Appendix A
MATLAB M-Files

A.1 MATLAB M-File for Calculating Statistical Properties

```
% Kenneth P. Kramp Masters Thesis
% May 1998

% This M-file calculates sample mean and sample standard deviation
% of alignment and profile data.

% Mean Calculations

algn_stats(1,1) = mean( lalgn_n );
algn_stats(2,1) = mean( ralgn_n );
prof_stats(1,1) = mean( lprof_n );
prof_stats(2,1) = mean( rprof_n );

% Standard Deviation Calculations

algn_stats(1,2) = std( lalgn_n );
algn_stats(2,2) = std( ralgn_n );
prof_stats(1,2) = std( lprof_n );
prof_stats(2,2) = std( rprof_n );
```

A.2 MATLAB M-File for Loading Track Geometry Data

```
% Kenneth P. Kramp Masters Thesis
% May 1998

% Loads data file with track geometry data and sample size
% Calls m-file “auto_sp” to perform FFT, see A.3

filen = input('Enter Filename of Geo data: ','s');
cmd = ['load ' filen];
eval(cmd)

% Determines number of windows
X=sample/2;
N = ( length( lalgn ) / X - 1;
H = hanning(sample);

% Mean zeros data and calls subroutine to calculate auto spectrum
% Repeats for each track geometry parameter
% ------------------------------------------------------------

var = (lprof_n - mean(lprof_n))';
auto_sp                 % M-file that calculates auto spectrum
auto_lp = auto_var(1:sample/2+1)';

% ------------------------------------------------------------

var = (rprof_n - mean(rprof_n))';
auto_sp                 % M-file that calculates auto spectrum
auto_rp = auto_var(1:sample/2+1)';

% ------------------------------------------------------------

var = (lalgn_n - mean(lalgn_n))';
auto_sp                 % M-file that calculates auto spectrum
auto_la = auto_var(1:sample/2+1)';

% ------------------------------------------------------------

var = (ralgn_n - mean(ralgn_n))';
auto_sp                 % M-file that calculates auto spectrum
auto_ra = auto_var(1:sample/2+1)';

% ------------------------------------------------------------
```

```
% Calculates x-axis
f = linspace(0, .5, sample/2+1)';

% Saves data to data file
file_out = input('Enter Filename for AutoSpectrum data: ','s');

cmd = ['save ' file_out ' f auto_lp auto_rp auto_la auto_ra'];
eval(cmd)

% Plots auto spectrums

figure(1)
plot(f,auto_lp,f,auto_rp,f,auto_la,f,auto_ra); grid
axis([ 0 .1 0 .15])
```

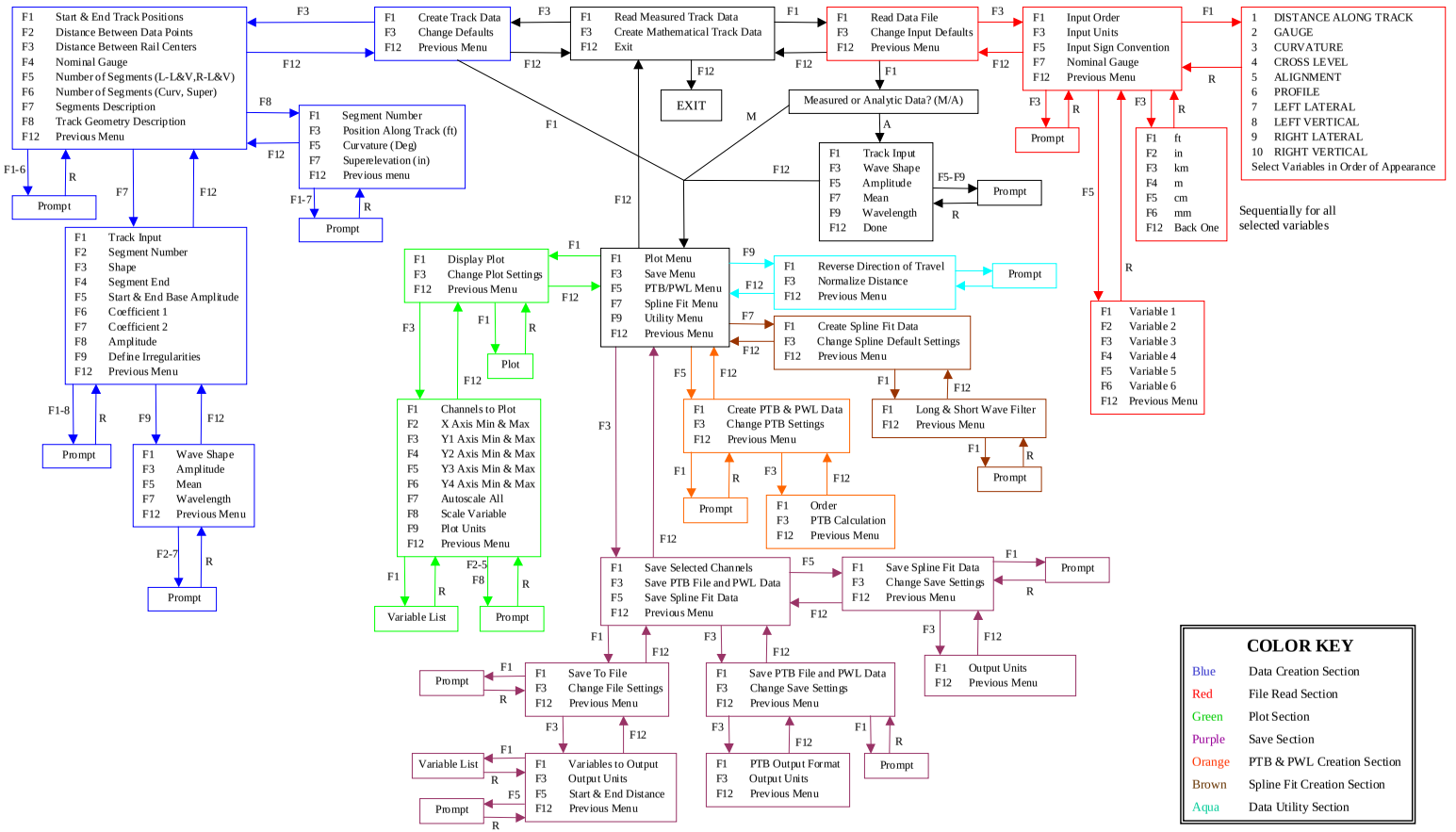
A.3 MATLAB M-File for Calculating FFT and Auto Spectrum

```
% Kenneth P. Kramp Masters Thesis
% May 1998

% This M-file calculates the auto spectrum for track geometry data
% This M-file is called from previous file, A.2

% Creates windows with 50% overlap

for I = 1:N,
  m = I - 1;
  varw(:,I) = var((m*sample - m*X + 1):(I*sample - m*X));
end

% Applies Hanning window and performs FFT of each window

for I = 1:N;
  f_var(:,I) =  fft( varw(1:sample,I).*H, sample);
end

% Calculates auto spectrm

for I = 1:N
  a_var(:,I) = (conj(f_var(:,I)) .* f_var(:,I));
end

% Averages and scales auto spectrum

auto_var = sqrt(2 * 2 / N * sum(a_var')) * 2 / sample;
```

