ENGINEERING DYNAMICS COMPANY

EDSVS

HVE Human Vehicle Environment

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

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EDSVS — Single Vehicle Simulator

Engineering Dynamics Company Single Vehicle Simulator

Version 7 — Sixth Edition (January 2006), converted to Markdown and updated to match the current HVE software (July 2026 edition).

EDSVS is a simulation analysis of the response of a motor vehicle (4-wheeled automobile, or truck having tandem axles and dual tires) to driver inputs (accelerating, braking and steering). It is based on the TBST program developed at the University of Michigan Transportation Research Institute. This manual describes the model features and use; input parameters and output reports are described at a high level. It is intended to be used in conjunction with the HVE-2D or HVE User's Manual, which provides in-depth coverage of the human, vehicle and environment models, as well as the Event Editor and Playback Editor.

How to Use This Manual

EDSVS is compatible with both HVE-2D and HVE. If you are using EDSVS within the HVE environment, the Human, Vehicle and Environment Editors will have additional features that are not available in HVE-2D. These features are described in great detail in the HVE User's Manual. While some dialogs do look different, the required input for EDSVS is found in both. Where there are differences related to the use of EDSVS, these differences are noted in this manual. Information specific to HVE was designated with a grey background in the original manual; in this edition it is marked with **HVE:** prefixed blockquotes.

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

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1. Chapter 1 — EDSVS Program Description — Overview, model inputs and outputs, validation, HVE-2D and HVE, basic procedure
2. Chapter 2 — EDSVS Program Input — Vehicles, environment, event set-up, driver controls, simulation controls, calculation options
3. Chapter 3 — EDSVS Program Output — Alpha-numeric reports, graphic reports, variable output table, trajectory simulations
4. Chapter 4 — EDSVS Calculation Method — Equations of motion, tire forces, antilock model, assumptions
5. Chapter 5 — EDSVS Tutorial — A complete run-off-road study, from vehicle creation to printed reports
6. Chapter 6 — EDSVS Messages — Complete list of EDSVS simulation messages
7. Chapter 7 — Technical References
8. Chapter 8 — Index — Topic-to-chapter guide (replaces the printed page index)

Related pages

- EDSVS Calculation Options — current defaults, ranges and the Get Surface Information Options dialog.

Notes on this edition

This Markdown edition preserves the substance of the Sixth Edition manual and has been checked against the behavior of the current EDSVS simulation program and the current HVE user interface. Where the original manual was stale, the text describes the current software and is marked with

(updated: ...)

notes. Key updates:

- EDSVS does not present or use a Calculation Options dialog; the Roll Couple Distribution used by the simulation is read from the vehicle's **Roll Couple Distribution** suspension value (default 0.55), not from a per-event calculation option.
- The terrain surface-search method is now selected in the separate **Get Surface Information Options** dialog; the **By Elevation** method is not supported.
- The message catalog now contains four termination messages (wheel lift-off, excessive roll/pitch, surface information failure, integration error).

Screenshots from the original manual are not reproduced; italic placeholders give the figure caption for each.

Chapter 1 — EDSVS Program Description

Overview

EDSVS (**E**ngineering **D**ynamics Corporation **S**ingle **V**ehicle **S**imulator) is a simulation analysis of a motor vehicle (4-wheeled automobile or truck having tandem axles and dual tires) to driver inputs (accelerating, braking and steering). It is based on a program called TBST developed at the University of Michigan Transportation Research Institute [14]. EDSVS determines how the vehicle responds to the inputs by generating the path, velocity, acceleration, tire force, and other data as a function of time.

Accident investigators can use EDSVS to determine how a driver may have lost vehicular control. By repeated adjustments of the throttle, braking and steering input tables, the user will converge on those driver inputs which match accident site evidence. EDSVS can also be used to study the handling effects due to changes in vehicle weight distribution, wheelbase, track width, CG height, tire friction, cornering stiffness, and other parameters.

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

what if

analysis, changes can be made to an isolated variable or set of variables and the effects are displayed immediately. For example, the sensitivity of the trajectory to various front/rear tire combinations can be studied simply by changing the tire data; the sensitivity to CG location can be studied by moving its position. However, the major purpose of EDSVS can be realized by changing the driver input tables (throttle, braking and steering) until the resulting trajectory matches the actual trajectory produced by the vehicle during a particular maneuver. Thus, the user learns how a driver's inputs may have affected the outcome of an accident.

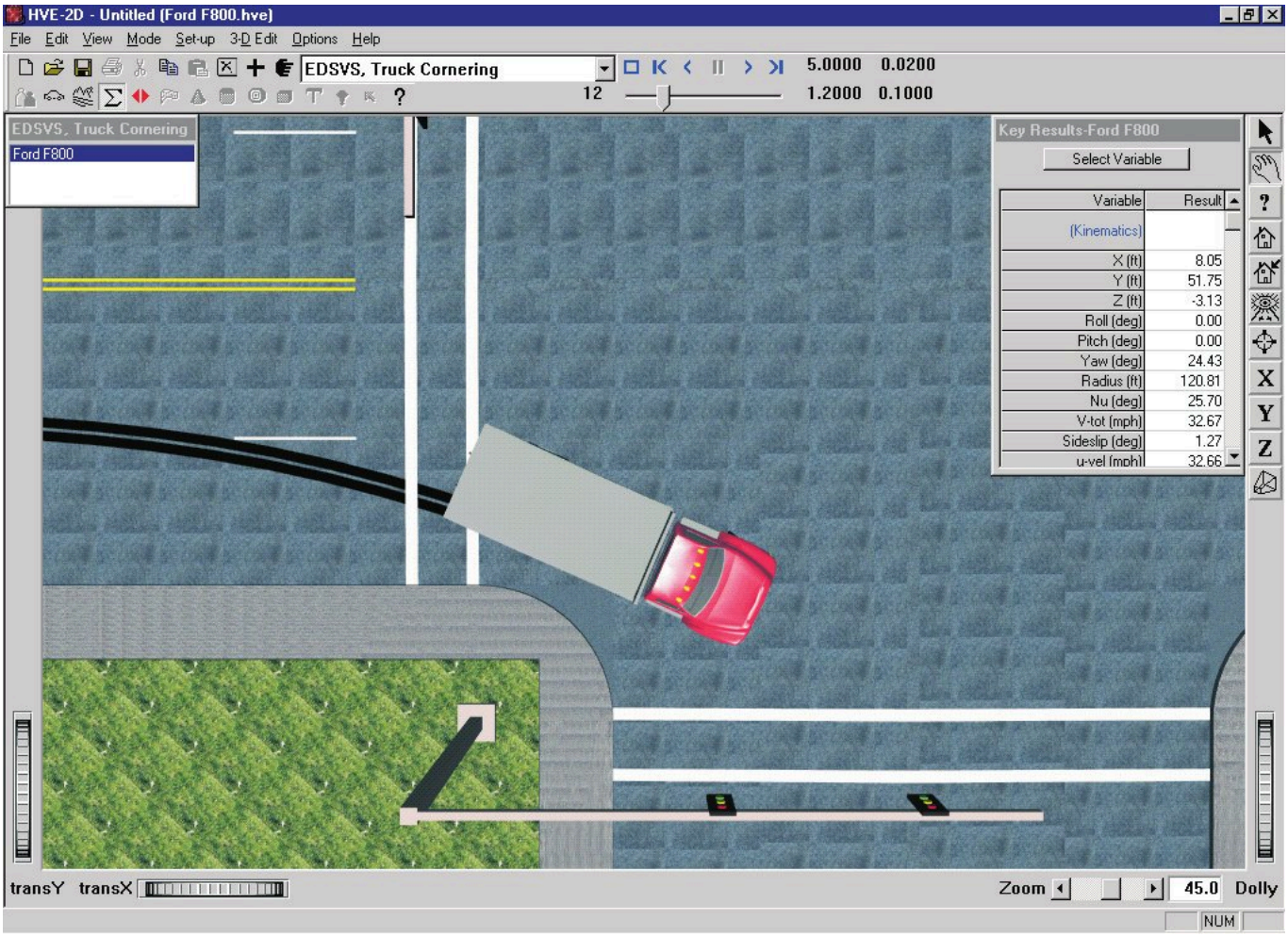


Figure 1-1: EDSVS Event.

Model Inputs

EDSVS inputs include one vehicle and an optional driving environment. Event set-up parameters include vehicle initial position and velocity, and various driver control options (steering, braking and throttle).

Model Outputs

EDSVS output reports include Accident History, Messages, Program Data, Trajectory Simulations, Variable Output and Vehicle Data.

Validation

The EDSVS simulation model was first validated by direct comparison with results using TBST. These in-house validations included a validation study in the original TBST research document.

The in-use accuracy of the program is dependent upon several factors. Because EDSVS is a 3-degree of freedom analysis, jounce and rebound suspension effects are ignored. Therefore, the program is well suited for the study of vehicle trajectories on low-friction surfaces, such as ice and/or snow. It also serves as an excellent first-order

approximation for normally encountered road surfaces, such as dry asphalt and concrete. Good geometrical, inertial, and tire data are essential for accurate results.

> **HVE:** EDSVS has been extended and revalidated for use in the HVE environment to account for 3-D terrain. Vehicle roll and pitch angles are allowed and accounted for within the limits of the small angle assumption (normally 15 degrees). See reference 25 for further details regarding the validation of EDSVS.

HVE-2D and HVE

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

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

Basic Procedure

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

1. Use the Vehicle Editor to add one or more vehicles to the case. Optionally, edit any of the default vehicle parameters.
2. Optionally, use the Environment Editor to create a visual and physical environment.
3. Use the Event Editor to set up and execute the EDSVS simulation model by performing the following steps:
4. Choose one vehicle from the list of vehicles created earlier.
5. Choose the EDSVS calculation model.
6. Position the vehicle in the environment, and assign an initial velocity.
7. Assign driver controls (Steering, Braking, Throttle).
8. Execute the simulation event.
9. Modify the initial conditions and driver inputs as required to achieve the desired match between the simulation and actual event.
10. Use the Playback Editor to view the various reports and trajectory simulations. If desired, produce a video output of the simulation.

Contents | Next: Chapter 2 — EDSVS Program Input

Chapter 2 — EDSVS Program Input

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

- **Objects** — The number of vehicles, and the specific vehicle parameters actually used by EDSVS.
- **Events** — The various HVE-2D options available for setting up and executing an EDSVS event.

Objects Overview

The objects used by the EDSVS model are:

- **Vehicles** — One vehicle may be studied by EDSVS.
- **Environment** — Like the *real* world, EDSVS has exactly one environment.

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

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

Vehicles

EDSVS uses one vehicle created using the Vehicle Editor (see Figure 2-1). Vehicles are selected from the Vehicle Database by choosing the following attributes:

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

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

- **Driver Location** — The *Driver Location* is not used by EDSVS. However, *Driver Location* must not be *None*; otherwise, the Driver Controls (Steering, Throttle, Brakes) will not be available during Event mode.
- **Engine Location** — The Engine Location is not used by EDSVS. However, *Engine Location* must not be *None*; otherwise, the Throttle Table will not be available during Event mode.
- **Number of Axles** — EDSVS supports 2- and 3-axle vehicles.
- **Drive Axle(s)** — EDSVS supports all drive axles.

To add a vehicle to the current 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.

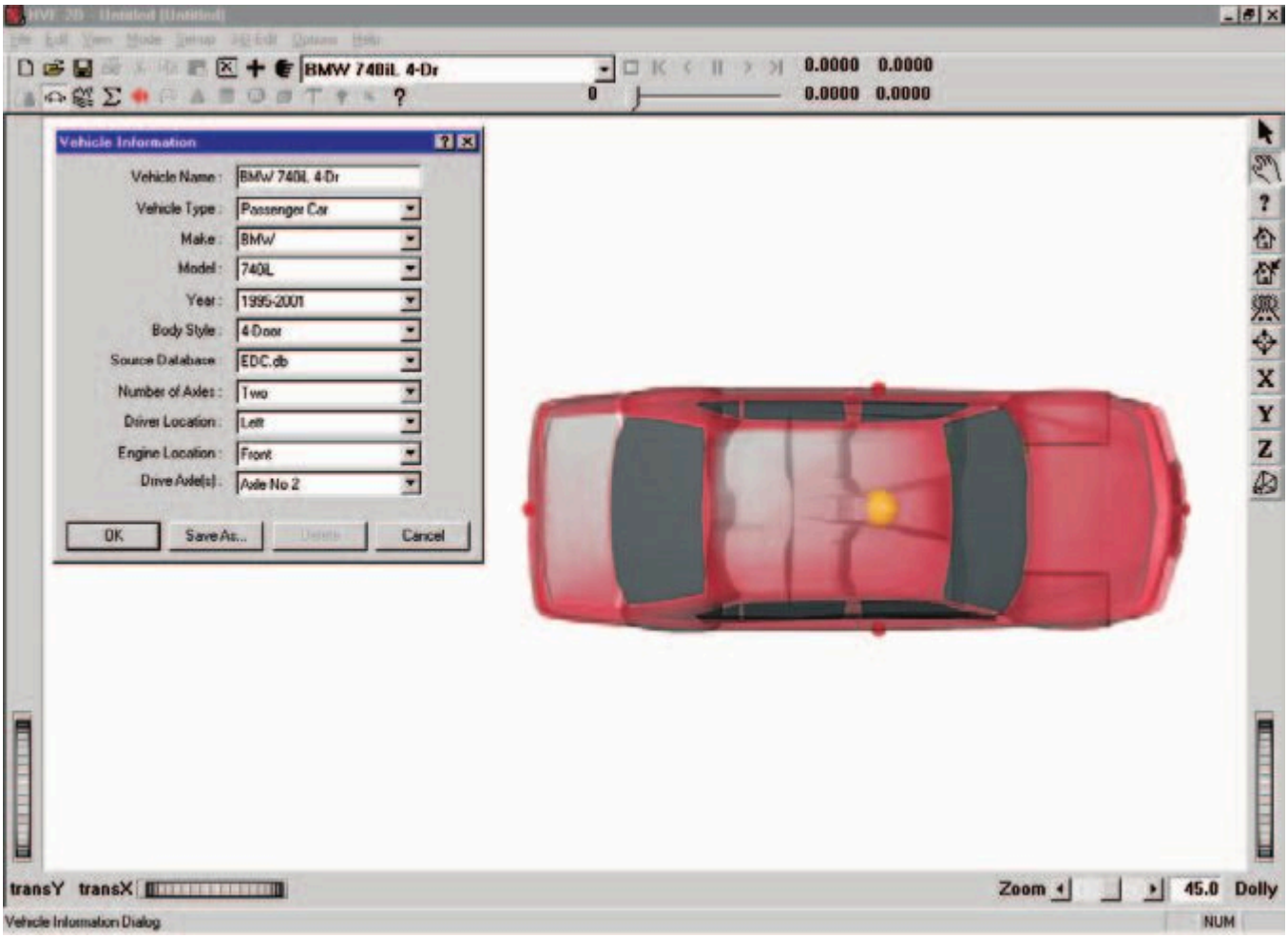


Figure 2-1: HVE-2D Vehicle Editor.

The following Vehicle Parameter groups are used by EDSVS:

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

- Brake Data
- Steering System

> NOTE: The Exterior Data Group (Overall Dimensions, Structural Stiffness Coefficients), Brake System and Drivetrain are not used by EDSVS.

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

Sprung Mass

The Sprung Mass parameters are shown in Table 2-1. Information on each group is provided below.

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

Parameter	Description
Weight	Total vehicle weight
Total Yaw Inertia	Rotational inertia of the sprung mass about the vehicle-fixed z axis
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., wheel locations).

Inertias

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

Move CG

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

> **HVE:** If using HVE, the CG may also be relocated in the vehicle-fixed y direction.

Geometry File

The Geometry File is not used by EDSVS.

Inter-vehicle Connections

Inter-vehicle Connection parameters are not used by EDSVS.

Unsprung Mass

The Unsprung Mass parameters used by EDSVS are shown in Table 2-2. Information on each group is provided below.

Table 2-2: Vehicle Unsprung Mass, Brake and Tire Parameters Used By EDSVS

Parameter	Description
Wheel Location	Vehicle-fixed x,y,z coordinates for each wheel
Anti-lock Effectiveness	The percentage of gain in longitudinal braking force due to anti-lock
Tire Unloaded Radius	Tire radius in unloaded condition (editable in HVE)
Tire Friction Table, Test Load/Speed	The load and speed for a given set of friction results (EDSVS uses the middle load and middle speed)
Peak Longitudinal Friction, Slide Friction, Slip at Peak Friction and Longitudinal Stiffness	Tire frictional properties
Friction In-use Factor	Multiplier for Peak and Slide Friction
Cornering Stiffness	Tire lateral force per unit of tire lateral slip for small amounts of lateral slip
Cornering Stiffness In-use Factor	Multiplier for Cornering Stiffness

Wheel Location

Although HVE-2D provides values for the vehicle-fixed x,y,z coordinates of each wheel, EDSVS uses only the following five values: a, the distance from the CG to the front axle; b, the distance from the CG to the rear axle; tw_f, the front track width; tw_r, the rear track width; and z_w, the vertical distance from the CG to the wheel (for each wheel).

