BUILDING VEHICLES FOR HVE

J. Travis Garvey
Engineering Dynamics Corporation

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

VEHICLE DATA FILE

This section is an overview of all the numerical information that is used to create a vehicle for the vehicle database. The vehicle data file is broken up into sections: Vehicle Main Data, Dimensional, Stiffness, Inertia, Drag, Drivetrain, Transmission, Differential, Wheel Location, Suspension, Tire and Brake, and Steering Data. Each section is required for the completion of the vehicle data file. The units used in the data file consist of lbs., in, sec, and derivatives there of. Each data field in the file is labeled with the required units.

Vehicle Main Data

This section includes the vehicles general information:

- Make
- Model
- Version
- Year
- Date Of Manufacture (DOM)
- Vehicle Identification Number (VIN)
- Number of axles
- Drive axle
- Driver side location
- Engine location

This information can be gathered from an inspection of the vehicle or vehicle specification sheet. The vehicle's geometry filename is also included in this section. This tells HVE which geometry file to use with this data file.

Dimensional Data

The dimensional data is determined either from physical measurements taken from the actual vehicle or from a manufacturer's specification sheet. The vehicle dimensions are then used in conjunction with the calculated center of gravity (CG) seen in Fig. 2 to define the vehicle boundaries relative to the CG. The dimensions included in this section are:

- CG to the front, rear, right, left, roof, and undercarriage of the vehicle

These dimensions represent a virtual shoebox into which the vehicle would fit.

Stiffness Data

The values necessary for this section are the A, B, and Kv stiffness coefficients. These values are needed for the:

- Front, Rear, Right, Left, Top, and Bottom surfaces of the vehicle

These values are obtained through Neptune Engineering. The stiffness coefficients are calculated from actual crash tests [1]. Generic values [2] are used for vehicles that are not available from Neptune Engineering.

Inertia Data

There are four inertial properties that make up the inertial data section. They are the:

- Total vehicle mass
- Sprung mass roll inertia
- Sprung mass pitch inertia
- Sprung mass yaw inertia

The total vehicle mass (sprung + unsprung) is either measured or obtained from a vehicle specification sheet. The roll, pitch, and yaw inertias are calculated using values from Garrott [3] as well as measured dimensions and weights of individual axles [10]. The values calculated from axle dimensions are subtracted from the total vehicle inertia's to produce the desired sprung mass inertias. "Measured Vehicle Inertial Parameters- NHTSA Data Through Sept. 1992" [3] is used for passenger, van, light truck, and sport utility vehicles. The University of Michigan Factbook [4] is used for heavy trucks, trailers, and dollys.

Drag Data

The coefficient of drag (C_D), the frontal area of the vehicle, and distance from the CG to the front of the vehicle are the three values needed in this section.

- Coefficient of Drag
- Frontal Area of the Vehicle
- Distance from the CG to the Front of the Vehicle

The coefficient of drag is a dimensionless number that indicates the overall sleekness of an object. The lower the C_D the lower the drag force. The C_D is estimated two different ways. The first way is by comparison to similar vehicles with known C_D's, using table 4.3 from Hucho & Wolf-Heinrich [5]. The second is using generic values for different body styles. For instance:

Passenger Cars	0.35
Vans	0.45
Sport Utility	0.40
Pickup Trucks	0.45

The frontal area of the vehicle is calculated to be 90% of the body height times the overall width.

Drive Train, Transmission Data & Differential Data

The engine's Net Horsepower at RPM, Net Torque at RPM, Compression Ratio, Stroke and Displacement are required for the completion of calculations necessary for this section. These values can be found in a manufacturer datasheet or a vehicle Service Manual. The data required in the data file are:

- Closed Throttle Torque (in-lb) at Multiple Engine Speeds (rad/sec)
- Wide Open Throttle Torque(in-lb) at Multiple Engine Speeds (rad/sec)

For the Closed Throttle calculations the friction horsepower is negative, and calculated at multiple engine speeds using equations from Lichty [6]:

$$Frhp = -1.10 \times 10^{-5} \times Cr^2 \times L \times Displ \times (rpm/100)^2 \qquad (1)$$

where:

Frhp	= Friction Horsepower	(hp)
Cr	= Compression Ratio	
L	= Stroke	(in)
Displ	= Engine Displacement	(in^3)
rpm	= Engine Speed	(rev/min)

$$T = Frhp \times 5252 / rpm \qquad (2)$$

where:

T=Torque(ft-lb)

For the Wide Open Throttle (WOT) engine table, the Net Horsepower at RPM and Net Torque at RPM are used as known points in the WOT power curve Fig.1. It is then necessary to estimate the other values in the power curve so that it resembles the graph in Fig. 1.

