation Controls, Timesteps), then uses numerical integration to advance to the next time step, and the calculations are repeated.

There are no degrees of freedom (and hence, no equations of motion) for vertical translation nor pitch or roll rotation. Thus, roll, pitch and vertical accelerations are ignored.

In HVE, at each time step, the vehicle's roll, pitch and CG elevation are computed using HVE's surface-information search [24]. This approach allows the vehicle to sense when it is on a grade, and the equations of motion account for the grade. Surface slopes up to about 15 degrees are allowed (a message will be issued if this angle is exceeded). Thus, vehicle motion on hills, super-elevations, road crowns and even sloped shoulders may be modeled using EDSMAC4.

*(updated: the current version also includes an optional dynamic **steer degree of freedom** — when enabled via the Steer DOF calculation option, wheel steer angles are computed from the torques acting on the steering system (tire friction, steering stops, gyroscopic precession, steering column friction) instead of being read directly from the driver steer tables; see EDSMAC4 Calculation Options.)*

Collision Phase

The EDSMAC4 collision model is described in detail in reference 22.

During the collision phase, each vehicle's crush perimeter is described by a set of radial RHO vectors extending from the CG to the vehicle exterior, spaced at the user-entered **Vector Spacing** angle (default 2 degrees). When the perimeters of two vehicles overlap, the collision calculation iteratively adjusts the lengths of corresponding RHO vectors, in steps of the **Vector Adjustment Increment**, until force equilibrium between the two vehicles is achieved within the **Vector Force Tolerance**. Collision forces are computed from the A and B stiffness coefficients of the crushed surfaces; friction forces tangent to the crush surface are computed using the inter-vehicle friction coefficient (set per vehicle pair in the Vehicle Mesh dialog), reduced linearly below the **Minimum Velocity for Friction**. Restitution is applied using the parametric model with coefficients C_0, C_1 and C_2. *(See references 21, 21a and 22 for the full derivation.)*

The crush-force relationship

Along each RHO vector the crush force per unit width — the *pressure*, in the sense used by the collision model — follows the vehicle's A and B stiffness coefficients for the surface engaged:

$$p = \begin{cases} A + B(C - C_0), & C > C_0 \\ [6pt] A\,\dfrac{C}{C_0}, & C \le C_0 \end{cases}$$

where C is the crush depth along that vector and C_0 is a small initial-crush threshold of 0.5 in.

> **NOTE:** The second branch matters more than its size suggests. The A coefficient is the force needed to *begin* producing damage, so the unmodified relationship would jump from zero to A the instant contact occurred. Ramping linearly up to A over the first half inch removes that step, which would otherwise appear as a spike in the collision force at first contact.

Crush is taken along the vector's deformation components. Where the vector engages a single face it is the deformation normal to that face; in the corner region, where a vector engages both a side and an end, the two are blended so that the crush varies smoothly around the corner rather than switching abruptly from one face to the other.

Resolving the collision force onto each vehicle

Once a vector pair is in equilibrium, the force carried along it is resolved into each vehicle's own frame. The normal force acts along the crush surface, and a friction force acts tangentially to it, so in the struck vehicle's frame

$$F_x = F_n(\sin\psi_s + \mu_t\cos\psi_s), \qquad F_y = F_n(\mu_t\sin\psi_s - \cos\psi_s)$$

where F_n is the normal force, ψ_s the orientation of the crush surface and μ_t the effective inter-vehicle friction coefficient (the entered value, reduced in proportion to sliding speed below the **Minimum Velocity for Friction**). The moment about that vehicle's CG follows from the mid-point of the vector pair:

$$M_z = -F_x\,\bar{y} + F_y\,\bar{x}$$

The force on the other vehicle is the same force rotated through the relative heading of the two vehicles and reversed, so that Newton's third law holds exactly at every vector pair rather than only in the sum. Its moment is then taken about its own CG using its own vector mid-point — which is why two vehicles in the same collision generally see different moments from the same force.

Restitution

At the end of each timestep every crushed vector is allowed to rebound toward its undamaged length. The restitution is a fraction computed from that vector's crush depth,

$$e(\delta) = C_0 - C_1\,\delta + C_2\,\delta^2$$

using the three restitution coefficients from the calculation options, and the restored length is a blend between the crushed and original lengths:

$$\rho_{Restored} = e\,\rho_{Original} + (1-e)\rho_{Crushed}$$

so $e = 0$ leaves the vector fully crushed and $e = 1$ restores it completely. Restitution is applied only while the crush depth is below the vertex of the parabola, $C_1 / 2C_2$; beyond that depth the vector does not rebound.

Reaching force equilibrium

The forces along a pair of corresponding RHO vectors must be equal and opposite. They are made so by iteration. At each pair, the two pressures are compared, and while

$$p_j - p_i > \lambda$$

— where λ is the **Vector Force Tolerance** — both vectors are shortened and the pressures recomputed. The iteration stops as soon as the difference falls within the tolerance.

The amount by which the vectors are shortened depends on how well matched the two vehicles are:

- **Comparable stiffnesses** — a single **Vector Adjustment Increment**, $\Delta\rho$, per pass.
- **Stiffnesses differing by more than a factor of two** — a single increment would converge far too slowly, so the program estimates how many increments are needed from the combined stiffness of the pair and jumps most of the way in one step:

$$\Delta = \left(\left\lfloor \frac{p_j - p_i}{(B_i + B_j)\Delta\rho} \right\rfloor + \tfrac{1}{2}\right)\Delta\rho$$

- **Either vehicle still below the initial-crush threshold** — the increment is reduced to 5% of $\Delta\rho$, because the pressure is changing rapidly along the ramp described above and a full increment would overshoot. The same estimate is used where the A coefficients differ by more than a factor of two.

Up to 3200 adjustments are allowed at a vector pair. Exceeding that is a fatal error, and it means the tolerance is too tight for the stiffnesses and increment in use — see the guidance under Chapter 6.

Trajectory Phase

All of the external forces applied to the vehicle which direct its motion during the pre- and post-impact phases are applied at the tires.

> **NOTE:** The tire forces continue to exist during the collision phase.

Accurate computation of the tire forces is essential. Unfortunately, pneumatic tires do not behave in an easy-to-calculate manner. Rather, these properties are functions of several variables, and are extremely non-linear.

In order to calculate tire forces, EDSMAC4 uses the Fiala tire model [10]. This model has seen use in many popular simulations, and is used in EDSVS, EDVTS, and EDCRASH. The user supplies the tire cornering stiffness, C_α, and tire/road slide friction data. The friction may be velocity dependent. A friction circle is used to limit longitudinal and lateral tire forces during combined braking and steering.

EDSMAC4 allows the vehicle to accelerate, brake and steer. The attempted acceleration, braking and steering are supplied by the user in tabular form using the Event Editor. It is important to understand these driver controls result in *attempted* forces; the Fiala tire model determines if these forces are sustainable at the tire-road interface and accounts for the condition if the available force is exceeded.

EDSMAC4 models quasi-static longitudinal and lateral load transfers. This is accomplished by applying the current inertial longitudinal and lateral forces at the vehicle's CG elevation, thus producing a pitch and/or roll moment. Lateral load transfer is apportioned to the front and rear axles using the vehicle's roll couple distribution. Roll couple distribution is primarily a function of the front-to-rear lateral stiffness ratio of the front and rear suspensions.

The transfers are computed as follows. Longitudinal transfer is taken about the wheelbase and is equal and opposite front to rear:

$$\Delta F_{z,Long} = \frac{h\,m}{L}(a_x + g\sin\theta_{Road})$$

where h is the CG height, L the wheelbase and $a_x = \dot{u} - vr$ the vehicle-fixed longitudinal acceleration. Lateral transfer is formed at each axle using that axle's share of the roll couple:

$$\Delta F_{z,Lat} = \frac{\gamma\,h\,m}{T}(a_y - g\sin\phi_{Road})$$

with γ the roll couple distribution at that axle — the entered value at the front, its complement at the rear — and T that axle's track width. The road pitch and roll terms hold a vehicle statically correct on a grade or a superelevated surface.

The axle loads are then split between the two wheels, and divided again where an axle is a tandem:

$$F_{z,Left} = \frac{\frac{1}{2}F_{z,Axle} - \Delta F_{z,Lat}}{n_{Axles}}, \qquad F_{z,Right} = \frac{\frac{1}{2}F_{z,Axle} + \Delta F_{z,Lat}}{n_{Axles}}$$

> **NOTE:** A towed unit's lateral transfer is computed differently, and does not use roll couple distribution. A trailer's roll moment is applied through the hitch rather than through its own suspension geometry, so its lateral transfer is formed from the connection force acting at the hitch height together with the inertial term taken about that height. Roll couple distribution entered for a trailer therefore has no effect.
>
> **NOTE:** The tire forces used in the transfer are those of the **previous** timestep. A load transfer is a consequence of the tire forces, and those forces in turn depend on the transferred load, so the circularity is broken by lagging one of them by a step.

(updated: earlier editions described the load transfer in prose without giving the relationships, and did not mention that towed units are treated differently.)

EDSMAC4's vehicle model allows the user to study vehicles with tandem axles and dual tires.

Tire force calculation

At each wheel, the friction coefficient is the tire's slide friction scaled by the friction multiplier of the surface beneath it — which the hydroplaning model further reduces when one is selected — and then adjusted for speed:

$$\mu = \mu_{Slide}\, f_{Surface}(1 + C_\mu\, s)$$

where s is the wheel's total slip speed and C_μ the speed reduction factor. A zero speed reduction factor leaves the friction speed-independent. The force available at the tire-road interface is then

$$F_{Avail} = \mu\, F_z$$

The attempted longitudinal force is the sum of the throttle and brake table entries at the current time; for the Percent Available Friction table method those entries are fractions and are multiplied by F_{Avail}. The longitudinal force developed, F_c, is the attempted force limited to what the tire can supply. At forward speeds below 2 in/sec the braking force is scaled by $|u| / 2$, so that a nearly stopped wheel does not develop full braking force; drive force is not reduced at low speed.

Whatever longitudinal force is used is unavailable laterally. The remaining lateral capacity follows the friction circle:

$$F_{s,max} = \sqrt{F_{Avail}^2 - F_c^2}$$

The Fiala model is applied to that remaining capacity through the non-dimensional sideslip parameter

$$\bar{\beta} = \frac{(1 + \delta_{dual}) C_\alpha\, \alpha}{F_{s,max}}$$

where δ_{dual} is 1 at a dual-tire wheel location and 0 otherwise, giving

$$F_s = \begin{cases} F_{s,max}\left(\bar{\beta} - \dfrac{\bar{\beta}|\bar{\beta}|}{3} + \dfrac{\bar{\beta}^3}{27}\right), & |\bar{\beta}| < 3 \\ [10pt] F_{s,max}\ \operatorname{sgn}\bar{\beta}, & |\bar{\beta}| \geq 3 \end{cases}$$

The two components are then resolved through the wheel's steer angle, δ, into vehicle-fixed components:

$$F_y = F_s \cos\delta + F_c \sin\delta, \qquad F_x = -F_s \sin\delta + F_c \cos\delta$$

(updated: earlier editions described the tire model in prose only. Note that the dual-tire factor is applied to the cornering stiffness rather than to the available force, which differs from EDSVS and EDVTS, where the factor multiplies the force; and that the friction circle is built on the slide friction rather than a peak friction value, so EDSMAC4 has no distinct peak-versus-slide behavior.)

*(updated: when the **Hydroplane Model** calculation option is set to NASA, the available tire friction is further modified at each tire travelling over a water polygon. The NASA model predicts the hydroplaning speed from the tire's inflation pressure (*$182.16\sqrt{P}$ *in/sec,* P *in lb/in²); above that speed the tire's friction switches to the water polygon's friction value. The extra drag of displacing water is not modeled. See EDSMAC4 Calculation Options.)*

Impact and Separation Times

The impact and separation times reported in the Accident History bound the collision phase. They are found by testing two conditions at every timestep.

The first condition is geometric: the original (undamaged) perimeter of one vehicle must overlap the other, which is tested by checking whether any corner of either vehicle lies inside the other. The second condition is selected by the **Accident History Basis** calculation option:

- **Impact Force** (default) — inter-vehicle collision force is acting at one or more points on the two vehicles.
- **Acceleration** — the total acceleration of either vehicle exceeds the **Threshold** value (default 1 g).

The impact time is the first time at which *both* conditions hold. Note that both are required: with the Acceleration basis, the collision phase still cannot begin before the perimeters overlap. At this time the integration timestep changes to the Vehicle Collision Integration Timestep.

The impact conditions stored for the Accident History — time, position, heading, total speed, forward and lateral components and yaw rate for both vehicles — are latched at that first detection and are never updated by later contact between the same pair. In a multiple-impact event the impact row therefore always describes the *first* contact between that pair. Impact and separation are tracked separately for each pair of vehicles, so a three-vehicle event produces one impact and one separation entry for each colliding pair.

The end of the collision phase uses the reverse test:

- **Impact Force** — no collision force is acting between the two vehicles.
- **Acceleration** — the total acceleration of *both* vehicles is below the Threshold.

The separation condition must be satisfied on consecutive timesteps before separation is declared: **one** timestep with the Impact Force basis, **six** with the Acceleration basis. Separation is then declared at the next time falling on a Vehicle Separation Integration Timestep boundary, at which point the timestep changes and the separation conditions are recorded. The reported separation time consequently lags the true end of contact slightly — by about one timestep with the Impact Force basis, and by up to six collision timesteps plus one separation timestep with the Acceleration basis.

> **NOTE:** The acceleration used by the Acceleration basis is the vehicle's *total* acceleration, which includes tire forces. If the Threshold is set low enough that hard braking or cornering alone exceeds it, separation can never be declared and the event will remain in the collision phase — and at the collision timestep — for the rest of the run. The 1 g default is above what tires normally produce, but a reduced threshold on a high-friction surface can reach this condition.

Repeated impact and separation

Nothing restricts the collision phase to a single occurrence. If the vehicle perimeters are still overlapping when contact resumes after separation has been declared, the collision phase simply restarts: the integration timestep returns to the Vehicle Collision Integration Timestep and the separation test begins again. With the Impact Force basis, where one force-free timestep is enough to declare separation, a disengagement in which contact flickers on and off can cycle through this several times within a few tens of milliseconds.

Only the first and the last of these appear in the Accident History. The impact conditions are recorded once, at first contact, and are never updated; the separation conditions are re-recorded at every separation, so the values shown are those of the **final** one. The report therefore spans the event as a whole — first contact to last separation — and gives no indication of intermittent contact in between.

Collision Severity Results: PDOF, Delta-V and Peak Acceleration

The PDOF, delta-V and peak acceleration reported in the Damage Data report are computed by one of two entirely separate methods, selected by the **Damage Data Format** calculation option. The two methods do not produce identical numbers; the Traditional format is retained for comparison with results from earlier releases.

In both cases the PDOF is reported in the conventional CDC sense (see reference 8) — a 12 o'clock PDOF is a force directed from front to rear, so the reported angle is 180 degrees opposite the direction in which the force acts on the vehicle. Angles are measured in the vehicle-fixed frame with zero forward and positive toward the right side, and are reported in the range ±180 degrees.

Collision Data format (default)

Each row of the Collision Summary table is one **collision pulse** — one period of sustained contact between that vehicle and one collision partner. For each pulse the report gives the pulse number, the vehicle or environment struck, the start and end times and the duration, the peak acceleration, the peak collision force, the delta-V and the PDOF, followed by the CDC, damage width and offset, maximum crush and the crush profile measurements.

How a pulse is delimited

The rule that decides where one pulse ends and the next begins is separate from the one that fixes the impact and separation times in the Accident History, and it is far less sensitive. The two reports can therefore describe the same contact differently.

Start. A pulse opens on the first timestep at which any point on the vehicle carries collision force from that partner. There is no force threshold — any non-zero contact force opens the pulse.

Continuation. On every timestep that contact persists, a provisional closing deadline is set 0.025 seconds ahead. The pulse is closed only once contact has been absent continuously until that deadline passes. Because the deadline is re-set on each contact timestep it is a rolling one: the pulse survives until a full 0.025 seconds have elapsed with no contact at all, however many times contact has come and gone before that. If contact resumes before the deadline, the vehicle rejoins the pulse already in progress against that partner instead of opening a new one.

The intent is that the intermittent contact typical of two vehicles disengaging is reported as one collision rather than a string of small ones. The consequence is that any contact separated from the previous one by less than 0.025 seconds is absorbed into it: its impulse contributes to that pulse's PDOF, its acceleration to the pulse's delta-V, and the vertices it touches to the pulse's CDC, with nothing in the report to show that a distinct contact occurred.

> **NOTE:** This matters when the later contact is severe. A secondary strike reaching a third of the peak collision force, occurring twenty milliseconds after contact was lost, is merged into the preceding pulse and appears nowhere as an event of its own. If the trajectory suggests a separate secondary contact, examine the collision force in the Variable Output, Kinetics group rather than relying on the pulse count.

A gap longer than 0.025 seconds does close the pulse, and the next contact opens a new one, producing a second row.

End. The time in the End column is **not** the time the pulse was closed. It is the last timestep at which the vehicle had not been declared separated from that partner, using the Accident History criterion described above; Length is simply End minus Start. Because the collision phase may be entered more than once, the End time follows the last contact episode rather than the first separation. The pulse's own closure — 0.025 seconds after the final contact — governs only whether a later contact starts a new row, and is never reported.

Limits. Up to ten pulses are tracked for each vehicle; an eleventh ends the run with a message. A pulse still open when the run ends is counted as complete and a diagnostic message is issued.

PDOF. The inter-vehicle collision forces acting on the vehicle are accumulated over the pulse, giving the total collision impulse in vehicle-fixed coordinates. The PDOF is the direction of that impulse:

$$\text{PDOF} = \text{atan2}(J_y,\ J_x) + 180^\circ$$

where J_x and J_y are the forward and lateral components of the accumulated collision impulse. A zenith angle, the elevation of the impulse out of the horizontal plane, is also stored, but since EDSMAC4 computes no vertical collision force it is always zero. The clock direction used for the first two characters of the CDC is this same angle rounded to the nearest hour. Both are frozen once separation is declared.

> **NOTE:** The PDOF is derived from the collision force alone. Tire forces do not affect it.

Delta-V. The vehicle's acceleration components are integrated through the pulse using the trapezoidal rule, accumulating a velocity-change vector in vehicle-fixed coordinates. The reported delta-V is the largest magnitude that vector reaches at any point during the pulse:

$$\Delta V = \max_{t_{Impact} \le t \le t_{Separation}} \left| \int_{t_{Impact}}^{t} \mathbf{a}\, dt \right|$$

Two properties of this calculation are worth understanding:

- The acceleration integrated is the vehicle's **total** acceleration, not the collision acceleration alone. Tire forces acting during contact therefore contribute to the reported delta-V. In a severe impact the contribution is negligible — a fraction of a g against tens of g — but in a low-severity sideswipe with heavy braking it is not.
- The components are integrated in the vehicle-fixed frame while the vehicle is yawing. For the short durations typical of a collision the yaw change is small and the result is very close to the change in the earth-fixed velocity vector, but a long, rotating sideswipe will accumulate a delta-V that differs from the vector difference between the velocities at impact and separation.

Peak acceleration is the largest total acceleration reached at any timestep on which collision force was acting; **peak force** is the largest total collision force, and the time at which it occurred is stored with it. As with delta-V, the peak acceleration includes the tire contribution.

Traditional format

The Traditional format reproduces the original SMAC reporting, which works from the acceleration history rather than from the contact force. It is available only for events with more than one vehicle.

Acceleration peaks. A peak is recorded each time the vehicle's total acceleration rises above the Threshold value and falls back below it. The peak magnitude, its forward and lateral components and its time are stored. Up to ten peaks are kept, after which a message is issued; the peaks are then sorted into descending order of magnitude.

Delta-V of a peak is the integral of the acceleration **magnitude** over the peak, again by the trapezoidal rule:

$$\Delta V = \int |\mathbf{a}| \, dt$$

Because this is a scalar integral rather than a vector one, a peak whose direction rotates produces a larger delta-V than the corresponding change in velocity. To limit this, the direction of the acceleration is tracked in sectors, and the contribution of an acceleration that has changed sector is suppressed.

PDOF of a peak is the direction of the acceleration at the instant of the peak, converted to the conventional sense as described above.

