ENGINEERING DYNAMICS COMPANY

EDHIS

HVE Human Vehicle Environment

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

Contents

1. EDHIS — Human Impact Simulator
2. Chapter 1 — EDHIS Program Description
3. Chapter 2 — EDHIS Program Input
4. Chapter 3 — EDHIS Program Output
5. Chapter 4 — Calculation Method
6. Chapter 5 — EDHIS Tutorial
7. Chapter 6 — Messages
8. Chapter 7 — References

EDHIS — Human Impact Simulator

Engineering Dynamics Company Human Impact Simulator, Version 3

Updated Markdown edition, converted from the Fifth Edition manual (January 2006) and revised to match the current HVE release.

How to Use This Manual

This manual is the user's manual for the EDHIS 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 User's Manual, which provides in-depth coverage of the human, vehicle and environment models, as well as the HVE Event Editor and Playback Editor. For specific model definitions, the user is referred to the HVE User's 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 Version Information (HVE Help System), and EDHIS Version Information (EDHIS Program Data report).

Contents

- 1 — EDHIS Program Description
- 2 — EDHIS Program Input
- 3 — EDHIS Program Output
- 4 — Calculation Method
- 5 — EDHIS Tutorial
- 6 — Messages
- 7 — References

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

Related reference pages:

- EDHIS Calculation Options
- Humans (HVE Human Editor)

Chapter 1 — EDHIS Program Description

Overview

EDHIS (**E**ngineering **D**ynamics Company **H**uman **I**mpact **S**imulator) is a 3-dimensional analysis of the response of a human occupant or pedestrian during a motor vehicle collision. EDHIS is based on the HSRI-3D model [2,3] developed at the University of Michigan Transportation Research Institute, and includes several extensions and refinements produced by Engineering Dynamics Company, LLC [1,6]. The model was developed as a tool to study advanced safety concepts and designs of seat restraint systems from the viewpoint of occupant protection [2]. EDHIS employs airbag and belt (torso and lap) models useful for studying issues related to restraint system effectiveness. EDHIS is useful for predicting and visualizing occupant and pedestrian motion during impact. The model also provides important injury predictions, including HIC, Chest SI and Maximum Femur Load.

EDHIS computes human kinematics (position, velocity and acceleration vs time), joint angles and torques, and contact force between the human and vehicle.

The EDHIS human model includes 12 degrees of freedom. The human is represented by three inertial segments (head, torso and lower extremities) and 2 joints (neck and hip). The body is visualized using the HVE 15-segment, 14-joint model by combining the head and neck into a single segment called the head; the HVE pelvis, abdomen and chest are combined to form the EDHIS torso; and the right and left upper legs, lower legs and feet are combined to form the lower extremities. 3-dimensional ellipsoids may be attached to any of these three segments to sense force-producing interactions with the vehicle interior or exterior.

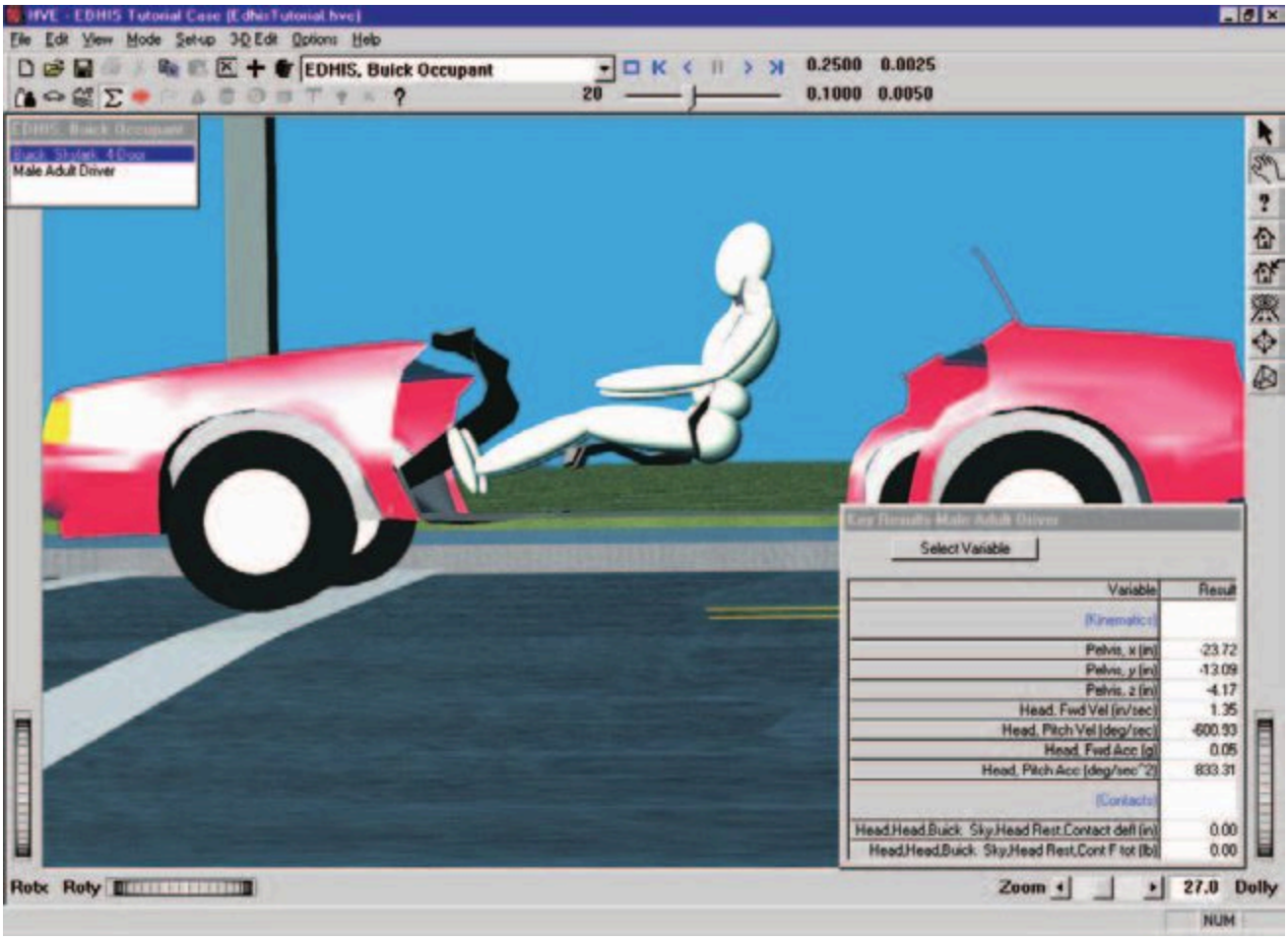


Figure 1-1: EDHIS Event.

The motion of the vehicle is defined by a 6 degree-of-freedom collision pulse (acceleration vs time history). The vehicle has attached to it a number of planar contact surfaces that may be arranged to form interior surfaces, such as seats, dashboards and windshields, and exterior surfaces, such as bumper, grill, hood and windshield. Forces are applied to the human whenever interaction is sensed between the human ellipsoids and the vehicle contact surfaces.

The motion and forces resulting from human vs vehicle interactions are recorded as EDHIS output tracks; the resulting motion is also visualized in the 3-D HVE visualization environment.

Model Inputs

EDHIS inputs include one human, one vehicle, and an optional environment. Event set-up parameters include initial position and velocity for the human and vehicle, a collision pulse (the source may be a user-entered table or taken directly from another HVE event, such as EDSMAC4 [5]), an optional inhibition of selected human ellipsoid vs vehicle contacts, and restraint system in-use factors.

Model Outputs

EDHIS output reports include the Accident History, Event Data, Human and Vehicle Data, Injury Predictions, Variable Output and Trajectory Simulation.

Validation

EDHIS was validated first by direct comparison with HSRI-3D to ensure the basic model was intact after porting the original FORTRAN code to C and making the model HVE-compatible. Additional validation was performed comparing EDHIS results to other models as well as direct comparison with staged collision tests. Validation results are reported in reference 1.

Basic Procedure

The procedure for using EDHIS is substantially the same as using any simulation model in the HVE environment:

1. Use the Human Editor to add one or more humans to the case. Optionally, edit the human properties.
2. Use the Vehicle Editor to add one or more vehicles to the case. Assign interior (occupant) or exterior (pedestrian) contact surfaces to each vehicle. Optionally, add a restraint system (belt and/or airbag) at the occupant seat position.
3. Optionally, use the Environment Editor to create a visual environment.

> **NOTE:** Although an environment is unnecessary, it provides a visual context for the movement of objects computed by EDHIS.

1. Use the Event Editor to set up and execute the EDHIS simulation model by performing the following steps:
2. Choose one human from the Active Humans list
3. Choose one vehicle from the Active Vehicles list
4. Choose the EDHIS calculation model
5. Position the vehicle in the environment at its initial position, and supply an initial velocity
6. Position the human in the vehicle (for occupants) or in the environment (for pedestrians), and supply an initial velocity
7. For occupant simulations, assign a collision pulse
8. Optionally, assign human vs vehicle contact inhibitions
9. Optionally, assign belt and/or airbag restraint system usage parameters
10. Execute the EDHIS event.
11. Edit and re-execute the event, if necessary, to achieve the desired match between simulation results and the actual event.
12. Finally, use the Playback Editor to view the various reports and trajectory simulations. If desired, use the Playback Window to produce a simulation movie of the simulation.

Next: Chapter 2 — EDHIS Program Input

Chapter 2 — EDHIS Program Input

This chapter defines the objects (humans, vehicles and environment) and the event set-up parameters (positions, damage profiles, driver controls, and so forth) used by the EDHIS analysis. The chapter is divided into the following sections:

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

Objects Overview

The objects used by the EDHIS model are:

- **Humans** — One human, either an occupant or a pedestrian, may be studied by EDHIS.
- **Vehicles** — One vehicle may be studied by EDHIS.
- **Environment** — Like the *real* world, EDHIS has exactly one environment.

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

The following sections describe how these humans, vehicles and environment provide the required inputs to the EDHIS calculation model.

Humans

EDHIS uses one human created using the Human Editor (see the Human Editor pages). Humans are selected from the Human Database by choosing the following attributes:

- **Location** — The user may choose from any available occupant position (i.e., *R/F, L/F*) or, alternatively, choose *Pedestrian*.

> **NOTE:** If an occupant position is selected, HVE displays the human's motion relative to the vehicle; if Pedestrian is selected, its motion is relative to the earth.

- **Sex** — The user may choose *Male* or *Female*.
- **Age** — The user may choose *Adult* or from a list of child ages.
- **Weight Percentile** — The user may choose from a list of available percentiles.
- **Height Percentile** — The user may choose from a list of available percentiles.

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

1. Choose Human Mode. The Human Editor is displayed.
2. Click *Add New Object*. The Human Information dialog is displayed.
3. Click on the *Location* option list and select a location for the current human.

> **NOTE:** If you choose R/F, L/F, etc., the human will be a vehicle occupant. If you choose Pedestrian, the human will be a pedestrian.

1. Click on the *Sex*, *Age*, *Weight Percentile* and *Height Percentile* option buttons to choose a human from the database.
2. Enter a name for the current human. A default name is supplied for each selected human. Its name is user-editable, and does not affect calculations.

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

1. Click *OK* to add the human to the current case.

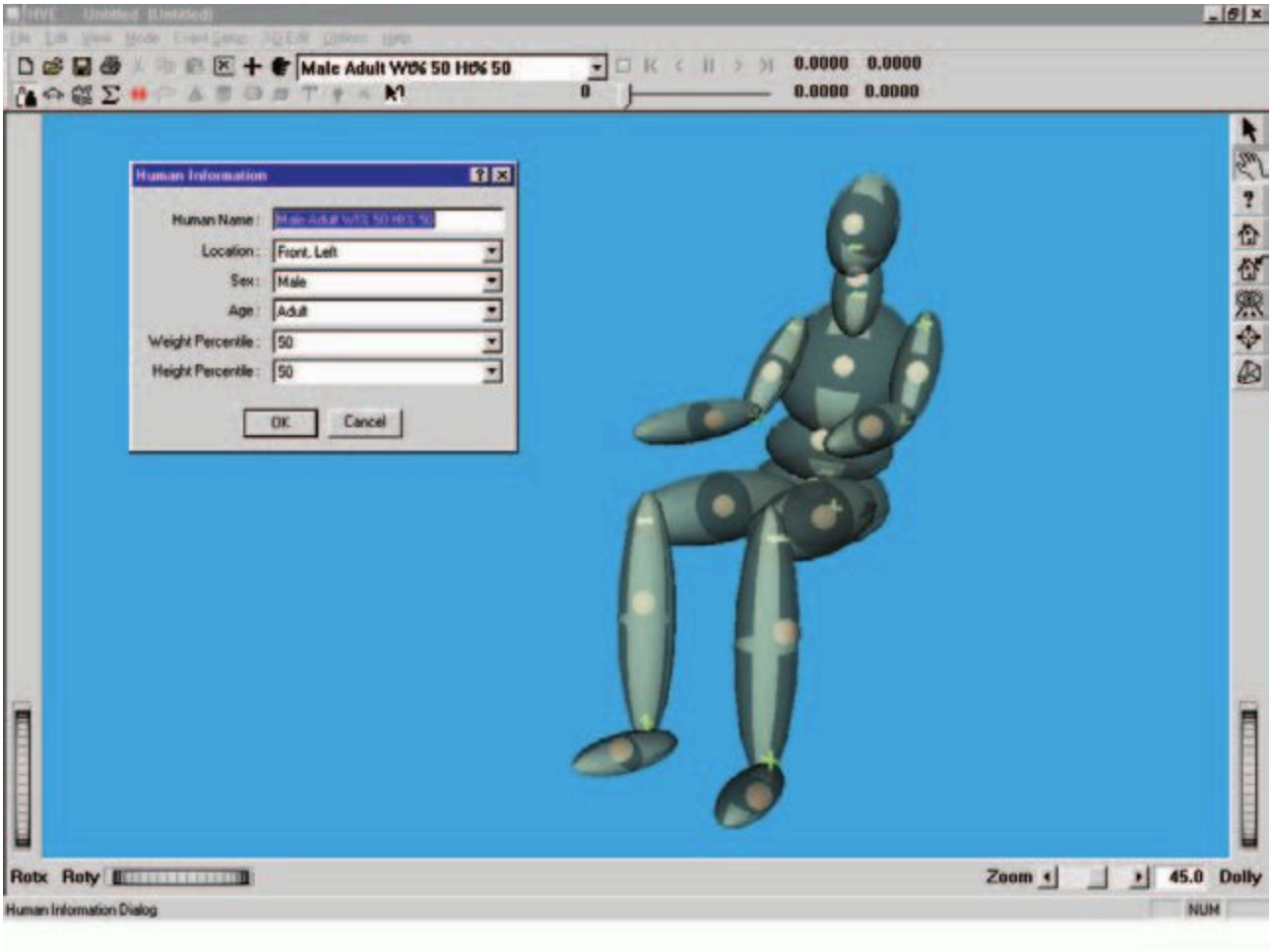


Figure 2-1: HVE Human Editor.

The following Human Parameter groups are used by EDHIS:

- Inertias
- Ellipsoids
- Joints
- Injury Tolerance

The EDHIS human is modeled by 3 mass segments (Head, Torso and Legs) connected by 2 ball-type joints (Neck and Hip). Refer to Chapter 4, Calculation Method, for important details describing how the EDHIS human model is derived.

The specific data in each of the above parameter groups that are actually used by EDHIS are defined in Tables 2-1 and 2-2.

> **NOTE:** For information about using the Human Editor to create and edit humans, refer to the HVE User's Manual, Human Editor section (see the Humans dialog reference).

Inertias

The Human Inertial Data used by EDHIS are shown in Table 2-1. EDHIS combines the pelvis, abdomen and chest masses into a single mass, named the Torso. The neck and head are combined into a single mass, named the Head, and the upper left and right legs are combined into a single mass, named the Legs. The parallel axis theorem is used to compute moments of inertia for the combined masses about the total resultant center of gravity for the combined segments.

Ellipsoids

Ellipsoids are used for predicting contact forces between the human and vehicle. Penetration of an ellipsoid into a vehicle contact surface results in the calculation of force on the human.

The Human Ellipsoid Data used by EDHIS are shown in Table 2-1. HVE allows up to 3 ellipsoids per HVE segment; EDHIS allows up to 25 total ellipsoids. The user should consider the following issues related to differences between the HVE Human Model and the EDHIS human model:

- Because the HVE Upper and Lower Arm segments are ignored, any ellipsoids attached to these segments are also ignored.
- Because the lower legs and feet are ignored, any lower extremity ellipsoids (e.g., Knee, Shin or Foot) should be attached to the upper leg segments.
- HVE allows the ellipsoids' principal axes to be rotated relative to the segment axis system; EDHIS does not consider such rotations.

> **NOTE:** If principal axes are rotated and you choose to show contact surfaces, you will not be looking at a true picture of the human-vehicle interaction. However, the forces will be correctly calculated according to the inputs being considered.

Joints

Joints are used to connect together each of the 15 segments. Although the HVE Human has 14 joints, EDHIS defines only 2: the *Neck* and *Hip*. The Neck joint is C7-T1, located between the Chest and Neck segments. The Hip joint is the average of the Right Hip and Left Hip. These joints are located between the Pelvis and Upper Leg (Right and Left) segments.

The Human Joint Data used by EDHIS are shown in Table 2-1. Both joints are considered to be

ball-and-socket

joints having 3 degrees of freedom (roll, pitch and yaw).

Table 2-1 — Human Inertial, Ellipsoid and Joint Parameters Used by EDHIS. The following parameters are supplied to each of the 15 human segments and 14 joints.

Parameter	Description
Weight	Weight of each segment
Roll, Pitch and Yaw Moments of Inertia	Rotational inertia of each segment about the segment-fixed i, j, k axes, respectively
Ellipsoid Name	Up to 30 characters, used to identify the ellipsoid
Ellipsoid Center i,j,k Coords	Coordinates of the center of the ellipsoid, defined relative to the segment principal axis system
Ellipsoid Semi-axis i,j,k Length	Half the ellipsoid length, defined in the ellipsoid principal axis system
Joint k Location	Distance from segment CG to joint along the segment-fixed k axis
Joint roll, pitch and yaw stop angles	Articulation roll, pitch and yaw angles at which joint stop properties are applied
Stop Elasticity, i, j, k axes	Elasticity of the joint stops for roll, pitch and yaw rotations. Applies to both (+) and (−) directions
Linear Elastic Coefficient	Elastic properties for the joint in the normal range of motion (i.e., between the joint stops)
Damping Constant	Damping properties for the joint
Maximum Joint Angles	Injury tolerance for joint rotations beyond the joint stops

The Joints are assumed to be located at i = j = 0.0 (k, the vertical distance from the segment origin to the joint, is used to locate the joint). If i or j is non-zero, the human will not be visualized as it is used in the EDHIS model.

> **NOTE:** You can ensure that the joints are correctly located for EDHIS by clicking on the Hip, Abdomen, Chest, Neck and Head segments and setting i equal to zero for each joint. Although j is left with its original values, calculations are not affected as long as matching ellipsoids are placed on right and left legs.

Injury Tolerance

Injury tolerances may help estimate the propensity for an injury during a crash. EDHIS compares the current levels of force and acceleration to these injury tolerances to produce the Injury Data Report (see Output).

The Human Injury Tolerance Data used by EDHIS are shown in Table 2-2. These values are based on reported tolerances [2, 4] for healthy humans. Although age and other factors can affect human injury tolerance, these values should be modified only with the greatest of care.

Table 2-2 — Injury Tolerance Values for current human (see References 2 and 4).

Parameter	Description
HIC	Head Injury Criterion
Head Pitch Concussion	Injury tolerance for head angular acceleration about the pitch axis
Head Side Acceleration	Injury tolerance for head side acceleration
Chest Severity Index	Injury tolerance for chest
Chest Force	Injury tolerance for chest force
Chest Forward Acceleration	Injury tolerance for chest forward acceleration
Maximum Femur Load	Injury tolerance for femur load
Maximum Torso Belt Force (Left, Right)	Injury tolerance for torso belt force, entered separately for the left and right torso belt sections
Maximum Lap Belt Force (Left, Right)	Injury tolerance for lap belt force, entered separately for the left and right lap belt sections

(updated: in the current HVE human model the belt injury tolerances are entered as four separate values — left lap, left torso, right lap and right torso — rather than the single combined torso and lap values described in the original manual.)

Vehicles

EDHIS uses one vehicle created using the HVE Vehicle Editor. Vehicles are selected from the Vehicle Database by choosing the following attributes:

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

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

- **Driver Location** — The driver location is used by EDHIS to determine if the airbag is a driver-type or a passenger-type airbag (a passenger-type airbag is modeled as a cylinder, whereas a driver-type airbag is modeled as a sphere).
- **Engine Location** — The engine location is not used by EDHIS.
- **Number of Axles** — EDHIS supports 2- and 3-axled vehicles.
- **Drive Axle(s)** — The drive axle attribute is not used by EDHIS.

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

1. Choose Vehicle Mode. The Vehicle Editor is displayed.
2. Click *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.

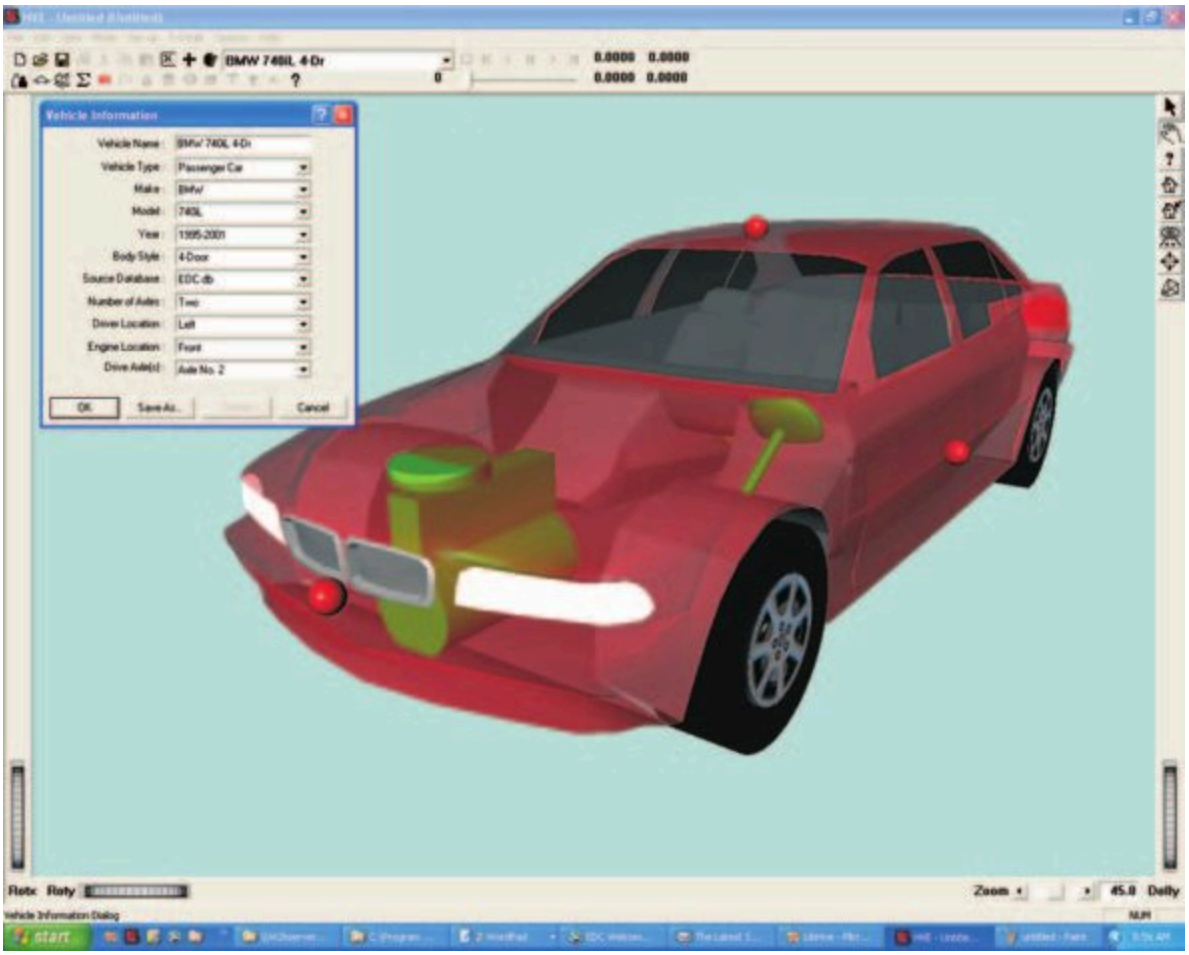


Figure 2-2: HVE Vehicle Editor.

The following Vehicle Parameter groups are used by EDHIS:

- Move CG
- Contact Surfaces
- Belt Restraints
- Airbag Restraints

The specific data used in each of the above parameter groups are defined in Tables 2-3 through 2-5.

Sprung Mass

Remember, EDHIS is not a

vehicle

simulator! The motion of the vehicle is determined by a user-supplied collision (acceleration) pulse, along with initial vehicle position and velocity. Therefore, the vehicle data required by EDHIS is limited to that which is required to establish interaction forces between the human and vehicle.

Inertias

Inertial parameters are not used by EDHIS. The vehicle's motion is supplied by assigning an initial velocity and a collision pulse (see Event Editor).

Table 2-3 — Vehicle Parameters Used by EDHIS.

Parameter	Description
Move CG x,y,z	Relocates the CG in the vehicle-fixed x, y and z directions. This entry causes an automatic adjustment of all vehicle coordinate-related parameters (e.g., contact surface, belt anchor points)
Contact Surface Name	Up to 30 characters, used to identify the contact surface
Contact Surface Location	Interior or Exterior; provides the default status that determines whether a contact surface is allowed or ignored during force calculations (see also Event Set-up Parameters, Contacts)
Contact Surface x,y,z corner coordinates	Vehicle-fixed x,y,z coordinates for three consecutive corners of the current contact surface, supplied in a counter-clockwise order. The positive side of the surface is specified by the right-hand rule
Contact Surface Linear Stiffness	Linear stiffness of the ellipsoid vs contact surface pair
Contact Surface Quadratic Stiffness	Second-order stiffness of the ellipsoid vs contact surface pair
Contact Surface Cubic Stiffness	Third-order stiffness of the ellipsoid vs contact surface pair
Contact Surface Damping Constant	Velocity-dependent damping properties between the ellipsoid and contact surface
Contact Surface Maximum Penetration	Determines if the ellipsoid is approaching the surface from the back side (see Corner Coordinates, above). If the ellipsoid surface is initially behind the contact surface and the distance is greater than this value, it is assumed the ellipsoid is not contacting the surface and no force calculations are performed
Contact Surface Maximum Force	The force is not allowed to exceed this value. Once it is reached the surface is saturated, and when the penetration begins to reverse the force falls along the unloading slope rather than back down the loading curve, leaving a permanent deformation. Leave this and the unloading slope unentered for a fully elastic surface
Contact Surface Edge Constant	Determines the fraction of contact force if a portion of the ellipsoid lies outside the boundary of the contact plane
Contact Surface Unloading Slope	The linear elastic property during unloading

Move CG

Move CG is not directly used by EDHIS. Its current value does not show up in the results. However, the Move CG fields may be used to quickly move the vehicle's center of gravity; the x,y,z coordinates for the contact surfaces, belt anchor points and airbag location are updated to reflect the new location.

Geometry File

The geometry file plays no role in the EDHIS calculations. However, there are some smart things that may be done for occupant simulation. Remembering that an occupant is inside the vehicle, and may be difficult to see, the following two suggestions will help greatly:

- Choose NoBody.h3d as the geometry file. As its name implies, NoBody.h3d is a null geometry file (it has all the required data structures, but no surface polygons), or
- Edit the vehicle's geometry file and remove the roof and roof supports.

> **NOTE:** Remember to save the file with a new name, such as PCFordTaurus4DrSNoRoof.xxx, to avoid losing the original geometry file!

Contact Surfaces

Vehicle contact surfaces are the surfaces that interact with human ellipsoids to produce forces on the human. Up to 25 contact surfaces are allowed by EDHIS, the properties for which are shown in Table 2-3.

Belt Restraints

Belt restraints are an extremely important aspect of EDHIS's functionality. The ability to study the effect of restraint system usage (or non-usage) is an important one.

A belt restraint system may be supplied for up to nine seat positions. Although HVE assigns default positions for each belt system, these locations are arbitrary and may be replaced by user-entered information. Belt Parameters used by EDHIS are shown in Table 2-4.

> **NOTE:** At this point, you are saying the vehicle has a belt installed at a specific location. Whether or not the belt is used is event-dependent! See Event Set-up, Restraints, for more information.

Table 2-4 — Vehicle Belt Restraint System Parameters used by EDHIS.

Parameter	Description
Seat Position	Seat position within vehicle (R/F, L/F, etc.)
Belt Section	Torso or Lap
Belt Anchor Point x,y,z Coords	Vehicle-fixed attachment point for the one end of the belt (the other end is attached to a human segment)
Belt Linear Stretch Rate	Linear stretch rate of the belt material
Belt Quadratic Stretch Rate	Second-order stretch rate of the belt material
Belt Cubic Stretch Rate	Third-order stretch rate of the belt material
Belt Damping Constant	Velocity-dependent contribution
Belt Breaking Strength	Maximum strength of the belt material, acting as a limit on the tension. Once reached, the tension is held at this value; when the belt then begins to shorten it unloads along the entered unloading slope, leaving it permanently stretched. *(updated: belt rupture is not modelled — compare the belt tension in the Variable Output against this value to judge whether a belt would have failed)*
Belt Unloading Slope	Linear elastic property during unloading (should be greater than the loading rate)

Airbag Restraints

Like belt restraints, airbag restraints are also an extremely important aspect of EDHIS's functionality.

An airbag restraint system may be supplied for up to nine seat positions. Like belt restraints, default positions for each airbag may be replaced by user-entered information. Airbag Parameters used by EDHIS are shown in Table 2-5.

> **NOTE:** At this point, you are saying the vehicle has an airbag installed at a specific location. Whether or not the airbag deploys is event-dependent! See Event Set-up, Restraints, for more information.

Table 2-5 — Vehicle Airbag Restraint System Parameters used by EDHIS.

Parameter	Description
Seat Position for current airbag	Seat position within vehicle (R/F, L/F, etc.)
Airbag Center x,y,z Coords	Vehicle-fixed x,y,z coordinates of the airbag
Initial Bag Radius	Initial radius of the airbag
Passenger Bag Length	If a passenger seat position (i.e., no steering column), the airbag length
Initial Bag Pressure	Initial pressure inside the airbag
Bag Membrane Thickness	Thickness of the airbag material
Bag Full Inflation Volume	Volume of the airbag at full inflation
Bag Vent Discharge Coef	Thermodynamic discharge coefficient of vent
Bag Discharge Vent Area	Area of the vent
Bag Vent Opening Pressure	Pressure required to open the vent
Bag Penetration For Force	Depth of penetration into the airbag over which the bag force is faded in. At shallower depths the force is reduced in proportion to the depth, reaching its full value at this penetration
Force Convergence Criterion	Allowable difference between force on airbag and force on human
Bag Elastic Modulus	Elastic modulus of the airbag membrane during force application
Bag Elastic Modulus on Rebound	Elastic modulus of the airbag during unloading
Bag Elastic Modulus When Bottomed Out	Elastic modulus of airbag at maximum penetration
Gas Density	Density of the fluid filling the airbag
Max Column Collapse Dist	Maximum column stroke before it bottoms out
Column Collapse Load	Force required to initiate column collapse
Column Angle	Pitch angle of the steering column
Backside Contact Surface	The name of the contact surface supporting the airbag (no force can exist between the human and airbag unless the airbag is supported on a contact surface that provides a reaction force)

Unsprung Mass

Unsprung Mass parameters (Wheel Location, Tire, Suspension and Brake) are not used by EDHIS.

> **NOTE:** Wheel location and tire size are used to visualize the vehicle, but play no role in the simulation's calculations.

Exterior

The Vehicle Exterior Data (Exterior Dimensions, Stiffness) are not used by EDHIS.

Steering System Data

Steering System Data are not used by EDHIS.

Brake System Data

Brake System Data are not used by EDHIS.

Drivetrain Data

Drivetrain Data are not used by EDHIS.

