CRITERIA FOR GUARDRAIL NEED AND LOCATION ON EMBANKMENTS

VOLUME II: COMPUTER INPUT AND SAMPLE OUTPUT

by

Hayes E. Ross, Jr.
Associate Research Engineer

and

Edward R. Post
Assistant Research Engineer

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Volume II

Evaluation of the Roadway Environment by Dynamic Analysis
of the Interaction Between the Vehicle, Passenger, and Roadway

Research Study No. 2-5-69-140

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FOREWORD

The information contained herein was developed on Research Project 2-5-69-140 entitled "Evaluation of the Roadside Environment by Dynamic Analysis of the Interaction Between the Vehicle, Passenger, and Roadway." It is a cooperative research study sponsored jointly by the Texas Highway Department and the U. S. Department of Transportation, Federal Highway Administration.

Basically, the objectives of the study are to apply mathemathical simulation techniques in determining the dynamic behavior of automobiles and their occupants when in collision with various roadside objects or when traversing curves in the road, shoulders, or other situations. It is a continuing study, having been initiated in September 1968.

As part of the first year's work, the computer program HVOSM (formerly known as CALSVA) was obtained from Cornell Aeronautical Laboratory and made operational on the IBM 360 computer facilities at Texas A&M University. In adapting the program, additions and modifications were made which increased its flexibility and usefulness. These changes and the input requirements of the program are documented in Research Report 140-1.

The primary emphasis of the second year's work was the development of an analytical model to predict the dynamic response of an automobile's occupant in three-dimensional space. Research Report 140-2 presents the derivation of the occupant model, a validation study, and a description of computer input data for determining the

occupant's response.

In the 1970-71 year, the emphasis was on application of HVOSM to specific roadway design problems. Volume I of Research Report 140-3 describes an investigation of the *traffic-safe* characteristics of different culvert sloping grate configurations. Criteria are presented for designing a *traffic-safe* sloping grate. Volume II contains computer input and sample output of that study.

Volume I of Research Report 140-4 describes the development of criteria for determining the need for and location of guardrail on embankments. Volume II contains computer input and sample output of the study.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Texas Highway Department or the Federal Highway Administration.

INTRODUCTION

Volume I of Research Report 140-4 presents a study of guardrail protection for embankments. In that study the HVOSM computer program was used in conjunction with full-scale crash test data to develop criteria for guardrail need and location on embankments.

Volume II of Research Report 140-4 was written to document the input data used by HVOSM and to present some sample output. The input data is given in two parts. The first relates to the data used in Chapter II of Volume I and the second relates to the data used in Chapter III of Volume I. There were 22 computer runs in II and 4 runs in III, for a total of 26 computer runs.

It should be pointed out that TTI's version of HVOSM is unique in some respects. TTI modified the original HVOSM program[1] to facilitate its use in specific problem studies. Most of these modifications and the additional input they require are documented in Research Report 140-1. With two exceptions, the modifications made to HVOSM by TTI subsequent to Report 140-1 are not applicable to the study described in Research Report 140-4. One exception is the change made to the idealization of the suspension bumpers. Cornell Aeronautical Laboratory Report No. VJ-2251-V-4 (pages 22 through 28) describes the changes and the additional input required. TTI's input format for the new suspension bumper data is given in the appendix of this report. The other exception is the addition of a "wagon tongue" device that

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[1]As documented in Cornell Aeronautical Laboratory Reports VJ-2251-V-1 and VJ-2251-V-3, dated July 1967 and December 1968, respectively.

permits the vehicle to be steered along a prescribed path. A brief description of the device and its input format is given in the Appendix.

INPUT

Chapters II and III data

Inclusion of all input and output data related to the study reported in Report 140-4 would result in an unnecessarily large report. Much of the input data is the same for all the computer runs, especially vehicle data. Thus, only that input which changes with each run will be tabulated. Input which remains the same for all runs will be presented only once. Figures 1 through 4 contain input for run number 5 of II (refer to Table 1 of Volume I) as printed out by HVOSM.

Data shown in Figure 1 are card images of the input. The first group of data listed is that pertaining to the automobile (1963 Ford) which is an integral part of the TTI program, being preset in subroutine STD. The remaining information in Figure 1 is that which is input by cards. This latter data supplements that preset in STD and when necessary will over-ride data in STD.

Figures 2 through 4 contain the input as printed in a more convenient format. As noted some of the data is not applicable to this study but is always printed out, irregardless. Data under headings INERTIAL DATA, DIMENSIONS, SUSPENSION DATA, ACCELEROMETER POSITIONS, VEHICLE MONITOR POINTS, and FRONT WHEEL CAMBER vs SUSPENSION DEFLECTION were the same for all 26 runs. Listings under TIRE DATA were as given in Figure 2 for all the Chapter II input. With the exception of the "No. Y TEMPS," all data in the TERRAIN TABLE ARGUMENTS were the same for all 26 runs.

In Chapter II, the number of Y templates equaled 5, whereas in Chapter III it equaled 4.

Chapter II data

Under the heading INITIAL CONDITIONS, the only variables which were different from those of Figure 2 were UO, PSIO, and YCO'. Table 1 lists these variables for each run. Under PROGRAM CONTROL DATA the only variable which changed was END TIME. Table 2 lists this variable for each run.

The other parameters which varied with each run were the coordinates of the templates which describe the terrain (ditch embankments). Tables 3 and 4 list the terrain data for the 22 runs. Refer to the numbers on the bottom of Figure 1 for the terrain data for run number 5.

Chapter III data

Under the heading INITIAL CONDITIONS of Figure 2, the only variables which changed were PSIO, XCO', YCO', and ZCO'. Table 5 lists these variables for the 4 runs in Chapter III. Under PROGRAM CONTROL DATA the only variable which changed was END TIME. Table 6 lists this variable for each run. Table 7 lists the terrain template data. AMU was the only variable which changed under the TIRE DATA listings. Table 8 lists the AMU values used in the Chapter III data.

The additional data used in the Chapter III runs pertained to the prescribed path chosen for the vehicle to attempt to follow. The variables used to describe the path (see Appendix) were as follows, for runs 2 through 4 (the vehicle was freewheeling on run number 1):

WT = 240.0 inches
C = 10,500.0 inches
B = 0.0

OUTPUT

Figures 5 through 14 contain printed output of run number 5 for the period of time between 1.533 seconds and 2.033 seconds. During this period, the automobile contacted the flat-bottom ditch. The maximum vertical accelerations, which occurred during this period, are shown in Figure 5. Other output data, such as roll angle, tire forces, and terrain elevations, are shown for the same time interval. Comments and/or graphical displays are made directly on the output listings to aid the reader.

A graphical display of the output parameters listed in Figure 6 are shown in more detail in Figure 15. The position of the center-of-mass of the automobile is measured relative to the space-fixed coordinate system. The pitch of the automobile occurs about the Y-axis, whereas, the roll occurs about the X-axis. The elevation of the terrain (GCP-ground contact point) at some instant in time is measured relative to the space-fixed coordinate system through the center of each wheel as shown in Figure 15.

FIGURE 1

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PROGRAM 2140  3:1 SIDE SLOPE  SPEED = 60 MPH  ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31  (RUN NO 5)

INPUT PRESET IN SUBROUTINE STD (ON DISK)

                                                                                                  (ICARD NO)
      1
   10.818        0.608        0.945      386.400     6000.000    30000.000    36000.000    -192.000     600.000      2
   54.517       64.483       61.000       60.000       10.138       12.088       -2.000      14.000    4400.000      3
  131.000        0.500        3.000        3.500       55.000        0.001   266000.000                              4
  192.000        0.500        4.000        3.900       50.000        0.001    61900.000      46.500       0.070      5
 1098.000        3.000       10.000        8.276     2900.000        1.780        0.800       1.000    3900.000      6
    0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0                     7
  -34.480        0.0          4.000       -5.983      -16.500        3.138                                         10
   -5.000        5.000        1.000                                                                                11
                                                                                                                   12 (FIRST CARD)

PHIC(I),I=1,11
  -3.550    -2.550    -1.800    -1.300    -0.950    -0.550    -0.300    -0.300    -0.400    -0.550    -0.800        12a (SECOND CARD)
   492.000    600.000      0.400   5000.000      0.075        1.500                                                 17
        4    4000.000      0.001      0.250                                                                       23 (FIRST CARD)
XVP(I),YVP(I),ZVP(I),I=1,4
    81.517      39.500      12.138 ]
    81.517     -39.500      12.138
  -117.483      39.000       8.138
  -117.483     -39.000       8.138 ]   BUMPER COORDINATES
                                       (ICARD 23a .... SECOND CARD)