Matching peaks to damage. Each damage range found on the crush profile is matched to the acceleration peak whose clock direction is closest to the mid-point of that range. If no peak lies within 60 degrees of the mid-point, the largest peak is used instead and a message is issued — a common and harmless outcome for sideswipes and secondary impacts.

Total delta-V of a damage range is the sum of the delta-Vs of *all* acceleration peaks whose clock direction lies within one hour either side of the matched peak's clock direction. Delta-V arising from separate impacts in the same general direction is therefore combined into a single figure for that damage range. If only one peak was found, all delta-V is assigned to it.

> **NOTE:** The Threshold value is used by the Traditional format regardless of the Accident History Basis. The dialog disables the Threshold field when the basis is Impact Force, but the stored value — 1 g by default — still sets the minimum acceleration at which an acceleration peak is recognized and delta-V is accumulated.

Assumptions

In order to provide a useful analysis without becoming burdensome and overly complex, EDSMAC4 makes several simplifying assumptions. If the user is to use EDSMAC4 properly, it is important 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. EDSMAC4 will issue results which may not be valid for the circumstances of the accident. Before using EDSMAC4, be sure your accident is within the scope of EDSMAC4's original design.

A thorough list of assumptions and how to properly use the program can be found in the References [1-7, 11-13, 15]. Some of the major program assumptions are defined below.

Surface Slope Up To 15 Degrees

The HVE physical environment allows EDSMAC4 to consider the general effects of roll and pitch, up to about 15 degrees (the limit is the result of the small angle assumption). Negotiating slopes within this range is generally well

modeled. However, traveling off an embankment is completely beyond the scope of EDSMAC4.

No Rollover Allowed

EDSMAC4 is a 3-degree-of-freedom analysis and does not consider roll or pitch degrees of freedom. If a vehicle rolls over, the equations of motion that apply during the trajectory phases no longer apply, since forces are no longer applied at the tires but are applied between the vehicle exterior and road. EDSMAC4 makes no provision for this condition.

All External Forces Applied at Tires

Other than during the collision, all forces which affect vehicle motion are applied at the tire/road interface. Aerodynamic effects are ignored. This assumption may become a factor at excessive speeds. In addition, forces caused by contact between the undercarriage and ground (sometimes resulting from impact damage) are not considered.

Homogeneous Vehicle Exterior

The collision phase analysis assumes there is a linear force vs crush relationship for each vehicle surface (front, sides or rear). The stiffness is assumed to be uniform for the entire surface. This means, for example, that the side stiffness is the same at the front fender, wheels, bumpers, doors and quarterpanel.

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Chapter 5 — EDSMAC4 Tutorial

Description

This tutorial illustrates a very common use of EDSMAC4, that is, to perform a time-distance study to evaluate accident avoidability.

Using HVE to execute this event further illustrates the power of visualization: while the EDSMAC4 event tells us the time available to avoid a crash, the visualization actually

shows

us. The capability to visualize is inherent to any HVE simulation.

This tutorial is a continuation of the EDCRASH Tutorial, wherein the initial vehicle velocities were estimated. You may wish to review that tutorial before continuing.

Like all EDSMAC4 events, the procedure involves the following basic steps:

- Create the vehicle(s)
- Create the environment
- Execute the EDSMAC4 event
- Review the EDSMAC4 output reports

> **NOTE:** It is assumed that either HVE-2D or HVE is up and running, and that the user is familiar with the program's 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 EDSMAC4 event.

Getting Started

> **NOTE:** If you just finished the EDCRASH Tutorial, you have already created your vehicles and environment and may proceed directly to *Creating Events*, below. The same suggestion applies if you already did the EDCRASH Tutorial and saved the case; if so, simply open that case and skip ahead.

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 Belt Anchors
- OFF: Show Velocity Vectors
- ON: Show Skidmarks
- OFF: Show Targets
- ON: AutoPosition
- Units equals S.I.

> **NOTE:** As we'll see when we create the environment, our EDSMAC4 Tutorial takes 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:

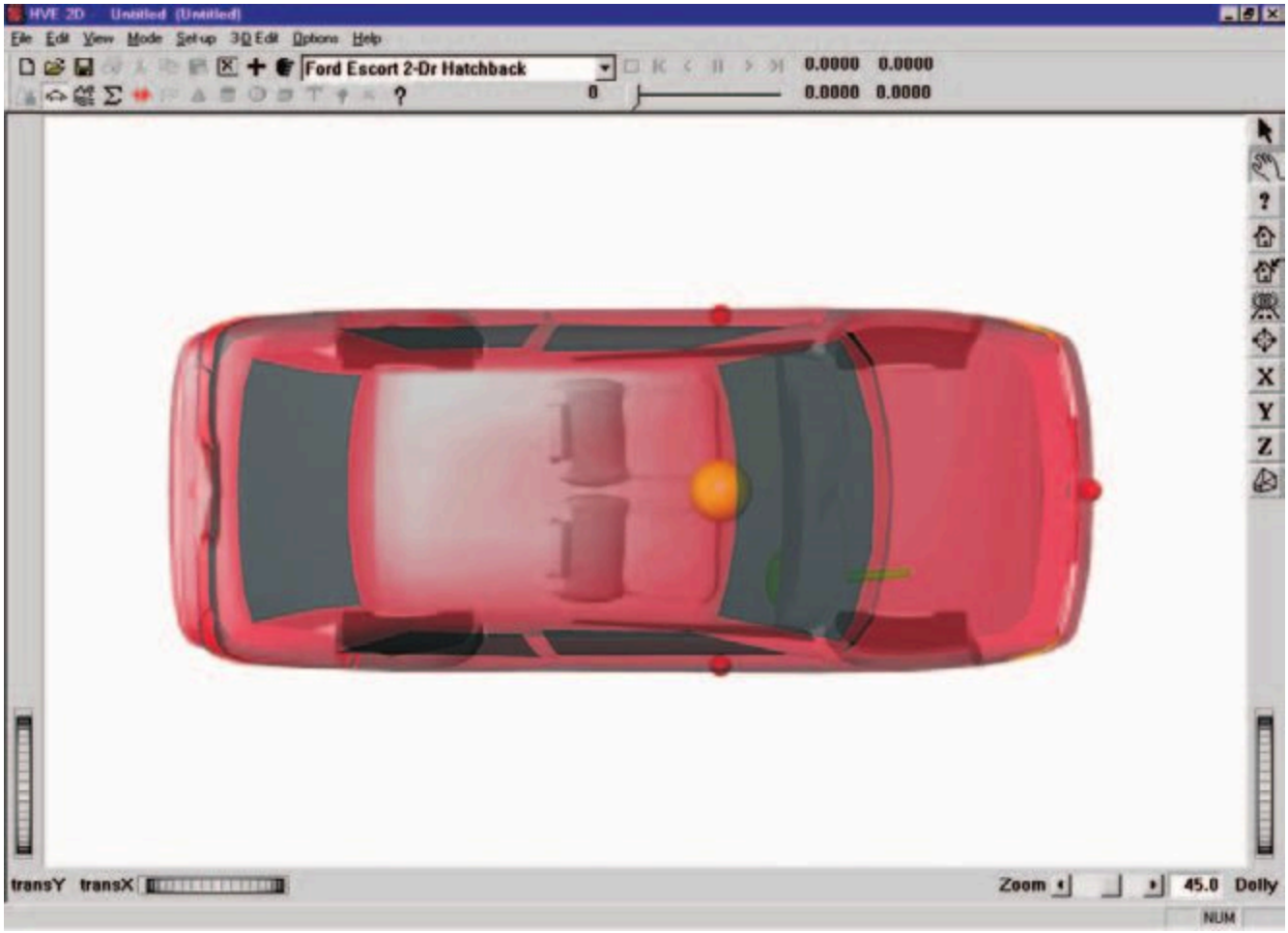
1. If the Vehicle Editor is not the current editor, choose Vehicle Mode. The Vehicle Editor is displayed.
2. Click Add New Object. The Vehicle Information dialog is displayed. The Vehicle Information dialog allows the user to select the basic vehicle attributes according to Type, Make, Model, Year and 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 assigned default values for each vehicle. For our tutorial, only driver location must be edited.

1. Using the option buttons, 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 the Ford Escort to the Active Vehicles list.

The Ford Escort is added to the case. Next, let's add the Nissan Sentra.



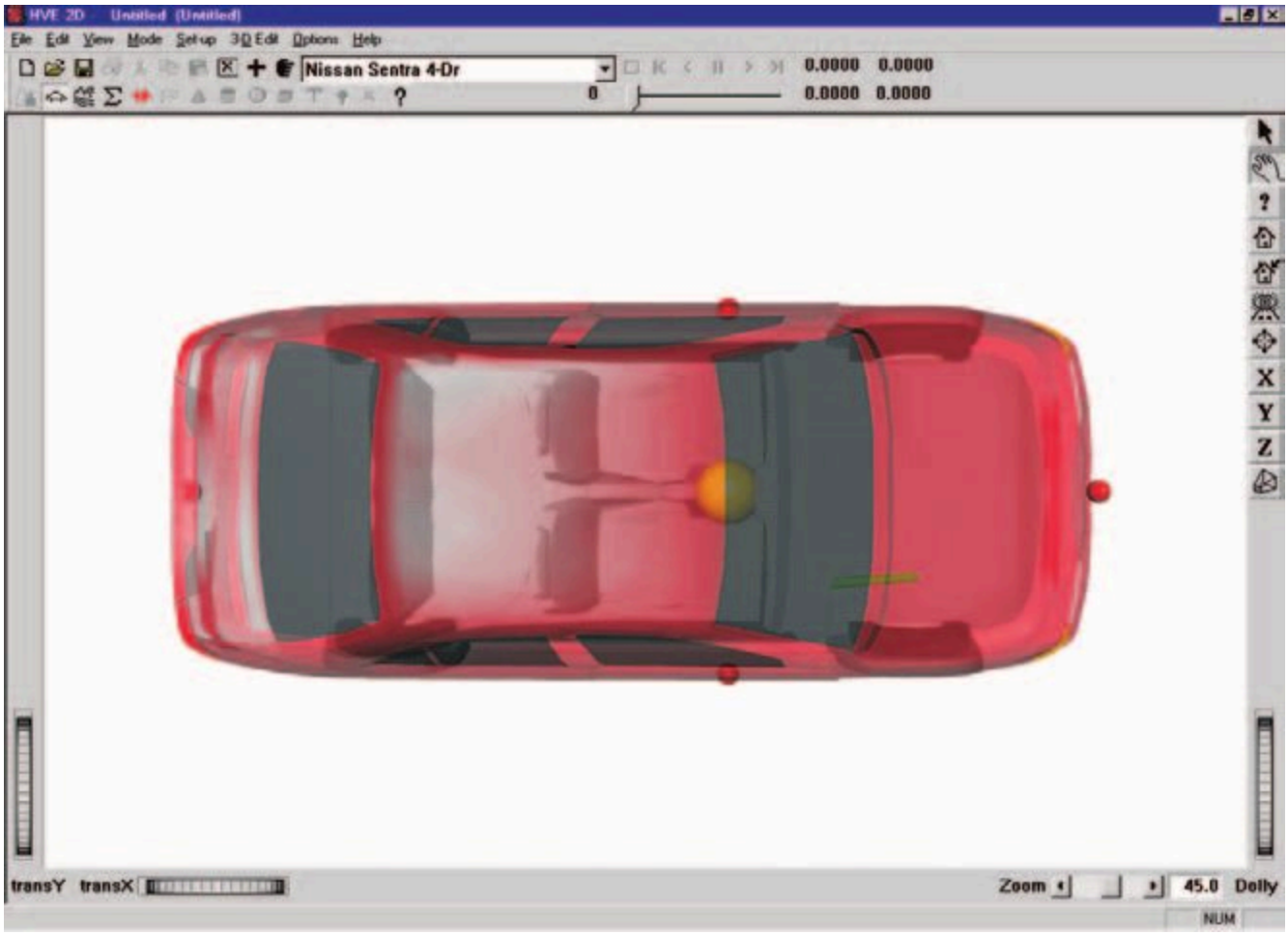


Figure 5-1: Ford Escort (above) and Nissan Sentra (below).

1. Click Add New Object. The Vehicle Information dialog is displayed.
2. Using the option buttons, 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 the Nissan Sentra to the Active Vehicles list.

We now have the vehicles required for our study, as shown in Figure 5-1.

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. Select the Ford Escort from the Active Vehicles drop-down 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 circle. To lighten the vehicle, click on the intensity slider and drag it to the far right end.



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

> **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.

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.

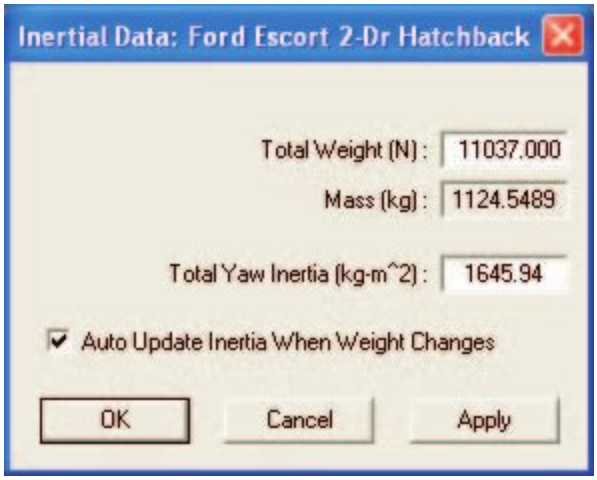


Figure 5-3: Vehicle Inertias dialog, used for editing the current weight and yaw inertia (roll and pitch inertias are not used by EDSMAC4).

> **NOTE:** The vehicle's roll, pitch and yaw moments of inertia and xz product of inertia are also displayed in the Inertias dialog; however, only the yaw inertia is used by the 3-DOF EDSMAC4 calculations.

1. In the Total Weight text field, replace the existing weight, 10283 Newtons, with the measured value, 11037 Newtons.

> **NOTE:** The weight is entered as a force (Newtons). Mass units (kg) are calculated and displayed.
>
> **NOTE:** The dialog might initially display 10283.5, 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.

The Ford Escort is now ready for use in our tutorial. Using the viewer thumb wheels and/or manipulators, 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.

> **NOTE:** It is important to be able to manipulate (pan, rotate and zoom) the objects in the current viewer. Refer to the User's Manual (see Window Manager Basics) for more information.

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

1. Click on Nissan Sentra 4-Dr 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.

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 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 of the vehicle. From a previous reconstruction analysis, the A and B stiffnesses were re-calculated in order to balance the forces (the technique is described in references [20] and [21]). Based on this analysis, 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.

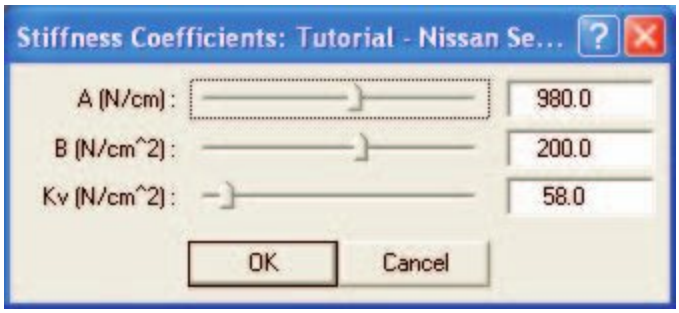


Figure 5-4: Vehicle Stiffness dialog, used for editing the current A, B and KL stiffness coefficients for the current surface. Note that EDSMAC4 uses the A and B stiffness for the selected surface; earlier programs used a single value of KL for the entire vehicle.

To edit the current A and B stiffness values:

1. In the A Stiffness field, replace the current value, 175.1, with the calculated value, 980 N/cm.
2. In the B Stiffness field, replace the current value, 45.6, with the calculated value, 200 N/cm².
3. Click OK to update the stiffness.
4. 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 controls (thumb wheels and manipulators), view the vehicle. 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.

> If you began this case using the EDCRASH Tutorial, your case will be saved using the existing filename, EdcrashTutorial.
>
> **NOTE:** If you started this tutorial as a new case, the Save-as dialog is displayed because the case has not been saved previously, so we need to enter a filename. Continue with the following steps.

1. In the Case Title text field, enter `EDSMAC4 Tutorial, Visibility Study`.

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

1. In the Filename text field, enter `Edsmac4Tutorial`.
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 (35.30.00S), 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 a new location name, latitude, longitude and GMT.

1. Edit the name for the accident site, `Blind Intersection`.
2. Edit the date and time of the incident we are studying, 7/23/97 and 1330, respectively.
3. Edit the angle from true north to the earth-fixed X axis in our environment, −10 degrees.

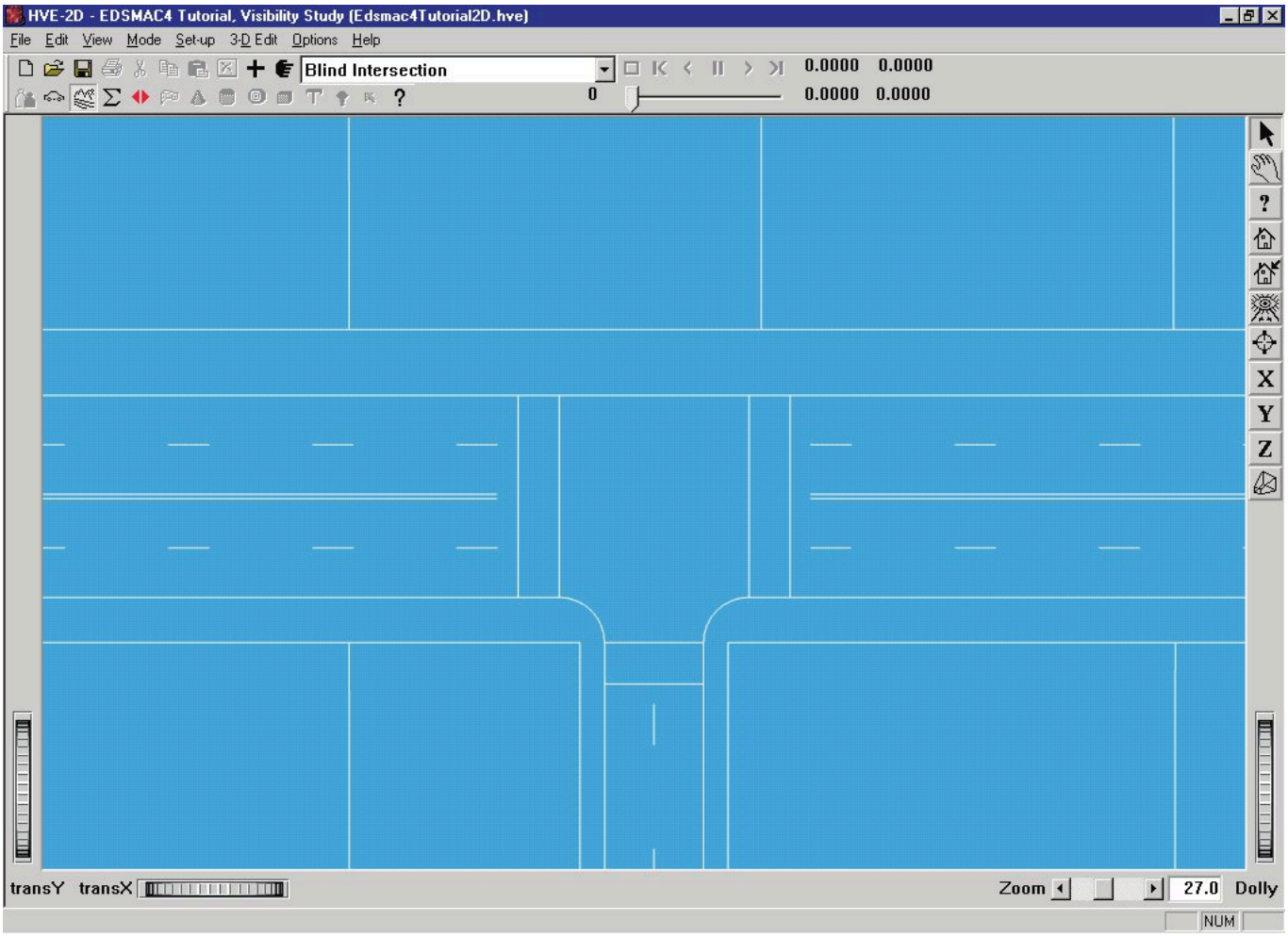
> **NOTE:** The Latitude, Longitude, GMT, Date/Time and angle from true north are used to position the sun in the scene. This is, of course, important because the sun is the primary light source for the scene.