Environment

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

- Visual Data
- Physical Data

Visual Data

The following visual parameters may be edited:

- **Environment Location** — A database containing the name (City/State/Country), Latitude and Longitude and GMT for the selected location.
- **Time and Date** — The local standard time and date for the event.
- **Angle of X Axis** — The angle of the earth-fixed X axis relative to true north.

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.

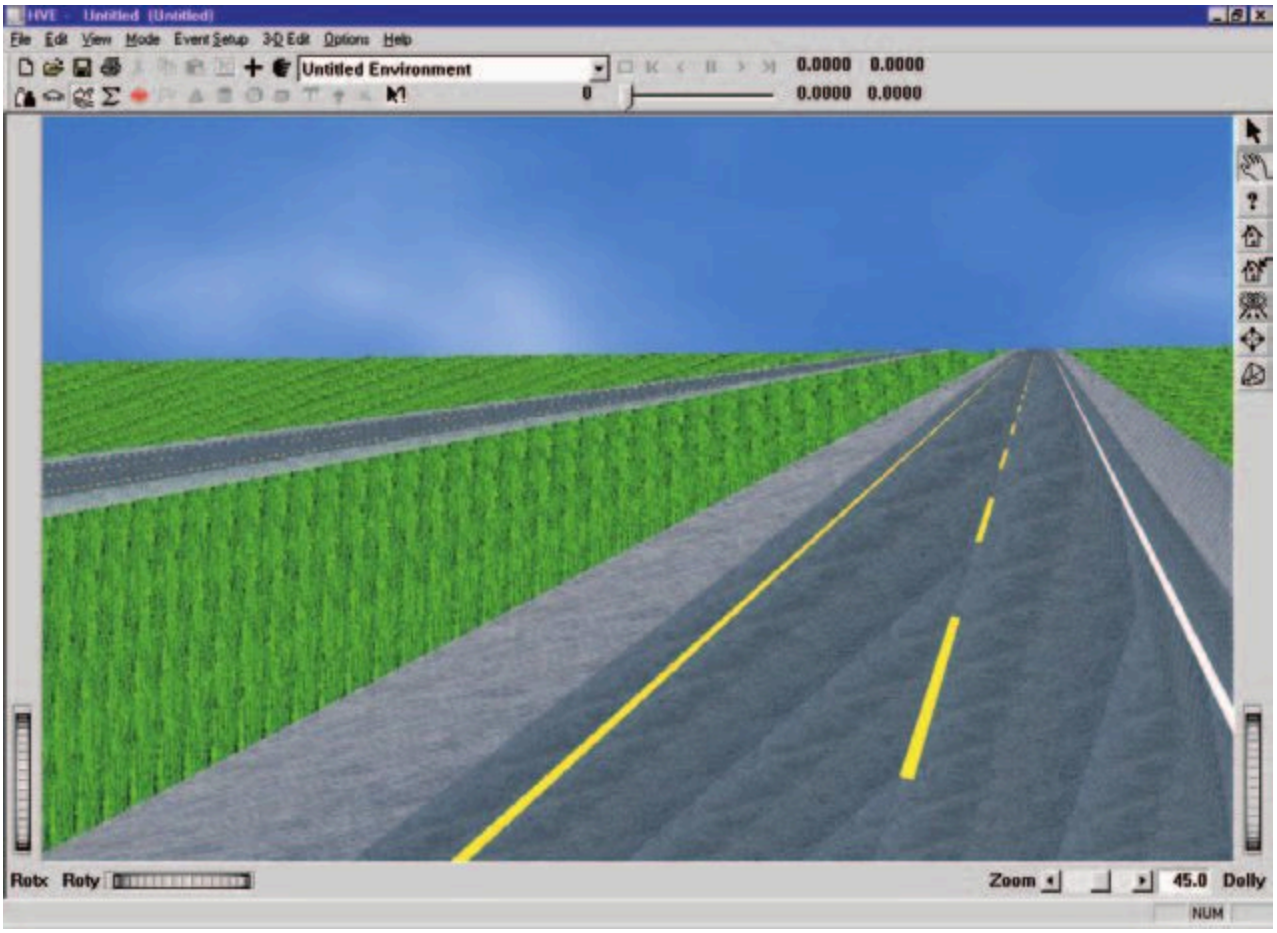


Figure 2-3: Environment Editor.

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

Physical Data

The Physical Data groups are:

- Wind Speed and Direction
- Atmospheric Temperature and Pressure
- Gravity Constant

- 3-D Surface Geometry

The specific physical environment data used by EDHIS are described below.

Angle Of X Axis

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

> **NOTE:** The angle is specified relative to true north. If you are using a compass to determine direction at the scene of an accident, you should provide a correction factor before entering this angle.
>
> **NOTE:** The angle of the X axis affects how you visualize an EDHIS event, but does not affect any calculations.

Wind Speed and Direction

Wind Speed and Direction are not used by EDHIS.

Atmospheric Temperature and Pressure

Atmospheric Temperature and Pressure are not used by EDHIS.

Gravity Constant

The gravity 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.

3-D Surface Geometry

The 3-D Surface Geometry is not used by EDHIS.

> **NOTE:** This means that a pedestrian will fall through the surface of the earth if you try to leave him/her standing for more than an instant! To avoid this problem, start your pedestrian simulation just before initial impact. Again, because EDHIS simulates only forces between the human and a vehicle, you'll have to end your pedestrian simulation when the human begins to interact with the ground surface.

Event

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

Creating An EDHIS Event

An EDHIS event is created using the Event Information dialog.

To create an EDHIS event:

1. Choose Event Mode. The Event Editor is displayed.
2. Choose *Add New Object*. The Event Information dialog is displayed.
3. Select one human from the Active Humans list.
4. Select one vehicle from the Active Vehicles list.
5. Select the calculation model, *EDHIS*, from the Calculation Model options list.
6. Click on Calculation Options and choose or set any options.

7. 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 EDHIS event.

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

Setting Up an EDHIS Event

EDHIS uses the following

event set-up

options:

- Position/Velocity
- Collision Pulse
- Contacts
- Restraints

The specific Event Set-up data used by EDHIS are defined in Table 2-6.

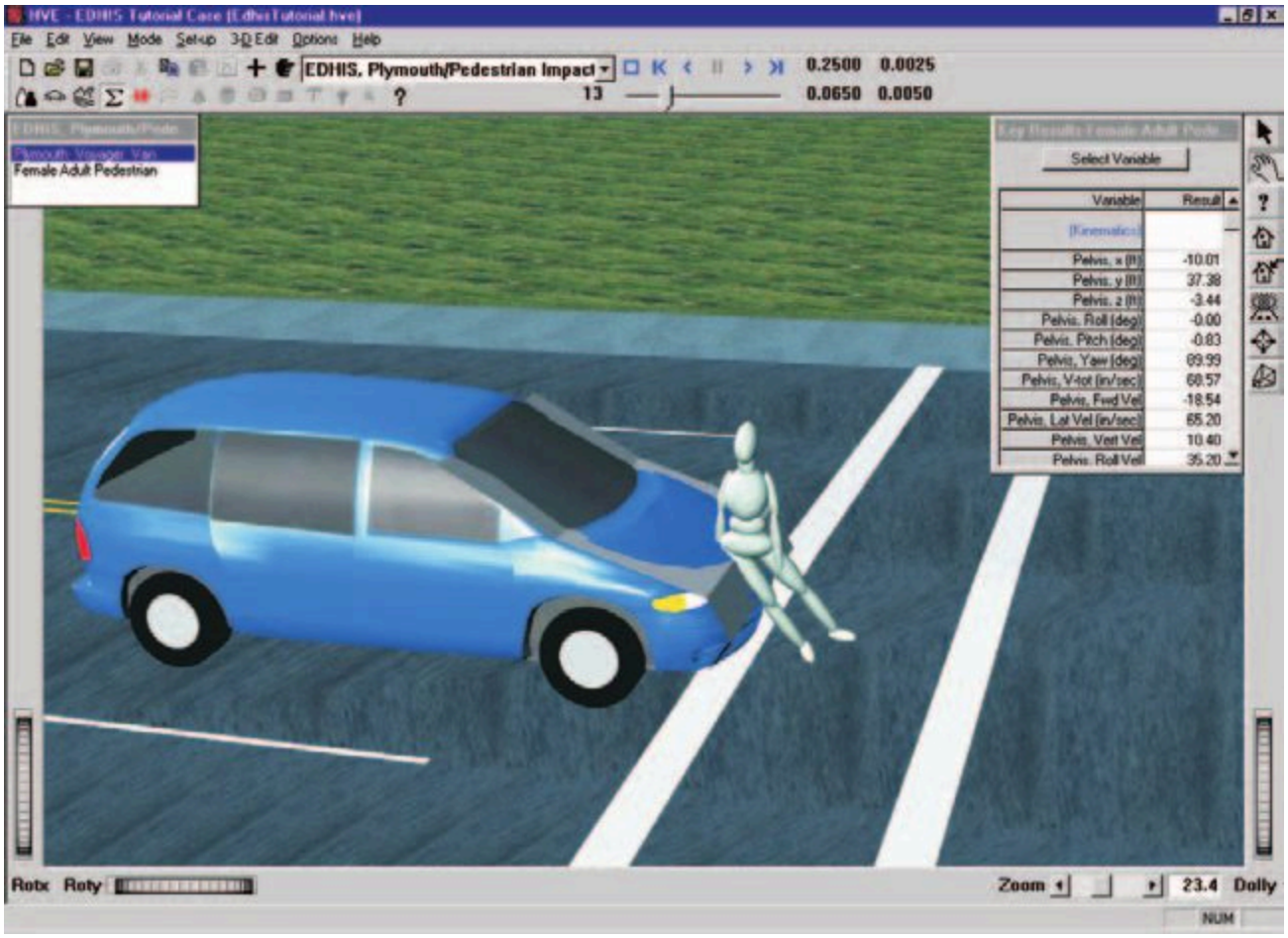


Figure 2-4: HVE Event Editor, setting up and executing an EDHIS event.

Position/Velocity

Like all simulations, EDHIS requires initial positions and velocities to be supplied by the user.

The vehicle is positioned relative to the earth-fixed coordinate system by supplying the X,Y,Z coordinates of its CG, and roll (Φ), pitch (Θ) and yaw (Ψ) angles about vehicle x, y and z axes, respectively. The vehicle velocities are supplied in the form of a total velocity, sideslip angle and vertical velocity.

> **NOTE:** The vehicle-fixed u (forward) and v (side) velocity components are calculated using the total velocity and sideslip angle.

Human positions and velocities are assigned differently, depending on whether the human is an occupant or a pedestrian: Occupant positions and velocities are assigned relative to the vehicle-fixed coordinate system, while pedestrian positions and velocities are assigned relative to the earth-fixed coordinate system.

> **NOTE:** The same is true for output reports: All the kinematic data displayed in Variable Output is reported relative to the vehicle for occupants and the earth for pedestrians.

Table 2-6 — Event Set-up Parameters used by EDHIS.

Parameter	Description
Vehicle Initial Position	The earth-fixed X,Y,Z coordinates and the roll, pitch and yaw orientations of the vehicle at the start of the run
Vehicle Initial Velocity	The forward, lateral and vertical linear velocities, and the roll, pitch and yaw angular velocities of the vehicle at the start of the run
Human Initial Position	The x,y,z coordinates and roll, pitch, yaw angles of the human at the start of the simulation
Human Initial Velocity	The forward, lateral and vertical linear velocities, and the roll, pitch and yaw angular velocities of the human at the start of the run
Vehicle Collision Pulse	Time-dependent table of the vehicle forward, lateral and vertical components of linear acceleration, and the roll, pitch and yaw angular accelerations
Contacts	A table of allowable interactions between human ellipsoids and vehicle contact surfaces
Belt Restraints In-Use Switch	Determines whether the selected belt restraint system (Torso or Lap) is in use
Segment Attachment	The name of the segment to which the belt ends are attached
Attachment Coordinates	The segment-fixed i,j,k coordinates for the belt attachment point
Belt Slack	Initial slack in the belt
Airbag Restraint In-Use Switch	Determines whether the airbag restraint system is in use
Airbag Begin Fill	Simulation time at which the airbag begins to fill
Fill Duration	Duration of filling before the gas shuts off

The position of a human is defined by the center of gravity of its pelvis segment (this is called the *main segment*). Thus, the positions and velocities are actually those assigned for the pelvis. However, human positions may be further defined for each additional segment (i.e., *Head*, *Left Upper Leg*, and so forth) by Ψ, Θ, Φ articulations (supplied in that order) at the joints. Angular velocities may be supplied as well.

EDHIS is a 3-mass, 2-joint model. Articulation angular positions and velocities may be entered by clicking on the neck segment (to set the initial conditions for the C7-T1, or Neck, joint), and by clicking on the Right and Left Upper Leg segments (to set the initial conditions for the Hip joint). These joints are modeled by EDHIS and their motion will be affected by subsequent human-vehicle interaction. Any of the other segment positions may be supplied as well (for example, the upper arms may be articulated so the human appears to be grasping the steering wheel). However, these joints will remain rigid during the simulation.

Driver Controls

The Driver Controls Data are not used by EDHIS.

Damage Profile

The Damage Profile Data are not used by EDHIS.

Payload

The Payload Data are not used by EDHIS.

Collision Pulse

The collision pulse provides the vehicle acceleration vs time history for the event. The data are provided in the form of a table. The current value of forward, side and vertical linear accelerations, and roll, pitch and yaw angular accelerations is obtained from this table using linear interpolation. Once obtained, the accelerations are integrated during each time step to determine vehicle velocity and position.

> **NOTE:** This approach, used in some form by all occupant and pedestrian impact simulation models, removes the need to provide a robust vehicle dynamics model.
>
> **NOTE:** HVE allows you to supply a collision pulse directly from a previously run EDSMAC4 event (or any event producing a collision pulse), as well as from a directory of user-saved collision pulses. See References 5 and 6 for additional information.
>
> **NOTE:** Because of the significant difference in the mass of a human compared to a vehicle, a collision pulse is not normally required for a pedestrian impact simulation. (Unfortunately, the vehicle does not slow down very much during impact.)

Contacts

The contacts dialog allows the user to selectively remove specific human ellipsoid vs vehicle contact surface interactions from consideration by the event. This practice is useful because every interaction requires computational overhead. Removing unnecessary calculations reduces calculation time.

By default, the Contacts dialog assumes interaction between every human ellipsoid and vehicle contact surface. When an ellipsoid name is selected from the ellipsoids listbox, all the vehicle contact surface names will be highlighted in the Contacts listbox. Click on any highlighted contact surface to remove it from consideration.

> **NOTE:** Actually, EDHIS does some pre-screening: If the current human is an occupant, only interior contact surfaces will be highlighted; if the current human is a pedestrian, only exterior surfaces will be highlighted.

Restraints

The Restraints dialog determines if a belt or airbag restraint system is in use for the current event.

> **NOTE:** If the current vehicle does not have a restraint system installed at the position specified for the current human, no restraints will be available for selection. If necessary, use the Vehicle Editor to install a restraint system at the desired seat position.

For belt restraint systems, Torso and Lap belt sections may be supplied individually. The following in-use parameters are required for each belt section:

- **Attached To** — The name of the human segment (Pelvis, Abdomen, Chest...) to which the belt is attached.
- **Attachment Coordinates** — The segment-fixed coordinates of the anchor point for the left and right belt sections.

> **NOTE:** EDHIS combines the Pelvis, Abdomen and Chest into a single mass, called the Torso. EDHIS computes the torso attachment point using the segment and joint geometry.

- **Belt Slack** — The initial slack in the belt for the left and right belt sections.

> **NOTE:** Negative slack may be supplied to model belt pre-loading.

For airbag restraint systems, the following in-use parameters may be supplied:

- **Deployment Time** — The simulation time at which the bag begins to inflate.
- **Fill Duration** — The time interval during which airbag filling occurs.

Simulation Controls

EDHIS uses the current simulation control parameters in the Simulation Controls dialog (see Options Menu, Simulation Controls). The Simulation parameters used by EDHIS are shown in Table 2-7.

Table 2-7 — Simulation Control Parameters used by EDHIS.

Parameter	Description
Human Collision Integration Timestep	The integration timestep used by the numerical integration routine
Output Interval	The timestep used to send output results back to HVE
Maximum Simulation Time	The length of the run
Maximum Bisections	The number of times the normal integration timestep may be halved in order to achieve velocity convergence, typically between 8 and 12
Velocity Convergence	The maximum error allowed between the predicted and actual velocity values
Velocity Change Limit	An additional stability test on the integration; if it is exceeded, the timestep is halved and the step retried rather than the run being stopped (if set to zero, this test is ignored). See the note below
Acceleration Change Limit	A second stability test of the same kind, also acting by halving the timestep (if set to zero, this test is ignored). See the note below

> **NOTE:** Both are stability tolerances rather than physical limits, and the quantity each is compared against is not the one its name would suggest — Chapter 4 gives both. Choose values from those relationships rather than from the parameter names, by trial on the case at hand. Entering zero for either turns that test off.

EDHIS Calculation Options

EDHIS has the following user-selectable simulation model options (see Calculation Options for EDHIS for full details, defaults and allowed ranges):

- **Integration Method (Start)** — A radio button providing three types of numerical integration methods used to start the solution: *Euler*, *Modified Runge-Kutta* (default) and *Runge-Kutta*.
- **Predictor-Corrector Method** — A radio button providing two types of predictor-corrector methods: *Adams-Moulton* and *Milne-Hamming* (default).

> **NOTE:** For details about the various integration options, see Calculation Method (Chapter 4) as well as references 1 and 2.

- **Minimum Acceleration** — Setting a non-zero value acts like a filter to remove tiny, non-zero values resulting from roundoff or loss of numerical precision. Default: 0.0000001 (1.0e-7).
- **Minimum Time Criterion (sec)** — The minimum time precision (time epsilon) used by the integration and output control logic. If entered as 0.0 (the default), EDHIS computes the value automatically.

(updated: the original manual listed an "Integration Weights" option; the current dialog instead provides the Minimum Time Criterion entry described above. Note also that in the current release the two numeric entries behave as though they were interchanged, and the minimum time criterion used is always 1×10^{-7} sec regardless of the value entered — see the discrepancy note in Calculation Options for EDHIS.)

To view and edit these options, click on the menu bar *Options* option and choose *Calculation Options*.

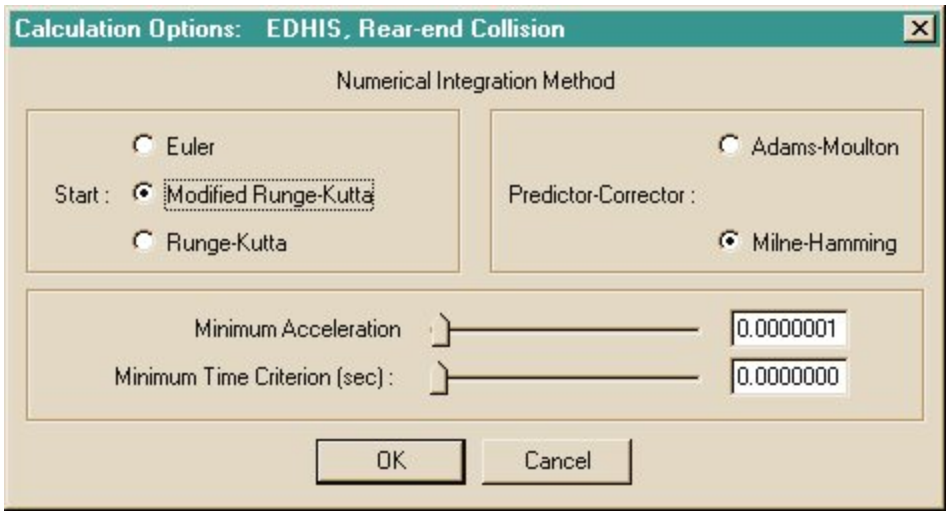


Figure 2-5: EDHIS Calculation Options dialog.

Executing An Event

To execute an EDHIS 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 2-6: Event Controller.

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

Previous: Chapter 1 — Program Description | Next: Chapter 3 — EDHIS Program Output

Chapter 3 — EDHIS Program Output

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

Overview

EDHIS produces four types of output reports:

- **Alpha-Numeric Reports** — Reports containing text and numeric information, such as vehicle dimensional parameters
- **Graphic Reports** — Reports containing static, visual data, such as vehicle damage profiles
- **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 HVE's Files menu or click on the Print icon in the toolbar. Refer to the HVE 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 EDHIS 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 HVE truncates the name to 30 characters, you should ensure that two truncated names are not the same.

1. Click *OK* to display the report.

Alpha-Numeric Reports

EDHIS produces the following alpha-numeric reports:

- **Messages** — A list of messages produced by the current run
- **Accident History** — A table of initial and final positions and velocities
- **Event Data** — A series of tables of the collision pulse, contact inhibition, airbag and belt data
- **Human Data** — A series of tables containing the human data used by EDHIS

- **Injury Data** — A table containing the injury tolerances, followed by a table containing values exceeding the allowable tolerances during the current run
- **Vehicle Data** — A series of tables containing the vehicle data used by EDHIS
- **Program Data** — A table containing program control information for the current run

An example of each of these numeric output reports from EDHIS is shown below.

Messages

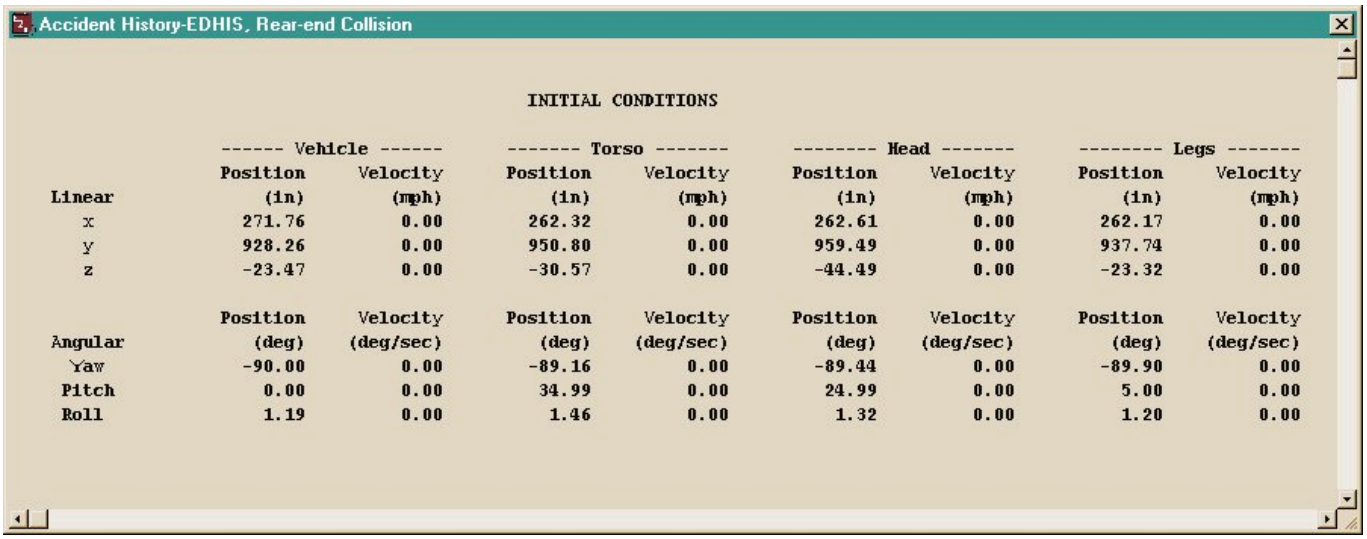
A typical Messages Report simply lists any messages produced by the run (often "No Messages"). For a complete listing of messages issued by EDHIS, see Chapter 6.



Figure 3-1: Typical Messages Report issued by EDHIS.

Accident History

The Accident History Report displays a table of initial and final positions and velocities for the human and vehicle. The table includes linear position (x, y, z, in) and velocity (mph) columns and angular position (deg: yaw, pitch, roll) and velocity (deg/sec) rows for the Vehicle and for the human Torso, Head and Legs segments.



	------ Vehicle ------		------- Torso -------		-------- Head -------		-------- Legs -------	
Linear	Position (in)	Velocity (mph)	Position (in)	Velocity (mph)	Position (in)	Velocity (mph)	Position (in)	Velocity (mph)
x	271.76	0.00	262.32	0.00	262.61	0.00	262.17	0.00
y	928.26	0.00	950.80	0.00	959.49	0.00	937.74	0.00
z	-23.47	0.00	-30.57	0.00	-44.49	0.00	-23.32	0.00
Angular	Position (deg)	Velocity (deg/sec)	Position (deg)	Velocity (deg/sec)	Position (deg)	Velocity (deg/sec)	Position (deg)	Velocity (deg/sec)
Yaw	-90.00	0.00	-89.16	0.00	-89.44	0.00	-89.90	0.00
Pitch	0.00	0.00	34.99	0.00	24.99	0.00	5.00	0.00
Roll	1.19	0.00	1.46	0.00	1.32	0.00	1.20	0.00

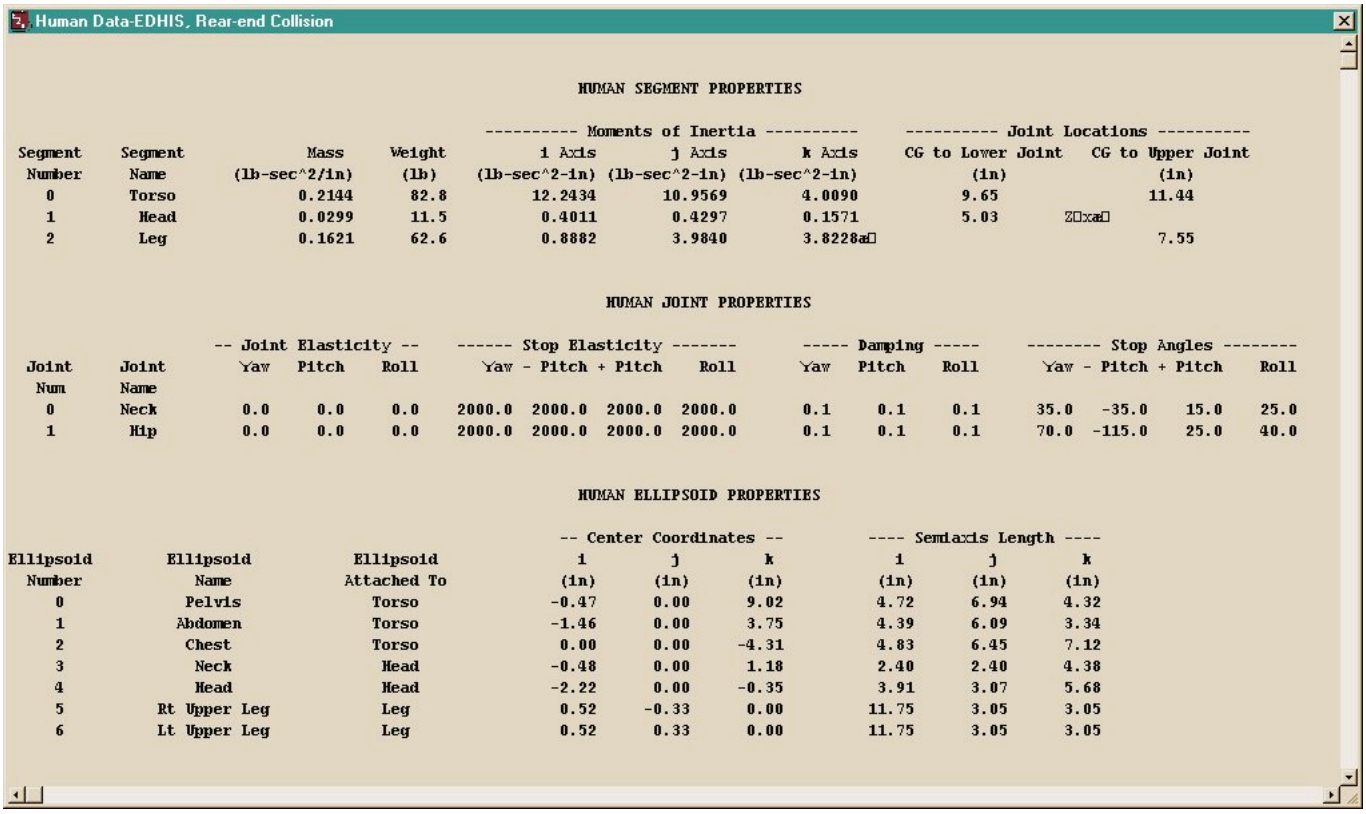
Figure 3-2: Typical Accident History Report issued by EDHIS.

Human Data

The Human Data Report includes the following information:

- **Segment Properties** — Inertial properties and joint locations for the Head, Torso and Leg segments.

- **Joint Properties** — Elastic, damping and stop angles for the Neck and Hip joints
- **Ellipsoid Properties** — Name, Segment, center coordinates and semi-axis lengths for each human ellipsoid



Human Data-EDHIS, Rear-end Collision

HUMAN SEGMENT PROPERTIES

Segment Number	Segment Name	Mass (lb-sec^2/in)	Weight (lb)	Moments of Inertia i Axis (lb-sec^2-in)	Moments of Inertia j Axis (lb-sec^2-in)	Moments of Inertia k Axis (lb-sec^2-in)	Joint Locations CG to Lower Joint (in)	Joint Locations CG to Upper Joint (in)
0	Torso	0.2144	82.8	12.2434	10.9569	4.0090	9.65	11.44
1	Head	0.0299	11.5	0.4011	0.4297	0.1571	5.03	
2	Leg	0.1621	62.6	0.8882	3.9840	3.8228		7.55

HUMAN JOINT PROPERTIES

Joint Num	Joint Name	Joint Elasticity Yaw	Joint Elasticity Pitch	Joint Elasticity Roll	Stop Elasticity Yaw -	Stop Elasticity Pitch +	Stop Elasticity Pitch +	Stop Elasticity Roll	Damping Yaw	Damping Pitch	Damping Roll	Stop Angles Yaw -	Stop Angles Pitch +	Stop Angles Pitch +	Stop Angles Roll
0	Neck	0.0	0.0	0.0	2000.0	2000.0	2000.0	2000.0	0.1	0.1	0.1	35.0	-35.0	15.0	25.0
1	Hip	0.0	0.0	0.0	2000.0	2000.0	2000.0	2000.0	0.1	0.1	0.1	70.0	-115.0	25.0	40.0

HUMAN ELLIPSOID PROPERTIES

Ellipsoid Number	Ellipsoid Name	Ellipsoid Attached To	Center Coordinates i (in)	Center Coordinates j (in)	Center Coordinates k (in)	Semiaxis Length i (in)	Semiaxis Length j (in)	Semiaxis Length k (in)
0	Pelvis	Torso	-0.47	0.00	9.02	4.72	6.94	4.32
1	Abdomen	Torso	-1.46	0.00	3.75	4.39	6.09	3.34
2	Chest	Torso	0.00	0.00	-4.31	4.83	6.45	7.12
3	Neck	Head	-0.48	0.00	1.18	2.40	2.40	4.38
4	Head	Head	-2.22	0.00	-0.35	3.91	3.07	5.68
5	Rt Upper Leg	Leg	0.52	-0.33	0.00	11.75	3.05	3.05
6	Lt Upper Leg	Leg	0.52	0.33	0.00	11.75	3.05	3.05

Figure 3-3: Typical Human Data Report issued by EDHIS.