Appendix B

TRAKVU Menu Structure

TRAKVU Menu Structure



Appendix C

Files Used for NUCARS Simulations

C.1 RUN Files

```
Run file (.RUN) for NUCARS Version 2.0
====================================
Run file for Pitch & Bounce comparison for TRAKVU Validation.
TRK file created using measured track data.

\RUN TITLE
    P&B Measured Track at 65 mph

\SYSTEM FILE
    'Trilevel.SYS'

\DATA FILE
    'Trilevel.DAT'

\INPUT FILE
    'PTTP&B.INP'

\CONTACT GEOMETRY FILE
    'Axle1.WRG'

\VELOCITY
    65

\FRICTION COEFFICIENTS
    0.5     0.5     0.5     0.5     0.5     0.5

\CONTROL CONSTANTS
    2       1       .F.

\STEPPING CONSTANTS
    0.03        800         35.00
```

```
 Run file (.RUN) for NUCARS Version 2.0
====================================
Run file for Pitch & Bounce comparison for TRAKVU Validation.
TRK file created using analytic track data with class 6 irregularities.

\RUN TITLE
    P&B Analytic Track at 65 mph

\SYSTEM FILE
    'Trilevel.SYS'

\DATA FILE
    'Trilevel.DAT'

\INPUT FILE
    'PTTP&B_A.INP'

\CONTACT GEOMETRY FILE
    'Axle1.WRG'

\VELOCITY
    65

\FRICTION COEFFICIENTS
    0.5     0.5     0.5     0.5     0.5     0.5

\CONTROL CONSTANTS
    2       1       .F.

\STEPPING CONSTANTS
    0.03        800         35.00
```

```
 Run file (.RUN) for NUCARS Version 2.0
====================================
Run file for Twist & Roll comparison for TRAKVU Validation.
TRK file created using measured track data.

\RUN TITLE
     T&R Measured Track at 20 mph

\SYSTEM FILE
     'Trilevel.SYS'

\DATA FILE
     'Trilevel.DAT'

\INPUT FILE
     'PTTT&R.INP'

\CONTACT GEOMETRY FILE
     'Axle1.WRG'

\VELOCITY
     20

\FRICTION COEFFICIENTS
     0.5      0.5      0.5      0.5      0.5      0.5

\CONTROL CONSTANTS
     2        1        .F.

\STEPPING CONSTANTS
     0.015        800          10.00
```

```
 Run file (.RUN) for NUCARS Version 2.0
====================================
Run file for Twist & Roll comparison for TRAKVU Validation.
TRK file created using analytic track data with class 6 irregularities.

\RUN TITLE
    T&R Analytic Track at 20 mph

\SYSTEM FILE
    'Trilevel.SYS'

\DATA FILE
    'Trilevel.DAT'

\INPUT FILE
    'PTTT&R_A.INP'

\CONTACT GEOMETRY FILE
    'Axle1.WRG'

\VELOCITY
    20

\FRICTION COEFFICIENTS
    0.5     0.5     0.5     0.5     0.5     0.5

\CONTROL CONSTANTS
    2       1       .F.

\STEPPING CONSTANTS
    0.015       800         10.00
```

C.2 SYS File

System file (.SYS) for NUCARS Version 2.0
==========

\SYSTEM TITLE
Loaded Trilevel Autorack ETTX 909115

Give the number of bodies, then for each, list the number, name, up to 15 characters in single quotes, and c.g. position, relative to a chosen datum, followed by the number and list of degrees of freedom required (from 1=x, 2=y, 3=z, 4=phi, 5=theta, 6=psi, 7=epsx, 8=epsy, 9=epsz), and the mass and inertias in roll, pitch, and yaw. The degrees of freedom required for each axle are 2, 3, 4, and 6.