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 choose the environment file `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.


HVE-2D - EDSMAC4 Tutorial, Visibility Study (Edsmac4Tutorial2D.hve)
File Edit View Mode Set-up 3-D Edit Options Help
Blind Intersection
0.0000 0.0000
0.0000 0.0000
0
X
Y
Z
transY transX
Zoom
27.0
Dolly
NUM

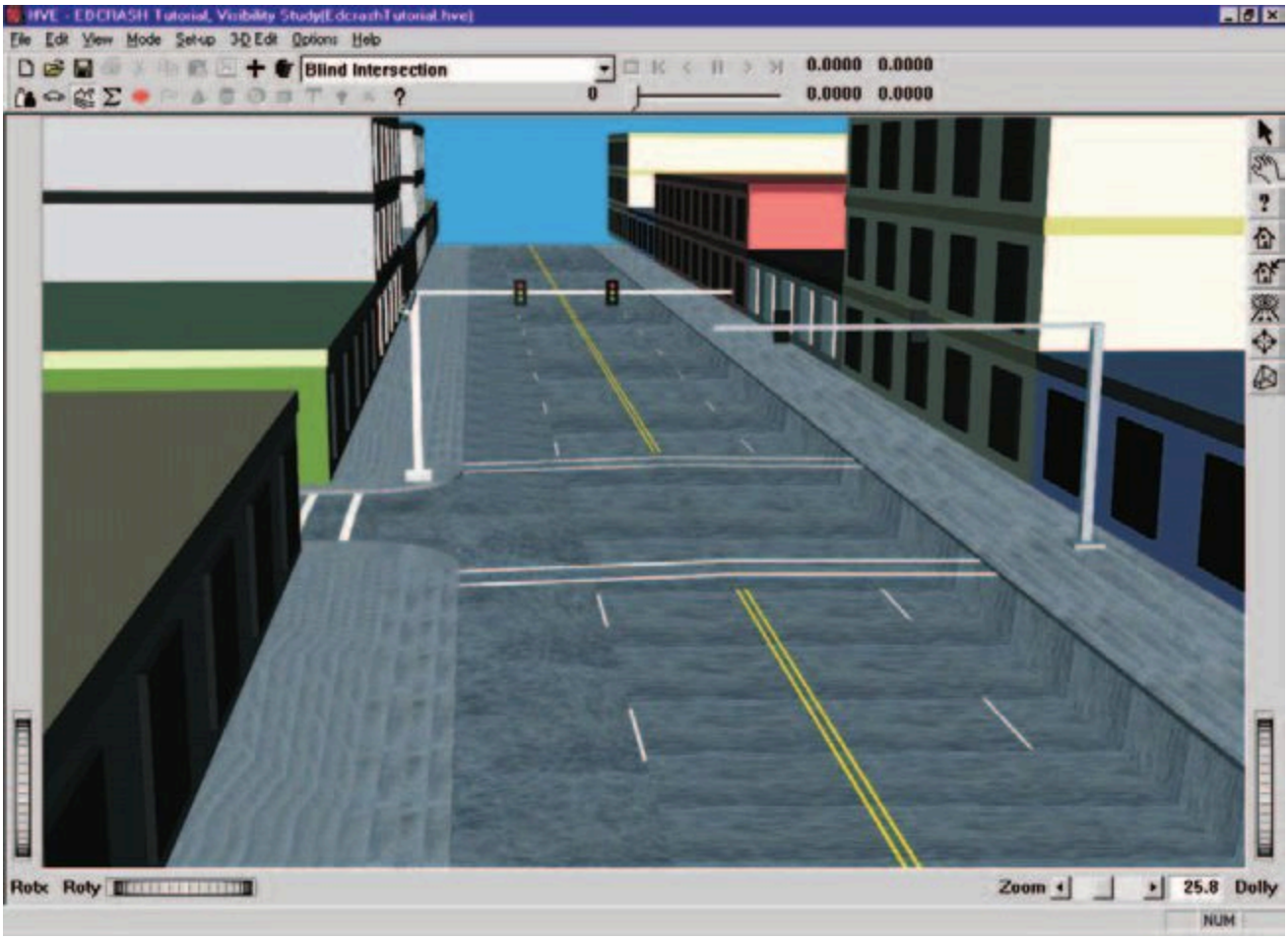


Figure 5-5: Environment used for the EDSMAC4 tutorial: HVE-2D (above) and HVE (below).

Creating Events

As mentioned at the outset, this EDSMAC4 tutorial is an avoidability study in which visibility plays a key role. With this in mind, we will start simulating the event well before impact to illustrate the visibility between vehicles, as obstructed by the building on the southwest corner of the intersection.

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 EDSMAC4 from the Calculation Method options list.
5. Enter a name for the event, `Visibility Study`.

> **NOTE:** The name of the calculation method will be appended to the event name, thus the complete event name will become "EDSMAC4, Visibility Study."

1. Press OK to display the event editor.

Now, we're ready to set up the event. This step involves placing the vehicles in the environment and assigning driver controls:

1. Select Ford Escort from the Event Humans & Vehicles list.
2. Choose Set-up from the menu bar, select Position/Velocity. The Escort is displayed in its initial position at the earth-fixed origin.
3. 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 initial position, X = 35 m, Y = 15 m. Click the Yaw field in the Position/Velocity dialog to replace the existing value with the heading angle, 180 degrees.

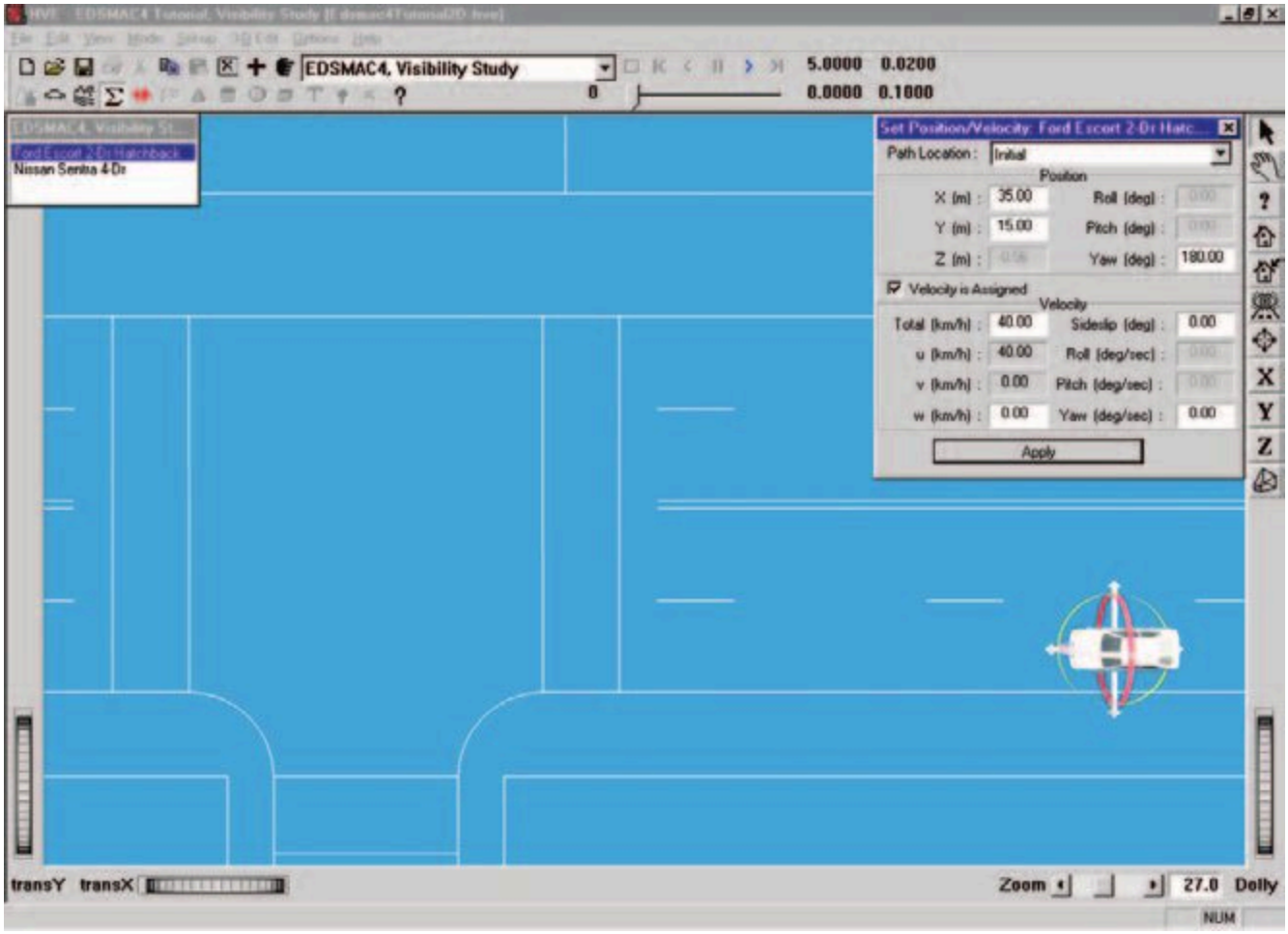


Figure 5-6: Positioning the Ford Escort using the Event Editor. The manipulators can be used to drag and drop the vehicle into position. Click on the cross-bars to drag the vehicle on the road surface; click on the circular yellow ribbon to rotate the vehicle about its yaw axis.

> **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:** Adjust the viewer by dollying back (using the Dolly thumb wheel) 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, simply enter them in the dialog (in fact, it's often easier to directly enter the coordinates using the dialog).
>
> **NOTE:** When entering coordinates using the Position/Velocity dialog, remember to press Enter; otherwise, the values will not be assigned.

1. Click the Velocity Is Assigned checkbox. Enter the initial total velocity, 40 km/h, followed by Apply (or simply press Enter).

Next, let's enter the driver controls:

1. Choose Set-up from the menu bar, select Driver Controls. The Driver Controls dialog is displayed. The default driver control table, Steering, is also displayed for editing.

> **NOTE:** Two Steer Table options are available: 'At Steering Wheel' and 'At Axle'. We'll use the default method, 'At Steering Wheel'.

1. Enter the values shown in Table 5-1 into the steer table:

Table 5-1: Steer table entries for the Ford Escort

Time (sec)	Steer Angle at Steering Wheel (degrees)
1.50	0.0
2.00	90.0

Next, let's assign the Brake Table for the Ford Escort:

1. Click the Brake tab on the Driver Controls dialog. The Brake dialog is displayed for the Ford Escort.

> **NOTE:** Two Brake Table options are available: 'Available Friction' and 'Wheel Force'. We'll use the default method, 'Available Friction'.

1. Enter the Escort's brake table using the Available Friction (default) method, per Table 5-2:

Table 5-2: Brake table for Ford Escort — Friction (%/100)

Time (sec)	R/F	L/F	R/R	L/R
2.25	0.00	0.00	0.00	0.00
2.35	1.00	1.00	1.00	1.00
2.70	1.00	1.00	1.00	1.00
2.80	1.00	1.00	0.01	0.01

1. Click OK to accept the Ford Escort's steering and brake tables.

Event set-up for the Ford Escort is now complete. Let's set up the Nissan Sentra:

1. Select the Nissan Sentra from the Event Humans and Vehicles list.
2. Choose Set-up from the menu bar, select Position/Velocity. The Nissan is displayed at its initial position 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 initial position, X = 3.5 m, Y = 39 m. In the Yaw field in the Position/Velocity dialog, replace the existing value with the heading angle, −90 degrees.

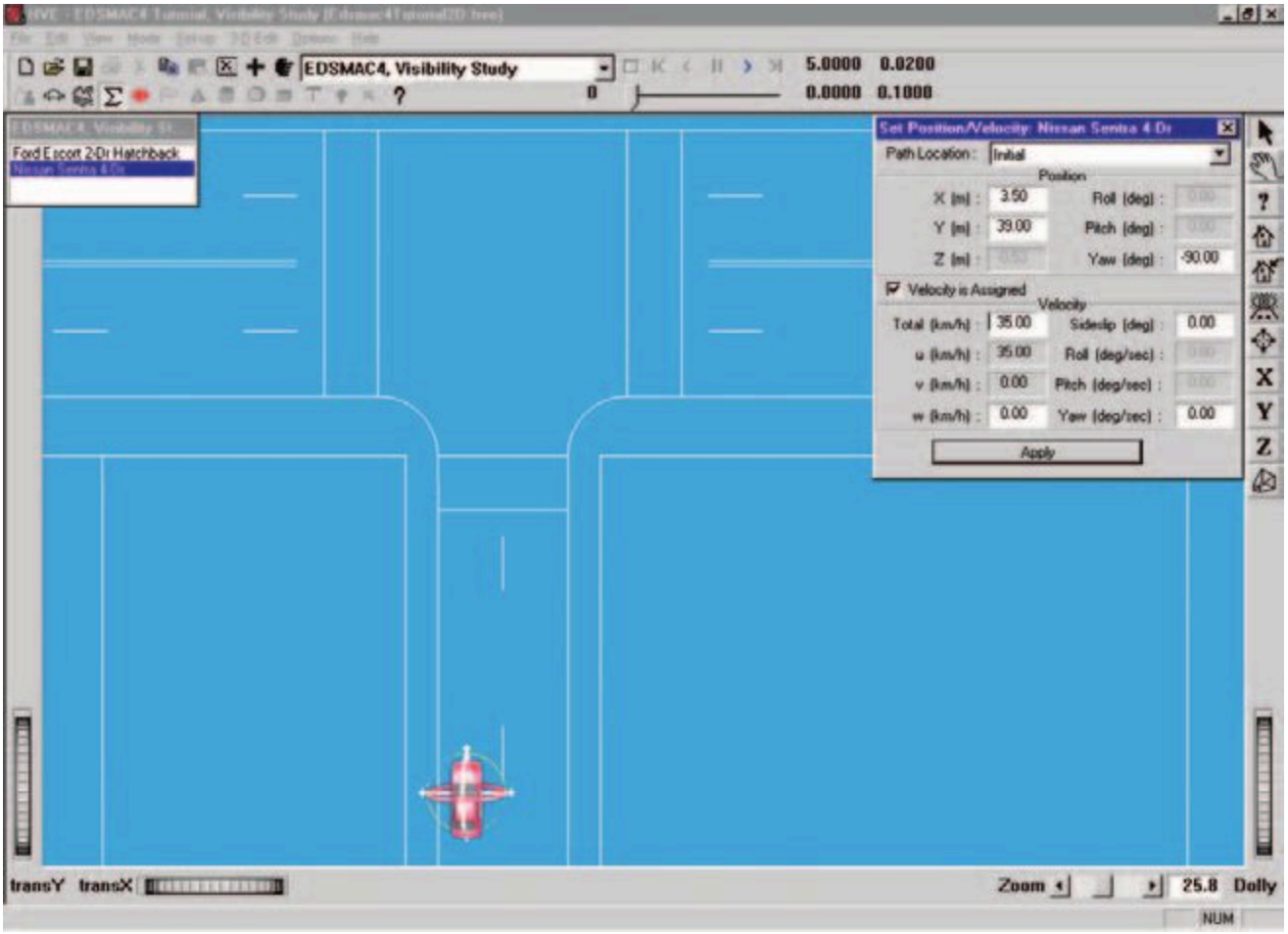


Figure 5-7: Positioning the Nissan Sentra using the Event Editor. The manipulators can be used to drag and drop the vehicle into position.

1. Click the Velocity Is Assigned check box and enter the initial velocity, 35 km/h, followed by Enter.

> **NOTE:** Remember to press Apply or Enter. Otherwise, the value will not be assigned.

The Nissan's initial position and velocity 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 Driver Controls dialog is displayed.
2. Click the Brake tab. The Brake Table is displayed.
3. Click on the Table Is option list and choose the Available Friction option.

4. Enter the rolling resistances after impact, as shown in Table 5-3:

Table 5-3: Post-impact rolling resistances for the Nissan Sentra — Friction (%/100)

Time (sec)	R/F	L/F	R/R	L/R
2.70	0.00	0.00	0.00	0.00
2.80	0.20	0.20	0.01	0.01

1. Press OK to accept the table.

This event lasts more than 5 seconds. To prevent premature termination, let's increase the default maximum simulation time:

1. Click on the Options menu and choose Simulation Controls. The Simulation Controls dialog is displayed.
2. Edit the Maximum Time, changing it from 5 to 10 seconds.
3. Press OK to update the simulation controls.

Now, we're ready to set the camera view for the event. Let's first view the sequence from a good overall vantage point:

- Use the viewer controls (thumb wheels, zoom slider and direct hand-in-viewer manipulator) to set the view similar to that shown in Figure 5-8. (In HVE-2D, set the view to an overhead view that contains both vehicles at their initial positions.)

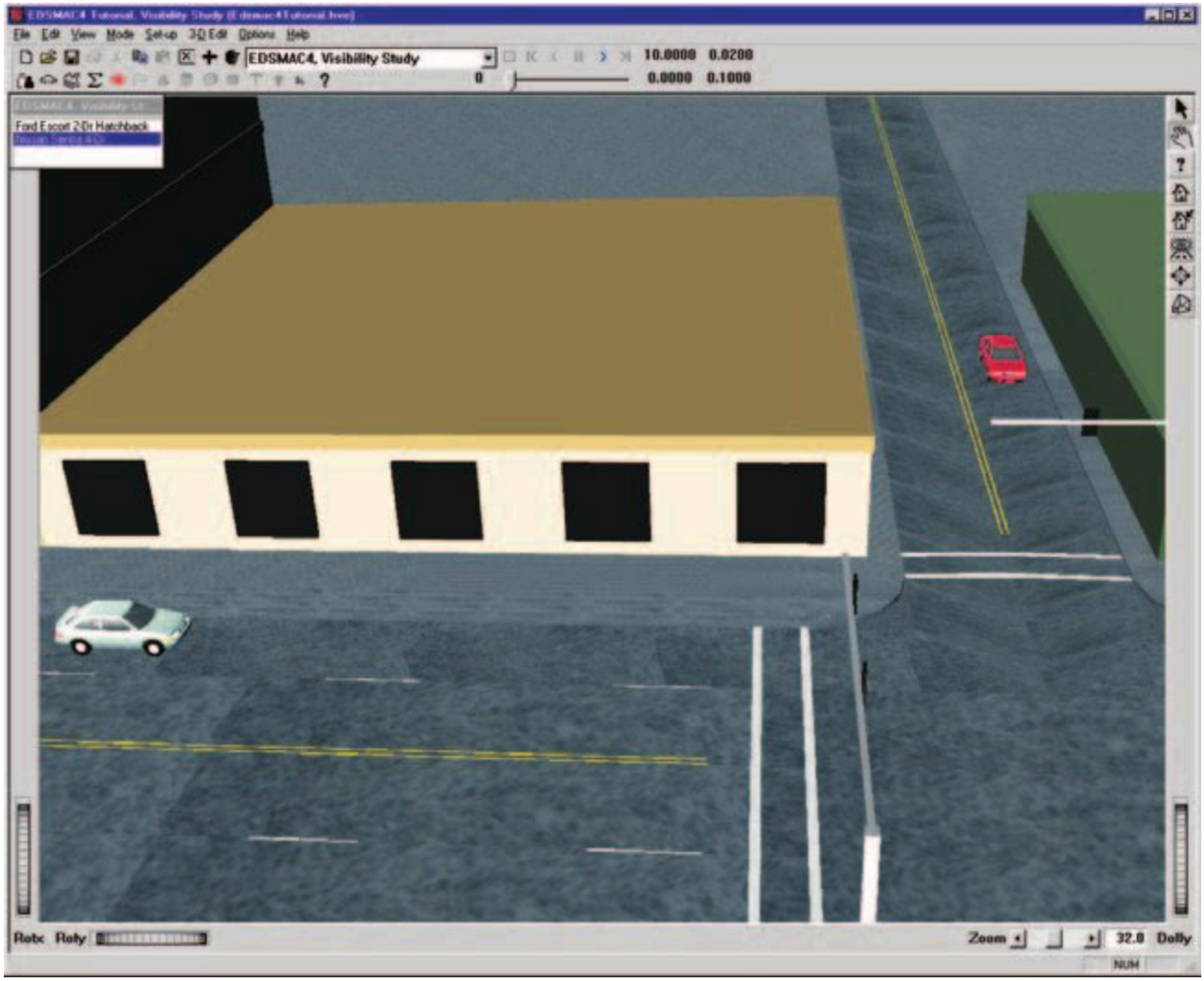


Figure 5-8: Overall view of the scene after event set-up is complete.

