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Ellipsoidal Man Plotting Package for MVMA 2-D and CVS(HSRI Version) Occupant Motion Models.

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16. Abstract

A graphics plotting routine has been developed for use with both the MVMA 2-D and CAL/HSRI 3-D occupant/pedestrian dynamic simulations. The Ellipsoidal Man Plotting Package makes up to three views for each time point from recorded model data. The views as each a user-specified region of an orthographic projection of the three dimensional occupant-vehicle situation onto a user-specified plane. User information and examples are given.

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1.0 INTRODUCTION

A graphics plotting routine has been developed for use with both the MVMA 2-D and CAL/HSRI 3-D occupant/pedestrian dynamic simulations (1,2). The Ellipsoidal Man Plotting Package makes up to three views for each time point from recorded model data. The views are each a user-specified region of an orthographic projection of the three dimension occupant-vehicle situation onto a user-specified plane.

Section 2 describes the interactive dialogue in which the user specifies instructions to the program. Section 3 discusses how to specify the "standard transformation" matrix and the "viewing" matrix which are input during the dialogue described in Section 2. Section 4 presents a summary of the analysis used to achieve the necessary coordinate transformations and the orthographic projection. The Appendix contains a specification of the information recorded by the models for use by the Ellipsoidal Man Plotting Package.

2.0 USER DIALOGUE

The interactive plotting program makes use of a file of character-form position data (generated by the CAL/HSRI-3D or MVMA-2D model). These data include both fixed and variable items and are described in the Appendix. The user tells the program what to do with these data through responses to a series of questions and prompts from the program.

The current interactive-video display version of the plotting package varies from the former batch-paper version in several ways. Most notable among them are:

1. The intermediate positional data file is in character form rather than binary form. This was done to allow the MCAUTO FTN (10 character/60 bit word) and XFO (4 character/word) FORTRAN compilers to be used efficiently. (The model itself was too large to be run under XFO, and the PLOT-10 package was only available in that version).

2. User controls come through an interactive dialog rather than a set of completely formatted control cards.

3. Some options available in the batch version have been dropped from the interactive version. These include: tabular listing of titles and labels; plotting of detailed features marking ellipsoid center points with an alphabetic descriptor; and the option to overlay all time points on one plot. It was felt that these facilities, while possibly useful on a paper plot, are of limited value o a video display while severely confusing the CRT image.

4. Some new options have been made available to aid interactive plotting: the user can adjust the plot scales and rotation within the program to produce more meaningful or attractive plots.

5. Improved "clipping" has been achieved through the use of PLOT-10 routines.

6. The overall format of the display has been altered, without loss of information.

2.1 PLOT DATA INPUT

The program expects to find a sequenced, formatted file of positional data as the basis for plotting. This file is user-specified and will be internally assigned to unit 1. The user will be prompted for the file name during the introductory dialogue. The Appendix describes the format for this file. Note that while titles and labels are no longer plotted, they are still written to the data file to maintain compatibility with previous versions of the plot program.

2.2 USER INPUT

As mentioned above, the user enters plotting parameters during an initialization dialogue. The remainder of this section will show these prompts.

The first two questions (Figure 1) ask the user to identify the Tektronix terminal type and the data transmission rate used. The Plot-10 system needs this information to drive the terminal properly. (Note: all development and testing have been done using a 30 character/ second, T4010 simulator).

Menu Screen 1:

After an introductory title, the user is asked which simulation type is wanted. If the choice is "MVMA:2-D", only one view of the data will be shown. If the choice is "CVS:3-D", up to three views may be displayed.

This is followed by a description of the form of the remaining questions, and instructions concerning defaults. The other items on this screen are:

"TAKE ALL DEFAULTS?" This should only be assumed "Y" when a quick look at the first plot of a run is desired, because some defaults, such as timing and plot titles, will not apply to actual data used.

"PLOT PANELS?" and "PLOT BELTS?" The default for these are "Y". If present (and if selected) they will be plotted.

"READ IN STANDARD TRANSFORMATION MATRIX?" If the user desires to alter the standard matrix, the response should be "Y". This matrix changes the model data before it is stored. Until experience is gained with this program, the default (identity) matrix should be used. (See Section 3 for an extended discussion of the standard traansformation and viewing matrices).

```
 ENTER THE DATA TRANSMISSION RATE FOR THE TERMINAL
 YOU ARE USING. (CHARACTERS/SECOND.)
 (NOMINAL CPS = BAUD RATE/10.)
?30
 ENTER TEKTRONIX TERMINAL TYPE:
    1 : 4010, 4012, OR 4013,
    2 : 4014 OR 4015, OR
    3 : 4014 OR 4015 WITH ENHANCED GRAPHICS PACKAGE
 ENTER 1, 2, OR 3, AND PRESS RETURN:
?1
```

Figure 1. Introductory Dialogue, Screen 1.

```
UMTRI 3-D PLOTTING PACKAGE FOR INTERACTIVE DISPLAY OF
CVS:3-D AND MVMA:2-D SIMULATION GRAPHIC OUTPUT


SIMULATION TYPE:
   1 : MVMA:2-D,
   2 : CVS:3-D,
OR 3 : NEITHER (EXIT).

ENTER 1, 2, OR 3:
?1

FOR THE NEXT FEW ITEMS, ACCEPTABLE RESPONSES AND
DEFAULT VALUES WILL BE SHOWN.  PLEASE ENTER YOUR
RESPONSE, FOLLOWED BY A (RETURN), OR A (RETURN) ALONE
TO TAKE THE DEFAULT.


TAKE ALL DEFAULTS? (Y/N : D=N)
?N
FLOT PANELS?  (Y/N : D=Y)
?Y
FLOT BELTS?  (Y/N : D=Y)
?Y
READ IN STANDARD TRANSFORMATION MATRIX?
(Y/N : D=N,=USE DEFAULT MATRIX: SIDE/FRONT/TOP)
?N
```

Figure 2. Introductory Dialogue, Screen 2 and Menu Screen 1.

Menu Screen 2:

"VIEWING COORDINATE SYSTEM." The user must select from three possible viewing systems: Inertial (outside the action); Vehicle (connected to the vehicle frame); or a frame defined by a particular body segment.

"...ACTUAL VALUES FOR TIME..." The time, in seconds, of the start of the plot sequence, the last plot, and the interval between plots should be entered. These values are used to generate the time value which appears on the status screen. (The time displayed on the plot itself comes directly from the data file.)

"... X,Y,Z OF STANDARD ORIGIN..." This item requests the coordinates of the origin of the plot. If offsets are needed from the standard (0.0, 0.0, 0.0) origin, they must be entered here.

Menu Screen 3:

For each view chosen (one for MVMA:2-D, up to three for CVS:3-D), the user is prompted for a cosine matrix defining the viewing system. Section 3 contains figures which show the effect of altering the viewing matrix. With appropriate changes the view can be inverted, swapped left for right, the perspective moved out of plane, etc. If the viewing matrix chosen initially is unsatisfactory, it can be adjusted during the plotting session.

"...X AND Z VALUES OF PLOT ORIGIN..." and "...LENGTH OF X AXIS..." For each view shown, the user enters the coordinate of the origin and the length of the X axis. As with the viewing matrix, these can be altered during the plotting session. The length of the Z axis is automatically set to 80% of the X axis. The tic mark intervals along the X and Z axes are the same.

"...PLOT STEP SIZE FOR DRAWING CURVES..." This value is used by the ellipse drawing routines. The larger the value, the coarser the ellipse will appear; the smaller the value, the greater the computing expense.

"...TITLE FOR VIEW..." For each view, a descriptive title of up to twelve characters may be entered.

```
 VIEWING COORDINATE SYSTEM:
 (-1 = INERTIAL; 0 = VEHICLE; >0 = SEGMENT #: D=0)
?0
 ENTER ACTUAL VALUES FOR TIME OF FIRST PLOT FRAME,
 LAST PLOT FRAME, AND INCREMENT.  UNITS ARE SECONDS.
 ENTER THREE VALUES, SEPARATED BY COMMAS.
 (DEFAULTS = 0.0, 0.05, 0.001)
?0.0,0.02,0.005
 ENTER X,Y,Z OF STANDARD ORIGIN IN INPUT SYSTEM:
 (MODEL UNITS.  THREE VALUES, SEPARATED BY COMMAS.
 DEFAULTS = 0.0, 0.0, 0.0)
?
```

Figure 3. Menu Screen 2.

```
 FOR VIEW # 1:
 ENTER ROW # 1 OF VIEWING MATRIX. THREE VALUES,
 SEPARATED BY COMMAS.  (DEFAULTS = 1.0, 0.0, 0.0)
?
 ENTER ROW # 2 OF VIEWING MATRIX. THREE VALUES,
 SEPARATED BY COMMAS.  (DEFAULTS = 0.0, 1.0, 0.0)
?
 ENTER ROW # 3 OF VIEWING MATRIX. THREE VALUES,
 SEPARATED BY COMMAS.  (DEFAULTS = 0.0, 0.0, 1.0)
?
 FOR VIEW # 1:
 ENTER X AND Z VALUES OF PLOT ORIGIN
 (MODEL UNITS).  ENTER TWO VALUES, SEPARATED BY COMMA.
 (DEFAULTS = -10.0, -10.0)
?0.0,0.0
 FOR VIEW # 1:
 ENTER LENGTH OF X AXIS (MODEL UNITS.  DEFAULT = 100.0)
?10.0
 ENTER PLOT STEP SIZE FOR DRAWING CURVES (PLOT UNITS).
 (DEFAULT = .2000)
?
 ENTER TITLE FOR VIEW # 1.  (DEFAULT=     X-Z    )
?EXAMPLE 1M
 ENTER PLOT DATA FILE NAME
?DATCHR
```

Figure 4. Menu Screen 3.

"...PLOT DATA FILE NAME" The name of the sequenced, formatted data file referred to in section 2.1 is entered here.

Figures 5 and 6 are the main plot selection menus for the MVMA 2-D and CVS 3-D types of plots, respectively. This display will appear prior to the first plot of a series, but may be displayed at any later time between plots. The status lines at the top give the frame number, time and view number. These refer to the plot most recently drawn. (In the example in figures 5 and 6, frame number and time are both zero prior to the first display. If the first plot is at 0.0 sec, the display will be unchanged after the plot). View number refers to the views defined earlier.

Frame number is an integer number in the range zero to INT (last-plot time/plot-interval). It is used when the user wishes to skip around in the plot file and view the plots in an order other than the strict sequence defined by the plot data file.

These menus allow the user to: re-display the same plot data with a different view (if defined); change scales or viewing matrix; display the menu again, or quit. The bottom line of the menu display is an abbreviated version of the same menu: when it appears, the program is ready for the user's next selection. It appears not only on the menu screens but also on the plot screen. Thus, the user never need display the menu in full after he has seen it once. (Of course, it may displayed at any time by selecting "M" - the Menu option.)

Specific menu items are:

S: SAME PLOT AGAIN (MVMA:2D version)

or S: VIEW #1 (SIDE) OF SAME PLOT

F: VIEW #2 (FRONT) OF SAME PLOT (CVS:3D version)

T: VIEW #3 (TOP) OF SAME PLOT

These are interpreted straightforwardly: the same data which produced the last plot will be used to produce the next plot.

#: INTEGER NUMBER OF FRAMES...FORWARD OR BACK...

```
STATUS
CURRENT FRAME #  0, @ TIME = 0.000 SEC.
VIEW # 1.

YOUR OPTIONS ARE:
   S : SAME PLOT AGAIN.
   # : AN INTEGER NUMBER INDICATING THE NUMBER
       OF FRAMES TO MOVE FORWARD OR BACK (-999<#<999).
   J#: JUMP TO ABSOLUTE FRAME NUMBER # ( 0<#<999).
   X : CHANGE AXIS SCALING.
   V : CHANGE VIEWING MATRIX.
   (RETURN) : DISPLAY NEXT FRAME (DEFAULT).
   Q : QUIT -- TERMINATE PROGRAM EXECUTION, OR
   M : MENU -- THIS DISPLAY.



SELECT: S / # / J# / X / V / M / Q : (CR)
```

Figure 5. MVMA 2-D Main Menu.

```
STATUS
CURRENT FRAME #  0, @ TIME = 0.000 SEC.
VIEW # 1.

YOUR OPTIONS ARE:
   S : PLOT VIEW #1 (SIDE ) OF CURRENT FRAME.
   F : PLOT VIEW #2 (FRONT) OF CURRENT FRAME (IF DEFINED).
   T : PLOT VIEW #3 ( TOP ) OF CURRENT FRAME (IF DEFINED).
   # : AN INTEGER NUMBER INDICATING THE NUMBER
       OF FRAMES TO MOVE FORWARD OR BACK (-999<#<999).
   J#: JUMP TO ABSOLUTE FRAME NUMBER # ( 0<#<999).
   X : CHANGE AXIS SCALING.
   V : CHANGE VIEWING MATRIX.
   (RETURN) : DISPLAY NEXT FRAME (DEFAULT).
   Q : QUIT -- TERMINATE PROGRAM EXECUTION, OR
   M : MENU -- THIS DISPLAY.


SELECT: S / F / T / # / J# / X / V / M / Q : (CR) B
```

Figure 6. CAL/HSRI 3-D Main Menu.