Body #	' 15 Char Name '	C.G. Posn in X, Y, & Z			
No.	& DoF List	Mass,	Roll,	Pitch,	& Yaw Inertia
\BODY DATA					
26					
1	'Trilevel Body '	-414.5	0.0	93.3	
	9 1 2 3 4 5 6 7 8 9	262.975	1.393E6	31.54E6	31.51E6
2	'Car 1 on Deck 1'	28	0	53.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
3	'Car 2 on Deck 1'	-173	0	53.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
4	'Car 3 on Deck 1'	-375	0	53.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
5	'Car 4 on Deck 1'	-580	0	53.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
6	'Car 5 on Deck 1'	-794	0	53.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
7	'Car 1 on Deck 2'	34	0	117.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
8	'Car 2 on Deck 2'	-176	0	117.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
9	'Car 3 on Deck 2'	-374	0	117.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
10	'Car 4 on Deck 2'	-573	0	117.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
11	'Car 5 on Deck 2'	-809	0	117.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
12	'Car 1 on Deck 3'	33	0	183.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
13	'Car 2 on Deck 3'	-167	0	183.6	
	6 1 2 3 4 5 6	7.53	4109	22165	21370
14	'Car 3 on Deck 3'	-374	0	183.6	

```
        6       1 2 3 4 5 6             7.53        4109        22165       21370
15      'Car 4 on Deck 3'               -574           0         183.6
        6       1 2 3 4 5 6             7.53        4109        22165       21370
16      'Car 5 on Deck 3'               -792           0         183.6
        6       1 2 3 4 5 6             7.53        4109        22165       21370
! "BASELINE" TRUCK PARAMETERS from "Harmonic Roll Series Vol. 2"
!                   Weight      Roll (lb in s^2)  Pitch       Yaw
!Sideframe          774 lb                        1026       956.4
!Bolster            1089 lb     1927.2                       1932
20      'Leading Bolster'               -30.5          0.0         13.0
        6       1 2 3 4 5 6             2.82        1927.2         100         1932
21      'Trailng Bolster'               -798.5         0.0         13.0
        6       1 2 3 4 5 6             2.82        1927.2         100         1932
22      'Lead Lft Sframe'               -30.5          39.0        15.0
        5       1 2 3 5 6               2.00           0.0         1026        956.4
23      'Lead Rgt Sframe'               -30.5          -39.0       15.0
        5       1 2 3 5 6               2.00           0.0         1026        956.4
24      'Trail Lt Sframe'               -798.5         39.0        15.0
        5       1 2 3 5 6               2.00           0.0         1026        956.4
25      'Trail Rt Sframe'               -798.5         -39.0       15.0
        5       1 2 3 5 6               2.00           0.0         1026        956.4
! Ratio 100 to 70 ton axles for inertias (i.e.(28/36)5890 2500 5890)
26      'Axle number 1  '               0.0            0.0         14.0
        4       2 3 4 6                 5.7         4581        1944        4581
27      'Axle number 2  '               -61.0          0.0         14.0
        5       1 2 3 4 6               5.7         4581        1944        4581
28      'Axle number 3  '               -768.0         0.0         14.0
        5       1 2 3 4 6               5.7         4581        1944        4581
29      'Axle number 4  '               -829.0         0.0         14.0
        5       1 2 3 4 6               5.7         4581        1944        4581
```

For all bodies with flexible modes, give the position of the body geometric center, in the X direction from the datum, its length, and the natural frequencies (Hz) and damping ratios in twist, vertical, and lateral bending.

```
Body #  c.g.    beam length   Freqs(Tor,Vert,Lat)   Damping Ratios
-------------------------------------------------------------------------
\FLEXIBLE MODES
! These parameters were measured during the unloaded VTU test.
!1      -414.5     1080.0        5.9 6.1  14.5        0.033  0.0289 0.0454
! Equivalent parameters for a free-free support condition
1       -414.5     1080.0        5.3 5.8 14.5         0.03 0.03 0.045
```

Give the number of connections, then for each, identify a name, in single quotes and of up to 20 characters, numbers for the bodies at each end, 0 for an earth in local track coords., a position relative to the chosen datum, a number indicating the degree of freedom,

translational 1,2,3 or rotational 4,5,6, in x,y,z resp., including 2 for lateral wheel motion, and the type:

1 - parallel pair of spring and damper characteristics
2 - series pair of spring and damper characteristics
3 - device with hysteresis between 2 PWL characteristics, e.g. carriage spring or load sensitive suspension
4 - lateral/longitudinal suspension of the wheel on rail
5 - connection force as a history of the distance moved and the identification number for each of type 1, 2 and 3, the axle number for type 4, input function number for type 5.

Note - single characteristics are treated as parallel pairs with the missing characteristic set to zero in the subsequent table.