Next, 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 us access to the viewer thumb wheel controls (in case we want to change the view).

Now, we're ready to execute the event:

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

Watch as the vehicles approach each other, collide, and roll to their rest positions.

> **NOTE:** You can adjust the view while the event is executing, or you can press Pause/Stop to temporarily stop the event while setting the view, then press Play to continue it.
>
> **NOTE:** Remember to pay attention to the Key Results windows; in this case, you might be interested in the position and velocity of each vehicle at initial visibility.

While it is not possible to set the camera to a driver's perspective in HVE-2D (by definition a 3-dimensional operation), you can use the overhead view to determine line of sight at each timestep.

Because the issue is avoidability, let's view the sequence from several locations, including from within the vehicles, to determine what the event was actually like for each driver. Now, let's replay the sequence as viewed by the driver of the Ford Escort.

- Using the Event Controller, press Rewind.

Setting the View

HVE has additional features that we will use in this visibility study to get a driver's view of the event. Therefore, while this section of the manual is of interest to both HVE and HVE-2D users, it is written primarily for users of HVE.

A very useful feature of HVE is the ability to simulate the driver's view by attaching the camera to the vehicle in the position of the driver's head and facing in the direction of the driver's sight. In HVE-2D, the camera may also be attached to any vehicle, but the view remains straight down, essentially providing a "helicopter" view.

Let's attach the camera to the Ford:

1. Choose Set Camera from the View menu. The Camera dialog is displayed.

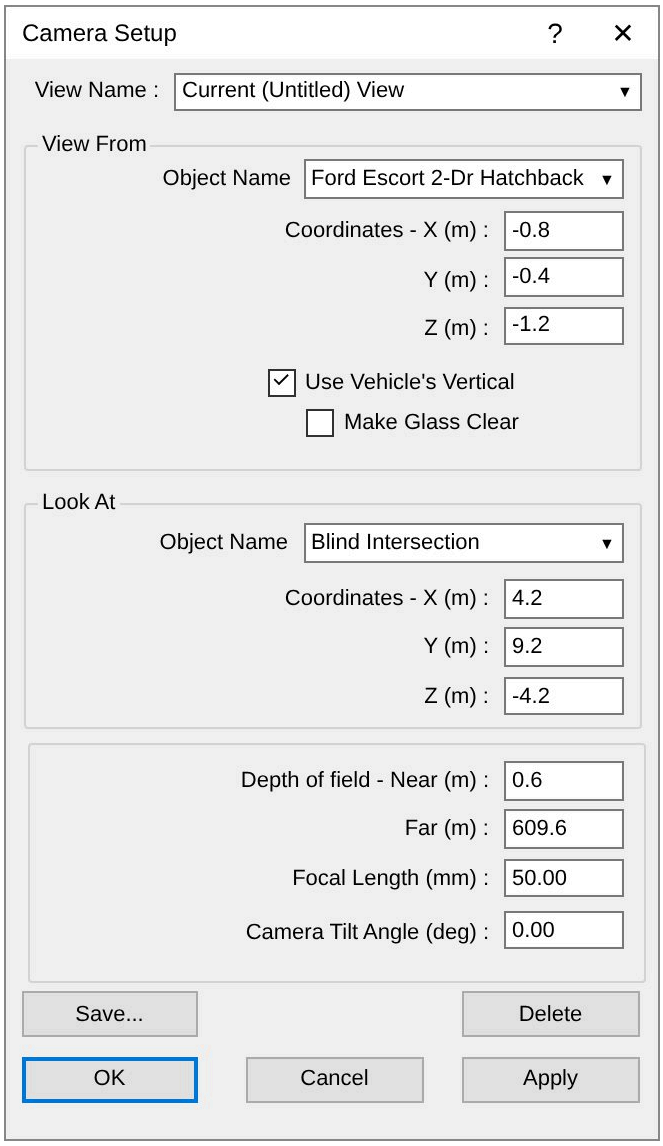


Figure 5-9: HVE Set Camera dialog, used for attaching the camera to the vehicle.

1. Click on the Object Name list in the View From group. The list displays each object in the event (Blind Intersection, Ford Escort and Nissan Sentra).
2. Choose Ford Escort from the Object Name list in the View From group.
3. Enter the Camera coordinates, x = 0.0 m, y = 0.5 m, z = −0.6 m.

> **NOTE:** These coordinates are vehicle-fixed, relative to the Ford Escort's coordinate system.
>
> **NOTE:** These coordinates define the driver's seat location just above the roof. We placed the camera outside the car because the windshield is tinted and difficult to see through.

1. Click on the Object Name list in the Look At group. The list displays each object in the event.
2. Choose Ford Escort from the Object Name list in the Look At group.
3. Enter the coordinates, x = 10.0 m, y = −2.5 m, z = −0.6 m.

> **NOTE:** These coordinates are also relative to the Ford Escort, and define a view angle looking forward and to the left, as shown in Figure 5-10.

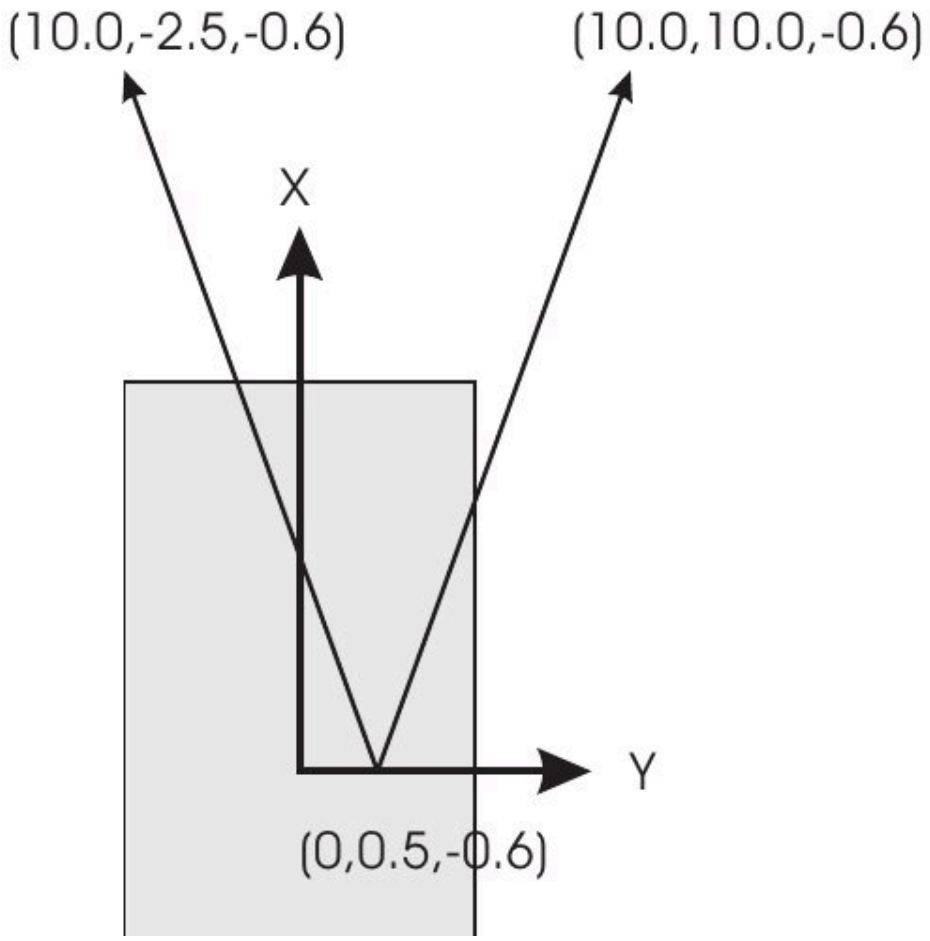


Figure 5-10: Relationship between the camera position and picture center coordinates.

> In HVE-2D, the view is restricted to the straight-down "helicopter" view, so there is no Look At group available on the HVE-2D Camera Setup dialog.

1. Press OK to assign the new camera position.

The viewer now shows the scene as viewed from the Ford Escort. Now we're ready to see how the accident occurred from the Ford driver's perspective.

- Press Play to view the accident sequence from the Ford driver's perspective.

Watch as the Nissan becomes visible at t = 1.2 seconds. Noting from the steer table that the Ford's driver began steering at t = 1.5 seconds and began braking at t = 2.25 seconds, we can draw some conclusions regarding the driver's perception/reaction time.

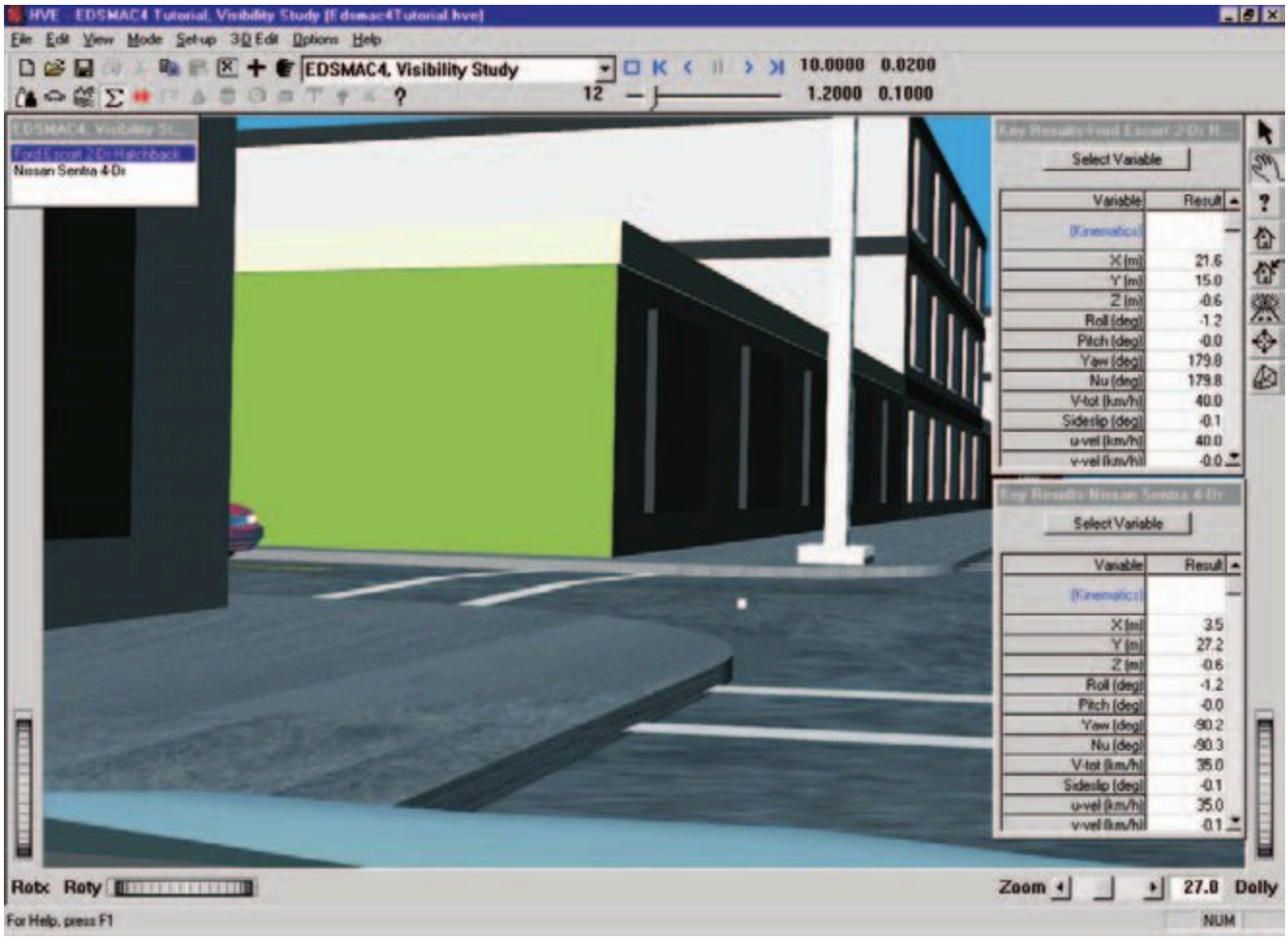


Figure 5-11: Accident sequence as viewed from the driver's position in the Ford Escort at t = 1.2 seconds; the Nissan is just becoming visible.

Allow the event to run to completion.

Next, we can repeat the above steps for the driver of the Nissan Sentra:

1. Choose Set Camera from the View menu. The Camera dialog is displayed.
2. Click on the Object Name list in the View From group and choose Nissan Sentra.
3. The Camera coordinates for the Ford Escort are acceptable for the Nissan as well.
4. Click on the Object Name list in the Look At group and choose Nissan Sentra.
5. Enter the coordinates, x = 10.0 m, y = 10.0 m, z = −0.6 m.

> **NOTE:** These coordinates are also vehicle-fixed, this time relative to the Nissan Sentra, and define a view angle looking forward and to the right.

1. Press OK to assign the new camera position.

Now we're ready to see how the accident occurred from the Nissan driver's perspective.

- Press Play to view the accident sequence from the Nissan driver's perspective.

Watch as the Ford becomes visible at t = 1.3 seconds. Because there was no pre-impact skidding of the Nissan, we cannot draw any conclusions regarding the Nissan driver's perception/reaction time (other than there was a lack of driver response).

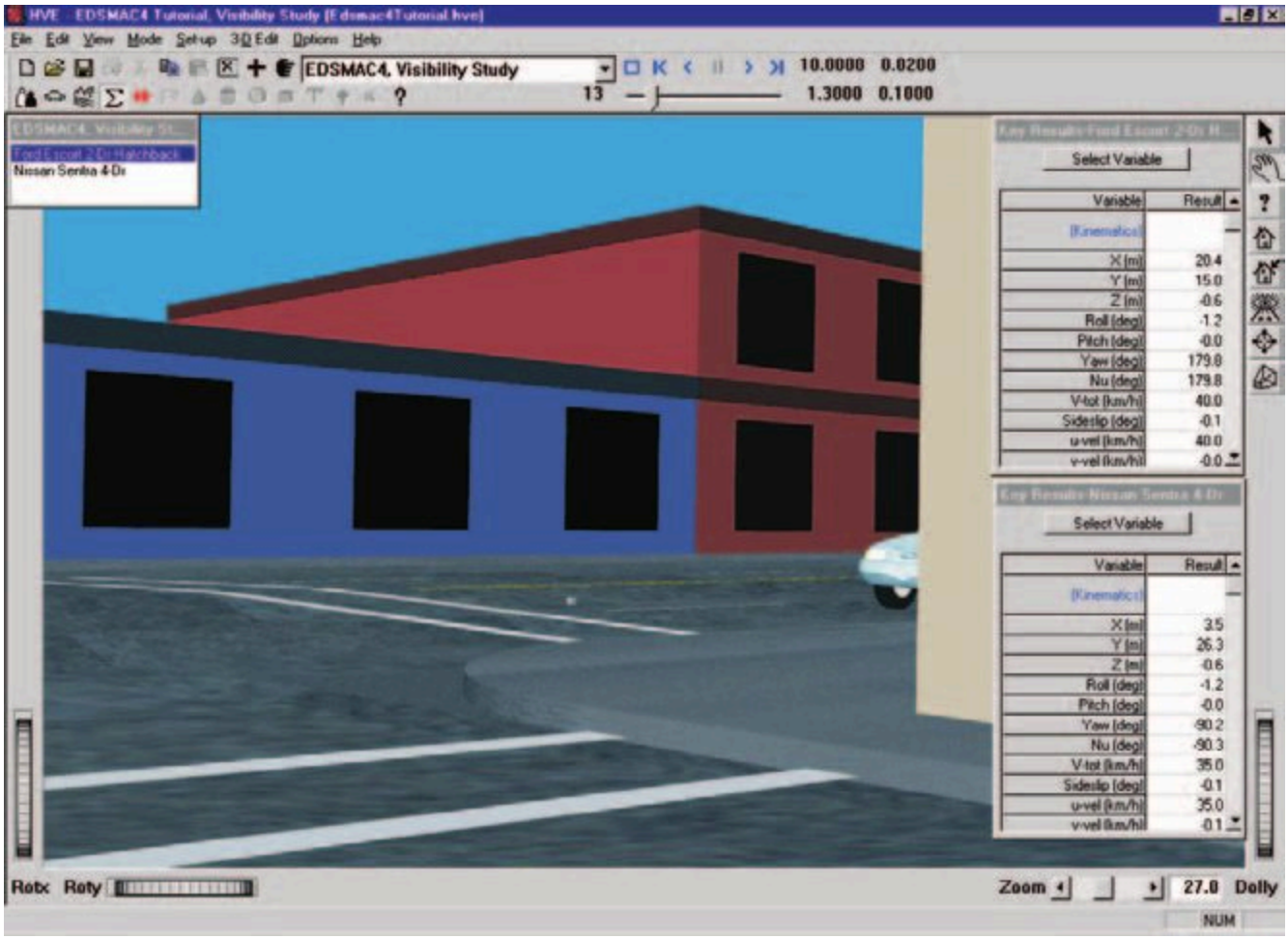


Figure 5-12: Accident sequence as viewed from the driver's position in the Nissan Sentra at t = 1.3 seconds; the Ford is just becoming visible.

- Allow the event to run to completion.

You may wish to view the sequence from other perspectives or to assign the Object Name list in the View From group to one vehicle and assign the Object Name list in the Look At group to the other vehicle. Doing so allows the view to follow the other vehicle throughout the simulation. Use the viewer controls or the Set Camera dialog to adjust the view as necessary.

We have now completed the event.

Viewing Results

Now that we have produced our EDSMAC4 simulations, let's take a detailed look at the results. The Playback Editor is used for reviewing and printing reports for each event in the current case, as well as for producing video output.

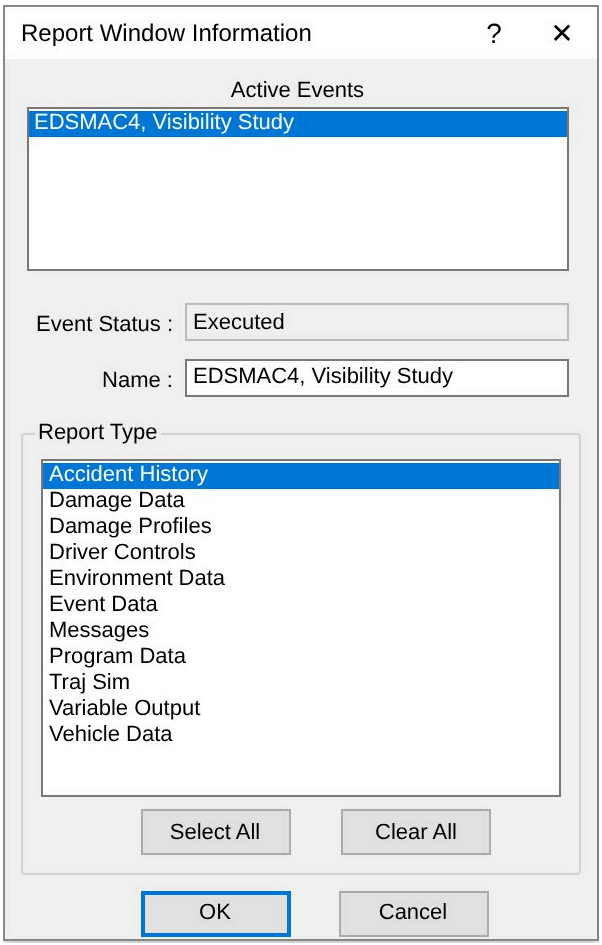


Figure 5-13: Report Window Information dialog, showing the name of the event(s) in the current case.

EDSMAC4 produces the following reports:

- **Accident History** — A table of initial, impact, separation and final positions and velocities for each vehicle
- **Damage Data** — A table of damage profile coordinates, CDC, PDOF, Delta-V and Peak Acceleration for each vehicle
- **Damage Profiles** — A 3-D visualization of the damage to each vehicle, linked to the Playback Controller
- **Driver Data** — Tables of driver input to each vehicle
- **Environment Data** — A list of physical environment variables used by the simulation
- **Event Data** — A list of event-related activities such as tire blowouts or wheel displacements during the current run
- **Messages** — A list of messages produced by the current run
- **Program Data** — A table containing program control information
- **Trajectory Simulation** — A 3-D visualization of the event, displayed at a user-selectable time interval
- **Variable Output** — A table containing user-selectable, time-dependent simulation results for each vehicle
- **Vehicle Data** — Tables containing all of the vehicle data used by the simulation

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

- 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.