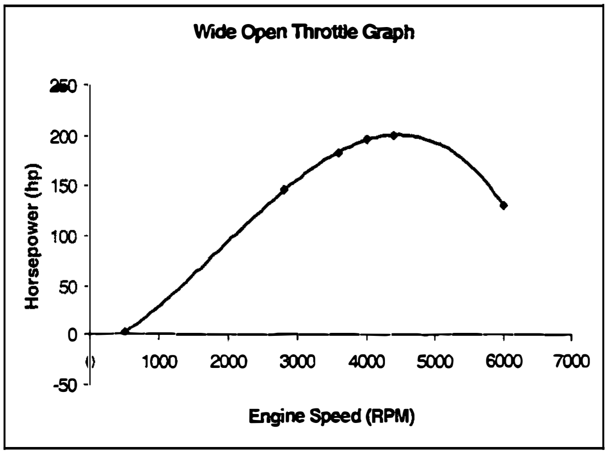

Fig. 1 Graph the Wide Open Throttle Curve

The transmission data are:

- Number of speeds
- Gear ratios

The differential data are:

- Number of differential ratios
- Differential ratio

The number of speeds and ratios can be found in a manufacturer datasheet or another vehicle specification document. The gear ratio order begins with neutral, reverse, first, etc. These values complete the drive train and transmission section.

Wheel Location

The wheel locations are referenced by their x, y, and z coordinates with respect to the sprung mass center of gravity. However, during the vehicle inspection, wheel vertical loads are measured for the total vehicle (sprung mass + axle/wheel mass). Therefore the unsprung mass weight must be calculated for each axle. The unsprung weight is the axle, tire, wheel, and brake weights. The weight of the tire and wheel is measured. The weights of the axle are either calculated using their dimensions and material density or from reference [10]. The brake weights are calculated from dimensions and material density. The unsprung weight is then subtracted from the vehicle weight measured at each axle. The required data for this section includes:

- x, y, and z coordinate locations for each wheel on the vehicle

The coordinates in the x direction are calculated by making a free-body diagram of the vehicle. The sum of the forces and moments are used to find the distance from the CG to the front and rear axles.

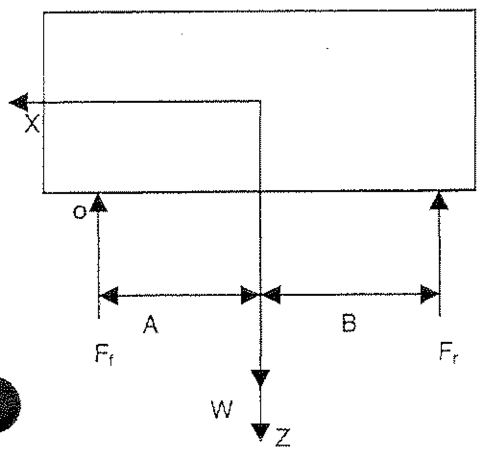

Fig.2 A free-body diagram used to calculate coordinates of the CG in the x direction.

$$\sum F_z = 0$$

$$F_f + F_r = W \tag{3}$$

$$\sum M_o = 0$$

$$W \times A = Fr \times (A + B) \tag{4}$$

$$Wb = A + B \tag{5}$$

$$A = Fr \times (A + B) / W \tag{6}$$

where:

F_f = sprung mass weight at front axle
F_r = sprung mass weight at rear axle
W = weight of the sprung mass
A = distance from the CG to front axle
B = distance from the CG to rear axle
Wb = wheelbase

The y coordinate locations depend upon the track width. For the front wheel locations on symmetric vehicles the front track width is divided by two and for the rear wheel locations the rear track width is also divided in half.

The z coordinates equal the CG height minus the unloaded tire radius. The tire radius can be found in The Tire and Rim Association Yearbook [9].