> NOTE: EDSVS uses the average x_{wheel} for the front wheels to calculate a and the average x_{wheel} for the rear wheels to calculate b. Similarly, EDSVS uses the total distance between right-side and left-side tires to calculate track width. Bilateral symmetry is assumed. Finally, EDSVS uses tire radius and z_{wheel} to calculate CG elevation above ground.
>
> **HVE:** In HVE, tire radius is user-editable.

Brake

EDSVS uses the wheel brake system Antilock Effectiveness. The specific parameters used by EDSVS are shown in Table 2-2.

Tire

The HVE-2D tire parameters provide the following data groups:

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

EDSVS's use of these parameters is described below.

Physical Data

The Tire Physical Data used by EDSVS are shown in Table 2-2. The tire's unloaded radius is used to establish the vehicle's CG elevation. Other physical data parameters are not used.

> **HVE:** In HVE, tire unloaded radius is user-editable.

Friction Data

The Friction Data used by EDSVS are shown in Table 2-2. EDSVS uses both Peak and Slide Friction values.

> **HVE:** The EDSVS tire model does not incorporate load- or speed-dependence. If friction data for more than one load or speed are supplied in the HVE Tire Data dialog, EDSVS uses the parameters for the middle load and/or speed.
>
> NOTE: If any doubt exists about which value is actually used by the EDSVS tire model, you can check the Vehicle Data output report.
>
> **HVE:** *In-use Factor*, available in HVE, is a convenient way to reduce or increase the friction values (peak and slide friction) by making just one adjustment.

Cornering Stiffness Data

EDSVS uses the Cornering Stiffness value, as shown in Table 2-2.

> **HVE:** EDSVS does not use the HVE F_y vs Slip Angle table, but instead uses the cornering stiffness parameter directly. If cornering stiffness data for more than one load or speed are supplied, EDSVS uses the parameters for the middle load and/or speed.
>
> NOTE: If any doubt exists about which value is actually used by the EDSVS tire model, you can check the Vehicle Data output report.
>
> **HVE:** Cornering Stiffness *In-use Factor*, available in HVE, is a convenient way to reduce or increase the dependent cornering stiffness values for all speeds and loads by making just one adjustment.
>
> NOTE: If you are simulating a vehicle with a flat tire, you'll probably want to reduce the In-use Factor to about 0.1.

Slip vs Rolloff Table

EDSVS uses the longitudinal Slip vs Rolloff Table.

Suspension

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

- Inter-tandem Load Transfer

EDSVS supports all suspension types, including those with tandem axles. However, the suspension at each wheel is not modeled, per se. Rather, *roll couple distribution* (see Event, Calculation Options) is used. *(updated: in the current version the roll couple distribution used by the simulation is read from the vehicle's **Roll Couple Distribution** suspension value, set on the Vehicle Editor's suspension screen — see EDSVS Calculation Options.)*

Inter-tandem Axle Load Transfer

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

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

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

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

where:

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

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

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

Exterior

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

Steering System Data

EDSVS uses the steering gear ratio if the

At Steering Wheel

Steering Table option is used during Event set-up (see Table 2-3). Otherwise, the steering system data are not used by EDSVS.

Brake System Data

The Brake System data are not used by EDSVS.

Environment

EDSVS uses the environment created by the Environment Editor (see Figure 2-2). The environment is created by defining the following groups of attributes:

- Visual Data
- Physical Data

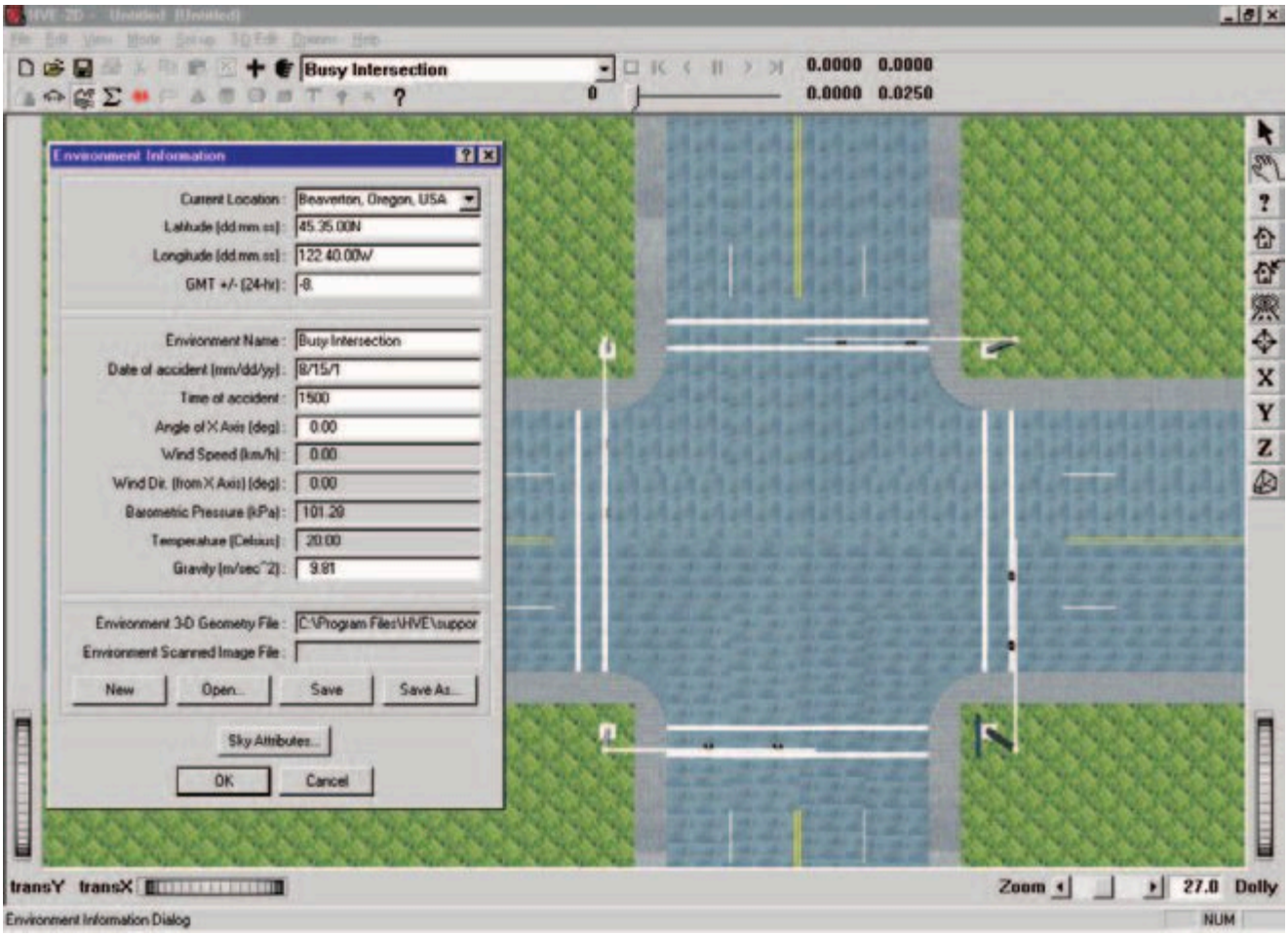


Figure 2-2: Environment Editor.

Creating an Environment

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

1. Choose Environment Mode. The Environment Editor is displayed.
2. Click *Add New Object*. The Environment Information dialog is displayed.
3. Click on the *Location* combo box to select the desired city, state and country, and associated *Latitude*, *Longitude* and *GMT*.
4. Enter the *Time* and *Date* for the event.
5. Enter the *Angle of the X axis*, *Wind Speed* and *Direction*, *Barometric Pressure* and *Temperature* for the event.
6. Enter the *Gravity Constant* for the event.
7. Enter an environment name. A default name is supplied for the current environment. The name is user-editable, and does not affect calculations.
8. Click *OK* to add the environment to the current case.

Visual Data

The following visual parameters may be edited:

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

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

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

Physical Data

The Physical Data groups are:

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

The specific physical environment data used by EDSVS are described below; see also Table 2-4.

Table 2-4: Environment Model Parameters Used By EDSVS

Parameter	Description
Gravitational Constant	Local gravitational constant
3-D Surface Geometry (Friction Factor, Elevation, Slope)	The polygon database used to create the environment

Angle Of X Axis

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

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

Wind Speed and Direction

Wind Speed and Direction are not used by EDSVS.

Atmospheric Temperature and Pressure

Atmospheric temperature and pressure are not used by EDSVS.

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.

Surface Geometry

The Surface Geometry is used by the tire model in EDSVS to calculate the friction multiplier for the current X,Y position of the tire.

> **HVE:** In HVE, it is also used to calculate the elevation and slope.
>
> **HVE:** If the elevation changes result in a vehicle roll or pitch that exceeds the allowable angle, EDSVS will terminate and report an error condition (Excessive Roll or Pitch Angle). See Chapter 6 — Messages for more information.

Event

EDSVS uses the Event Editor (see Figure 2-3) to create, set up and execute an event. Each of these topics is described below.

Creating an Event

An EDSVS event is created using the Event Information dialog.

To create an EDSVS event:

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

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

1. Click *OK* to create the EDSVS event.

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

Setting Up an Event

EDSVS uses the following

event set-up

options:

- Position/Velocity
- Driver Controls

- Payload Data

The specific Event Set-up data used by EDSVS are defined in Table 2-5.

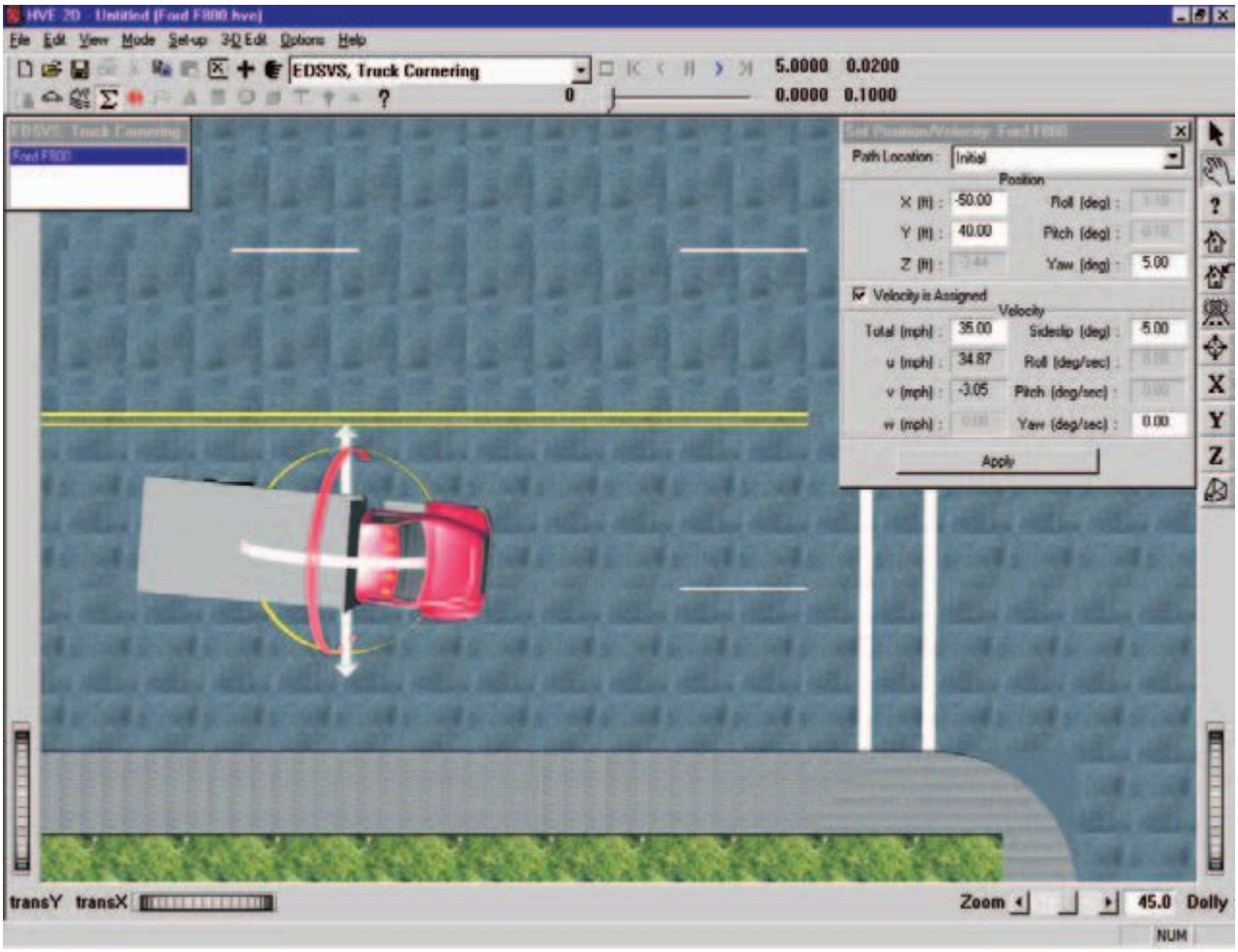


Figure 2-3: HVE-2D Event Editor, setting up and executing an EDSVS event.

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

Parameter	Description
Vehicle Initial Position	The earth-fixed X,Y coordinates and heading angle of the vehicle at the start of the simulation
Vehicle Initial Velocity	The forward linear velocity and sideslip, and the yaw angular velocity at the start of the run
Driver Controls, Steer Table	Steer Table Option: Steering Wheel Angle vs Time or Tire Steer Angle vs Time
Driver Controls, Brake Table	Brake Table Option: Wheel Force vs Time or Percent Available Friction vs Time
Driver Controls, Throttle Table	Throttle Table Option: Wheel Force vs Time or Percent Available Friction vs Time
Payload Data	Payload Exists option; Payload vehicle-fixed x,y,z coordinates; Payload Weight, Yaw Inertia

Position/Velocity

Like all simulations, EDSVS 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.

> NOTE: In HVE-2D, Z is equal to the CG height above ground, and roll and pitch are equal to 0.0.
>
> **HVE:** In HVE, Z, roll and pitch are supplied automatically using AutoPosition.

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

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

Driver Controls

EDSVS uses the following Driver Controls:

- **Steering** — A table of steering inputs as a function of time. The *At Steering Wheel* and *At Axle* options are supported.
- **Braking** — A table of braking inputs as a function of time. The *Wheel Force* and *Percent Available Friction* options are supported.
- **Throttle** — A table of throttle inputs as a function of time. The *Wheel Force* and *Percent Available Friction* options are supported.

The Driver Controls Data used by EDSVS are shown in Table 2-5.

Brake

Typical values for non-braking rolling resistance for passenger car tires are provided below for reference in Table 2-6 [11]. These values should be entered in the Driver Controls - Brakes dialog using the Percent Available Friction option.

Representative values for locked-wheel (slide) friction coefficients for passenger car tires on a variety of surfaces are also provided, in Table 2-7 [10]. While the table is very complete, EDC makes no claim as to the accuracy of the data. The user is urged to perform thorough research in order to supply EDSVS with the best possible data.

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

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

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

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

Damage Profile

The Damage Profile Data are not used by EDSVS.

Payload

The Payload Data used by EDSVS include the payload coordinates relative to the vehicle's CG, the payload mass and yaw inertia.

> NOTE: Payload positioning is relative to the vehicle CG, not the rear suspension.

Simulation Controls

EDSVS uses the current simulation control parameters in the Simulation Controls dialog (see Options Menu, Simulation Controls). The Simulation parameters used by EDSVS are shown in Table 2-8.

> NOTE: The output time interval should be an even multiple of the vehicle trajectory integration timestep. For example, if the integration timestep is 0.02, the output interval might be 5 x 0.02, or 0.10.

Table 2-8: Simulation Control Parameters Used By EDSVS

Parameter	Description
Vehicle Trajectory Integration Timestep	The integration timestep used by the numerical integration routine
Output Interval	The timestep used to send output results back to HVE-2D
Maximum Simulation Time	Maximum length of the run
Min Linear Velocity	The linear velocity used to terminate the run (if the linear and angular velocities are simultaneously less than these termination velocities, the run terminates)

Calculation Options

EDSVS does not have a Calculation Options dialog. The Roll Couple Distribution used by the simulation is taken from the vehicle's suspension data (see below), and the terrain surface-search method is selected in the separate **Get Surface Information Options** dialog on the Options menu.

Roll Couple Distribution describes the ratio of lateral load transferred between the front and rear suspensions during cornering. This distribution depends directly on the characteristics of the front and rear suspension systems and chassis stiffness. As EDSVS is a 3-degree of freedom analysis, the effects of the suspension system and chassis are included in this one parameter. A good approximation for the fraction of the total load transfer borne by the front axle can be obtained by dividing the roll moment produced at the front suspension by the total roll moment (i.e., the total produced by both front and rear suspensions together) during a steady turn. Note that a neutral vehicle will tend to have a lateral load transfer coefficient equal to the percentage of load on the front axle; an understeering vehicle will tend to have a greater value and an oversteering vehicle will have a lesser value.