   300.000       2.000      -3.000     300.000       2.000       3.000
   300.000       2.000      -4.000     300.000       2.000       4.000        SEE APPENDIX [ 26
                                                                              27

INPUT READ BY CALSVA (READ IN ON CARDS)

                                                                                                  (ICARD NO)
  0.0     3.16     .005     0.0      .01      70.      0.0      0.0     -1.0                        1
                                                                                                              THESE CARDS WILL SUPPLEMENT AND/OR
                                                                                                              OVER-RIDE THOSE SAME CARDS
1098.0   3.0      10.0     8.276   2900.0   1.780    2.0      1.0     3900.0                      7          CONTAINED ABOVE IN SUBROUTINE
  0.0      0.0      25.0     0.0      0.0      0.0      0.0      0.0                              8          STD WHICH ARE ON DISK
240.0    120.0    -24.138  1056.0    0.0      0.0                                               9
300.0    2.00     -3.00    300.0    2.00     5.00                                              26
300.0    2.00     -4.00    300.0    2.00     4.50                    SEE APPENDIX [            27
2.0      5.0        0.0                                                                        14
XGP(I,1),YGP(I,J),ZGP(I,J),I=1, 2 J=1, 5                                                                     ] TERRAIN DATA
    0.0        0.0       10.000    20.000    10.000    30.000    10.500    90.000    30.000    300.000    30.000   (ICARD 14a)

  999.000      0.0       10.000    20.000    10.000    30.000    10.500    90.000    30.000    300.000    30.000 ]
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FIGURE 2

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

INERTIAL DATA (ICARD 3)

MS	= 10.8180	LB.-SEC.**2/IN
MUF	= 0.6080	"
MUR	= 0.9450	"
IX	= 6000.0	LB.-SEC.**2-IN
IY	= 30000.0	"
IZ	= 36000.0	"
IXZ	=-192.000	"
IR	= 600.00	"
G	= 386.400	IN/SEC.**2

DIMENSIONS (ICARD 4)

A	= 54.5170	INCHES
B	= 64.4830	"
TF	= 61.0000	"
TR	= 60.0000	"
ZF	= 10.1380	"
ZR	= 12.0880	"
RHO	= -2.0000	"
RW	= 14.0000	"

KF	= 131.000	LB./IN.
KR	= 192.000	LB./IN.
CF'	= 55.000	LBS.
CR'	= 50.000	LBS.
EPSILONF	= 0.001	IN./SEC.
EPSILONR	= 0.001	IN./SEC.
CF	= 3.500	LB-SEC/IN
CR	= 3.900	LB-SEC/IN

SUSPENSION DATA (ICARDS 7 and 8)

LAMBDAF	= 0.500	
LAMBDAR	= 0.500	
OMEGAF	= 3.000	INCHES
OMEGAR	= 4.000	INCHES
TS	= 46.500	INCHES
RR	= 61900.0	LB-IN/RAD
RF	=266000.0	LB-IN/RAD
KRS	= 0.070	ROLL STEER COEFF.

ICARD 26 SEE APPENDIX

AKFC	= 300.000	LB/IN	
AKFCP	= 2.000	LB/IN3	
OMEGFC	= -3.000	IN	
AKFE	= 300.000	LB/IN	
AKFEP	= 2.000	LB/IN3	
OMEGFE	= 5.000	IN	

AKRC	= 300.000	LB/IN
AKRCP	= 2.000	LB/IN3
OMEGRC	= -4.000	IN
AKRE	= 300.000	LB/IN
AKREP	= 2.000	LB/IN3
OMEGRE	= 4.500	IN

ICARD 27 SEE APPENDIX

INITIAL CONDITIONS (ICARDS 8, 9, and 10)

PHI0	= 0.068	DEGREES	XC0'	= 240.000	INCHES	P0	= 0.0	DEG/SEC	U0	=1056.000	IN/SEC
THETA0	= 0.068	"	YC0'	= 120.000	"	Q0	= 0.0	"	V0	= 0.0	"
PSI0	= 25.000	"	ZC0'	= 95.862	"	R0	= 0.0	"	W0	= 0.0	"
PHIR0	= 0.0	"	DELTA1	= 0.0	"	D(PHIR)/DT	= 0.0	"	D(DEL1)/DT	= 0.0	"
PSIFI0	= 0.0	"	DELTA2	= 0.0	"	D(PSIF)/DT	= 0.0	RAD/SC	D(DEL2)/DT	= 0.0	"
			DELTA3	= 0.0	"				D(DEL3)/DT	= 0.0	"

ACCELEROMETER POSITIONS (ICARD 11)

X1	= -34.480	INCHES
Y1	= 0.0	"
Z1	= 4.000	"
X2	= -5.983	"
Y2	= -16.500	"
Z2	= 3.138	"

DRIVER CONTROL TABLES (NOT APPLICABLE)

T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT	T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT	T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT	T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT
0.0	0.0	0.0	0.0												

TIRE DATA (ICARD 7)

KT	1098.000	LB/IN
SIGMAT	= 3.000	
LAMBDAT	= 10.000	
A0	=4400.000	
A1	= 8.276	
A2	=2900.000	
A3	= 1.780	
A4	=3900.000	
AMU	= 2.000	
OMEGT	= 1.000	

TERRAIN TABLE ARGUMENTS

ICARD 23

SOIL DAMPING	= 0.001 SPI
SOIL FRICT.	= 0.250
SSTIFF	= 4000. LB/IN

ICARD 14

NO.X TEMPS.	= 2
NO.Y TEMPS.	= 5
NO. VAR AMU	= 0
TABLES	

PROGRAM CONTROL DATA (ICARD 1)

START TIME	= 0.0	SEC
END TIME	= 3.160	
INCR FOR INTEGRATION	= 0.0050	"
PRINT INTERVAL	= 0.010	"
THETA MAX (TO SWITCH)	= 70.000	DEG
UVWMIN(STOP)	= 0.0	
PQRMIN(STOP)	= 0.0	
INDCRB	= -1	(=0.NO CURB,=1 CURB,=-1 STEER DEG.OF FREEDOM)
MODE OF INTEGRATION	= 1	(=0 VAR.ADAMS-MOULT.,=1 RUNGE-KUTTA,=2FIX.AM)
DTCMP1	= 0.	(=1.0 SUPPLY INITIAL POSITION)
		(=0.0 CAR RESTS ON TERRAIN)

COEFF. OF TIRE FRICTION
VS.
(SPEED AND LOAD) DATA
ALPHA= 0.0 1/(LB-MPH)

NOT APPLICABLE

FIGURE 3

XKVTH= 0.0 1/ MPH
XKL= 0.0 1/LB
] NOT APPLICABLE

VEHICLE MONITOR POINTS (BUMPERS) ICARD 23

	X (IN.)	Y (IN.)	Z (IN.)
POINT 1	81.517	39.500	12.138
POINT 2	81.517	-39.500	12.138
POINT 3	-117.483	39.000	8.138
POINT 4	-117.483	-39.000	8.138

FRONT WHEEL CAMBER VS SUSPENSION DEFLECTION

DELTAF (Inches)	PHIC (Degrees)
-5.00	-3.55
-4.00	-2.55
-3.00	-1.80
-2.00	-1.30
-1.00	-0.95
0.00	-0.55
1.00	-0.30
2.00	-0.30
3.00	-0.40
4.00	-0.55
5.00	-0.80

This data on front wheel camber versus suspension deflection will be printed out on later programs

FIGURE 4

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

**** CURB AND BARRIER DATA ****

(NOT APPLICABLE TO THIS STUDY)

CURB IMPACT DATA

YC1'	=	0.0	INCHES
YC2'	=	0.0	"
ZC2'	=	0.0	"
DELTC	=	0.0	SEC(INTEG.INCR.)
PHIC1	=	0.0	DEGREES
PHIC2	=	0.0	"
MUC	=	0.0	
IPSI	=	492.000	LB-SEC**2-IN
CPSI'	=	600.000	LB-IN
OMEGA PSI	=	0.400	RAD
KPSI	=	5000.000	LB-IN/RAD
EPSILON PSI	=	0.075	RAD/SEC
TRAIL,FRONT(PT)	=	1.500	INCHES

BARRIER DIMENSIONS

(YB')0	=	0.0	INCHES
DELYB'	=	0.0	"
ZBT'	=	0.0	"
ZBB'	=	0.0	"

VEHICLE DIMENSIONS

XVF	=	0.0	INCHES
XVR	=	0.0	"
YV	=	0.0	"
ZVT	=	0.0	"
ZVB	=	0.0	"

INDB = 0 (=1 RIGID BARRIER, FINITE VERT. DIM.)
=2 " " INFINITE " ")
=3 DEFORM.BARRIER,FINITE " ")
=4 " " INFINITE " ")

SPRUNG MASS-BARRIER IMPACT DATA

KV	=	0.0	LB/IN**3
SET	=	0.0	DEFL.RATIO
CONS	=	0.0	ENERGY RATIO
MUB	=	0.0	
EPSILON V	=	0.0	IN/SEC
EPSILON B	=	0.0	LB
DELTB	=	0.0	SEC (INTEG.INCR)

BARRIER LOAD DEFLECT.