Conn # ' 15 Char Name ' Type Body 1 Body 2 Posn X,Y and Z DoF Char #

\CONNECTION DATA
121
! AUTOMOBILE TO DECK CONNECTIONS
! Longitudinal,Lateral, and Vertical connections made at axle locations
! Roll connection made at automobile c.g. location

!	Name	Type	Body	Location		DOF	Char #
1	'C 1 D 1 Ld Axle'	1.1	2 1	68	0 43.5	3 1 2 3	1 2 3
2	'C 1 D 1 Rr Axle'	1.1	2 1	-34	0 43.5	3 1 2 3	1 2 3
3	'C 1 D 1 Roll Cn'	1	2 1	28	0 53.6	4	4
4	'C 2 D 1 Ld Axle'	1.1	3 1	-133	0 43.5	3 1 2 3	1 2 3
5	'C 2 D 1 Rr Axle'	1.1	3 1	-235	0 43.5	3 1 2 3	1 2 3
6	'C 2 D 1 Roll Cn'	1	3 1	-173	0 53.6	4	4
7	'C 3 D 1 Ld Axle'	1.1	4 1	-335	0 43.5	3 1 2 3	1 2 3
8	'C 3 D 1 Rr Axle'	1.1	4 1	-437	0 43.5	3 1 2 3	1 2 3
9	'C 3 D 1 Roll Cn'	1	4 1	-375	0 53.6	4	4
10	'C 4 D 1 Ld Axle'	1.1	5 1	-540	0 43.5	3 1 2 3	1 2 3
11	'C 4 D 1 Rr Axle'	1.1	5 1	-642	0 43.5	3 1 2 3	1 2 3
12	'C 4 D 1 Roll Cn'	1	5 1	-580	0 53.6	4	4
13	'C 5 D 1 Ld Axle'	1.1	6 1	-754	0 43.5	3 1 2 3	1 2 3
14	'C 5 D 1 Rr Axle'	1.1	6 1	-856	0 43.5	3 1 2 3	1 2 3
15	'C 5 D 1 Roll Cn'	1	6 1	-794	0 53.6	4	4
16	'C 1 D 2 Ld Axle'	1.1	7 1	74	0 107.5	3 1 2 3	1 2 3
17	'C 1 D 2 Rr Axle'	1.1	7 1	-28	0 107.5	3 1 2 3	1 2 3
18	'C 1 D 2 Roll Cn'	1	7 1	34	0 117.6	4	4
19	'C 2 D 2 Ld Axle'	1.1	8 1	-136	0 107.5	3 1 2 3	1 2 3
20	'C 2 D 2 Rr Axle'	1.1	8 1	-238	0 107.5	3 1 2 3	1 2 3
21	'C 2 D 2 Roll Cn'	1	8 1	-176	0 117.6	4	4
22	'C 3 D 2 Ld Axle'	1.1	9 1	-334	0 107.5	3 1 2 3	1 2 3
23	'C 3 D 2 Rr Axle'	1.1	9 1	-436	0 107.5	3 1 2 3	1 2 3
24	'C 3 D 2 Roll Cn'	1	9 1	-374	0 117.6	4	4

```
25      'C 4 D 2 Ld Axle'   1.1      10 1   -533    0 107.5    3 1 2 3      1 2 3
26      'C 4 D 2 Rr Axle'   1.1      10 1   -635    0 107.5    3 1 2 3      1 2 3
27      'C 4 D 2 Roll Cn'   1        10 1   -573    0 117.6    4            4
28      'C 5 D 2 Ld Axle'   1.1      11 1   -769    0 107.5    3 1 2 3      1 2 3
29      'C 5 D 2 Rr Axle'   1.1      11 1   -871    0 107.5    3 1 2 3      1 2 3
30      'C 5 D 2 Roll Cn'   1        11 1   -809    0 117.6    4            4
31      'C 1 D 3 Ld Axle'   1.1      12 1     73    0 173.5    3 1 2 3      1 2 3
32      'C 1 D 3 Rr Axle'   1.1      12 1    -29    0 173.5    3 1 2 3      1 2 3
33      'C 1 D 3 Roll Cn'   1        12 1     33    0 183.6    4            4
34      'C 2 D 3 Ld Axle'   1.1      13 1   -127    0 173.5    3 1 2 3      1 2 3
35      'C 2 D 3 Rr Axle'   1.1      13 1   -229    0 173.5    3 1 2 3      1 2 3
36      'C 2 D 3 Roll Cn'   1        13 1   -167    0 183.6    4            4
37      'C 3 D 3 Ld Axle'   1.1      14 1   -334    0 173.5    3 1 2 3      1 2 3
38      'C 3 D 3 Rr Axle'   1.1      14 1   -436    0 173.5    3 1 2 3      1 2 3
39      'C 3 D 3 Roll Cn'   1        14 1   -374    0 183.6    4            4
40      'C 4 D 3 Ld Axle'   1.1      15 1   -534    0 173.5    3 1 2 3      1 2 3
41      'C 4 D 3 Rr Axle'   1.1      15 1   -636    0 173.5    3 1 2 3      1 2 3
42      'C 4 D 3 Roll Cn'   1        15 1   -574    0 183.6    4            4
43      'C 5 D 3 Ld Axle'   1.1      16 1   -752    0 173.5    3 1 2 3      1 2 3
44      'C 5 D 3 Rr Axle'   1.1      16 1   -854    0 173.5    3 1 2 3      1 2 3
45      'C 5 D 3 Roll Cn'   1        16 1   -792    0 183.6    4            4
! CARBODY TO BOLSTER CONNECTIONS
! Longitudinal car body/center plate to bolster connections
!              Name           Type    Body      Location          DOF       Char #
101     'Ld CB-Bolster  '      1       1 20    -30.5    0.0      20.0 1       11
102     'Tr CB-Bolster  '      1       1 21   -798.5    0.0      20.0 1       11
! Lateral car body/center plate to bolster connections
103     'Ld CB-Bolster  '      1       1 20    -30.5    0.0      20.0 2       11