*(updated: the Roll Couple Distribution is not entered through an EDSVS Calculation Options dialog. The current EDSVS simulation program takes it directly from the vehicle's **Roll Couple Distribution** suspension value (default 0.55), and computes the rear fraction as one minus the front fraction — so the value used by the simulation follows the Vehicle Editor's suspension setting. See EDSVS Calculation Options.)*

Get Surface Information

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

The default surface-search method is

From Previous Polygon

. This results in fastest execution, but does not work for all environments. Refer to the User's Manual for further information about how the surface information lookup works.

(updated: the surface-search method is no longer part of the EDSVS Calculation Options dialog. It is selected in the separate Get Surface Information Options dialog (Options menu), which offers From First Polygon, From Previous Polygon and From Previous Polygon (Sorted); the By Elevation method is not supported. See EDSVS Calculation Options.)

Executing An Event



Figure 2-4: Event Controller, used for starting and stopping event execution. The Event Controller can also be used for replaying previously executed events, both forward and backward.

To execute an EDSVS event, use the Event Controller, shown in Figure 2-4. 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

> 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 the Options Menu to choose useful options, such as Key Results, Axes, Velocity Vectors and Skidmarks.

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Chapter 3 — EDSVS Program Output

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

Overview

EDSVS produces three types of output reports:

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

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

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

1. Choose Playback Mode. The Playback Editor is displayed.
2. Click *Add New Object*. The Report Window Information dialog is displayed, showing a list of all the current events in the case.
3. Select an EDSVS event from the Active Events 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. The available output reports are:
5. Messages
6. Accident History
7. Program Data
8. Vehicle Data
9. Trajectory Simulation
10. Variable Output
11. 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 names are truncated to 30 characters, you should ensure that two truncated names are not the same.

1. Click *OK* to display the report.

Alpha-Numeric Reports

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

An example of each of these numeric output reports from EDSVS is shown on the following pages.

Accident History

The Accident History Report displays a table of initial and final positions and velocities for the vehicle. A typical Accident History Report is shown in Figure 3-1.

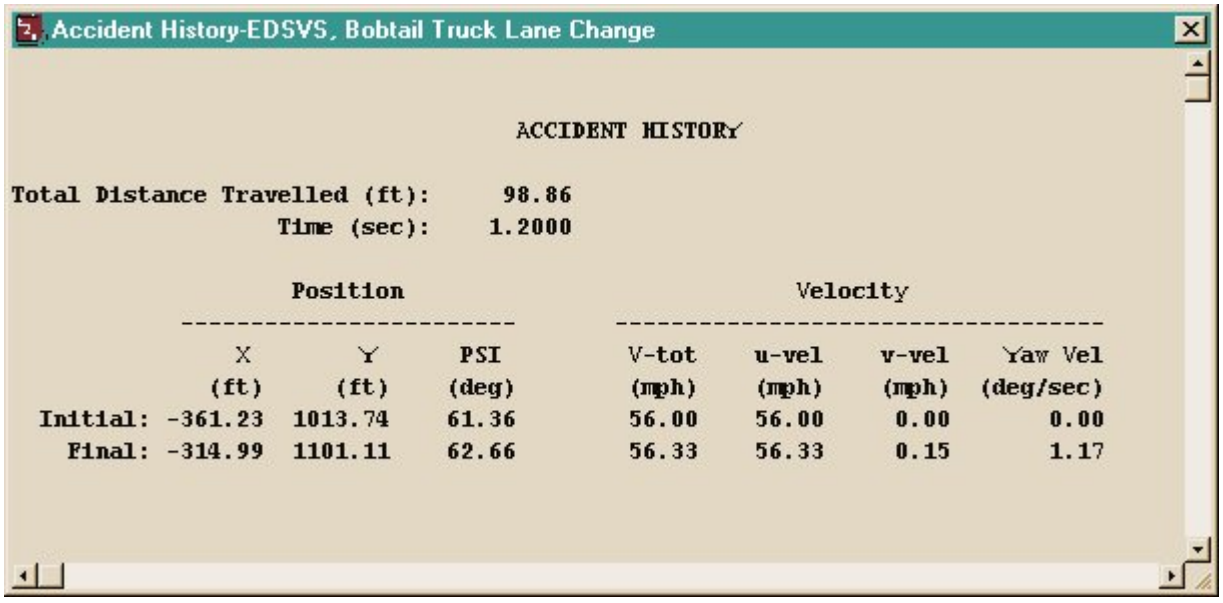


Figure 3-1: Typical Accident History Output Report issued by EDSVS.

The report shows the Total Distance Travelled and Time, along with Initial and Final rows containing Position (X, Y, PSI) and Velocity (V-tot, u-vel, v-vel, Yaw Vel) values.

(updated: the current report layout also supports a "Rest" row.)

Messages

A typical Messages Report is shown in Figure 3-2. For a complete listing of messages issued by EDSVS, see Chapter 6.

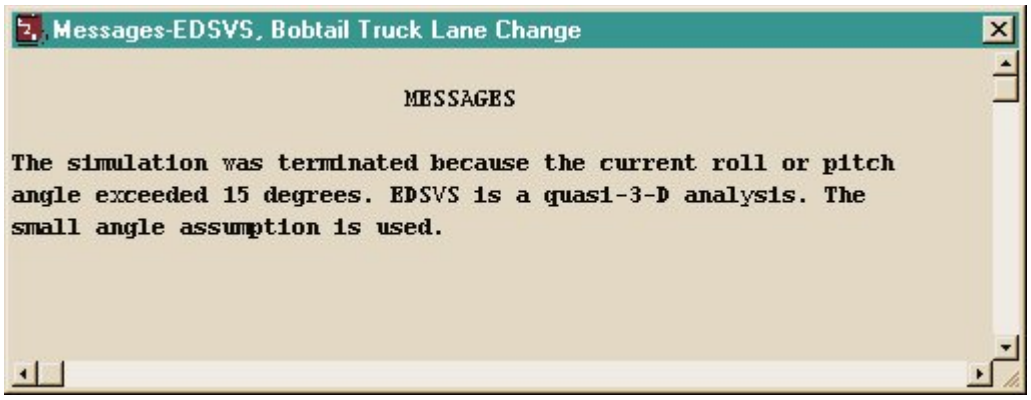


Figure 3-2: Typical Messages Output Report issued by EDSVS.

Program Data

The Program Data Report includes the following information:

- **Simulation Controls** — Integration parameters used for the current event (Max Simulation Time, Trajectory Phase dt, Output Interval, Linear Term Vel)

(updated: the current Program Data report also includes a General Program Information section — HVE Version, EDSVS Version, Date and Time of Execution, Dimension Basis — and General Environment Data and 3-D Environment Terrain Data sections, including the 3-D geometry filename, number of polygons, the Get Surface Information method in use, minimum/maximum terrain elevation, and counts of water, curb, friction-zone and road polygons.)

A typical Program Data Report is shown in Figure 3-3.

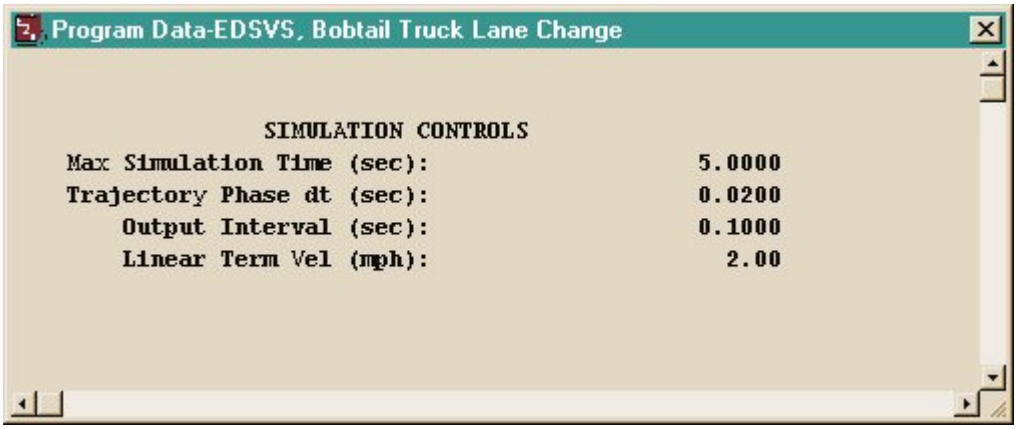


Figure 3-3: Typical Program Data Output Report issued by EDSVS.

Vehicle Data

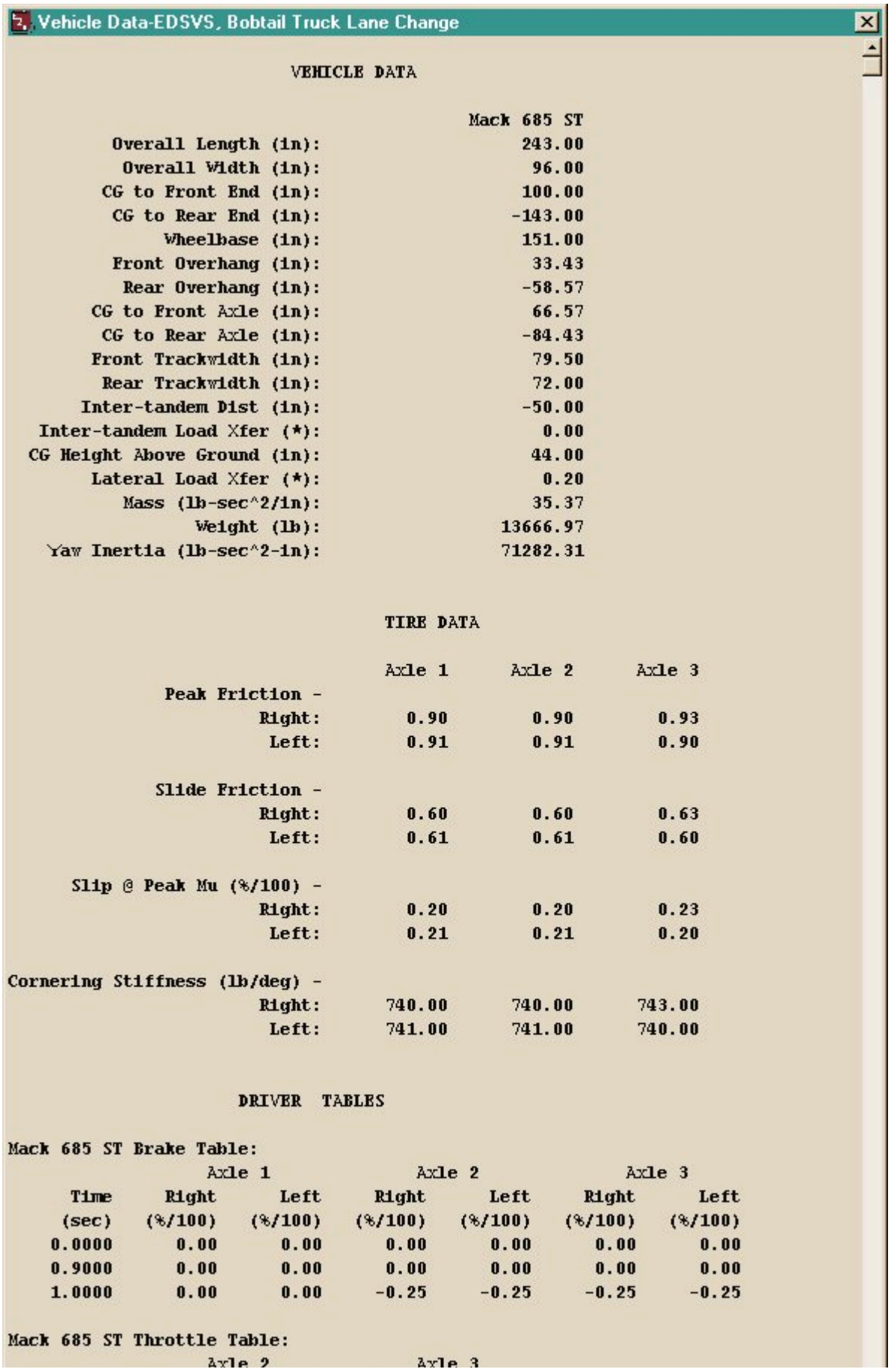
The Vehicle Data Report includes the following information:

- **Vehicle Dimensional and Inertial Properties** — The dimensional and inertial parameters used by EDSVS in the current event (Overall Length and Width, CG to Front/Rear End, Wheelbase, Front/Rear Overhang, CG to Front/Rear Axle, Front/Rear Trackwidth, Inter-tandem Distance and Load Transfer, CG Height Above Ground, Lateral Load Transfer, Mass, Weight, Yaw Inertia).

> NOTE: The Total Yaw Inertia adds the effect of the unsprung masses (i.e., the wheel and axle masses) to the sprung mass; thus, the value printed is greater than the one displayed in the Vehicle Editor's Inertias dialog.

- **Tire Properties** — The tire parameters used by EDSVS in the current event (Peak Friction, Slide Friction, Slip @ Peak Mu, Cornering Stiffness and Antilock Efficiency, right and left, for each axle).
- **Driver Tables** — Individual Driver Control tables for steering, braking, throttle and gear selection used by EDSVS in the current event.

A portion of a typical Vehicle Data Report is shown in Figure 3-4.


Vehicle Data-EDSVS, Bobtail Truck Lane Change
VEHICLE DATA
Mack 685 ST
Overall Length (in): 243.00
Overall Width (in): 96.00
CG to Front End (in): 100.00
CG to Rear End (in): -143.00
Wheelbase (in): 151.00
Front Overhang (in): 33.43
Rear Overhang (in): -58.57
CG to Front Axle (in): 66.57
CG to Rear Axle (in): -84.43
Front Trackwidth (in): 79.50
Rear Trackwidth (in): 72.00
Inter-tandem Dist (in): -50.00
Inter-tandem Load Xfer (*): 0.00
CG Height Above Ground (in): 44.00
Lateral Load Xfer (*): 0.20
Mass (lb-sec^2/in): 35.37
Weight (lb): 13666.97
Yaw Inertia (lb-sec^2-in): 71282.31
TIRE DATA
Axle 1 Axle 2 Axle 3
Peak Friction -
Right: 0.90 0.90 0.93
Left: 0.91 0.91 0.90
Slide Friction -
Right: 0.60 0.60 0.63
Left: 0.61 0.61 0.60
Slip @ Peak Mu (%/100) -
Right: 0.20 0.20 0.23
Left: 0.21 0.21 0.20
Cornering Stiffness (lb/deg) -
Right: 740.00 740.00 743.00
Left: 741.00 741.00 740.00
DRIVER TABLES
Mack 685 ST Brake Table:
Axle 1 Axle 2 Axle 3
Time Right Left Right Left Right Left
(sec) (%/100) (%/100) (%/100) (%/100) (%/100) (%/100)
0.0000 0.00 0.00 0.00 0.00 0.00 0.00
0.9000 0.00 0.00 0.00 0.00 0.00 0.00
1.0000 0.00 0.00 -0.25 -0.25 -0.25 -0.25
Mack 685 ST Throttle Table:
Axle 2 Axle 3

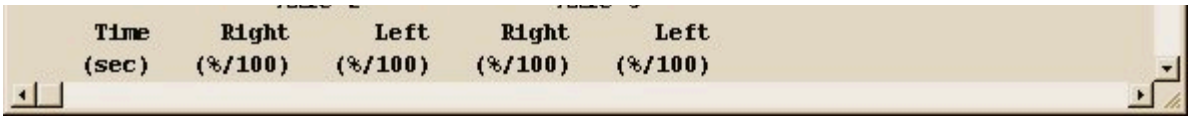


Figure 3-4: Typical Vehicle Data Output Report issued by EDSVS (only a portion of the total report is shown).

Graphic Reports

EDSVS 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

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

Vehicle Output Groups

- **Kinematics** — Position, velocity and acceleration for the vehicle
- **Tire** — The tire output parameters existing at the tire contact patch (compare with Wheel Output, below)
- **Wheel** — The wheel output parameters existing at the wheel's hub position of each wheel (compare with Tire output, above)
- **Driver** — Current levels of driver inputs (steering, braking and throttle)

An example of a Variable Output table is shown in Figure 3-5. A detailed listing of each Variable Output parameter produced by EDSVS is found in Table 3-1. For more information about Variable Output parameters, refer to the User's Manual, Chapter 16, Event Model.