Event Data

- **Collision Pulse** — Linear and angular acceleration pulse applied to the vehicle.
- **Contact Inhibitions** — Ellipsoid-to-Contact Surface contacts that are inhibited during the event.
- **Airbag Event History** — Airbag inflation, contact, and collapse parameters and steering column collapse parameters
- **Belt Event History** — Belt attachment points, slack, and contacts

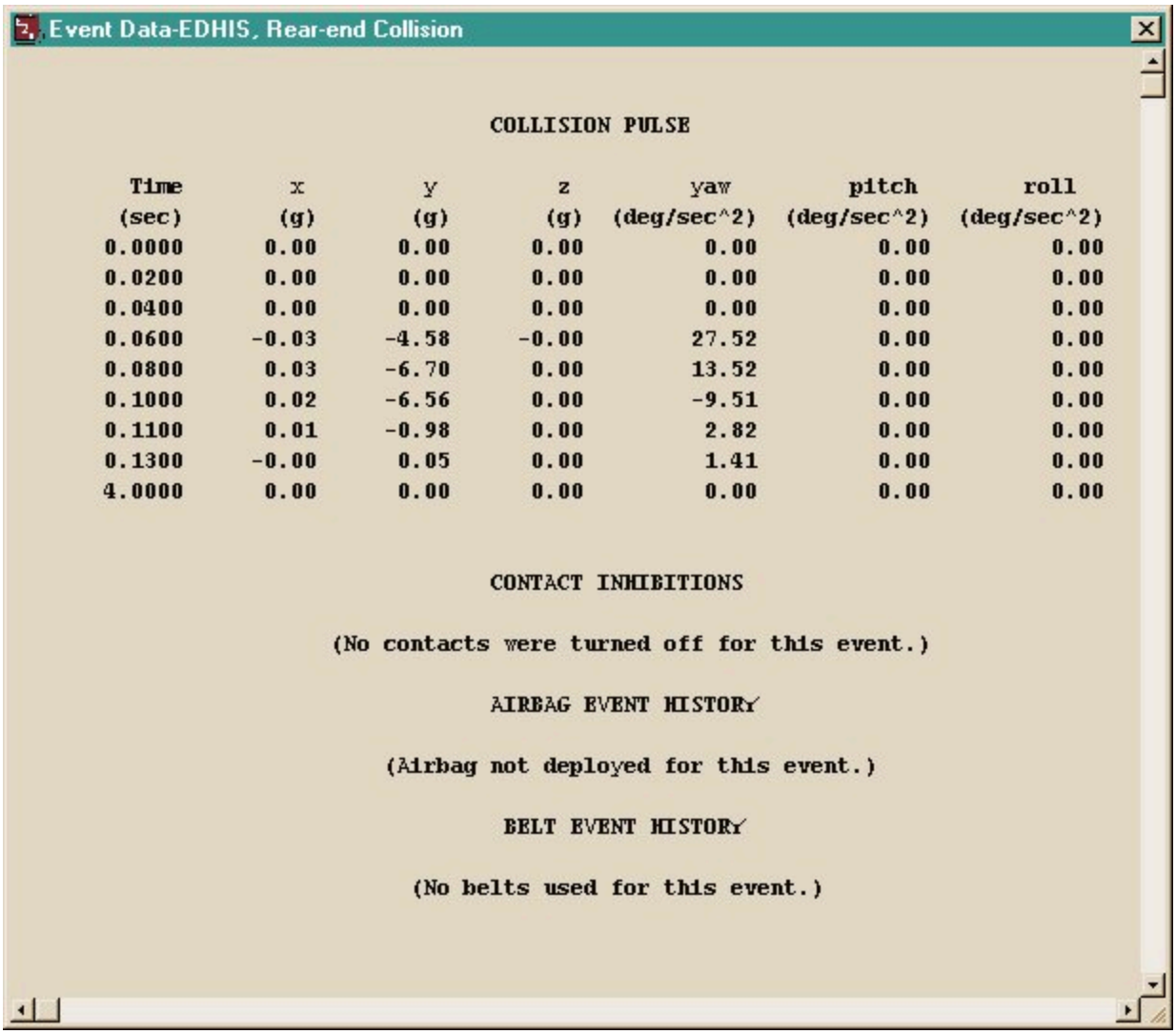


Figure 3-4: Typical Event Data Report issued by EDHIS.

Injury Data

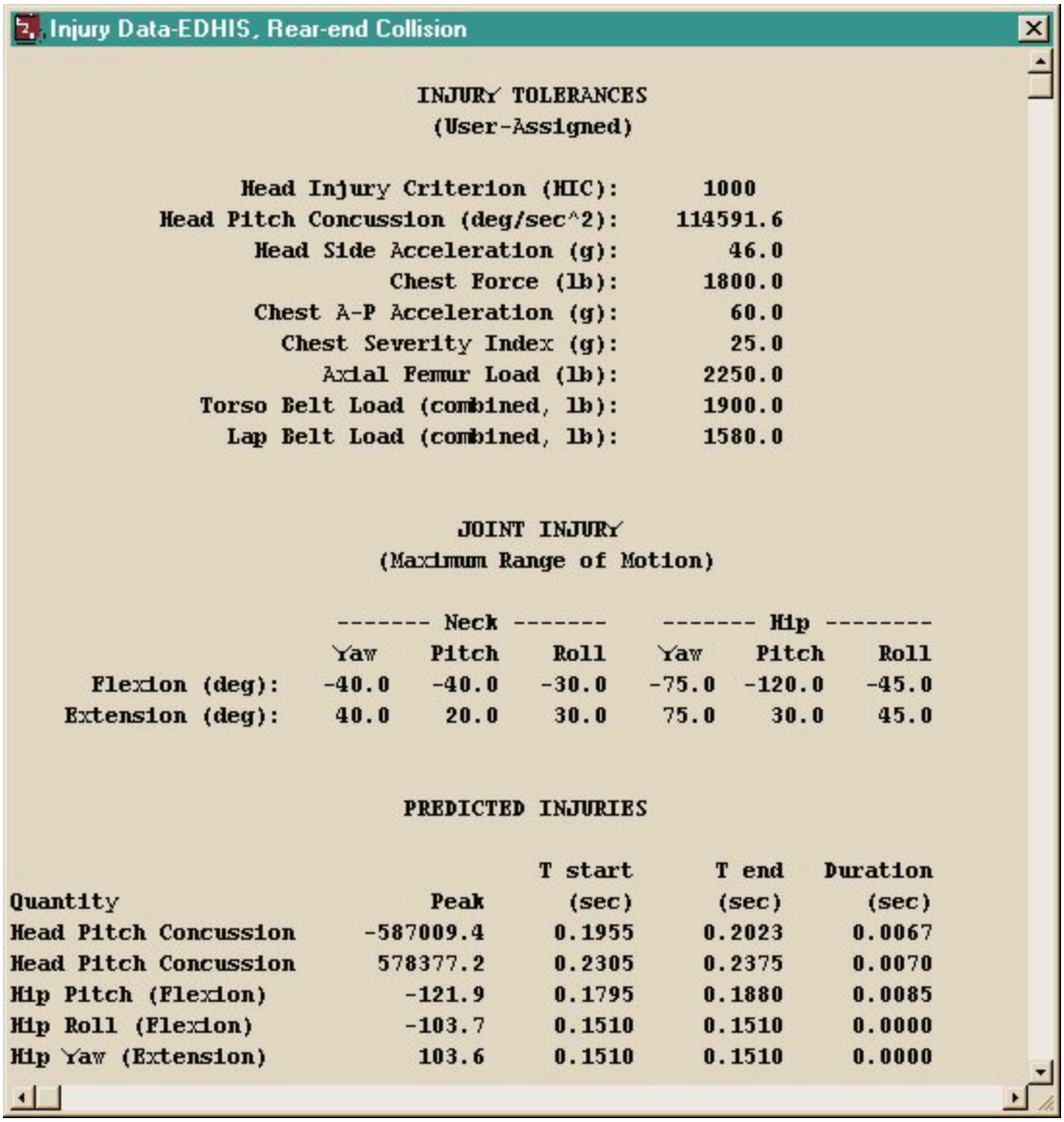
The Injury Data Report includes the following information:

- **User-assigned Injury Tolerances** — Human tolerances to impact injury.
- **User-assigned Joint Range** — Human range of normal motion for the Neck and Hip joints
- **Predicted Injuries** — Table of injury tolerances that were exceeded, the maximum value achieved, and the time interval during which the value exceeded the tolerance.

The tolerances listed include Head Injury Criterion (HIC), Head Pitch Concussion (deg/sec²), Head Side Acceleration (g), Chest Force (lb), Chest A-P Acceleration (g), Chest Severity Index, Axial Femur Load (lb), Torso Belt Load (combined, lb) and Lap Belt Load (combined, lb).

(updated: in the current human model the torso and lap belt tolerances are held separately for the left and right belt sections, rather than as the single combined values shown in the original report figure.)

> **NOTE:** Three of these headings are narrower than their names suggest, and Chapter 4 gives the quantity behind each one. In summary: *Head Injury Criterion* is a Gadd severity index accumulated over the whole run from the fore-aft component of head acceleration, not the FMVSS 208 sliding-window HIC; *Chest Severity Index* is the superior-inferior (vertical) chest acceleration, not a severity index; and *Axial Femur Load* is the largest contact force on the knee ellipsoid, not a load computed within the femur. Compare each reported value against the tolerance carried by the human, which is expressed on the same basis. The Joint Injury table lists maximum range of motion (flexion and extension, in degrees) for yaw, pitch and roll of the Neck and Hip joints. The Predicted Injuries table lists each exceeded quantity, its peak value, and the start time, end time and duration of the interval during which the tolerance was exceeded.



Injury Data-EDHIS, Rear-end Collision

INJURY TOLERANCES
(User-Assigned)

Head Injury Criterion (HIC):	1000
Head Pitch Concussion (deg/sec^2):	114591.6
Head Side Acceleration (g):	46.0
Chest Force (lb):	1800.0
Chest A-P Acceleration (g):	60.0
Chest Severity Index (g):	25.0
Axial Femur Load (lb):	2250.0
Torso Belt Load (combined, lb):	1900.0
Lap Belt Load (combined, lb):	1580.0

JOINT INJURY
(Maximum Range of Motion)

	Neck			Hip		
	Yaw	Pitch	Roll	Yaw	Pitch	Roll
Flexion (deg):	-40.0	-40.0	-30.0	-75.0	-120.0	-45.0
Extension (deg):	40.0	20.0	30.0	75.0	30.0	45.0

PREDICTED INJURIES

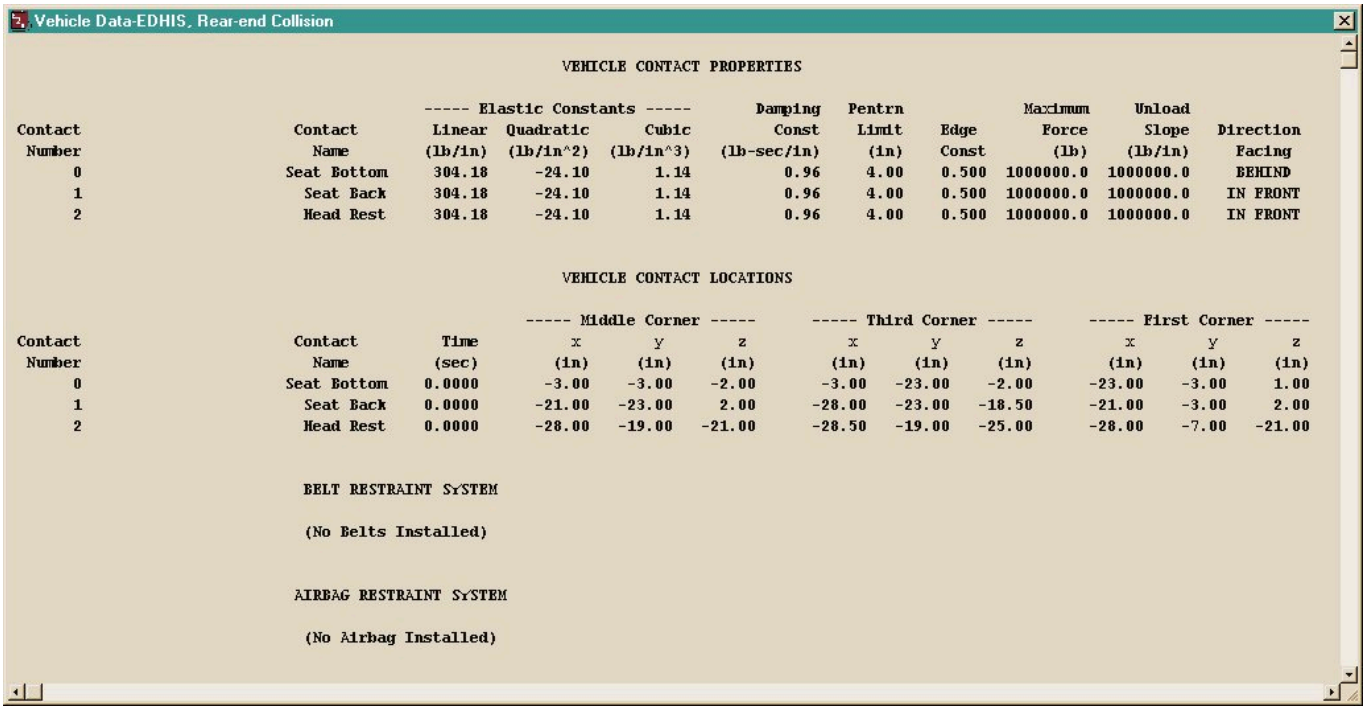
Quantity	Peak	T start (sec)	T end (sec)	Duration (sec)
Head Pitch Concussion	-587009.4	0.1955	0.2023	0.0067
Head Pitch Concussion	578377.2	0.2305	0.2375	0.0070
Hip Pitch (Flexion)	-121.9	0.1795	0.1880	0.0085
Hip Roll (Flexion)	-103.7	0.1510	0.1510	0.0000
Hip Yaw (Extension)	103.6	0.1510	0.1510	0.0000

Figure 3-5: Typical Injury Data Report issued by EDHIS.

Vehicle Data

The Vehicle Data Report includes the following information:

- **Contact Surface Properties** — Name, elastic and damping properties, penetration limit, edge constant, maximum force, unloading slope and relative initial position of the human with respect to the contact surface.
- **Contact Surface Location** — Name and corner coordinates for each contact surface.
- **Belt Restraints** — If in use, this section displays the name, location and mechanical properties for each installed belt segment. In addition, this section also displays the human attachment point and initial belt slack.
- **Airbag Restraints** — If in use, this section displays the location, mechanical and thermodynamic properties of the airbag, as well as its deployment time and fill duration.



Vehicle Data-EDHIS, Rear-end Collision

VEHICLE CONTACT PROPERTIES

Contact Number	Contact Name	Elastic Constants – Linear (lb/in)	Elastic Constants – Quadratic (lb/in^2)	Elastic Constants – Cubic (lb/in^3)	Damping Const (lb-sec/in)	Pentrn Limit (in)	Edge Const	Maximum Force (lb)	Unload Slope (lb/in)	Direction Facing
0	Seat Bottom	304.18	-24.10	1.14	0.96	4.00	0.500	1000000.0	1000000.0	BEHIND
1	Seat Back	304.18	-24.10	1.14	0.96	4.00	0.500	1000000.0	1000000.0	IN FRONT
2	Head Rest	304.18	-24.10	1.14	0.96	4.00	0.500	1000000.0	1000000.0	IN FRONT

VEHICLE CONTACT LOCATIONS

Contact Number	Contact Name	Time (sec)	Middle Corner x (in)	Middle Corner y (in)	Middle Corner z (in)	Third Corner x (in)	Third Corner y (in)	Third Corner z (in)	First Corner x (in)	First Corner y (in)	First Corner z (in)
0	Seat Bottom	0.0000	-3.00	-3.00	-2.00	-3.00	-23.00	-2.00	-23.00	-3.00	1.00
1	Seat Back	0.0000	-21.00	-23.00	2.00	-28.00	-23.00	-18.50	-21.00	-3.00	2.00
2	Head Rest	0.0000	-28.00	-19.00	-21.00	-28.50	-19.00	-25.00	-28.00	-7.00	-21.00

BELT RESTRAINT SYSTEM

(No Belts Installed)

AIRBAG RESTRAINT SYSTEM

(No Airbag Installed)

Figure 3-6: Typical Vehicle Data Report issued by EDHIS.

Program Data

The Program Data Report includes the following information:

- **Simulation Controls** — Integration parameters used for the current event
- **Collision Pulse** — The acceleration vs time history for the current event.
- **Contacts** — A list of all human ellipsoid vs vehicle contact surface interactions that were ignored for the current event.

The General Information section reports the EDHIS Version Number. The Simulation Controls section reports Max Simulation Time, Max Timestep, Output Interval, Starting Method, Predictor-Corrector Method, Velocity Change Limit, Acceleration Change Limit, Min Acceleration, Velocity Convergence Criterion, Maximum Bisections and Time Epsilon.

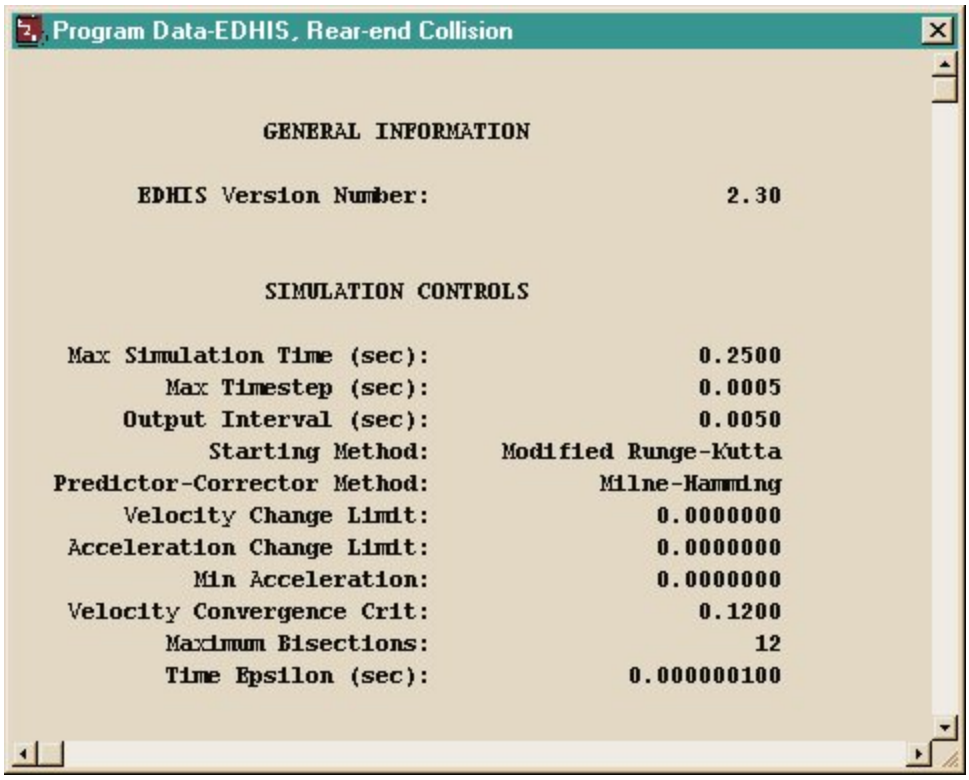


Figure 3-7: Typical Program Data Report issued by EDHIS.

Graphic Reports

EDHIS 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

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

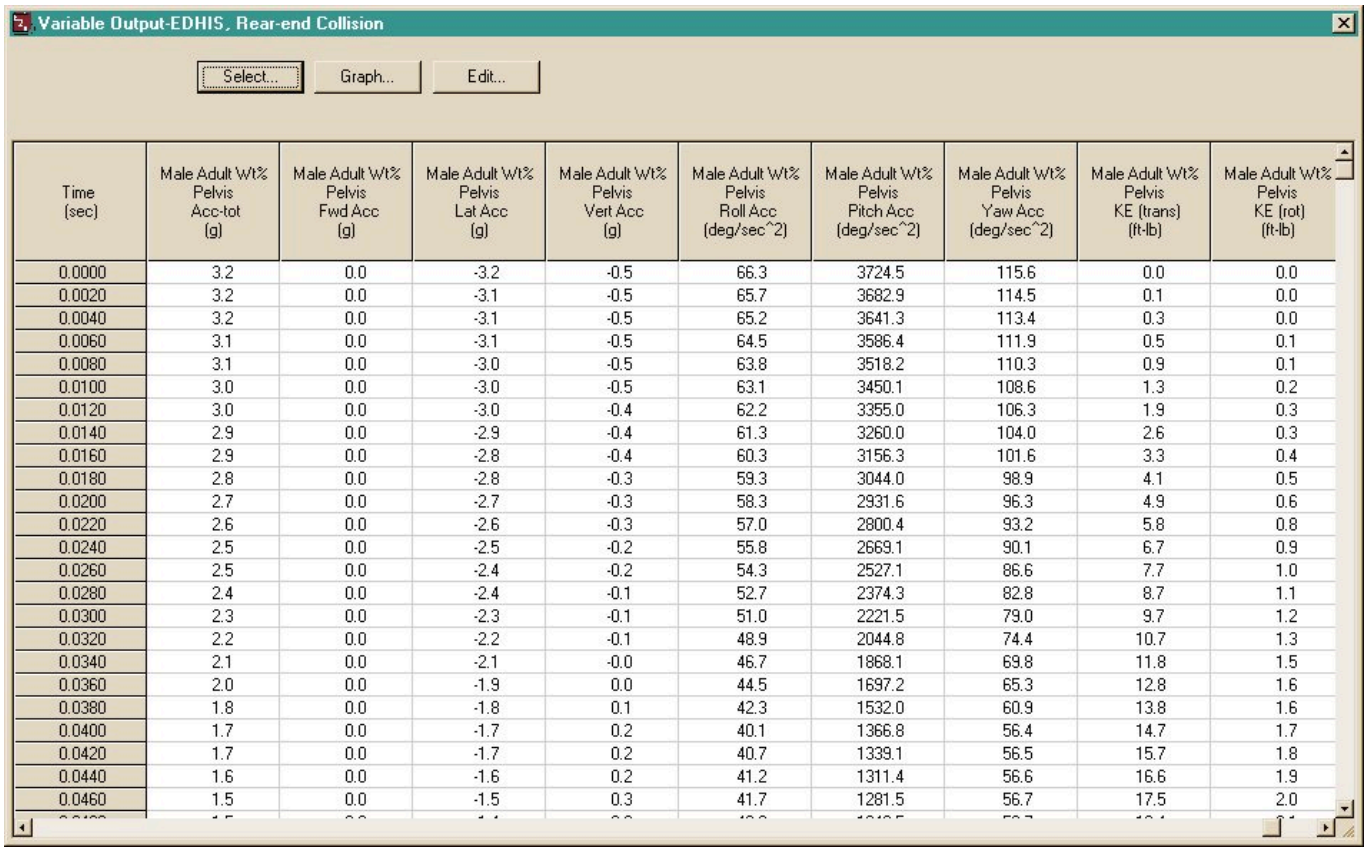
Human Output Groups

- **Human Kinematics** — Position, velocity, acceleration and kinetic energy for each human segment
- **Joints** — Articulation angles and torque for the Neck and Hip joints
- **Contacts** — Contact force, deflection and x,y contact coordinate for each human ellipsoid vs vehicle contact impingement
- **Belts** — Belt tension and stretch for each belt segment
- **Airbag** — Airbag pressure, radius, contact force and deflection

Vehicle Output Groups

- **Vehicle Kinematics** — Position, velocity and acceleration for the vehicle
- **Wheel** — The position of each wheel (required only to visualize the wheels during an event; not used in the calculations)
- **Contacts** — Contact force, deflection and x,y contact coordinate for each human ellipsoid vs vehicle contact impingement
- **Belts** — Belt tension and stretch for each belt segment
- **Airbag** — Airbag pressure, radius, contact force and deflection

> **NOTE:** The Contacts, Belts and Airbag results for Human and Vehicle output groups are identical (Newton's 3rd law at work!)



Time (sec)	Male Adult Wt% Pelvis Acc-tot (g)	Male Adult Wt% Pelvis Fwd Acc (g)	Male Adult Wt% Pelvis Lat Acc (g)	Male Adult Wt% Pelvis Vert Acc (g)	Male Adult Wt% Pelvis Roll Acc (deg/sec^2)	Male Adult Wt% Pelvis Pitch Acc (deg/sec^2)	Male Adult Wt% Pelvis Yaw Acc (deg/sec^2)	Male Adult Wt% Pelvis KE (trans) (ft-lb)	Male Adult Wt% Pelvis KE (rot) (ft-lb)
0.0000	3.2	0.0	-3.2	-0.5	66.3	3724.5	115.6	0.0	0.0
0.0020	3.2	0.0	-3.1	-0.5	65.7	3682.9	114.5	0.1	0.0
0.0040	3.2	0.0	-3.1	-0.5	65.2	3641.3	113.4	0.3	0.0
0.0060	3.1	0.0	-3.1	-0.5	64.5	3586.4	111.9	0.5	0.1
0.0080	3.1	0.0	-3.0	-0.5	63.8	3518.2	110.3	0.9	0.1
0.0100	3.0	0.0	-3.0	-0.5	63.1	3450.1	108.6	1.3	0.2
0.0120	3.0	0.0	-3.0	-0.4	62.2	3355.0	106.3	1.9	0.3
0.0140	2.9	0.0	-2.9	-0.4	61.3	3260.0	104.0	2.6	0.3
0.0160	2.9	0.0	-2.8	-0.4	60.3	3156.3	101.6	3.3	0.4
0.0180	2.8	0.0	-2.8	-0.3	59.3	3044.0	98.9	4.1	0.5
0.0200	2.7	0.0	-2.7	-0.3	58.3	2931.6	96.3	4.9	0.6
0.0220	2.6	0.0	-2.6	-0.3	57.0	2800.4	93.2	5.8	0.8
0.0240	2.5	0.0	-2.5	-0.2	55.8	2669.1	90.1	6.7	0.9
0.0260	2.5	0.0	-2.4	-0.2	54.3	2527.1	86.6	7.7	1.0
0.0280	2.4	0.0	-2.4	-0.1	52.7	2374.3	82.8	8.7	1.1
0.0300	2.3	0.0	-2.3	-0.1	51.0	2221.5	79.0	9.7	1.2
0.0320	2.2	0.0	-2.2	-0.1	48.9	2044.8	74.4	10.7	1.3
0.0340	2.1	0.0	-2.1	-0.0	46.7	1868.1	69.8	11.8	1.5
0.0360	2.0	0.0	-1.9	0.0	44.5	1697.2	65.3	12.8	1.6
0.0380	1.8	0.0	-1.8	0.1	42.3	1532.0	60.9	13.8	1.6
0.0400	1.7	0.0	-1.7	0.2	40.1	1366.8	56.4	14.7	1.7
0.0420	1.7	0.0	-1.7	0.2	40.7	1339.1	56.5	15.7	1.8
0.0440	1.6	0.0	-1.6	0.2	41.2	1311.4	56.6	16.6	1.9
0.0460	1.5	0.0	-1.5	0.3	41.7	1281.5	56.7	17.5	2.0

Figure 3-8: Variable Output dialog.

A detailed listing of each Variable Output parameter produced by EDHIS is found in Tables 3-1 and 3-2.

Table 3-1 — Human Variable Output Data

Parameter	Description
Human Kinematic Data (for Hip, Head and Leg segments)	x, y, z coordinates; ϕ, θ, ψ angles; total velocity, fwd, side, vert components; $\dot{\phi}, \dot{\theta}, \dot{\psi}$ angular velocities; total acceleration, fwd, side, vert components; $\ddot{\phi}, \ddot{\theta}, \ddot{\psi}$ angular accelerations (see note below)
Joint Data (for Neck and Hip joints)	ϕ, θ, ψ joint articulation angles; ϕ, θ, ψ joint elastic moments
Contact Data (for each human ellipsoid and vehicle contact surface)	Contact surface x,y contact coordinate; Contact Normal Force; Contact deflection
Belts (for each belt section)	Belt tension and stretch
Airbag	Airbag pressure, radius; Airbag contact force, deflection

> **NOTE:** For human occupants, the human segment kinematics are defined relative to the vehicle-fixed coordinate system; for human pedestrians, the segment kinematics are defined relative to the earth-fixed coordinate system.

Table 3-2 — 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, course angles; p, q, r angular velocity; total linear accel, fwd, side, vert components; $\dot{u}, \dot{v}, \dot{w}$ linear components; $\dot{p}, \dot{q}, \dot{r}$ angular components
Wheel Data	x, y, z location of each wheel
Contact Data (for each human ellipsoid and vehicle contact surface)	Contact surface x,y contact coordinate; Contact Normal Force; Contact deflection
Belts (for each belt section)	Belt tension and stretch
Airbag	Airbag pressure, radius; Airbag contact force, deflection

Trajectory Simulations

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

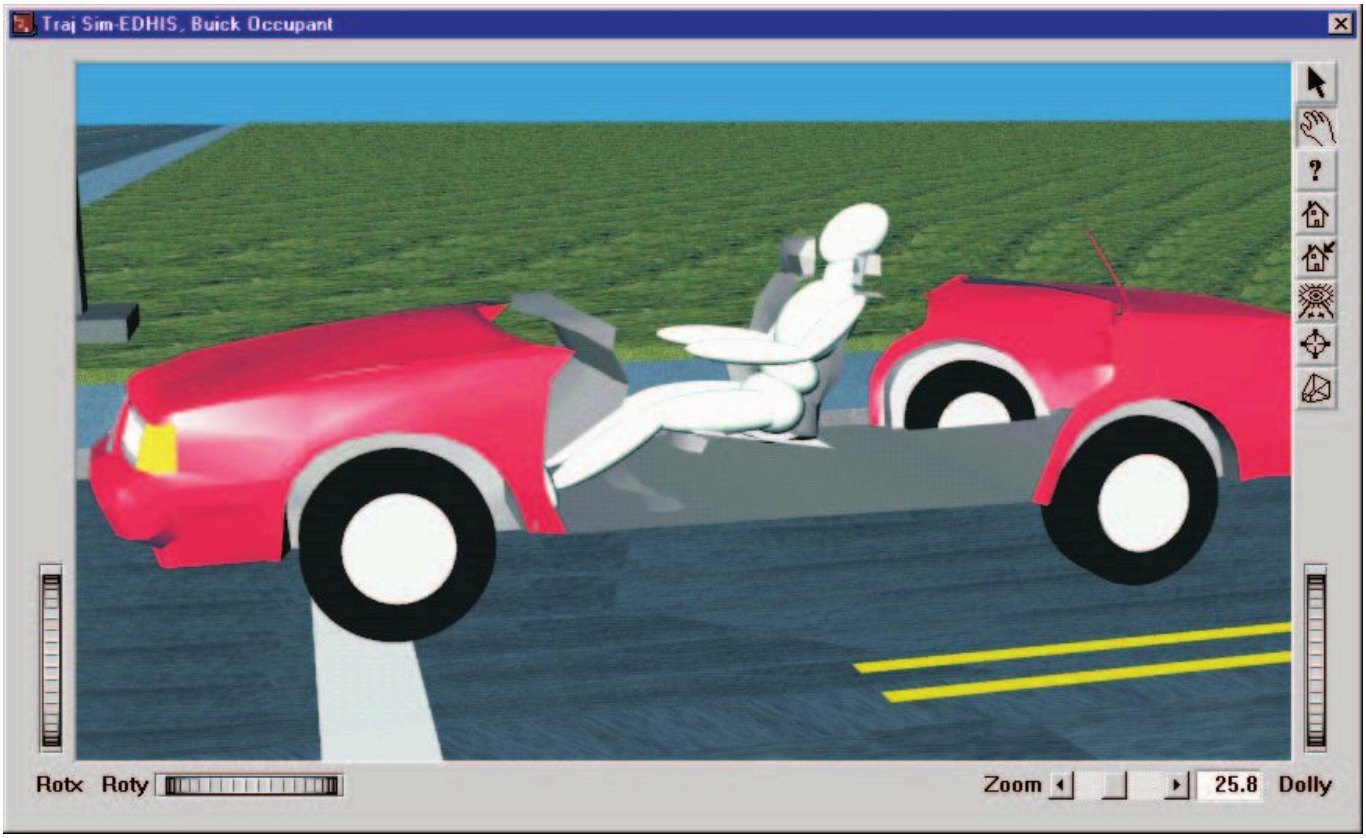


Figure 3-9: EDHIS Trajectory simulation.

Displaying a Trajectory Simulation

The Trajectory Simulation is controlled using the Playback Controller.



Figure 3-10: Playback Controller.

The Playback Controller's buttons have the following functions:

- **Reset** — Returns to the start of the simulation and reinitialize the video output device (this applies a hardware reset and is otherwise the same as the *Rewind to Start* button, below).
- **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

> **NOTE:** The Playback Controller also includes additional features used for creating video. Refer to the HVE User's Manual, Playback Editor and Video Output sections, for further details.

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

Chapter 4 — Calculation Method

In the original Fifth Edition manual this chapter was marked

(Reserved For Future Use)

.

> **NOTE:** See Reference 2 (Robbins, Bennett & Bowman, *User-Oriented Mathematical Crash Victim Simulator*, HSRI, University of Michigan) for the original derivation of the model on which EDHIS is based — see Chapter 7 — References. The description below documents what the current EDHIS engine computes.