104     'Tr CB-Bolster  '      1       1 21   -798.5    0.0      20.0 2       11
! Vertical and rotational connections for center plates using a line friction element
!              Name           Type   Bodies      Location          N/T     Dir Char#
105     'Ld CB-Bolster F'      6.2     1 20     -23.5    0.0 20.0   3 2       16
106     'Ld CB-Bolster B'      6.2     1 20     -37.5    0.0 20.0   3 2       16
107     'Tr CB-Bolster F'      6.2     1 21    -791.5    0.0 20.0   3 2       16
108     'Tr CB-Bolster B'      6.2     1 21    -805.5    0.0 20.0   3 2       16
109     'Ld CB-Bolster L'      6.2     1 20     -30.5    7.0 20.0   3 1       16
110     'Ld CB-Bolster R'      6.2     1 20     -30.5   -7.0 20.0   31        16
111     'Tr CB-Bolster L'      6.2     1 21    -798.5    7.0 20.0   3 1       16
112     'Tr CB-Bolster R'      6.2     1 21    -798.5   -7.0 20.0   3 1       16
! Vertical center plate to bolster connection damping
!              Name           Type   Bodies      Location          DOF       Char #
113     'Ld CB-Bolster F'      1       1 20     -23.5    0.0 20.0   3         20
114     'Ld CB-Bolster B'      1       1 20     -37.5    0.0 20.0   3         20
115     'Tr CB-Bolster F'      1       1 21    -791.5    0.0 20.0   3         20
116     'Tr CB-Bolster B'      1       1 21    -805.5    0.0 20.0   3         20
117     'Ld CB-Bolster L'      1       1 20     -30.5    7.0 20.0   3         20
```

```
118     'Ld CB-Bolster R'   1       1 20      -30.5  -7.0 20.0     3          20
119     'Tr CB-Bolster L'   1       1 21     -798.5   7.0 20.0     3          20
120     'Tr CB-Bolster R'   1       1 21     -798.5  -7.0 20.0     3          20
! Constant Contact Side Bearings using line friction element
!         Name              Type  Bodies        Location          N/T    Dir   Char#
121     'Lead  Bol SB Lt'   6.2     1 20    -30.5  25.0 22.625     3      1     13
122     'Lead  Bol SB Rt'   6.2     1 20    -30.5 -25.0 22.625     3      1     13
123     'Trail Bol SB Lt'   6.2     1 21    -798.5  25.0 22.625     3      1     13
124     'Trail Bol SB Rt'   6.2     1 21    -798.5 -25.0 22.625     3      1     13
! BOLSTER TO SIDEFRAME CONNNECTIONS
! Vertical bolster to sideframe connections (30.5+/-3.06)(798.5+/-3.06)
!         Name              Type  Bodies        Location          DOF    Char #
125     'Ld Ld Bol-SF Lt'   1       20 22     -27.5  39.0 11.0     3          17
126     'Ld Tr Bol-SF Lt'   1       20 22     -33.5  39.0 11.0     3          17
127     'Ld Ld Bol-SF Rt'   1       20 23     -27.5  39.0 11.0     3          17
128     'Ld Tr Bol-SF Rt'   1       20 23       -33. 39.0 11.0     3          17
129     'Tr Ld Bol-SF Lt'   1       21 24     -795.5  39.0 11.0     3          17
130     'Tr Tr Bol-SF Lt'   1       21 24     -801.5  39.0 11.0     3          17
131     'Tr Ld Bol-SF Rt'   1       21 25     -795.5  39.0 11.0     3          17
132     'Tr Tr Bol-SF Rt'   1       21 25     -801.5  39.0 11.0     3          17
! Longitudinal, Lateral, and Yaw bolster to sideframe connections
!         Name              Type  Bodies        Location          DOF    Char #
133     'Ld L Bol-SFrame'   1.1     20 22     -30.5   39.0 17.5   3 1 2 6  11 12 18
134     'Ld R Bol-SFrame'   1.1     20 23     -30.5  -39.0 17.5   3 1 2 6  11 12 18
135     'Tr L Bol-SFrame'   1.1     21 24     -798.5   39.0 17.5   3 1 2 6  11 12 18
136     'Tr R Bol-SFrame'   1.1     21 25     -798.5  -39.0 17.5   3 1 2 6  11 12 18
! SIDE FRAMES TO AXLES CONNECTIONS
! Longitudinal and lateral side frame to axle connections
!         Name              Type  Bodies        Location          DOF    Char #