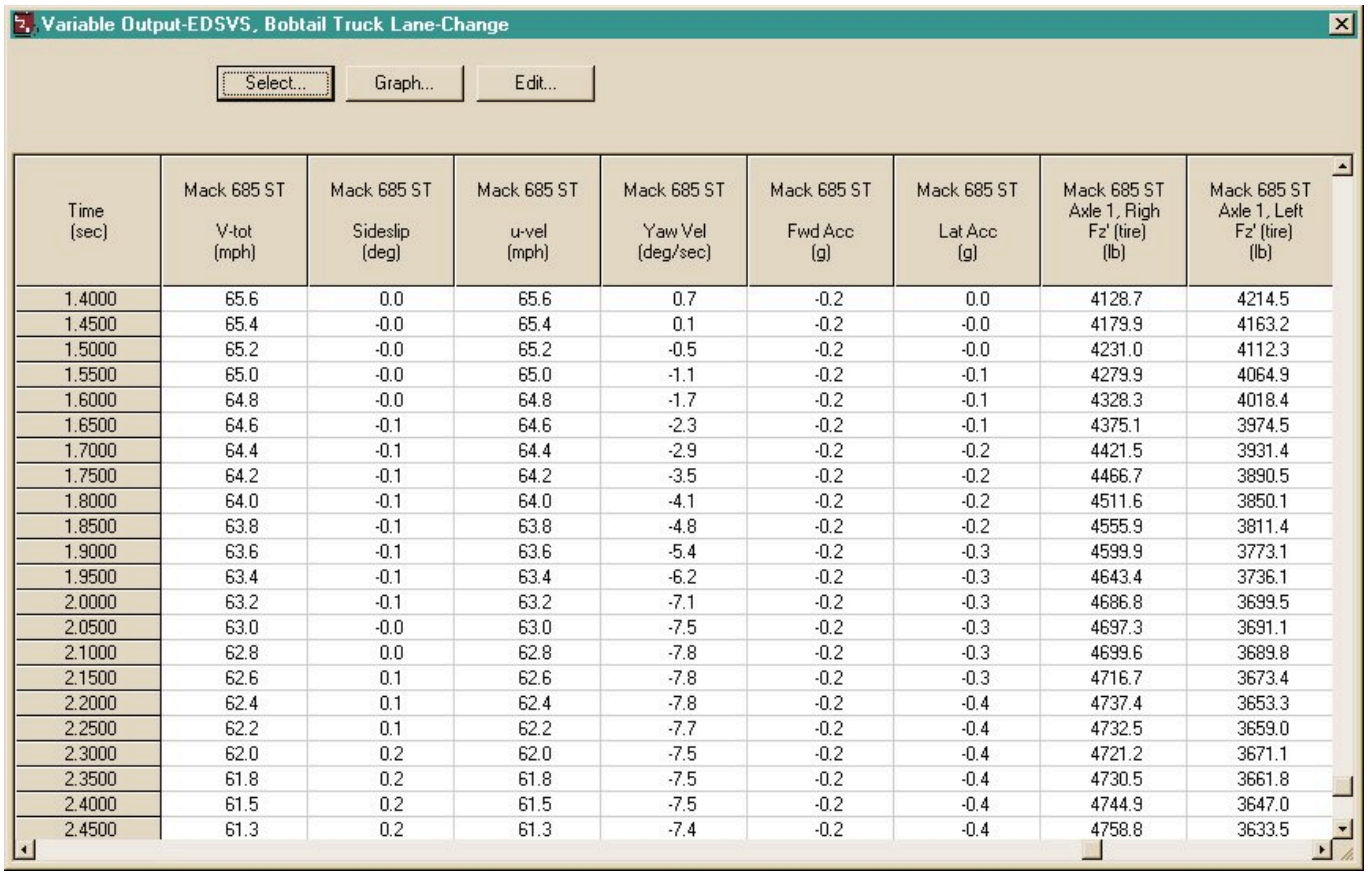
Table 3-1: Vehicle Variable Output Data

Parameter	Description
Vehicle Kinematic Data	X,Y,Z position of CG; Φ, Θ, Ψ orientation; Path Radius of CG; ν (Course Angle); Total linear velocity, u,v,w components; Sideslip angle; r angular velocity; Total linear acceleration, forward and side components; u-dot, v-dot linear components; r-dot angular components
Tire Data	X,Y,Z position of tire contact patch; Slip Angle; F'_x, F'_y, F'_z; Skid Flag
Wheel Data	x,y,z location of each wheel; F_x, F_y, F_z; Steer Angle (δ) at each steerable wheel
Driver Data (*)	Steering wheel angle

(*) If Driver Control option was

At Steering Wheel

.



Time (sec)	Mack 685 ST V-tot (mph)	Mack 685 ST Sideslip (deg)	Mack 685 ST u-vel (mph)	Mack 685 ST Yaw Vel (deg/sec)	Mack 685 ST Fwd Acc (g)	Mack 685 ST Lat Acc (g)	Mack 685 ST Axle 1, Righ Fz' (tire) (lb)	Mack 685 ST Axle 1, Left Fz' (tire) (lb)
1.4000	65.6	0.0	65.6	0.7	-0.2	0.0	4128.7	4214.5
1.4500	65.4	-0.0	65.4	0.1	-0.2	-0.0	4179.9	4163.2
1.5000	65.2	-0.0	65.2	-0.5	-0.2	-0.0	4231.0	4112.3
1.5500	65.0	-0.0	65.0	-1.1	-0.2	-0.1	4279.9	4064.9
1.6000	64.8	-0.0	64.8	-1.7	-0.2	-0.1	4328.3	4018.4
1.6500	64.6	-0.1	64.6	-2.3	-0.2	-0.1	4375.1	3974.5
1.7000	64.4	-0.1	64.4	-2.9	-0.2	-0.2	4421.5	3931.4
1.7500	64.2	-0.1	64.2	-3.5	-0.2	-0.2	4466.7	3890.5
1.8000	64.0	-0.1	64.0	-4.1	-0.2	-0.2	4511.6	3850.1
1.8500	63.8	-0.1	63.8	-4.8	-0.2	-0.2	4555.9	3811.4
1.9000	63.6	-0.1	63.6	-5.4	-0.2	-0.3	4599.9	3773.1
1.9500	63.4	-0.1	63.4	-6.2	-0.2	-0.3	4643.4	3736.1
2.0000	63.2	-0.1	63.2	-7.1	-0.2	-0.3	4686.8	3699.5
2.0500	63.0	-0.0	63.0	-7.5	-0.2	-0.3	4697.3	3691.1
2.1000	62.8	0.0	62.8	-7.8	-0.2	-0.3	4699.6	3689.8
2.1500	62.6	0.1	62.6	-7.8	-0.2	-0.3	4716.7	3673.4
2.2000	62.4	0.1	62.4	-7.8	-0.2	-0.4	4737.4	3653.3
2.2500	62.2	0.1	62.2	-7.7	-0.2	-0.4	4732.5	3659.0
2.3000	62.0	0.2	62.0	-7.5	-0.2	-0.4	4721.2	3671.1
2.3500	61.8	0.2	61.8	-7.5	-0.2	-0.4	4730.5	3661.8
2.4000	61.5	0.2	61.5	-7.5	-0.2	-0.4	4744.9	3647.0
2.4500	61.3	0.2	61.3	-7.4	-0.2	-0.4	4758.8	3633.5

Figure 3-5: Typical Variable Output report.

Trajectory Simulations

EDSVS produces a trajectory simulation of the current event. The trajectory simulation is a visualization of the data displayed in the Variable Output table (see previous section). An example of a trajectory simulation is shown in Figure 3-6.

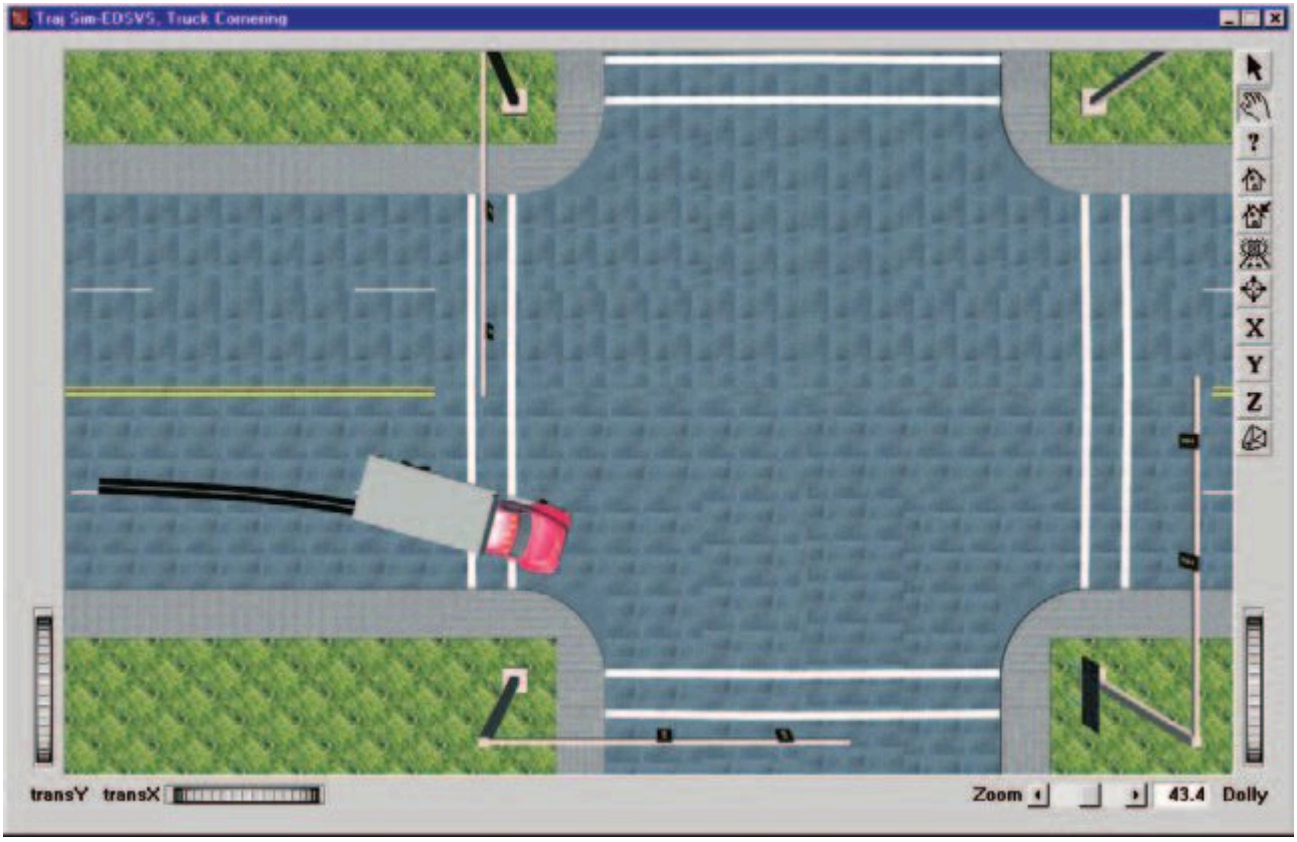


Figure 3-6: Typical EDSVS Trajectory Simulation.

Displaying a Trajectory Simulation

The Trajectory Simulation is controlled using the Playback Controller (see Figure 3-7).

The Playback Controller's buttons have the following functions:

- **Reset** — Returns to the start of the simulation and reinitializes 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



Figure 3-7: Playback Controller.

> NOTE: The Playback Controller is also used for controlling the Playback Window. This window is used for combining events and for making movie files. Refer to the User's Manual for more information on the Playback Window and making movie files.

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Chapter 4 — EDSVS Calculation Method

Basis for Analysis

EDSVS is a dynamic analysis of vehicle motion in the horizontal (yaw) plane. Using the standard engineering approach, the equations of motion are written from a free-body analysis. The mathematical model for EDSVS was developed and validated at the University of Michigan Transportation Research Institute [1-3, 14], and extended by EDC [25].

For successful use of EDSVS, a good understanding of vehicle dynamics is extremely useful and is recommended. However, the following discussion is limited to the general analytical approach. For a detailed treatise on the subject of vehicle dynamics and simulation programs, the user is referred to the references listed at the end of this Physics Manual as well as those listed in HVE-2D Appendix VII, References.

Equations of Motion

The 3-degree of freedom analysis solves the equations of motion in the horizontal (yaw) plane. In this plane, the vehicle x- and y- linear motion can be analyzed, as well as angular rotation about the z-axis, where the coordinates are specified with respect to the vehicle-fixed coordinate system (see HVE-2D Appendix III, Coordinate Systems; for more information, refer to SAE J670e - Vehicle Dynamics Terminology [6.2], portions of which are found in the Help Index).

The required equations of motion are written below:

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

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

$$I_{zz}\dot{r} = \Sigma M_z$$

where:

Symbol	Meaning
m	total mass
I_{zz}	total yaw moment of inertia
u	forward velocity (vehicle-fixed component)
v	lateral velocity (vehicle-fixed component)
r	angular yaw velocity
ΣF_x	summation of external forces in the x-direction
ΣF_y	summation of external forces in the y-direction
ΣM_z	summation of external moments about the z-axis

EDSVS solves these equations of motion at discrete time intervals (specified by the vehicle trajectory integration timestep, see User's Manual, Simulation Controls). The current accelerations are integrated, using numerical integration, to predict velocity and position at the start of the next timestep. EDSVS uses **Hamming's modified predictor-corrector** method, which helps to ensure stable results. Where the predicted and corrected values disagree by more than the Velocity Convergence Criterion, the integration timestep is halved and the step retried; exceeding the Maximum

Bisections terminates the run (see Simulation Controls). A predictor-corrector method estimates the future position and velocity based on the current acceleration history, and then, once they are calculated, compares the predicted results with the calculated results.

There are no degrees of freedom (and hence no equations of motion) for vertical motion, or pitch or roll rotation. Therefore, suspension dynamics cannot be studied directly. However, EDSVS considers the suspension as it affects tire forces by using the

roll couple distribution

(the ratio of lateral load transferred at the front and rear suspensions during cornering). The CG elevation above ground is used in conjunction with longitudinal and lateral accelerations to compute quasi-static load transfers due to pitch and roll, respectively.

Load transfer

EDSVS has no vertical, pitch or roll degree of freedom, so load transfer is computed quasi-statically from the current accelerations and applied as a change in vertical force at each wheel. The transfers sum to zero — load is moved between wheels, never added.

Lateral transfer is apportioned between the axles by the roll couple distribution:

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

where γ is the fraction of the roll couple carried by that axle, h the CG height, T the track width at that axle, and $a_y = \dot{v} + ur$ the vehicle-fixed lateral acceleration. The road roll angle term removes the component of gravity acting across a superelevated surface, so a vehicle standing on a banked road carries the correct static crossfall load without any lateral acceleration.

Longitudinal transfer is taken about the wheelbase:

$$\Delta F_{z,Long} = \frac{-m(a_x + g\sin\theta_{Road})h + \gamma_T \ell_T \sum F_{x,Rear}}{2(a+b)}$$

where $a_x = \dot{u} - vr$, a and b are the CG distances to the front and rear axles, and the final term is the inter-tandem transfer: γ_T is the inter-tandem load transfer coefficient entered with the suspension, ℓ_T the spacing between the tandem axles, and the sum is the longitudinal force at the rear wheels. For a vehicle without tandem axles the coefficient is zero and the term vanishes.

Where tandem axles are present, the rear-axle share of both transfers is split equally between the two tandem axles before the inter-tandem term is applied.

> **NOTE:** The accelerations used are those from the **previous** timestep, not the current one. This is inherent to a quasi-static treatment computed alongside the tire forces that produce it — the load transfer at any instant reflects the acceleration that has just occurred. At normal timesteps the difference is immaterial, but it is one reason a very coarse timestep degrades results in hard transient manoeuvres.

Tire Forces

All of the external forces applied to the vehicle which direct its motion are applied at the tires. Therefore, accurate computation of these forces is essential. Unfortunately, pneumatic tires do not behave in an easy-to-calculate manner. Rather, these properties are functions of several variables and are extremely non-linear.

Historically, two methods have been used to compute tire forces. Either formulas utilizing experimental coefficients are used (this method is referred to as a *tire model*) or tables containing test data at various speed and load conditions are applied according to the current speed and load conditions (this method is referred to as a *table look-up*). EDSVS uses the Fiala tire model [5] to compute the lateral forces on a free rolling tire. This model has been used in many popular simulations developed at Calspan [8]. Using this model, the tire forces are computed for the current integration timestep as follows:

Symbol	Meaning
C_α	tire cornering stiffness (lb/radian)
α	tire slip angle (radians)
F_z	tire vertical force (lb)
F_{sx}	attempted brake or acceleration force (lb)
μ_p	peak coefficient of friction
μ_s	slide coefficient of friction
μ_{slip}	% slip at μ_p
δ_{dual}	dual-tire factor (1 for dual tires, 0 for a single tire)
s_{fx}	determines direction of wheel force relative to vehicle

At the current simulation time, the force is computed for each tire, one tire at a time. If the percent wheel lock-up method was used to supply wheel forces when entering the Brake and/or Throttle Table, the percent lock-up must be converted into the actual wheel force:

$$F_{sx} = F_{sx}\ \mu_p F_z (1 + \delta_{dual})$$

(updated: earlier editions applied this conversion whenever the tabulated value was less than 1.0. It is applied according to the table method selected, not the magnitude of the entry. The Brake table offers three methods and the Throttle table two:

Table method	Attempted wheel force
Wheel Force	*Used directly as entered*
Percent Available Friction	*Converted as shown above*
Pedal Force (brake only)	*Converted through the vehicle's brake pressure ratio and the wheel's brake torque ratio, divided by the tire radius*

The Pedal Force brake method was not described in earlier editions.)

The attempted wheel force is assigned as the longitudinal wheel force (lb),

$$F_x = F_{sx} \cdot s_{fx}$$

where s_{fx} determines the direction of the wheel force relative to the vehicle-fixed coordinate system.