This is a relative movement command. An integer 5 from frame number 10 would display frame 15 next, and a -5 from frame number 10 will display frame 5. All other parameters are unchanged. Attempts to plot past either end of the data file will be trapped and the pointer returned to frame zero.

J#: JUMP TO ABSOLUTE FRAME NUMBER...

As stated, this is an absolute movement command. A J5 from frame number 10 would display frame number 5 next. Otherwise it is like the relative jump command. (NOTE: NO blanks between the "J" and the number.)

X: CHANGE AXIS SCALES

This command allows the user to alter the axes to expand, window, center the view, and so forth. It evokes a screen of its own (figure 7), which has responses just like those on Menu Screen 3. It ends with an abbreviated menu (not shown), allowing the user to call for the next plot directly.

V: CHANGE VIEWING MATRIX

This command allows the user to change the viewing matrix, usually to rotate or erect the view. It evokes a screen of its own (figure 8), which has responses just like those on screen menu 3. It ends with an abbreviated menu (not shown). Since a rotation frequently changes the domain of the data, this command is often used in conjunction with "X", Change Axis Scales.

Q: QUIT

```
CHANGE AXIS SCALES

FOR VIEW # 1:
ENTER X AND Z VALUES OF PLOT ORIGIN
(MODEL UNITS).  ENTER TWO VALUES, SEPARATED BY COMMA.
(DEFAULTS =  -2.0,   -.2)
-1.0,0.3
FOR VIEW # 1:
ENTER LENGTH OF X AXIS (MODEL UNITS.  DEFAULT =   2.0)
1.0
ENTER PLOT STEP SIZE FOR DRAWING CURVES (PLOT UNITS).
(DEFAULT = .1000)
0.05
```

Figure 7. Change Axis Screen

```
CHANGE VIEWING MATRIX:

FOR VIEW # 1:
ENTER ROW # 1 OF VIEWING MATRIX. THREE VALUES,
SEPARATED BY COMMAS.  (DEFAULTS =-1.0, 0.0, 0.0)
1.,0.,0.
ENTER ROW # 2 OF VIEWING MATRIX. THREE VALUES,
SEPARATED BY COMMAS.  (DEFAULTS = 0.0, 1.0, 0.0)

ENTER ROW # 3 OF VIEWING MATRIX. THREE VALUES,
SEPARATED BY COMMAS.  (DEFAULTS = 0.0, 0.0,-1.0)
0.,0.,1.



SELECT: S / # / J# / X / V / M / Q : (CR)
```

Figure 8. Change Viewing Matrix Screen.

This command terminates execution of the program.

M: MENU

This command displays the full menu, including status display. It is usually called from the abbreviated menu, after plotting, as a memory aid.

(RETURN): DISPLAY NEXT FRAME

This is the default. It's effect is to display the next frame in the series. It's the same as typing "1(RETURN)".

3.0 SPECIFICATION OF STANDARD TRANSFORMATION AND VIEWING MATRICES

The positional data recorded by the models is in either the inertial or vehicle coordinate systems specified for the particular model and run. The plotter package begins by transforming all the data to one coordinate system of the user's choice and recording it in internal tables in that format. The plotter package then allows the user to change perspective and scale in viewing the situation described as much and as often as desired.

Figure 9 shows a seated occupant specified in the MVMA 2-D Model Vehicle Coordinate System expressed in metric units. The plotting system shows the x-axis positive to the right and the z-axis positive upwards whereas the MVMA 2-D shows the x-axis positive to the right and the z-axis positive downwards. The effect of viewing without transformation then is to show the occupant upside down. Figure 10 shows the result of using the viewing matrix to view that data with both x and z reversed. The viewing matrix used to accomplish this example is

$$\begin{vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{vmatrix} .$$

Figure 11 leaves the viewing matrix the same but changes the scale to show part of the occupant.

3.1 STANDARD TRANSFORMATION SELECTION

In general, the standard transformation would be used to condition the data for change of directions of coordinate axes between model and model run while the viewing matrix would be used to change perspective

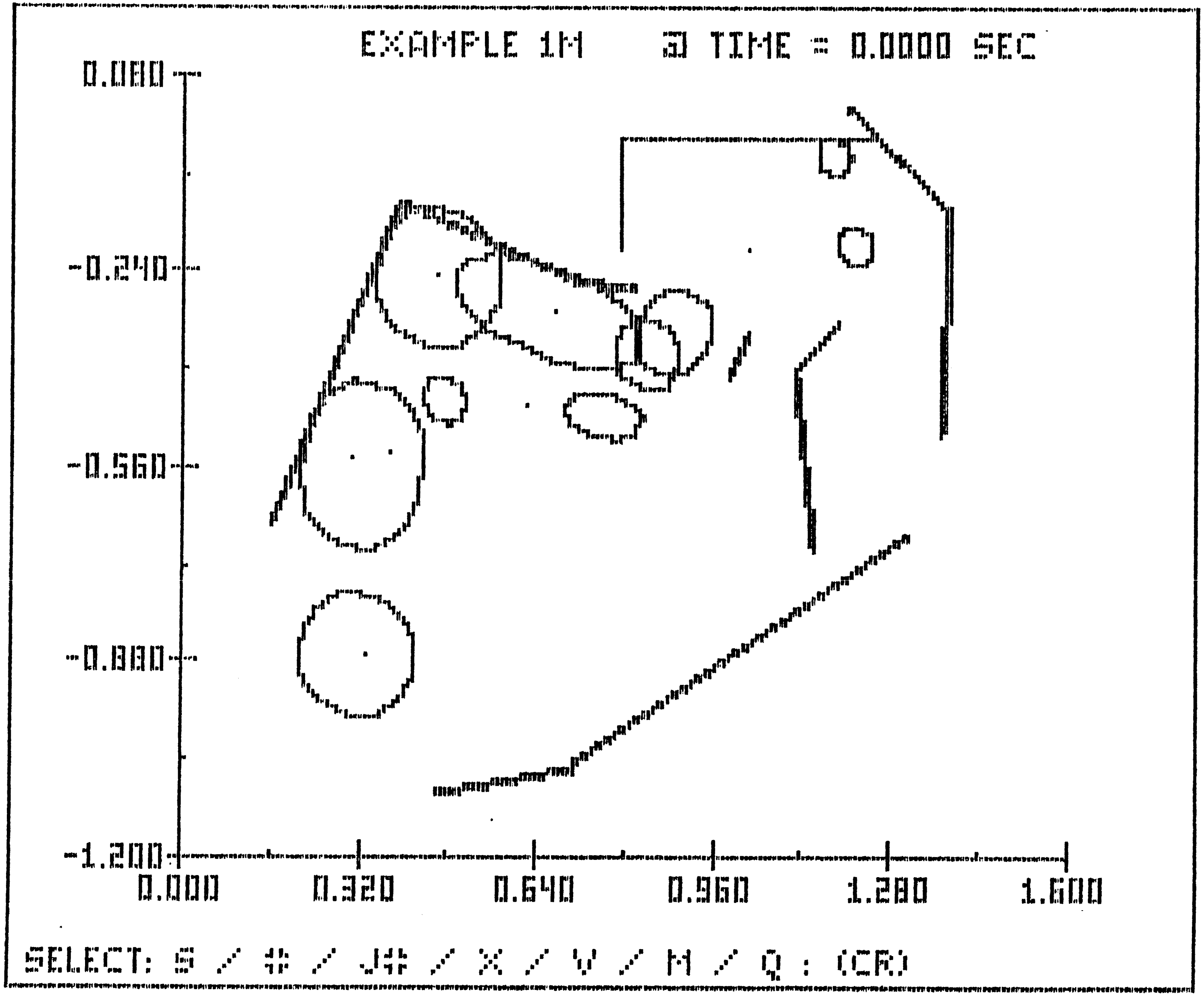


Figure 9. MVMA 2-D Seated Occupant in Model Vehicle Coordinates.

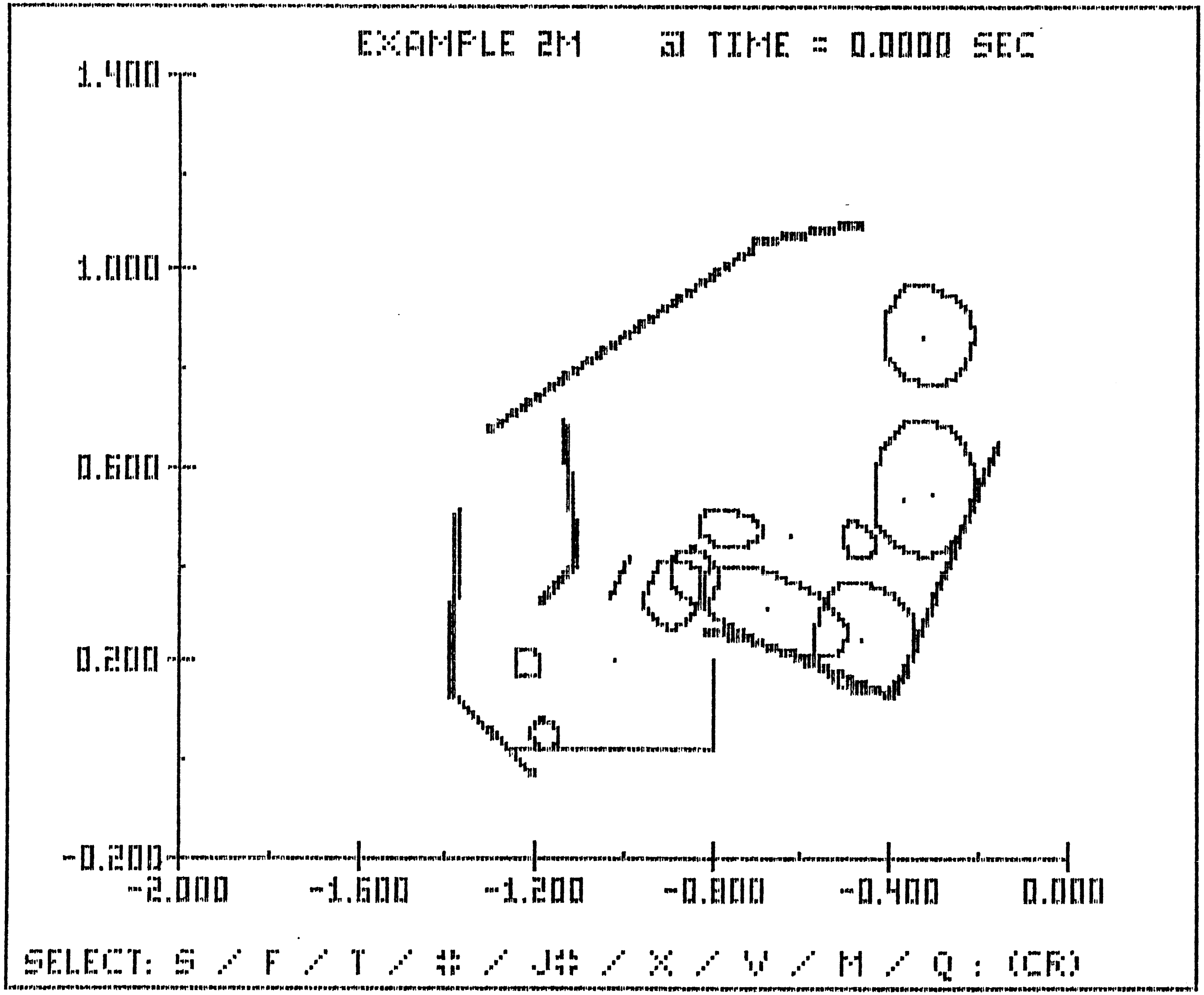


Figure 10. Same Occupant Seen in More Convenient Coordinates.