Basis for Analysis

EDHIS is a rigid-body simulation of an occupant inside a vehicle whose motion is prescribed. The occupant is a three-segment, two-joint body with twelve degrees of freedom, derived from the HSRI-3D crash victim simulator. The vehicle itself is **not** simulated: its motion comes from the collision pulse the user supplies, so EDHIS solves only for the occupant's response to that pulse.

At each timestep the program locates contact between the occupant's ellipsoids and the vehicle's contact surfaces, evaluates the resulting forces, adds joint, belt, airbag and gravity effects, and solves for the segment accelerations.

The Human Model

Condensing the HVE human to three segments

HVE's human is a 15-segment model. EDHIS uses three segments — **head**, **torso** and **legs** — so the HVE segments are lumped into those three. Masses add directly, and the moments of inertia are transferred to the EDHIS segment reference using the parallel axis theorem:

$$I = \sum_{i} (I_i + m_i \, d_i^2)$$

where d_i is the distance from each contributing segment's centre of mass to the EDHIS segment reference. The transfer is applied to the pitch and roll axes; the yaw axis is left as the direct sum of the contributing inertias.

Each EDHIS segment carries up to 25 contact ellipsoids in total across the body, which are the geometry actually tested against the vehicle interior.

Equations of Motion

The model is formulated in generalized coordinates. Writing $\mathbf{q}$ for the twelve generalized coordinates, the equations of motion are assembled as a mass matrix acting on the generalized accelerations, balanced against the sum of the generalized forces:

$$\mathbf{M}(\mathbf{q})\,\ddot{\mathbf{q}} = \mathbf{Q}_{Inertial} + \mathbf{Q}_{Contact} + \mathbf{Q}_{Joint} + \mathbf{Q}_{Gravity} + \mathbf{Q}_{Belt}$$

where

Term	Meaning
$\mathbf{M}(\mathbf{q})$	Generalized mass matrix. Part of it is constant; the remainder depends on the current joint angles and is rebuilt every timestep.
$\mathbf{Q}_{Inertial}$	Coriolis and centrifugal terms arising from the rotating segment frames
$\mathbf{Q}_{Contact}$	Contact surface forces, including airbag forces
$\mathbf{Q}_{Joint}$	Neck and hip joint torques
$\mathbf{Q}_{Gravity}$	Segment weights
$\mathbf{Q}_{Belt}$	Belt and harness tensions

The system is solved for $\ddot{\mathbf{q}}$ each timestep by Gaussian elimination. A singular mass matrix is a fatal error and terminates the run.

> **NOTE:** Where the **Minimum Acceleration** calculation option is non-zero, any generalized acceleration whose magnitude falls below it is set to zero before integration. This suppresses numerical noise in a body at rest; setting it too high will suppress real response. In the current release the threshold is taken from the value entered as *Minimum Time Criterion* — see Calculation Options for EDHIS.

Contact Forces

Detecting contact

Each of the occupant's ellipsoids is tested every timestep against each vehicle contact surface. A surface is a plane bounded by its four corner coordinates. Where an ellipsoid has passed through that plane, the **penetration**, δ, is the depth of the intrusion measured along the surface normal.

Two further tests decide whether a penetration develops any force.

Which side the occupant came from. Each ellipsoid/surface pair records the side from which contact was made. If, at a step where front-side contact has not already been established, the ellipsoid lies behind the plane by more than the surface's **maximum penetration**, the pair is marked as approached from the back and no force is computed. That status is permanent for the pair, so a surface the occupant began behind never pushes them forward — which is what allows surfaces to be placed around the occupant without trapping them.

Where the contact falls on the surface. The contact point is expressed as two dimensionless coordinates s and r, each running from 0 at one edge of the plane to 1 at the opposite edge. The surface's **edge constant**, ε, is also dimensionless and defines a border of that width inside and outside each edge:

- If either coordinate lies outside $[-\varepsilon,\ 1+\varepsilon]$ the contact is off the surface altogether and no force is computed.
- If both lie in the interior, $[\varepsilon,\ 1-\varepsilon]$, the full force is applied.
- In the border, the force is scaled by a factor falling linearly from 1 at the inner boundary to 0 at the outer one, evaluated independently in each direction:

$$k_s = \frac{s+\varepsilon}{2\varepsilon}\ (s < 0.5), \qquad k_s = \frac{1+\varepsilon-s}{2\varepsilon}\ (s \geq 0.5)$$

with k_r formed the same way from r. The contact force computed below is multiplied by $k_s\ k_r$. The effect is that an ellipsoid sliding off the edge of a surface loses its force gradually rather than having it vanish in one timestep, which would otherwise show up as a spike in the accelerations.

> **NOTE:** The edge constant scales the force; it does not alter the penetration. A larger edge constant therefore widens the taper — it softens the surface near its boundary and extends the surface's reach slightly beyond its corner coordinates, but it does not change the force developed in the middle of the surface.

The force-deflection law

While the penetration is increasing, the contact force is a cubic in the penetration depth plus a damping term proportional to the penetration rate:

$$F = C_3\,\delta^3 + C_2\,\delta^2 + C_1\,\delta + C_d\,\dot{\delta}\ \min(\delta, 1)$$

where C_1, C_2 and C_3 are the surface's linear, quadratic and cubic force coefficients and C_d is its rate damping coefficient.

The $\min(\delta, 1)$ on the damping term is important to understand: the damping contribution is faded in linearly over the first inch of penetration and is at full strength thereafter. Without it, a contact that begins at a high closing speed would produce a force discontinuity at the instant of touch.

The force is limited to the surface's **maximum force**; once that value is reached the surface is treated as saturated and the force is held there.

Unloading and permanent deformation

When the penetration rate becomes negative after saturation, the force does not retrace the loading curve. It falls along a straight line of the user-entered **unloading slope**, drawn through the point at which saturation occurred:

$$F = F_{Max} + S(\delta - \delta_{Max})$$

where S is the unloading slope and δ_{Max} the penetration at saturation. The line reaches zero force at

$$\delta_0 = \delta_{Max} - \frac{F_{Max}}{S}$$

and δ_0 is the permanent deformation left in the surface: below it no force is developed, and a later contact at that location begins from the deformed shape rather than the original one. A negative permanent deformation is not physically meaningful and is reported as a fatal error.

Where no maximum force and unloading slope are entered, the surface is fully elastic and unloads back down the cubic loading curve.

Joint Torques

Each of the two joints — neck and hip — is a ball-and-socket carrying a torque about each of its three axes. The total is an elastic term plus a joint-stop term:

$$T = T_{Elastic} + T_{Stop}$$

The elastic term is a linear spring referred to the joint's **initial** angle, so an undisturbed occupant is in equilibrium:

$$T_{Elastic} = k(\theta_{Initial} - \theta)$$

The joint stop acts only once the joint has rotated past its permitted range. Writing θ_{Stop} for that limit and

$$\varepsilon = |\theta| - \theta_{Stop}$$

for the amount of over-rotation, the stop contributes nothing while $\varepsilon \le 0$, and while $\varepsilon > 0$,

$$T_{Stop} = -k_{Stop}\,\varepsilon\,\operatorname{sgn}\theta - c\,\dot{\theta}\,\min\left(\frac{\varepsilon}{0.1},\,1\right)$$

where k_{Stop} is the joint-stop elasticity and c the joint damping. As with the contact damping, the damping contribution is faded in — here over the first 0.1 radian of over-rotation — so that the stop engages smoothly.

A sign test is applied afterwards: if the damping term is large enough to reverse the sign of the total stop torque, the stop torque is set to zero instead. A joint stop can therefore resist over-rotation but can never drive the joint.

> **NOTE:** The pitch axis is treated asymmetrically, because flexion and extension of the neck and hip are not symmetric. It carries two separate limits with their own stop elasticities — one reached in positive rotation and one in negative — while the yaw and roll axes use a single limit applied to the magnitude of the angle.

The joint torques enter the equations of motion as generalized forces through the joint articulation geometry:

$$\mathbf{Q}_{Joint} = \sum_{Joints}\ \sum_{Axes} T\,\frac{\partial\theta}{\partial\mathbf{q}}$$

Vehicle Motion

The vehicle is not simulated. Its six acceleration components come from the user's collision pulse table, and within each table interval the acceleration is taken to vary linearly with time — that is, at constant jerk. Integrating that assumption gives the vehicle's velocity and position directly:

$$a(t) = a_0 + \dot{a}\,t$$

$$v(t) = v_0 + a_0\,t + \tfrac{1}{2}\dot{a}\,t^2$$

$$s(t) = s_0 + v_0\,t + \tfrac{1}{2}a_0\,t^2 + \tfrac{1}{6}\dot{a}\,t^3$$

where t is measured from the start of the current table interval and $\dot{a}$ is the slope of the acceleration across it. Each of the six components is scaled independently by its own pulse factor before integration, which is what the pulse scaling controls in the Event Editor adjust.

Belts

A belt segment runs between an anchor on the vehicle and a point on the occupant. Its **initial length** is the geometric length at the start of the run plus the user-entered slack, so a belt with slack develops no tension until the occupant has moved far enough to take the slack up. The **stretch** is the amount by which the current length exceeds that initial length:

$$\delta = L - (L_0 + Slack)$$

Tension follows the same force law as a contact surface — cubic in the deformation with a rate-damping term, limited by a maximum force, and unloading along a straight line of the entered slope:

$$F = C_3\,\delta^3 + C_2\,\delta^2 + C_1\,\delta + C_d\,\dot{\delta}\ \min(\delta,\,1)$$

using the belt's own stiffness and damping coefficients. The stretch rate is the component of the relative velocity between the two ends resolved along the belt's current direction, so a belt lying slack across a moving occupant develops no damping force either.

The tension acts along the belt's direction cosines, and enters the equations of motion as a generalized force through them:

$$\mathbf{Q}_{Belt} = -\sum_{Segments} F\,\frac{\partial L}{\partial \mathbf{q}}$$

The belt angles reported in the output are the direction cosines of each segment expressed as angles.

> **NOTE:** Because belt tension uses the same law as contact, a belt also carries a permanent set: once its maximum force has been exceeded it unloads along the entered slope rather than back down the loading curve, and does not recover its original stiffness.

Airbag Model

When an airbag is specified, its inflation is **solved** alongside the occupant equations rather than prescribed. A driver bag is modelled as a sphere and a passenger bag as a cylinder of the entered length. The bag carries two state variables of its own — its internal pressure and its radius — and they are integrated on their own sub-step within each occupant timestep.

Gas state and mass balance

The gas is treated as isentropic, so its density follows the pressure:

$$\rho = \rho_0\left(\frac{P}{P_0}\right)^{1/\kappa}$$

where P is the **absolute** pressure (gauge pressure plus atmospheric) and κ the ratio of specific heats. The governing equation is conservation of mass in the bag:

$$\frac{d}{dt}(\rho V) = \dot{m}_{In} - \dot{m}_{Out}$$

Carrying out the differentiation, with the bag volume V depending on both the radius and — after contact — on how far the occupant has pushed into the bag:

$$\frac{1}{\kappa}P^{\frac{1}{\kappa}-1}V\,\dot{P} + P^{\frac{1}{\kappa}}\dot{V} = \frac{P_0^{1/\kappa}}{\rho_0}(\dot{m}_{In} - \dot{m}_{Out})$$

The inflow $\dot{m}_{In}$ is the entered mass flow rate, held constant until the gas is shut off. Shut-off occurs at whichever comes first: the bag reaching its entered maximum volume, or the end of the entered inflation time.

The vent

The vent stays closed, and the outflow is zero, while the internal pressure is below the entered **vent pressure**. Once it is exceeded, the outflow is the standard compressible orifice discharge:

$$\dot{m}_{Out} = C_d \, A_{Vent} \, \Phi \sqrt{2 \, P_{Gauge} \, \rho}$$

where C_d is the discharge coefficient, A_{Vent} the vent area and Φ the compressibility factor:

$$\Phi = \sqrt{\frac{\kappa}{\kappa - 1} \bar{P}^{\,2/\kappa} (1 - \bar{P}^{\,(\kappa-1)/\kappa}) \frac{1 - \bar{R}}{(1 - \bar{P})(1 - \bar{R}\,\bar{P}^{\,2/\kappa})}}$$

in which $\bar{P}$ is the ratio of atmospheric to absolute bag pressure and $\bar{R}$ is the fourth power of the ratio of vent radius to bag radius. The second of these is the approach-velocity correction: it matters only when the vent is not small compared with the bag.

The fabric

The second equation closing the system is the bag's own stiffness. The fabric is treated as a membrane whose stress is the entered elastic modulus times its **true** (logarithmic) strain. For the spherical driver bag the membrane stress is $PR / 2h$ and for the cylindrical passenger bag PR / h, giving

$$\frac{P\,R}{2h} = E \ln\left(\frac{R}{R_0}\right) \quad \text{(driver)}, \qquad \frac{P\,R}{h} = E \ln\left(\frac{R}{R_0}\right) \quad \text{(passenger)}$$

where h is the fabric thickness and R_0 the unstretched radius. It is the time derivative of this relation, together with the mass balance above, that is solved each sub-step for the rate of change of pressure and of radius.

Contact with the occupant

Contact begins when the torso, head or hip reaches the bag surface, allowing for half the occupant's chest depth. From that instant the bag is treated as flattened against the occupant: its radius is reduced by half the distance the torso has travelled since contact, and the diameter of the flattened patch becomes the second state variable in place of the free radius. The volume is then a sphere with a spherical cap replaced by a flat disc,

$$V = \tfrac{4}{3}\pi a^3 + \tfrac{1}{2}\pi \, a \, d^2 \quad \text{(driver)}$$

$$V = \pi a^2 L + 2 \, a \, d \, L \quad \text{(passenger)}$$

with a the current bag radius, d the contact patch dimension and L the entered bag length.

The force on the occupant is the bag pressure acting over the contact patch,

$$F = P_{Gauge} \, \frac{\pi}{4} \, d \, w$$

with w equal to d for a driver bag (a circular patch) and to the occupant's chest width for a passenger bag (an elliptical patch). This force is then faded in linearly over the entered **Bag Penetration For Force**, so that a bag which the occupant has only just touched does not apply its full pressure force at the first step:

$$F_{Applied} = F \, \min\left(\frac{\delta}{\delta_{Bag}}, 1\right)$$

and it is scaled by the same edge factors as any other contact surface.

Bottoming out and rebound

If the bag radius reaches zero the bag has **bottomed out**: the gas model no longer governs and the force rises linearly from its value at bottoming out, with the entered bottomed-out stiffness, as the occupant continues forward. Separately, once the occupant begins to move away from the bag the fabric modulus is switched to the entered **rebound** modulus, so that the bag does not return energy along its loading curve.

Where a steering column is set to collapse, the column collapse is tracked alongside, and after collapse the force decays with the remaining collapse distance.

> **NOTE:** The airbag model turns itself off, with a message, in two circumstances: if the computed bag pressure goes negative, and if the computed rates of change of pressure or radius become very large, which is taken as numerical instability. In both cases the bag stops producing force for the remainder of the run and the simulation continues without it, so any run carrying one of these messages should be re-examined — the occupant kinematics after that point are those of an unrestrained occupant. See the Vehicle Data Report for the airbag parameters in use.

Numerical Integration

Integration proceeds in two stages, both selectable in the calculation options (see Calculation Options for EDHIS).

A **starting method** generates the first few points, since a predictor-corrector method needs a history before it can run. The choices are Euler, Runge-Kutta-Ralston (the default, listed in the dialog as *Modified Runge-Kutta*) and classical fourth-order Runge-Kutta.

A **predictor-corrector method** then carries the solution forward. The choices are Adams-Bashforth/Adams-Moulton, and Milne with Hamming's modification (the default). The Hamming modification blends the predicted and corrected values rather than accepting the corrector outright, which suppresses the instability that the plain Milne corrector is prone to.

The step size is controlled by comparing the predictor against the corrector. The measure is a weighted sum, over the degrees of freedom, of the difference between the predicted and corrected velocities:

$$\varepsilon = \sum_i w_i |v_i - \hat{v}_i|$$

and it is tested against the user-entered **Velocity Convergence** parameter:

- ε **greater than** the parameter — the step is rejected, the timestep is halved and the step retried. Exceeding the allowed number of halvings ends the run with an integration error.
- ε **at or below** the parameter — the step is accepted.
- ε **at or below one fiftieth** of the parameter — the step is accepted and the timestep is then **doubled**, on the grounds that the solution is far more converged than it needs to be.

Two guards restrain the doubling: at least seven points must have been accepted at the current step size, and the doubled step must not skip past the next output time. The effective timestep therefore contracts sharply through a hard contact and relaxes again afterwards, without the output interval drifting.

The two change limits

Before the corrector is evaluated, two further stability tests are applied. Either one, if failed, halves the timestep and retries the step in exactly the same way as a convergence failure; neither one stops the run.

The first compares the velocity change implied by the current accelerations over the current step against the **Acceleration Change Limit**:

$$\Delta t \sum_i w_i |a_i| > Limit_{Accel} \;\Rightarrow\; \text{halve}$$

The second compares the current accelerations against a four-point extrapolation of them, and so measures how far the acceleration is departing from a smooth curve. Writing $\tilde{a}$ for the extrapolated value, the step is halved when

$$\sum_i w_i |\tilde{a}_i - a_i| > Limit_{Vel} \quad \text{and} \quad \frac{\sum_i w_i |\tilde{a}_i - a_i|}{\sum_i w_i |a_i|} > Limit_{Vel}$$

that is, both the absolute departure and its size relative to the accelerations themselves must exceed the **Velocity Change Limit**. Entering zero for either limit turns that test off.

> **NOTE:** Both parameters are stability tolerances rather than physical limits, and the quantity each is compared against — given by the equations above — is not the one its name would suggest. Use the equations, not the names, when choosing values: tighten a limit if a run shows a sudden unphysical jump, and loosen it if the timestep is being driven down without benefit.

Injury Measures

EDHIS accumulates several measures during the run and compares each against the corresponding tolerance carried by the human. Where a measure exceeds its tolerance, the time and magnitude are recorded and reported.

Head severity index

The measure the report labels

Head Injury Criterion

is computed as

$$SI = \int_0^T |a_{AP}|^{2.5}\, dt$$

where a_{AP} is the **anterior-posterior component** of the head acceleration.

> **NOTE:** This is the Gadd Severity Index form, and three properties of it are worth knowing before quoting the number as HIC. It is accumulated over the **whole run** rather than maximized over a sliding window; it uses the fore-aft **component** of head acceleration rather than the resultant; and it is not divided by the averaging interval. The Head Injury Criterion as defined in FMVSS 208 differs on all three points and will not generally produce the same value. Compare the reported figure against the tolerance carried by the human, which is expressed on the same basis, rather than against a published HIC limit.

Other measures

Reported as	What is actually compared
Head pitch concussion	Pitch angular acceleration of the head relative to the torso — that is, of the neck articulation, not of the head in space
Head side acceleration	Lateral component of head acceleration
Chest force	Largest contact force on the chest ellipsoid at this timestep
Chest forward acceleration	Anterior-posterior component of chest acceleration
Chest SI	**Superior-inferior** (vertical) component of chest acceleration — despite the abbreviation, this is an acceleration and not a severity index
Axial femur load	Largest contact force on the knee ellipsoid at this timestep — no load is computed within the femur itself
Torso belt load, lap belt load	Sum of the tensions in the belt segments
Joint angles	Each joint angle against separate flexion and extension tolerances

(updated: this chapter previously consisted of a short summary with no equations. The relationships above were taken from the current EDHIS engine. Note in particular the two naming points called out above — the head measure is a severity index rather than HIC, and Chest SI is the superior-inferior acceleration.)

Previous: Chapter 3 — Program Output | Next: Chapter 5 — EDHIS Tutorial

Chapter 5 — EDHIS Tutorial

This tutorial provides complete examples for two uses of EDHIS. The first example is a low-speed collision, where the occupant motion is simulated in an effort to determine the potential for injury. The second example is a pedestrian impact, where the issue is the speed of the striking vehicle. These examples illustrate common applications of EDHIS.

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

- Create the humans
- Create the vehicles
- Create the environment
- Execute the EDHIS events
- Review the EDHIS output reports

This basic procedure is described in detail in this tutorial.

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

Getting Started

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

> **NOTE:** Most options simply affect the appearance in a viewer during Event or Playback mode. However, some options affect 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
- ON: Show Contacts
- OFF: Show Velocity Vectors
- ON: Show Skidmarks
- OFF: Show Targets
- ON: AutoPosition
- Units equals US
- Render Options:
- Show Humans as *Actual*

- Show Vehicles as *Actual*
- *Phong* Render Method
- Complexity equals *Object*
- Render Quality equals *5*
- 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 Humans

To create the humans for both events (the occupant in the intersection collision and the pedestrian in the pedestrian impact), perform the following steps:

- If the HVE Human Editor is not the current editor, choose *Human Mode*.

First, let's add the human occupant to the case.

- Click *Add New Object*. The Human Information dialog is displayed. The Human Information dialog includes option buttons allowing the user to select a seat position within the vehicle (alternatively, *Pedestrian* could be selected), and assign the human's attributes according to *Sex, Age, Weight Percentile* and *Height Percentile*.
- Using these option buttons, click each button to choose the following human attributes:
- Location =

  Front, Left

  (i.e., driver)

  > **NOTE:** By definition, we must choose sides here. We're going to assign the driver's position to the left side of the vehicle (sorry to our friends in Great Britain, Australia and other countries whose drivers are stuck on the wrong side of the vehicle!).

- Sex =

  Male

- Age = *Adult*
- Weight Percentile = *50*
- Height Percentile = *50*
- Edit the default human name: `Male Adult Driver`.
- Click *OK* to add *Male Adult Driver* to the Active Humans list.

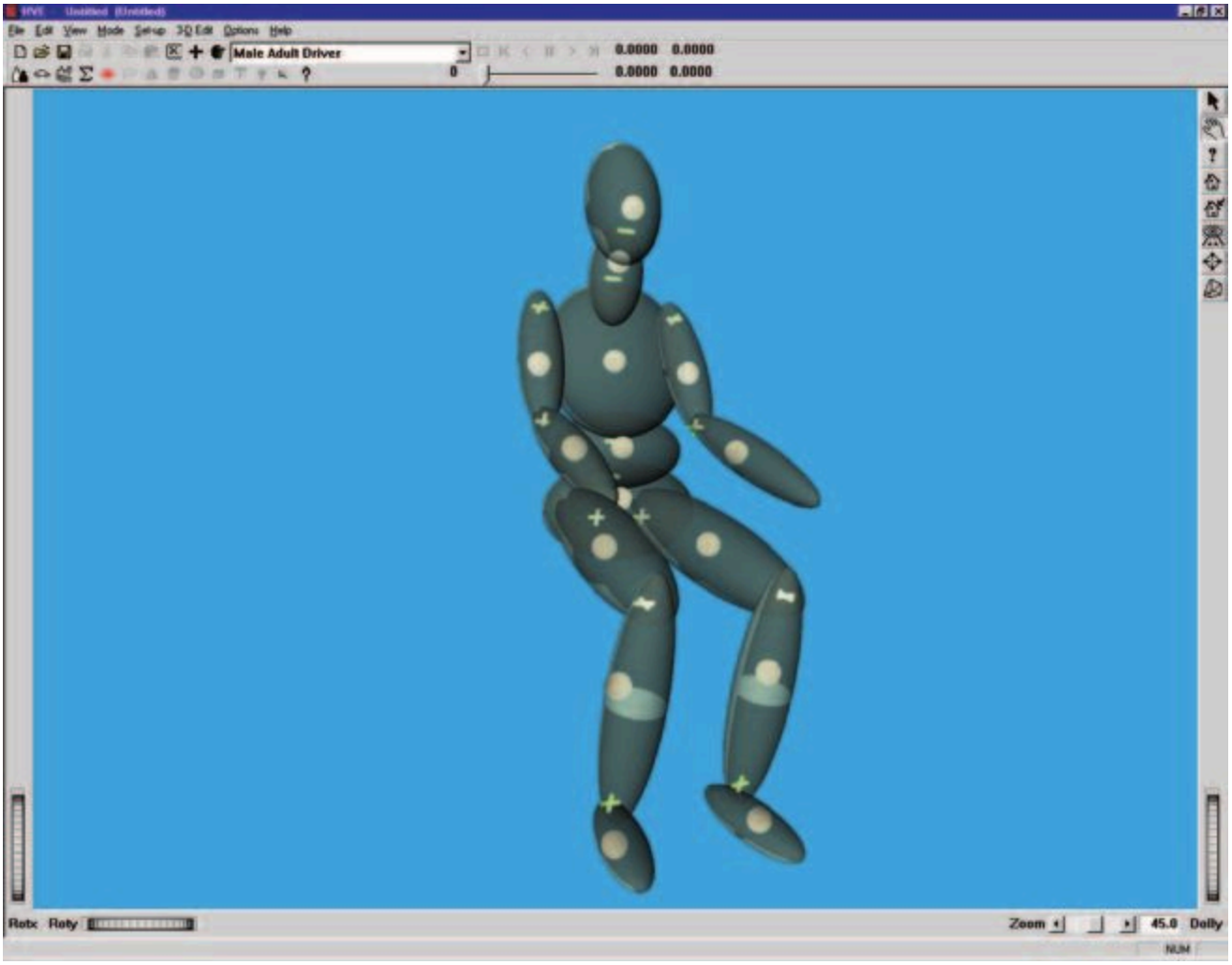
Now, let's add the female pedestrian.

- Click *Add New Object*. The Human Information dialog is displayed.
- Click on the option buttons in the Human Information dialog to choose the following human attributes:
- Location = *Pedestrian*
- Sex = *Female*
- Age = *Adult*

- Weight Percentile = *50*
- Height Percentile = *97.5*
- Edit the default name: `Female Adult Pedestrian`.
- Click *OK* to add *Female Adult Pedestrian* to the Active Humans list.

> **NOTE:** By choosing Pedestrian, HVE will define the human's motion relative to the earth-fixed coordinate system (occupant motion is defined relative to the vehicle-fixed coordinate system).

After the above steps are performed, both humans have been added to the case and are ready to be analyzed.



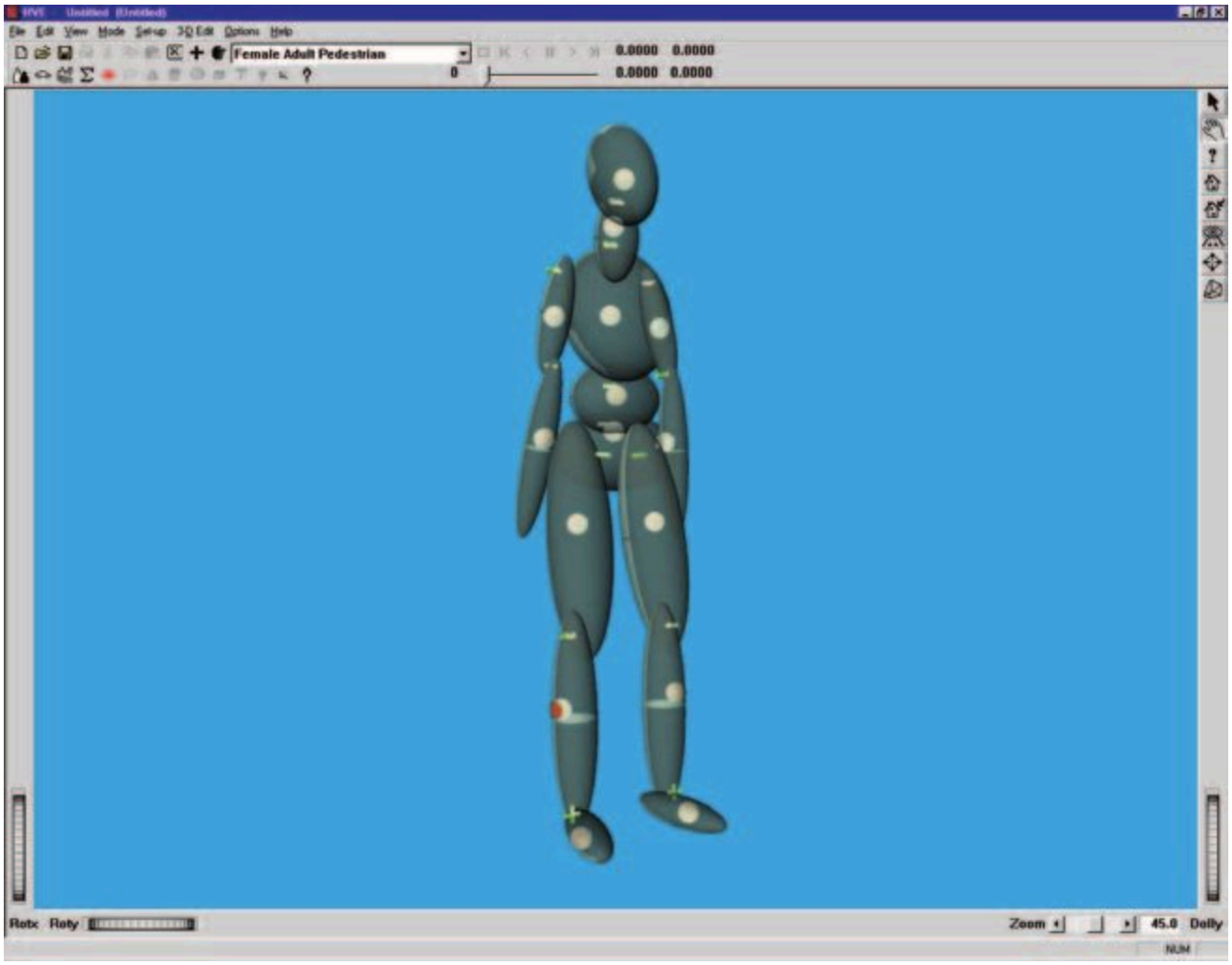


Figure 5-1: Male Adult Driver and Female Adult Pedestrian, ready for analysis.

Creating the Vehicles

Now we have our humans, so let's add the vehicles. First, let's add the two vehicles involved in a low-speed, rear-end collision. One vehicle is a dark red 1991 Buick Skylark and the second is a forest green 1989 Ford F-150 Pickup:

- Choose *Vehicle Mode*. The Vehicle Editor is displayed.
- 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 affect the basic vehicle configuration and do not need to be changed for our tutorial.

- Using the option buttons, click each button to choose the following vehicle from the database:
- Type = *Passenger Car*
- Make = *Buick*
- Model = *Skylark*

- Year = *1985-1991*
- Body Style = *4-Door*
- Source Database = *Tutorial.db*
- Click *OK* to add *Buick Skylark* to the Active Vehicles list.