Next, the non-dimensional sideslip parameter, $\bar{\alpha}$, is determined as

$$\bar{\alpha} = C_\alpha \sin(\alpha) / (\mu_p F_z)$$

If $|\bar{\alpha}|$ is equal to or greater than 3, the tire's ability to produce a cornering force, F_y (lb), is saturated. In this case,

$$F_y = -\mu_p F_z (1 + \delta_{dual}) \operatorname{sign}(\bar{\alpha})$$

Since the tire is saturated, it is assumed to be generating a scuff mark due to the excessive lateral forces, and the skid flag is turned on.

Otherwise, $|\bar{\alpha}|$ is less than 3, and the Fiala tire model computes the lateral force, F_y, using a 3rd-order polynomial in $\bar{\alpha}$:

$$F_y = -\mu_p F_z (\bar{\alpha} - \frac{\bar{\alpha} \mid \bar{\alpha}|}{3} + \frac{\bar{\alpha}^3}{27})(1 + \delta_{dual})$$

In this case, the tire is operating within its traction limits, and the skid flag is turned off.

In either case, the direction of the lateral force, F_y, is determined by the sign of $\bar{\alpha}$.

Next, a potential reduction in tire forces, F_x and F_y, due to the amount of lateral tire slip is determined. μ_p is modified by the tire slip angle, α:

$$\mu_{mod} = \mu_p (1 - 1.72 \mid \alpha \mid)$$

If $\mu_{mod} < |\mu_s \cos(\alpha)|$ then

$$\mu_{mod} = |\mu_s \cos(\alpha)|$$

The attempted longitudinal wheel force, F_x (see above), is compared to available force at the current slip angle, α. This available force, F_{max} (lb) is

$$F_{max} = \mu_{mod} F_z (1 + \delta_{dual})$$

If the attempted force, F_x, is less than F_{max}, the amount of longitudinal tire slip, S, is computed:

$$\mu_x = |F_x / (F_z (1 + \delta_{dual}))|$$

$$S = (\mu_x / \mu_p) \mu_{slip}$$

The longitudinal tire slip, S, is used in the slip vs. rolloff table to determine the reduction in lateral tire force, F_y. The following table illustrates this effect for typical tires [14]:

Slip, S	Rolloff
0.00	1.00
0.05	0.88
0.10	0.64
0.15	0.46
0.20	0.33

Linear interpolation is used to determine the amount of rolloff for values of slip between the table values of S. The computed lateral force, F_y, is then adjusted by the rolloff:

$$F_y = F_y \cdot Rolloff$$

The skid flag is set for this tire if the longitudinal slip has reached the slip at peak friction, $S \geq \mu_{slip}$, which is wheel lock-up.

(updated: earlier editions stated that the tire is reported as not skidding in this case. It is reported as skidding if either the lock-up test above or the saturation test applies.)

If the attempted longitudinal wheel force, F_x, is greater than F_{max}, the longitudinal slip exceeds the slip at μ_p and the tire is either locked (braking) or spinning (accelerating). The skid flag is turned on and the forward and lateral tire forces are:

$$F_x = \mu_s |\cos(\alpha)| F_z (1 + \delta_{dual})\, s_{fx}$$

(updated: the magnitude of $\cos\alpha$ *is used here, so that the longitudinal force keeps the direction given by* s_{fx} *at slip angles beyond 90 degrees.)*

$$F_y = -\mu_s \sin(\alpha) F_z (1 + \delta_{dual})$$

*(updated: hydroplaning is **not** modeled by EDSVS. Hydroplaning models (NASA, NASA-TTI, Gallaway) are available in HVE, but only through SIMON and EDSMAC4; EDSVS offers no Hydroplaning Model calculation option, and any water-related tire output variables it reports are unused placeholders. See SIMON — Hydroplaning Model.)*

Run termination from the tire forces

After all tire forces are computed, EDSVS checks whether the vehicle has come to rest: if the forward and lateral velocities are both below the minimum linear velocity and the sum of the attempted longitudinal wheel forces is zero or negative, the run terminates normally. A vehicle that is stopped but still has net forward drive force applied continues to run.

(updated: this termination condition was not described in earlier editions.)

Antilock Model

EDSVS allows the use of a simple antilock model to study the effects of improvements due to

perfect braking

. Perfect braking is defined as "braking which maintains the longitudinal braking force at the level associated with the peak friction coefficient". Under normal conditions (without antilock), it is nearly impossible to hold this level of

braking. The tire locks up, thus causing a reduction in brake force from that associated with the peak friction coefficient to that associated with the slide friction coefficient.

The Vehicle Brake Model includes an antilock effectiveness coefficient, η_a, which defines the effectiveness of the antilock system; an antilock coefficient equal to 0.0 is the same as no antilock, while a coefficient equal to 1.0 defines the perfect system. The same antilock coefficient applies to both longitudinal and lateral tire forces. The antilock parameters are assigned using the Vehicle Editor's Wheel Brake dialog (see User's Manual, Section 4 (Vehicle Editor) for more information).

The antilock model is only applicable if the attempted brake force, F_x, is greater than F_{max} (see above). Under this condition, an additional amount of force, ΔF, is generated because of the difference between μ_p and μ_s. For longitudinal tire force:

$$\Delta F_x = (\mu_p - \mu_s)\cos(\alpha)\, F_z\, s_{fx}\, (1 + \delta_{dual})\, \eta_a$$

$$F_x = \mu_s F_z (1 + \delta_{dual})\cos(\alpha)\, s_{fx} + \Delta F_x$$

For lateral tire force:

$$\Delta F_y = (F_y + \mu_s F_z (1 + \delta_{dual})\sin(\alpha))\eta_a$$

$$F_y = -\mu_s F_z (1 + \delta_{dual})\sin(\alpha) + \Delta F_y$$

(updated: with antilock active, the longitudinal force takes the sign of the attempted wheel force directly, rather than the vehicle-fixed direction s_{fx} used without antilock. The two differ only when the tire is travelling rearward.)

Assumptions

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

Before using EDSVS, be sure the events you wish to simulate are within the scope of the program analysis defined by the following assumptions:

No Rollover Allowed

EDSVS is a yaw plane analysis and does not consider roll or pitch degrees of freedom. The analysis is only valid while all wheels are generating a positive (downward) force on the road surface. As soon as a wheel load becomes negative, wheel lift-off is assumed and computations are halted. A warning message will be displayed indicating the time at which wheel lift-off occurred and the wheel that lifted.

No Suspension Effects

EDSVS assumes the wheels remain vertical at all times. Therefore, camber stiffness does not contribute to lateral force generation. There is no roll degree of freedom, so bump steer and roll steer are also ignored. (See Roll Couple Distribution for information about how the suspension affects the front/rear distribution of lateral forces.)

All External Forces Applied At Tires

Aerodynamic effects are ignored. This assumption may become a significant factor at excessive speeds. In addition, undercarriage contact with the ground caused by impact-related damage is not considered.

Small Angle Assumption for Roll and Pitch

> **HVE:** EDSVS has been extended for use in the HVE 3-D environment to include a gravity vector. Thus, vehicle motion on sloped surfaces may be accommodated. However, the model is valid only for small roll and pitch angles. If the allowable angle (normally 15 degrees) is exceeded, a message is issued (*Excessive Roll or Pitch*) and the run is terminated (see below).

Roll/Pitch Not Greater Than 15 Degrees

> **HVE:** EDSVS uses the small angle assumption; if the roll and/or pitch exceed about 15 degrees, errors may become significant. To prevent this problem, EDSVS returns a fatal message under this condition.

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Chapter 5 — EDSVS Tutorial

This tutorial comes from the EDC Simulations seminar. It provides a good example of the use of the driver input tables. In particular, it illustrates how the driver tables use linear interpolation to compute the current steer angle.

The goal of this tutorial is simply to make the simulated vehicle follow the desired path. Only steering is required, so the scope is limited, but extremely useful.

Like all EDSVS events, the procedures involve the following basic steps:

- Create the vehicles
- Create the environment
- Execute the EDSVS event
- Review the EDSVS output reports

These basic procedures are described in detail in this tutorial.

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

Getting Started

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

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

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

- ON: *Show* Key Results
- OFF: *Show* Axes
- OFF: *Show* Contacts *(HVE)*
- OFF: *Show* Belt Anchors *(HVE)*
- OFF: *Show* Velocity Vectors
- ON: *Show* Skidmarks
- OFF: *Show* Targets
- ON: *AutoPosition (HVE)*
- Units equals *U.S.*

- Render Options:
- Show Humans as *Actual (HVE)*
- Show Vehicles as *Actual (HVE)*
- *Phong* Shading Mode *(HVE)*
- Complexity equals *Object (HVE)*
- Render Quality equals *5*
- Texture Quality equals *1 (HVE)*
- Anti-aliasing equals *1*

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

Our goal is to use EDSVS to drive a 1997 Ford Explorer along the path described in Figure 5-1. This tutorial shows us how to perform this simulation.

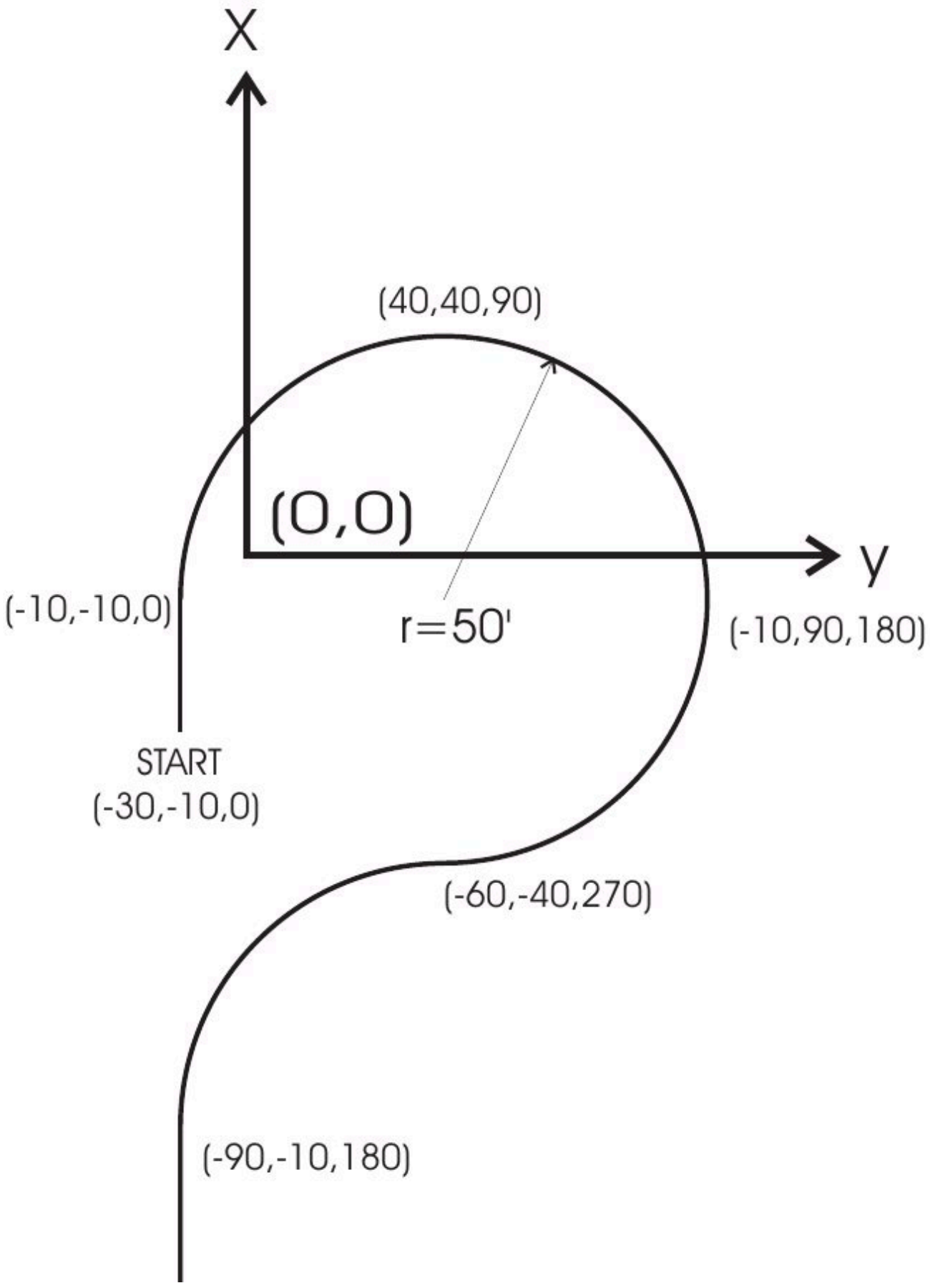

X
(40,40,90)
(0,0)
y
(-10,-10,0)
r=50'
(-10,90,180)
START
(-30,-10,0)
(-60,-40,270)
(-90,-10,180)



Figure 5-1: Path for EDSVS Simulation Tutorial. The path starts at (-30,-10,0), passes (-10,-10,0), follows a circle of radius 50 ft through (40,40,90) and (-10,90,180), reverses curvature through (-60,-40,270), then continues through (-90,-10,180) to (-150,-10,180). Coordinates are (X, Y, heading in degrees).

Creating the Vehicle

Now let's add the vehicle to our case. The vehicle is a dark green 1997 Ford Explorer:

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

> NOTE: The Vehicle Information dialog also allows you to edit the Driver Location, Engine Location, Number of Axles and Drive Axle(s). The Ford Explorer is a 4-wheel drive vehicle, but we're going to select 2-wheel drive for the tutorial.

1. Using the option buttons, click each button to choose the following vehicle from the database:
2. Type = *Sport Utility*
3. Make = *Ford*
4. Model = *Explorer*
5. Year = *1995-1999*
6. Body Style = *4-Door*
7. Source Database = *Tutorial.db*
8. Drive Axles = *Axle No. 2*
9. Click *OK* to add *Ford Explorer* to the Active Vehicles list.

The Ford Explorer is displayed in the viewer, as shown in Figure 5-2.

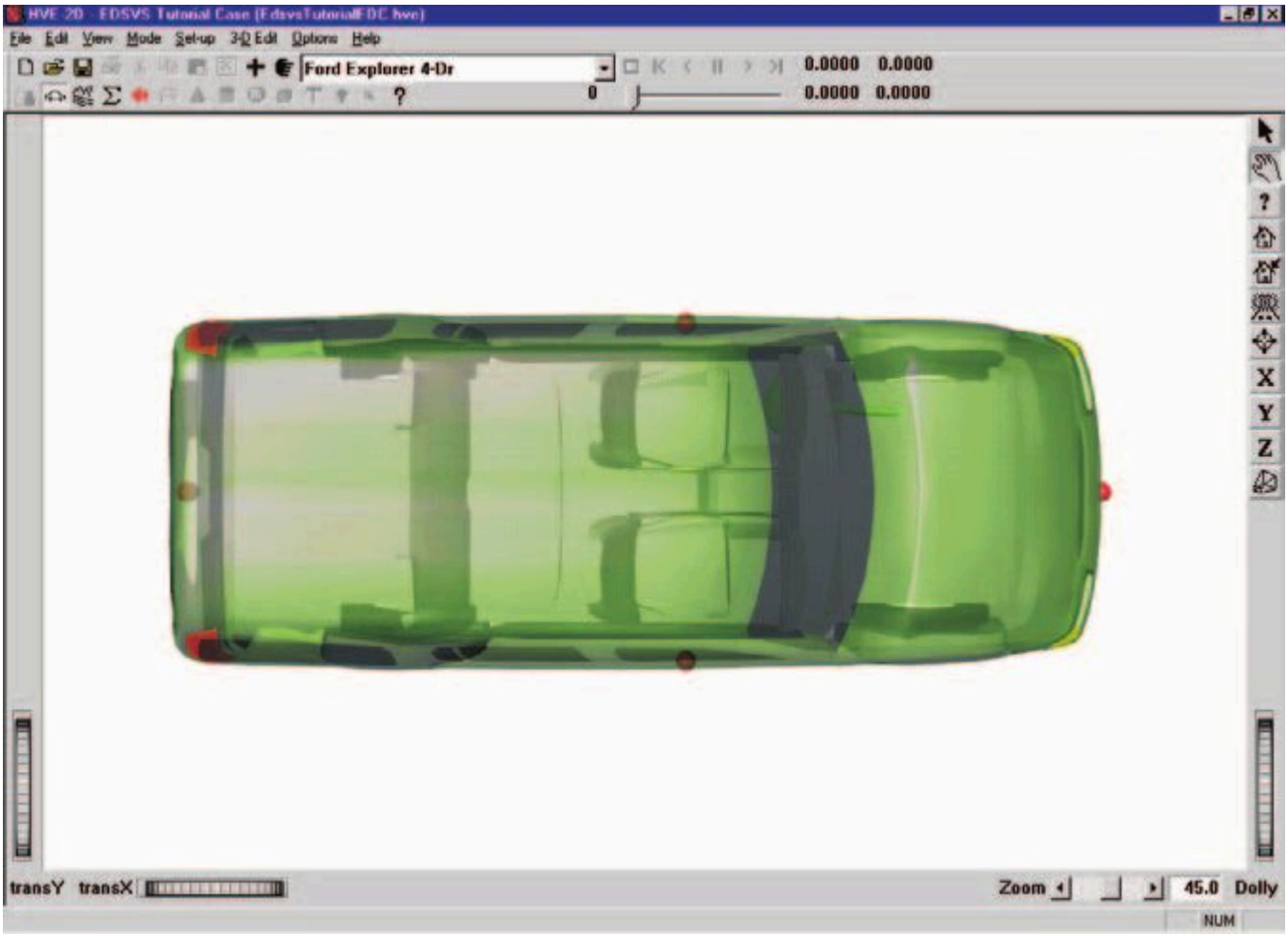


Figure 5-2: Ford Explorer before editing.