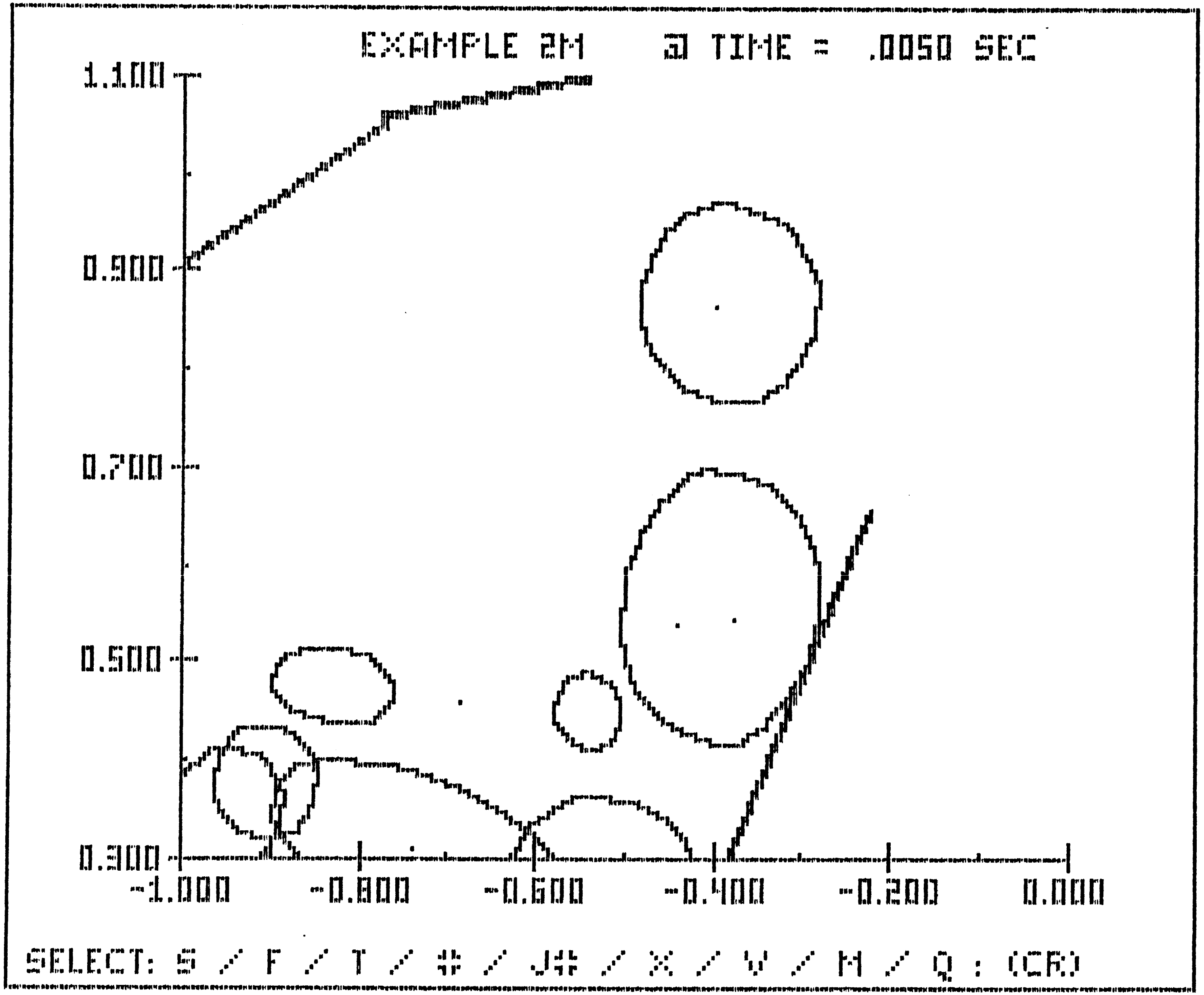


Figure 11. Same Occupant With Expanded Scale.

without changing the data stored. This subsection deals with the Standard Transformation and the next subsection deals with the selection of the Viewing Matrix.

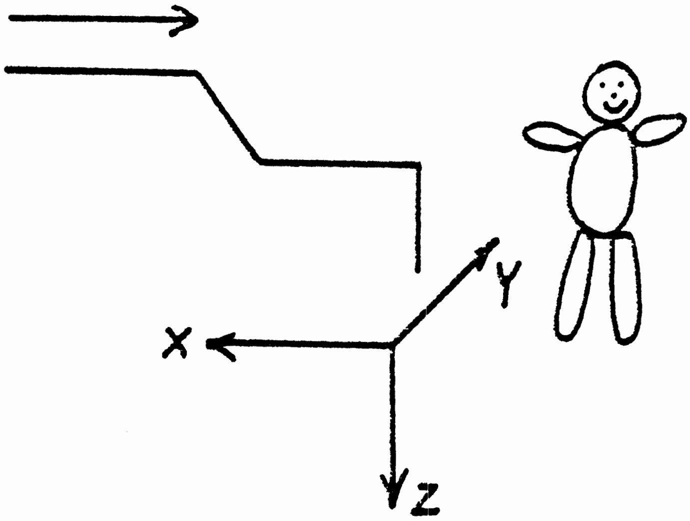
In what follows, an example will be discussed of a CAL/HSRI 3-D model run of a pedestrian struck by a moving vehicle. The original inertial axes in the CVS system for this run are x-forward, y-left, and z-down to define the positive axes. The vehicle in this run is placed so that it is moving parallel to the x-axis and in the negative direction. The pedestrian is placed standing up in the negative z-direction and facing the negative y-direction; thus his right side is facing the approaching vehicle front.

The plot system chosen has z-positive up and x-positive forward (relative to the vehicle motion) thus y will be positive to the vehicle left and to the rear of the pedestrian. This is accomplished by using a standard transformation matrix to relabel selected inertial axes to match the plot system axes, as shown in figure 12. Note that the vehicle and pedestrian do not move; it is only the axes that are relabeled and the data modified to watch.

Other standard transformation matrices are possible, depending on the orientation of the original simulation inertial axes and the desired plot system axes. The user should be warned that the transformation worked out should preserve the righthandedness of the axis system or strange results may be generated.

For MVMA 2-D data, a typical standard transformation matrix would be selected to make the "identity" view conform with the printer plot stick figures produced by the model. This could be accomplished either by

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{vmatrix}$$



Original Axes

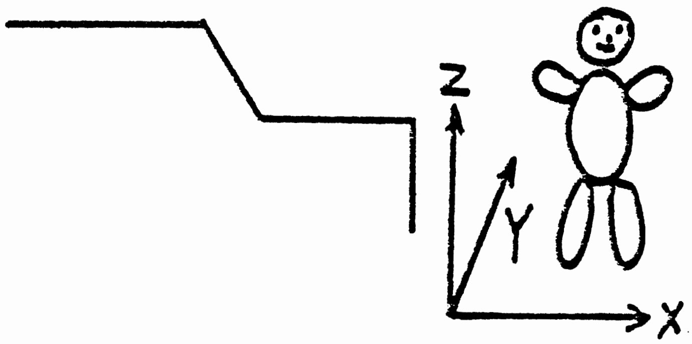
⇓

Standard Transformation Matrix

$$\begin{vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{vmatrix}$$

Relabels the X and Z axes

⇓



Plot System Axes

Figure 12. Effect of Standard Transformation.

or

$$\begin{vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{vmatrix}$$

in order to set up the "identity" view from the opposite side.

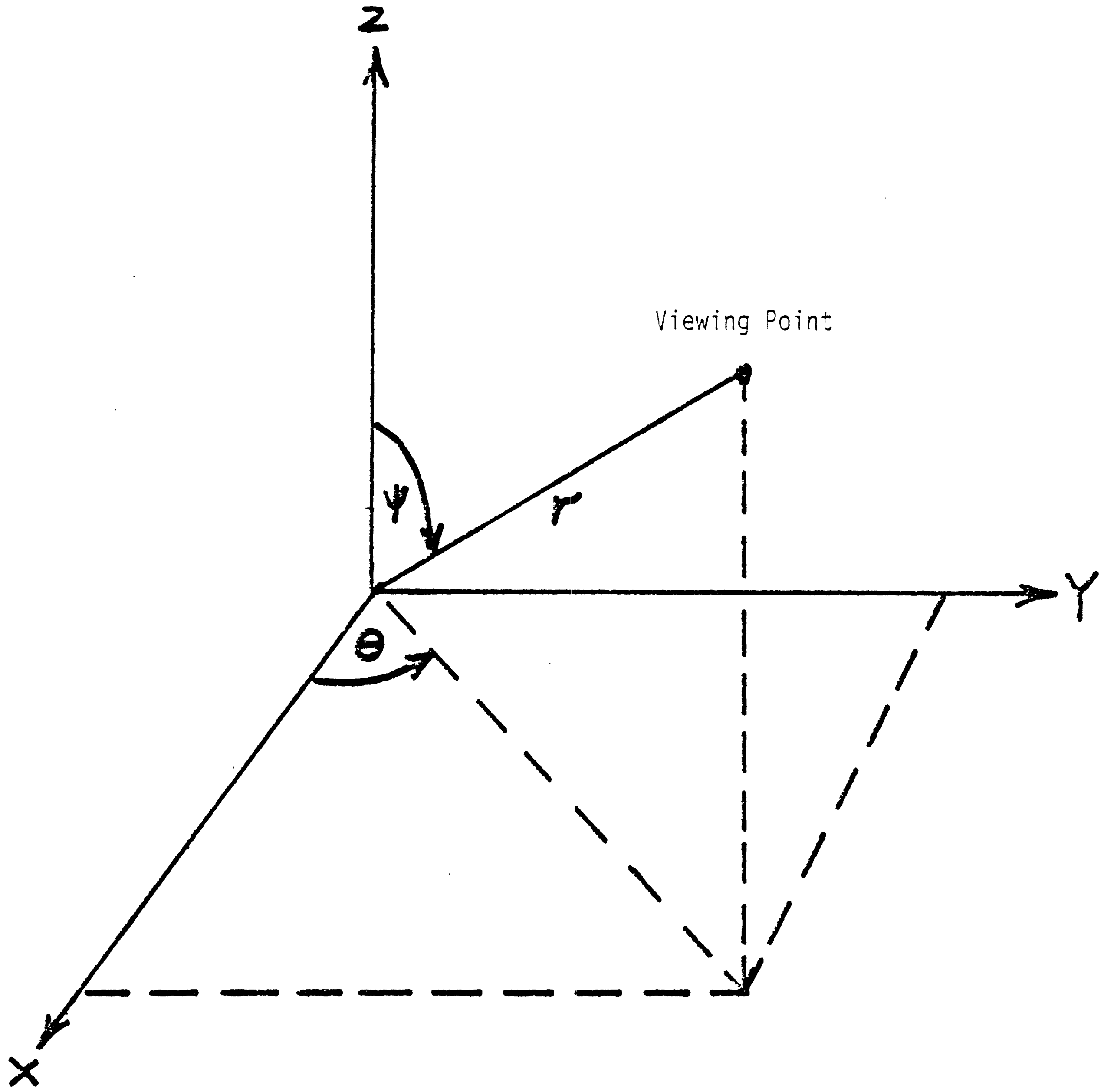
The data may also be translated with respect to a user-specified origin if desired, although usually this is not done.

3.2 VIEWING MATRIX SELECTION

The second step in setting up the plots is determining the proper viewing matrix. It should be noted that this is done wholly in the plot system and with rspect to the standard system discussed in the last section. The user now chooses a prospective viewing point. (To make the signs easy, it should be set up in the first octant. For the CAL/HSRI 3-D pedestrian example, this would show the car front and the pedestrian back and left side, all from above.) See Figure 13.