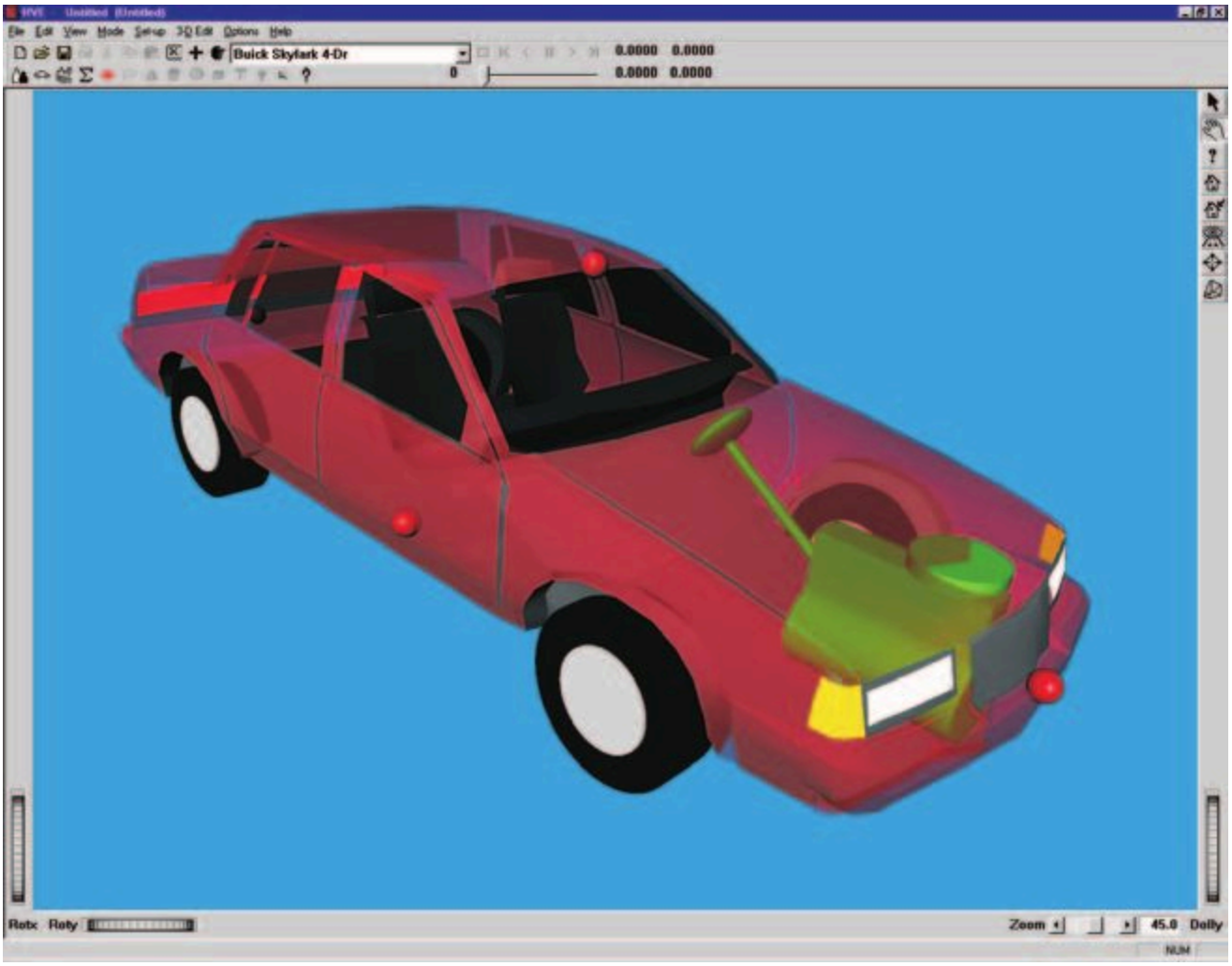
Now, let's add the 1989 Ford F-150 pickup:

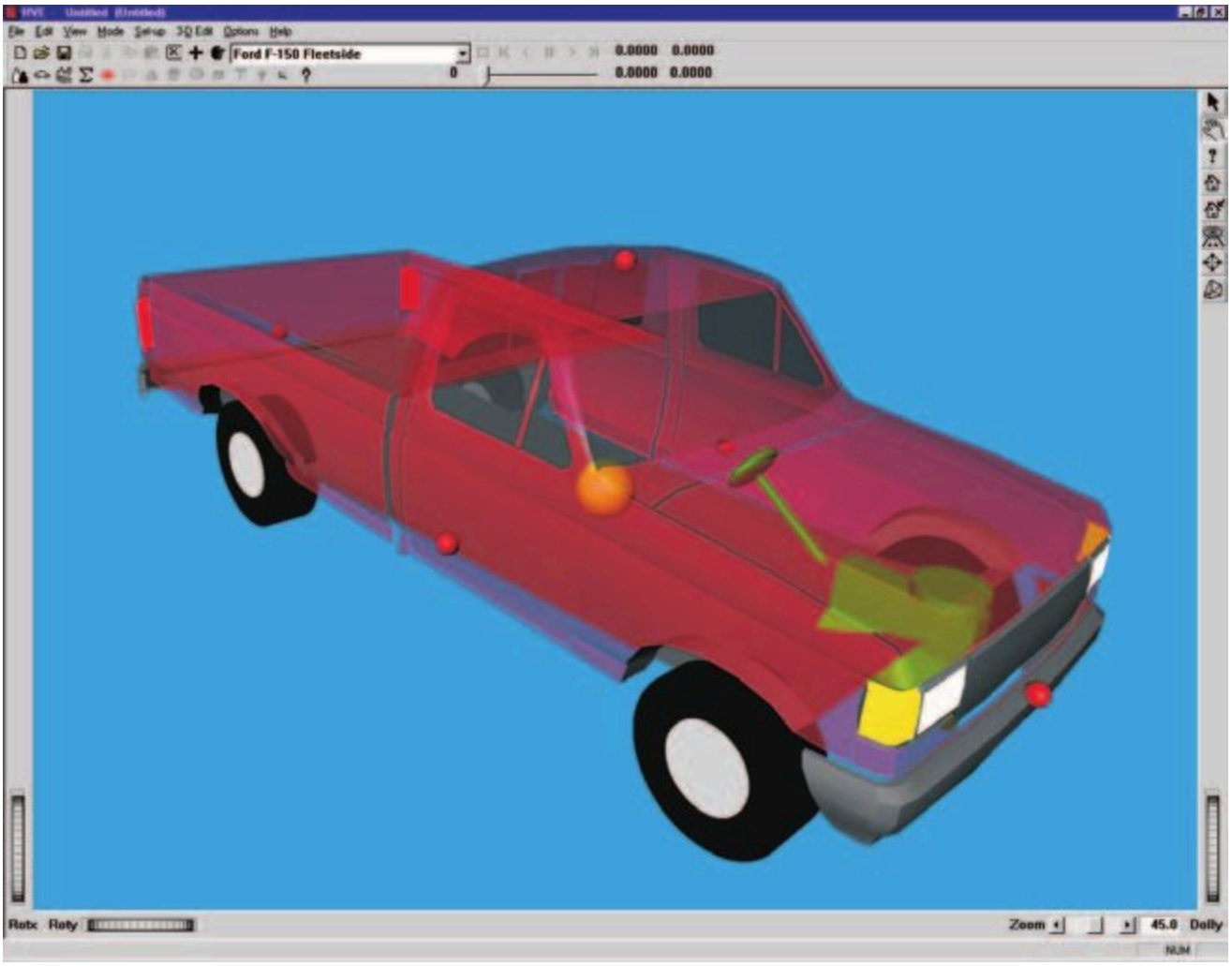
- Click *Add New Object*. The Vehicle Information dialog is displayed.
- Click on the option buttons in the Vehicle Information dialog to choose the second vehicle according to the following attributes:
- Type = *Pickup*
- Make = *Ford*
- Model = *F-150*
- Year = *1988-1991*
- Body Style = *Fleetside*
- Source Database = *Tutorial.db*
- Click *OK* to add *Ford F-150* to the Active Vehicles list.

Finally, let's add the aqua blue 1997 Plymouth Van to the case. The Plymouth Van was involved in the pedestrian impact.

- Click *Add New Object*. The Vehicle Information dialog is displayed.
- Click on the option buttons in the Vehicle Information dialog to choose the following vehicle from the database:
- Type = *Van*
- Make = *Plymouth*
- Model = *Voyager*
- Year = *1996-1999*
- Body Style = *Van*
- Source Database = *Tutorial.db*
- Click *OK* to add *Plymouth Voyager* to the Active Vehicles list.

Now, we have all the vehicles required for our case.


File Edit View Mode Setup 3D Edit Options Help
Buick Skylark 4-Dr
0.0000 0.0000
0.0000 0.0000
Rotx Roty
Zoom 45.0 Dolly


File Edit View Mode Setup 3D Edit Options Help
Ford F-150 Fleetside
0.0000 0.0000
0.0000 0.0000
Rotx Roty
Zoom 45.0 Dolly

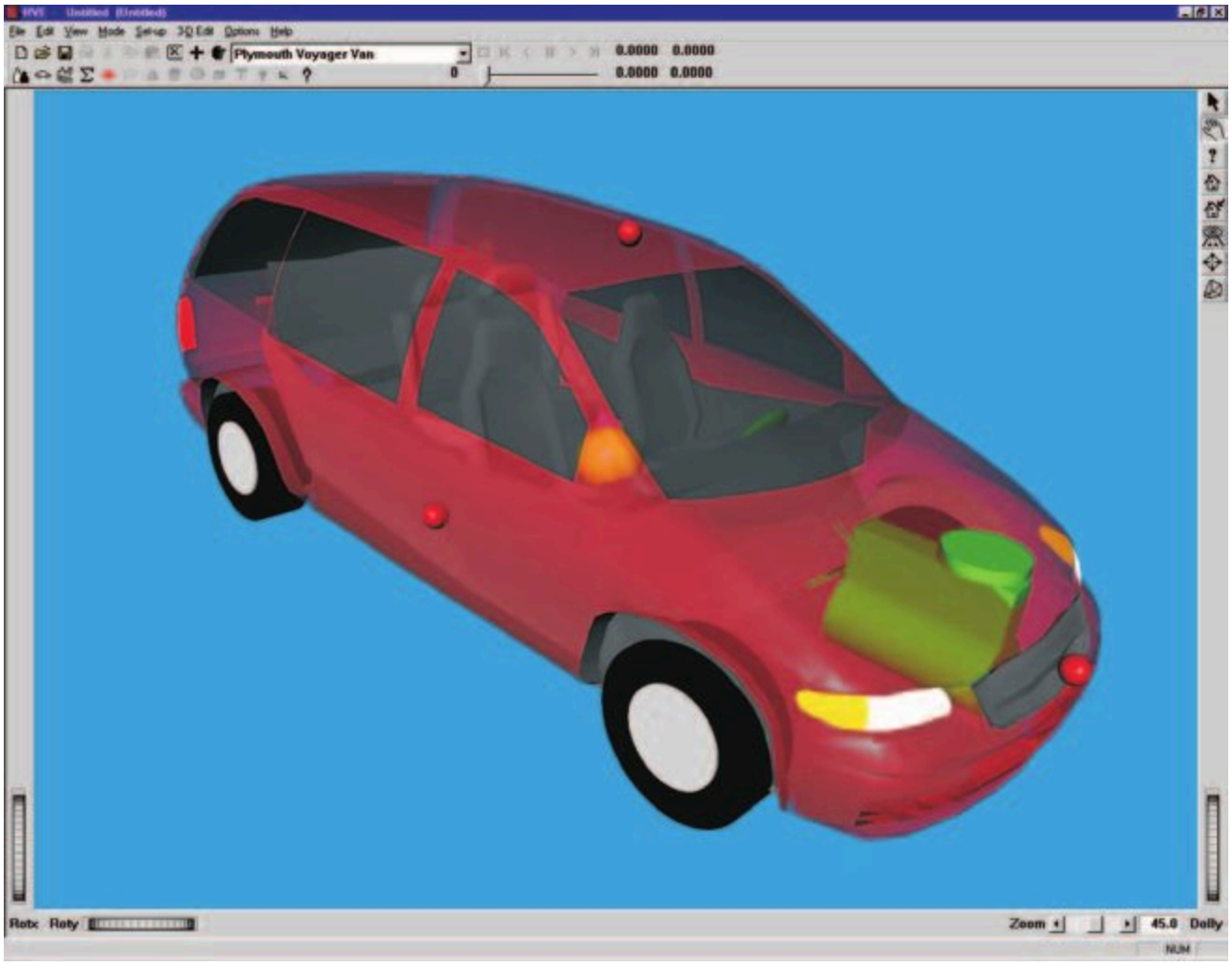


Figure 5-2: Buick Skylark 4-Dr, Ford F-150 Fleetside and Plymouth Voyager Van.

Editing the Vehicles

Next, we will edit the vehicles to change their color. In addition, we need to add contact surfaces to the Buick and Plymouth Van for the human simulations. The contact surfaces are the

physical

surfaces that interact with the human ellipsoids to produce forces.

Let's start with the Buick. This vehicle was struck from the rear, and we wish to simulate its occupant during the low-speed impact.

To edit the Buick, perform the following steps:

- First, select the *Buick Skylark* from the Active Vehicles drop-down list, making it the current vehicle. The Buick is now displayed in the Vehicle Editor.

Let's remove a portion of the vehicle exterior so we can see inside the vehicle more easily. The HVE 3-D Editor was previously used to remove the passenger compartment, and we saved the modified geometry file by the name `PCBuickNoTop.h3d`. To assign the modified geometry file:

- Click on the CG and choose *Geometry File, Open*. The Drawing File Selection dialog is displayed. Double-click on *PCBuickNoTop.h3d*. The vehicle is redisplayed with the new geometry file exposing the vehicle interior.
- To change the vehicle's color from bright red to dark red, click on the CG and choose *Color*. The Vehicle Color dialog is displayed (see Figure 5-3), showing the vehicle's current color (the small black square in the *color wheel*) and intensity (the arrow in the *intensity slider*). Leave the color unchanged; to darken the vehicle, click on the intensity slider and drag it from the right end of the slider towards the middle.

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

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

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



Figure 5-3: Vehicle Color dialog.

Next, let's add the contact surfaces for the Buick. We'll need a minimum of three surfaces for our simulation: a seat bottom, a seat back and a head rest.

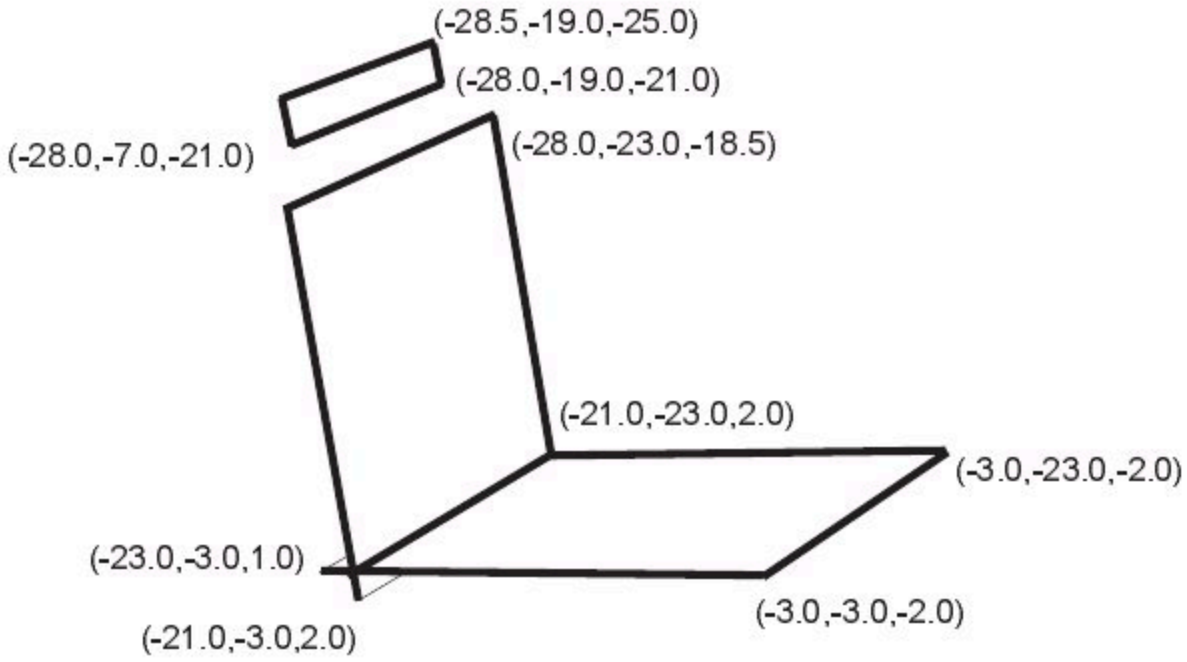


Figure 5-4: Seat Bottom, Seat Back and Head Rest contact surfaces.

To add the contact surfaces, perform the following steps:

- Click on the CG and choose *Contact Surfaces*. The Contact Surfaces dialog is displayed (see Figure 5-5), and we're ready to create the contact surfaces for the Buick.
- Click *Add* and enter `Seat Bottom`, followed by \<*Enter*>.
- *Interior* is already selected as the default location to identify this contact as an interior contact surface.
- Enter the coordinates for 3 corners of the seat bottom, as shown in the table below:

Table 5-1 — Seat Bottom Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	-23.0	-3.0	-3.0
y	-3.0	-3.0	-23.0
z	1.0	-2.0	-2.0

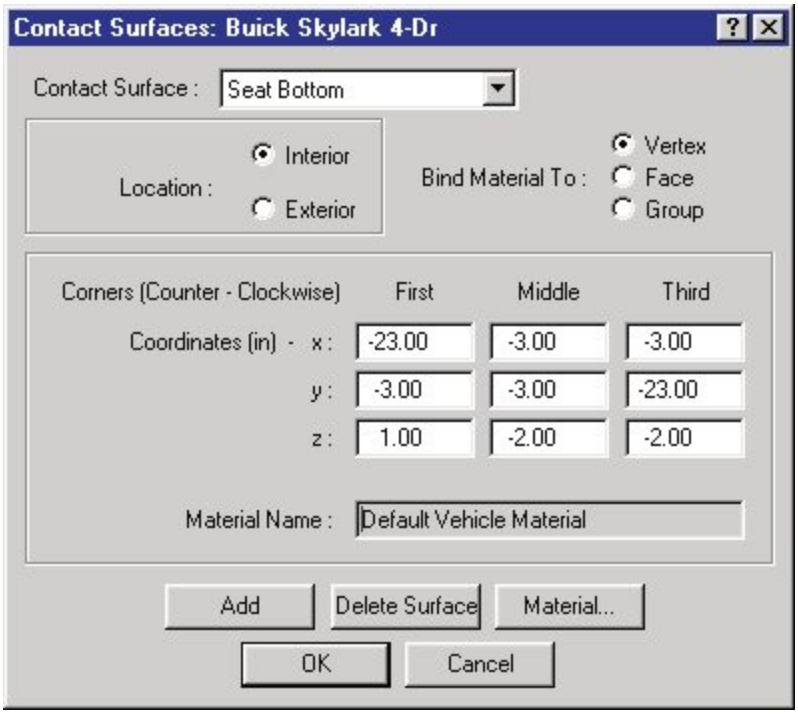


Figure 5-5: Contact Surface dialog.

> **NOTE:** Remember to enter three consecutive corners in counter-clockwise order to establish the positive side of the surface.
>
> **NOTE:** The order is important! If we enter the coordinates in the wrong order, no force will be produced between the human and vehicle.
>
> **NOTE:** You can tab between fields in this dialog, making it quicker to enter the coordinate data.

The

Seat Bottom

contact surface is complete. Next, let's create a contact surface for the seat back:

- Again, click *Add* and enter `Seat Back`, followed by \<*Enter*>. *Interior* is already selected. Enter the coordinates for three corners of the seat back (Table 5-2):

Table 5-2 — Seat Back Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	-21.0	-21.0	-28.0
y	-3.0	-23.0	-23.0
z	2.0	2.0	-18.5

Finally, let's create a contact surface for the head rest:

- Again, click *Add* and enter `Head Rest`, followed by \<*Enter*>. *Interior* is already selected. Enter the coordinates for three corners of the head rest (Table 5-3):

Table 5-3 — Head Rest Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	-28.0	-28.0	-28.5
y	-7.0	-19.0	-19.0
z	-21.0	-21.0	-25.0

- Click *OK* to remove the Contact Surface dialog.

The Buick is displayed with its surfaces.

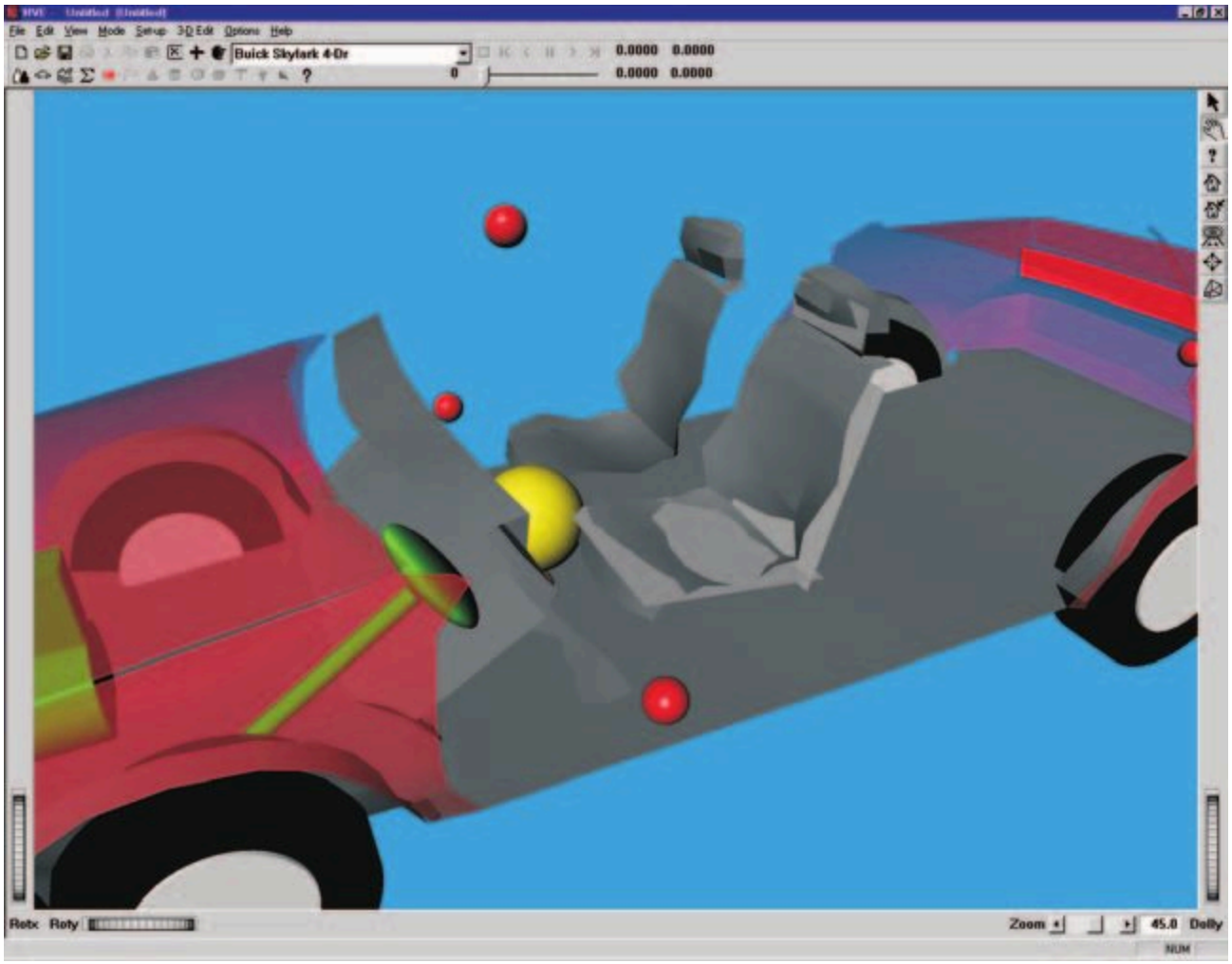


Figure 5-6: Buick Skylark after adding contact surfaces for the seat and headrest.

> **NOTE:** If the contact surfaces are not displayed, choose Options in the main menu bar and click on Show Contacts.

Using the viewer thumb wheels, rotate the vehicle and look at each side of the surfaces. Note the contact side is light colored (i.e., the positive side), while the other side is dark.

Now, let's change the color of the Plymouth Van, and add *Bumper*, *Grille*, *Hood* and *Windshield* contacts to its exterior (see Figure 5-7). These contact surfaces will be used for the pedestrian impact simulation.

To change the vehicle's color from red to blue, perform the following steps:

- Select the *Plymouth Voyager* from the Active Vehicles drop-down list, making it the current vehicle. The vehicle is displayed in the viewer, ready to edit.
- Click on the CG and choose *Color*. The Vehicle Color dialog is displayed, showing the vehicle's current color (in the *color wheel*) and intensity (in the *intensity slider*). Click on the hot spot (the small black square in the color wheel) and drag it to the middle of the blue area. Next, darken the vehicle slightly by dragging the intensity slider from the right end of the slider towards the middle.
- When the color is to your liking, close the dialog by clicking on the close button in the upper right-hand corner of the dialog.

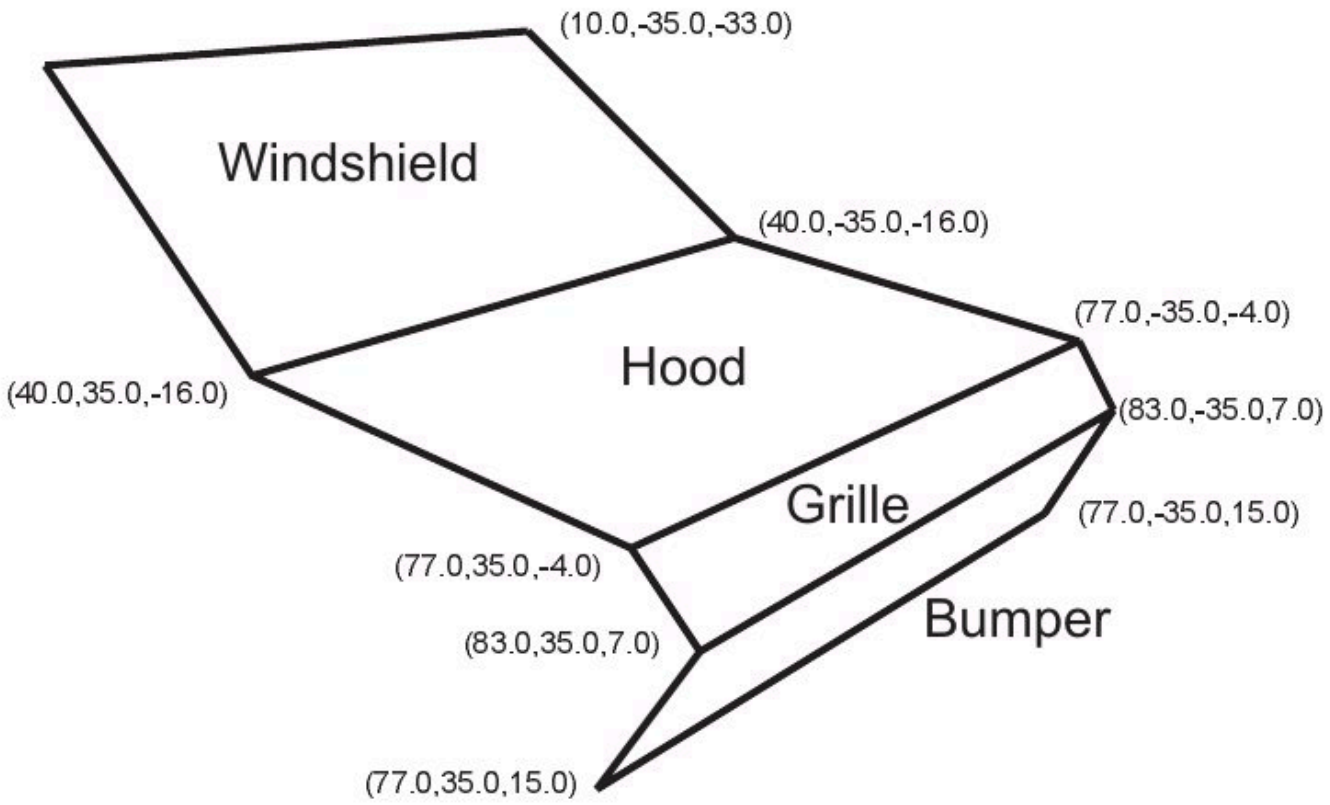


Figure 5-7: Bumper, Grille, Hood and Windshield contact surfaces.

To create the contact surfaces for the van, perform the following steps:

- Click on the CG and choose *Contact Surfaces*. The Contact Surfaces dialog is displayed.
- Click *Add* and enter `Bumper`, followed by \<*Enter*>. Click on *Exterior* and enter the coordinates for 3 corners of the front end (Table 5-4).

Table 5-4 — Plymouth Van Bumper Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	83.0	77.0	77.0
y	35.0	35.0	-35.0
z	7.0	15.0	15.0

Now, let's create the Grille contact surface:

- Again, click *Add* and enter `Grille`, followed by \<*Enter*>. Click on *Exterior* and enter the coordinates for three corners of the grille:

Table 5-5 — Plymouth Van Grille Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	83.0	83.0	77.0
y	35.0	-35.0	-35.0
z	7.0	7.0	-4.0

Now, let's create the Hood contact surface:

- Again, click *Add* and enter `Hood`, followed by \<*Enter*>. Click on *Exterior* and enter the coordinates for three corners of the hood:

Table 5-6 — Plymouth Van Hood Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	40.0	77.0	77.0
y	35.0	35.0	-35.0
z	-16.0	-4.0	-4.0

The last contact surface for the

Plymouth Van

is the Windshield:

- Again, click *Add* and enter `Windshield`, followed by \<*Enter*>. Click on *Exterior* and enter the coordinates for three corners of the windshield:

Table 5-7 — Plymouth Van Windshield Contact Surface Coordinates

	First Corner	Middle Corner	Third Corner
x	40.0	40.0	10.0
y	35.0	-35.0	-35.0
z	-16.0	-16.0	-33.0

- Click *OK* to remove the Contact Surface dialog.

The vehicle is displayed with its surfaces.

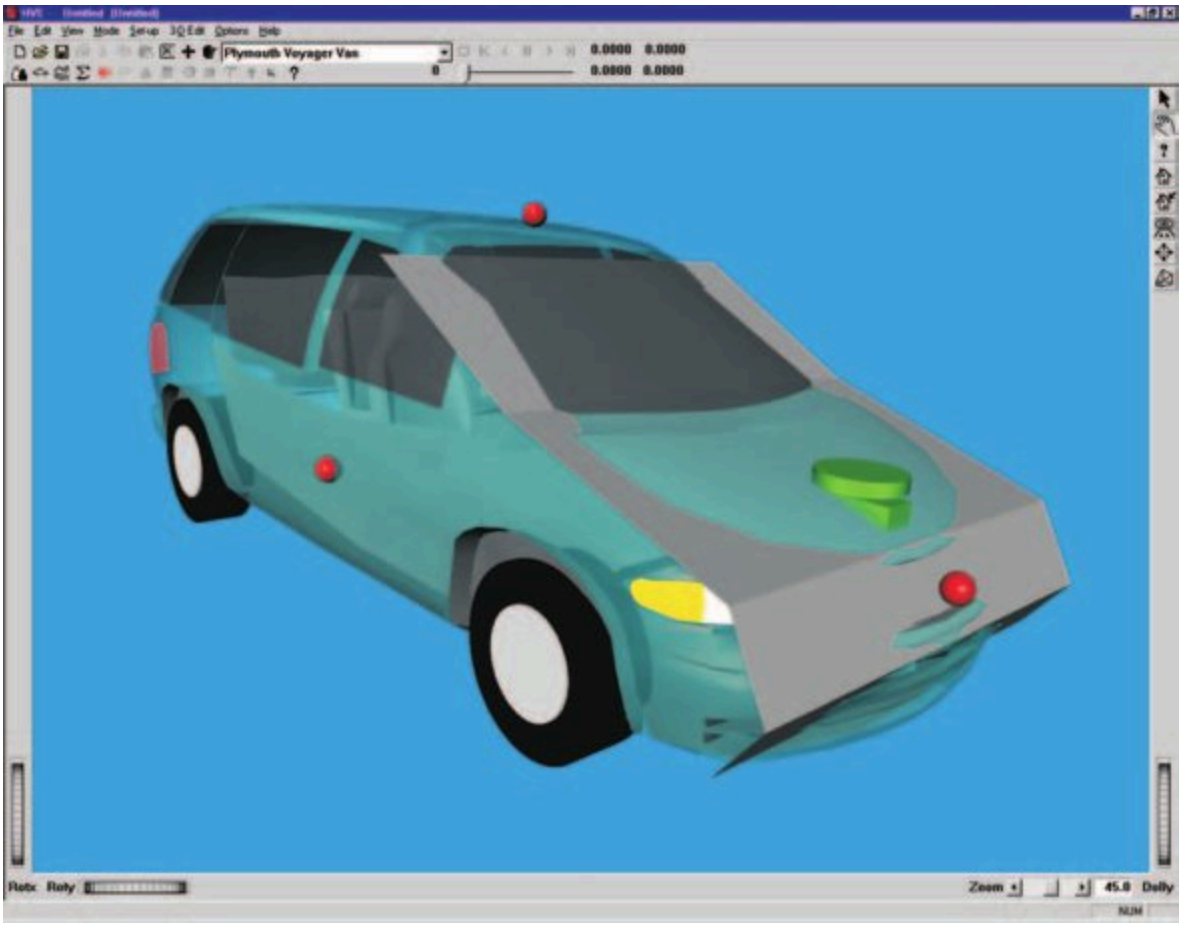


Figure 5-8: Plymouth Van after adding the Bumper, Grille, Hood and Windshield contact surfaces.

Again, use the viewer thumb wheels to rotate the vehicle and look at each side of the surfaces. Note the contact side is light colored (i.e., the positive side), while the other side is dark.