To view the reports produced by the EDSMAC4, Visibility Study event, perform the following steps:

1. Choose Playback Mode. The Playback Editor is displayed.
2. Click Add New Object. The Report Window Information dialog is displayed and includes a list of the active events (EDSMAC4, 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.
3. Select EDSMAC4, Visibility Study from the Active Events list.
4. 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.
5. Press OK to display the report.

The selected report will be displayed in a resizable window. The following sections illustrate the reports produced for the EDSMAC4, Visibility Study event.

> **NOTE:** If you are using HVE, the difference in the environment geometry will cause very slight differences in the results.

Accident History

The Accident History report displays the positions and velocities for each vehicle at key times (Start of Run, Impact, Separation and Final/Rest) during the run.

To view the Accident History report: click Add New Object, select EDSMAC4, Visibility Study from the Active Events list, choose Accident History from the Report Type list, and press OK.

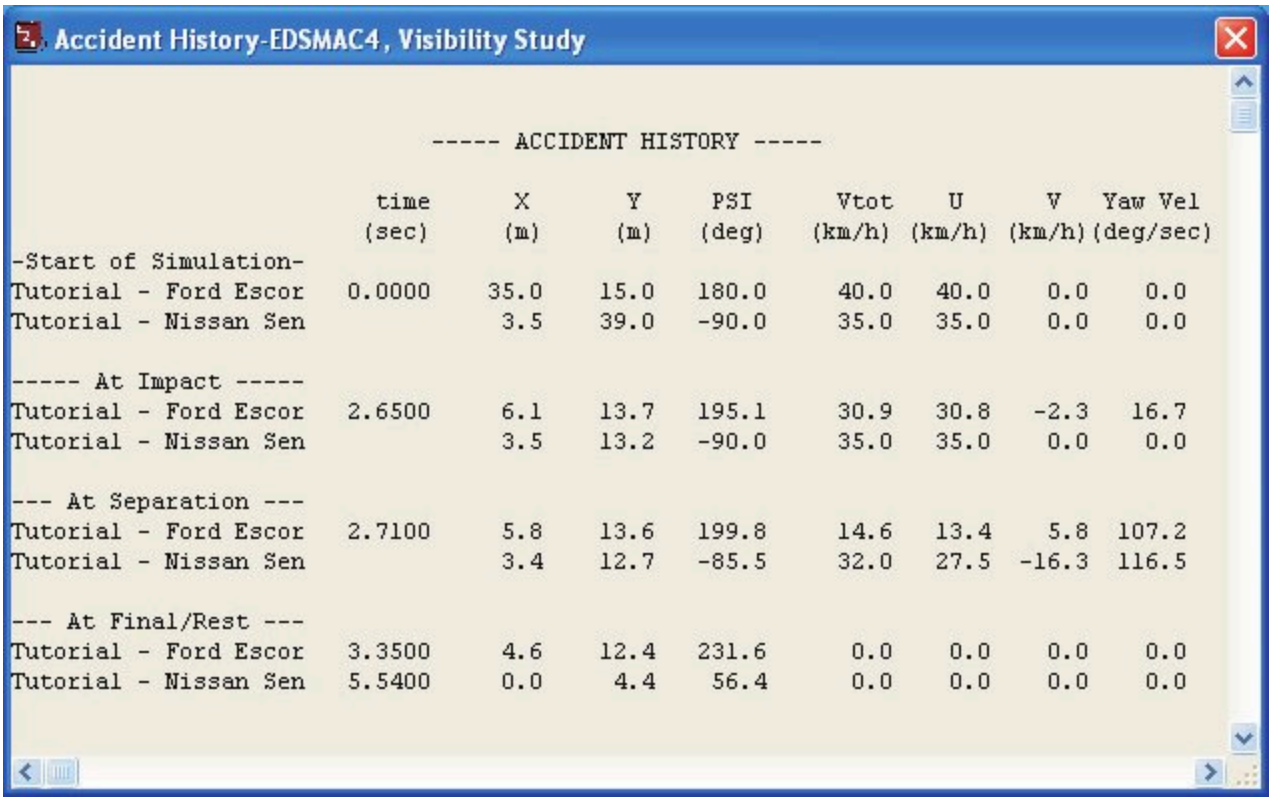
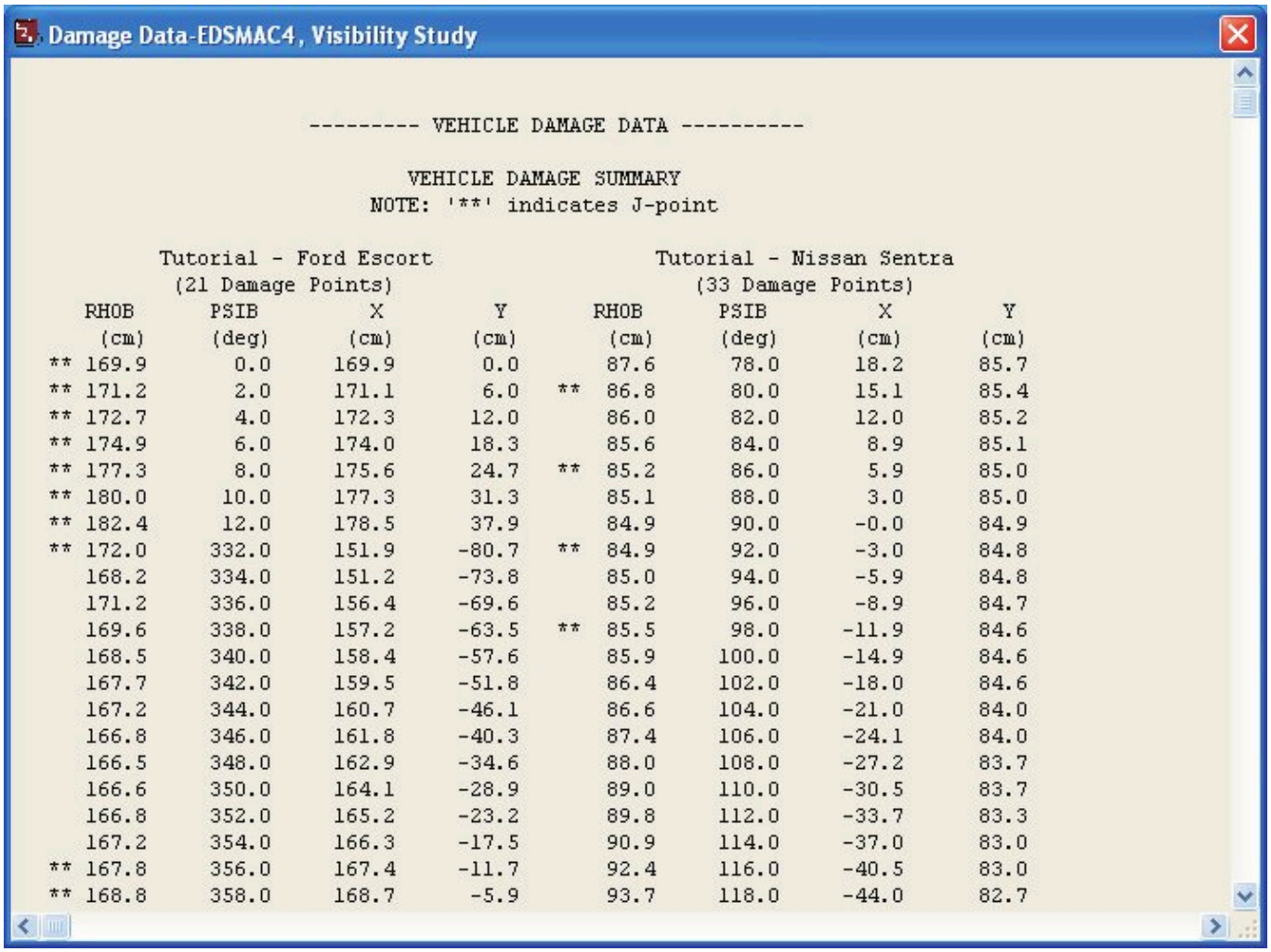


Figure 5-14: Accident History Report for EDSMAC4, Visibility Study.

Damage Data

The Damage Data report displays a table of collision vector results for each vehicle. The collision vectors determine the total force on each vehicle. In addition, the endpoints of the collision vectors define the damage profile. The collision vectors are displayed both in cylindrical coordinates (RHO, PSI) and Cartesian coordinates (x,y).

Following the table of collision vectors, the Damage Ranges are displayed. The Damage Ranges report includes the beginning and ending point for each damaged region on the exterior (up to 10 regions may be displayed for each vehicle), followed by the CDC, PDOF, Delta-V and Peak Acceleration for each damage region.



--------- VEHICLE DAMAGE DATA ----------

VEHICLE DAMAGE SUMMARY
NOTE: '**' indicates J-point

	Tutorial - Ford Escort (21 Damage Points)					Tutorial - Nissan Sentra (33 Damage Points)			
	RHOB (cm)	PSIB (deg)	X (cm)	Y (cm)		RHOB (cm)	PSIB (deg)	X (cm)	Y (cm)
**	169.9	0.0	169.9	0.0		87.6	78.0	18.2	85.7
**	171.2	2.0	171.1	6.0	**	86.8	80.0	15.1	85.4
**	172.7	4.0	172.3	12.0		86.0	82.0	12.0	85.2
**	174.9	6.0	174.0	18.3		85.6	84.0	8.9	85.1
**	177.3	8.0	175.6	24.7	**	85.2	86.0	5.9	85.0
**	180.0	10.0	177.3	31.3		85.1	88.0	3.0	85.0
**	182.4	12.0	178.5	37.9		84.9	90.0	-0.0	84.9
**	172.0	332.0	151.9	-80.7	**	84.9	92.0	-3.0	84.8
	168.2	334.0	151.2	-73.8		85.0	94.0	-5.9	84.8
	171.2	336.0	156.4	-69.6		85.2	96.0	-8.9	84.7
	169.6	338.0	157.2	-63.5	**	85.5	98.0	-11.9	84.6
	168.5	340.0	158.4	-57.6		85.9	100.0	-14.9	84.6
	167.7	342.0	159.5	-51.8		86.4	102.0	-18.0	84.6
	167.2	344.0	160.7	-46.1		86.6	104.0	-21.0	84.0
	166.8	346.0	161.8	-40.3		87.4	106.0	-24.1	84.0
	166.5	348.0	162.9	-34.6		88.0	108.0	-27.2	83.7
	166.6	350.0	164.1	-28.9		89.0	110.0	-30.5	83.7
	166.8	352.0	165.2	-23.2		89.8	112.0	-33.7	83.3
	167.2	354.0	166.3	-17.5		90.9	114.0	-37.0	83.0
**	167.8	356.0	167.4	-11.7		92.4	116.0	-40.5	83.0
**	168.8	358.0	168.7	-5.9		93.7	118.0	-44.0	82.7

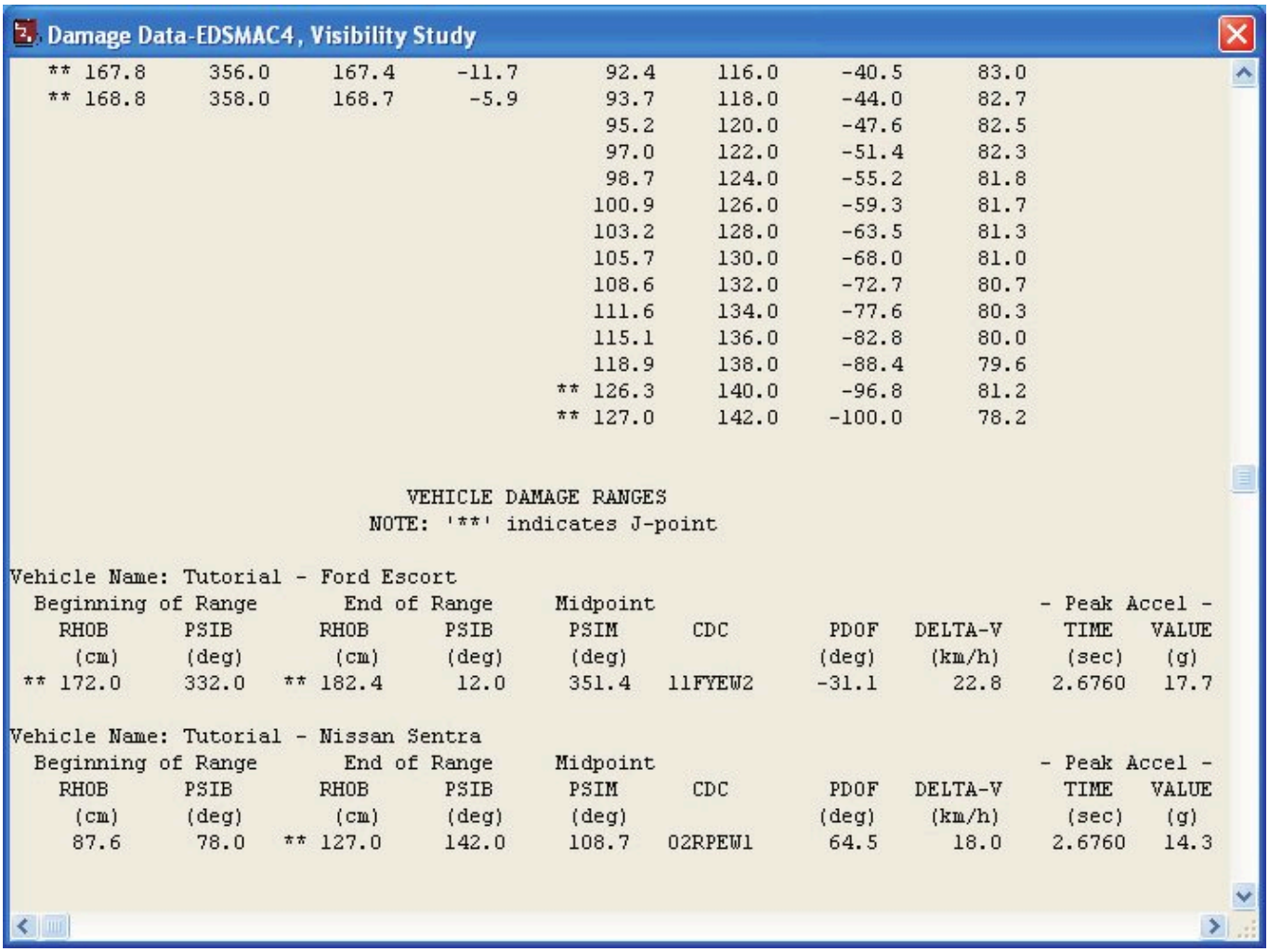


Figure 5-15: Damage Data Report for EDSMAC4, Visibility Study.

To view the Damage Data report: click Add New Object, select EDSMAC4, Visibility Study, choose Damage Data from the Report Type list, and press OK.

Damage Profiles

The Damage Profiles report provides a 3-D visual representation of the damage to each vehicle. This report is linked to the Playback Controller through the Trajectory Simulation. Therefore, in order to see any damage in the Damage Profiles report window, you must first open a Trajectory Simulation for the event.

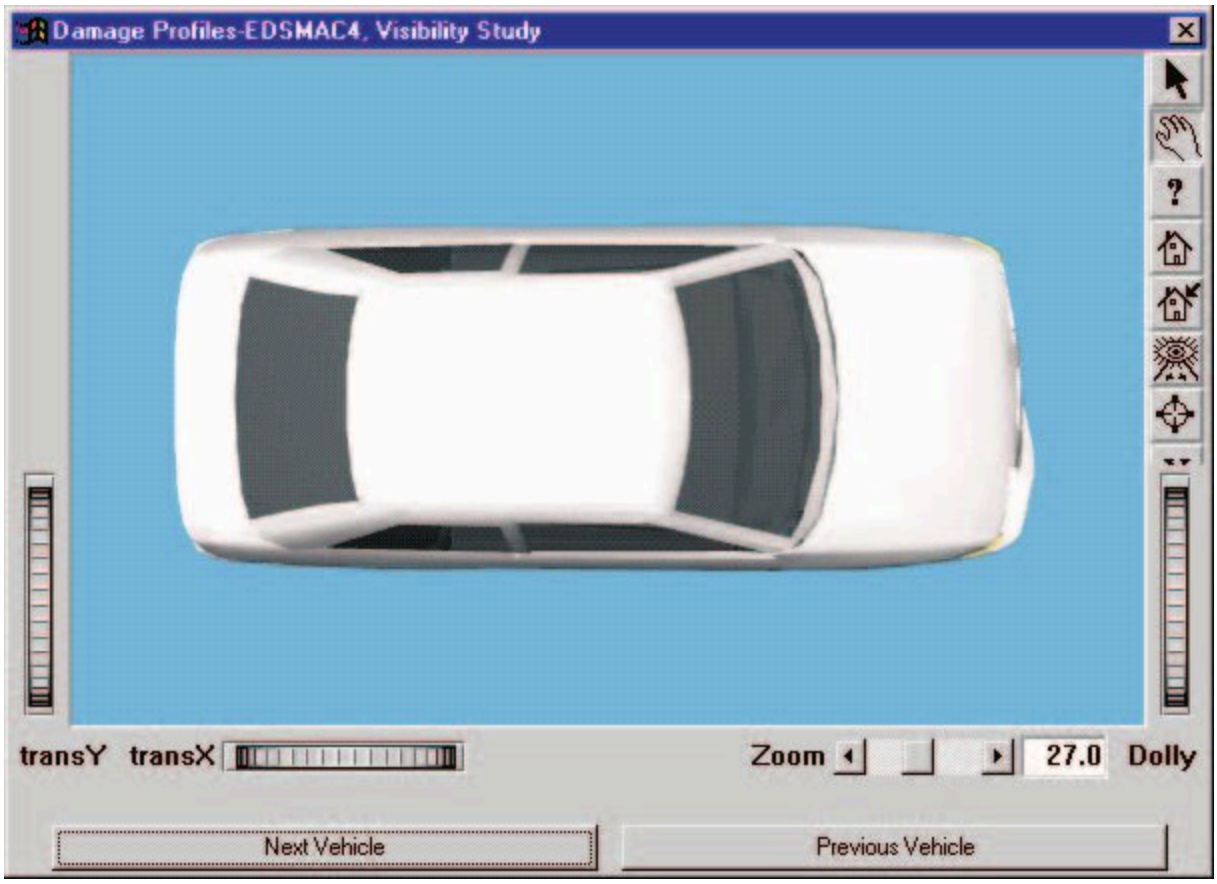


Figure 5-16: Damage Profile Report for Nissan Sentra in EDSMAC4, Visibility Study.

To view the Damage Profiles report: click Add New Object, select EDSMAC4, Visibility Study, choose Damage Profiles from the Report Type list, and press OK. With a Trajectory Simulation also open, use the Playback Controller to view the damage to each vehicle dynamically.

Driver Data

All driver input that was entered in the Event Editor is reported in the Driver Data output report.