Suspension Data

The suspension type, maximum rebound deflection, and spindle offset can be obtained from a vehicle specification sheet or by inspection. The maximum jounce deflection and ride rate are measured during the collection of physical measurements. The jounce measurements are used to determine the suspensions ride rate. Ride rate is equal to the slope of the linear regression of vertical tire force vs. vehicle jounce. Thus, the slope must be divided in half to get the correct ride rate for each side of the suspension.

Assuming critical damping the damp rate is calculated from the ride rate and suspension mass as seen below:

$$Damprate = \sqrt{(K / M)} \tag{7}$$

where:

K = ride rate.
M = mass of the suspension at that tire.

$$M = (x / Wb) \times CW \times 0.5 / 386.4 \tag{8}$$

where:

x = distance from the CG to the axle
Wb = wheelbase
CW = Curb Weight

The rest of the information in this section either comes from measured values or generic data that is based on the vehicles class category or suspension type. Required values for this section of the data file are:

- Axle Type
- Ride Rate
- Damp Rate
- Spring friction
- Roll Center Height
- Lateral Spring Spacing
- Max. Jounce Deflection
- Max. Rebound Deflection
- Caster
- Toe In
- Stop angles

Tire Data

Five data groups define tires: the physical data, frictional data, cornering stiffness data, camber stiffness data, and the slip vs. roll off data. For passenger cars there are two sources. The first is a 1983 CALSPAN report entitled "Extended Tire Testing" [7]. The second is "EDC Flatbed Tire Test Data" [8]. This report consists of data from tests of 26 different tires tested similarly to those done by CALSPAN, in 1999. The data for truck tires comes from flatbed tire testing that was conducted at the University of Michigan from the late 1970's to the early 1980's. The only required data for this section are:

- Number of tires
- Tire Spacing
- Tire Filename for each side of the axles

Brake & Steering Data

Information regarding the presence of a proportioning valve, anti-lock braking system, and the steering gear ratio data are located in a vehicle specification sheet. The brake pedal ratio can usually be found in the vehicle specification sheet but if it is not, a generic value from [2] can be entered. In addition, the torque ratio is calculated using the Brake Designer program in HVE. Required data for the Wheel Brake data, Brake System data, and Steering System data include:

- Torque Ratio
- Pedal Ratio
- Steering Ratio

PHYSICAL MEASUREMENTS

Physical measurements made on an actual exemplar vehicle provide the raw data used in creating the HVE vehicle data file. It is very important to be organized and prepared with the proper equipment in order to gather as much physical data as possible in one session. In Appendix A is an example of a data sheet on which to record measurements. The equipment needed for these measurements include:

Equipment List:

1. Metal Measuring Tape
2. Cloth Measuring Tape
3. Calipers
4. Heavy Duty Floor Jack
5. Masking Tape
6. Vehicle Platform Scales (4)
7. Free-Standing Fixed Horizontal Arm
8. Plum Bob
9. Camera with Flash

General Information

First, record the vehicle's general information. This includes Vehicle Make, Model, Year, Body Style, Date of Manufacture (DOM), and VIN number. The DOM can be found on the inside of the driver's side door B pillar, and the VIN can be found on the driver's side dash.

Inertias Measurements

After the general information is recorded, the weight distribution measurements will be made using the Vehicle Platform Scales. One individual scale is placed beneath each tire on the vehicle. To do this, the vehicle must be raised using the 2-ton jack and then lowered slowly onto the scales. Once this is done, the weights at each tire are recorded.

Suspension Measurements

With the vehicle still resting on the scales, the jounce measurements are recorded at both the front and rear suspension. The cloth measuring tape must be taped vertically to the front bumper (Fig 3,A). The Free-Standing Fixed Horizontal Arm should then be pointed at a selected point on the cloth tape (Fig 3,B). The vehicle should be allowed to move five inches vertically without interfering with the horizontal arm. The jack is then placed beneath the front axle. The weight of the front of the vehicle is recorded and then recorded again at every half-inch the vehicle is raised until the scales read zero. These same steps should then be repeated for the rear suspension by placing the cloth tape and horizontal arm at the rear of the vehicle and placing the jack underneath the rear axle. When the jounce measurements are finished, the scales are then removed from beneath the vehicle's tires.