Finally, let's change the color of the Ford pickup from red to forest green:

- Click on *Ford F-150* in the Active Vehicles list. The vehicle is displayed in the viewer, ready to edit.
- Click on the CG and choose *Color*. The Vehicle Color dialog is displayed. Click on the hot spot in the color wheel and drag it to the middle of the green area. Next, darken the vehicle by dragging the intensity slider from the right end of the slider towards the middle. Remember, the color chip on the left shows the current color.
- When the color is to your liking, close the dialog by clicking on the close button in the upper right-hand corner of the dialog.

We now have all three vehicles required for the two simulation studies in this case.

Creating the Environment

Now, let's add the environment.

- Choose *Environment Mode*. The Environment Editor is displayed.

Let's use one of the sample environments shipped with HVE.

- Click on *Add New Object*. The Environment Information dialog is displayed.
- Using the Location Database combo box, choose *Beaverton, Oregon, USA*. The latitude, longitude and GMT (hours from the prime meridian) are displayed for the selected location.
- Edit the date and time of the incident we are studying, `4/22/96` and `1630`, respectively.
- Edit the angle from *true north* to the earth-fixed X axis in our environment, `56` 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.

- To add the environment geometry file to our case, click on *Open*. The Environment Geometry File Selection dialog is displayed.
- Click on the *Files of Type* option list and choose *HVE Geometry Files (*.h3d)*. A list of environment geometry files using the HVE file format is displayed in a list box.
- Double-click on *2T4_Intersection.h3d* to choose the environment file and remove the dialog.
- Press *OK*.

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

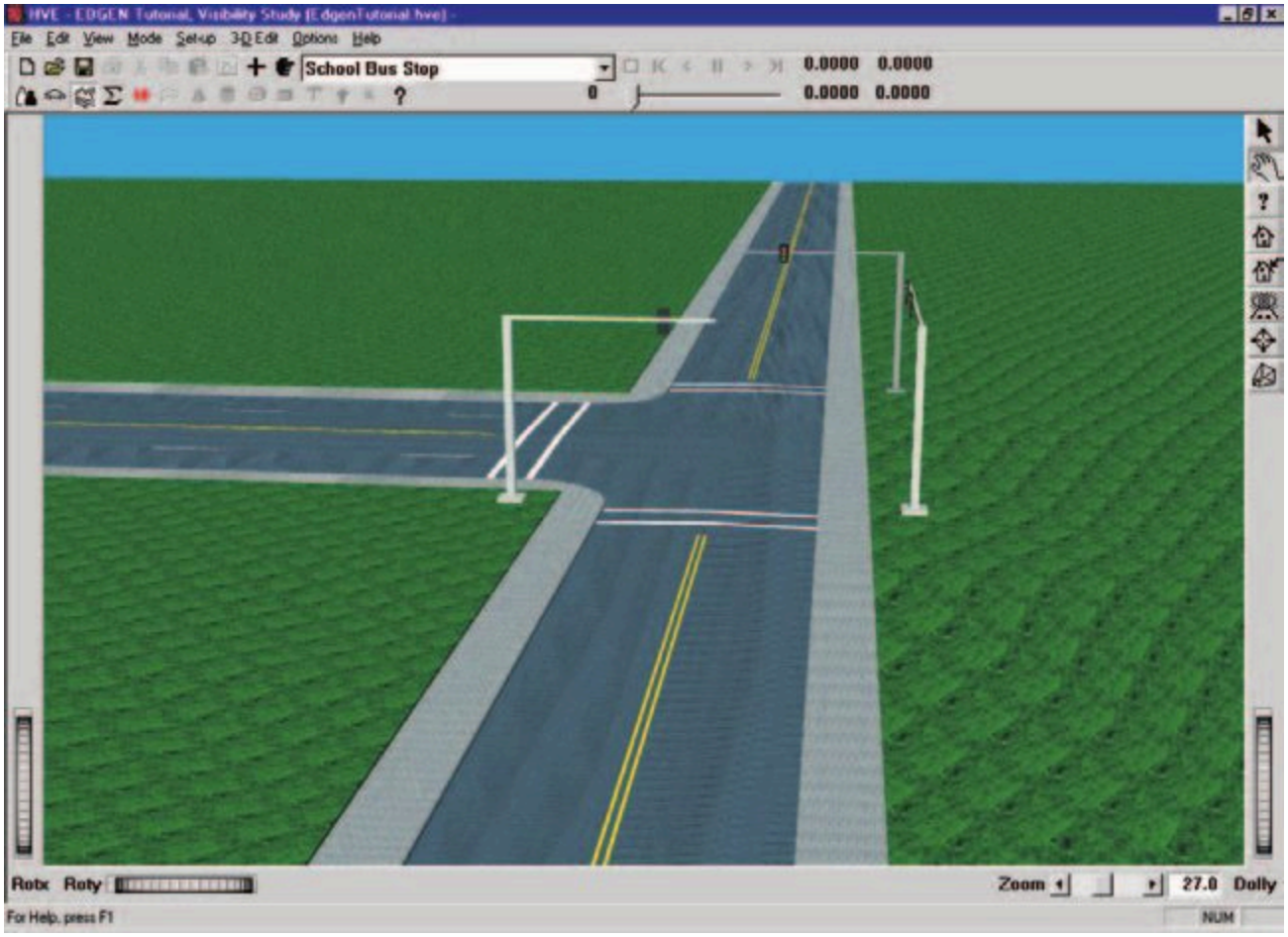


Figure 5-9: 3-D Environment used for our tutorial.

Saving the Case

Now that we've created all the objects (*humans*, *vehicles* and *environment*) for our case, let's save the case file.

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

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

- In the Case Title text field, replace Untitled with `EDHIS Tutorial Case`.

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

- In the Filename text field, enter `EdhisTutorial`.
- Click *SAVE*. The current case data are saved in the `hve/supportFiles/case` subdirectory.

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

Creating the Events

We are going to perform two simulation studies: one study is an occupant simulation of a low-speed, rear-end collision and the other is a pedestrian impact.

Collision Simulation

For the low-speed rear-end collision, we need a collision pulse. We can get the collision pulse directly using the EDSMAC4 collision simulator:

> **NOTE:** If you don't have EDSMAC4 on your HVE system, you may skip the EDSMAC4 event. The collision pulse for this event is shipped with HVE, and may be loaded by selecting EdhisTutorialCollisionPulse from the Collision Pulse File Selection dialog.

- Choose *Event Mode*. The Event Editor is displayed.
- Click on *Add New Object*. The Event Information dialog is displayed.
- Select *Buick Skylark* and the *Ford F-150* from the Active Vehicles list.
- Select *EDSMAC4* from the *Calculation Method* options list.
- Enter a name for the event, `Buick vs Ford`.

> **NOTE:** HVE will append the name of the calculation method to the event name, thus the complete event name will become "EDSMAC4, Buick vs Ford."

- Press *OK* to create the event and display the event editor.

Now, we're ready to set up the first event.

- Choose *Set-up* from the menu bar and select *Position/Velocity*. The Buick is displayed at the earth-fixed origin.

- Click on the vehicle's X-Y manipulator (see Figure 5-10), wait for it to turn bright yellow (indicating it has been selected), and drag it to its impact position, X=`24` ft, Y=`75` ft. Click the yaw manipulator and rotate it to its heading angle, `-90` degrees.

> **NOTE:** Be sure to keep the mouse button depressed while you drag the manipulators.

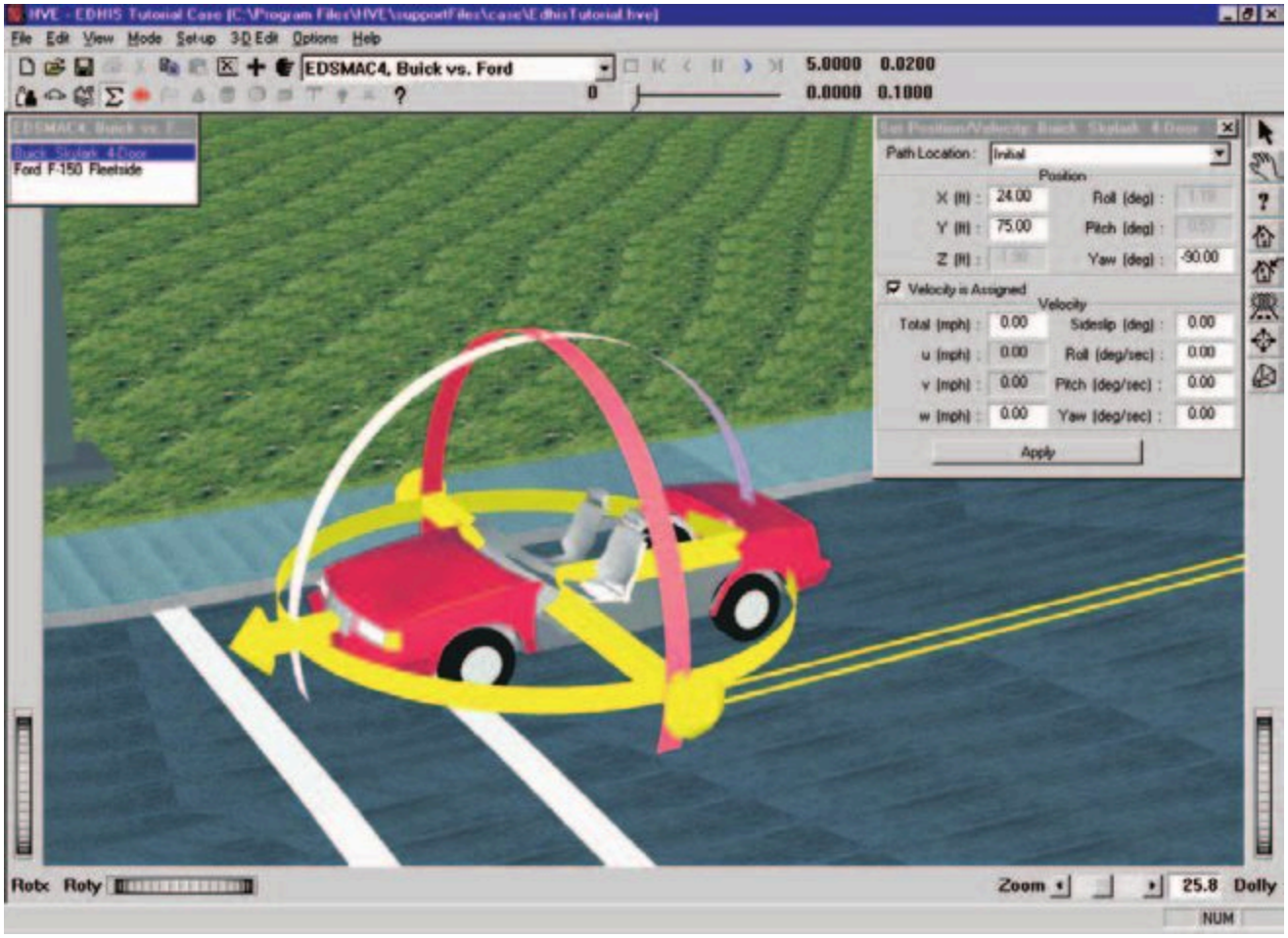


Figure 5-10: Positioning the Buick Skylark using the manipulators.

> **NOTE:** Adjust the viewer by dollying back (using the Dolly thumb wheel) until you can see the entire intersection.
>
> **NOTE:** To select the X-Y manipulator, the viewer must be in Pick mode, as indicated by the highlighted arrow in the upper right corner of the viewer.
>
> **NOTE:** If 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).

- Click the *Velocity Is Assigned* checkbox. Since it was stopped at impact, leave the value assigned at `0` mph.

Event set-up for the Buick is now complete. Let's set up the Ford pickup.

- Select *Ford F-150* in the Event Humans & Vehicles list, then choose *Position/Velocity* from the *Set-up* menu. The Ford is displayed at the earth-fixed origin. Drag it to its impact position, X=`24` ft, Y=`91` ft, Yaw=`-90` degrees. Click *Velocity Is Assigned*, and enter an initial velocity of `10` mph.

- Choose *Simulation Controls* from the Options menu and change the Output Time Interval from `0.1` sec to `0.005` sec. Click *OK* to accept the change.

> **NOTE:** We reduced the output interval because we're going to use the acceleration output from this simulation as the collision pulse for our occupant simulation, so we want more detail; selecting the smaller output interval provides the acceleration at 0.005 second increments, rather than the default value, 0.1 second. Note the entire duration of a collision is only about 0.1 second, so the default interval might actually skip the entire collision!

- Using the Event Controller, click *Play* to execute the event. Allow the event to run until just after the vehicles separate, t = `0.25` sec. Then press *Pause/Stop* to end the event.

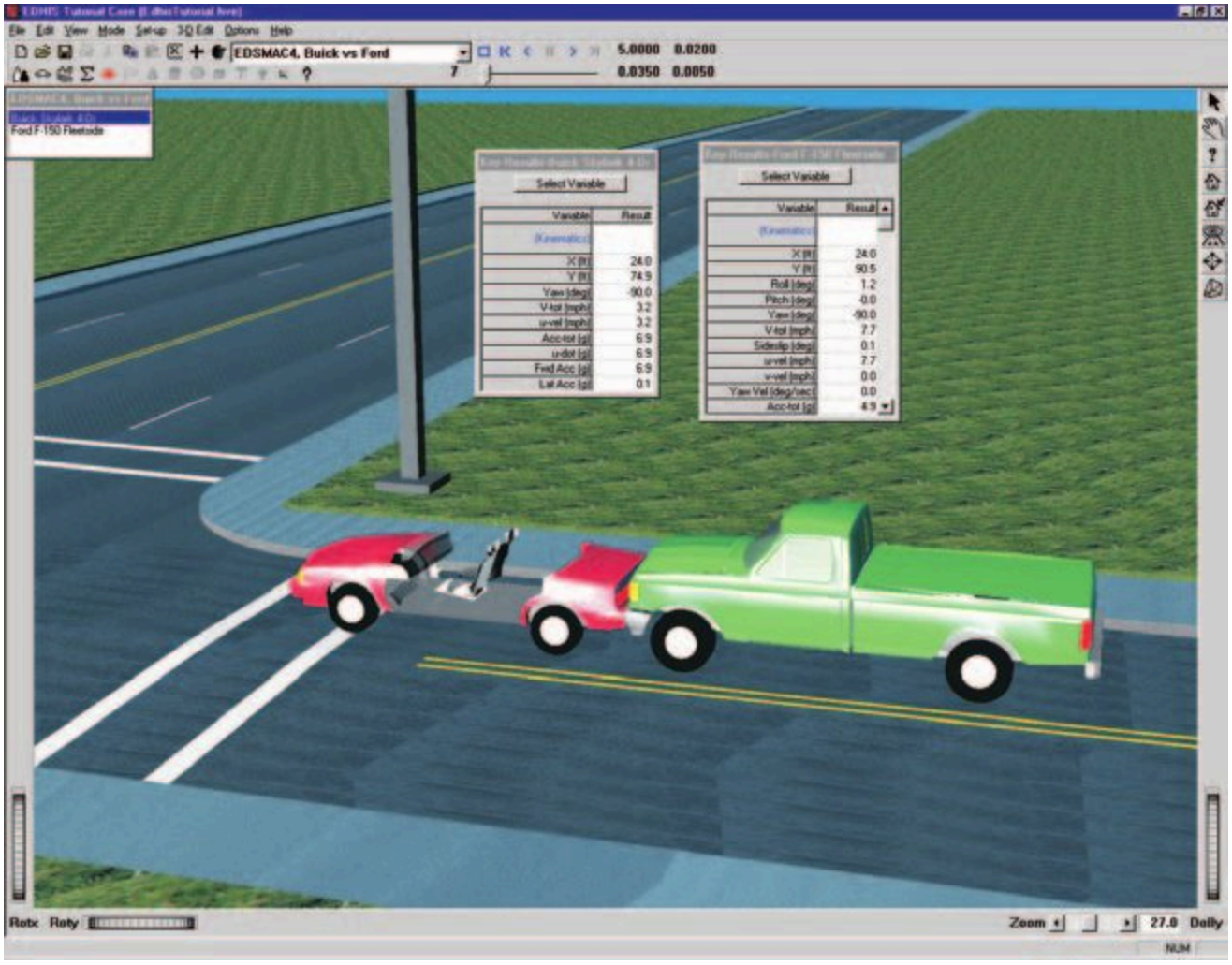


Figure 5-11: HVE Event Editor executing the EDSMAC4 Event.

> **NOTE:** While the event is executing, watch the current results (especially acceleration) in Key Results windows.

Occupant Simulation

The EDSMAC4 event has provided us with the collision pulse; now let's use EDHIS to study the driver's behavior during impact.

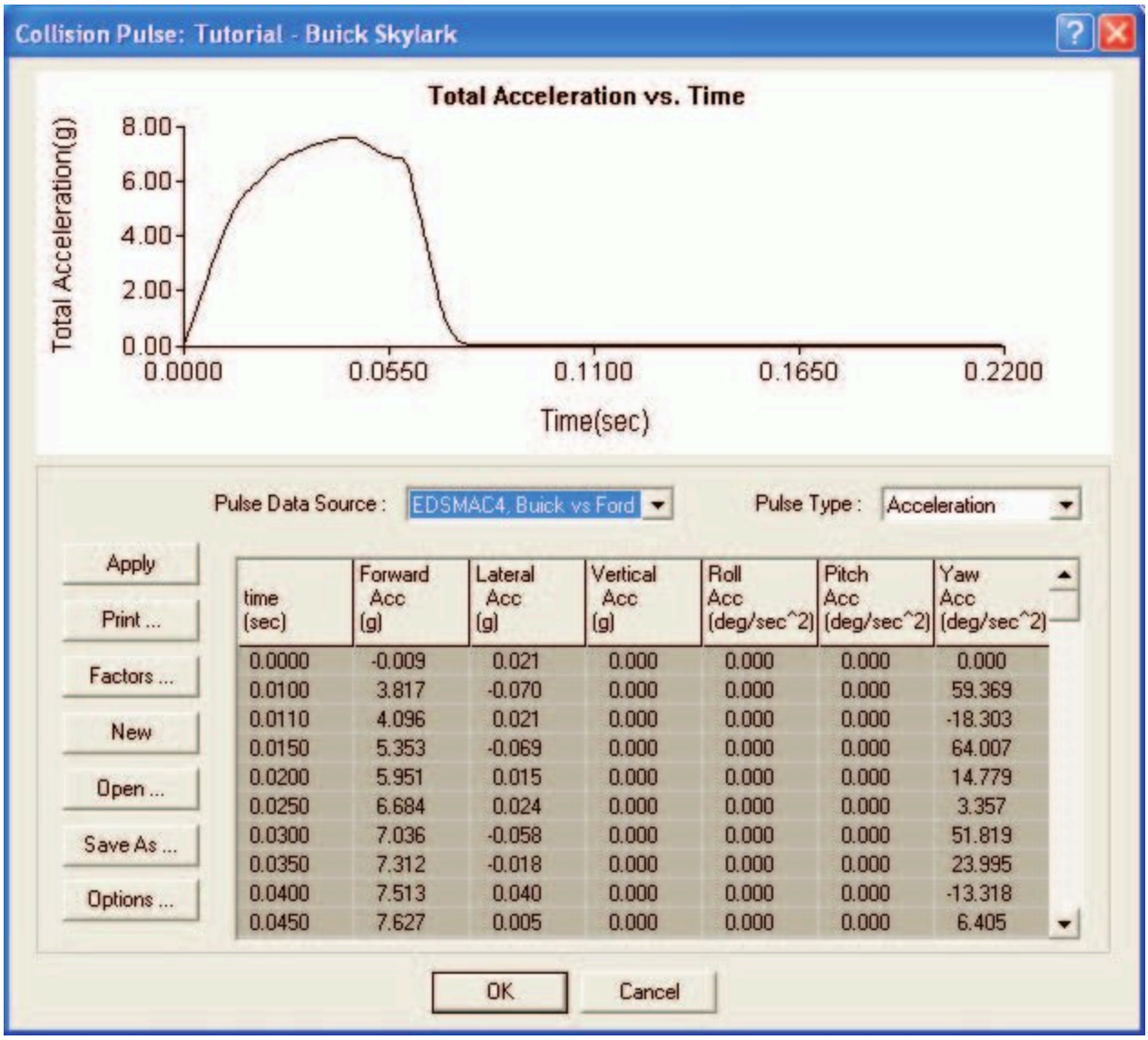
- Select *Add New Object*. The Event Information dialog is displayed.
- Select *Buick Skylark* and the *Male Adult Driver* from the Active Vehicles list and Active Human list, respectively.
- Select *EDHIS* from the Calculation Methods options list.
- Enter a name for the first EDHIS event: `Buick Occupant`.
- Press *OK* to display the event editor.

Now, let's set up and execute the occupant simulation event using EDHIS:

- Using the Event Editor dialog, select *Buick Skylark* from the Event Humans & Vehicles list, then select *Set-up* from the menu bar and choose *Position/Velocity*. The Buick is displayed at the earth-fixed origin.
- Use the Position/Velocity dialog to assign the same initial position as the one used in the previous EDSMAC4 event, X=`24` ft, Y=`75` ft and heading=`-90` deg.

> **NOTE:** Be sure to press \<Enter> to apply the values displayed in the Position/Velocity dialog.

- Click the *Velocity Is Assigned* check box. Leave the value assigned at `0` mph.
- Choose *Collision Pulse* from the Set-up menu. The collision pulse dialog is displayed (see Figure 5-12). Click on the *Pulse Data Source* option list and choose *EDSMAC4, Buick vs Ford*. The collision pulse (acceleration vs time history) for the Buick Skylark during the low-speed impact is displayed numerically (in a user-editable table) and graphically.
- Press *OK* to accept the collision pulse.



time (sec)	Forward Acc (g)	Lateral Acc (g)	Vertical Acc (g)	Roll Acc (deg/sec^2)	Pitch Acc (deg/sec^2)	Yaw Acc (deg/sec^2)
0.0000	-0.009	0.021	0.000	0.000	0.000	0.000
0.0100	3.817	-0.070	0.000	0.000	0.000	59.369
0.0110	4.096	0.021	0.000	0.000	0.000	-18.303
0.0150	5.353	-0.069	0.000	0.000	0.000	64.007
0.0200	5.951	0.015	0.000	0.000	0.000	14.779
0.0250	6.684	0.024	0.000	0.000	0.000	3.357
0.0300	7.036	-0.058	0.000	0.000	0.000	51.819
0.0350	7.312	-0.018	0.000	0.000	0.000	23.995
0.0400	7.513	0.040	0.000	0.000	0.000	-13.318
0.0450	7.627	0.005	0.000	0.000	0.000	6.405

Figure 5-12: Collision Pulse dialog for Buick Skylark.

Before we position the human, we'll attach the camera to the vehicle.

> **NOTE:** This tip really helps while positioning occupants because it allows you to move the camera relative to the vehicle, thus you can quickly focus on the interaction between the human and the seat cushion, an important part of placing the human in an equilibrium position.

To attach the camera to the vehicle, perform the following steps:

- Choose *Set Camera* from the View menu. The Set Camera dialog is displayed (see Figure 5-13).
- Click the *Object Name* list in the View From group and choose *Buick Skylark 4-Dr*. Enter the Camera Position coordinates, x=`0`, y=`-20`, z=`0`.
- Click the *Object Name* list in the Look At group and choose *Buick Skylark 4-Dr*. Enter the coordinates, x=`0`, y=`0`, z=`0`.
- Press *OK*.

The viewer displays the vehicle as viewed from the vehicle-fixed coordinates, 0, -20, 0.

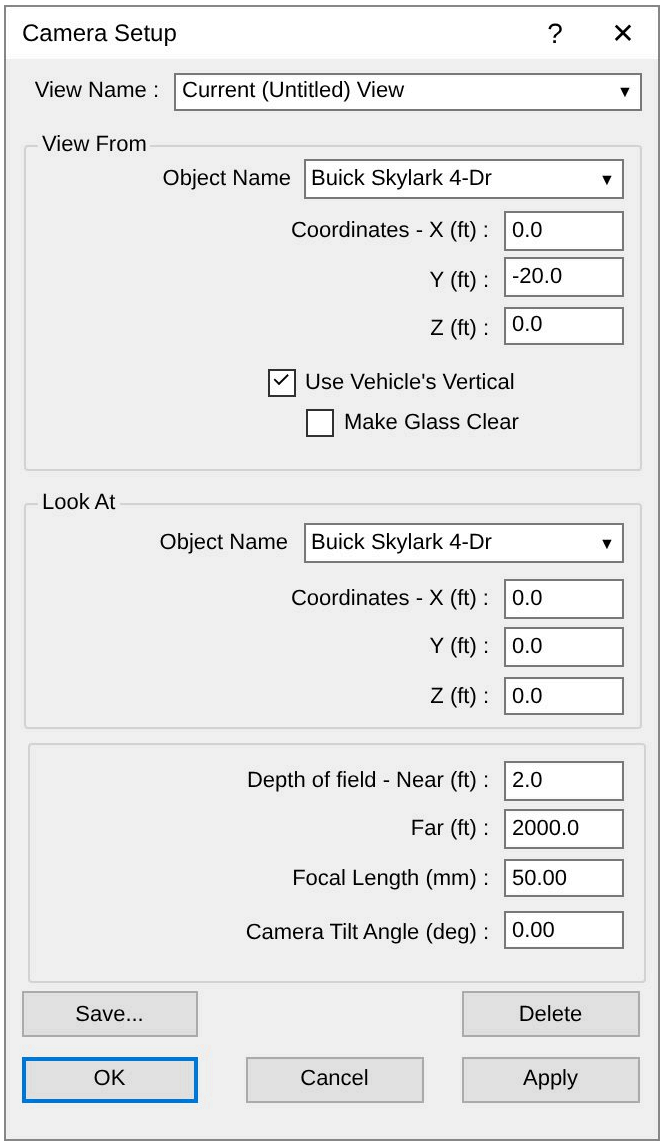


Figure 5-13: Set Camera dialog.

Now we're ready to position the driver in the Buick.

- Select *Male Adult Driver* from the Event Humans & Vehicles list, then choose *Position/Velocity* from the Set-up menu. The occupant is displayed at the vehicle-fixed origin. A set of manipulators is attached to the human to allow us to position him in the seat (refer to Figure 5-14).

> **NOTE:** The Position/Velocity dialog displays the current position and orientation of the human relative to the vehicle-fixed coordinate system.

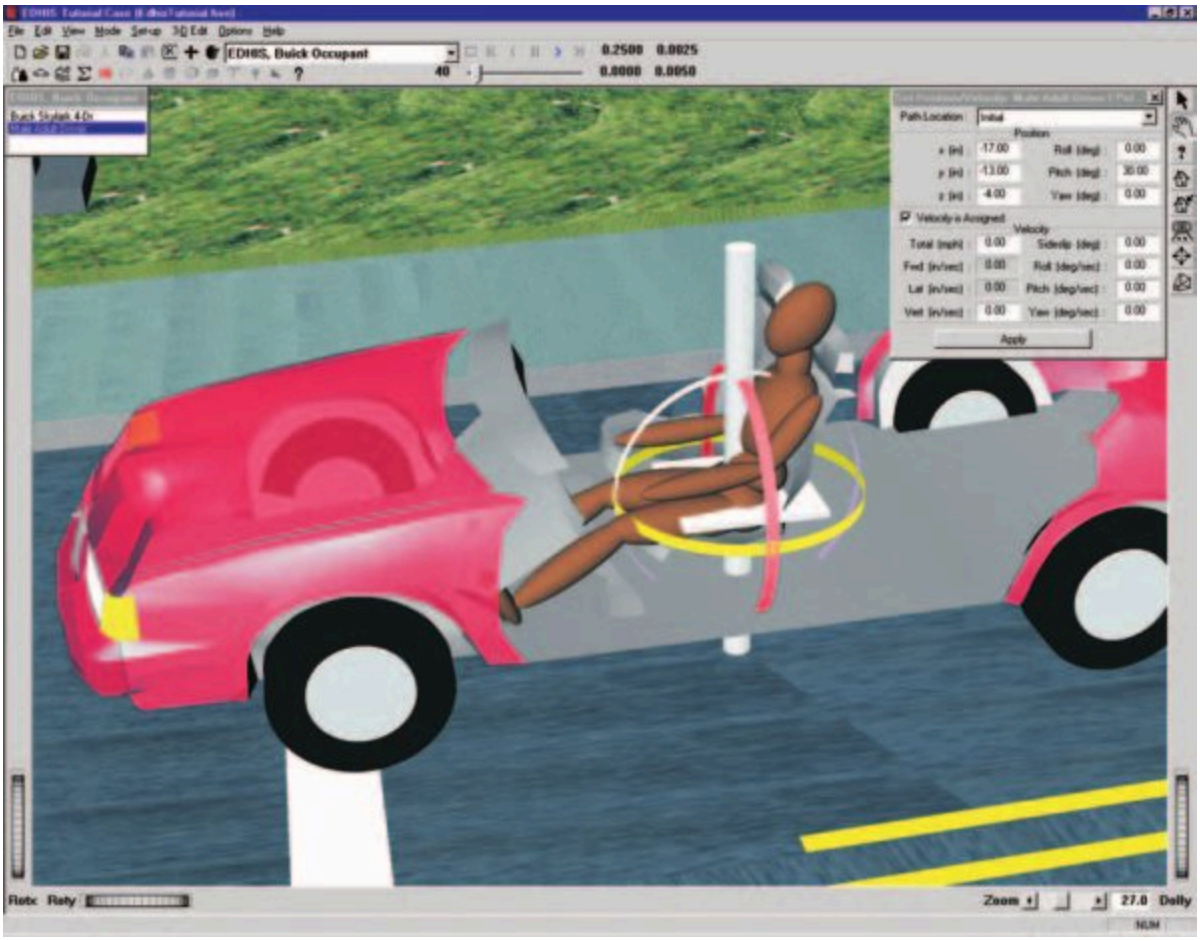


Figure 5-14: Human manipulators used for positioning the human.

To position the occupant, let's first use the x-y plane manipulator to position the human over the middle of the seat at x = -17 in, y = -13 in.

- Click on the x-y plane manipulator (a white, horizontal plane through the human's pelvis segment) and drag the human to x=`-17`, y=`-13`, then release the mouse.

> **NOTE:** You may wish to use the rotX thumb wheel to get a better view of the human relative to the seat.
>
> **NOTE:** If the human is not located exactly at -17, -13, you can enter the values directly in the Position/Velocity dialog.

Use the z manipulator (a white rod along the human's z axis) to set the elevation.

- Click on the z manipulator and drag the human up to `-5` inches (again, you may use the dialog to enter the exact value).

Next, we'll use the pitch manipulator to lean the occupant back in the seat:

- Click on the purple pitch band and drag the human, tilting him back until the pitch equals 30 degrees.

> **NOTE:** Again, you may wish to use the rotX and rotY thumb wheels to gain a better view. You might also want to rotate the scene to get a better angle on the pitch manipulator band in order to select it.

Now the human is seated properly, but his legs protrude through the floorboard (we won't make the obvious comment!). Let's position the legs:

- Click on the lower left leg. The orientation manipulators are displayed.
- Click on the pitch manipulator and drag the leg until the pitch angle is `-30.0` degrees.
- Repeat the above two steps to position the lower right leg.

The human is now properly positioned in the seat. The last step in positioning is to assign an initial velocity:

- Click on the human pelvis segment in order to select it.

> **NOTE:** We must select the pelvis, which is the main segment, in order to assign an initial velocity to the human; otherwise, we would have simply assigned an initial velocity to the lower left leg.

- Click the *Velocity Is Assigned* checkbox in the Position/Velocity dialog, and enter a forward velocity of `0` mph.

> **NOTE:** Because the human is defined as an occupant (as opposed to a pedestrian), the initial velocity is defined relative to the vehicle.

The final step in the event set-up is to set up contacts and assign combined material property data for the human ellipsoid to contact surface interactions:

- If the Male is not currently selected in the Event Humans and Vehicles list, click on it, making it the current object.
- Choose *Contacts* from the *Set-up* Menu (Figure 5-15).
- Under the Objects list, click *Select All*.
- Under the Targets list, click *Select All*.
- Below, in the Combined Material Properties section, click *Select All*.