SIGMAR 0	=	0.0
SIGMAR 1	=	0.0
SIGMAR 2	=	0.0
SIGMAR 3	=	0.0
SIGMAR 4	=	0.0
SIGMAR 5	=	0.0
SIGMAR 6	=	0.0
SIGMAR 7	=	0.0
SIGMAR 8	=	0.0
SIGMAR 9	=	0.0
SIGMAR10	=	0.0

STRUCTURAL HARDPOINTS RELATIVE TO C. G.

		X	Y	Z	STIFFNESS
		(INCHES)			LB/IN
POINT	1	0.0	0.0	0.0	0.0
POINT	2	0.0	0.0	0.0	0.0
POINT	3	0.0	0.0	0.0	0.0

WHEEL RADIUS-RADIAL SPRING FOR TABLE (NOT APPLICABLE)

RWHJB(BEGIN)	=	0.0	INCHES
RWHJE(END)	=	0.0	"
DRWHJ(INCRE.)	=	0.0	"

ANTI-PITCH TABLES FOR CIRCUMFERENTIAL TIRE FORCE (NOT APPLICABLE)

APF=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
APR=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

TABLE 1 INITIAL CONDITIONS, II

RUN NO.	DEPARTURE SPEED (UO) mph	DEPARTURE ANGLE (PSIO) deg.	COORDINATE (YCO') inches
1	60	25.0	72.0
2	60	25.0	72.0
3	60	25.0	72.0
4	60	25.0	120.0
5	60	25.0	120.0
6	60	25.0	120.0
7	60	25.0	120.0
8	60	25.0	120.0
9	60	25.0	72.0
10	60	25.0	72.0
11	60	25.0	72.0
12	60	25.0	72.0
13	60	25.0	72.0
14	60	25.0	72.0
15	50	10.0	120.0
16	50	17.5	120.0
17	50	25.0	120.0
18	60	10.0	120.0
19	60	17.5	120.0
5	60	25.0	120.0
20	70	10.0	120.0
21	70	17.5	120.0
22	70	25.0	120.0

TABLE 2 PROGRAM CONTROL DATA, II

RUN NUMBER	END TIME (Sec)
1	2.00
2	2.30
3	3.10
4	2.60
5	3.16
6	5.00
7	3.35
8	3.70
9	3.10
10	3.90
11	6.30
12	4.20
13	5.50
14	9.50
15	7.86
16	4.67
17	3.60
18	6.00
19	4.04
5	3.16
20	5.99
21	3.60
22	2.85

TABLE 3 TERRAIN DATA, II

RUN NUMBER	TEMPLATE	SPACE FIXED COORDINATES (feet)										
		X'_1	Y'_1	Z'_1	Y'_2	Z'_2	Y'_3	Z'_3	Y'_4	Z'_4	Y'_5	Z'_5
1	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	42.0	30.5	400.0	30.5
1	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	42.0	30.5	400.0	30.5
2	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	52.0	30.5	400.0	30.5
2	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	52.0	30.5	400.0	30.5
3	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	82.0	30.5	600.0	30.5
3	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	82.0	30.5	600.0	30.5
4	1	0.0	0.0	10.0	20.0	10.0	30.0	10.5	70.0	30.0	300.0	30.0
4	2	999.0	0.0	10.0	20.0	10.0	30.0	10.5	70.0	30.0	300.0	30.0
5	1	0.0	0.0	10.0	20.0	10.0	30.0	10.5	90.0	30.0	300.0	30.0
5	2	999.0	0.0	10.0	20.0	10.0	30.0	10.5	90.0	30.0	300.0	30.0
6	1	0.0	0.0	10.0	20.0	10.0	30.0	10.5	150.0	30.0	300.0	30.0
6	2	999.0	0.0	10.0	20.0	10.0	30.0	10.5	150.0	30.0	300.0	30.0
7	1	0.0	0.0	10.0	20.0	10.0	30.0	10.5	95.0	30.0	300.0	30.0
7	2	999.0	0.0	10.0	20.0	10.0	30.0	10.5	95.0	30.0	300.0	30.0
8	1	0.0	0.0	10.0	20.0	10.0	30.0	10.5	110.0	30.0	300.0	30.0
8	2	999.0	0.0	10.0	20.0	10.0	30.0	10.5	110.0	30.0	300.0	30.0
9	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	82.0	50.5	400.0	50.5
9	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	82.0	50.5	400.0	50.5
10	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	112.0	50.5	400.0	50.5
10	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	112.0	50.5	400.0	50.5
11	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	202.0	50.5	750.0	50.5
11	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	202.0	50.5	750.0	50.5
12	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	122.0	70.5	400.0	70.5
12	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	122.0	70.5	400.0	70.5
13	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	172.0	70.5	400.0	70.5
13	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	172.0	70.5	400.0	70.5
14	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	322.0	70.5	875.0	70.5
14	2	3000.0	0.0	20.0	12.0	20.0	22.0	20.5	322.0	70.5	875.0	70.5

TABLE 4 TERRAIN DATA, II

(RUN NUMBERS 15 through 22)

TEMPLATE	SPACE FIXED COORDINATES (feet)										
	X'_1	Y'_1	Z'_1	Y'_2	Z'_2	Y'_3	Z'_3	Y'_4	Z'_4	Y'_5	Z'_5
1	0.0	0.0	10.0	20.0	10.0	30.0	10.5	90.5	30.0	300.0	30.0
2	999.0	0.0	10.0	20.0	10.0	30.0	10.5	90.0	30.0	300.0	30.0

TABLE 5. INITIAL CONDITIONS, III

RUN NO.	DEPARTURE ANGLE (PSIO) deg.	COORDINATES		
		(XCO') in.	(YCO') in.	(ZCO') in.
1	25.0	240.000	72.000	215.862
2, 3, & 4	15.0	116996.00	130063.00	215.862

TABLE 6. PROGRAM CONTROL DATA, III

RUN NO.	END TIME (sec.)
1	2.0
2	5.0
3	5.0
4	5.0

TABLE 7. TERRAIN DATA, III

RUN NO.	TEMPLATE	SPACED FIXED COORDINATES (feet)								
		X_1'	Y_1'	Z_1'	Y_2'	Z_2'	Y_3'	Z_3'	Y_4'	Z_4'
1	1	0.0	0.0	20.0	12.0	20.0	22.0	20.5	82.0	30.5
	2	1000.0	0.0	20.0	12.0	20.0	22.0	20.5	82.0	30.5
2,3,&4	1	0.0	0.0	20.0	10845.0	20.0	10855.0	20.5	1200.0	212.1
	2	200000.0	0.0	20.0	10845.0	20.0	10855.0	20.5	1200.0	212.1