137     'Ld L SF-LdAxle'    1.1     22 26       0.0   39.0 18.0     2 1 2    11 11
138     'Ld L SF-TrAxle'    1.1     22 27     -61.0   39.0 18.0     2 1 2    11 11
139     'Ld R SF-LdAxle'    1.1     23 26       0.0  -39.0 18.0     2 1 2    11 11
140     'Ld R SF-TrAxle'    1.1     23 27     -61.0  -39.0 18.0     2 1 2    11 11
141     'Tr L SF-LdAxle'    1.1     24 28    -768.0   39.0 18.0     2 1 2    11 11
142     'Tr L SF-TrAxle'    1.1     24 29    -829.0   39.0 18.0     2 1 2    11 11
143     'Tr R SF-LdAxle'    1.1     25 28    -768.0  -39.0 18.0     2 1 2    11 11
144     'Tr R SF-TrAxle'    1.1     25 29    -829.0  -39.0 18.0     2 1 2    11 11
! Vertical/rotational side frame-axle connections using line friction element
!         Name              Type  Bodies        Location          N/T  Dir    Char#
145     'SdFrame-Ax 1 L'    6.2     22 26       0.0   39.0 18.0     3 6        15
146     'SdFrame-Ax 1 R'    6.2     23 26       0.0  -39.0 18.0     3 6        15
147     'SdFrame-Ax 2 L'    6.2     22 27     -61.0   39.0 18.0     3 6        15
148     'SdFrame-Ax 2 R'    6.2     23 27     -61.0  -39.0 18.0     3 6        15
149     'SdFrame-Ax 3 L'    6.2     24 28    -768.0   39.0 18.0     3 6        15
150     'SdFrame-Ax 3 R'    6.2     25 28    -768.0  -39.0 18.0     3 6        15
151     'SdFrame-Ax 4 L'    6.2     24 29    -829.0   39.0 18.0     3 6        15
```

```
152     'SdFrame-Ax 4 R'    6.2     25 29   -829.0  -39.0 18.0      3 6             15
! Vertical side frame-axle connection damping
!          Name                 Type   Bodies      Location          DOF     Char #
153     'SdFm-Axle 1 L '        1       22 26       0.0   39.0 18.0     3         19
154     'SdFm-Axle 1 R '        1       23 26       0.0  -39.0 18.0     3         19
155     'SdFm-Axle 2 L '        1       22 27     -61.0   39.0 18.0     3         19
156     'SdFm-Axle 2 R '        1       23 27     -61.0  -39.0 18.0     3         19
157     'SdFm-Axle 3 L '        1       24 28    -768.0   39.0 18.0     3         19
158     'SdFm-Axle 3 R '        1       25 28    -768.0  -39.0 18.0     3         19
159     'SdFm-Axle 4 L '        1       24 29    -829.0   39.0 18.0     3         19
160     'SdFm-Axle 4 R '        1       25 29    -829.0  -39.0 18.0     3         19
! WHEELS TO RAIL/VTU CONNECTIONS
! Add 8 Wheel/rail connections
161     'Axle 1 Left W/R'   4   26      0.0     29.75     0.0     1
162     'Axle 1 Rght W/R'   4   26      0.0    -29.75     0.0     1
163     'Axle 2 Left W/R'   4   27    -61.0     29.75     0.0     2
164     'Axle 2 Rght W/R'   4   27    -61.0    -29.75     0.0     2
165     'Axle 3 Left W/R'   4   28   -768.0     29.75     0.0     3
166     'Axle 3 Rght W/R'   4   28   -768.0    -29.75     0.0     3
167     'Axle 4 Left W/R'   4   29   -829.0     29.75     0.0     4
168     'Axle 4 Rght W/R'   4   29   -829.0    -29.75     0.0     4
! 2D Friction wedge connection between bolster and side frame-798.530.5
169     'Ld Bol-SF LL Wg'   6.3 20  22      -22.0     39.0     13    3 2   14
170     'Ld Bol-SF LR Wg'   6.3 20  23      -22.0    -39.0     13    3 2   14
171     'Tr Bol-SF LL Wg'   6.3 21  24     -790.0     39.0     13    3 2   14
172     'Tr Bol-SF LR Wg'   6.3 21  25     -790.0    -39.0     13    3 2   14
173     'Ld Bol-SF TL Wg'   6.3 20  22      -39.0     39.0     13    3 2   14
174     'Ld Bol-SF TR Wg'   6.3 20  23      -39.0    -39.0     13    3 2   14
175     'Tr Bol-SF TL Wg'   6.3 21  24     -807.0     39.0     13    3 2   14
176     'Tr Bol-SF TR Wg'   6.3 21  25     -807.0    -39.0     13    3 2   14
```