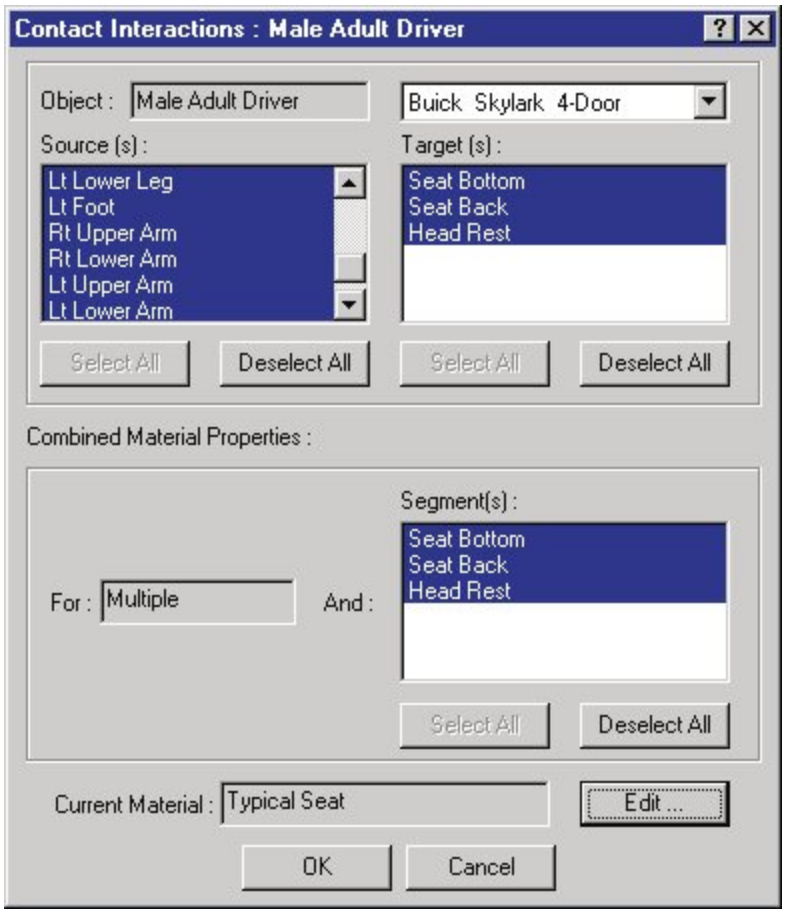


Figure 5-15: Combined Material Properties dialog.

- Click *Edit* to edit the combined material properties.
- Click *Open* to open a saved combined material property data set.
- Double-click on `TypicalSeat.matl` to select it and close the dialog.
- Click *OK* to accept the new material properties.
- Click *OK* to accept the assigned contacts.

The contacts are now assigned and we are ready to proceed with executing the simulation.

- Using the Event Controller, click *Play* to execute the event. Allow the event to run until the end of the simulation.

Since our goal for this event is to study how the impact severity affects force and head acceleration, let's look at some Key Results during execution:

- If Key Results windows are not displayed, choose *Show Key Results* from the Options menu.
- 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).
- Click on *Select Variable* in the *Male Adult Driver* Key Results window. The Variable Selection dialog for *Male Adult Driver* is displayed.

Let's add *Head Forward Acceleration* and *Head Pitch Acceleration* to the Key Results window:

- Click *Kinematics*, *Head*. The Variable Selection list for Head Kinematics is displayed.

- Select *Fwd Accel* (Forward Acceleration) and *Pitch Accel* (Pitch Acceleration) from the list.

Next, let's add the *Head* vs *Head Rest* contact force:

- Click *Contacts* and choose *Head, Head* and *Buick Skylark Head Rest* from the cascade menus. The Variable Selection list for Head vs Head Rest contact is displayed (see Figure 5-16).

> **NOTE:** The first time Head is displayed, it refers to the Head segment; the second time refers to the contact ellipsoid named Head that is attached to the Head segment.

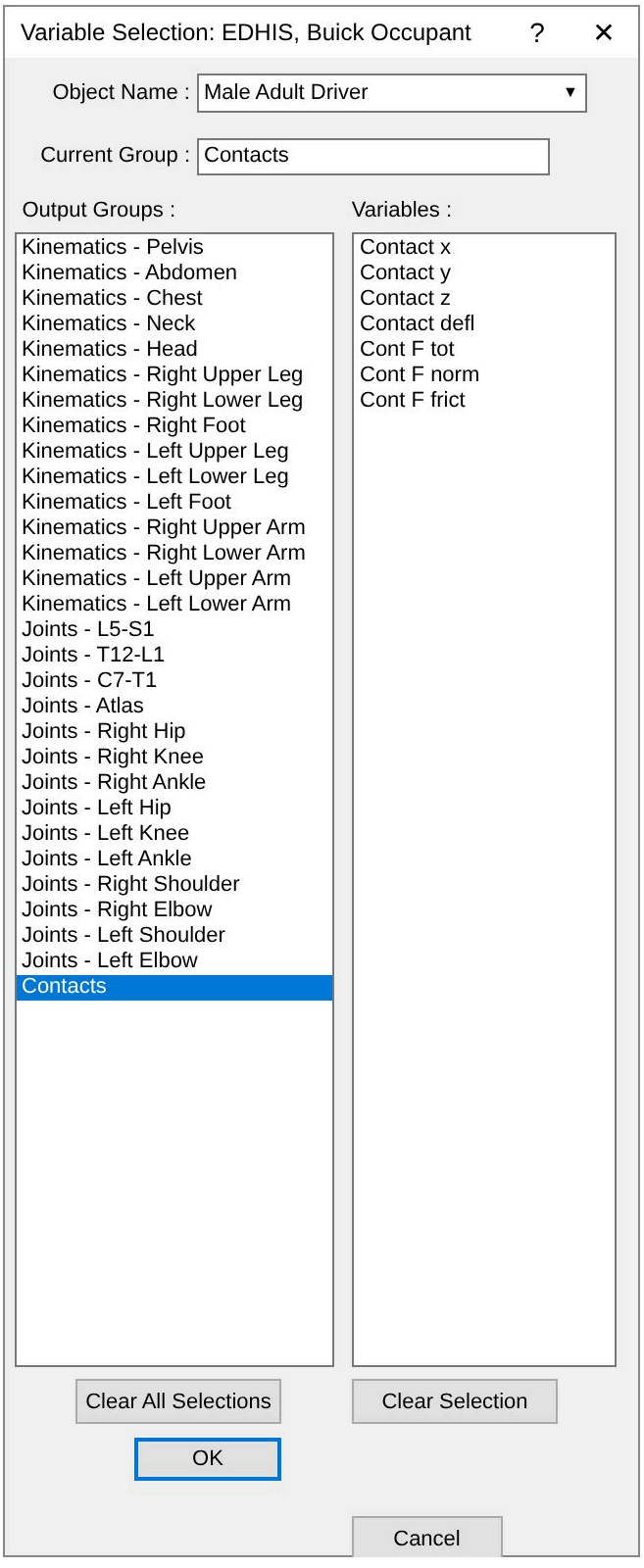


Figure 5-16: Key Results Variable Selection dialog.

- Select *Force* from the list.
- Press *OK* to add the selected variables to the Key Results window.

Now, we're ready to execute the event once again:

- Using the Event Controller, click *Reset* to clear the previous results and then click *Play* to execute the event.

We have finished our occupant simulation. You may wish to view it a few more times by pressing *Reverse* and *Play*. Note the time-dependent results displayed in the Key Results windows. You might also wish to add additional output variables to the Key Results window.

Pedestrian Simulation

Using EDHIS to simulate a pedestrian impact is very similar to the previous occupant simulation. Let's proceed:

- Click *Add New Object*. The Event Information dialog is displayed.
- Select *Plymouth Voyager* and the *Female Adult Pedestrian* from the Active Vehicles list and Active Humans list, respectively.
- Select *EDHIS* from the Calculation Methods options list.
- Edit the event name: `Plymouth/Pedestrian Impact`.
- Press *OK* to display the event editor.

Now, let's set up and execute the pedestrian simulation event using EDHIS, as shown in Figure 5-17.

- Using the Event Editor dialog, select *Plymouth Voyager* from the Event Humans & Vehicles list, then select *Set-up* from the menu bar and choose *Position/Velocity*. The Plymouth Van is displayed at the earth-fixed origin. Drag the vehicle to its impact position, X=`-20` ft, Y=`37` ft, Yaw=`0` degrees.
- Click the *Velocity Is Assigned* check box. Enter the Plymouth Van's impact speed, `35` mph.

Next, position the pedestrian.

- Select *Female Adult Pedestrian* from the Event Humans & Vehicles list, then select *Set-up* from the menu bar and choose *Position/Velocity*. The human is displayed at the earth-fixed origin.

> **NOTE:** The human is half buried in the environment; this occurs because AutoPosition does not apply to humans.

- Use the Position/Velocity dialog to enter the impact position of the human relative to the earth-fixed coordinate system: X=`-10` ft, Y=`37` ft, Z=`-3.5` ft, Yaw=`90` degrees.

> **NOTE:** Be sure to press \<Enter>, otherwise, the entered values do not take effect.

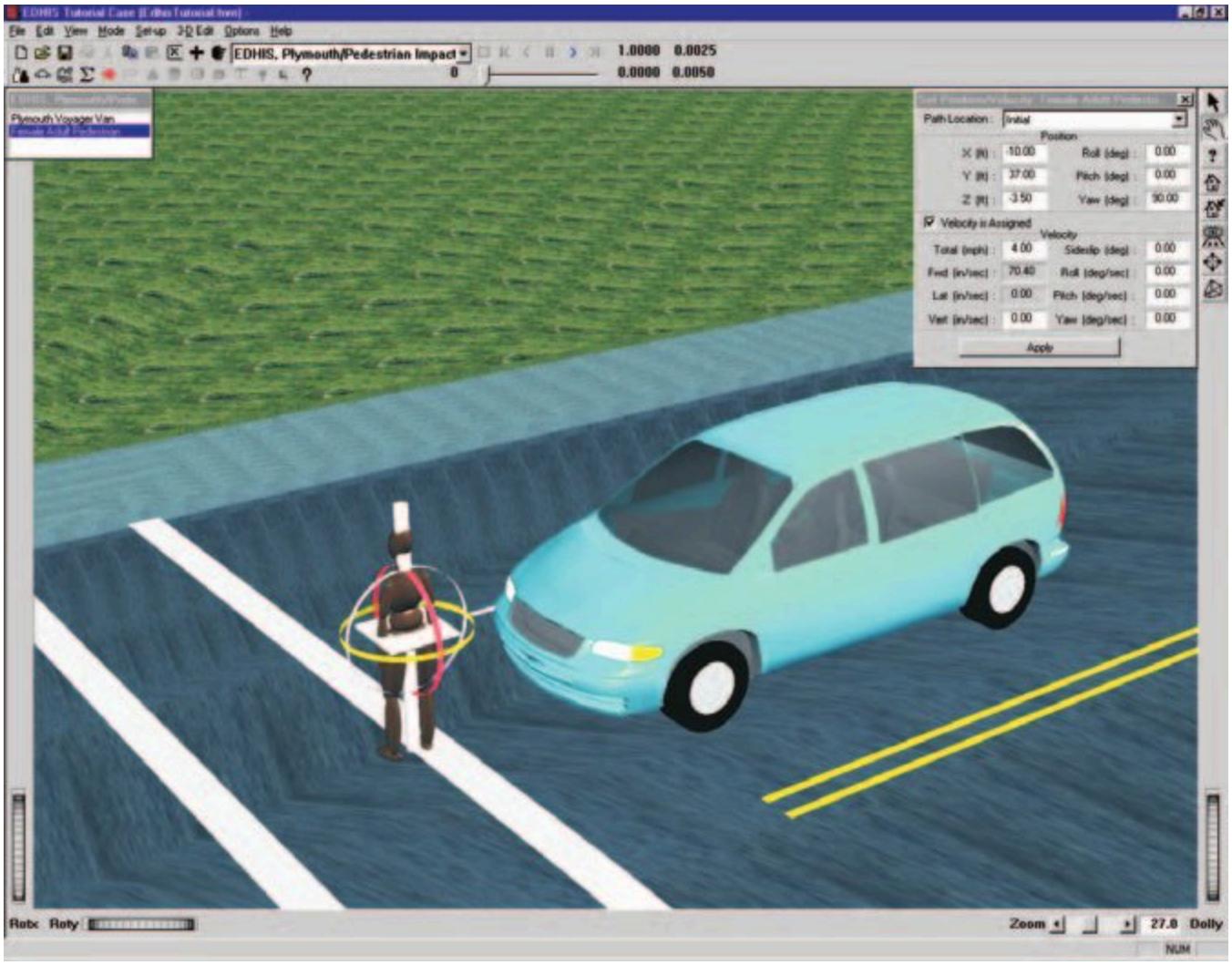


Figure 5-17: Setting up the EDHIS Pedestrian Impact simulation.

Now, let's enter the initial velocity of the pedestrian:

- Click on the *Velocity Is Assigned* checkbox and enter the velocity, `4` mph.

The final step in the event set-up is to set up contacts and assign combined material property data for the human ellipsoid to contact surface interactions. Let's start with the Bumper.

- If the Female is not currently selected in the Event Humans and Vehicles list, click on it, making it the current object.
- Choose *Contacts* from the Set-up Menu.
- Under the Objects list, click *Select All*.
- Under the Targets list, click *Select All*.
- Below, in the Combined Material Properties section, first select *Bumper*.
- Click *Edit* to edit the combined material properties.
- Click *Open* to open a saved combined material property data set.
- Double-click on `TypicalRoofPillar.matl` to select it and close the dialog.
- Click *OK* to accept the new material properties.

The Grille and Hood have the same material properties, so we will assign them together.

- Click on *Bumper* to deselect it and click on both *Grille* and *Hood* to select them.
- Click *Edit* to edit the combined material properties.
- Click *Open* to open a saved combined material property data set.
- Double-click on `TypicalDoorUndamaged.matl` to select it and close the dialog.
- Click *OK* to accept the new material properties.

Finally, we assign the material properties for the Female to Windshield contact.

- Click on both *Grille and Hood* to deselect them and click on *Windshield* to select it.
- Click *Edit* to edit the combined material properties.
- Click *Open* to open a saved combined material property data set.
- Double-click on `TypicalWindshield.matl` to select it and close the dialog.
- Click OK to close the Combined Material Properties dialog.

The pedestrian impact is now set up and ready to execute.

- Using the Event Controller, click *Play* to execute the event. Allow the event to run until the pedestrian rebounds from the collision.

> **NOTE:** EDHIS is designed to simulate human occupant or pedestrian motion up to the point of first impact. We should therefore terminate the event no later than 0.15 seconds.

We have now completed the three events.

Viewing Results

Now that we have produced our EDHIS 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.

> **NOTE:** The events simulated in this tutorial might be included, along with the results from several other EDC Reconstruction and Simulation Model tutorials, in the HVE User's Manual Tutorial, Chapter 32.
>
> **NOTE:** In this tutorial, we will only review the output reports produced by the EDHIS Buick Occupant event. Feel free to view the EDSMAC4 and EDHIS Pedestrian events as well.

EDHIS produces the following reports:

- **Messages** — A list of messages produced by the current run
- **Accident History** — A table of initial and final positions and velocities
- **Event Data** — A table containing the collision pulse used in the EDHIS event
- **Human Data** — A series of tables containing the human data used by EDHIS
- **Injury Data** — A table containing the injury tolerances, followed by a table containing values exceeding the allowable tolerances during the event
- **Vehicle Data** — A series of tables containing the vehicle data used by EDHIS
- **Program Data** — A table containing program control information

- **Variable Output** — A table containing time-dependent simulation results
- **Trajectory Simulation** — A 3-D visualization of the event, displayed at a user-selectable time interval

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.

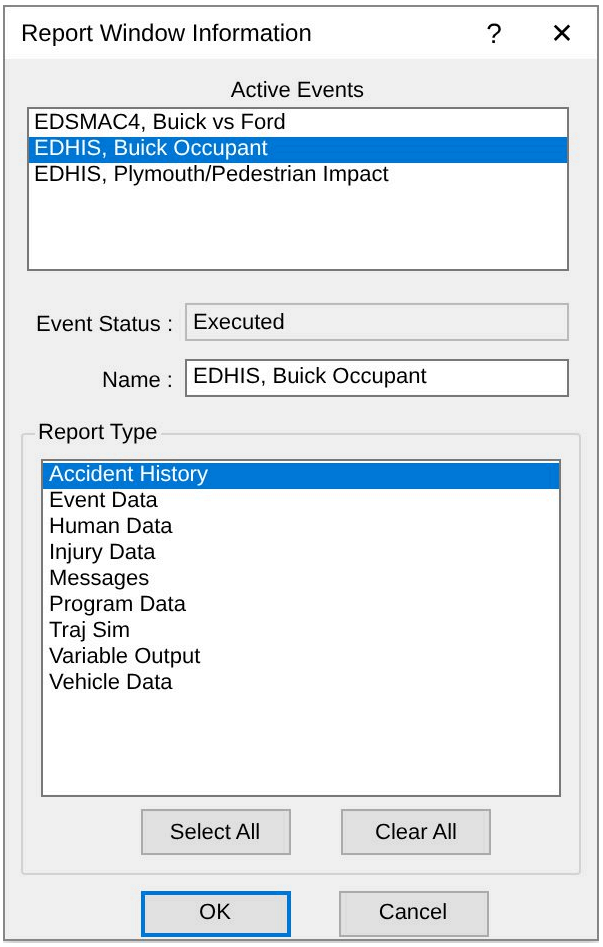


Figure 5-18: Report Window Information dialog.

To view the reports produced by the

EDHIS Tutorial

Case, perform the following steps:

- Click *Add New Object*. The Report Window Information dialog is displayed, and includes a list of the active events (*EDSMAC4, Buick vs Ford*, *EDHIS, Buick Occupant* and *EDHIS, Plymouth/Pedestrian Impact* are the events in this tutorial). The Report Window Information dialog also includes the user-editable *Report Window Name* text field and the *Report Type* list.
- Select the desired event name from the Active Events list.
- 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.

- Press OK to display the report.

The selected report is displayed in a resizable window. The following sections illustrate the reports produced for the *EDHIS, Buick Occupant* event.

Messages

EDHIS produces several messages, depending on the outcome of the event. For a complete listing and explanation of these messages, refer to Chapter 6.

To view the Messages report: click *Add New Object*, select *EDHIS, Buick Occupant* from the Active Events list, choose *Messages* from the *Report Type* list, and press *OK*.



Figure 5-19: Messages Report for EDHIS, Buick Occupant.

Accident History

The Accident History report displays the earth-fixed positions and velocities for the three human segments and the vehicle at the start of the run.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Accident History* from the *Report Type* list, and press *OK*.

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

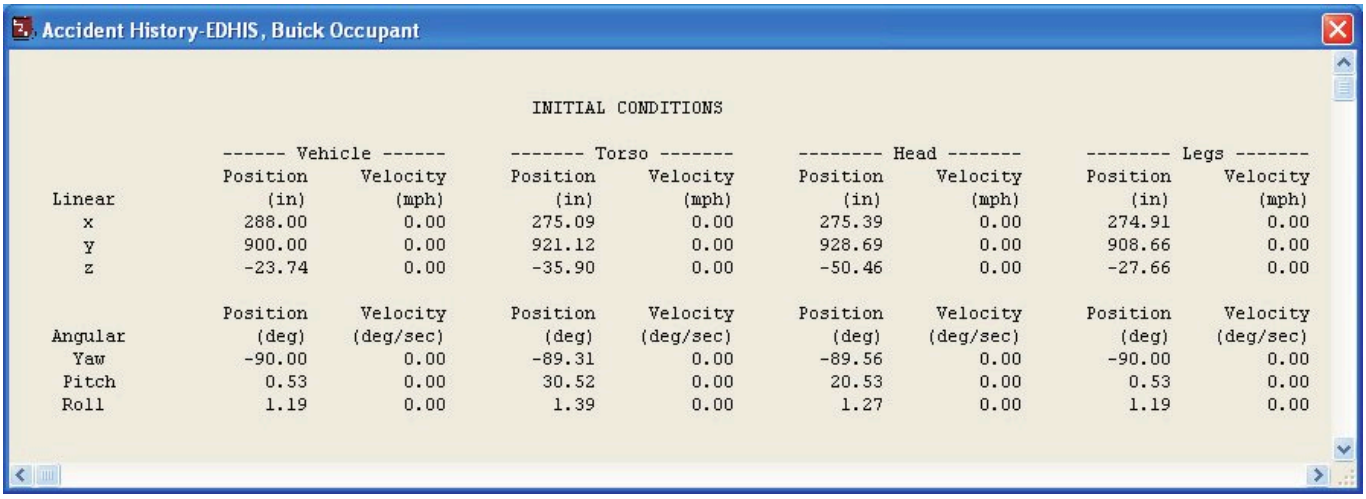
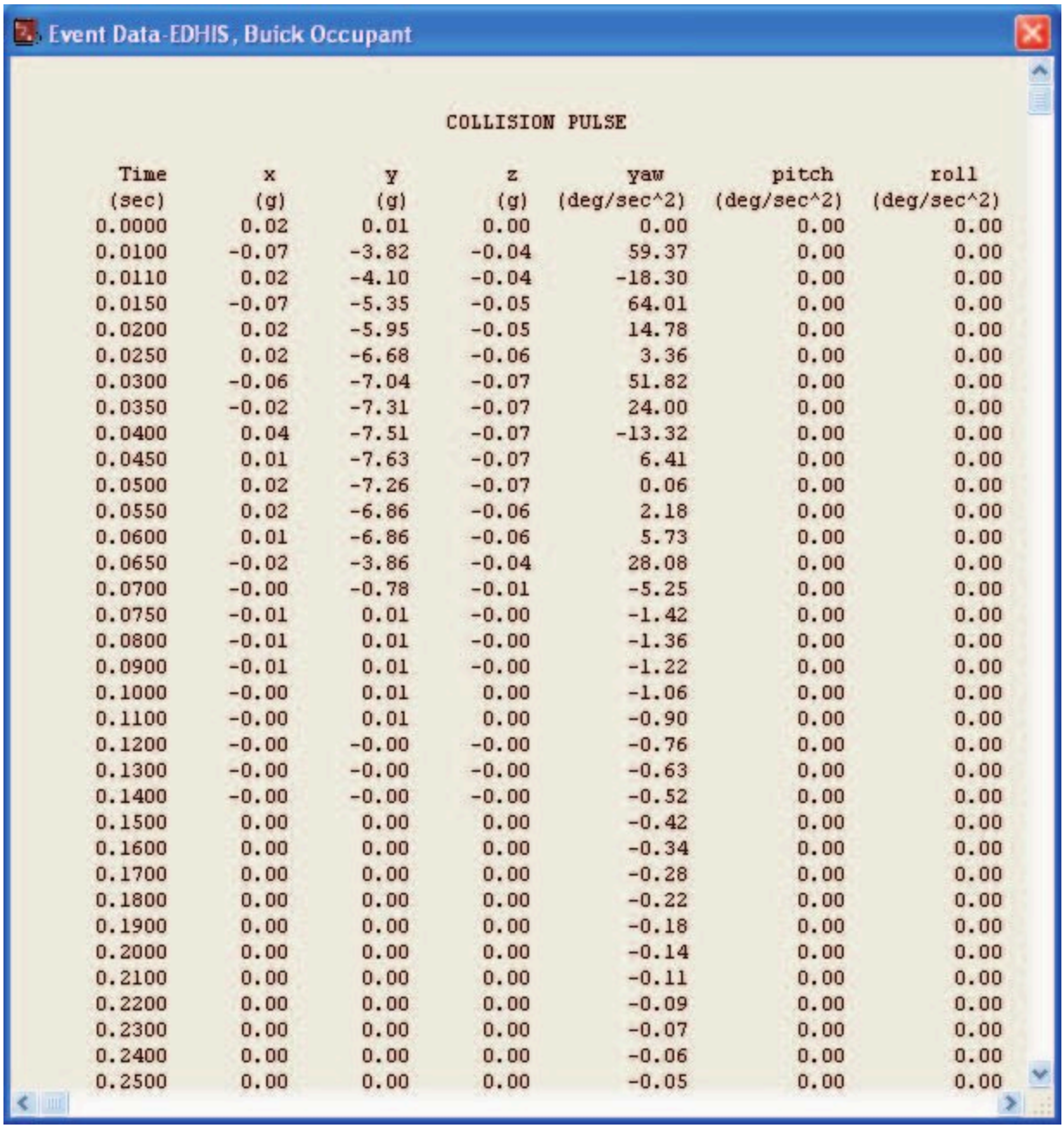


Figure 5-20: Accident History Report for EDHIS Buick Occupant.

Event Data

The Event Data report displays the acceleration pulse used in the EDHIS event.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Event Data* from the *Report Type* list, and press *OK*.



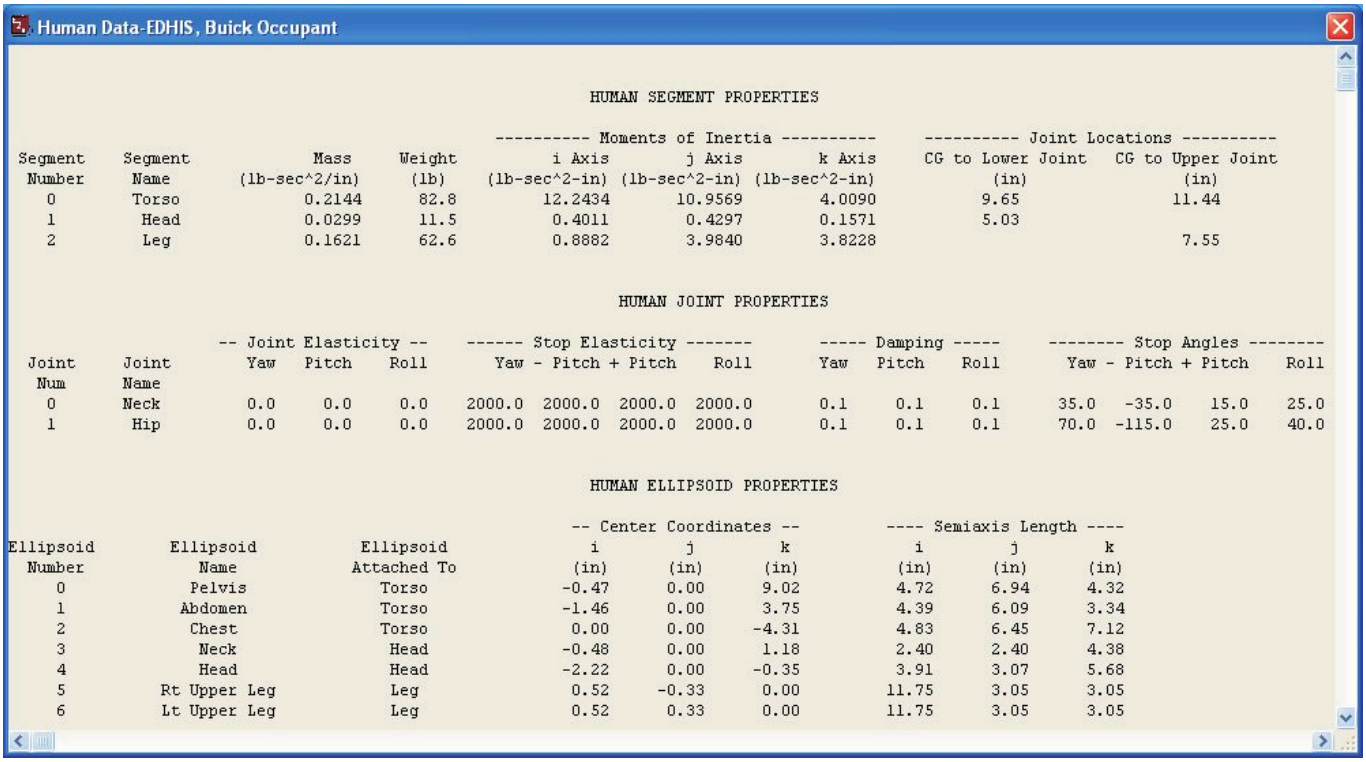
Time (sec)	x (g)	y (g)	z (g)	yaw (deg/sec^2)	pitch (deg/sec^2)	roll (deg/sec^2)
0.0000	0.02	0.01	0.00	0.00	0.00	0.00
0.0100	-0.07	-3.82	-0.04	59.37	0.00	0.00
0.0110	0.02	-4.10	-0.04	-18.30	0.00	0.00
0.0150	-0.07	-5.35	-0.05	64.01	0.00	0.00
0.0200	0.02	-5.95	-0.05	14.78	0.00	0.00
0.0250	0.02	-6.68	-0.06	3.36	0.00	0.00
0.0300	-0.06	-7.04	-0.07	51.82	0.00	0.00
0.0350	-0.02	-7.31	-0.07	24.00	0.00	0.00
0.0400	0.04	-7.51	-0.07	-13.32	0.00	0.00
0.0450	0.01	-7.63	-0.07	6.41	0.00	0.00
0.0500	0.02	-7.26	-0.07	0.06	0.00	0.00
0.0550	0.02	-6.86	-0.06	2.18	0.00	0.00
0.0600	0.01	-6.86	-0.06	5.73	0.00	0.00
0.0650	-0.02	-3.86	-0.04	28.08	0.00	0.00
0.0700	-0.00	-0.78	-0.01	-5.25	0.00	0.00
0.0750	-0.01	0.01	-0.00	-1.42	0.00	0.00
0.0800	-0.01	0.01	-0.00	-1.36	0.00	0.00
0.0900	-0.01	0.01	-0.00	-1.22	0.00	0.00
0.1000	-0.00	0.01	0.00	-1.06	0.00	0.00
0.1100	-0.00	0.01	0.00	-0.90	0.00	0.00
0.1200	-0.00	-0.00	-0.00	-0.76	0.00	0.00
0.1300	-0.00	-0.00	-0.00	-0.63	0.00	0.00
0.1400	-0.00	-0.00	-0.00	-0.52	0.00	0.00
0.1500	0.00	0.00	0.00	-0.42	0.00	0.00
0.1600	0.00	0.00	0.00	-0.34	0.00	0.00
0.1700	0.00	0.00	0.00	-0.28	0.00	0.00
0.1800	0.00	0.00	0.00	-0.22	0.00	0.00
0.1900	0.00	0.00	0.00	-0.18	0.00	0.00
0.2000	0.00	0.00	0.00	-0.14	0.00	0.00
0.2100	0.00	0.00	0.00	-0.11	0.00	0.00
0.2200	0.00	0.00	0.00	-0.09	0.00	0.00
0.2300	0.00	0.00	0.00	-0.07	0.00	0.00
0.2400	0.00	0.00	0.00	-0.06	0.00	0.00
0.2500	0.00	0.00	0.00	-0.05	0.00	0.00

Figure 5-21: Event Data Report for EDHIS Buick Occupant.

Human Data

The Human Data report displays the human segment and joint properties, as well as the human contact ellipsoid information.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Human Data* from the *Report Type* list, and press *OK*.



Human Data-EDHIS, Buick Occupant

HUMAN SEGMENT PROPERTIES

Segment Number	Segment Name	Mass (lb-sec^2/in)	Weight (lb)	Moments of Inertia i Axis (lb-sec^2-in)	Moments of Inertia j Axis (lb-sec^2-in)	Moments of Inertia k Axis (lb-sec^2-in)	Joint Locations CG to Lower Joint (in)	Joint Locations CG to Upper Joint (in)
0	Torso	0.2144	82.8	12.2434	10.9569	4.0090	9.65	11.44
1	Head	0.0299	11.5	0.4011	0.4297	0.1571	5.03	
2	Leg	0.1621	62.6	0.8882	3.9840	3.8228		7.55

HUMAN JOINT PROPERTIES

Joint Num	Joint Name	Joint Elasticity -- Yaw	Joint Elasticity -- Pitch	Joint Elasticity -- Roll	Stop Elasticity -- Yaw	Stop Elasticity -- - Pitch	Stop Elasticity -- + Pitch	Stop Elasticity -- Roll	Damping -- Yaw	Damping -- Pitch	Damping -- Roll	Stop Angles -- Yaw	Stop Angles -- - Pitch	Stop Angles -- + Pitch	Stop Angles -- Roll
0	Neck	0.0	0.0	0.0	2000.0	2000.0	2000.0	2000.0	0.1	0.1	0.1	35.0	-35.0	15.0	25.0
1	Hip	0.0	0.0	0.0	2000.0	2000.0	2000.0	2000.0	0.1	0.1	0.1	70.0	-115.0	25.0	40.0

HUMAN ELLIPSOID PROPERTIES

Ellipsoid Number	Ellipsoid Name	Ellipsoid Attached To	Center Coordinates i (in)	Center Coordinates j (in)	Center Coordinates k (in)	Semiaxis Length i (in)	Semiaxis Length j (in)	Semiaxis Length k (in)
0	Pelvis	Torso	-0.47	0.00	9.02	4.72	6.94	4.32
1	Abdomen	Torso	-1.46	0.00	3.75	4.39	6.09	3.34
2	Chest	Torso	0.00	0.00	-4.31	4.83	6.45	7.12
3	Neck	Head	-0.48	0.00	1.18	2.40	2.40	4.38
4	Head	Head	-2.22	0.00	-0.35	3.91	3.07	5.68
5	Rt Upper Leg	Leg	0.52	-0.33	0.00	11.75	3.05	3.05
6	Lt Upper Leg	Leg	0.52	0.33	0.00	11.75	3.05	3.05

Figure 5-22: Human Data Report for EDHIS, Buick Occupant.