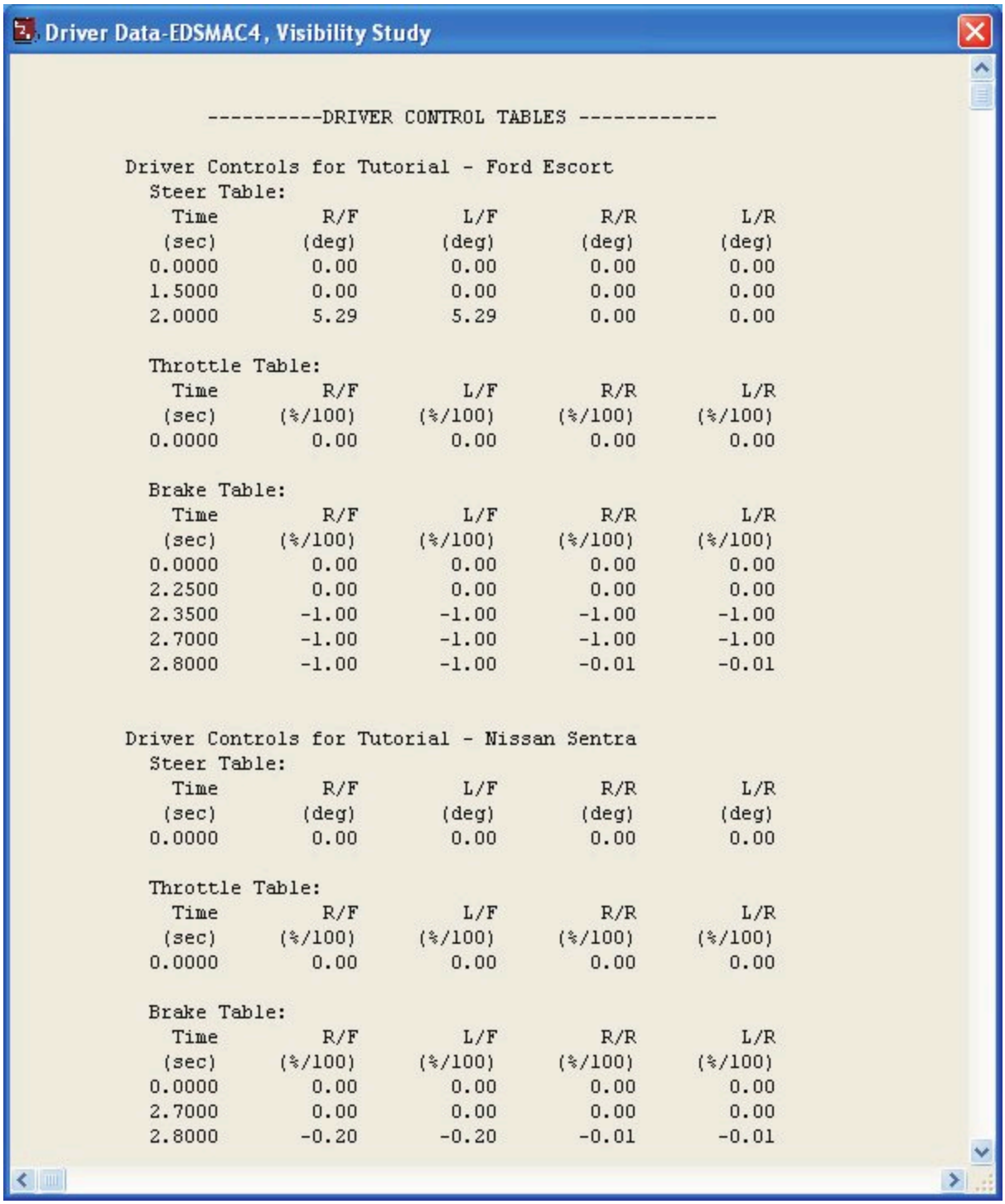


Figure 5-17: Driver Data Report for EDSMAC4, Visibility Study.

To view the Driver Data report: click Add New Object, select EDSMAC4, Visibility Study, choose Driver Data from the Report Type list, and press OK.

Environment Data

The Environment Data output report gives the values of the physical environment variables used by the simulation.

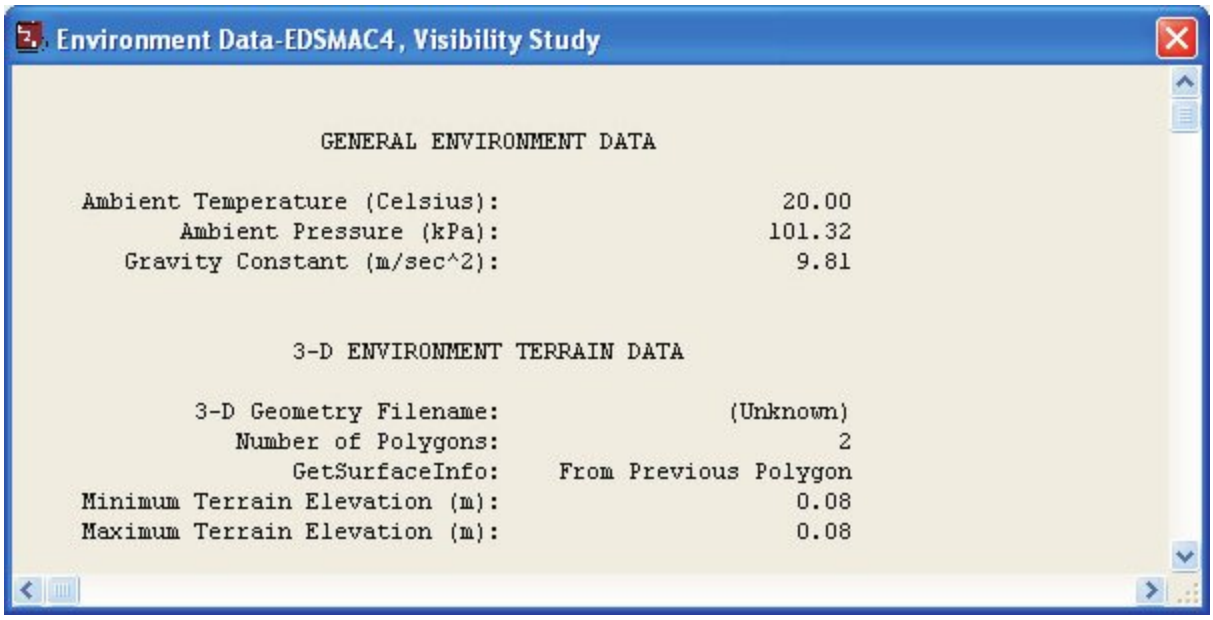


Figure 5-18: Environment Report for EDSMAC4, Visibility Study.

To view the Environment Data report: click Add New Object, select EDSMAC4, Visibility Study, choose Environment Data from the Report Type list, and press OK.

Event Data

Event-related activities such as wheel displacements or tire blowouts are reported in the Event Data report.

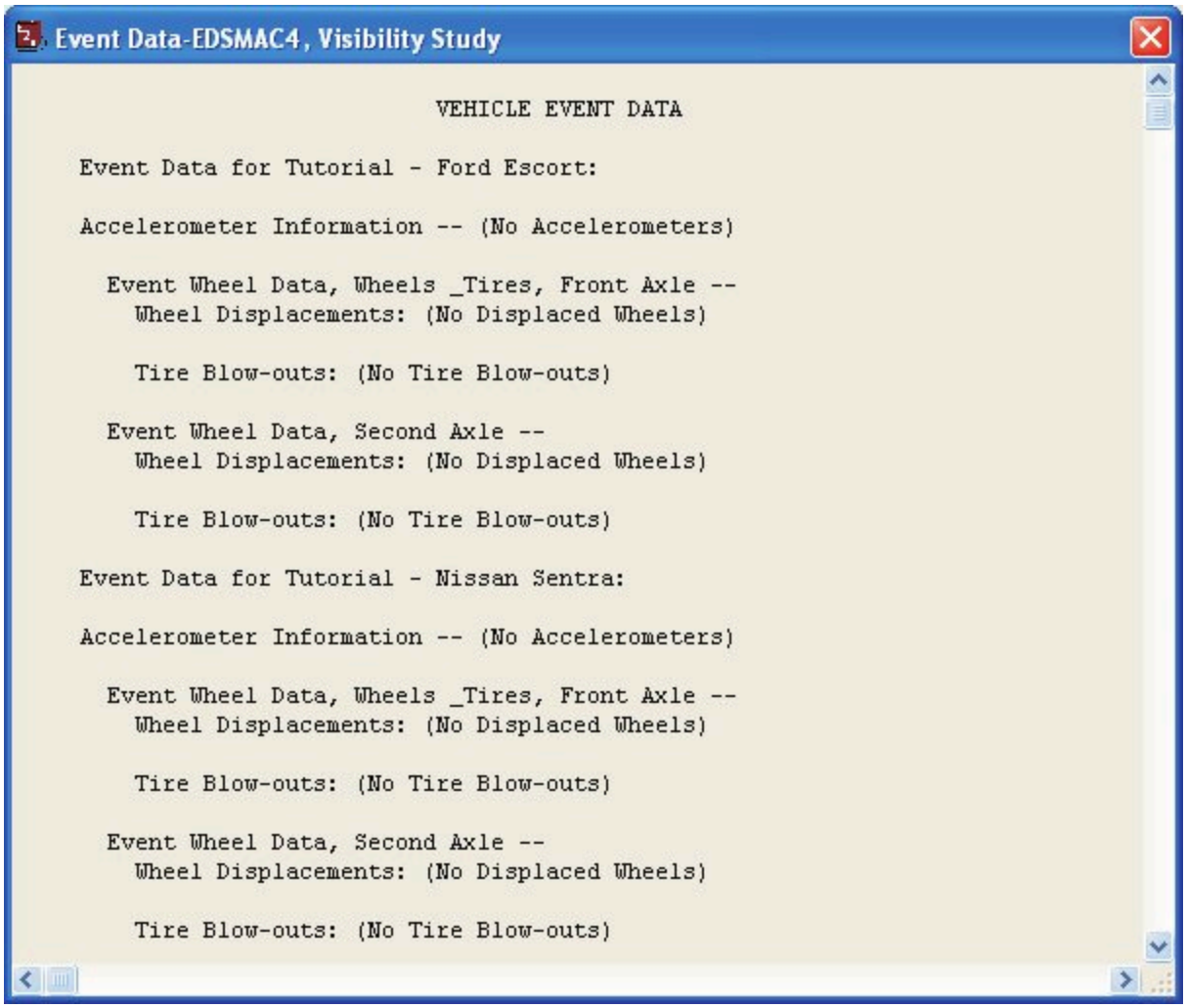


Figure 5-19: Event Data Report for EDSMAC4, Visibility Study.

To view the Event Data report: click Add New Object, select EDSMAC4, Visibility Study, choose Event Data from the Report Type list, and press OK.

Messages

EDSMAC4 produces several messages, depending on the outcome of the run. For a complete list and explanation of these messages, refer to Chapter 6.

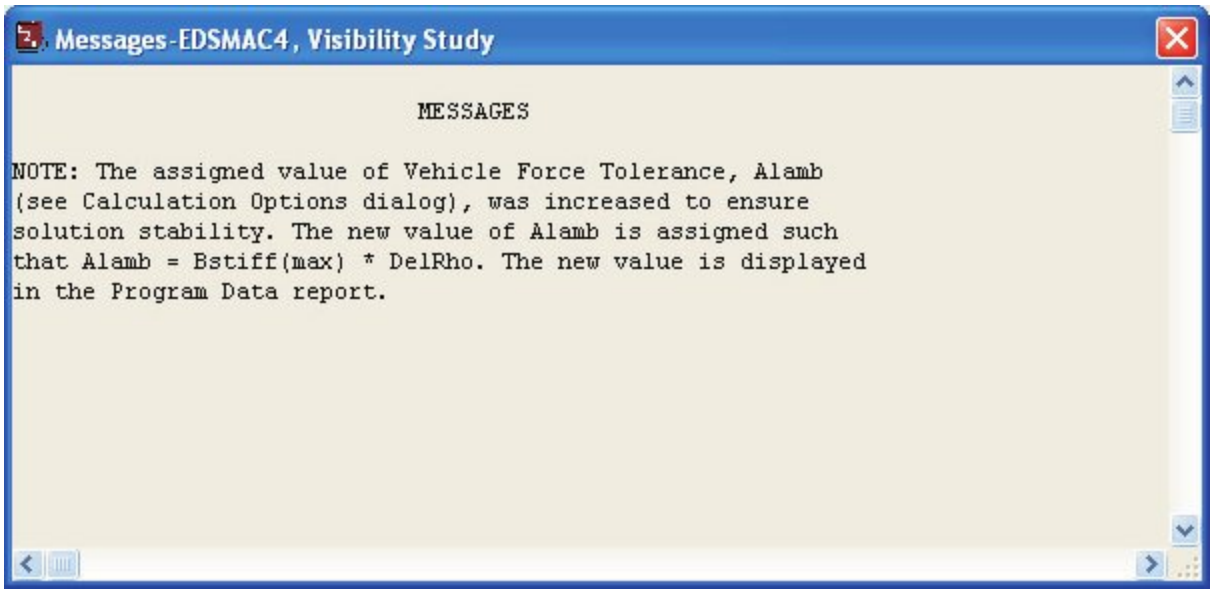


Figure 5-20: Messages Report for EDSMAC4, Visibility Study.

To view the Messages report: click Add New Object, select EDSMAC4, Visibility Study, choose Messages from the Report Type list, and press OK.

Program Data

The Program Data report displays the simulation controls (integration time steps and termination conditions), collision parameters used by the EDSMAC4 collision algorithm and the fixed values (RHOB Tests), which cannot be changed by the user, that determine if a vector passes through the end (front or back) or side (left or right).

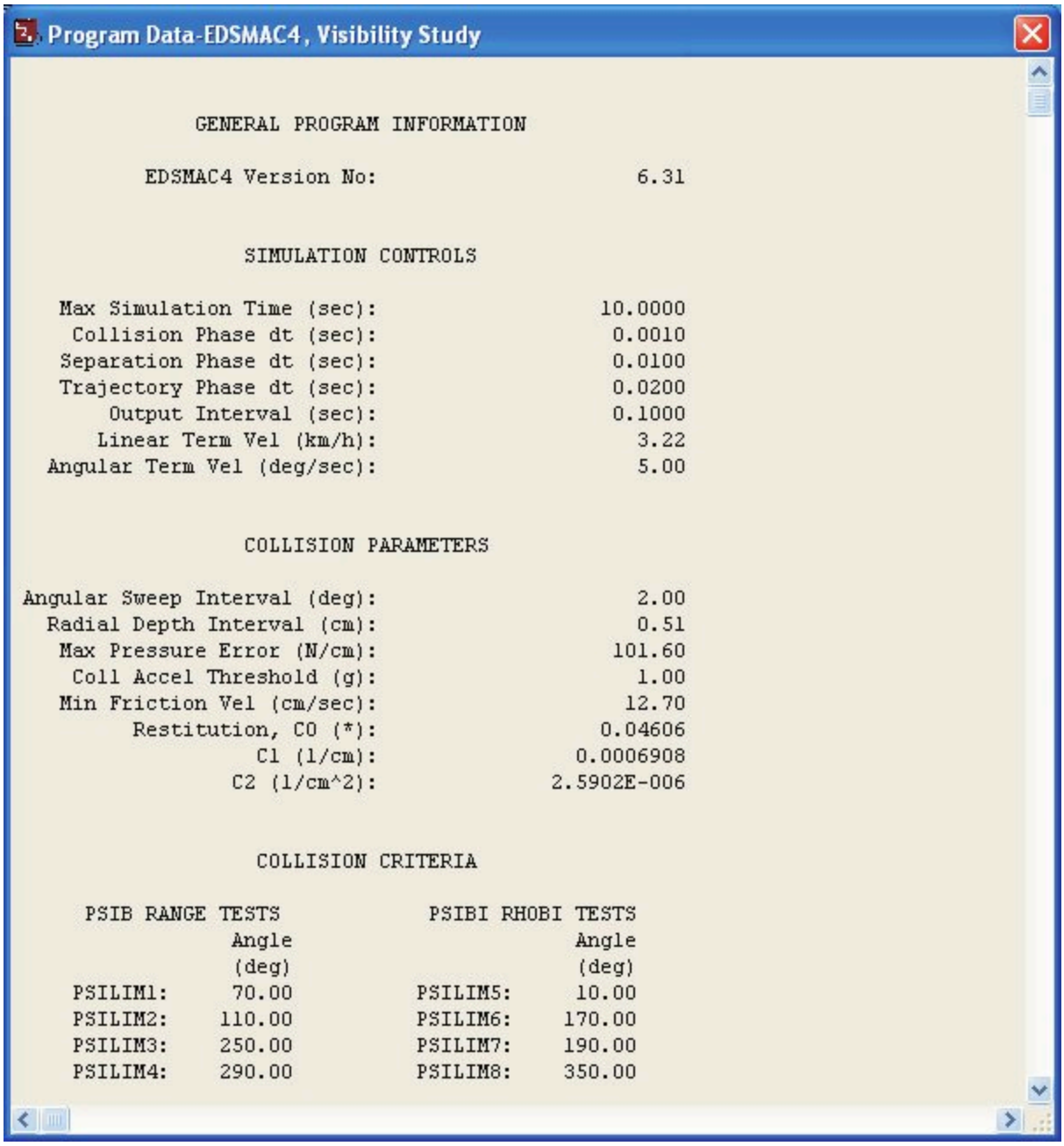


Figure 5-21: Program Data Report for EDSMAC4, Visibility Study.

To view the Program Data report: click Add New Object, select EDSMAC4, Visibility Study, choose Program Data from the Report Type list, and press OK.

Trajectory Simulation

The Trajectory Simulation report is a dynamic visualization, much like the Event mode viewer, controlled by the Playback Controller.

> **NOTE:** A significant difference between the simulation in the Event Editor and the Playback Editor is that no calculations take place in Playback mode.

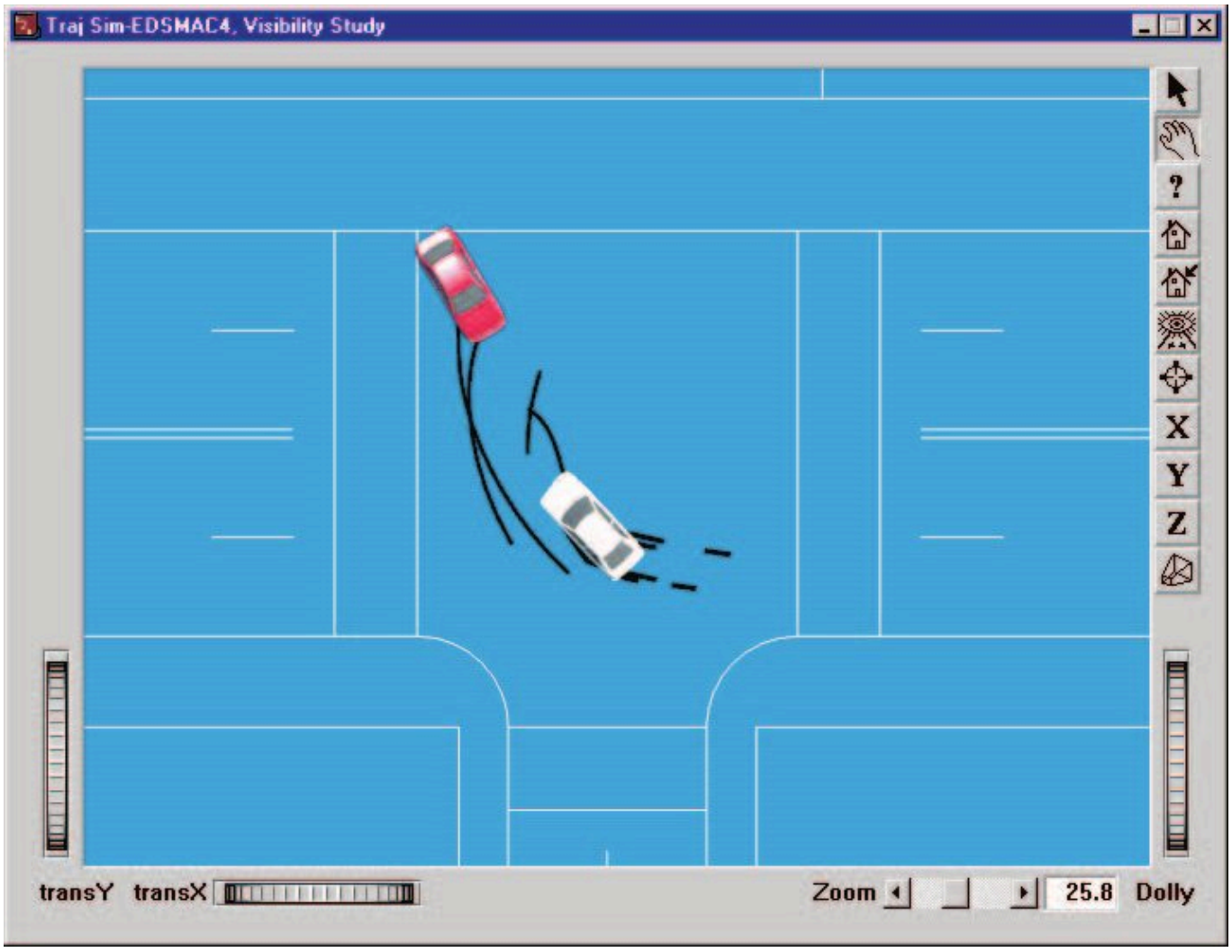
To view the Trajectory Simulation: click Add New Object, select EDSMAC4, Visibility Study, choose Traj Sim from the Report Type list, and press OK. The Trajectory Simulation viewer is displayed with the vehicles shown at their initial positions.