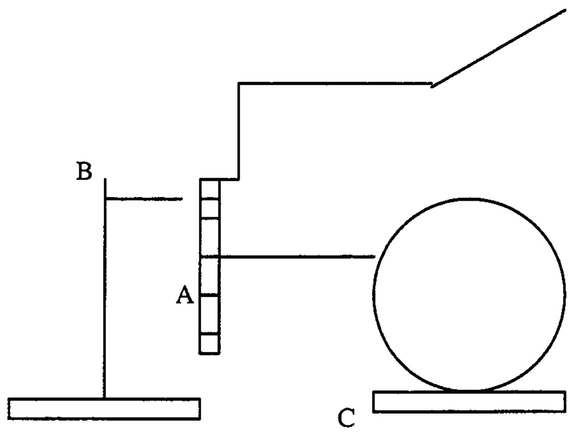

Fig. 3 A schematic of the jounce measurement. A= cloth tape, B= free-standing fixed horizontal arm, C= platform wheel scale.

Documenting the suspension of a vehicle requires a combination of identifying and measuring its components. Observations that can be made include the suspension, shock, and spring types. Then, with a tape measure and calipers, the coil diameter, wire diameter, or leaf length can be measured. In most cases the front suspension is an independent suspension that will call for measurements of upper and lower control arm lengths. For the lower control arm, the measurements consist of measuring from bolt to bolt, spring to spring, and ball joint to ball joint. For the upper control arm, the measurements are taken from the bolt to outer tire, ball joint to outer tire, and bolt to bolt. If there is a sway bar, it is necessary to measure the bar diameter. For a leaf spring rear suspension, the measurements needed include the lateral spring spacing, length of spring, and distance from the axle to the rear leaf pin.

Vehicle Dimension Measurements

The next measurements are the vehicle wheelbase, front overhang, track width, and rear overhang. Wheelbase is measured with the measuring tape from the center of the front wheel to the center of the rear wheel. This is done for both sides of the vehicle. To measure the front overhang, the measurement is taken from the center of the front axle to the end of the front bumper. It is necessary to use a plumb bob to accurately align the front of the bumper with the tape measure. The track width for both the front and rear axles is measured using the tape measure, measuring from the center of the right side to the left side tire tread. To measure the rear overhang, the measurement is taken from the center of the rear axle to the end of the rear bumper. Again, the plumb bob is needed to align the rear of the bumper to the tape measure.

Brake Measurements

It is possible to document the type and diameter of both the front and rear brakes. The detail of the measurements taken on a drum brake can be much more involved than that of a disc brake. For instance, the drum brake measurements can involve removing the tire and taking detailed measurements of the drum diameter, shoe width, shoe thickness, leading shoe included angle (deg.), trailing shoe included angle (deg), shoe pin radius, etc... The data required for a disc brake includes the outer diameter, inside diameter, rotor thickness, lining thickness, and piston diameter. This data is found in both a vehicle specification sheet and a service manual.

Tire Measurements

Each tire on the vehicle is recorded by manufacturer, model, size, max pressure, and max load. This information can found on the tire. For example if this is written on the tire:

Firestone 721 P225/75R15
Maxload 1742@35psi

The tire information is:
Manufacturer = Firestone
Model = 721
Size = P225/75R15
The "P" in the tire size refers to it being a passenger tire.

Engine Measurements

There are three important pieces of information to collect when inspecting a vehicle engine: engine configuration, location, and displacement. Typical engine configurations are the L4, L6, V6, and the V8. Typical engine locations are in the front or the rear. Displacement is referred to in units of liters. The displacement can be found on the vehicle engine, a specification sheet, or in a service manual.

Transmission Measurements

The Transmission data is easily recorded by inspection. The vehicle is either a manual or automatic transmission. This can be determined quickly by observing whether or not the vehicle has a clutch pedal. It is also valuable to note the number of speeds available for the transmission.

Steering Measurements

There are two pieces of steering data that are recorded upon inspection. The first is the number of turns to lock. Turn the steering wheel all the way to the left and then count the number of turns it takes to for the wheel to stop turning to the right. Second is the angle of the tire when it is in the locked position. This can be done by drawing a line from the center-outside of the tire in a straight line towards the front of the vehicle and then marking the outside of the tire in its locked position. This will require the use of a protractor or a trigonometric calculation of the angle.