For each connection characteristic, list its number, identification numbers for the piecewise linear stiffness and damping characteristics, respectively, zero if absent, and the force, moment, or stroke limits in extn and compn, (if no limit exists, set the values outside the expected range).

```
Pair #  Stiffness & Damping  F/S-extn.  F/S-comp.    K/D-parameters
-------------------------------------------------------------------------
\CHARACTERISTIC DATA
! AUTOMOBILE CHARACTERISTICS
! Automobile Longitudinal Axle
1       1       2       1.0E09     -1.0E09
! Automobile Lateral Axle
2       3       4       1.0E09     -1.0E09
! Automobile Vertical Axle
3       5       6       1.0E09     -1.0E09
! Automobile Roll Characteristics
```

```
4      7      8      1.0E09     -1.0E09
! TRUCK CHARACTERISTICS
! Steel to Steel
11     21     22     1.0E09     -1.0E09
! Lateral bolster to side frame.
12     23     0      1.0E09      -1.0E09
! Constant contact side bearing data
!#    Stiff  Damp  Stroke Limits    Stop K    Tan. K    and C   Mu(.3)
13     24     31       3.0       -3.0        0.0      1.0E06    1.0E03    0.2
! 6.3 wedge char for vert, lat and warp friction between bolster/side frame.
! Constant force wedge with wedge angle, force, LVB, and friction.
14      0       0       37.5    1938    1.0E04  0.4
! # 15 & 16 are 6.2 friction line element with pwl numbers, stroke stops,
! force limit, parallel spring and damper, and effective Mu*R, Mu=.5
15      29      0       0.030   -0.030  1.0E09  1.0E09  1.0E05  1.0
! Cw = Car weight
! Mu1 = friction coeff. for the center plate
! Mu2 = effective friction coeff. for this simulation
! R = radius of center plate
! The normal formula for calculating the center plate breakout
! torque for one bowl is (Cw*Mu1*R)/3.  This model assumes all loads are
! carried at the lateral edges of the center plate.  This produces a breakout
! torque equal to (Mu2*Cw*R)/4 for each edge.  Setting the two equations
! equal to each other produces the effective Mu, R relationship.  Therefore,
! Mu1*2/3 = Mu2.  For this simulation Mu1 was assumed to be 0.3 producing
! an effective Mu2 for the 6.2 connection of 0.2
16      25      0       3.0     -3.0    0.0     1.0E06  1.0E03 0.13
! Vertical bolster to sideframe
17    27    0          0.0     -1.0E9
! Yaw bolster to sideframe
18    28    0      1.0E9   -1.0E9
! Vertical sideframe to axle damping (allows liftoff)
19    0     22     0.0       -1.0E8
! Vertical carbody to bolster damping (allows liftoff)
20    0  26    0.0          -1.0E8

! Center Plate Yaw connection
!25    22    0   1.0E9   -1.0E9
! Vertical VTU to wheel (allows liftoff)
!21   30         22       0.0     -1.0E9
```