If the viewing point is specified in spherical coordinate, then the viewing matrix expected by the program is:

$$\begin{vmatrix} -\sin\theta & \cos\theta & 0 \\ -\sin\psi\cos\theta & -\sin\psi\sin\theta & -\cos\psi \\ -\cos\psi\cos\theta & -\cos\psi\sin\theta & \sin\psi \end{vmatrix}$$



Notes: 1. r, θ, ψ are shown positive

2. Magnitude of r is irrelevant

3. $0 \leq \psi \leq 180$

4. $0 \leq \theta \leq 360$

Figure 13. The Viewing Point in Spherical Coordinates Relative to Standard System.

If the viewing point is along a line with direction cosine ($\cos\alpha$, $\cos\beta$, $\cos\gamma$) then

$$\begin{vmatrix} \frac{\cos\beta}{\sin\gamma} & -\frac{\cos\alpha}{\sin\gamma} & 0 \\ \cos\alpha & \cos\beta & \cos\gamma \\ -\frac{\cos\alpha}{\tan\gamma} & -\frac{\cos\beta}{\tan\gamma} & \sin\gamma \end{vmatrix} \qquad \text{IF} \quad \cos^2\alpha \neq 1$$

or

$$\begin{vmatrix} \pm 1 & 0 & 0 \\ 0 & 0 & \mp 1 \\ 0 & 1 & 0 \end{vmatrix} \qquad \text{IF} \quad \cos\gamma = \pm 1$$

If the viewing point is (x_p, y_p, z_p), then

$$\cos\alpha = \frac{x_p}{D} \;; \qquad \cos\beta = \frac{y_p}{D} \;; \qquad \cos\gamma = \frac{z_p}{D}$$

where

$$D = \pm\sqrt{x_p^2 + y_p^2 + z_p^2}$$

The set of plots labeled PED-1 FRONT (Figures 14, 17, and 20), which actually show the front of the pedestrian and the inside of the vehicle, were made using a viewing point on the negative plot system y-axis. The angles are then ψ = 90° and θ= -90° giving a viewing matrix of:

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

since $\sin\psi=+1$, $\sin\theta= -1$. and $\cos\psi = \cos\theta = 0$.

The set of plots labeled PED-1 SIDE (Figures 15, 18, 21, and 22), showing the left side of the pedestrian with the front of the vehicle beyond him, were made using a viewing point on the positive plot system x-axis. The angles for this are $\psi = 90°$ and $\theta = 0°$ giving a viewing matrix of:

$$\begin{vmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

since $\sin\psi = +1. = \cos\theta$ and $\cos\psi = 0. = \sin\theta$. Figure 22 is an enlargement of the central portion of figure 21, made for the purposes of showing enhanced detail and demonstrating the effect of the Change Axis Scales (X) command.

The set of plots labeled PED-A SKEW (Figures 16, 19, and 23), showing the top, front and left side of the pedestrian and the top, front and inside of the vehicle, were made using a viewing point at the corner of a cube whose sides are the positive x- and z-axes and the negative axis (all in the plot system). Thus $\psi = 54.7356°$ and $\theta = -45°$, $\sin\theta = -.707107$, $\cos\theta = +.707107$, $\sin\psi = +.816497$, $\cos\psi = +.57335$ and the viewing matrix is:

$$\begin{vmatrix} +.707107 & +.707107 & 0. \\ -.57735 & +.57735 & -.57735 \\ -.40825 & +.40825 & +.816497 \end{vmatrix}$$

It should be noted that some of the panels in this view come out looking more like triangles than parallelograms. This is due to a minor error in the program's processing of end points which are calculated to plot off the permissable plot area. (This problem has been fixed in the current McAuto version).