The vehicle can now be photographed. Pictures should be taken from the front, back, right, left, and every corner of the vehicle. It is also a good idea to photograph the brakes and the suspensions at each axle as well. These pictures will come in handy if any questions arise about the measurements taken.

MAKING A GEOMETRY FILE

On the computer, it is necessary to create a wireframe mesh of polygons to produce an acceptable image file. This is done by collecting the x, y, and z locations of points on the vehicle exterior. These points are then used to create the polygons. A good reference for learning how the wireframe meshes should look for various vehicle types is the "Viewpoint Premier Catalog" [11]. This makes visualizing how the wireframe should be laid out easier.

Another way to become more familiar with wireframes is be to look at the vehicle models in the HVE Vehicle Editor. First, select a vehicle from the database. Then on the main menu bar under Options, select Render. The render option allows the model to be viewed as either a wireframe or a wireframe with hidden lines in addition to the usual phong option. This is useful in viewing the model's wireframe from every possible angle. In observing these models, it should become apparent that curved sections on vehicles contain many more polygons than do straight sections. Sharp geometries are much more straightforward to layout because it is only necessary to record points at the corners. There is no straightforward approach to mapping the curved sections of a vehicle. This process is more of an art. It is up to the vehicle builder to determine how finely the mesh will be through the curved sections.

Topics of discussion in this section consist of the equipment used, an approach to mapping the vehicle to create a wireframe, and editing the image file.

The equipment list includes:

1. Masking Tape
2. Fabric Tape Measure
3. 3-D Digitizer
4. Washable Felt Tip Pen

The masking tape is used to visually map the vehicle exterior and interior into a wireframe. It is helpful in identifying potential problems in creating your mesh ahead of time. It also allows for a felt pen to be used to plot points on the vehicle without leaving permanent marks on the vehicle. The 3-D digitizer is the most vital piece of equipment used for measuring the geometric shape of the vehicle. The digitizer is used to record points from the vehicle to the computer. The fabric tape is used to determine the centerline on the vehicle for digitizing the exterior.

Mapping

The approach used by EDC to digitize a vehicle has been developed through trial and error. This is the process that has worked best for us.

First, using the fabric tape, locate the centerline of the vehicle. Once the centerline has been located, mark it by running a piece of masking tape down the length of the centerline. This is done because only half of the vehicle will be digitized. Using computer software, it is possible to reflect the mesh about its centerline to make the vehicle image complete. After the centerline has been marked, the vehicle mesh should be laid out using masking tape and a felt tip pen to plot out points. The masking tape is placed on the vehicle and the points are put on the tape with the pen. The most efficient way to digitize involves making a line out of points, then creating another line of points, and finally, connecting those two lines to create polygons between the points on each line. This process should be kept in mind when laying out points.

It is recommended that the layout of points begin at the edge of the fender well, and then extended in a radial direction from the center of the wells to the limits of the fender. It is important to keep a constant number of points for each line so that the polygons are created in a consistent pattern. Once the edge of the fender next to the hood has been reached, compare the density of points required to capture the door or hood. Adjust the number of points by creating a new line along the edge of the fender to meet the requirements of the new area to be digitized. This procedure will be repeated throughout the digitizing process for each new area until the entire exterior is completely measured. The exterior mesh is now ready to be digitized.

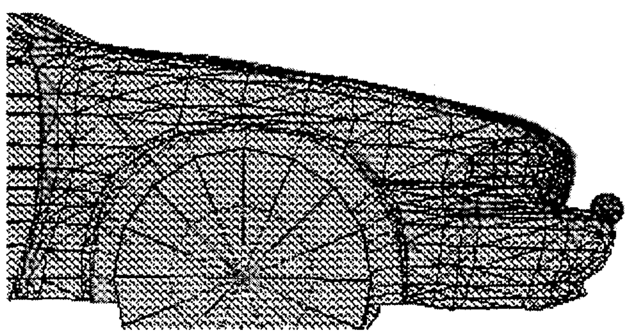

Fig. 4 An example of a wireframe for the right front fender of a vehicle.