Editing the Vehicle

Next, we will edit the vehicle to change its color and weight. To edit the color, perform the following steps:

1. Click on the CG (the CG may be hidden under the seat or other interior object; however, the CG icon is located at the vehicle CG; therefore, if you click at the intersection of lines connecting the exterior balls (left-right and front-rear), you will select 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, or *hot spot*, in the *color wheel*) and intensity (the arrow in the *intensity slider*). Click on the hot spot and drag it to the middle of the green area. 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.

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

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



Figure 5-3: Vehicle Color dialog, used for assigning the vehicle color.

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

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

> NOTE: Only total weight and total yaw inertia is used by the 3-DOF EDSVS calculations.

1. In the *Total Weight* text field, replace the existing weight, `4295`, with the measured value, `4405` lb (see Figure 5-4).

> NOTE: The dialog might initially display 4294.836, or a similar number, because the weight is actually divided by the current gravity constant and stored as mass. Extra precision results when the mass is multiplied by the current gravity constant and redisplayed.

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

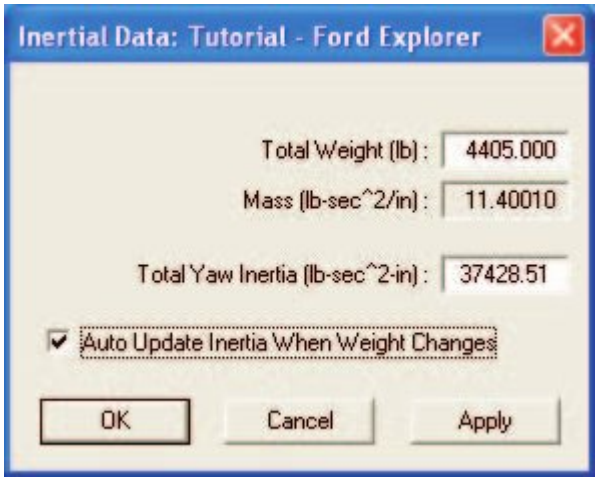


Figure 5-4: Vehicle Inertias dialog, used for editing the current weight and yaw inertia. The values in this dialog are customized for this simulation.

Creating the Environment

Now, let's add the environment:

1. Choose *Environment Mode*. The Environment Editor is displayed.
2. Click *Add New Object*. The Environment Information dialog is displayed.
3. 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.
4. Enter the date and time of the incident we are studying, `8/8/97` and `1230`, respectively.
5. Enter the angle from *true north* to the earth-fixed X axis in our environment, `165` degrees.

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

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

The selected environment is added to our case and displayed in the Environment Viewer (see Figure 5-5). Use the viewer thumb wheels and/or manipulators to view the scene.

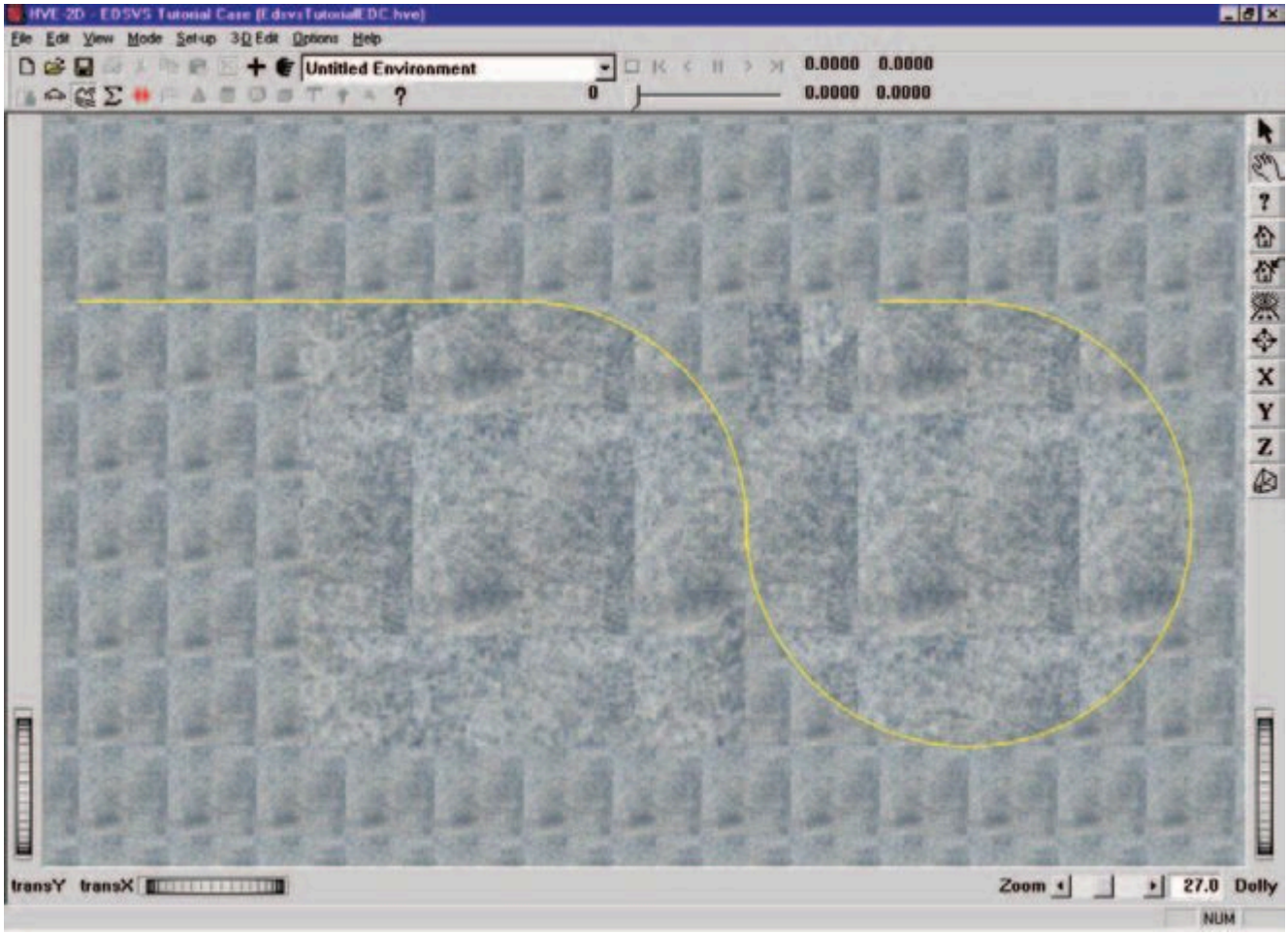


Figure 5-5: Environment used for our EDSVS tutorial.

Saving the Case

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

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

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

1. Place the mouse cursor in the Case Title text field and enter `EDSVS Tutorial Case`.

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

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

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

Creating Events

As mentioned at the outset of the tutorial, we are going to simulate a vehicle traveling along a pre-determined path to learn more about the use of HVE-2D driver tables. To create the event, perform the following steps:

1. Choose *Event Mode*. The Event Editor is displayed.
2. Click *Add New Object*. The Event Information dialog is displayed.
3. Select *Ford Explorer* from the Active Vehicles list.
4. Select *EDSVS* from the *Calculation Method* options list.
5. Enter a name for the event, `Steering Maneuver`.

> NOTE: HVE-2D will append the name of the calculation method to the event name, thus the complete event name will become "EDSVS, Steering Maneuver."

1. Press *OK* to display the event editor.

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

1. Using the Event Editor dialog, select *Ford Explorer* from the Event Humans & Vehicles list, then choose *Set-up* from the menu bar and select *Position/Velocity*. The Explorer is displayed at the earth-fixed origin.
2. Click on the vehicle's X-Y manipulator (see Figure 5-6), wait for it to turn bright yellow (indicating it has been selected), and drag it to its initial position, X = `-30` ft, Y = `-10` ft. Click the yaw manipulator and rotate it to its heading angle, `0` degrees.

> NOTE: To select the X-Y manipulator, the viewer must be in Pick mode, as indicated by the highlighted arrow in the upper right corner of the viewer (see Figure 5-6).
>
> NOTE: Be sure to keep the mouse button depressed while you drag the manipulators.
>
> NOTE: Adjust the viewer by dollying back (using the Dolly thumb wheel) until you can see the entire course.
>
> 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, especially for heading angle).

1. Click the *Velocity Is Assigned* checkbox. Enter the initial velocity, `20` mph, then click *Apply*.

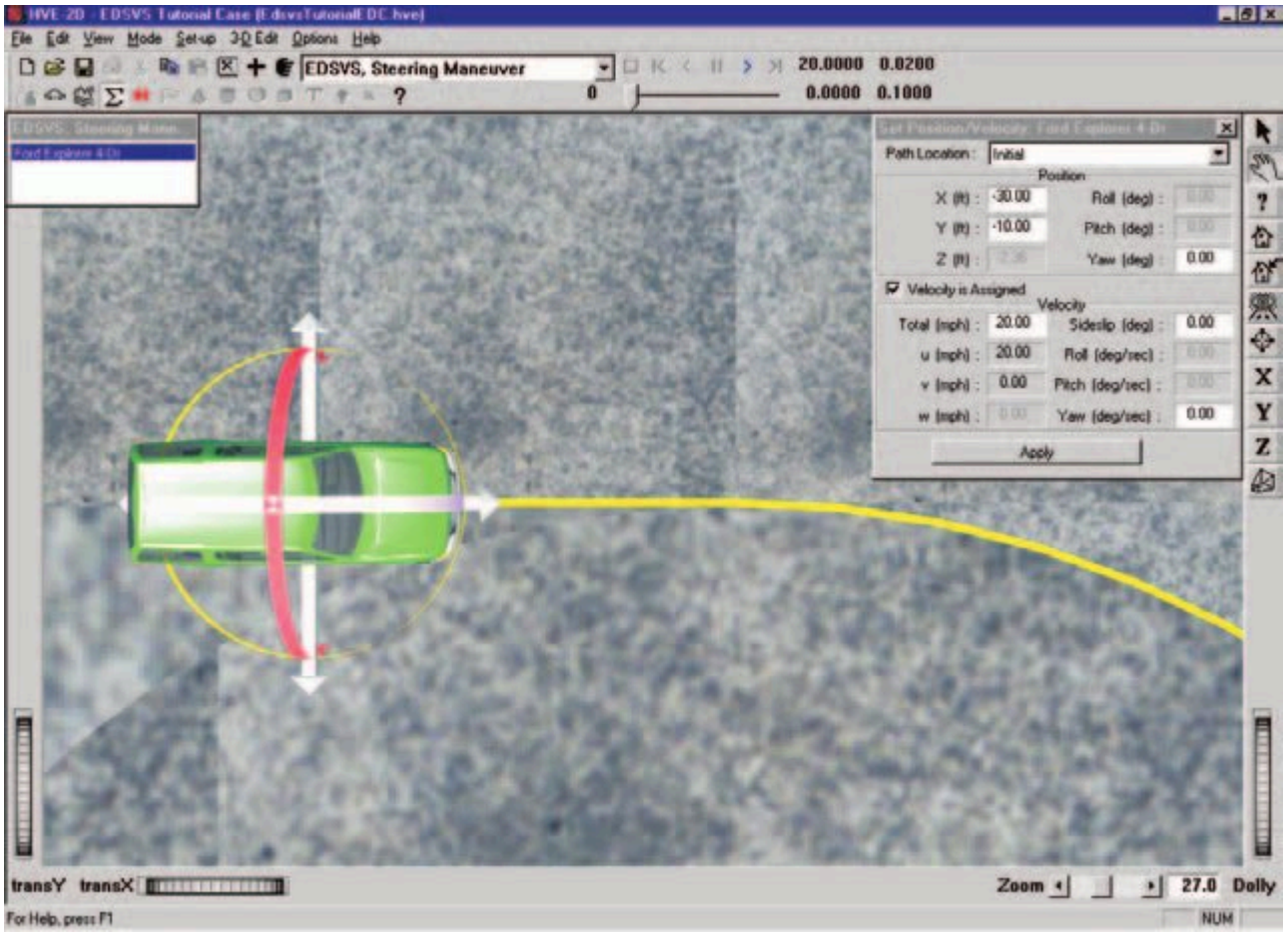


Figure 5-6: Vehicle positioning using the HVE-2D Event Editor. The manipulators can be used to drag and drop the vehicle into position.

> NOTE: When entering coordinates and velocities using the Position/Velocity dialog, remember to press \<Enter>; otherwise, the values will not be assigned.

The vehicle initial conditions are now established. Let's enter the driver controls. But, before we enter the steer angle data, let's be smart: Although we could simply find the steer angles by trial and error, instead we'll use a simple formula to arrive at a very good estimate. From the vehicle wheelbase and desired path radius, it can be shown the required steer angle is approximated by:

$$\delta = \arctan(\frac{wheelbase}{radius})$$

> NOTE: The accuracy of this estimate is normally an acceptable initial estimate unless the vehicle is sideslipping.

Noting the wheelbase of the vehicle is 112 inches and the desired path radius is 50 feet (600 in), the required steer angle is about 11 degrees at the wheels.

> NOTE: An initial attempt using 11 degrees caused the vehicle's path to be too large. We'll use 11.25 degrees in our table.

To enter the steer angles, perform the following steps:

1. Click on the Set-up Menu and select *Driver Controls*. The Driver Controls dialog appears and the Steering Table is displayed.
2. Click on the *Table Is* option list and choose the *At Axle* option.
3. Enter the steer angles for the front wheels, as shown below:

Table 5-1: Steering Table for the EDSVS, Steering Maneuver event

Time (sec)	Steer Angle at Axle (deg) — Axle 1, Right	Steer Angle at Axle (deg) — Axle 1, Left
0.50	0.00	0.00
0.60	11.25	11.25
9.50	11.25	11.25
10.00	-11.25	-11.25
12.65	-11.25	-11.25
13.75	0.00	0.00

1. Press *OK* to accept the steering table.

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

1. Click on the Options menu and choose *Simulation Controls*. The Simulation Controls dialog is displayed.
2. Edit the *Maximum Time*, changing it from `5` to `20` seconds.
3. Press *OK* to update the simulation controls.

Since our goal for this event is to follow a desired path, let's look at some Key Results during execution:

1. If Key Results windows are not displayed, choose *Show Key Results* from the Options menu.
2. Drag the Key Results windows to a convenient location, where they do not block the view but still allow us access to the viewer thumb wheel controls (in case we want to change the view).
3. Click on *Select Variables* in the *Ford Explorer* Key Results window. The Variable Selection dialog for *Ford Explorer* is displayed.

Let's add *Wheel Fx, Fy, Fz* and *Steer Angle* to the Key Results window:

1. Choose *Wheels, Axle 1, Right* from the variable output groups list. The Variable Selection list for the right front wheel is displayed (see Figure 5-7).
2. Select *Fx, Fy, Fz* wheel forces and *Delta (whl)* (Steer Angle) from the list.

> NOTE: The above procedure adds the forces for the right front wheel only; you might wish to add the variables for the remaining three tires.

1. Press *OK* to add the selected variables to the list.

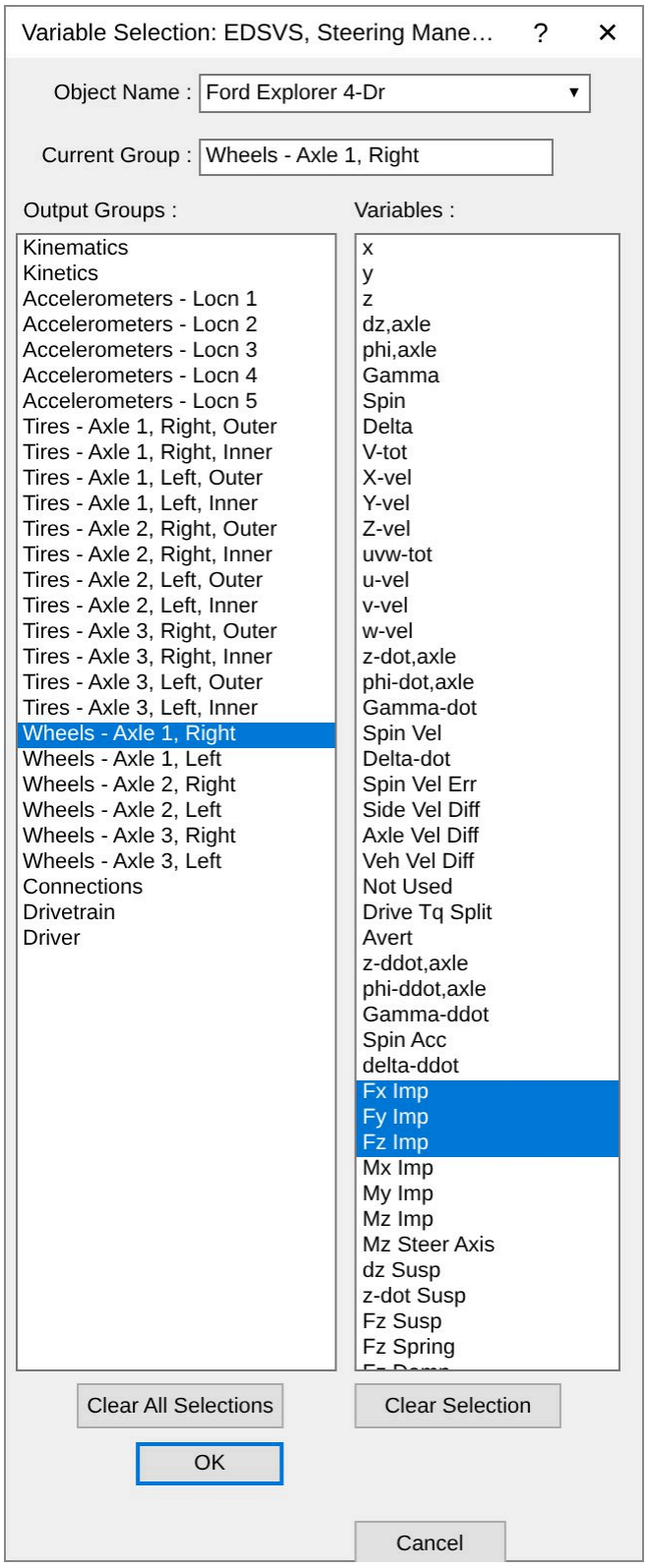


Figure 5-7: Key Results Variable Selection dialog, used for selecting variables to be displayed in the Key Results window.