TABLE 8. TIRE DATA, III

RUN NO.	FRICTION COEFFICIENT (AMU)
1	0.8
2	0.2
3	0.6
4	1.0

FIGURE 5

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	STEERING INPUT DEG.	TORQUE INPUTS POUND-FEET FRONT	REAR	SPRUNG MASS CG ACCEL. G-UNITS LONG.	LAT.	VERT.	ANGULAR VELOCITIES DEG./SEC. ROLL	PITCH	YAW	FORWARD SPEED FT./SEC.
1.5329	5.53	0.0	0.0	0.142	0.494	0.353	25.24	-1.75	18.24	91.69
1.5429	5.48	0.0	0.0	0.146	0.493	0.341	23.01	-0.40	18.95	91.75
1.5529	5.44	0.0	0.0	0.149	0.493	0.343	20.69	0.81	19.63	91.80
1.5629	5.39	0.0	0.0	0.151	0.493	0.357	18.32	1.92	20.29	91.86
1.5729	5.35	0.0	0.0	0.151	0.496	0.399	16.07	3.11	20.93	91.92
1.5829	5.31	0.0	0.0	0.151	0.493	0.447	13.74	4.31	21.56	91.98
1.5929	5.26	0.0	0.0	0.152	0.492	0.471	11.15	5.64	22.18	92.05
1.6029	5.22	0.0	0.0	0.153	0.490	0.497	8.50	6.99	22.79	92.11
1.6129	5.18	0.0	0.0	0.153	0.488	0.522	5.78	8.38	23.39	92.17
1.6229	5.13	0.0	0.0	0.154	0.484	0.546	2.99	9.81	23.99	92.24
1.6329	5.09	0.0	0.0	0.154	0.481	0.569	0.15	11.28	24.59	92.30
1.6429	5.04	0.0	0.0	0.155	0.477	0.588	-2.77	12.77	25.18	92.37
1.6529	5.00	0.0	0.0	0.156	0.470	0.582	-5.86	14.20	25.78	92.43
1.6629	4.95	0.0	0.0	0.156	0.467	0.598	-9.06	15.59	26.39	92.50
1.6729	4.91	0.0	0.0	0.156	0.465	0.616	-12.29	16.97	27.00	92.56
1.6829	4.86	0.0	0.0	0.155	0.461	0.640	-15.62	18.39	27.63	92.62
1.6929	4.81	0.0	0.0	0.155	0.458	0.659	-18.97	19.87	28.28	92.68
1.7029	4.75	0.0	0.0	0.154	0.459	0.645	-22.30	21.36	28.95	92.74
1.7129	4.70	0.0	0.0	0.154	0.463	0.626	-25.32	22.88	29.65	92.79
1.7229	4.64	0.0	0.0	0.154	0.465	0.624	-28.03	24.25	30.38	92.84
1.7329	4.57	0.0	0.0	0.153	0.468	0.618	-30.52	25.55	31.14	92.88
1.7429	4.50	0.0	0.0	0.153	0.470	0.609	-32.75	26.79	31.92	92.92
1.7529	4.42	0.0	0.0	0.152	0.530	0.597	-35.09	27.91	32.56	92.96
1.7629	4.33	0.0	0.0	0.152	0.612	0.562	-37.87	28.90	32.86	92.99
1.7729	4.24	0.0	0.0	0.157	0.634	0.497	-40.79	29.61	32.96	93.01
1.7829	4.13	0.0	0.0	0.165	0.646	0.430	-43.50	29.99	33.00	93.03
1.7929	4.01	0.0	0.0	0.175	0.664	0.347	-45.82	29.97	32.98	93.05
1.8029	3.88	0.0	0.0	0.182	0.695	0.259	-47.67	29.51	32.86	93.07
1.8128	3.74	0.0	0.0	0.187	0.724	0.175	-49.03	28.59	32.60	93.09
1.8228	3.58	0.0	0.0	0.187	0.735	0.106	-49.78	27.28	32.25	93.10
1.8328	3.41	0.0	0.0	0.186	0.729	0.055	-49.85	25.68	31.87	93.11
1.8428	3.22	0.0	0.0	0.184	0.722	0.021	-49.26	23.88	31.50	93.12
1.8528	3.02	0.0	0.0	0.184	0.724	-0.000	-48.15	22.01	31.10	93.12
1.8628	2.80	0.0	0.0	0.187	0.728	-0.007	-46.59	20.09	30.65	93.13
1.8728	2.56	0.0	0.0	0.194	0.720	-0.017	-44.50	18.14	30.15	93.14
1.8828	2.31	0.0	0.0	0.203	0.691	-0.039	-41.80	16.14	29.65	93.15
1.8928	2.05	0.0	0.0	0.212	0.660	-0.076	-38.28	14.06	29.10	93.16
1.9028	1.77	0.0	0.0	0.187	0.807	-0.179	-34.82	11.91	28.51	93.17
1.9128	1.49	0.0	0.0	0.142	0.748	-0.378	-32.14	9.52	28.12	93.18
1.9228	1.19	0.0	0.0	0.012	0.627	-0.807	-27.58	6.47	27.25	93.16
1.9328	0.89	0.0	0.0	0.149	0.727	-1.226	-23.41	2.91	26.30	93.14
1.9428	0.58	0.0	0.0	0.219	0.828	-1.390	-21.66	-0.39	25.49	93.16
1.9528	0.26	0.0	0.0	0.220	0.829	-2.771	-22.53	-3.32	24.50	93.20
1.9608	-0.01	0.0	0.0	0.191	0.834	-3.095	-35.63	-1.64	23.48	93.22
1.9708	-0.34	0.0	0.0	-0.802	0.251	-3.566	-43.23	-1.93	22.39	93.14
1.9808	-0.65	0.0	0.0	-1.398	-0.164	-9.543	-81.53	9.95	21.17	92.76
1.9908	-0.94	0.0	0.0	-1.325	0.297	-5.404	-143.55	30.22	19.71	92.27
2.0008	-1.21	0.0	0.0	-1.063	0.828	-8.765	-158.71	41.89	19.89	91.87
2.0128	-1.51	0.0	0.0	-1.504	1.242	-8.478	-142.09	59.95	18.04	91.38
2.0228	-1.74	0.0	0.0	-1.155	1.613	-9.499	-91.12	69.11	14.44	90.95
2.0328	-1.98	0.0	0.0	-1.064	0.908	-3.648	-44.87	79.93	10.97	90.69

Avg=1.252 Avg=0.787 Avg=7.556

*** ACCELERATIONS AVERAGED OVER *** 50 MILLISECONDS

FIGURE 6

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

ROLL (FIG. 15) — PITCH (FIG. 15) — YAW (FIG. 15)