Digitizing the interior of a vehicle requires much of the same procedures as those used to digitize the exterior. The areas of the interior that should be digitized are the dash, door panels, floor, front seat, and back seat. First, it is necessary to measure the centerline of the interior. Then mark it by running a piece of masking tape down the length of the centerline, starting at the top of the windshield. Depending on the digitizing software being used, there may be a need for some common points between the exterior and interior vehicle images so that they may be merged together as one. These common points would be located at the top-center, bottom-center, top-right corner, and bottom-right corner of the windshield. This is why we need to measure the centerline of the interior windshield. Then, with the rest of the masking tape, layout the lines for the interior of the passenger-side of the vehicle. Start at the top of the dashboard where the windshield meets the dashboard, and work down towards the floor. There are usually plenty of seams to use as a guide for the lines. Now that the layout is finished, the interior is ready to be digitized.

Editing the Image File

Editing image files is done back in the office after the digitizing process is complete. There will be two files to edit: the interior and exterior image files. Each file must be examined for holes. Shading or rendering the image can help with this. When the image is shaded, it will shade the existing polygons. If there are areas where a shaded polygon should be and it does not exist, then a polygon needs to be created from the surrounding points in the image. There might also be points or lines that need to be joined together to fill holes in the image. The examination of these files should be done from every possible view until the file is perfect.

The following steps are necessary to the editing of the image files but the instructions on how to do them will depend on the software that is being used.

1. The first step is reflecting the image files so that they become a complete exterior and interior. Select the points along the centerline of the image and make them a line. This will be the line around which the image is reflected around.
2. Create the undercarriage polygons on the exterior image.
3. The next step is to align the exterior image to an axis.
4. Align the interior image with the exterior image using the common points on the windshield.
5. Group the polygons using the number map in Appendix B as a guide. This will assign material properties to the polygons. One way of grouping polygons is to copy and then paste them into another file but first the *ID on copy* option must be selected. This option will ask for an ID number for the polygons that are being copied. These numbers are found in the number map in Appendix B.
6. Inspect the image files again for holes and discontinuities.
7. Merge the interior and exterior image files.
8. Translate this file into a DXF file.
9. Copy the DXF file into the /usr/people/hve/supportFiles/images/vehicles

directory on the Unix Workstation. Next translate the DXF file to a h3d file using the command DxfToHve filename.dxf filename.h3d.

10. The editing of the image file within the digitizing software is now finished.

The finishing bits and pieces of editing on the geometry file are done on the Unix workstation.

ORIENTING THE GEOMETRY FILE

There are two programs used in the final editing of the new geometry file. One is the SceneViewer Program and the other is HVE. HVE is used to see how well the geometry file lines up with the vehicle's Center of Gravity and tires. SceneViewer is where the changes in the geometry file's orientation can be made. With these two tools, the geometry file will be finished

The SceneViewer program allows for the editing of the x, y, z translations, scale factors, rotations, scale orientations, and the center of the geometry file. Initially use the SceneViewer program to view the vehicle in order to make sure that material properties were assigned properly. In addition make sure the windows are transparent and brake lights are red. After the vehicle has been inspected in SceneViewer, open HVE and add this vehicle to a file using the vehicle editor. The vehicle will most likely not be resting perfectly on its wheels. To adjust the vehicle so that it does rest perfectly on its wheels, it is necessary to edit the geometry file in SceneViewer. To edit the vehicle, go to the "edit" pull-down and choose "Pick All". This will put a red box around the entire vehicle so that the changes will apply to the vehicle in its entirety. Then go to the "Editors" pull-down and choose "Transform Sliders". Transform Sliders will allow the use of the x, y, z translations, scale factors, rotations, scale orientations, and the center editing functions. When the edits have been made, save the file. Then go back to HVE, click on the center of gravity in the vehicle editor window, choose geometry file, "new" and then choose your filename. This will put the changes made into effect. Keep repeating this process until the vehicle appears perfect in HVE.

QUALITY CONTROL

Quality control is also a necessary step in the process of creating a new vehicle for the HVE program. With all the data that has been collected and entered into the vehicle data file and geometry file, there is a definite possibility of an error. Therefore, at least one other person must review these two files. In this meeting, the reference for every piece of entered data is reviewed and checked for clerical mistakes. The review process should go by sections. When all the data in a given section has been reviewed, the section is checked off. If there is even one piece of data that is not satisfactory or referenced, then the section should remain unfinished. This review should continue until each section has been checked off. Then the vehicle can be placed into the vehicle database.