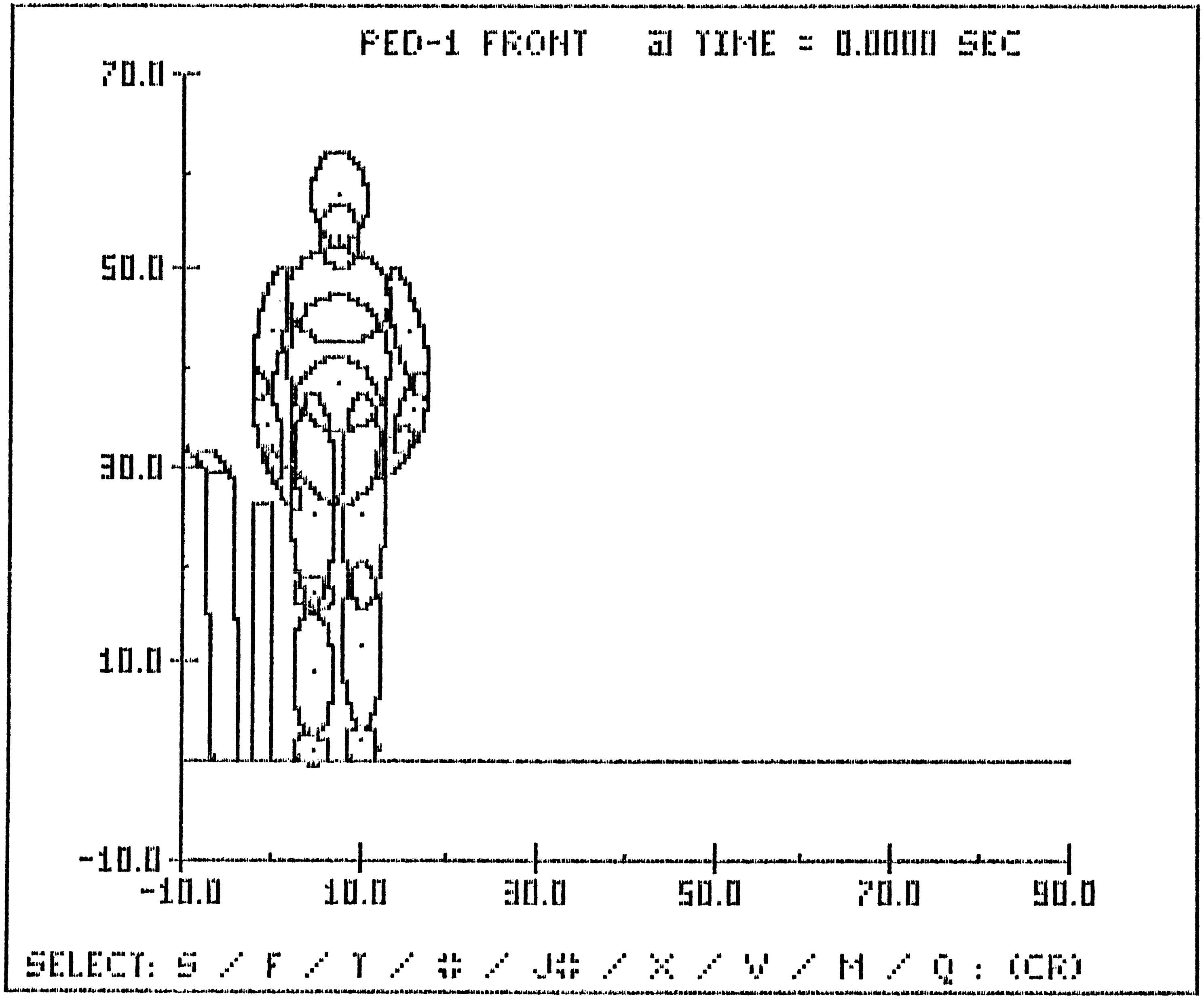


Figure 14. CVS-3D Pedestrian Front, Vehicle Side View at t=o

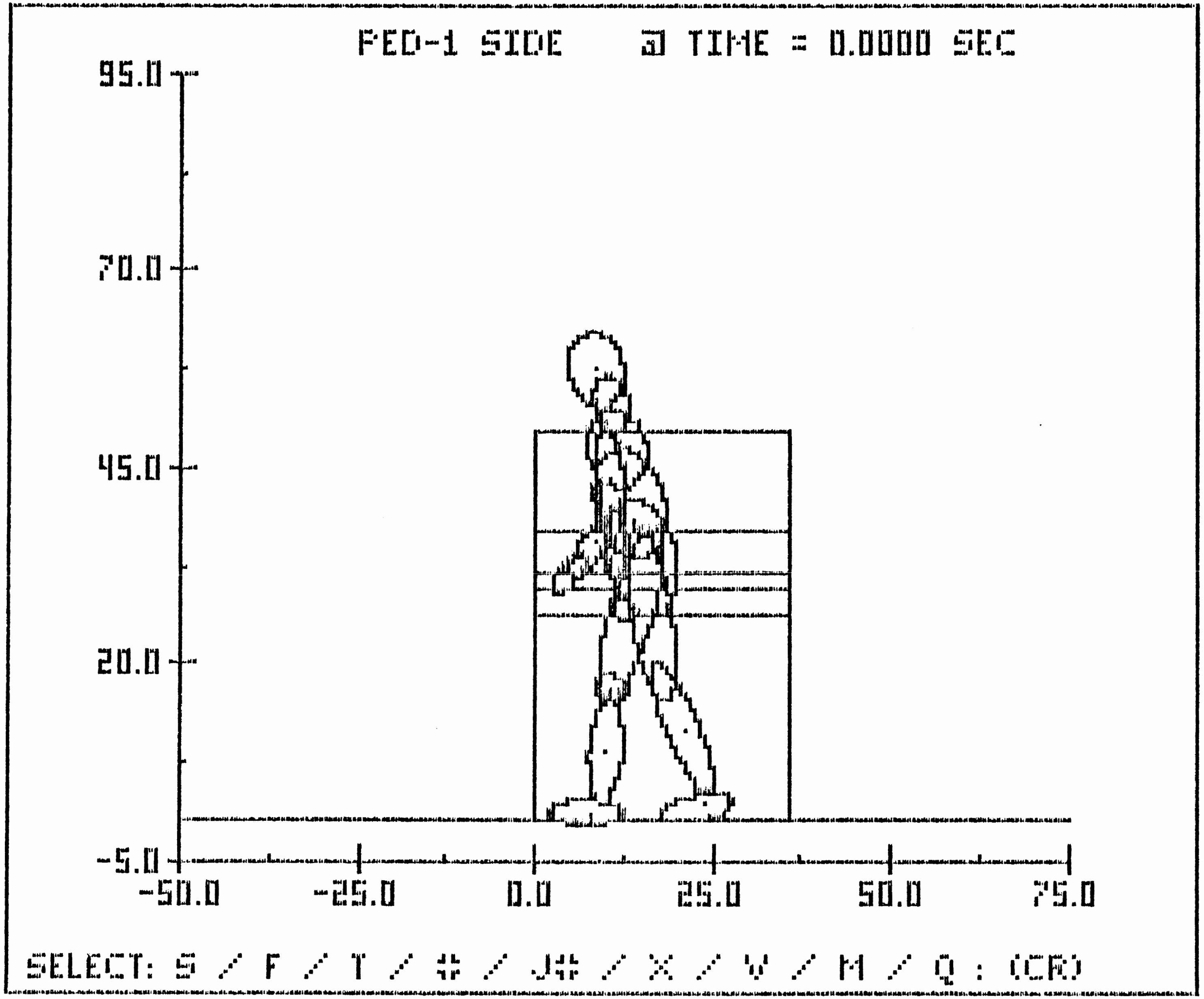


Figure 15. CVS-3D Pedestrian Side, Vehicle Front View at t=o

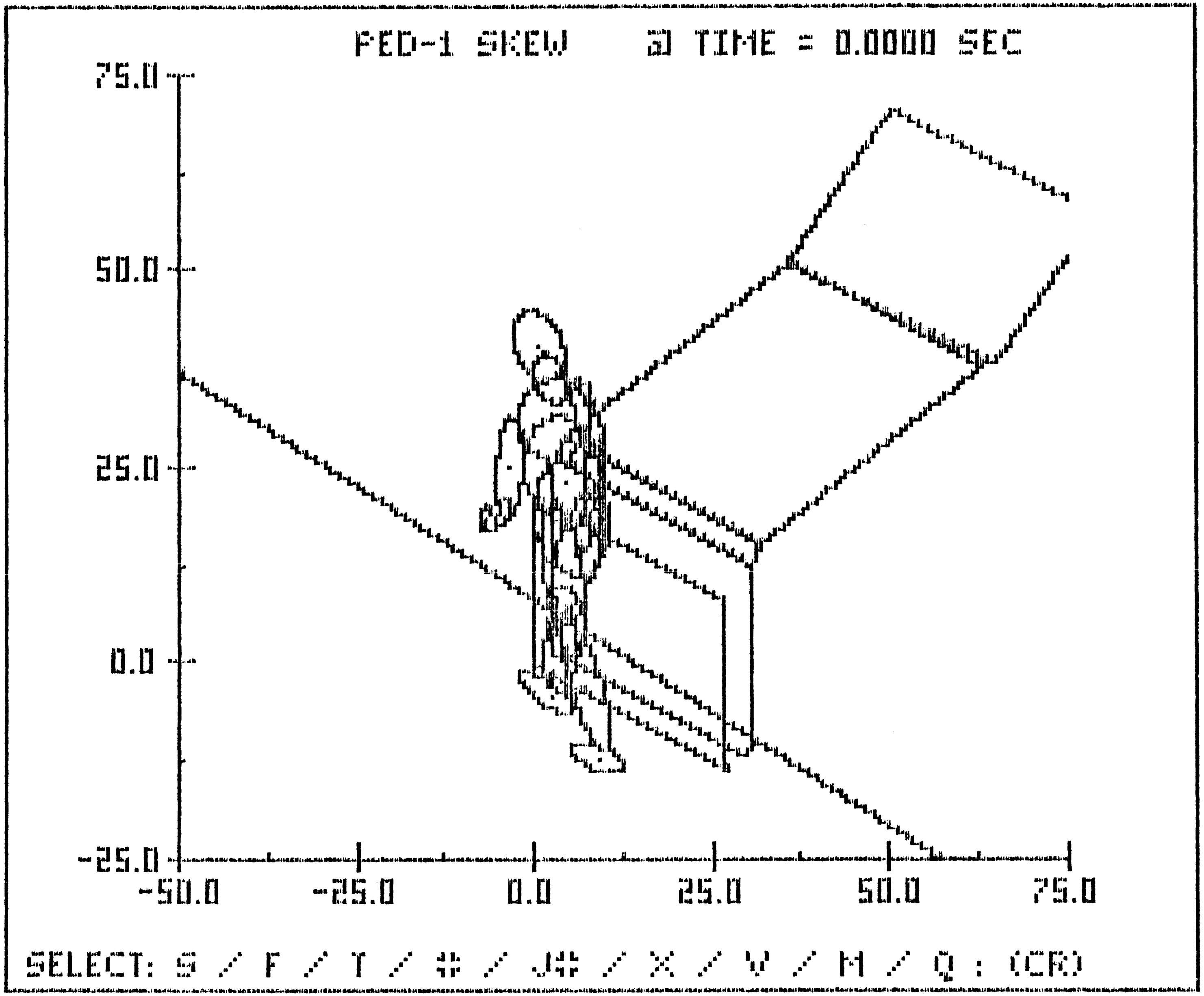


Figure 16. CVS-3D Pedestrian Skew View at t=o

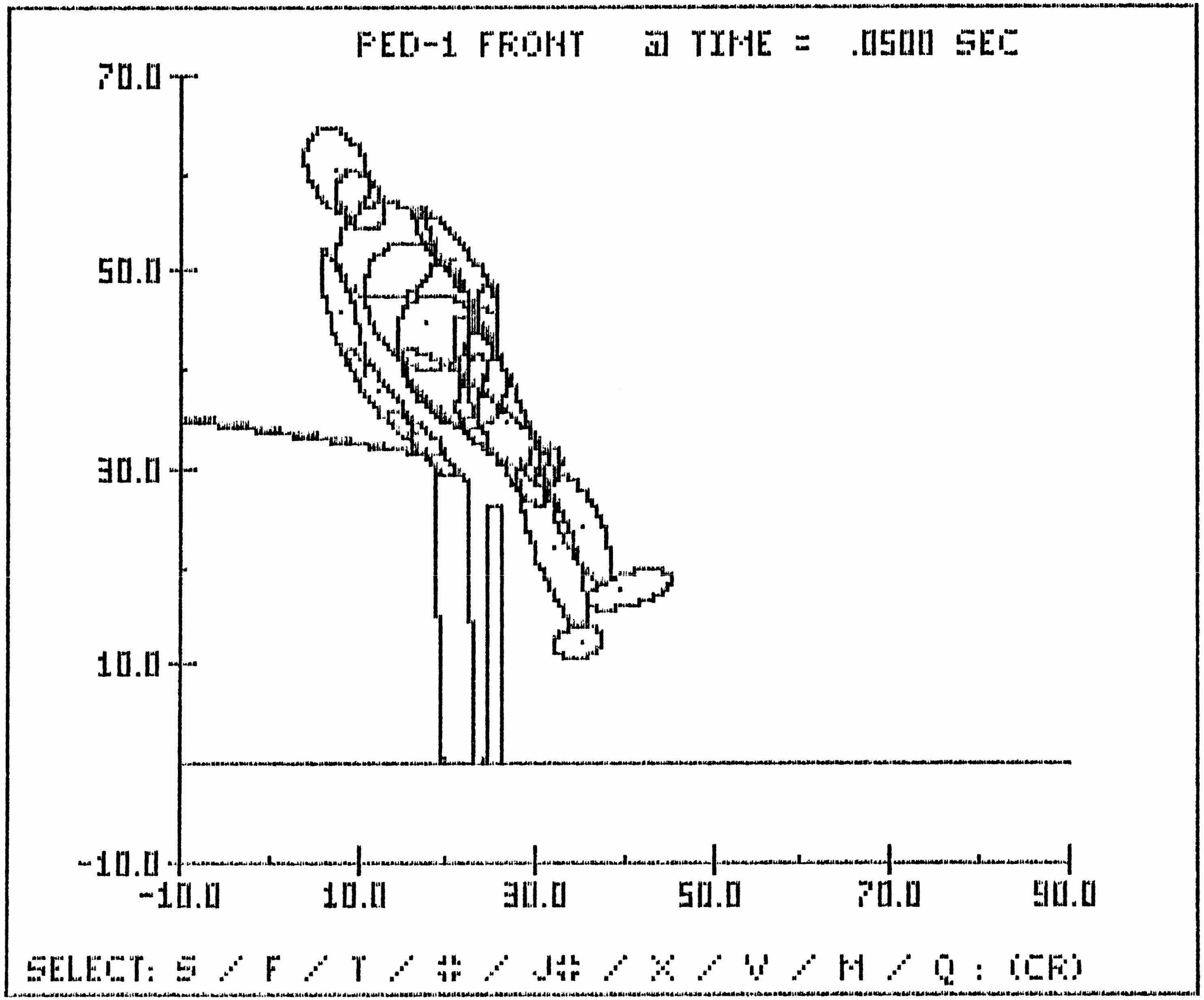


Figure 17. CVS-3D Pedestrian Front, Vehicle Side View at t=50 msec.

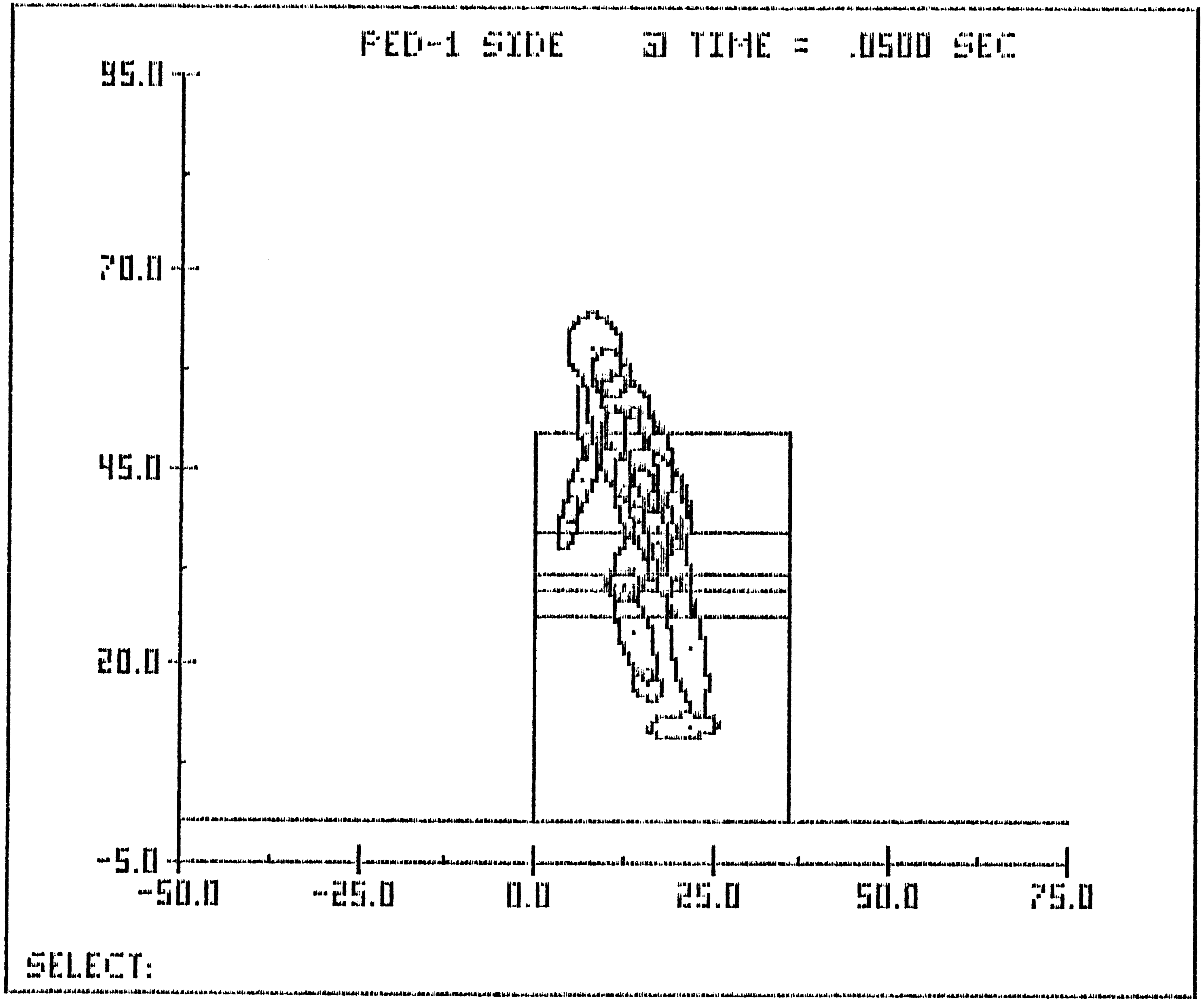


Figure 18. CVS-3D Pedestrian Side, Vehicle Front View at t=50 msec.