TIME SEC.	SPACE FIXED COORDINATES POSITION (INCHES) FIG. 15			SPRUNG MASS CG ORIENTATION (DEGREES)			VELOCITY (FT /SEC.)		TERRAIN ELEVATION AT GCP (SEE FIG. 15) (INCHES)			
	X'	Y'	Z'	PHI (ϕ)	THETA (θ)	PSI (ψ)	LAT.	VERT.	RF	LF	RR	LR
1.5329	1709.34	828.35	250.08	17.61	-11.70	25.44	2.98	-7.95	291.50	274.73	274.14	257.71
1.5429	1718.94	833.62	251.53	17.81	-11.76	25.62	2.80	-7.87	293.19	276.45	275.70	259.30
1.5529	1728.54	838.91	253.01	17.99	-11.82	25.81	2.62	-7.76	294.89	278.19	277.26	260.89
1.5629	1738.14	844.21	254.50	18.14	-11.87	26.01	2.44	-7.64	296.60	279.93	278.84	262.50
1.5729	1747.73	849.52	256.02	18.27	-11.91	26.22	2.24	-7.48	298.32	281.68	280.43	264.12
1.5829	1757.31	854.85	257.55	18.38	-11.94	26.43	2.04	-7.29	300.05	283.45	282.04	265.75
1.5929	1766.89	860.19	259.11	18.45	-11.96	26.66	1.84	-7.07	301.79	285.22	283.65	267.40
1.6029	1776.47	865.54	260.69	18.50	-11.97	26.90	1.62	-6.81	303.54	287.01	285.28	269.06
1.6129	1786.04	870.90	262.30	18.52	-11.97	27.15	1.40	-6.53	305.30	288.81	286.92	270.74
1.6229	1795.61	876.27	263.93	18.51	-11.96	27.41	1.17	-6.21	307.07	290.62	288.57	272.43
1.6329	1805.17	881.65	265.59	18.47	-11.94	27.68	0.93	-5.86	308.85	292.44	290.23	274.13
1.6429	1814.73	887.04	267.28	18.40	-11.90	27.96	0.69	-5.48	310.65	294.27	291.90	275.85
1.6529	1824.28	892.44	269.00	18.30	-11.85	28.25	0.43	-5.08	312.45	296.12	293.59	277.58
1.6629	1833.83	897.85	270.74	18.16	-11.79	28.55	0.17	-4.64	314.26	297.98	295.28	279.31
1.6729	1843.37	903.27	272.51	17.99	-11.72	28.86	-0.10	-4.18	316.09	299.85	296.98	281.06
1.6829	1852.91	908.69	274.31	17.79	-11.64	29.18	-0.39	-3.70	317.92	301.73	298.68	282.81
1.6929	1862.45	914.13	276.14	17.55	-11.54	29.51	-0.68	-3.18	319.77	303.63	300.39	284.57
1.7029	1871.98	919.57	278.00	17.27	-11.43	29.85	-0.99	-2.63	321.63	305.54	302.10	286.33
1.7129	1881.50	925.02	279.89	16.96	-11.30	30.21	-1.30	-2.07	323.50	307.46	303.82	288.09
1.7229	1891.02	930.48	281.81	16.62	-11.16	30.57	-1.63	-1.50	325.37	309.39	305.53	289.86
1.7329	1900.54	935.95	283.75	16.26	-11.01	30.94	-1.97	-0.90	327.26	311.33	307.26	291.64
1.7429	1910.05	941.43	285.73	15.87	-10.85	31.32	-2.33	-0.29	329.16	313.29	308.99	293.42
1.7529	1919.55	946.91	287.73	15.46	-10.67	31.71	-2.69	0.34	331.07	315.25	310.72	295.22
1.7629	1929.05	952.41	289.77	15.02	-10.48	32.11	-3.04	0.97	332.98	317.23	312.47	297.02
1.7729	1938.54	957.93	291.83	14.55	-10.28	32.51	-3.38	1.59	334.91	319.21	314.23	298.84
1.7829	1948.02	963.46	293.91	14.06	-10.07	32.91	-3.72	2.20	336.85	321.21	315.99	300.66
1.7929	1957.49	969.01	296.02	13.54	-9.86	33.31	-4.07	2.78	338.79	323.21	317.75	302.48
1.8029	1966.96	974.58	298.15	13.01	-9.65	33.70	-4.41	3.33	340.75	325.23	319.51	304.29
1.8128	1976.41	980.18	300.30	12.46	-9.43	34.09	-4.74	3.83	342.71	327.25	321.26	306.11
1.8228	1985.85	985.79	302.46	11.90	-9.23	34.47	-5.07	4.29	344.69	329.27	323.03	307.92
1.8328	1995.28	991.43	304.62	11.35	-9.03	34.84	-5.39	4.70	346.67	331.30	324.80	309.74
1.8428	2004.71	997.10	306.80	10.79	-8.85	35.21	-5.72	5.06	348.65	333.34	326.58	311.58
1.8528	2014.12	1002.79	308.99	10.25	-8.68	35.56	-6.04	5.39	350.64	335.38	328.38	313.43
1.8628	2023.52	1008.51	311.18	9.73	-8.53	35.91	-6.35	5.68	352.64	337.42	330.19	315.30
1.8728	2032.91	1014.26	313.38	9.22	-8.39	36.24	-6.66	5.94	354.63	339.46	332.02	317.18
1.8828	2042.28	1020.03	315.58	8.74	-8.26	36.57	-6.96	6.15	356.63	341.51	333.85	319.06
1.8928	2051.65	1025.83	317.78	8.29	-8.16	36.88	-7.27	6.33	358.63	343.55	335.68	320.95
1.9028	2061.01	1031.65	319.99	7.89	-8.07	37.19	-7.55	6.46	360.00	345.59	337.51	322.82
1.9128	2070.36	1037.51	322.19	7.51	-8.00	37.49	-7.78	6.50	360.00	347.64	339.35	324.70
1.9228	2079.69	1043.39	324.39	7.17	-7.96	37.77	-8.05	6.41	360.00	349.69	341.18	326.58
1.9328	2089.01	1049.29	326.55	6.88	-7.94	38.05	-8.29	6.11	360.00	351.73	343.04	328.49
1.9428	2098.32	1055.24	328.68	6.62	-7.96	38.31	-8.48	5.68	360.00	353.77	344.91	330.42
1.9528	2107.62	1061.22	330.76	6.37	-8.01	38.56	-8.64	5.04	360.00	355.82	346.77	332.33
1.9608	2115.05	1066.03	332.34	6.11	-8.05	38.75	-8.77	4.02	360.00	357.46	348.27	333.86
1.9708	2124.32	1072.10	334.22	5.68	-8.09	38.98	-8.96	2.98	360.00	360.00	350.18	335.81
1.9808	2133.58	1078.18	335.95	5.08	-8.09	39.20	-9.29	1.26	360.00	360.00	352.09	337.75
1.9908	2142.81	1084.28	337.40	3.86	-7.88	39.42	-9.61	-1.15	360.00	360.00	354.04	339.69
2.0008	2152.02	1090.38	338.57	2.28	-7.54	39.64	-9.72	-3.25	360.00	360.00	356.03	341.68
2.0128	2163.03	1097.75	339.52	0.45	-6.92	39.89	-9.62	-6.18	360.00	360.00	358.43	344.03
2.0228	2172.17	1103.92	339.91	-0.75	-6.28	40.05	-9.34	-8.50	360.00	360.00	360.00	345.97
2.0328	2181.27	1110.12	339.96	-1.39	-5.55	40.16	-9.05	-9.60	360.00	360.00	360.00	347.95

FIGURE 7

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	DEFLECTIONS (IN. AND DEG.)			UNSPRUNG MASSES	VELOCITIES (IN./SEC. , DEG./SEC.)				FRONT WHEEL CAMBER (DEG.)	
	DELTA 1	DELTA 2	DELTA 3	PHI R	D(DEL1)/DT	D(DEL2)/DT	D(DEL3)/DT	D(PHIR)/DT	PHI 1	PHI 2
1.5329	-0.35	0.77	4.46	0.64	8.93	30.23	-29.98	37.94	-0.70	0.34
1.5429	-0.25	1.07	4.19	1.00	10.58	29.46	-23.66	32.78	-0.66	0.29
1.5529	-0.14	1.36	3.99	1.30	12.32	28.82	-16.41	27.35	-0.61	0.27
1.5629	-0.01	1.64	3.86	1.54	13.76	28.08	-8.90	21.47	-0.55	0.27
1.5729	0.13	1.92	3.80	1.72	14.55	27.13	-2.79	13.02	-0.51	0.29
1.5829	0.28	2.18	3.81	1.80	14.76	25.69	2.61	4.55	-0.46	0.31
1.5929	0.43	2.43	3.85	1.82	14.65	23.68	6.11	-1.64	-0.42	0.33
1.6029	0.57	2.65	3.92	1.77	14.36	21.34	8.79	-7.64	-0.39	0.35
1.6129	0.71	2.86	4.02	1.67	14.19	18.89	10.57	-13.26	-0.36	0.38
1.6229	0.86	3.03	4.13	1.51	14.35	16.53	11.46	-18.28	-0.33	0.40
1.6329	1.00	3.19	4.25	1.30	14.87	14.39	11.53	-22.46	-0.30	0.42
1.6429	1.16	3.32	4.36	1.06	15.64	12.47	10.93	-25.57	-0.28	0.44
1.6529	1.32	3.44	4.47	0.80	16.51	10.58	10.46	-26.20	-0.27	0.46
1.6629	1.49	3.53	4.57	0.55	17.25	8.63	9.95	-24.87	-0.27	0.47
1.6729	1.66	3.61	4.67	0.31	17.70	6.53	9.02	-22.52	-0.27	0.49
1.6829	1.84	3.66	4.75	0.10	17.88	4.16	7.38	-18.28	-0.28	0.49
1.6929	2.02	3.69	4.81	-0.05	17.89	1.56	4.71	-12.68	-0.30	0.50
1.7029	2.20	3.69	4.84	-0.15	17.88	-0.26	1.82	-5.37	-0.31	0.50
1.7129	2.38	3.69	4.85	-0.16	17.95	-0.12	-0.82	1.35	-0.33	0.50
1.7229	2.56	3.69	4.83	-0.13	18.13	-1.13	-2.27	5.37	-0.34	0.50
1.7329	2.74	3.67	4.80	-0.06	18.48	-3.88	-3.36	7.84	-0.36	0.49
1.7429	2.93	3.61	4.77	0.02	18.86	-7.82	-3.89	8.71	-0.39	0.49
1.7529	3.12	3.51	4.72	0.09	19.29	-12.16	-5.13	2.57	-0.41	0.47
1.7629	3.31	3.37	4.64	0.07	19.72	-16.03	-12.61	-6.15	-0.44	0.45
1.7729	3.51	3.19	4.45	0.01	19.88	-18.62	-27.40	-2.32	-0.47	0.42
1.7829	3.71	3.00	4.08	0.06	19.67	-19.68	-46.12	13.71	-0.50	0.40
1.7929	3.90	2.80	3.53	0.31	19.22	-19.65	-64.42	36.30	-0.53	0.37
1.8029	4.09	2.61	2.81	0.78	18.74	-19.37	-77.84	57.44	-0.57	0.35
1.8128	4.28	2.41	2.00	1.43	18.35	-19.60	-83.44	70.06	-0.61	0.33
1.8228	4.46	2.21	1.17	2.14	18.01	-20.72	-80.44	70.90	-0.65	0.31
1.8328	4.64	1.99	0.41	2.81	17.53	-22.64	-70.25	61.19	-0.70	0.30
1.8428	4.81	1.76	-0.22	3.35	16.73	-24.90	-55.93	45.33	-0.74	0.28
1.8528	4.97	1.50	-0.71	3.72	15.47	-26.95	-41.26	28.86	-0.79	0.27
1.8628	5.11	1.22	-1.06	3.94	13.22	-28.26	-29.67	17.11	-0.80	0.28
1.8728	5.23	0.94	-1.32	4.09	9.34	-28.59	-23.45	13.68	-0.80	0.31
1.8828	5.30	0.65	-1.55	4.24	4.87	-28.00	-23.29	19.20	-0.80	0.37
1.8928	5.33	0.38	-1.80	4.49	1.05	-26.74	-28.12	30.36	-0.80	0.44
1.9028	5.32	0.12	-2.12	4.85	-6.37	-25.63	-35.45	41.10	-0.80	0.51
1.9128	5.02	-0.14	-2.50	5.29	-61.11	-25.34	-40.51	44.10	-0.80	0.61
1.9228	3.86	-0.39	-2.89	5.66	-200.35	-25.40	-35.35	25.46	-0.53	0.71
1.9328	1.10	-0.66	-3.16	5.71	-312.24	-28.33	-15.73	-15.40	-0.29	0.82
1.9428	-2.05	-0.97	-3.27	5.55	-307.78	-35.08	-12.53	0.03	-1.32	0.94
1.9528	-4.83	-1.35	-3.43	5.82	-222.46	-40.67	-15.57	43.95	-3.36	1.06
1.9608	-5.56	-1.67	-3.48	6.15	38.18	-38.10	6.30	30.13	-3.55	1.17
1.9708	-4.73	-2.00	-3.29	6.33	23.18	-21.79	24.75	23.13	-3.26	1.30
1.9808	-6.17	-2.19	-3.10	6.92	-194.19	-27.38	14.18	100.23	-3.55	1.38
1.9908	-6.46	-3.12	-2.90	8.17	5.62	-211.10	35.08	121.79	-3.55	1.88
2.0008	-6.42	-5.75	-2.39	9.29	5.55	-177.48	57.32	116.22	-3.55	3.55
2.0128	-6.18	-5.60	-1.76	11.03	46.79	29.66	53.80	165.28	-3.55	3.55
2.0228	-5.91	-5.97	-1.04	12.42	67.68	-54.73	88.12	96.56	-3.55	3.55
2.0328	-5.35	-5.99	-0.18	12.86	54.92	13.68	66.42	-7.03	-3.55	3.55