Now, we're ready to execute the event.

- Using the Event Controller, click *Play* to execute the event. Allow the event to run until completion at t = 20 seconds.

The EDSVS event is shown at time t = 3.10 seconds in Figure 5-8. Note the vehicle travels within 2 feet and 2 degrees of each path position defined in Figure 5-1.

> NOTE: While the event is executing, watch the current results (especially the X,Y path coordinates and heading angle) in the Key Results windows.

We have now completed the event.

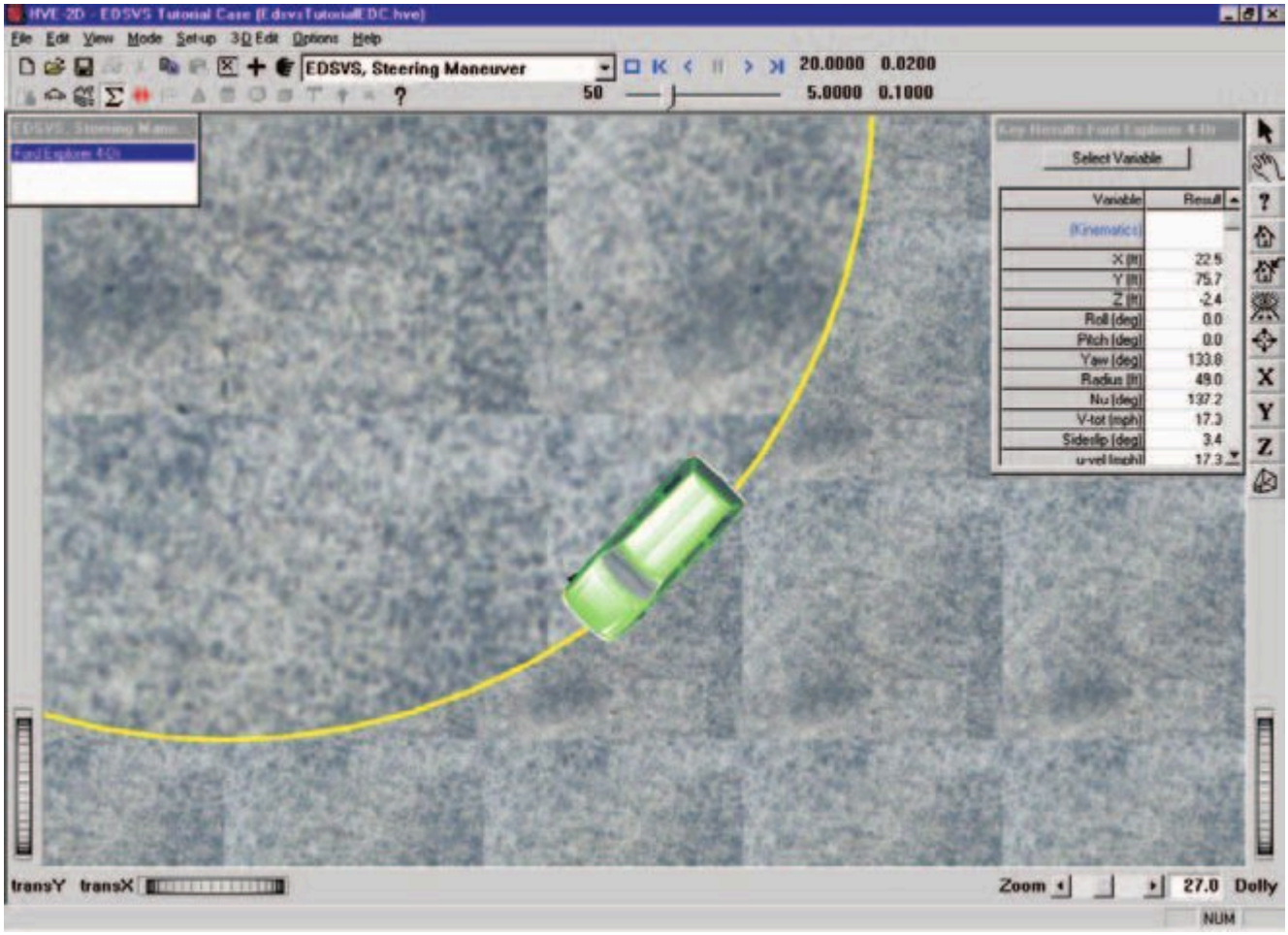


Figure 5-8: HVE-2D Event Editor executing the EDSVS Event.

Viewing Results

Now that we have produced our EDSVS 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.

EDSVS produces the following reports:

- **Accident History** — A table of initial and final positions and velocities
- **Messages** — A list of messages produced by the current run
- **Program Data** — A table containing program control information
- **Trajectory Simulation** — A visualization of the event, displayed at a user-selectable time interval
- **Variable Output** — A table containing time-dependent simulation results

- **Vehicle Data** — A series of tables containing the vehicle data used by EDSVS

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.

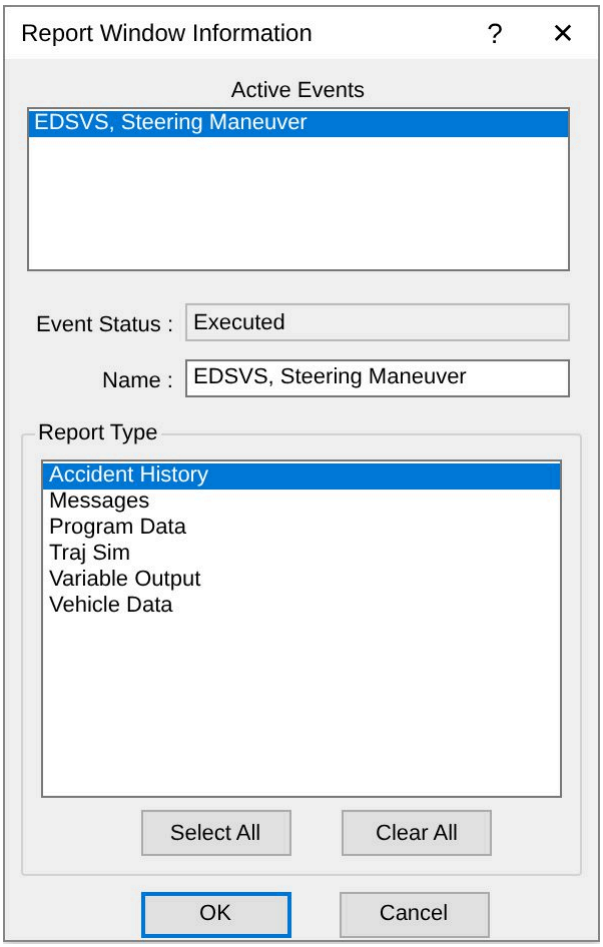


Figure 5-9: Report Window Information dialog, showing the name of the event(s) in the current case.

To view the reports produced by the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed, as shown in Figure 5-9, and includes a list of the active events (*EDSVS, Steering Maneuver* is the only event in this tutorial). The Report Window Information dialog also includes the user-editable *Report Window Name* text field and the *Report Type* list.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select one or more of the available reports. *Select All* selects every report; each selected report opens in its own Report Window.
4. Press *OK* to display the report.

The selected report will be displayed in a resizable window. The following pages illustrate the reports produced for the

EDSVS, Steering Maneuver

event.

Accident History

The Accident History report displays the time and total distance traveled, as well as position and velocity information for the start and end of the run.

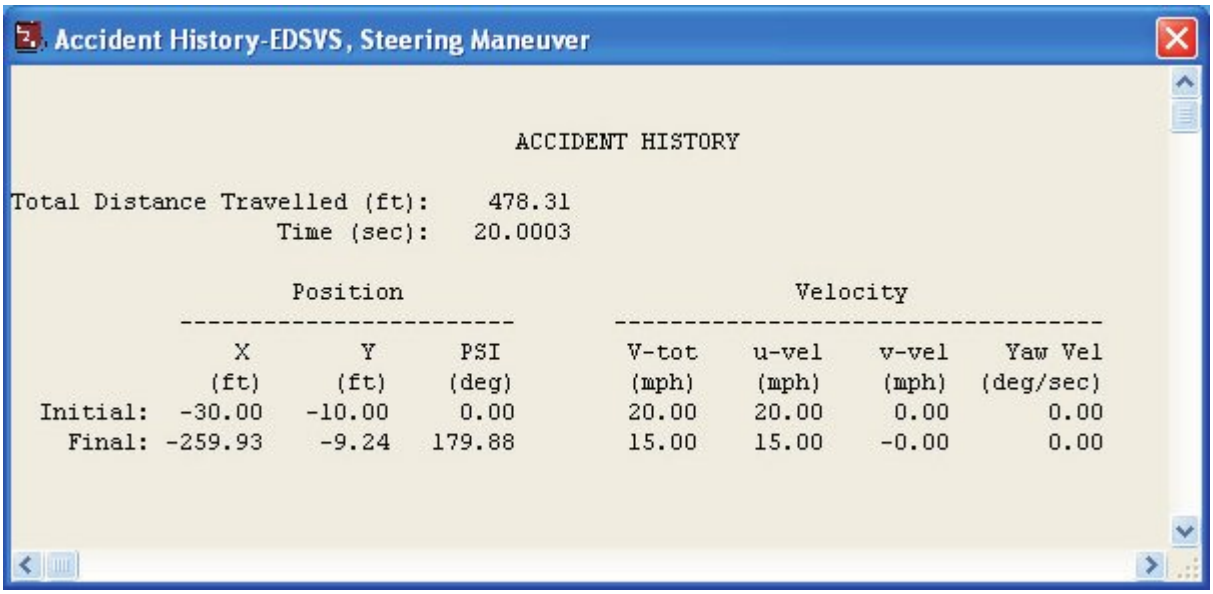


Figure 5-10: Accident History Report for EDSVS, Steering Maneuver. Total distance travelled 478.31 ft in 20.0 sec; Initial: X = -30.00, Y = -10.00, PSI = 0.00, V-tot = 20.00 mph; Final: X = -259.93, Y = -9.24, PSI = 179.88, V-tot = 15.00 mph.

To view the Accident History report for the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select *Accident History*.
4. Press *OK*.

The Accident History report is displayed for the

EDSVS, Steering Maneuver

event, as shown in Figure 5-10.

> 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.

Messages

EDSVS produces a number of messages, depending on the outcome of the event. For a complete list and explanation of the messages produced by EDSVS, see Chapter 6.



Figure 5-11: Messages Report for EDSVS, Steering Maneuver (showing "No Messages").

To view the Messages report produced by the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select *Messages*.
4. Press *OK*.

The Messages report is displayed for the

EDSVS, Steering Maneuver

event, as shown in Figure 5-11.

Program Data

The Program Data report for EDSVS displays the simulation controls used for the current event.

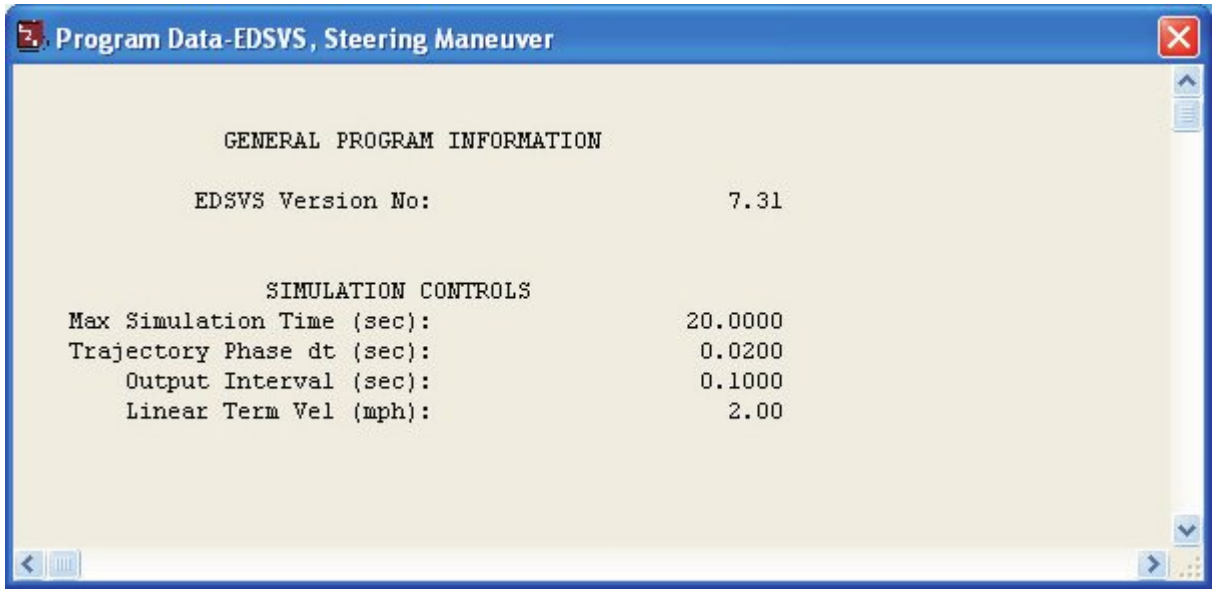


Figure 5-12: Program Data Report for EDSVS, Steering Maneuver. Shows General Program Information (EDSVS Version No: 7.31 in the original) and Simulation Controls (Max Simulation Time 20.0 sec, Trajectory Phase dt 0.0200 sec, Output Interval 0.1000 sec, Linear Term Vel 2.00 mph).

To view the Program Data report for the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select *Program Data*.
4. Press *OK*.

The Program Data report is displayed for the

EDSVS, Steering Maneuver

event, as shown in Figure 5-12.

Vehicle Data

The Vehicle Data report displays the vehicle data, tire data and driver control tables for the EDSVS vehicle.