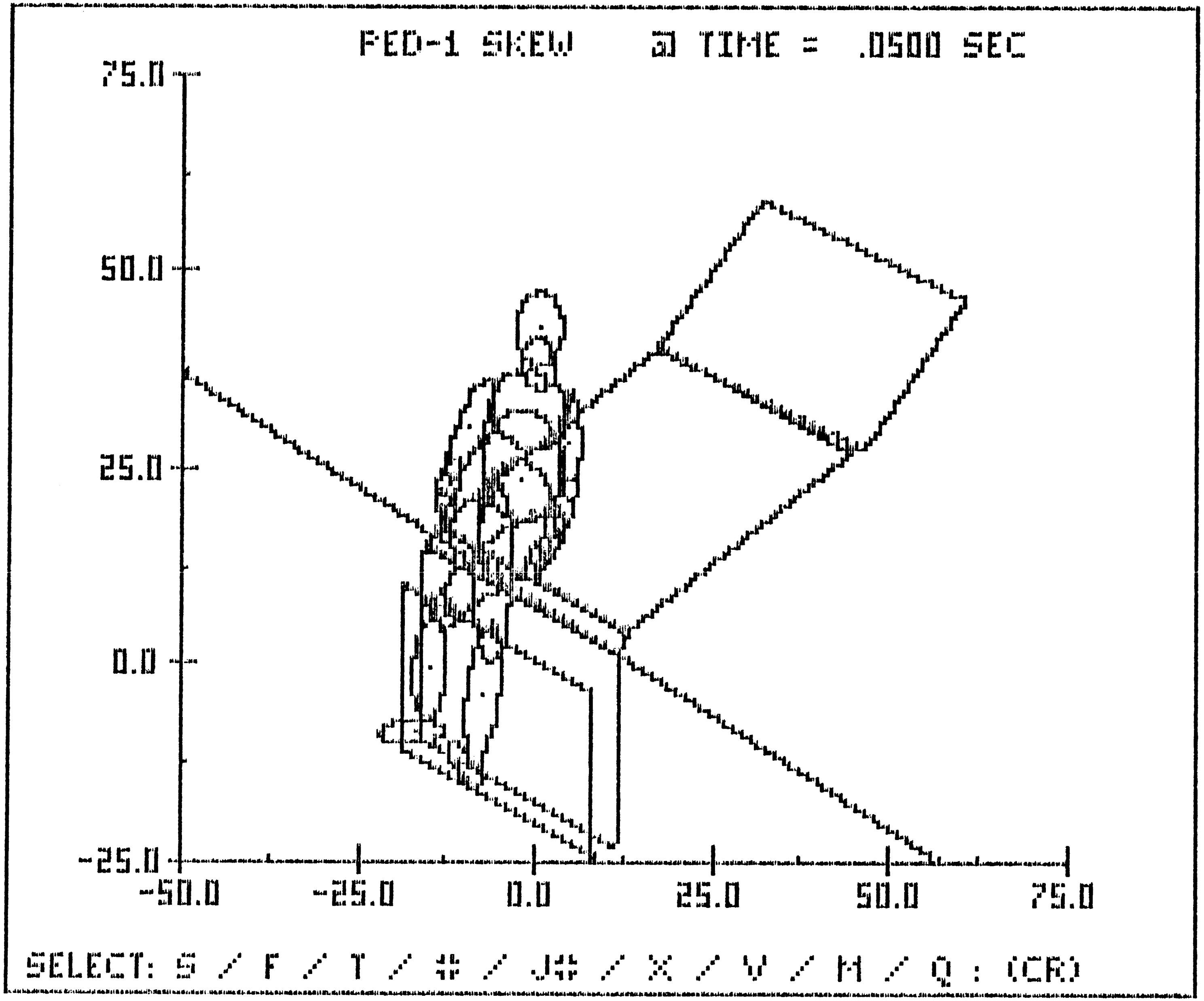


Figure 19. CVS-3D Pedestrian Skew View at t=50msec

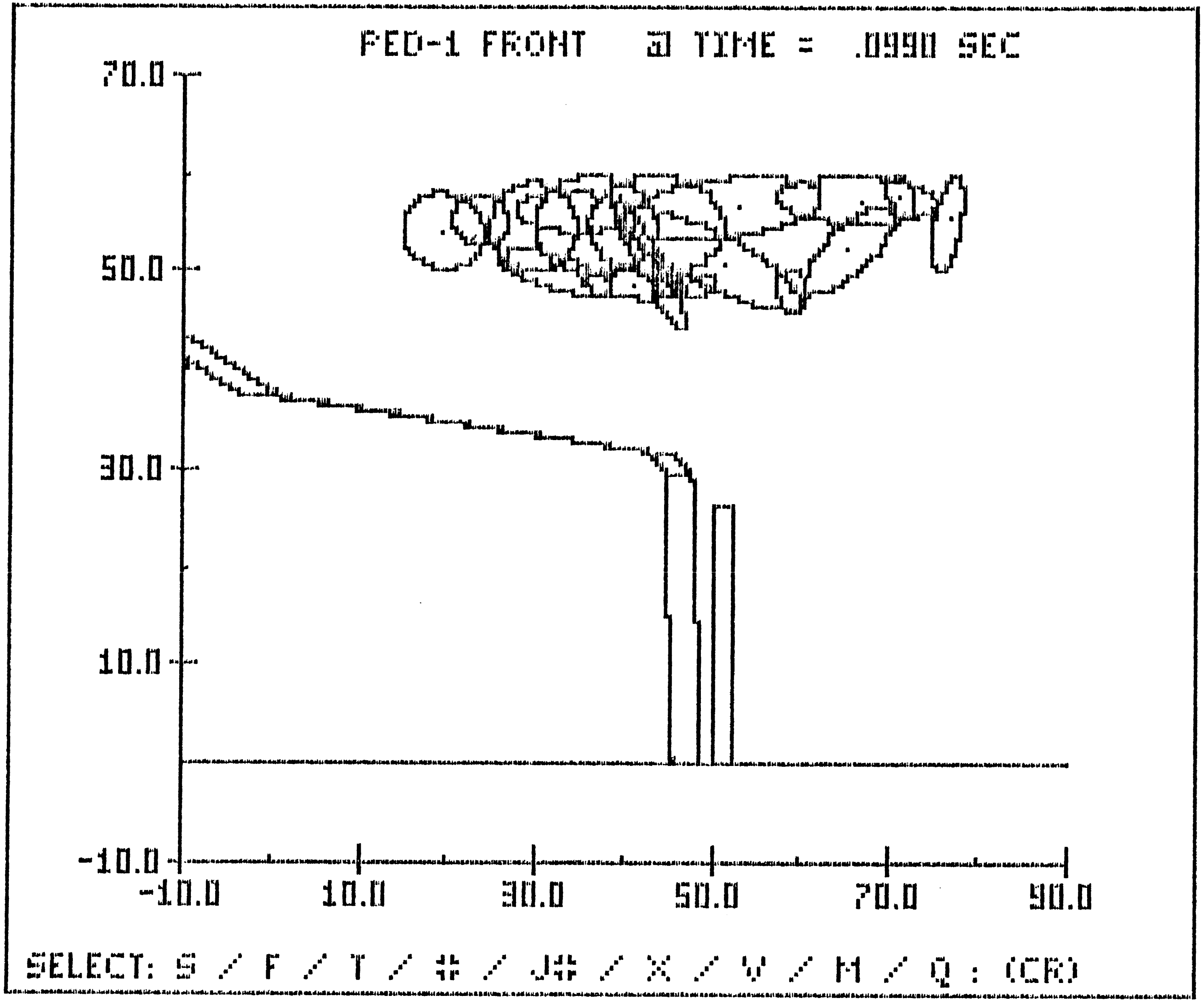


Figure 20. CVS-3D Pedestrian Front, Vehicle Side View at t=99 msec.

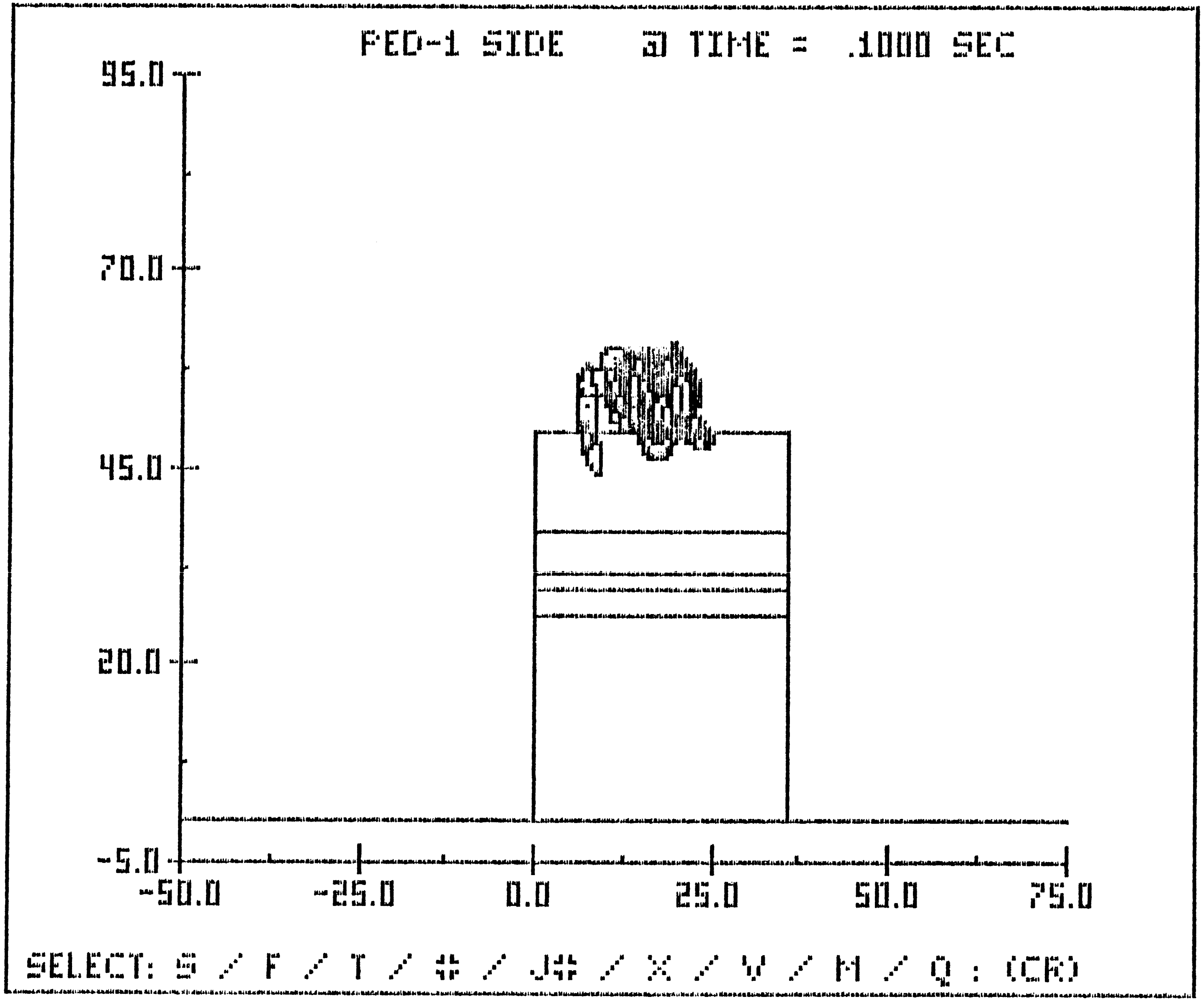


Figure 21. CVS-3D Pedestrian Side, Vehicle Front View at t=100 msec.

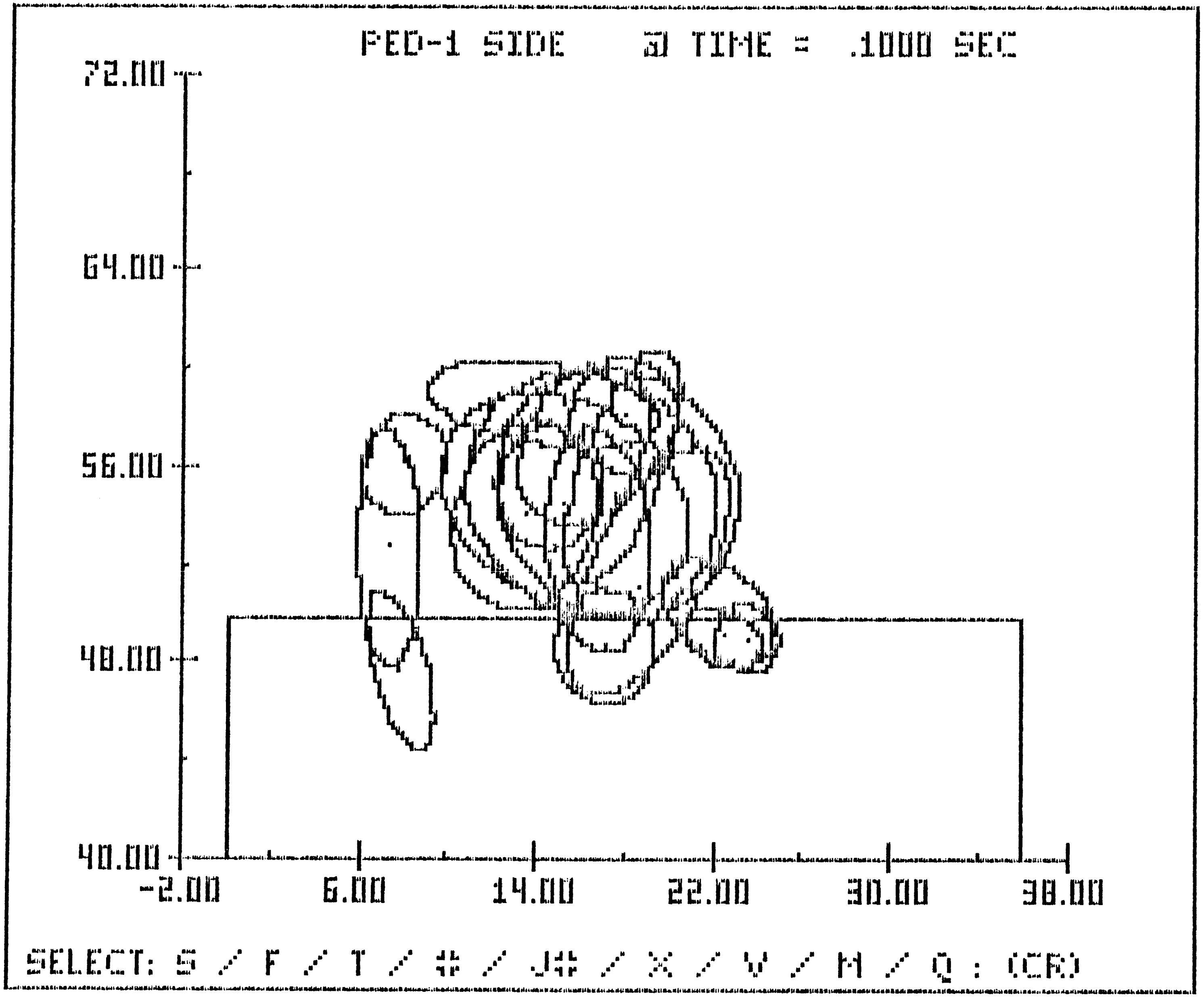


Figure 22. CVS-3D Pedestrian Skew View at t=100 msec (Enlarged).