Injury Data

The Injury Data report displays the results of injury calculations that compare simulated tolerance levels with those specified for the human.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Injury Data* from the *Report Type* list, and press *OK*.

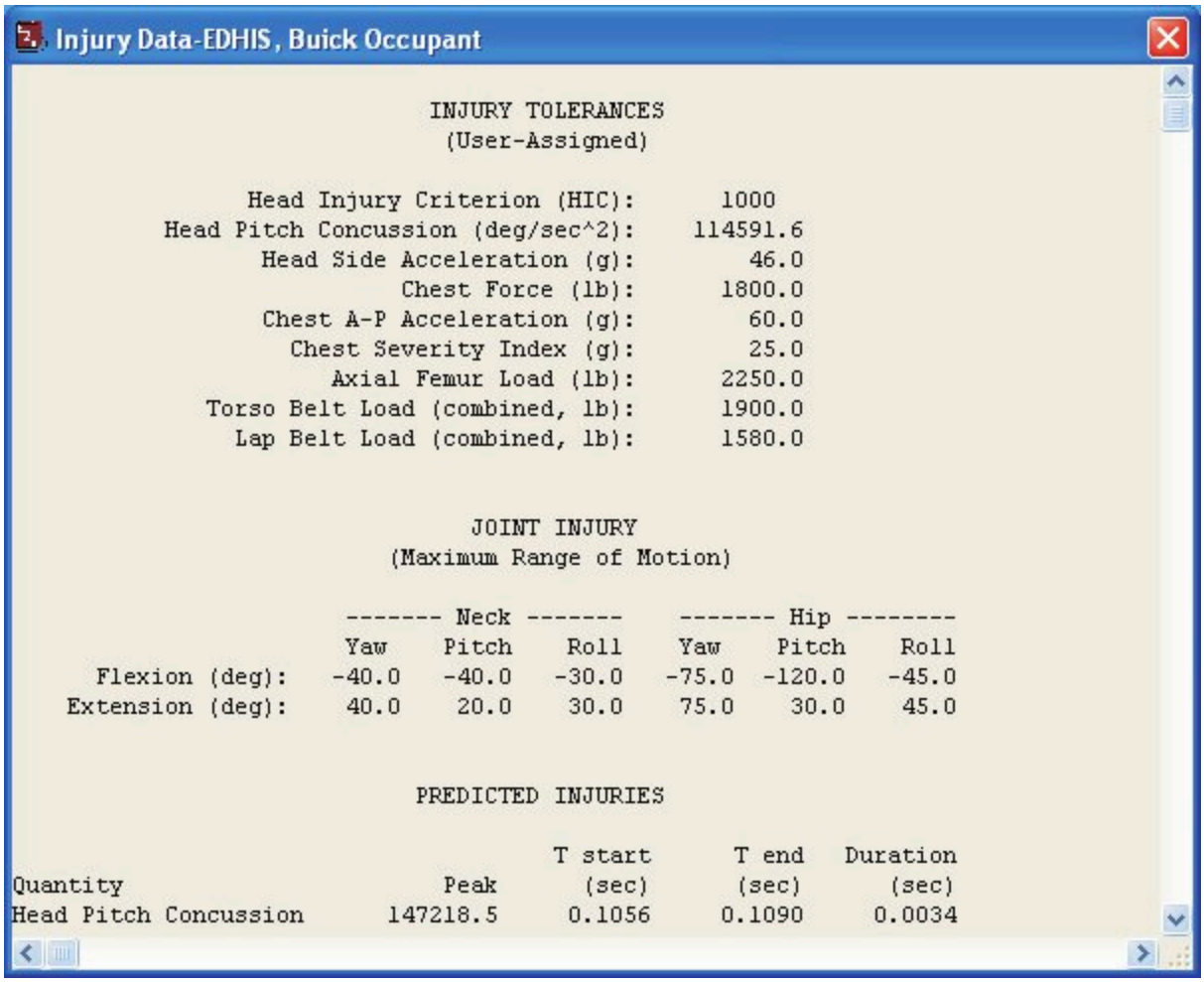


Figure 5-23: Injury Data Report for EDHIS, Buick Occupant.

Vehicle Data

The Vehicle Data report displays the contact properties (location and physical properties), collision pulse and restraint systems parameters.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Vehicle Data* from the *Report Type* list, and press *OK*.

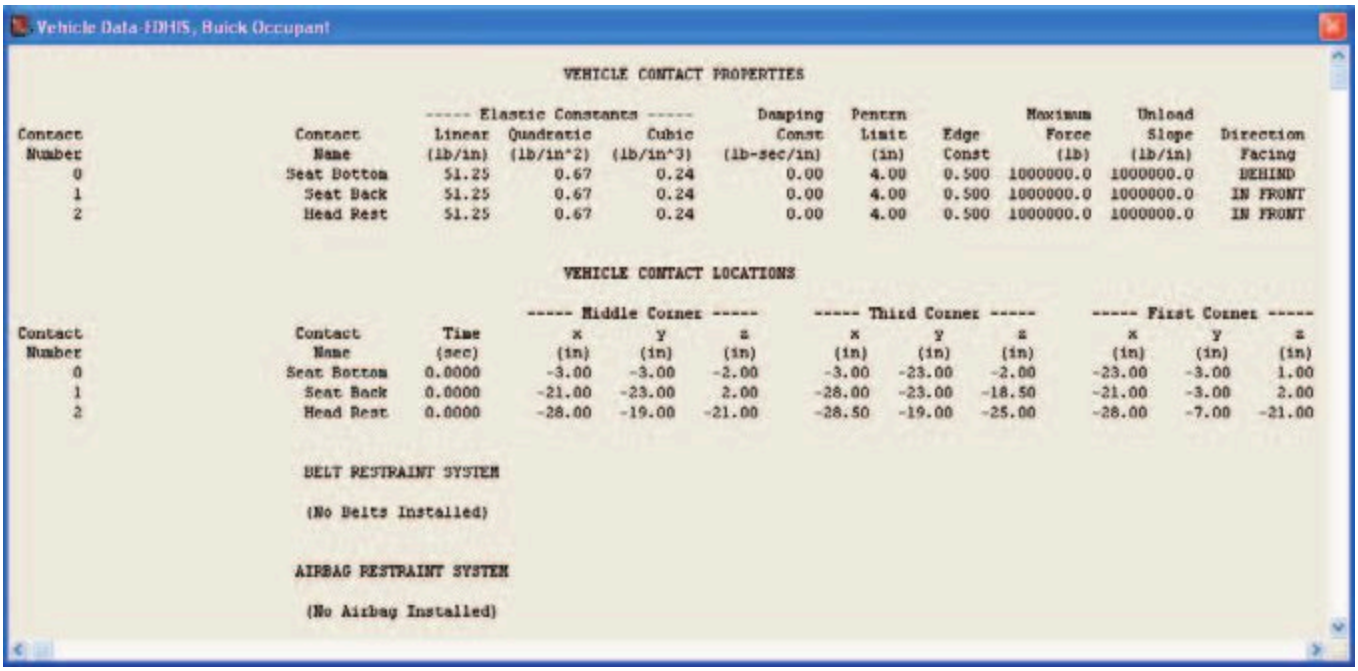


Figure 5-24: Vehicle Data Report for EDHIS, Buick Occupant.

Program Data

The Program Data report displays the simulation controls and other program control information.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Program Data* from the *Report Type* list, and press *OK*.

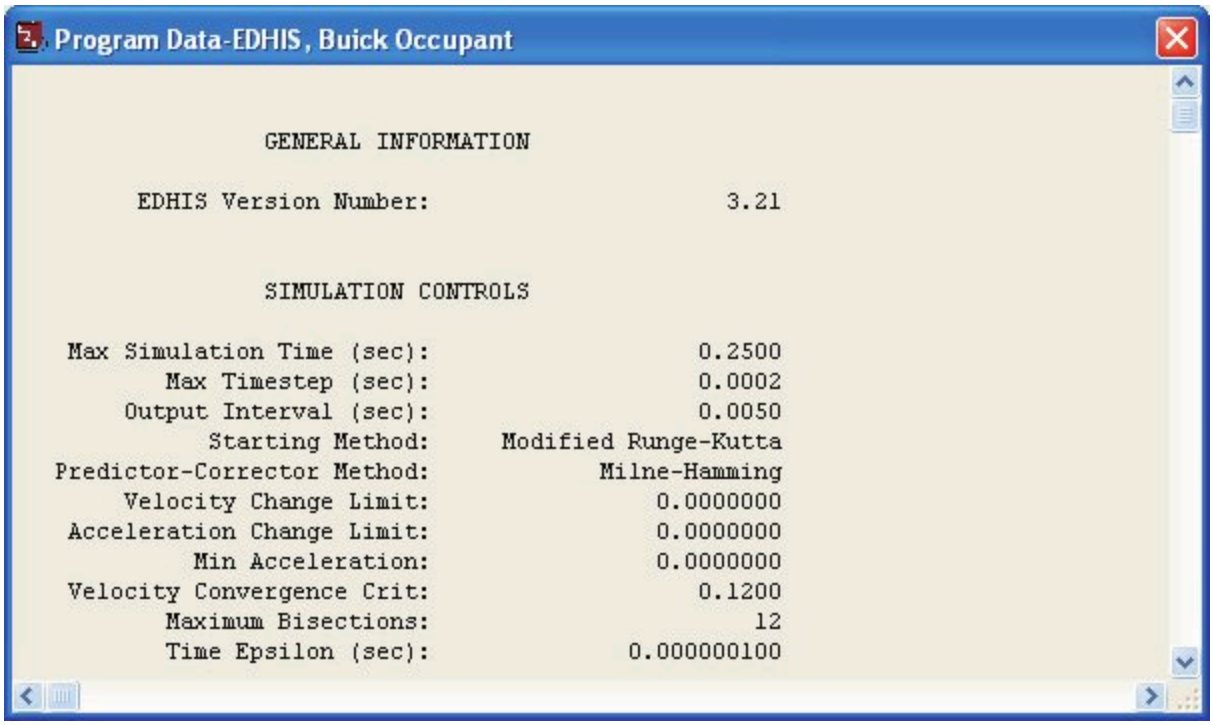


Figure 5-25: Program Data Report for EDHIS, Buick Occupant.

Variable Output

To view the Variable Output report for the *EDHIS, Buick Occupant* event: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Variable Output* from the *Report Type* list, and press *OK*.

The Variable Output report is displayed for the

EDHIS, Buick Occupant

event. The table is initially empty, so the next step is to select the time-dependent results we wish to display in the table.

Variable Selection

The purpose of our study is to determine the potential for head or neck injury, so let's select head position and velocity and forward and pitch accelerations from the Kinematics output group. Let's also add head vs headrest contact force from the Contacts output group. To display these variables:

- Click on *Select Variables* in the Variable Output window. The Variable Selection dialog is displayed.
- Click on the Object Name option list and choose *Male Adult Driver*. The Human Variable Groups list is displayed.

Let's add the Kinematics variables first:

- Click *Kinematics*, *Head*. The Variable Selection list for Head Kinematics is displayed.
- Select *x, y, z* positions, *pitch* orientation, *Fwd Velocity*, *Pitch Velocity*, *Fwd Acceleration* and *Pitch Acceleration* from the list.

Next, let's add the Head vs Head Rest contact force:

- Click *Contacts* and choose *Head, Head, Buick Skylark*, and *Head Rest* from the cascade menus. The Variable Selection list for Head vs Head Rest contact is displayed (see Figure 5-26).

> **NOTE:** The first time Head is displayed, it refers to the Head segment; the second time refers to the ellipsoid named Head that is attached to the Head segment.

- Select *Cont F tot* (total contact force) from the variable list.
- Press *OK* to add the selected variables to the Variable Output window.

The Variable Output report for the

EDHIS, Buick Occupant

now includes Forward and Pitch Head Accelerations and the contact force between the headrest and head, as shown in Figure 5-27. Feel free to use the above steps to add additional parameters to the variable output table and view the results.

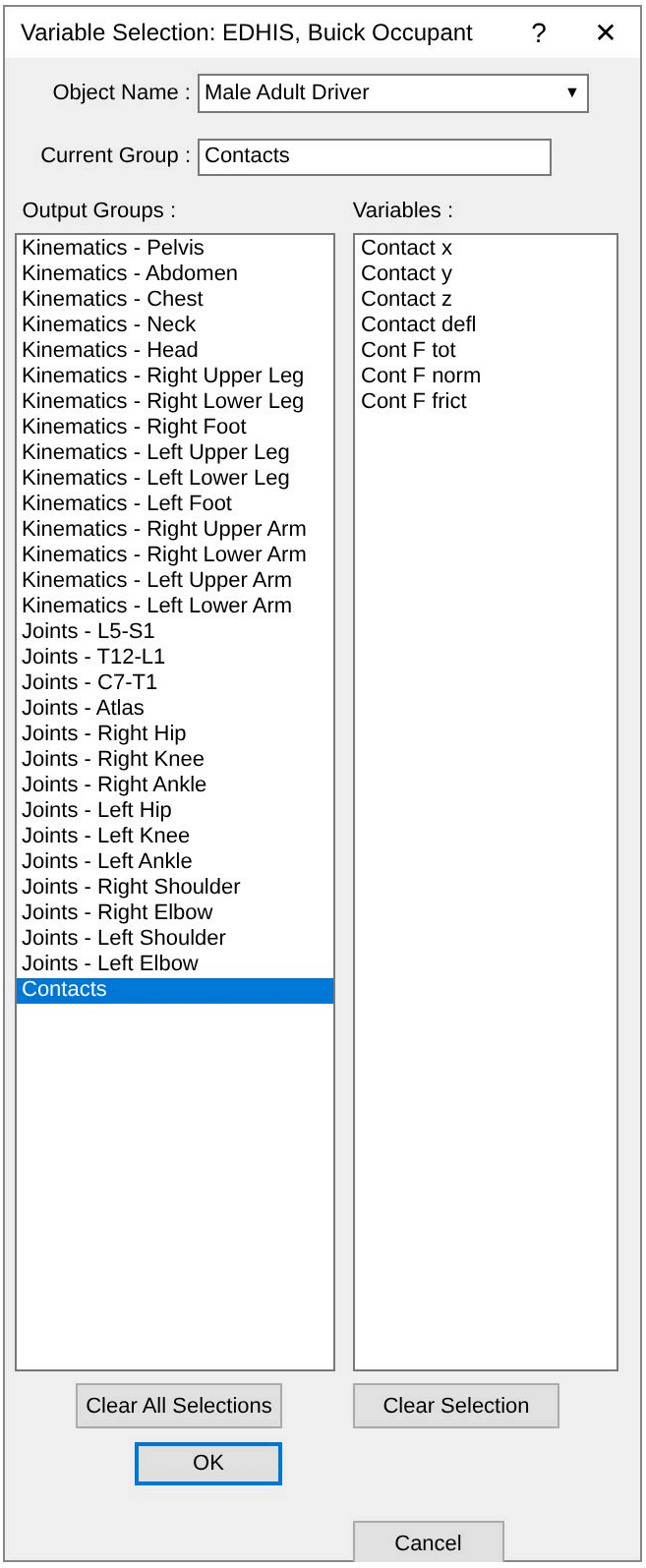
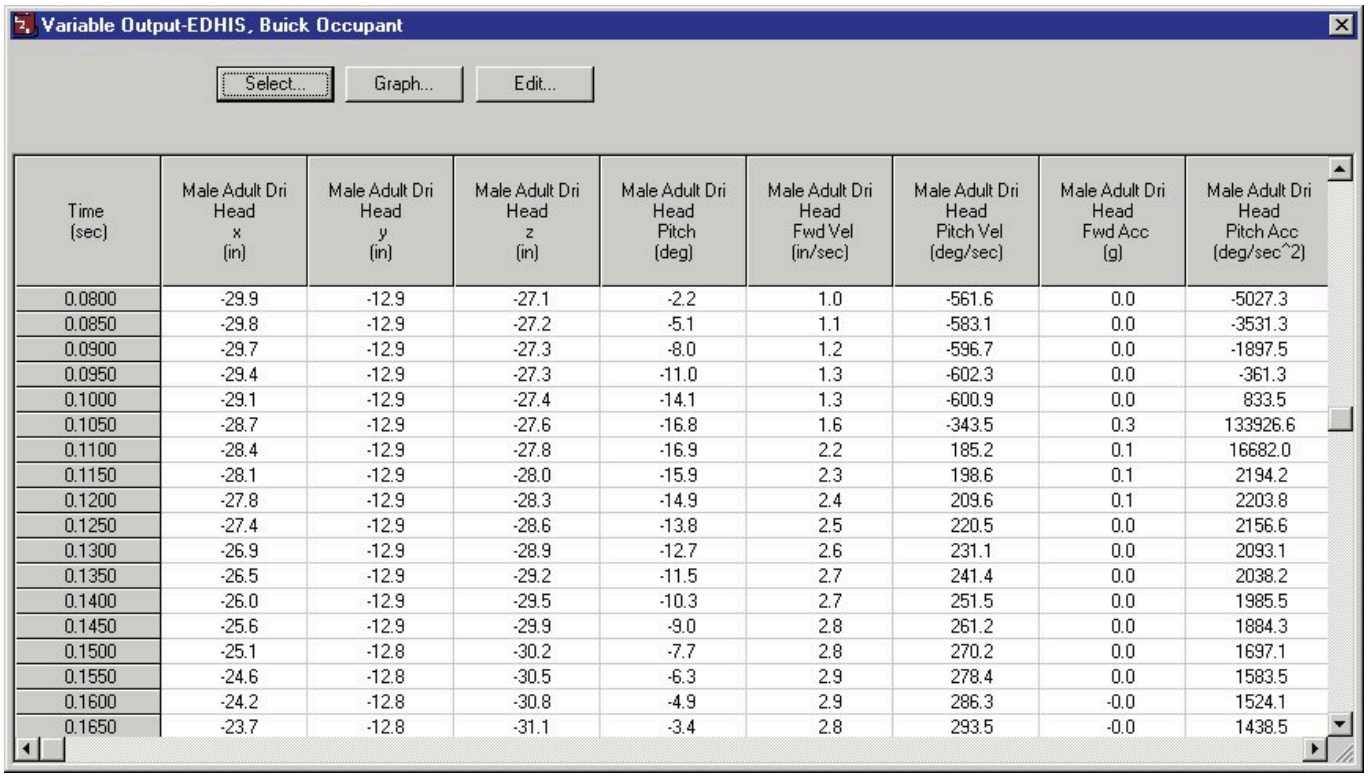


Figure 5-26: Variable Selection dialog.



Time (sec)	Male Adult Dri Head x (in)	Male Adult Dri Head y (in)	Male Adult Dri Head z (in)	Male Adult Dri Head Pitch (deg)	Male Adult Dri Head Fwd Vel (in/sec)	Male Adult Dri Head Pitch Vel (deg/sec)	Male Adult Dri Head Fwd Acc (g)	Male Adult Dri Head Pitch Acc (deg/sec^2)
0.0800	-29.9	-12.9	-27.1	-2.2	1.0	-561.6	0.0	-5027.3
0.0850	-29.8	-12.9	-27.2	-5.1	1.1	-583.1	0.0	-3531.3
0.0900	-29.7	-12.9	-27.3	-8.0	1.2	-596.7	0.0	-1897.5
0.0950	-29.4	-12.9	-27.3	-11.0	1.3	-602.3	0.0	-361.3
0.1000	-29.1	-12.9	-27.4	-14.1	1.3	-600.9	0.0	833.5
0.1050	-28.7	-12.9	-27.6	-16.8	1.6	-343.5	0.3	133926.6
0.1100	-28.4	-12.9	-27.8	-16.9	2.2	185.2	0.1	16682.0
0.1150	-28.1	-12.9	-28.0	-15.9	2.3	198.6	0.1	2194.2
0.1200	-27.8	-12.9	-28.3	-14.9	2.4	209.6	0.1	2203.8
0.1250	-27.4	-12.9	-28.6	-13.8	2.5	220.5	0.0	2156.6
0.1300	-26.9	-12.9	-28.9	-12.7	2.6	231.1	0.0	2093.1
0.1350	-26.5	-12.9	-29.2	-11.5	2.7	241.4	0.0	2038.2
0.1400	-26.0	-12.9	-29.5	-10.3	2.7	251.5	0.0	1985.5
0.1450	-25.6	-12.9	-29.9	-9.0	2.8	261.2	0.0	1884.3
0.1500	-25.1	-12.8	-30.2	-7.7	2.8	270.2	0.0	1697.1
0.1550	-24.6	-12.8	-30.5	-6.3	2.9	278.4	0.0	1583.5
0.1600	-24.2	-12.8	-30.8	-4.9	2.9	286.3	-0.0	1524.1
0.1650	-23.7	-12.8	-31.1	-3.4	2.8	293.5	-0.0	1438.5

Figure 5-27: Variable Output report for EDHIS, Buick Occupant.

Trajectory Simulation

The Trajectory Simulation provides a 3-dimensional visualization of the vehicle and occupant motion during the event.

To view it: click *Add New Object*, select *EDHIS, Buick Occupant*, choose *Trajectory Simulation* from the *Report Type* list, and press *OK*.

The Trajectory Simulation viewer is displayed for the

EDHIS, Buick Occupant

event. The human and vehicle are shown at their initial positions.

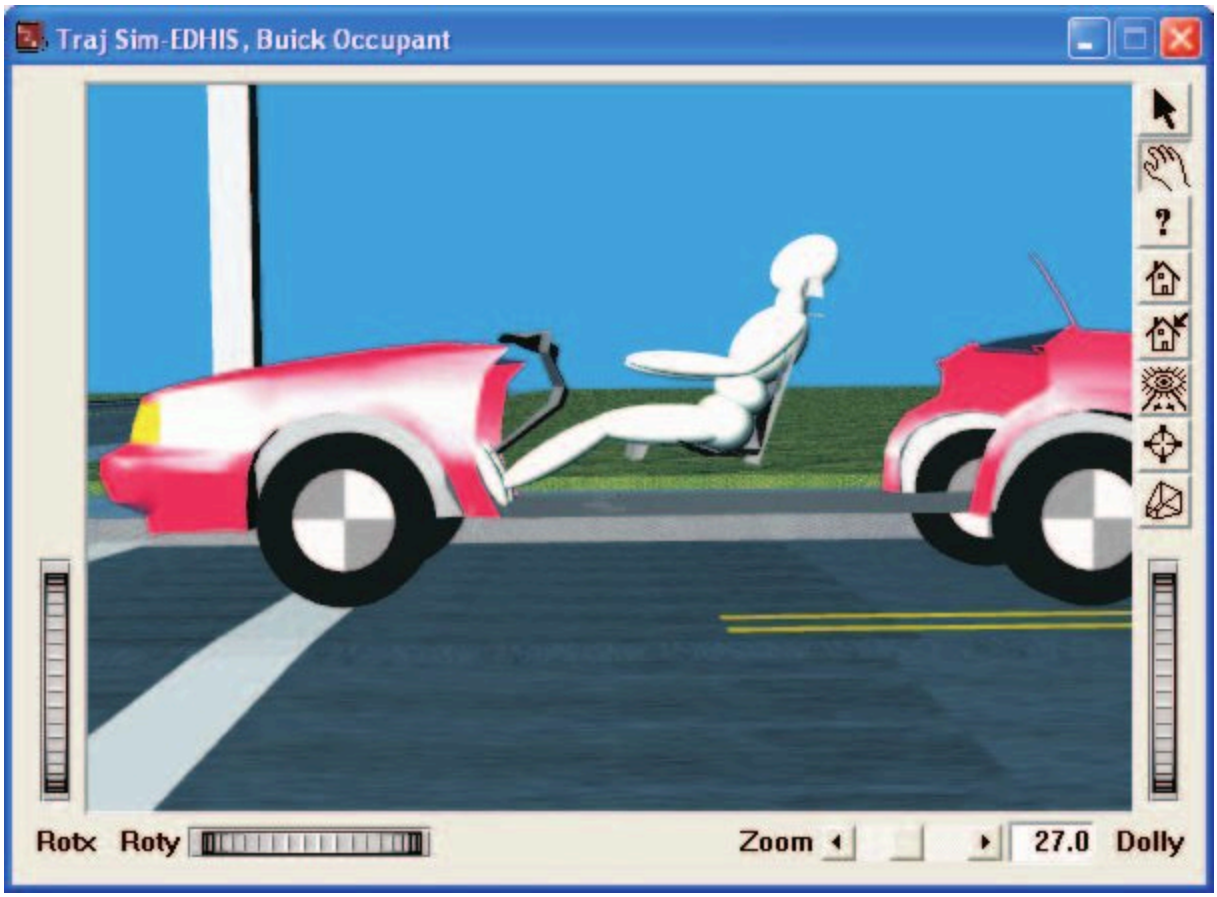


Figure 5-28: Trajectory Simulation for EDHIS, Buick Occupant.

To visualize the motion, perform the following steps:

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

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:

- Click the dialog header for *Variable Output - EDHIS, Buick Occupant*. The dialog header is highlighted and the Variable Output window pops to the top of the display (if it isn't there already), indicating it is the current window.
- Click on the *File* menu and choose *Print*. The Print dialog is displayed, allowing the user to select from several available options.

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

- 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 two steps described above.

> **NOTE:** The Print dialog provides several options. Refer to the Windows or Printer User's 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, or by EDHIS. Some of the more common operating system messages are described in the HVE Appendix. A more thorough discussion of operating system messages may be found in the operating system manual.

Messages produced by HVE are described in the HVE User's Manual, Appendix II.

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

- **Fatal Messages (Level 1)** — These messages halt execution and are caused by the program's inability to continue the calculation procedure based on intermediate results which are inconsistent or incompatible with basic program assumptions.
- **Diagnostic Messages (Level 2)** — These messages 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 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 EDHIS 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 or operating system message by referring to the HVE Appendix or your computer's operating system manual. If the message is not listed in either place, please contact EDC immediately with the offending error message and the input file that caused the error.

*(updated: this list has been checked against, and extended from, the messages carried by the current release. Messages 14–19 below are carried by the current release but were not listed in the original manual. A few entries are marked as **not produced by the current release**; they are retained so that a message seen in an earlier version can still be looked up, and each carries a note on where to look instead.)*

No Messages

No messages were produced; no action is necessary.

Integration Error *The simulation was terminated due to an integration error during initialization of the Runge-Kutta method because the integration routine failed to converge to the specified Velocity Convergence Criterion after Maximum Bisections. These parameters are set in the Simulation Controls dialog. NOTE: Velocity Convergence should be about 0.001 and Max Bisections should be about 10.*

(Level 1 - Fatal)

Integration Error *The numerical integration routine failed to converge to the specified Velocity Convergence Criterion after Maximum Bisections. These parameters are set in the Simulation Controls dialog. NOTE: Velocity Convergence should be about 0.001 and Max Bisections should be about 10.*

(Level 1 - Fatal)

The simulation was terminated during the initial timestep.

(Level 1 - Fatal)

The simulation was terminated because of a singular mass matrix in the equations of motion. Send your offending case to EDC for evaluation.

(Level 1 - Fatal)

The simulation was terminated in function Accel() because a joint angle exceeds the maximum allowed.

(Level 2 - Diagnostic)

The simulation was terminated in function Contact() because a problem was encountered calculating a human ellipsoid vs vehicle contact force.

(Level 1 - Fatal)

The simulation was terminated in function Belt() because a problem was encountered calculating a belt force.

(Level 1 - Fatal)

The simulation was terminated because a problem was encountered calculating an airbag force.

(Level 1 - Fatal)
(updated: not produced by the current release. An airbag difficulty now produces one of the two airbag shut-off messages at the end of this chapter, and the run continues without the bag.)

The simulation was terminated because the selected integration timestep was too large. Reduce the value to 0.001 sec or less (Simulation Controls dialog, Human Collision Integration Timestep).

(Level 1 - Fatal)
(updated: not produced by the current release. A timestep that is too large is handled by the automatic halving described in Chapter 4; if the solution still cannot be made to converge, the run ends with an Integration Error.)

The simulation was terminated because the Get Surface Information terrain search failed.

(Level 1 - Fatal)
(updated: not produced by the current release; not listed in the original manual either.)

The simulation terminated because an initial joint articulation angle was outside of the specified range of motion for the joint. (The range of motion is specified by the + and − joint stop angles in the HVE Human Editor.)

(Level 3 - Informative)

Integration Error *The velocity change for one integration timestep was greater than the user-entered maximum (see Simulation Controls dialog, Max Velocity Change). NOTE: This check may be turned off by setting Max Velocity Change*

equal to 0.0.

(Level 1 - Fatal)

(updated: not produced by the current release. The Velocity Change Limit is applied as a stability test: exceeding it halves the timestep and retries the step, so the run continues — see Chapter 4.)

Integration Error *The acceleration change for one integration timestep was greater than the user-entered maximum (see Simulation Controls dialog, Max Acceleration Change). NOTE: This check may be turned off by setting Max Acceleration Change equal to 0.0.*

(Level 1 - Fatal)

(updated: not produced by the current release, for the same reason as the message above — the limit halves the timestep and the run continues.)

NOTE: The number of peaks exceeded the available number of peaks in the Injury Tolerance.

(Informative)

(updated: issued by the current release; not listed in the original manual)

Torso Restraint System Failure!

(Informative)

(updated: not produced by the current release. Belt rupture is not modelled: the Belt Breaking Strength acts as a limit on tension, above which the belt unloads along the entered slope and is left permanently stretched. To judge whether a belt would have failed, compare the belt tension in the Variable Output against the entered breaking strength.)

Lap Restraint System Failure!

(Informative)

(updated: not produced by the current release, for the same reason as the message above.)

An Ellipsoid vs Contact Surface force exceeded the maximum allowable force.

(Informative — the contact surface saturates and then unloads along the entered slope; see Contact Surface Maximum Force in Table 2-3)

(updated: not produced by the current release. The saturation and unloading behave as described; to see which surfaces reached their maximum, compare the contact forces in the Variable Output against the entered maximum force.)

The airbag model was turned off because pressure became negative. Check the Vehicle Data Report (see Airbag) for more information.

(Informative)

(updated: issued by the current release; not listed in the original manual)

The airbag model was turned off because it became unstable. Check the Vehicle Data Report (see Airbag) for more information.

(Informative)

(updated: issued by the current release; not listed in the original manual)

Previous: Chapter 5 — EDHIS Tutorial | Next: Chapter 7 — References

Chapter 7 — References

1. Day, T.D., "Differences Between EDHIS and HSRI-3D," SAE Paper published at the 1997 SAE International Congress, Detroit MI.
2. Robbins, D.H., Bennett, R.O., Roberts, V.L., "HSRI Three-Dimensional Crash Victim Simulator: Analysis, Verification and User's Manual, and Pictorial Section," HSRI Report No. BIO M-70-9, HSRI, University of Michigan, 1971.
3. Bennett, R.O., Bowman, B.M., Robbins, D.H., "Supplement to the HSRI Three-Dimensional Crash Victim Simulation Report," HSRI Report No. UM-HSRI-77-20, University of Michigan, 1977.
4. *Human Tolerance to Impact Conditions as Related to Motor Vehicle Design*, SAE Technical Report No. J885, Society of Automotive Engineers, Warrendale, PA, 1986.
5. *EDSMAC User's Manual*, Second Edition, Engineering Dynamics Corp., Beaverton, Oregon, October, 1997.
6. *HVE User's Manual*, Second Edition, Engineering Dynamics Corp., Beaverton, Oregon, October, 1997.

Previous: Chapter 6 — Messages | Back to Contents