FIGURE 8

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	CAMBER, STEER ANGLES RELATIVE TO GROUND PLANES								SUSPENSION FORCES (POUNDS)			
	PHI CG (DEG.)				PSI* (DEG.)							
	RF	LF	RR	LR	RF	LF	RR	LR	RF	LF	RR	LR
1.5329	0.32	1.35	2.00	2.00	5.52	5.51	0.04	0.04	1172.3	791.3	70.6	393.4
1.5429	0.58	1.53	2.58	2.58	5.47	5.47	0.07	0.07	1168.2	740.5	113.7	448.1
1.5529	0.84	1.72	3.09	3.09	5.43	5.42	0.09	0.09	1159.7	692.0	126.2	480.2
1.5629	1.08	1.90	3.51	3.51	5.38	5.38	0.11	0.11	1148.6	646.3	110.6	490.6
1.5729	1.29	2.08	3.84	3.84	5.34	5.33	0.12	0.12	1136.8	603.8	-6.8	482.0
1.5829	1.47	2.24	4.07	4.07	5.29	5.29	0.13	0.13	1125.2	565.8	-33.9	356.3
1.5929	1.63	2.38	4.19	4.19	5.25	5.25	0.13	0.13	1113.4	533.3	-63.2	325.8
1.6029	1.75	2.50	4.23	4.23	5.21	5.20	0.12	0.12	1101.2	506.2	-92.1	286.7
1.6129	1.85	2.59	4.18	4.18	5.16	5.16	0.12	0.12	1087.2	484.3	-117.7	241.6
1.6229	1.92	2.65	4.05	4.05	5.12	5.12	0.11	0.11	1070.5	466.9	-136.6	192.9
1.6329	1.96	2.68	3.85	3.85	5.08	5.07	0.09	0.09	1050.2	453.5	-145.5	143.1
1.6429	1.96	2.69	3.59	3.59	5.03	5.03	0.07	0.07	1026.3	444.0	-142.2	94.5
1.6529	1.93	2.66	3.27	3.27	4.99	4.98	0.06	0.06	998.9	438.7	-33.3	48.4
1.6629	1.86	2.60	2.93	2.93	4.94	4.94	0.04	0.04	968.9	438.2	-27.1	6.9
1.6729	1.75	2.51	2.57	2.57	4.90	4.89	0.02	0.02	937.4	442.7	-21.5	-40.5
1.6829	1.61	2.38	2.21	2.21	4.85	4.85	0.01	0.01	904.5	452.8	-16.6	-119.3
1.6929	1.42	2.22	1.87	1.87	4.80	4.80	-0.00	-0.00	870.3	468.9	-9.3	-181.3
1.7029	1.21	2.02	1.56	1.56	4.75	4.75	-0.01	-0.01	834.4	597.4	-5.1	-211.8
1.7129	0.97	1.79	1.30	1.30	4.69	4.69	-0.01	-0.01	797.8	609.8	-2.7	-100.0
1.7229	0.70	1.54	1.06	1.06	4.64	4.63	-0.01	-0.01	760.3	627.3	-3.7	-64.1
1.7329	0.40	1.26	0.82	0.82	4.57	4.57	-0.00	-0.00	720.4	654.8	-3.4	-14.1
1.7429	0.07	0.94	0.58	0.58	4.50	4.50	0.00	0.00	677.1	693.6	-4.2	37.0
1.7529	-0.28	0.61	0.30	0.30	4.42	4.42	0.01	0.01	629.8	742.7	18.3	74.3
1.7629	-0.65	0.24	-0.09	-0.09	4.33	4.33	0.00	0.00	578.6	798.9	114.8	126.7
1.7729	-1.05	-0.16	-0.54	-0.54	4.24	4.24	0.00	0.00	525.4	857.5	263.0	258.2
1.7829	-1.48	-0.58	-0.92	-0.92	4.13	4.13	0.00	0.00	472.3	914.4	376.0	431.7
1.7929	-1.94	-1.03	-1.12	-1.12	4.01	4.01	0.02	0.02	420.4	968.1	493.1	670.4
1.8029	-2.42	-1.50	-1.11	-1.11	3.88	3.88	0.05	0.05	369.7	1020.2	601.8	941.7
1.8128	-2.92	-1.98	-0.94	-0.94	3.73	3.73	0.10	0.10	319.7	1073.6	694.5	1205.2
1.8228	-3.44	-2.47	-0.72	-0.72	3.57	3.57	0.15	0.15	269.7	1131.1	767.8	1425.8
1.8328	-3.96	-2.96	-0.54	-0.54	3.40	3.40	0.20	0.20	219.9	1194.4	821.5	1583.8
1.8428	-4.48	-3.46	-0.49	-0.49	3.21	3.21	0.23	0.23	170.9	1262.7	858.1	1678.5
1.8528	-5.00	-3.94	-0.60	-0.60	3.00	3.01	0.26	0.26	124.1	1334.0	882.6	1725.6
1.8628	-5.47	-4.39	-0.83	-0.83	2.78	2.79	0.28	0.28	47.5	1405.0	900.7	1751.8
1.8728	-5.91	-4.80	-1.13	-1.13	2.55	2.55	0.29	0.29	-22.8	1472.0	917.2	1787.0
1.8828	-6.33	-5.16	-1.39	-1.39	2.30	2.30	0.30	0.30	-72.0	1532.4	935.8	1855.0
1.8928	-6.73	-5.49	-1.53	-1.53	2.03	2.04	0.31	0.31	-97.7	1585.6	960.9	1965.1
1.9028	6.76	-5.77	-1.52	-1.52	1.74	1.76	0.34	0.34	83.3	1633.9	997.0	2133.9
1.9128	6.43	-6.01	-1.40	-1.40	1.46	1.48	0.37	0.37	370.3	1663.4	1041.5	2607.9
1.9228	6.41	-6.21	-1.31	-1.31	1.17	1.19	0.40	0.40	1079.5	1631.4	1088.6	3681.8
1.9328	6.40	-6.35	-1.49	-1.49	0.88	0.88	0.40	0.40	2009.8	1498.4	1121.5	4603.1
1.9428	5.17	-6.46	-1.86	-1.86	0.57	0.57	0.39	0.39	2609.5	1360.7	1122.5	4831.4
1.9528	2.94	-6.56	-1.80	-1.80	0.25	0.25	0.41	0.41	7075.2	1258.8	969.3	6392.4
1.9608	2.53	-6.69	-1.69	-1.69	-0.01	-0.01	0.43	0.43	7357.3	1262.5	882.4	7549.6
1.9708	2.45	6.96	-1.88	-1.88	-0.34	-0.33	0.44	0.44	3632.4	1329.7	766.0	6562.8
1.9808	1.61	6.48	-1.86	-1.86	-0.65	-0.64	0.48	0.48	23065.4	1285.8	588.9	7117.7
1.9908	0.43	5.81	-1.78	-1.78	-0.93	-0.93	0.57	0.57	15099.9	2132.5	307.7	9608.1
2.0008	-1.10	5.94	-2.18	-2.18	-1.20	-1.20	0.65	0.65	14477.9	15813.6	20.1	8973.0
2.0128	-2.90	4.15	-2.22	-2.22	-1.49	-1.49	0.77	0.77	11883.8	7354.6	-341.5	9876.8
2.0228	-4.08	2.98	11.51	-1.98	-1.73	-1.73	0.85	0.86	9459.1	18728.9	-644.8	8239.5
2.0328	-4.73	2.34	11.32	-2.17	-1.97	-1.97	0.88	0.89	5785.5	10361.7	-857.2	4038.5