During Event mode, HVE users changed the camera's View From object to the Nissan. The Playback Editor inherits the camera position from Event mode, so it's still attached to the Nissan. Before we view the trajectory simulation, we will change the view back to the environment:

1. Choose Set Camera from the View menu. The Camera dialog is displayed.
2. Click on the Object Name list in the View From group and choose Blind Intersection. Enter the desired camera coordinates, X = 50.0 m, Y = 10.0 m, Z = −3.5 m.
3. Click on the Object Name list in the Look At group and choose Blind Intersection. Enter the desired picture center coordinates, X = 0.0 m, Y = 8.0 m, Z = 0.0 m.
4. Press OK to update the camera position.

The view is now looking down the street. To visualize the motion, perform the following steps:

1. Click Play (single right-arrow). The simulation begins and is displayed at the current Playback output interval.
2. Click Pause. The simulation stops.
3. Click Reverse (single left-arrow). The simulation plays in reverse.
4. Click Pause. The simulation stops.
5. Click Rewind (left arrow with bar). The simulation returns to the start.
6. Click Advance to End (right arrow with bar). The simulation advances to the end of the run.


Traj Sim-EDSMAC4, Visibility Study
?
X
Y
Z
transY
transX
Zoom
25.8
Dolly

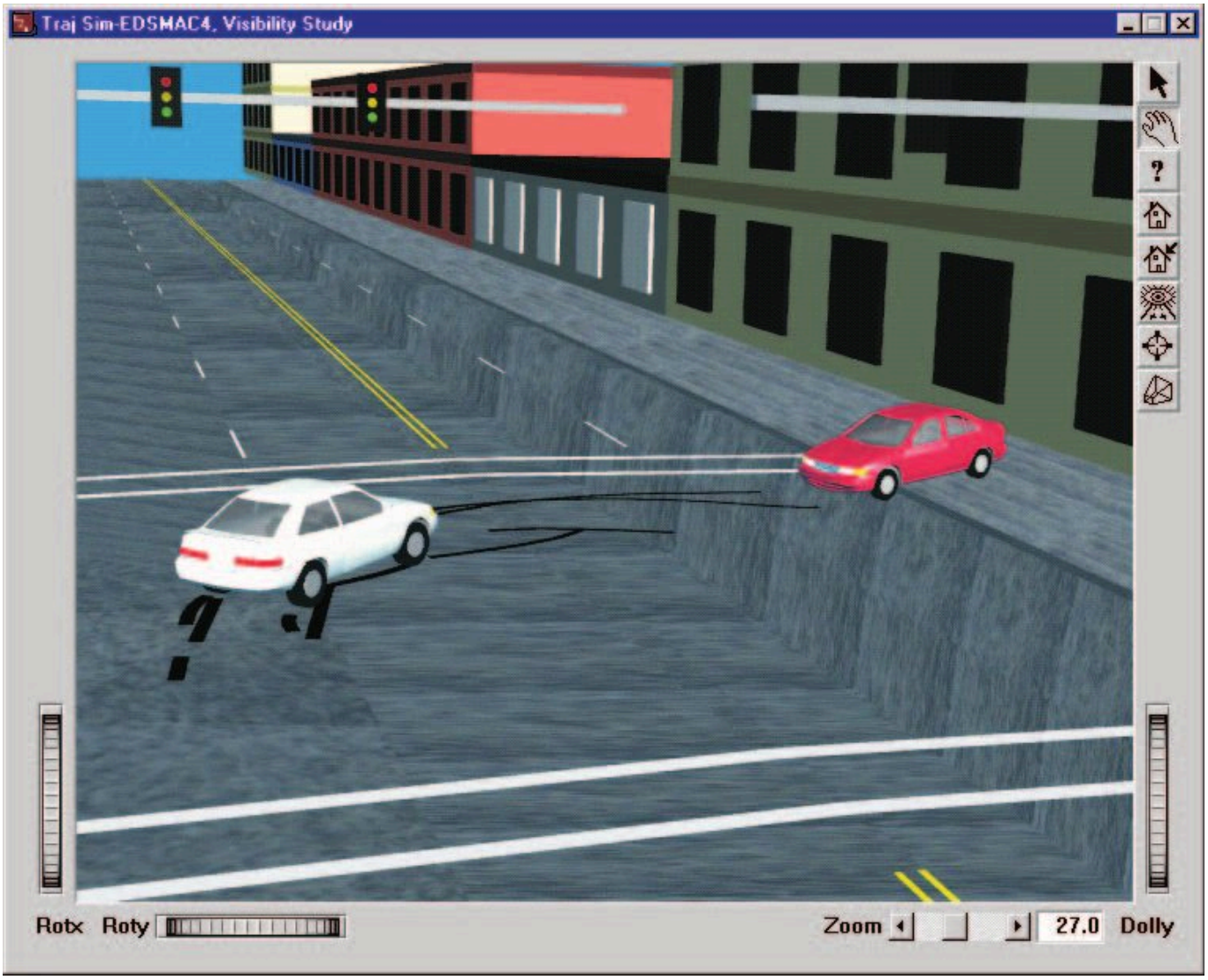


Figure 5-22: Trajectory Simulation for EDSMAC4, Visibility Study, displaying the crash sequence at the end of the event (HVE-2D above, HVE below). In the lower figure, the Nissan has come to rest on the sidewalk after mounting the curb.

Variable Output

The Variable Output table displays all the time-dependent results computed by EDSMAC4. To view the Variable Output report: click Add New Object, select EDSMAC4, Visibility Study, choose Variable Output from the Report Type list, and press OK.

The Variable Output report is displayed for the EDSMAC4, Visibility Study event. The next step is to select the time-dependent results we wish to display in the table.

Variable Selection

The purpose of our EDSMAC4 study is to evaluate the avoidability of the accident based on speeds and visibility. To document the path positions as a function of time, let's select the position, velocity and acceleration from the Variable Selection dialog.

1. Click on Select Variables in the Variable Output window. The Variable Selection dialog is displayed.

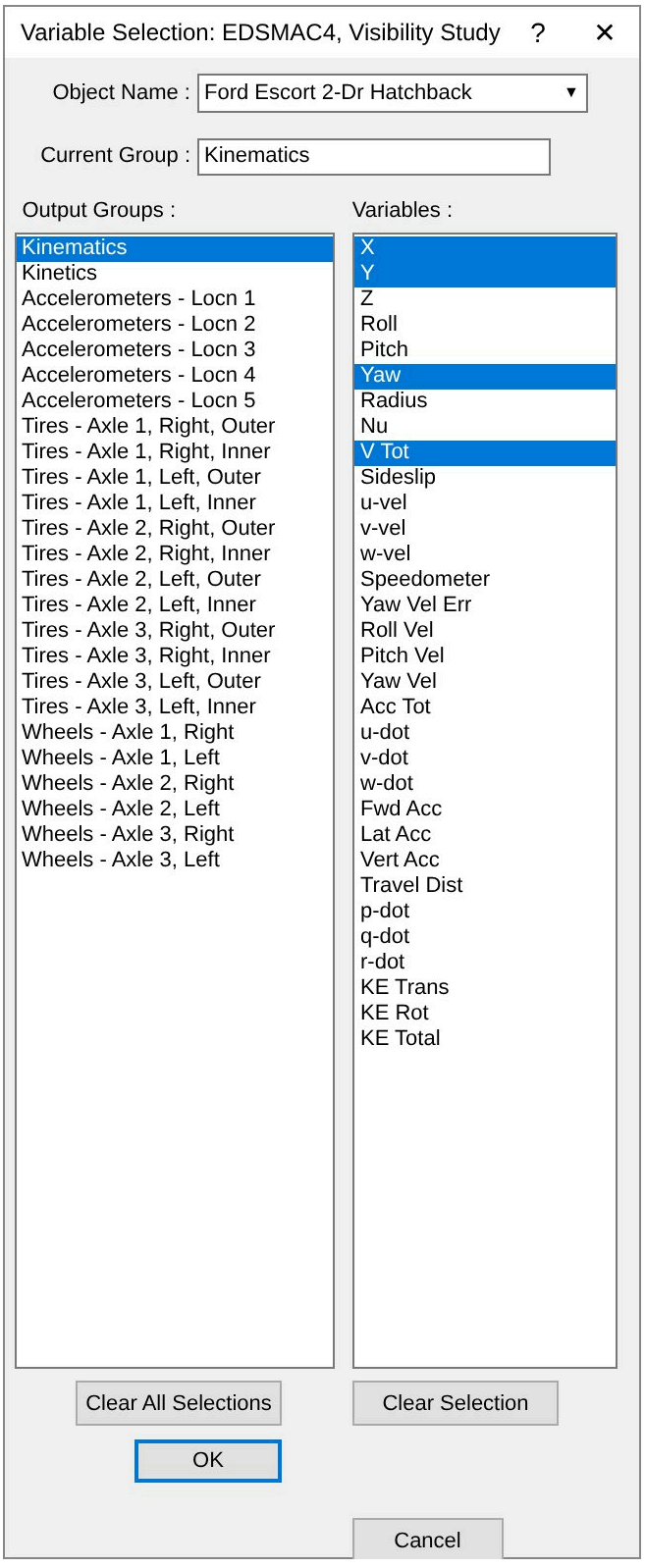


Figure 5-23: Variable Selection dialog.

The Object Name option list displays the first vehicle, Ford Escort. The Kinematics output group is the default selection and the Kinematics Variables list is displayed. Let's add X, Y, Yaw, Vtotal and Accel total:

1. Select X, Y, Yaw, V-tot and Acc-tot from the list.

Next, let's add the same parameters for the Nissan Sentra:

1. Click on the Object Name option list and choose Nissan Sentra 4-Dr. The Kinematics variable list is displayed.
2. Select X, Y, Yaw, V-tot and Acc-tot from the list.

> **NOTE:** Feel free to add additional variables to the Variable Output window.

1. Press OK to add the selected variables to the Variable Output window.

The Variable Output report for the EDSMAC4, Visibility Study event now includes position, velocity and acceleration for both vehicles, plus any other variables you may have added.

Variable Output-EDSMAC4, Visibility Study

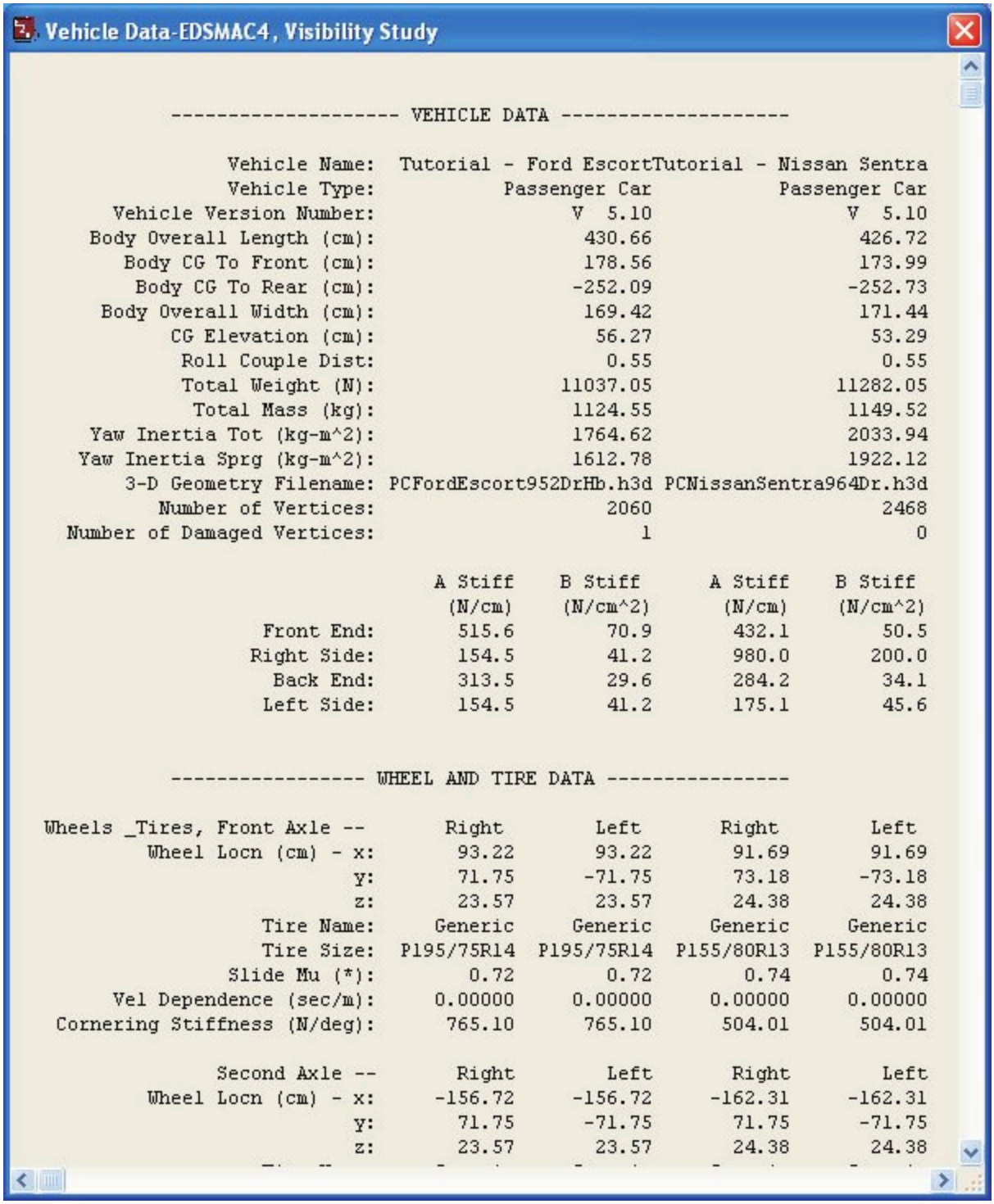
Select... Graph... Edit...

Time (sec)	Ford Escort 2- X (m)	Ford Escort 2- Y (m)	Ford Escort 2- Yaw (deg)	Ford Escort 2- V-tot (km/h)	Ford Escort 2- Acc-tot (g)	Nissan Sentra X (m)	Nissan Sentra Y (m)
0.0000	35.00	15.00	180.00	40.00	0.00	3.50	39.00
0.0250	34.72	15.00	180.00	40.00	0.00	3.50	38.76
0.0500	34.44	15.00	180.00	40.00	0.00	3.50	38.51
0.0750	34.17	15.00	180.00	40.00	0.00	3.50	38.27
0.1000	33.89	15.00	180.00	40.00	0.00	3.50	38.03
0.1250	33.61	15.00	180.00	40.00	0.00	3.50	37.78
0.1500	33.33	15.00	180.00	40.00	0.00	3.50	37.54
0.1750	33.06	15.00	180.00	40.00	0.00	3.50	37.30
0.2000	32.78	15.00	180.00	40.00	0.00	3.50	37.06
0.2250	32.50	15.00	180.00	40.00	0.00	3.50	36.81
0.2500	32.22	15.00	180.00	40.00	0.00	3.50	36.57
0.2750	31.94	15.00	180.00	40.00	0.00	3.50	36.33
0.3000	31.67	15.00	180.00	40.00	0.00	3.50	36.08
0.3250	31.39	15.00	180.00	40.00	0.00	3.50	35.84
0.3500	31.11	15.00	180.00	40.00	0.00	3.50	35.60
0.3750	30.83	15.00	180.00	40.00	0.00	3.50	35.35
0.4000	30.56	15.00	180.00	40.00	0.00	3.50	35.11
0.4250	30.28	15.00	180.00	40.00	0.00	3.50	34.87
0.4500	30.00	15.00	180.00	40.00	0.00	3.50	34.62
0.4750	29.72	15.00	180.00	40.00	0.00	3.50	34.38
0.5000	29.44	15.00	180.00	40.00	0.00	3.50	34.14
0.5250	29.17	15.00	180.00	40.00	0.00	3.50	33.90
0.5500	28.89	15.00	180.00	40.00	0.00	3.50	33.65
0.5750	28.61	15.00	180.00	40.00	0.00	3.50	33.41
0.6000	28.33	15.00	180.00	40.00	0.00	3.50	33.17
0.6250	28.06	15.00	180.00	40.00	0.00	3.50	32.92
0.6500	27.78	15.00	180.00	40.00	0.00	3.50	32.68
0.6750	27.50	15.00	180.00	40.00	0.00	3.50	32.44
0.7000	27.22	15.00	180.00	40.00	0.00	3.50	32.19
0.7250	26.94	15.00	180.00	40.00	0.00	3.50	31.95
0.7500	26.67	15.00	180.00	40.00	0.00	3.50	31.71
0.7750	26.39	15.00	180.00	40.00	0.00	3.50	31.47
0.8000	26.11	15.00	180.00	40.00	0.00	3.50	31.22

Figure 5-24: Variable Output report for EDSMAC4, Visibility Study.

Vehicle Data

The Vehicle Data report displays the vehicle data, tire data and driver tables for each vehicle in the event.



---------- VEHICLE DATA ----------

Vehicle Name:	Tutorial - Ford Escort	Tutorial - Nissan Sentra
Vehicle Type:	Passenger Car	Passenger Car
Vehicle Version Number:	V 5.10	V 5.10
Body Overall Length (cm):	430.66	426.72
Body CG To Front (cm):	178.56	173.99
Body CG To Rear (cm):	-252.09	-252.73
Body Overall Width (cm):	169.42	171.44
CG Elevation (cm):	56.27	53.29
Roll Couple Dist:	0.55	0.55
Total Weight (N):	11037.05	11282.05
Total Mass (kg):	1124.55	1149.52
Yaw Inertia Tot (kg-m^2):	1764.62	2033.94
Yaw Inertia Sprg (kg-m^2):	1612.78	1922.12
3-D Geometry Filename:	PCFordEscort952DrHb.h3d	PCNissanSentra964Dr.h3d
Number of Vertices:	2060	2468
Number of Damaged Vertices:	1	0

	A Stiff (N/cm)	B Stiff (N/cm^2)	A Stiff (N/cm)	B Stiff (N/cm^2)
Front End:	515.6	70.9	432.1	50.5
Right Side:	154.5	41.2	980.0	200.0
Back End:	313.5	29.6	284.2	34.1
Left Side:	154.5	41.2	175.1	45.6

---------- WHEEL AND TIRE DATA ----------

Wheels _Tires, Front Axle --	Right	Left	Right	Left
Wheel Locn (cm) - x:	93.22	93.22	91.69	91.69
y:	71.75	-71.75	73.18	-73.18
z:	23.57	23.57	24.38	24.38
Tire Name:	Generic	Generic	Generic	Generic
Tire Size:	P195/75R14	P195/75R14	P155/80R13	P155/80R13
Slide Mu (*):	0.72	0.72	0.74	0.74
Vel Dependence (sec/m):	0.00000	0.00000	0.00000	0.00000
Cornering Stiffness (N/deg):	765.10	765.10	504.01	504.01
Second Axle --	Right	Left	Right	Left
Wheel Locn (cm) - x:	-156.72	-156.72	-162.31	-162.31
y:	71.75	-71.75	71.75	-71.75
z:	23.57	23.57	24.38	24.38

Figure 5-25: Vehicle Data Report for EDSMAC4, Visibility Study.

To view the Vehicle Data report: click Add New Object, select EDSMAC4, Visibility Study, choose Vehicle Data from the Report Type list, and press OK.

> **NOTE:** The Vehicle Data, Damage Data and several other reports contain more information than fits into the default window size. Use the scroll bars, resize the dialog, or adjust the font size 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 Variable Output — EDSMAC4, Visibility Study report window. The window is highlighted and 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 main menu bar.

1. Press OK. The Variable Output report is printed on the system printer.

That's all there is to it! You can print any other report using the same three 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 can be issued by either the operating system, HVE-2D or HVE, or by EDSMAC4. Some of the more common operating system messages are described in the Appendix (of the User's Manual). 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 EDSMAC4 appear in the EDSMAC4 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 that 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, but 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 EDSMAC4 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/HVE or operating system message by referring to the User's Manual Appendix or your computer's operating system manual. If the message is not listed in either place, please contact EDC with the offending error.