For type 4 - axle to track characteristics, give a lateral stiffness and damping and identification numbers for the vertical PWL stiffness and damping, then for each, list an identification number, the nominal wheel radius, WRAD, a wheel rotation index, INDWH, .F. for solid, .T. for independent wheels, traction torque input nos., ITRQ, for left and right

wheels, 0 for none, and, for independent wheels, KWHL, DWHL, the axle torsional stiffness and damping.

```
   Axle #    WRAD   INDWH   ITRQ-L   ITRQ-R   KWHL    DWHL
------------------------------------------------------------------------------
\WHEEL/RAIL ELEMENT
    1.E5      1.E3      15    16
    1         14        .F.        0          0
    2         14        .F.        0          0
    3         14        .F.        0          0
    4         14        .F.        0          0
```

For each piecewise linear function, list the identification number, the number of break points, and the ordinate, lb or in-lb, over abscissa, inches or rad, at each break point.
Note - extension is assumed to be positive for both ordinate and abscissa and 0.0 for the first break point indicates symmetry about the origin.

```
  PWL    IBP    Ordinates over Abscissa
------------------------------------------------------------------------------
\PWL DATA
! AUTOMOBILE SUSPENSION DATA
! From VTU test vertical nat. freq. = 1.65 Hz w/ .10 damping
! wn=sqrt(k/m),m=90.34 lb/ft/s^2,wn= 1.65 cyc/s * 2pi rad/cyc = 10.37 rad/s
! k = wn^2 * m = 9714.88 lb /ft = 809.57 lb/in
! z=c/2*sqrt(k*m), c=2*z*sqrt(k*m)=187.36 lb/ft/s= 15.6 lb/ in/s
! Long and Lat Stiff ratioed from Michigan Scientific tests on a Cutlass Ciera:
! wt. = 2,978 lb vert = 0.96 Hz, lat = 1.68 Hz, and long = 2.8 Hz
! Longitudinal Stiffness of Axle 1 = (1.65*(2.8/0.96)*6.28)^2*(90.34lb/ft/s^2*1/12)/2
1      2      0.0    3438
              0.0    1.0
! Longitudinal Damping of Axle 1 = 3438 * (7.8/404.57)
2      2      0.0    66.3
              0.0    1.0
! Lateral Stiffness of Axle 1 = (1.65*(1.68/0.96)*6.28)^2*(90.34lb/ft/s^2*1/12)/2
3      2      0.0    1238
              0.0    1.0
! Lateral Damping of Axle 1 = 1238 * (7.8/404.57)
4      2      0.0    23.9
              0.0    1.0
! Vertical Stiffness of Axle 1
5      2      0.0    404.57
              0.0    1.0
! Vertical Damping of Axle 1
6      2      0.0    7.8
              0.0    1.0
! Roll Stiffness = Kv*(wheelbase/2)^2=809.14lb/in*(57.65in/2)^2
```

```
7     2       0.0     6.723E5
              0.0     1.0
! Roll Damping = 672299*(7.8/404.57)
8     2       0.0     1.296E4
              0.0     1.0
! Vertical wheel/rail  159,241/8 = 19905
15    4    -2.69905E5   -19905  0.0      0.0
          -1.0         0.0     0.0645   1.0
16    2     0.0       2.5E3
          0.0       1.0
! Steel to steel stiffness
21        2         0.0      1.E6
                    0.0      1.0
! Steel to steel damping
22      2       0.0      1.E3
                  0.0      1.0
! Lateral Stiffness of bolster to side frame connection
! Shear stiff of spring nest = 7506.9 lb/in (0.5 inch clearance)
23      3       0.0     3.753E3 1.0E6
              0.0     0.50    1.0
! Vertical Stiffness of Stucki 656-CRH side bearings
24      7       -14.0E3  -8.0E3  -5.0E3 -2.5E3  -750    0.0     0.0
              -0.25    -0.125  0.0    0.125   0.25    0.375   0.50
! Vertical Stiffness of center plate
! 99,106 carbody - 24,000 sidebearings = 75106/8 = 9,388.25/1E7 = 0.00094 in
25      4       -1.0E7  -9.429E3        0.0     0.0
              -1.0    0.0             0.00094 1.0
! Vertical Damping of center plate
26      2       0.0     5.0E3
              0.0     1.0
! Vertical Stiffness of spring nests ( use 2 springs/nest for pitch stiff.)
! 5-D4 outers (2980.6 lb/in) and 4-D4 inners (1121 lb/in)
! k theoretical = 19,387 lb./in. per nest
! D4 max spring travel = 3.0625 inches
! k mohr's circle = 17,124.3 lb/in per nest
! Difference from k theory believed to be due to bolster/side frame stiffness
! Car+bolster wt. = 102,106 lbs
! Equilibrium spring disp.=102,106lbs/4*17,124.2lb/in= 1.4906 in
!   27      5   -1000000 -52968          -25526  0.0     0.0
!             -2.0     -1.60255        0.0     1.4906  2.0
! 1/2 vertical characteristic to account for 2 springs/nest
27      5       -1.0E6  -2.6484E4  -1.2763E4    0.0     0.0
              -2.0    -1.60255   0.0          1.4906  2.0
! Warp or Yaw Stiffness of spring nest
! Kyaw = Kshear * r^2, where r is radius of springs from center of nest
! Kyaw = 7506.9 lb / in * (6^2 +6^2) = 540,496.8 lb / rad
```

```
28      3       0.0     1.62E3  6.5E5
                0.0     0.030   0.050
! Vertical Stiffness of bearing adaptors
! Carbody + 2 bolsters + 4 sideframes = 107,133.5 lbs
! Wt. on each bearing adaptor = 107,133.5 lbs / 8 = 13,391.7 lbs
! Spring displacement at equilibrium 13,391.7 / 1.0E6 =  0.0134
29      4       -1.013E6        -1.34E4         0.0     0.0
                -1.0            0.0             0.0134  1.0
! Vertical damping of CCSB
31    3         0.0       5.0E2    5.0E2
                0.0       0.025    1.0
! Vertical Stiffness of Solid Side Bearings
!24      2       -1.0E6  0.0     0.0
!               -1.0    0.0     1.0
! Vertical Stiffness of VTU to wheel connection
!30      3       -1.0E7  0.0     0.0
!               -1.0    0.0     1.0
! Vertical damping of Solid Side Bearings
!31      2       0.0       1.0E3
!               0.0       1.0
! Vertical damping for spring nests
!32      2       0.0     100
!               0.0     1.0
! Lateral and Longitudinal damping for spring nest = (Kl/Kv)*Cv
!33      2       0.0     44
!               0.0     1.0
```

C.3 INP Files

```
Input file (.INP) for NUCARS Version 2.0
========================================
INP file for Pitch & Bounce comparison for TRAKVU Validation.
TRK file created using measured track data.

\INPUT TITLE
TTC PTT Pitch & Bounce Zone, Measured Summer 1989

\MEASURED TRACK FILE
 'PTTP&B.TRK'
```

```
Input file (.INP) for NUCARS Version 2.0
========================================
Run file for Pitch & Bounce comparison for TRAKVU Validation.
TRK file created using analytic track data with class 6 irregularities.

\INPUT TITLE
TTC PTT Pitch & Bounce Zone, Analytic Track Data Created By TRAKVU

\MEASURED TRACK FILE
 'PTTP&B_A.TRK'
```

```
Input file (.INP) for NUCARS Version 2.0
========================================
Run file for Twist & Roll comparison for TRAKVU Validation.
TRK file created using measured track data.

\INPUT TITLE
TTC PTT Twist and Roll Test Zone, Measured Summer 1989

\MEASURED TRACK FILE
 'PTTT&R.TRK'
```

```
Input file (.INP) for NUCARS Version 2.0
========================================
Run file for Twist & Roll comparison for TRAKVU Validation.
TRK file created using analytic track data with class 6 irregularities.

\INPUT TITLE
TTC PTT Twist and Roll Test Zone, Analytic Track Data Created By TRAKVU

\MEASURED TRACK FILE
 'PTTT&R_A.TRK'
```

C.4 DAT File

```
Data file (.DAT) for NUCARS Version 2.086
=======================================
Data file used for TRAKVU Validation Runs
Outputs Lateral and Vertical Wheel Forces

\EQUILIBRIUM

\LATERAL W/R FORCE
8
1   2   1   2   1   2   1   2
1   1   2   2   3   3   4   4

\VERTICAL W/R FORCE
8
1   2   1   2   1   2   1   2
1   1   2   2   3   3   4   4
```