FIGURE 9

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	HUB VELOCITY PARALLEL TO GROUND PLANES (FT./SEC.) LONGITUDINAL				LATERAL				VERTICAL TIRE FORCES (POUNDS)			
	RF	LF	RR	LR	RF	LF	RR	LR	RF	LF	RR	LR
1.5329	91.05	92.69	91.17	93.11	3.73	3.69	-0.28	-0.09	-1064.6	-710.3	0.0	0.0
1.5429	91.09	92.80	91.20	93.16	3.71	3.67	-0.32	-0.10	-1047.6	-653.3	0.0	0.0
1.5529	91.13	92.90	91.22	93.20	3.68	3.63	-0.36	-0.14	-1039.0	-604.2	0.0	0.0
1.5629	91.18	93.00	91.25	93.23	3.63	3.59	-0.40	-0.19	-1037.7	-565.3	0.0	0.0
1.5729	91.22	93.11	91.28	93.26	3.58	3.54	-0.40	-0.23	-1040.3	-535.0	0.0	0.0
1.5829	91.28	93.22	91.33	93.29	3.52	3.48	-0.41	-0.29	-1041.7	-512.0	0.0	0.0
1.5929	91.33	93.33	91.37	93.34	3.45	3.42	-0.45	-0.39	-1037.7	-491.5	0.0	0.0
1.6029	91.39	93.44	91.43	93.40	3.38	3.36	-0.50	-0.49	-1024.4	-470.7	0.0	0.0
1.6129	91.45	93.55	91.48	93.46	3.31	3.29	-0.56	-0.61	-1003.3	-448.9	0.0	0.0
1.6229	91.51	93.67	91.54	93.53	3.22	3.21	-0.64	-0.74	-975.9	-427.1	0.0	0.0
1.6329	91.56	93.78	91.60	93.61	3.12	3.12	-0.75	-0.88	-946.9	-406.8	0.0	0.0
1.6429	91.62	93.89	91.66	93.70	3.01	3.02	-0.89	-1.04	-919.2	-391.5	0.0	0.0
1.6529	91.67	93.99	91.72	93.80	2.90	2.92	-1.08	-1.24	-895.6	-384.3	0.0	0.0
1.6629	91.72	94.10	91.76	93.90	2.78	2.81	-1.32	-1.47	-874.5	-384.4	0.0	0.0
1.6729	91.77	94.20	91.81	94.01	2.66	2.70	-1.59	-1.72	-854.2	-392.6	0.0	0.0
1.6829	91.82	94.31	91.85	94.13	2.53	2.57	-1.90	-2.01	-831.6	-407.3	0.0	0.0
1.6929	91.87	94.41	91.89	94.25	2.40	2.44	-2.24	-2.33	-805.1	-425.7	0.0	0.0
1.7029	91.91	94.51	91.93	94.37	2.25	2.30	-2.62	-2.69	-773.3	-449.2	0.0	0.0
1.7129	91.96	94.60	91.97	94.49	2.08	2.12	-3.02	-3.06	-734.9	-493.2	0.0	0.0
1.7229	91.99	94.70	92.01	94.60	1.90	1.93	-3.39	-3.42	-694.1	-557.8	0.0	0.0
1.7329	92.02	94.80	92.04	94.71	1.70	1.73	-3.75	-3.78	-652.8	-627.7	0.0	0.0
1.7429	92.04	94.89	92.07	94.81	1.48	1.50	-4.11	-4.13	-613.8	-687.4	0.0	0.0
1.7529	92.07	94.97	92.11	94.90	1.26	1.27	-4.33	-4.33	-577.6	-727.3	-258.4	-0.3
1.7629	92.10	95.02	92.16	94.98	1.04	1.03	-4.46	-4.46	-543.2	-749.9	-516.1	-613.5
1.7729	92.14	95.05	92.20	95.05	0.83	0.80	-4.78	-4.78	-507.6	-764.7	-667.2	-1248.2
1.7829	92.17	95.07	92.21	95.09	0.61	0.56	-5.31	-5.31	-468.2	-786.0	-711.5	-1710.8
1.7929	92.20	95.08	92.21	95.08	0.38	0.30	-5.96	-5.96	-422.4	-825.3	-674.6	-1897.5
1.8029	92.22	95.08	92.20	95.03	0.14	0.03	-6.62	-6.62	-371.9	-888.6	-595.6	-1800.4
1.8128	92.24	95.07	92.19	94.95	-0.12	-0.25	-7.14	-7.14	-319.8	-972.0	-509.4	-1512.1
1.8228	92.26	95.05	92.18	94.87	-0.39	-0.55	-7.46	-7.46	-269.9	-1067.3	-439.4	-1183.5
1.8328	92.26	95.02	92.18	94.82	-0.69	-0.88	-7.57	-7.57	-225.8	-1160.8	-402.0	-954.9
1.8428	92.27	94.98	92.18	94.81	-1.00	-1.23	-7.56	-7.56	-189.2	-1244.8	-406.6	-911.3
1.8528	92.27	94.94	92.18	94.83	-1.33	-1.60	-7.52	-7.52	-159.1	-1312.9	-455.0	-1082.0
1.8628	92.27	94.90	92.19	94.85	-1.68	-1.97	-7.56	-7.56	-132.4	-1369.5	-546.2	-1447.4
1.8728	92.26	94.85	92.21	94.84	-2.07	-2.35	-7.76	-7.76	-97.4	-1419.9	-672.5	-1936.5
1.8828	92.25	94.82	92.23	94.80	-2.48	-2.75	-8.15	-8.15	-49.4	-1472.1	-824.4	-2435.6
1.8928	92.25	94.78	92.24	94.71	-2.92	-3.17	-8.70	-8.70	-1.3	-1531.5	-986.6	-2797.9
1.9028	90.76	94.75	92.24	94.61	-4.28	-3.56	-9.23	-9.23	-857.8	-1598.0	-1137.3	-2952.3
1.9128	91.34	94.70	92.20	94.52	-4.18	-3.89	-9.61	-9.61	-2749.8	-1667.1	-1245.7	-2943.3
1.9228	92.86	94.59	92.14	94.47	-3.34	-4.36	-9.63	-9.63	-7575.2	-1723.3	-1288.4	-2898.7
1.9328	94.07	94.45	92.08	94.54	-2.86	-4.84	-9.18	-9.18	-2932.8	-1739.5	-1261.6	-3252.4
1.9428	94.04	94.34	92.10	94.44	-3.36	-5.25	-9.61	-9.61	-1734.6	-1669.0	-1185.3	-6501.9
1.9528	93.18	94.25	92.18	94.23	-4.48	-5.56	-10.41	-10.41	-968.4	-1492.2	-1176.6	-5888.0
1.9608	90.45	94.23	92.26	94.35	-6.61	-5.40	-9.75	-9.75	-1818.1	-1295.7	-1214.2	-5086.1
1.9708	90.77	92.70	92.21	94.28	-6.52	-6.15	-9.42	-9.42	-16433.2	-837.4	-1222.7	-7181.5
1.9808	93.70	92.61	92.07	93.71	-4.25	-5.49	-9.83	-9.83	-16527.7	-2960.9	-1228.4	-7177.8
1.9908	92.00	94.59	91.96	93.42	-4.67	-3.46	-8.29	-8.29	-20165.2	-11289.5	-1212.9	-6295.8
2.0008	92.16	94.07	91.79	93.20	-4.61	-4.01	-7.48	-7.48	-20941.1	-3073.1	-1078.2	-9695.1
2.0128	91.88	92.14	91.90	92.30	-5.27	-5.26	-8.35	-8.35	-16968.8	-17932.3	-896.9	-9335.2
2.0228	91.56	93.04	90.73	91.90	-6.43	-6.56	-9.28	-7.68	-10561.2	-18744.4	-1604.1	-6642.7
2.0328	91.63	92.47	91.59	91.63	-7.50	-7.58	-8.13	-7.33	-5677.4	-15128.9	-6955.2	-5201.6