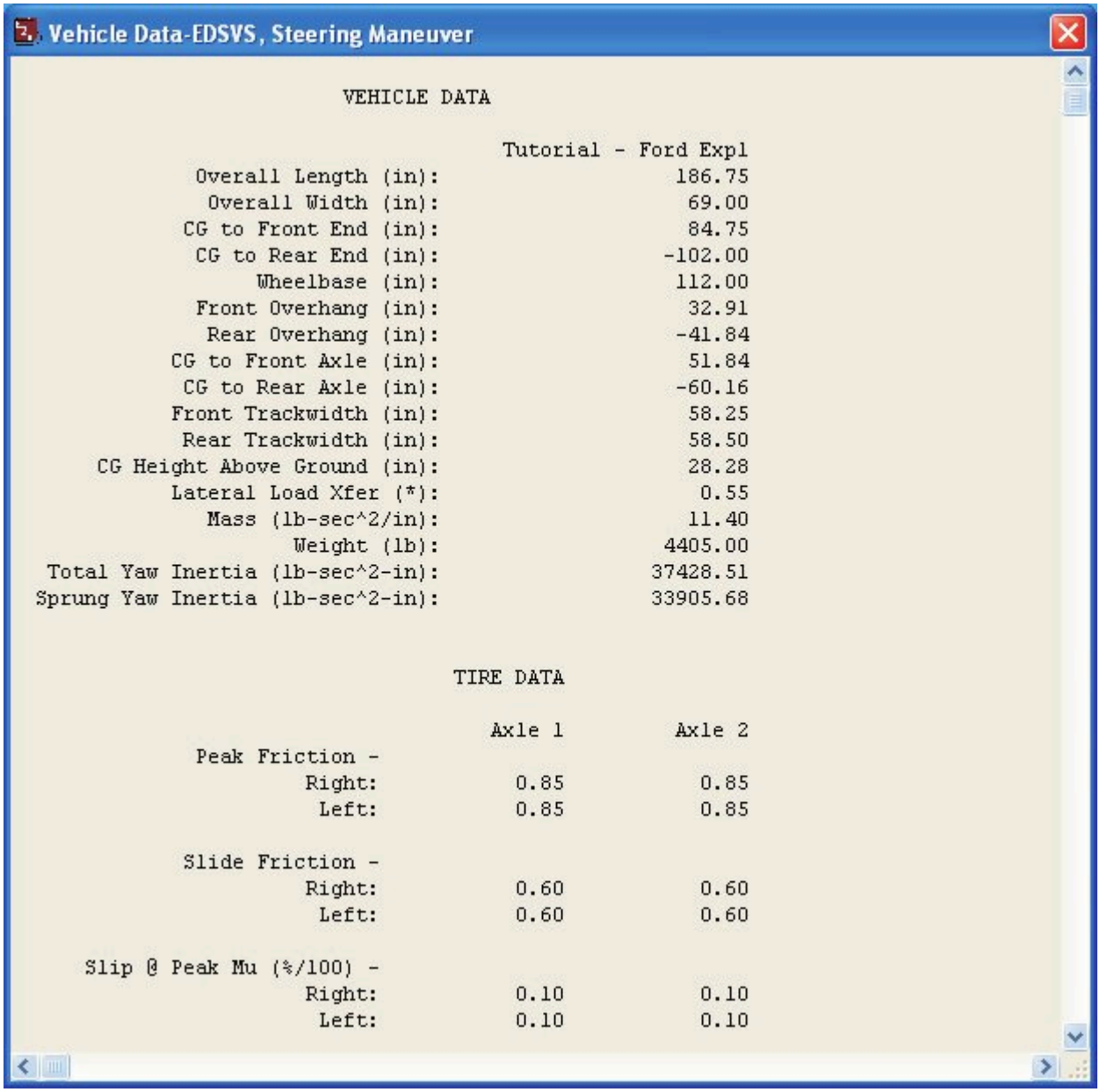


Figure 5-13: Vehicle Data Report for EDSVS, Steering Maneuver. Shows dimensional data (Overall Length 186.75 in, Wheelbase 112.00 in, CG Height Above Ground 28.28 in, Lateral Load Xfer 0.55, Weight 4405.00 lb, Total Yaw Inertia 37428.51 lb-sec²-in, Sprung Yaw Inertia 33905.68 lb-sec²-in) and Tire Data (Peak Friction 0.85, Slide Friction 0.60, Slip @ Peak Mu 0.10).

To view the Vehicle Data report for the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select *Vehicle Data*.
4. Press *OK*.

A portion of the Vehicle Data report displayed for

EDSVS, Steering Maneuver

is shown in Figure 5-13.

Variable Output

To view the Variable Output report for the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select *Variable Output*.
4. Press *OK*.

The Variable Output report is displayed for the

EDSVS, Steering Maneuver

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 EDSVS study is to make our vehicle follow a desired path. To document the resulting path, as well as some other pertinent results, let's select the CG path coordinates and path radius from the Variable Selection dialog.

1. Click on *Select* in the Variable Output window. The Variable Selection dialog for *Ford Explorer* is displayed, as shown in Figure 5-14.

The Kinematics Output group is the default selection and the Kinematics variable list is displayed. Let's add *X, Y, Yaw* and *Path Radius* to the Variable Output window:

1. Select *X, Y, Yaw* and *Radius* from the list.

Next, let's add the right front tire forces and steer angle:

1. Choose *Wheels, Axle 1, Right* from the variable groups list. The Variable Selection list is displayed.
2. Select *Fx, Fy, Fz* and *Delta (whl)* from the variable list.

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

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

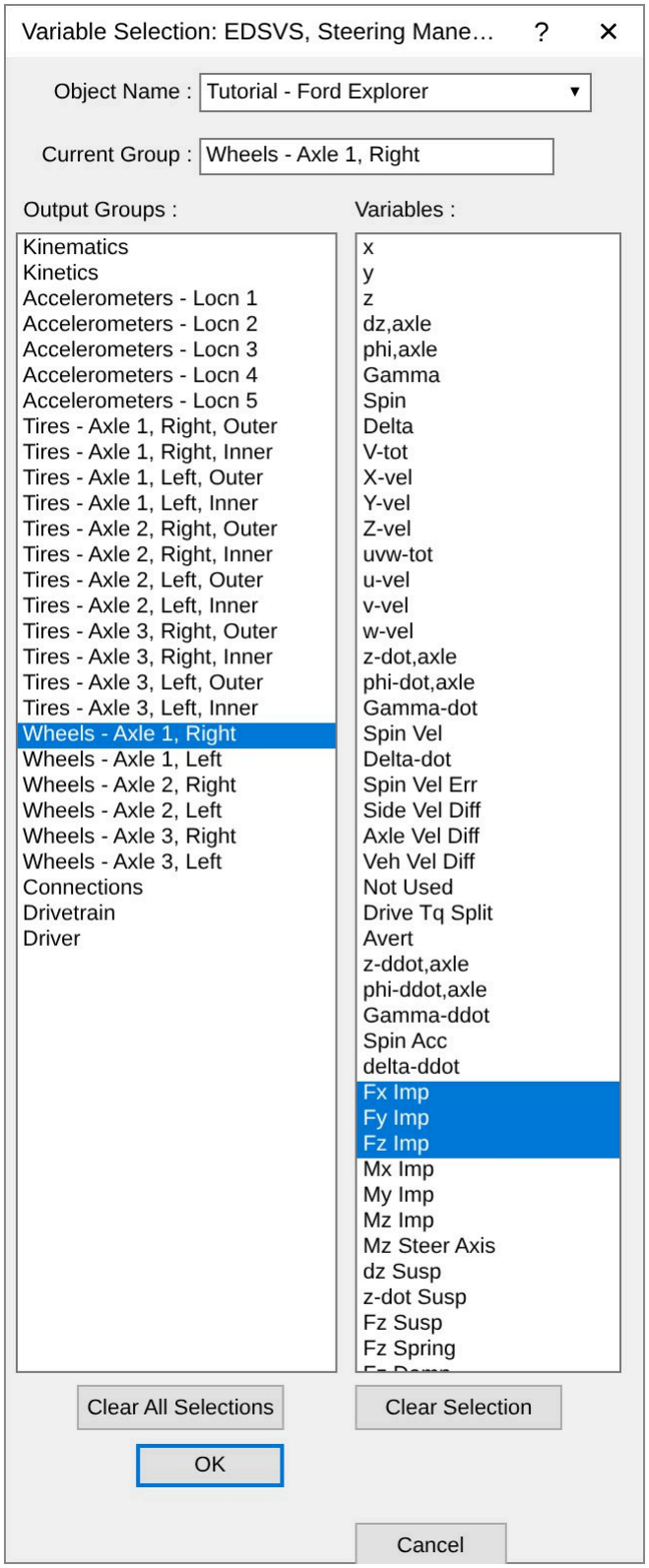
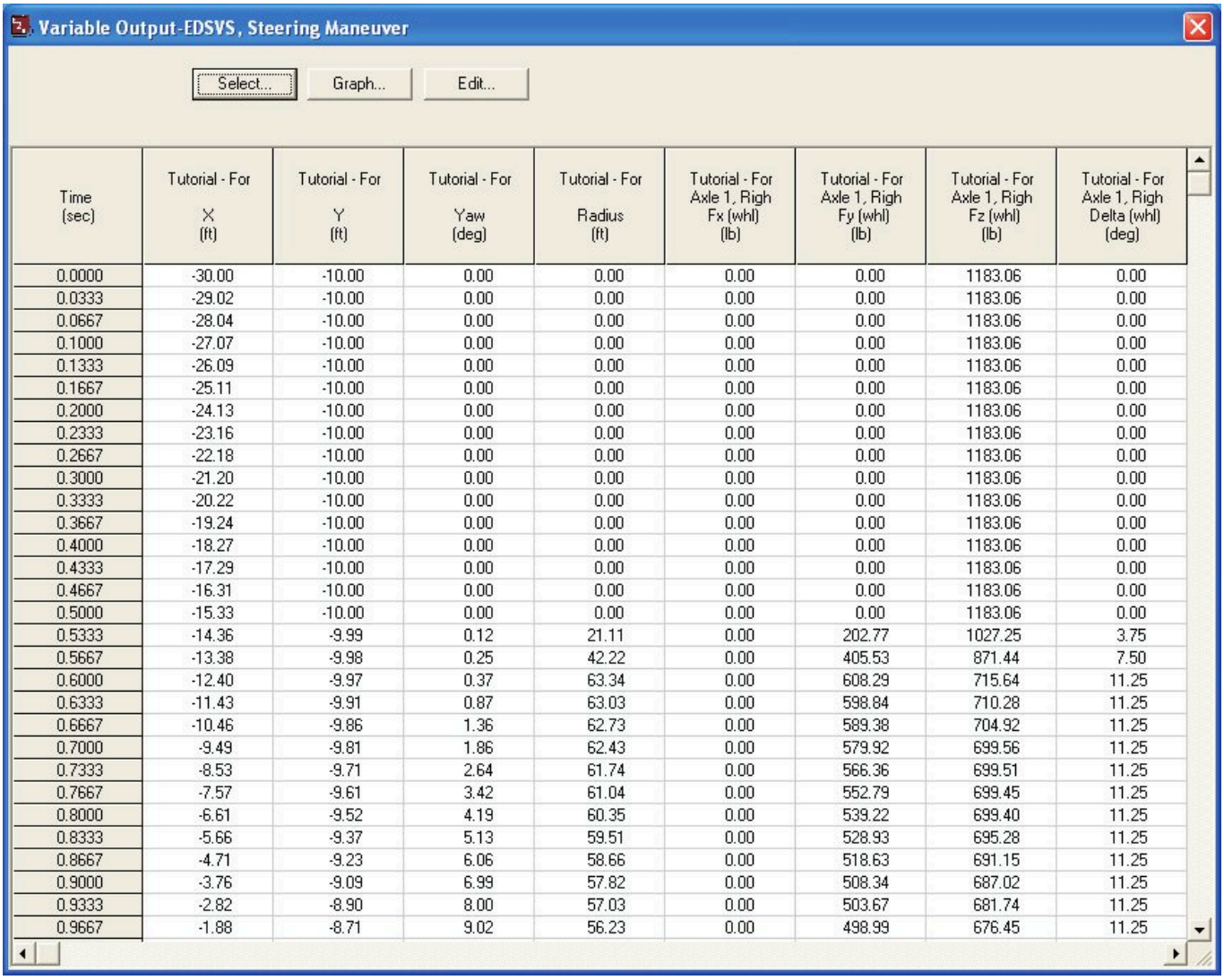


Figure 5-14: Variable Selection dialog, used for selecting the results displayed in the Output Report. The variable list is displayed after selecting the Wheels group and selecting Axle 1, Right Side.

The Variable Output report for the

EDSVS, Steering Maneuver

event now includes X,Y path coordinates and heading angle, path radius, and right front Fx, Fy, Fz tire forces, steer angle, plus any other variables you may have added (see Figure 5-15).



Variable Output-EDSVS, Steering Maneuver

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

Time (sec)	Tutorial - For X (ft)	Tutorial - For Y (ft)	Tutorial - For Yaw (deg)	Tutorial - For Radius (ft)	Tutorial - For Axle 1, Righ Fx (whl) (lb)	Tutorial - For Axle 1, Righ Fy (whl) (lb)	Tutorial - For Axle 1, Righ Fz (whl) (lb)	Tutorial - For Axle 1, Righ Delta (whl) (deg)
0.0000	-30.00	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.0333	-29.02	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.0667	-28.04	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.1000	-27.07	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.1333	-26.09	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.1667	-25.11	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.2000	-24.13	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.2333	-23.16	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.2667	-22.18	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.3000	-21.20	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.3333	-20.22	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.3667	-19.24	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.4000	-18.27	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.4333	-17.29	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.4667	-16.31	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.5000	-15.33	-10.00	0.00	0.00	0.00	0.00	1183.06	0.00
0.5333	-14.36	-9.99	0.12	21.11	0.00	202.77	1027.25	3.75
0.5667	-13.38	-9.98	0.25	42.22	0.00	405.53	871.44	7.50
0.6000	-12.40	-9.97	0.37	63.34	0.00	608.29	715.64	11.25
0.6333	-11.43	-9.91	0.87	63.03	0.00	598.84	710.28	11.25
0.6667	-10.46	-9.86	1.36	62.73	0.00	589.38	704.92	11.25
0.7000	-9.49	-9.81	1.86	62.43	0.00	579.92	699.56	11.25
0.7333	-8.53	-9.71	2.64	61.74	0.00	566.36	699.51	11.25
0.7667	-7.57	-9.61	3.42	61.04	0.00	552.79	699.45	11.25
0.8000	-6.61	-9.52	4.19	60.35	0.00	539.22	699.40	11.25
0.8333	-5.66	-9.37	5.13	59.51	0.00	528.93	695.28	11.25
0.8667	-4.71	-9.23	6.06	58.66	0.00	518.63	691.15	11.25
0.9000	-3.76	-9.09	6.99	57.82	0.00	508.34	687.02	11.25
0.9333	-2.82	-8.90	8.00	57.03	0.00	503.67	681.74	11.25
0.9667	-1.88	-8.71	9.02	56.23	0.00	498.99	676.45	11.25

Figure 5-15: Variable Output report for EDSVS, Steering Maneuver, displaying the selected results.

Trajectory Simulation

Finally, let's display a trajectory simulation for this event. To view the Trajectory Simulation for the

EDSVS, Steering Maneuver

event, perform the following steps:

1. Click *Add New Object*. The Report Window Information dialog is displayed.
2. Select *EDSVS, Steering Maneuver* from the Active Events list.
3. In the *Report Type* list, select *Trajectory Simulation*.
4. Press *OK*.

The Trajectory Simulation viewer is displayed for the

EDSVS, Steering Maneuver

event (see Figure 5-16). The vehicle is shown at its initial position.

To visualize the motion, use the Playback Controller to perform the following steps:

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



Figure 5-16: Trajectory Simulation for EDSVS, Steering Maneuver, displaying the selected results.

Printing

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

1. Click on the dialog header of the *Variable Output - EDSVS, Steering Maneuver* report. Your selection 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.
2. Click on the *File* menu and choose *Print*. The Print dialog is displayed, allowing the user to select from several available print options.

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

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

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

> NOTE: The Print dialog provides several options. Refer to the 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 changed by clicking on the Options menu and choosing Preferences. Use the Font Size option list to change the size.

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Chapter 6 — EDSVS Messages

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

Messages produced by HVE-2D or HVE are described in the User's Manual, Appendix II.

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

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

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

(updated: the current EDSVS message catalog contains exactly the four messages listed below; none have been added or removed since the Sixth Edition, and all four are Level 1 (Fatal) run-termination messages.)

Message Catalog

Wheel Lift-off

> *The simulation was terminated because a wheel lifted off the ground. For more information, check the Variable Output Table to see where Fz (Wheel Number) became negative.*

(Level 1 — Fatal)

This message occurs when EDSVS calculates a negative vertical tire load, Fz. EDSVS is a quasi-2D analysis and cannot handle the condition where a wheel leaves the ground. This condition occurs during hard cornering maneuvers or extremely hard braking, normally coupled with a relatively high center of gravity. This condition might also occur at the start of the simulation if the event begins under extremely dynamic conditions, such as high sideslip or angular velocity.

Excessive Roll or Pitch Angle

> *The simulation was terminated because the current roll or pitch angle exceeded 15 degrees. EDSVS is a quasi-3-D analysis. The small angle assumption is used.*

(Level 1 — Fatal)

HVE: This message applies to the 3-D terrain capability available in the HVE environment.

This message occurs when the vehicle travels over a surface with a significant slope. At each timestep, EDSVS uses the Get Surface Information search to determine the current roll and pitch angles. If either of these angles exceeds the allowable value, the run terminates. The termination reflects the fact that the small angle assumption is used, and the error may become significant.

Get Surface Information Failure

> *The simulation was terminated because GetSurfaceInfo() failed*

(Level 1 — Fatal)

This message occurs if the Get Surface Information search failed to return a valid surface elevation. EDSVS should not return this condition; contact EDC if it occurs.

*(updated: the surface search method is now selected in the separate **Get Surface Information Options** dialog, not the EDSVS Calculation Options dialog; the **By Elevation** method is not supported. See EDSVS Calculation Options.)*

Integration Error

> *The simulation was terminated due to an 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 0.1 and Max Bisections should be about 10.*

(Level 1 — Fatal)

This condition indicates dynamic instability. Experience suggests if reasonable integration timesteps and maximum bisections are used, this condition should not occur. If you confirm reasonable simulation controls are used and the condition still occurs, please contact EDC.

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Chapter 7 — Technical References

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Chapter 8 — Index

The printed Sixth Edition ended with a page-number index. Page numbers are meaningless in this Markdown edition, so the index below preserves the original topics and *See/See Also* cross-references, but points to chapters instead of pages. Chapter links: 1 — Program Description, 2 — Program Input, 3 — Program Output, 4 — Calculation Method, 5 — Tutorial, 6 — Messages, 7 — Technical References.

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