(updated: the message texts below reflect the current version of EDSMAC4. Where the current wording or limits differ from the original manual, the current value is given with an italic note. Messages new to the current version are listed at the end of this chapter.)

A CDC and clock direction of force were not computed for vehicle *, damage range *

(Level 3 — Informative)

If execution is halted by the user prior to the end of calculations, the damage tables may not be complete. The last damage calculation to be performed is the CDC (Collision Deformation Classification). If all the information necessary to produce the CDC is not available, this message is produced.

No response by the user is necessary.

Analysis for a single vehicle without a collision

(Level 3 — Informative)

This message indicates EDSMAC4 is being used as a single vehicle trajectory simulator.

No response by the user is necessary.

An error occurred during the collision phase at t=*. sec. because RHOBIT became negative.**

(Level 1 — Fatal)

During the collision phase, crush occurs along the vector, RHO, from the vehicle exterior towards the CG (refer to Chapter 4 — Calculation Method). The quantity named in the message is the adjusted length of the current RHO vector, after restitution has been accounted for. This message indicates that, while seeking equilibrium of the RHO vector lengths for both vehicles, one of their lengths became negative. The angle reported with the message is the clock angle of the defective vector.

Since this error occurs during the iterative adjustment phase, reducing the Vector Adjustment Increment (the quantity the message text calls DELRHO; see Calculation Options) may eliminate the problem. If you continue to experience the problem, send the offending input file to EDC for evaluation.

(The current version issues a related message when the vector length becomes negative after the restitution calculation.)

An error occurred during the collision phase at t=*. sec. because the damage range spanned more than half of Vehicle *.**

(Level 1 — Fatal)

The damage range computed by EDSMAC4 spanned more than 180 degrees of the vehicle's outer surface. This error usually occurs in a very severe collision when the inter-vehicle forces go beyond the CG of one of the vehicles.

If the suspected damage did go beyond half of the vehicle's exterior, there is no correction for this error. The condition exceeds the capabilities of EDSMAC4. However, if the results are questionable, increasing the stiffness coefficient for the vehicle may improve the results (see the Vehicle Editor, Exterior Stiffness).

An error occurred during the collision phase because the longitudinal and lateral components of damage were equal to zero.

(Level 1 — Fatal)

Execution was halted due to an internal error associated with the angle of the damage vector used during the collision phase.

This is a mathematical error which should be prevented by the editing done by EDSMAC4 during the input session. Thus, if this error occurs, it is a symptom of another problem. Send the offending input file to EDC for evaluation.

An error occurred during the collision phase because the damage increment was too coarse.

(Level 1 — Fatal)

Execution was halted due to an excessive increment of damage. This error is sometimes caused by the proximity of the vehicles at impact, particularly if they are overlapping. In this case, the integration subroutine has failed to stabilize during the simulation.

Check to ensure the vehicles are not overlapping at impact; if necessary, separate the vehicles at their initial positions. This condition may also occur for some impact configurations when the angle between the RHO vectors for vehicle 1 and vehicle 2 approaches 90 degrees. A slight adjustment of impact positions may help to solve the problem.

An error occurred during the collision phase. The damage region required too many collision vectors to span its entire width. To correct the error, increase DELPSI (see Calculation Options).

(Level 1 — Fatal)

EDSMAC4 divides the damage region into a number of small, discrete angular intervals. The width of each interval is the user-entered Vector Spacing (the quantity the message text calls DELPSI; see Calculation Options). If the Vector Spacing is too small, the number of intervals required to span the entire damage width becomes too large and the above error message is issued.

Increase the Vector Spacing (see Calculation Options).

(updated: the original manual stated a limit of 360 discrete intervals per damage region; the current message reads "the damage region required more than 100 collision vectors to span its width. To correct the error, try doubling the value of DELPSI.")

An error occurred during the collision phase at t=*. sec. The difference in inter-vehicle contact pressure was greater than the user-entered maximum (ALAMB) after 200 bisections.**

(Level 1 — Fatal)

During the collision phase, force equilibrium is sought between each of the vehicle crush vectors using an iterative adjustment of the vector lengths, RHO. If, after the maximum number of adjustments (200 in the current version), the force equilibrium is not reached (i.e., the difference in the inter-vehicle contact force is greater than the user-entered acceptable limit, the Vector Force Tolerance, which the message text calls ALAMB), the above error is issued.

Increase the Vector Force Tolerance or decrease the Vector Adjustment Increment (see Calculation Options).

(updated: the original manual said "after 3200 bisections"; the current message says 200 and suggests "try halving the value of DELRHO or doubling the value of ALAMB.")

An error occurred while saving the acceleration or damage array maxima.

(Level 2 — Diagnostic)

As the run progresses, a history of accelerations and damage severity (delta-V) is accumulated. Certain logical computations are performed to meet this need. If the resulting history creates a logical error, the above error is issued.

(current wording: "Only the first 10 acceleration peaks are stored. Additional peaks are ignored. The simulation results in Variable Output are not affected by this condition.")

Save the offending input file and send it to EDC for evaluation.

At the time execution was halted, vehicle * was still moving.

(Level 3 — Informative)

If either vehicle is still moving at the end of the simulation, whether halted as a result of an interruption by the user, or as a result of reaching the maximum simulation time, this message is issued to indicate that both vehicles have not reached their rest positions.

No response by the user is necessary.

At the time execution was halted, both vehicles were still moving with the following velocities: ...

(Level 3 — Informative)

If both vehicles are still moving at the end of the simulation, this message is issued (with a table of each vehicle's linear and angular velocity) to remind the user that the vehicles have not come to rest.

No response by the user is necessary.

NOTE: The simulation was terminated due to excessive articulation angle between a tow vehicle and its trailer. This is normally a sign that a 'jackknife' occurred.

(Level 3 — Informative)

EDSMAC4 does not calculate the forces and moments produced between the body of a tow vehicle and the body of its trailer. Therefore the simulation terminates when the current articulation angle exceeds the user-entered maximum (see Vehicle Editor, Connections).

An error occurred while calculating a CDC for vehicle *. The error code is **.

(Level 2 — Diagnostic)

EDSMAC4 divides the vehicle exterior into specific damage regions. Each region is associated with a certain location of damage defined by the CDC (Collision Deformation Classification), columns 3, 4, 5, and 6 (see SAE J224 MAR80 or the HVE Operations Manual, Damage Profiles). This message indicates a logical error has occurred while assigning the damage regions. The error codes and the affected CDC columns are listed below:

Table 6-1: CDC Error Codes

Error Code	CDC Column
41 – 43	3
44 – 45	4
46	3
47 – 50	4
51	3
52 – 55	4
56	3
57 – 59	4
60 – 62	General error
63	3
64 – 66	General error

General errors usually refer to computations of the damage width, column 6. Column 5 is always set equal to E, since all damage is assumed to occur uniformly below the belt line (see SAE J224 MAR80 for an explanation).

If you encounter this error, please document the error code and send the offending input file to EDC for evaluation.

During the examination of individual damage ranges, no match was found for damage range no. *.

(Level 2 — Diagnostic)

During the collision phase, a clock direction of the PDOF is computed for each damage range. The angle at the midpoint of each damage range is also computed. If the angle of the PDOF is more than 60 degrees different from the associated damage midpoint, the above warning is issued and the range is matched to the largest acceleration peak instead.

This condition suggests a sideswipe collision occurred. It does not indicate any error in the results.

Processing was interrupted by the user at t=*. seconds.**

(Level 3 — Informative)

If the user terminates execution during processing, calculations will stop prior to reaching the termination velocities or maximum simulation time.

No response by the user is necessary.

The collision resulted in more than 10 individual regions of vehicle damage. EDSMAC4 limits the analysis of the collision to 10 regions.

(Level 3 — Informative)

Rapid rotation during the collision may result in subsequent inter-vehicle contact. EDSMAC4 allows up to ten individual ranges of impact damage. If more than ten individual damage regions are detected, only the first 10 ranges are stored; additional peaks are ignored. The simulation results in Variable Output are not affected by this condition.

NOTE: The assigned value of Vehicle Force Tolerance, Alamb (see Calculation Options dialog), was increased to ensure solution stability. The new value of Alamb is assigned such that Alamb = Bstiff(max) * DelRho. The new value is displayed in the Program Data report.

(Level 2 — Diagnostic)

During the collision phase, inter-vehicle force balance between impacting vehicles is achieved through an incremental adjustment of each RHO vector. The amount of the adjustment is the **Vector Adjustment Increment** (called DelRho in the message), assigned in the EDSMAC4 Calculation Options dialog. Because the adjustment is discrete, an exact balance of forces between RHO vectors will never be achieved. Therefore, a test is performed after each adjustment to determine if the force balance is within an allowable tolerance, the **Vector Force Tolerance** (called Alamb in the message), also assigned in that dialog. If the tolerance is too small, it is possible that a force balance between RHO vectors will never be achieved and the solution for collision force will fail to converge, resulting in a fatal error. To ensure solution stability, the tolerance is automatically increased to the product of the largest B stiffness coefficient and the Vector Adjustment Increment, and the new value is shown in the Program Data report.

NOTE: The damage midpoint (PSIM) does not match the PDOF specified by the clock direction. This condition is fairly common for sideswipes and collisions involving secondary impact.

(Level 3 — Informative)

As part of its post-processing routine, EDSMAC4 attempts to match a CDC with each vehicle damage range. The procedure for accomplishing this task is based on the assumption that the PDOF for each damage range will be approximately equal to the angle at the midpoint of that damage range (the quantity the message calls PSIM). This is not normally the case for sideswipes and some collisions involving secondary impact. It is important to note that this message has no reflection on the integrity of the simulation.

The simulation was terminated by the HVE Driver Model because the maneuver resulted in a lateral acceleration that exceeded the user-defined Driver Lateral Acceleration Comfort Level (see Driver Controls, HVE Path Follower dialog).

(Level 1 — Fatal)

In order to complete the required maneuver, the user should increase the Driver Lateral Acceleration Comfort Level. However, this suggests the attempted maneuver is beyond the comfort level of the typical driver.

The inter-vehicle connections for two connected vehicles have different elevations above ground.

(Level 1 — Fatal in the original version)

The original manual instructed: to confirm the difference in connection heights, go to the Vehicle Editor and choose Move CG to obtain the static CG height (it is displayed as a positive value; however, it is negative with respect to the earth-fixed coordinate system), then choose Connections to obtain the connection z-coordinate. Do this for both vehicles (note that you'll use the rear connection for the tow vehicle and the front connection for the trailer). The connection elevation is −CG Height + Connection z-coordinate. Adjust the connection z-coordinate for either or both vehicles if you wish to make the connection elevations the same.

*(updated: the current version can reconcile the mismatch automatically. Unless the **Inter-Vehicle Connection** calculation option is set to Manual, EDSMAC4 adjusts the connection z-coordinate(s) at event initialization and issues the informative message: "NOTE: The vehicle-fixed connection z-coordinate was automatically calculated by EDSMAC4 to make the earth-fixed connection height equal on each tow vehicle/trailer pair. The updated connection z-coordinate is displayed in the Vehicle Data Report." See EDSMAC4 Calculation Options.)*

Additional messages in the current version

The following messages were added after the Sixth Edition manual was printed:

- **Connection z-coordinate automatically calculated** (Informative) — See the note under the inter-vehicle connections message above.
- **Negative crush depth** (Informative) — "One or more vehicles has (have) a negative crush depth. Refer to the Damage Data report's Crush Depth Tables to identify the specific vehicle(s). This may be the result of a vehicle geometry with reversed surface normals or missing polygons. It may also be the result of normal folding of the damaged surface. Inspect the vehicle geometry for these conditions."
- **More than 10 impulses** (Informative) — "The collision resulted in more than 10 impulses on one or more vehicles. This does not result in event termination. However, only the first 10 impulses will be included in the CollisionData report and DamageStudio window."
- **Vehicle handling properties error** — "An error occurred while calculating vehicle handling properties."

- **Integration timesteps reduced for trailers** (Informative) — "The assigned integration timestep(s) (see Simulation Controls dialog) were too large for an event with trailers. In order to help ensure solution stability, one or more integration timestep values were reduced. The modified values are displayed in the Program Data output report."
- **Output interval large for a collision simulation** (Informative) — "The simulation output interval (see Simulation Controls dialog) is rather large for a collision simulation. Peak collision forces and/or accelerations may be filtered from Key Results and Variable Output. This issue has no effect on the overall accuracy of the simulated trajectories or damage profiles. To avoid this issue, reduce the output interval to 0.02 seconds (or less)."
- **HVE Driver Model steering rate exceeded** — "The HVE Driver Model predicted the maneuver required a steering wheel input rate that exceeded the user-defined Maximum Steering Velocity (see Driver Controls, HVE Path Follower dialog)."
- **HVE Driver Model turned off at impact** (Informative) — "The HVE Driver Model was turned off at impact for one or more vehicles because of a collision. The HVE Driver Model is not valid during or after impact."
- **Negative coefficient of restitution** (Warning) — "The coefficient of restitution is negative. This implies the striking vehicle traveled through the struck vehicle during impact. A negative restitution coefficient may also occur as a result of a large angular velocity (> 100 deg/sec) at separation, in which case this message may be ignored."
- **Coefficient of restitution greater than 1.0** (Warning) — "This implies the crash created energy. The normal range is ~0 to 0.25, perhaps slightly greater for low-speed impacts."
- **Coefficient of restitution larger than normal** (Informative) — "The normal range is ~0 to 0.25, perhaps slightly greater for low-speed impacts."
- **Closing velocity less than zero** (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."
- **Restitution not calculated for sustained contact** (Informative) — "The method used to calculate the coefficient of restitution in the Event Data output report (see INTER-VEHICLE COLLISION DATA) assumes an instantaneous impact. One or more collisions resulted in sustained contact (more than 0.5 seconds). A coefficient of restitution was not calculated for those collisions."
- **Increased tessellation required** (Error) — "Increased tessellation of the vehicle geometry is required when using the option to initialize the Rho Vector lengths using the vehicle geometry. Use the Set-up, Vehicle Mesh dialog for this purpose." (Issued when the **Use Vehicle Geometry for Rho Vector Init** calculation option is checked but the vehicle mesh is too coarse.)
- **Damage profile vertex index error** (Error) — "An error occurred in MakeProfile() because the vertex index was not within the damage table range."
- **Mesh dimensions differ from overall dimensions** (Informative) — "One or more vehicle(s) have mesh exterior dimensions that differ from the vehicle overall dimensions (CG to Front, CG to Back, CG to Right or CG to Left) by more than 0.5 inches (12.7 mm). As a result, the Damage Data output report for the affected vehicle(s) is subject to errors."
- **Collision in progress at termination** (Informative) — "At the time the simulation was terminated, one or more vehicles were still undergoing a collision. The CollisionData results (see Damage Data output report) are incomplete for the last recorded impulse."
- **Bad CDC** (Informative) — "One or more vehicles has a bad CDC (see Damage Data output report). This usually occurs while EDSMAC4 attempts to build the damage profile using the damaged vehicle geometry. There may be an insufficient number of damaged vertices to build the damage profile. Review the Damage Data report's Damage Width, Offset and Crush Depth table."

Previous: Chapter 5 — EDSMAC4 Tutorial — Next: Chapter 7 — Technical References

Chapter 7 — Technical References

1. McHenry, R.R., and DeLeys, N.J., "Vehicle Dynamics in Single Vehicle Accidents — Validation and Extensions of a Computer Simulation," Calspan Report No. VJ-2251-V-3, NTIS-PB 182 663, 1968.
2. McHenry, R.R., Segal, D.J., Lynch, J.P., Henderson, P.M., "Mathematical Reconstruction of Highway Accidents," NTIS PB-220 150, January 1973.
3. McHenry, R.R., "Development of a Computer Program to Aid the Investigation of Highway Accidents," Calspan Report No. VJ-2979-V-1, DOT HS 800 821, December 1971.
4. McHenry, R.R., Jones, I.S., Lynch, J.P., "Mathematical Reconstruction of Highway Accidents — Scene Measurement and Data Processing System," Calspan Report No. ZQ-5341-V-2, DOT HS-801 405, December 1974.
5. Solomon, P.L., "The Simulation Model of Automobile Collisions (SMAC) Operator's Manual," US DOT, NHTSA, Accident Investigation Division, Washington, D.C., 1974.
6. Day, T., Hargens, R., "An Overview of the Way EDSMAC Computes Delta-V," SAE Paper No. 880069, Society of Automotive Engineers, 1988.
7. EDSMAC Version 2 Source Code Listing, EDC Library Ref. No. 2006, Engineering Dynamics Corp., Lake Oswego, 1989.
8. "Collision Deformation Classification," SAE Technical Report J224 MAR80, Society of Automotive Engineers, March 1980.
9. U.S. and Foreign Passenger Car Specifications, Motor Vehicle Manufacturers Association, Detroit, 1982, EDC Library Ref. No. 1046, Engineering Dynamics Corporation, Lake Oswego.
10. Fiala, E., "Seitenkräfte am Rollenden Luftreifen" (Lateral Forces on Rolling Pneumatic Tires), Zeitschrift V.D.I., 96, No. 29, 1954, EDC Library Ref. No. 1011, Engineering Dynamics Corporation, Lake Oswego.
11. Jones, I.S., Baum, A.S., "Research Input for Computer Simulation of Automobile Collisions, Volume IV — Staged Collision Reconstructions," Calspan Report No. ZQ-6057-V-6, HS 805 040, December 1978.
12. Jones, I.S., "Results of Selected Applications to Actual Highway Accidents of the SMAC Reconstruction Program," SAE Paper No. 741179, Society of Automotive Engineers, 1974.
13. Jones, I.S., "The Application of the SMAC Accident Reconstruction Program to Actual Highway Accidents," Proceedings of the Eighteenth Conference of the American Association of Automotive Medicine, 1974.
14. Vehicle Crush Stiffness Coefficients for Model Years 1970–1984, EDC Library Ref. No. 1042, Engineering Dynamics Corporation, Lake Oswego, 1986.
15. Day, T., Hargens, R., "Application and Misapplication of Computer Programs for Accident Reconstruction," SAE Paper No. 890738, Society of Automotive Engineers, March 1989.
16. Taborek, J.J., "Mechanics of Vehicles," Machine Design, The Penton Publishing Co., Cleveland, 1957.
17. Baker, J.S., Traffic Accident Investigation Manual, The Traffic Institute, Northwestern University, Evanston, Ill., 1975.
18. Noga, T., Oppenheim, T., "CRASH3 User's Guide and Technical Manual," U.S. DOT, Washington, D.C., January 1981.
19. Hargens, R.H., Day, T.D., "Data Sources for Accident Reconstruction," SAE Paper No. 880068, Society of Automotive Engineers, February 1988.
20. Day, T.D., Siddall, D.E., "Validation of Several Reconstruction and Simulation Models in the HVE 3-D Environment," SAE Paper No. 960891, Society of Automotive Engineers, February 1996.

21. Hull, W.C., Newton, B.C., "Estimating Crush Stiffness When Reconstructing Vehicle Accidents," SAE Paper No. 930898, Society of Automotive Engineers, February 1993. 21a. Neptune, J.A., Flynn, J.E., "A Method for Determining Accident Specific Crush Stiffness Coefficients," SAE Paper No. 940913, Society of Automotive Engineers, February 1994. *(The original manual numbered both this and the previous entry "21.")*
22. EDC Technical Newsletter, Technical Session, Engineering Dynamics Corporation, Beaverton, OR, December 1997.
23. Day, T., "An Overview of the EDSMAC4 Collision Simulation Model," SAE Paper No. 1999-01-0102, Society of Automotive Engineers, Warrendale, PA, 1999.
24. Day, T., "An Overview of the HVE Developer's Toolkit," SAE Paper No. 940923, Society of Automotive Engineers, February 1994.
25. Day, T.D. and Metz, L.D., "The Simulation of Driver Inputs Using a Vehicle Driver Model," SAE Paper No. 2000-01-1313, Society of Automotive Engineers, Warrendale, PA, 2000.

(Additional references cited by the current program's Program Data report include Day, T.D., Hargens, R.L., "Further Validation of EDSMAC Using the RICSAC Staged Collisions," SAE Paper No. 900102, February 1990, and the "EDC Simulations Training Manual," Engineering Dynamics Corporation, Beaverton, OR, 1989.)

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