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11. Viewpoint Digital, "Viewpoint Premier Catalog," Orem, UT, 2000.

APPENDIX A

PHYSICAL MEASUREMENTS DATA SHEET

File No. ______________________ Date________________________

Location ____

Inspected By ____

Vehicle Make ____

Model ____

Year ____

Body Style ____

Color ____

DOM ____

VIN ____

Notes: (Special Features, Alterations, Modifications) _____________________

____

____

____

____

____

____

____

MEASUREMENTS

WEIGHT DISTRIBUTION

Location	Weight (lbs)
RF	
LF	
RR	
LR	

VEHICLE WHEELBASE

Location	Length (in)	
R		
L		

DEFLECTION MEASUREMENT LOCATION

From	To	Length (in)	

JOUNCE

Deflection	Weight (lbs)	
(in)	Front	Rear
0.00		
0.25		
0.50		
0.75		
1.00		
1.25		
1.50		
1.75		
2.00		
2.25		
2.50		
2.75		
3.00		
3.25		
3.50		
3.75		
4.00		
4.25		
4.50		
4.75		
5.00		

VEHICLE INFO

Total Vehicle Weight (lbs.)	
Fuel Gauge Reading (Estimate o.k.)	
Location of fuel Tank	

SUSPENSION

AXLE # 1

Suspension Type	
Shocks	
Spring Type	
# Coils/Leafs	
Width/Coil Dia.	
Thickness/Wire Dia.	
Lower Control Arm	
Bolt to Bolt	
Spring to Spring	
Ball Jt. to Ball Jt.	
Upper Control Arm	
Bolt to Outer Tire	
Outer Tire to Ball Jt.	
Bolt to Ball Jt.	
Bolt to Bolt	
Sway Bar	
Sway Bar Dia.	
Torsion Length	
Tire Track Width	

AXLE # 2

Suspension Type	
Shocks	
Spring Type	
# Coils/Leafs	
Width/Coil Dia.	
Thickness/Wire Dia.	
Lat. Spring Spacing	
Length of Spring	
Axle - Rear Leaf Pin	
Sway Bar	
Tire Track Width	

BRAKES

ASSEMBLY

	Axle # 1		Axle # 2
Type			
Dia. (in)			

SYSTEM

Brake Pedal Type: ____________________

Master Cylinder Type: ____________________

Vacuum Booster: Y N ABS: Y N

TIRES

	RF	LF	RR	LR
Manf., Model, Size				
Max Pressure (psi)				
Max Load (psi)				