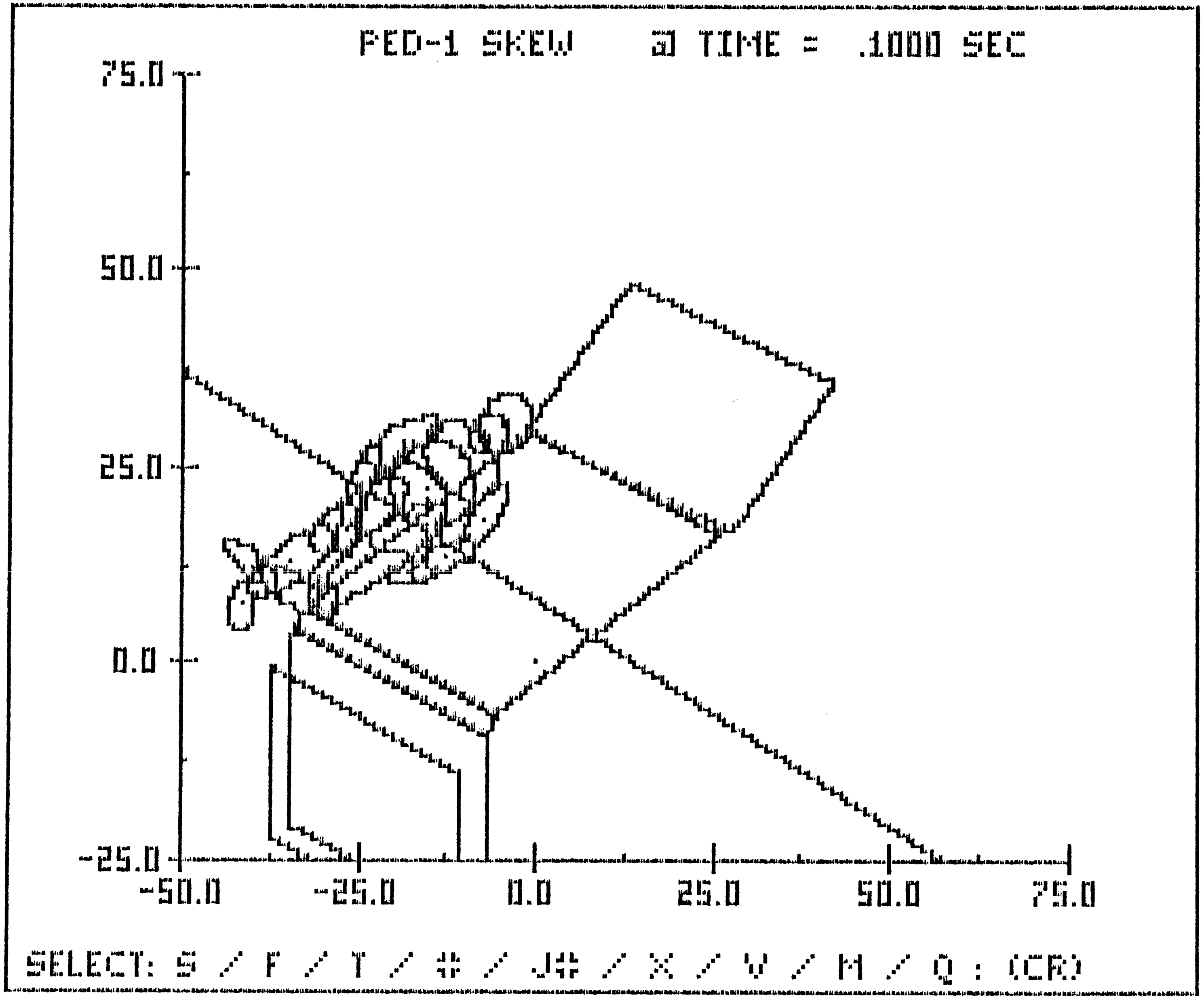


Figure 23. CVS-3D Pedestrian Skew View at 100 ms

4.0 SUMMARY OF ANALYSIS

The analysis is summarized in two parts. The first subsection deals with establishing standard plot coordinates and the second deals with the orthographic projection from standard coordinates to the viewing plane which is always defined with respect to standard coordinates.

4.1 THE STANDARD TRANSFORMATION

The Standard Transformation is defined in three steps:

1. Selection of a "base" coordinate system (which may be inertial, vehicle, or one of the body segment systems);
2. Specification of a new origin with respect to the "base" system; and,
3. A general rotation about the new origin defined with respect to axes parallel to the "base" system at the new origin.

The Standard Transformation is applied to the positional data recorded by the models in either vehicle or inertial coordinates depending on the quantity involved. Let us define the base system by the index J which has values I, V, or N (the number of the body segment). Let us further define the new origin by a positional vector r_s with respect to the J system and the rotation by the direction cosine matrix d_s also with respect to the S system. Let us lastly define R_K as any positional vector with respect to either the interial or vehicle sysem for K = I or V respectively and R_S is a vector to the same point from the Standard Plotting System.

Then

$$R_S = R'_{JK} + D_{JK} R_K$$

where the effective rotation and translation are defined in Table 1. Figure 24 illustrates this terminology.

The equation of an ellipsoid in the viewing system is:

$$\alpha x^2 + \beta y^2 + \delta z^2 + 2\gamma xy + 2\varepsilon xz + 2\eta yz = 1$$

where

$$\alpha = \frac{D_{11}^2}{a^2} + \frac{D_{21}^2}{b^2} + \frac{D_{31}^2}{c^2}, \qquad \beta = \frac{D_{12}^2}{a^2} + \frac{D_{22}^2}{b^2} + \frac{D_{32}^2}{c^2},$$

$$\delta = \frac{D_{13}^2}{a^2} + \frac{D_{23}^2}{b^2} + \frac{D_{33}^2}{c^2}, \qquad \gamma = \frac{D_{11}D_{12}}{a^2} + \frac{D_{21}D_{22}}{b^2} + \frac{D_{31}D_{32}}{c^2},$$

$$\varepsilon = \frac{D_{11}D_{13}}{a^2} + \frac{D_{21}D_{23}}{b^2} + \frac{D_{31}D_{33}}{c^2}, \qquad \eta = \frac{D_{12}D_{13}}{a^2} + \frac{D_{22}D_{23}}{b^2} + \frac{D_{32}D_{33}}{c^2}.$$

Here, a, b, c are the semiaxes of the ellipsoid and D_{ij} is the i-th row and j-th column element of the final direction cosine matrix of the ellipsoid relative to the viewing system. The y-axis is chosen to be the view axis. Then what is seen (and hence can be plotted) is the shadow (or projection of the ellipsoid onto any plane parallel to the x-z plane and hence perpendicular to the y-axis. Another way of describing it is that what is seen is the end-on view of an ellipsoid cylinder, the axis of which is the y-axis and which is continuously tangent to the ellipsoid being viewed. The equation of this ellipse can be obtained by solving the above equation for y and setting the discriminant equal to zero:

$$y = \frac{-(\gamma x + \eta z) \pm \sqrt{(\gamma^2 - \alpha\beta)x^2 + (\eta^2 - \beta\delta)z^2 + 2(\gamma\eta - \beta\varepsilon)xz - \beta}}{\beta}$$

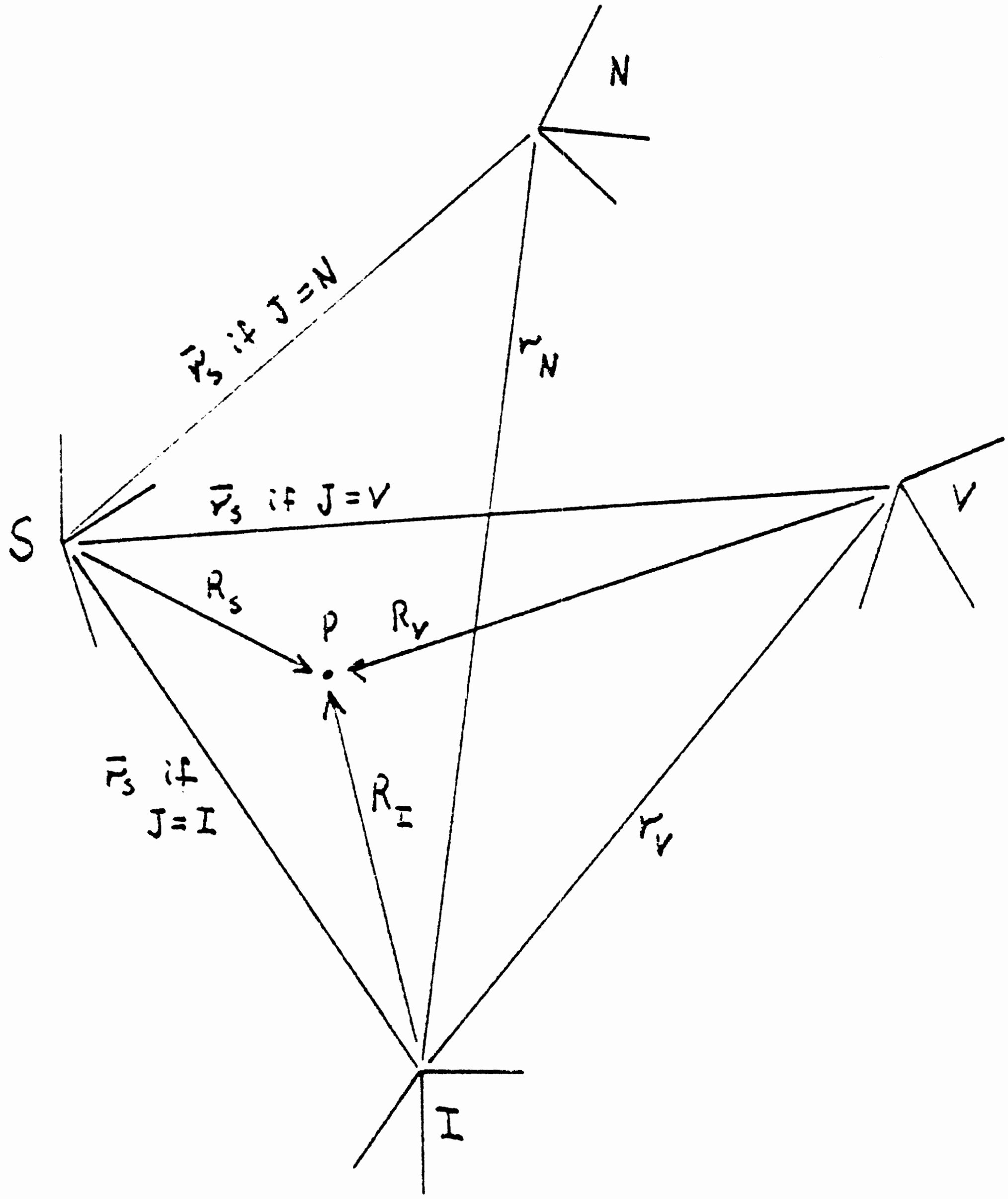


Figure 24. Relationship Between S, I, V, and N Systems.

and

$$(\gamma^2-\alpha\beta)x^2+(\eta^2-\beta\delta)z^2+2(\gamma\eta-\beta\varepsilon)xz-\beta=0$$

The reason for this is that points of the ellipsoid which project as the circumference of the shadow ellipse are those for which there is a single unique solution for y. To make the plotting simpler, the equation of the ellipse is written in parametric form

$$x = A\cos\phi\cos\theta - B\sin\phi\sin\theta$$

$$z = A\sin\phi\cos\theta + B\cos\phi\sin\theta$$

where A and B are the semiaxes of the ellipse, ϕ is the angle of the A axis with the x-axis, and θ is the parametric variable as shown in Figure 25. Then by letting θ vary from 0° to 360°, the x and z values of the shadow ellipse can be calculated and plotted. First A, B and ϕ must be computed in terms of α, β, γ, δ, ε and η. If x and z are substituted back into the last equation above and terms are collected on θ, the following equation results:

$$A^2\left[(\gamma^2-\alpha\beta)\cos^2\phi+(\eta^2-\beta\delta)\sin^2\phi+2(\gamma\eta-\beta\varepsilon)\sin\phi\cos\phi\right]\cos^2\theta$$
$$+B^2\left[(\gamma^2-\alpha\beta)\sin^2\phi+(\eta^2-\beta\delta)\cos^2\phi-2(\gamma\eta-\beta\varepsilon)\sin\phi\cos\phi\right]\sin^2\theta-\beta$$
$$+2AB\left[(\gamma\eta-\beta\varepsilon)(\cos^2\phi-\sin^2\phi)+(\eta^2-\gamma^2-\beta\delta+\alpha\beta)\sin\phi\cos\phi\right]\sin\theta\cos\theta$$
$$=0$$

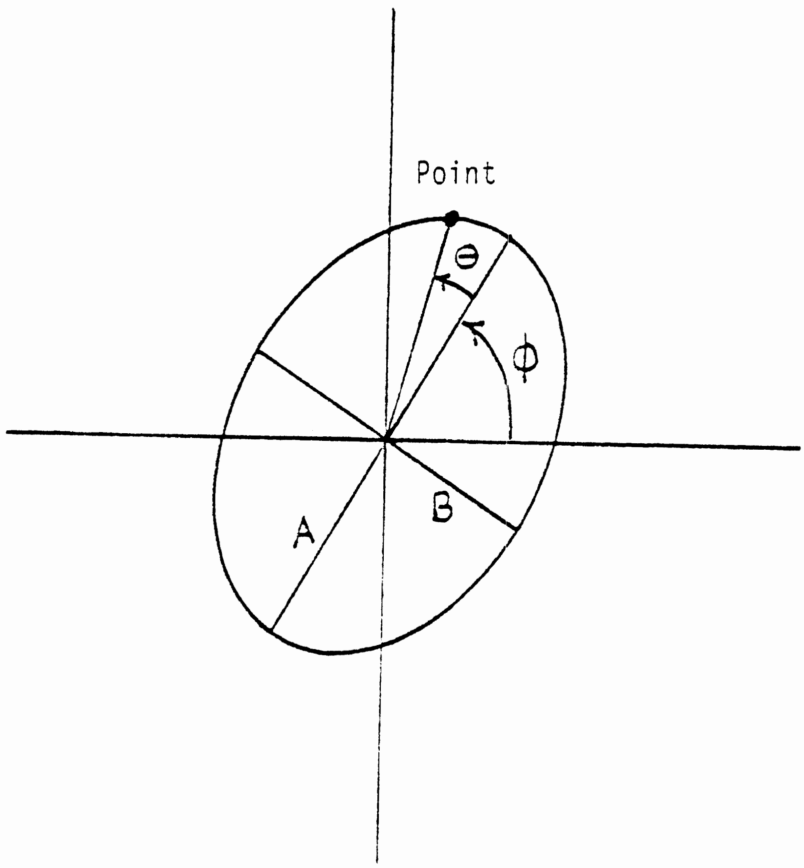


Figure 25. The Shadow Ellipse in the Viewing Plane.

This equation must be satisfied for all values of θ, which will be true if the first three terms sum to zero and if the coefficient in brackets of the last term is identically zero. The latter condition thus defines ϕ:

$$\frac{\sin\phi\cos\phi}{\cos^2\phi - \sin^2\phi} = \frac{\gamma\eta - \beta\varepsilon}{\gamma^2 - \eta^2 - \alpha\beta + \beta\delta} = \frac{1}{2}\tan 2\phi \ .$$

The former implies that:

$$A^2\left[(\gamma^2 - \alpha\beta)\cos^2\phi + (\eta^2 - \beta\delta)\sin^2\phi + 2(\gamma\eta - \beta\varepsilon)\sin\phi\cos\phi\right] = \beta$$

and

$$B^2\left[(\gamma^2 - \alpha\beta)\sin^2\phi + (\eta^2 - \beta\delta)\cos^2\phi - 2(\gamma\eta - \beta\varepsilon)\sin\phi\cos\phi\right] = \beta$$

or

$$A = \frac{\sqrt{\beta}}{\sqrt{(\gamma^2 - \alpha\beta)\cos^2\phi + (\eta^2 - \beta\delta)\sin^2\phi + 2(\gamma\eta - \beta\varepsilon)\sin\phi\cos\phi}}$$

and

$$B = \frac{\sqrt{\beta}}{\sqrt{(\gamma^2 - \alpha\beta)\sin^2\phi + (\eta^2 - \beta\delta)\cos^2\phi - 2(\gamma\eta - \beta\varepsilon)\sin\phi\cos\phi}}$$

If the Viewing Matrix defined with respect to the Standard System is d_{VS} and the direction cosine matrix of the body segment system M to which the ellipsoid is attached is d_{MS} then

$$D = d_{MS}\, d_{VS}^{T}$$

where

$$d_{MS} = d_{M}\, d_{JI}$$

using the notation where d_{JI} is defined in Table 1 for J in the base system and d_{M} is the body segment system with respect to the inertial system.

TABLE 1. EFFECTIVE ROTATION AND TRANSLATION TABLE.

J \ Effective Quantity	D_{JI}	R'_{JI}	D_{JV}	R'_{JV}
I	d_s	$-d_s \bar{r}_s$	$d_s d_V^T$	$d_s (r_V - \bar{r}_s)$
V	$d_s d_V$	$-d_s (r_s + d_V r_V)$	d_s	$-d_s \bar{r}_s$
N	$d_s d_N$	$-d_s (\bar{r}_s + d_N r_N)$	$d_s d_N d_V^T$	$-d_s (\bar{r}_s - d_N (r_N - r_V))$

where:

1. r_V and r_N are inertial vectors to the vehicle and body segment N origins.

2. d_V and d_N are direction cosine matrices of vehicle and body segment N systems with respect to the inertial systems.

5.0 REFERENCES

1. Bowman, B.M., Bennett, R.O., and Robbins, D.H., "MVMA Two-Dimensional Crash Victim Simulation, Version 4," Report No. UM-HSRI-79-5-1,2,3. 3 Vols. University of Michigan Transportation Research Institute, June 1979.

2. Bennett, R.O. and Robbins, D.H., "HSRI Version of the Improved Three Dimensional Computer Simulation of Vehicle Crash Victims," 3 Vols., Report Nos. UM-HSRI-82-8-1,2,3. Final Report on Contract No. DOT-HS-7-01659. University of Michigan Transportation Research Institute, March 1982.

APPENDIX. INTERMEDIATE POSITIONAL DATA FILE FORMATS

Tables A-1 and A-2 contain the quantities and the format expected to be recorded by the model runs. Table A-1 contains the basic model parameters which are needed and Table A-2, the information required for each of the recorded time points.

TABLE A-1. INPUT FILE LAYOUT FOR HEADER RECORDS (ONE SET REQUIRED FOR RUN)

Number, Records Required	Format	Contents	Range	Type	Definition
1	(7I4,3A4)	NSEG	1-22	Integer	Number of Body Segments
		NJNT	0-21	Integer	Number of Body Segments
		NBLT	0-8	Integer	Number of Belts
		NBAG	0-8	Integer	Number of Airbags
		NPL	0-20	Integer	Number of Planes
		NELP	0-27	Integer	Number of Ellipses
		NUMB	(3-2 +NSEB +NBAG)	Integer	Number of Items in some arrays
		DATE**		Character**	Calender Date (12 char)
2	(20A4)	COMENT**		Character	Run Title (160 char)
1	(204A)	VPSTIL**		Character	Vehicle Title (80 char)
1	(5A4)	BDYTIL**		Character	Body Description (20 char)
MAX(1,NBLT)	(5A4)	BLTTIL**		Character	Belt Titles (20 char each)
MAX(1,NPL)	(5A4)	PLTTL**		Character	Plane Titles (20 char each)
MAX(1,NBAG)	(5A4)	BAGTIL**		Character	Bag Titles (20 char each)
1	(20A4)	SEG**		Character	Segment Names (4 char each)
1	(20(1A1,3X))	CGS**		Character	Segment CG plot characters
1	(20(1A1,3X))	JJS**		Character	Body joint plot characters

TABLE A-1. INPUT FILE LAYOUT FOR HEADER RECORDS (ONE SET REQUIRED PER RUN (CONTINUED)

Number, Records Required	Format	Contents	Range	Type	Definition
1+INT(NELP/2) if NELP Odd MAX(1,INT(NELP/2)) if NELP Even	(3E13.6,3E13.6)	BD		Real	Body Contact Ellipsoid Semi Axes (a,b,c)
1+INT(NELP/2) if NELP Odd MAXO(1,INT(NELP/2)) if NELP Even	(3E13.6,2X,3E13.6)	SOFT		Real	Body Ellipsoid center (X,Y,Z) offset from body segment center of gravity
1+INT(3*NELP/2), if NELP Odd NG=MAX (1,INT(3*NELP/2)) if NELP Even	(3E13.6,2X,3E13.6)	DELP		Real	Body Ellipsoid Direction Cosine
1 if NELP ≤ 20 2 if NELP > 20	(20I4)	IELSEG		Integer	Body Segment index to which each body ellipsoid is attached
1+INT(NBAG/2) if NBAG Odd MAX(1,INT(NBAG/2)) if NBAG Even	(3E13.6,2X,3E13.6)	BOFT		Real	Airbag Center (x,y,z) offset
MAX(1,NBLT)	3E13.6,2X,3E13.6	ZBELT		Real	Belt Attachment Points in Vehicle

*Character data are stored in integer arrays, 4 characters per element.
**Not used in present version.

TABLE A-2. INPUT FILE LAYOUT FOR TIME POINT RECORDS (ONE SET REQUIRED PER DISPLAYED FRAME)

Number, Records Required	Format	Contents	Definition
1	F10.5	Time	Time (sec.) of frame
INT(NUMB/2) +1 if NUMB ODD	(3E13.6,2X,3E13.6)	SEGLP	Center of gravity of segments, vehicle, airbags and ground (in that order x,y,z)
INT(1.5*NUMB) +1 if NUMB ODD	(3E13.6,2X,3E13.6)	D	Direction cosine matrices for segments, vehicle, airbags and ground
INT(NBAG/2)+1 if NUMB ODD, MAX (1,INT(NBAG/2)) if NUMB EVEN	(3E13.6,2X,3E13.6)	BD	Airbag Semiaxes (a,b,c)
MAX(1,NBLT)	(3E13.6,2X,3E13.6)	TPTS	Belt Tangent Points on occupant
2*NPL	3E13.6,2X,3E13.6)	PLTIN	Panel Corner Coordinates (x,y,z). (Corner #4 is Panel Origin. Corner #3 is end of X-Axis. Corner #1 is end of second defining line. Corner #2 is opposite to origin).