ENGINE DATA

CONFIGURATION: L4 L6 V6 V8 OTHER ______________________

LOCATION: Front Mid Rear X-Verse Other ____________________

DISPLACEMENT ________

NOTES (Manufacturer) ____

____

____

TRANSMISSION DATA

TYPE: Auto Manual SPEEDS: 2 3 4 5 Other ________

NOTES (Manufacturer) ____

____

____

STEERING DATA

POWER? Y N

Number of turns lock to lock ____

NOTES ____

____

____

APPENDIX B

Subject: Vehicle Geometry Standard Group names and DXF surnames

These are copied from the DxfToHVE tool in /usr/local/bin/

Dxf refrence number; h3d refrence name; h3d reference material

```
1001 "GLASS WINDSHIELD"                GLASS
1002 "GLASS SIDE LEFT FRONT DOOR"      GLASS
1003 "GLASS SIDE LEFT REAR DOOR"       GLASS
1004 "GLASS SIDE LEFT QUARTER"         GLASS
1005 "GLASS SIDE RIGHT FRONT DOOR"     GLASS
1006 "GLASS SIDE RIGHT READ DOOR"      GLASS
1007 "GLASS SIDE RIGHT QUARTER"        GLASS
1008 "GLASS BACK"                      GLASS
1009 "GLASS SUNROOF"                   GLASS
1010 "GLASS RIGHT WING"                GLASS
1011 "GLASS LEFT WING"                 GLASS
1999 "GLASS MISC"                      GLASS

2001 "BODY ROOF"                       BODY
2002 "BODY HOOD"                       BODY
2003 "BODY FENDER LEFT"                BODY
2004 "BODY FENDER RIGHT"               BODY
2005 "BODY DOOR LEFT FRONT"            BODY
2006 "BODY DOOR LEFT REAR"             BODY
2007 "BODY DOOR RIGHT FRONT"           BODY
2008 "BODY DOOR RIGHT REAR"            BODY
2009 "BODY QUARTERPANEL LEFT"          BODY
2010 "BODY QUARTERPANEL RIGHT"         BODY
2011 "BODY DECKLID"                    BODY
2012 "BODY TAILGATE"                   BODY
2013 "BODY BED FRONT"                  BODY
2014 "BODY BED REAR"                   BODY
2015 "BODY BED SIDE RIGHT"             BODY
2016 "BODY BED SIDE LEFT"              BODY
2017 "BODY UNDERCARRIAGE"               TRIM
2018 "BODY BUMPER FRONT"                TRIM
2019 "BODY BUMPER REAR"                 TRIM
2020 "BODY BUMPER COVER FRONT"         BODY
2021 "BODY BUMPER COVER REAR"          BODY
2022 "BODY COWL FRONT"                 BODY
2023 "BODY COWL REAR"                  BODY
2024 "BODY CAB BACK"                   BODY
# no cab front?
2025 "BODY REAR PAN"                   BODY
2026 "BODY FRONT DAM"                  BODY
2027 "BODY CANOPY"                     BODY
2999 "BODY MISC"                       BODY

3001 "TRIM GRILL"                      TRIM
3002 "TRIM SIDE"                       TRIM
3003 "TRIM BUMPER"                     TRIM
3004 "TRIM FRONT"                      TRIM
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3005	"TRIM REAR"	TRIM
3006	"TRIM ROOF"	TRIM
3999	"TRIM MISC"	TRIM
4001	"INTERIOR STEERING WHEEL"	TRIM
4002	"INTERIOR SEAT BACK LEFT"	TRIM
4003	"INTERIOR SEAT CUSHION LEFT"	TRIM
4004	"INTERIOR SEAT HEADREST LEFT"	TRIM
4005	"INTERIOR SEAT BACK RIGHT"	TRIM
4006	"INTERIOR SEAT CUSHION RIGHT"	TRIM
4007	"INTERIOR SEAT HEADREST RIGHT"	TRIM
4008	"INTERIOR DOOR PANEL LEFT"	TRIM
4009	"INTERIOR DOOR PANEL RIGHT"	TRIM
4010	"INTERIOR DASHBOARD LEFT"	TRIM
4011	"INTERIOR DASHBOARD RIGHT"	TRIM
4012	"INTERIOR FLOORBOARD LEFT"	TRIM
4013	"INTERIOR FLOORBOARD RIGHT"	TRIM
4014	"INTERIOR CONSOLE"	TRIM
4015	"INTERIOR HEADLINER"	TRIM
4016	"INTERIOR GLASS"	GLASS
4999	"INTERIOR MISC"	TRIM
5001	"LIGHT HEADLAMP RIGHT"	LIGHTWHITE
5002	"LIGHT HEADLAMP LEFT"	LIGHTWHITE
5003	"LIGHT PARKING LEFT"	LIGHTAMBER
5004	"LIGHT PARKING RIGHT"	LIGHTAMBER
5005	"LIGHT SIGNAL LEFT"	LIGHTAMBER
5006	"LIGHT SIGNAL RIGHT"	LIGHTAMBER
5007	"LIGHT TAIL LEFT"	LIGHTRED
5008	"LIGHT TAIL RIGHT"	LIGHTRED
5009	"LIGHT BRAKE LEFT"	LIGHTRED
5010	"LIGHT BRAKE RIGHT"	LIGHTRED
5011	"LIGHT BRAKE CENTER"	LIGHTRED
5012	"LIGHT BACKUP LEFT"	LIGHTWHITE
5013	"LIGHT BACKUP RIGHT"	LIGHTWHITE
5014	"LIGHT MARKER LEFT"	LIGHTAMBER
5015	"LIGHT MARKER RIGHT"	LIGHTAMBER
5016	"LIGHT FOG LEFT"	LIGHTWHITE
5017	"LIGHT FOG RIGHT"	LIGHTWHITE
5997	"LIGHT MISC"	LIGHTWHITE