FIGURE 10

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	CIRCUMFERENTIAL TIRE FORCES (POUNDS)				TIRE SIDE FORCES (POUNDS)			
	RF	LF	RR	LR	RF	LF	RR	LR
1.5329	0.0	0.0	0.0	0.0	535.01	506.02	0.0	0.0
1.5429	0.0	0.0	0.0	0.0	534.91	489.92	0.0	0.0
1.5529	0.0	0.0	0.0	0.0	536.19	475.40	0.0	0.0
1.5629	0.0	0.0	0.0	0.0	538.76	463.49	0.0	0.0
1.5729	0.0	0.0	0.0	0.0	542.37	454.64	0.0	0.0
1.5829	0.0	0.0	0.0	0.0	545.99	447.95	0.0	0.0
1.5929	0.0	0.0	0.0	0.0	548.55	441.45	0.0	0.0
1.6029	0.0	0.0	0.0	0.0	550.02	434.66	0.0	0.0
1.6129	0.0	0.0	0.0	0.0	550.57	427.34	0.0	0.0
1.6229	0.0	0.0	0.0	0.0	550.08	419.80	0.0	0.0
1.6329	0.0	0.0	0.0	0.0	549.31	412.78	0.0	0.0
1.6429	0.0	0.0	0.0	0.0	548.41	407.92	0.0	0.0
1.6529	0.0	0.0	0.0	0.0	547.59	406.50	0.0	0.0
1.6629	0.0	0.0	0.0	0.0	546.63	408.39	0.0	0.0
1.6729	0.0	0.0	0.0	0.0	545.38	414.01	0.0	0.0
1.6829	0.0	0.0	0.0	0.0	542.97	422.38	0.0	0.0
1.6929	0.0	0.0	0.0	0.0	539.10	432.23	0.0	0.0
1.7029	0.0	0.0	0.0	0.0	533.75	444.04	0.0	0.0
1.7129	0.0	0.0	0.0	0.0	526.94	464.89	0.0	0.0
1.7229	0.0	0.0	0.0	0.0	519.39	492.25	0.0	0.0
1.7329	0.0	0.0	0.0	0.0	511.02	519.08	0.0	0.0
1.7429	0.0	0.0	0.0	0.0	502.72	540.67	0.0	0.0
1.7529	0.0	0.0	0.0	0.0	493.70	554.46	280.39	1.52 *
1.7629	0.0	0.0	0.0	0.0	482.61	560.94	369.69	382.92
1.7729	0.0	0.0	0.0	0.0	468.94	563.34	425.20	478.24
1.7829	0.0	0.0	0.0	0.0	452.48	565.77	474.58	493.57
1.7929	0.0	0.0	0.0	0.0	432.52	570.49	521.00	516.00
1.8029	0.0	0.0	0.0	0.0	409.40	577.42	555.41	595.72
1.8128	0.0	0.0	0.0	0.0	384.01	583.83	569.91	696.38
1.8228	0.0	0.0	0.0	0.0	357.99	587.14	567.20	747.07
1.8328	0.0	0.0	0.0	0.0	333.09	585.90	561.11	742.51
1.8428	0.0	0.0	0.0	0.0	310.58	580.23	567.05	739.38
1.8528	0.0	0.0	0.0	0.0	290.11	571.41	592.12	763.81
1.8628	0.0	0.0	0.0	0.0	270.14	560.20	637.66	768.88
1.8728	0.0	0.0	0.0	0.0	240.26	547.21	701.04	684.90
1.8828	0.0	0.0	0.0	0.0	176.91	532.79	778.70	496.21
1.8928	0.0	0.0	0.0	0.0	5.62 *	518.04	861.54	383.83
1.9028	0.0	0.0	0.0	0.0	723.16	498.54	932.09	410.33
1.9128	0.0	0.0	0.0	0.0	529.90	470.42	977.89	432.04
1.9228	0.0	0.0	0.0	0.0	382.73	456.30	986.48	437.01
1.9328	0.0	0.0	0.0	0.0	331.77	450.09	944.04	414.16
1.9428	0.0	0.0	0.0	0.0	575.51	449.07	969.29	429.29
1.9528	0.0	0.0	0.0	0.0	520.52	447.27	1040.70	468.58
1.9608	0.0	0.0	0.0	0.0	745.96	398.97	990.62	441.42
1.9708	0.0	0.0	0.0	0.0	343.41	603.21	961.18	425.78
1.9808	0.0	0.0	0.0	0.0	185.94	343.11	1004.17	450.55
1.9908	0.0	0.0	0.0	0.0	161.16	214.29	883.40	389.27
2.0008	0.0	0.0	0.0	0.0	102.39	221.00	803.69	350.95
2.0128	0.0	0.0	0.0	0.0	72.37	227.07	863.35	403.12
2.0228	0.0	0.0	0.0	0.0	85.80	242.97	1278.95	384.88
2.0328	0.0	0.0	0.0	0.0	104.26	260.22	674.60	366.85

FIGURE 11

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	ACCELERATION COMPONENTS AT POINTS 1 AND 2 ON SPRUNG MASS (G-UNITS)					
	AX1	AY1	AZ1	AX2	AY2	AZ2
1.5329	0.178	0.422	0.563	0.219	0.518	0.550
1.5429	0.180	0.427	0.525	0.218	0.518	0.542
1.5529	0.181	0.431	0.510	0.217	0.519	0.546
1.5629	0.183	0.435	0.516	0.217	0.519	0.562
1.5729	0.186	0.438	0.574	0.218	0.520	0.597
1.5829	0.189	0.441	0.643	0.218	0.521	0.669
1.5929	0.191	0.442	0.672	0.219	0.521	0.699
1.6029	0.193	0.443	0.704	0.219	0.520	0.730
1.6129	0.196	0.443	0.738	0.220	0.518	0.761
1.6229	0.198	0.443	0.770	0.222	0.516	0.791
1.6329	0.201	0.441	0.799	0.223	0.514	0.819
1.6429	0.203	0.440	0.822	0.224	0.512	0.844
1.6529	0.204	0.438	0.798	0.225	0.510	0.854
1.6629	0.206	0.436	0.817	0.227	0.509	0.873
1.6729	0.207	0.434	0.838	0.229	0.508	0.893
1.6829	0.210	0.432	0.873	0.231	0.508	0.925
1.6929	0.212	0.430	0.900	0.234	0.507	0.947
1.7029	0.215	0.423	0.905	0.238	0.506	0.910
1.7129	0.215	0.421	0.860	0.240	0.508	0.863
1.7229	0.216	0.418	0.849	0.242	0.510	0.848
1.7329	0.217	0.415	0.831	0.244	0.512	0.822
1.7429	0.218	0.410	0.812	0.246	0.512	0.791
1.7529	0.217	0.517	0.788	0.226	0.586	0.794
1.7629	0.216	0.671	0.726	0.197	0.689	0.792
1.7729	0.216	0.712	0.609	0.191	0.717	0.712
1.7829	0.218	0.728	0.491	0.192	0.729	0.611
1.7929	0.220	0.752	0.342	0.190	0.746	0.484
1.8029	0.218	0.794	0.183	0.182	0.775	0.348
1.8128	0.212	0.833	0.034	0.170	0.801	0.213
1.8228	0.204	0.841	-0.090	0.161	0.806	0.085
1.8328	0.195	0.820	-0.180	0.154	0.789	-0.023
1.8428	0.188	0.800	-0.235	0.149	0.772	-0.104
1.8528	0.185	0.796	-0.264	0.143	0.766	-0.159
1.8628	0.184	0.797	-0.278	0.139	0.761	-0.203
1.8728	0.188	0.779	-0.295	0.141	0.742	-0.254
1.8828	0.193	0.733	-0.328	0.148	0.699	-0.328
1.8928	0.199	0.707	-0.384	0.142	0.655	-0.433
1.9028	0.170	0.828	-0.498	0.139	0.812	-0.418
1.9128	0.116	0.797	-0.761	0.061	0.741	-0.719
1.9228	-0.033	0.696	-1.337	-0.110	0.601	-1.295
1.9328	0.102	0.812	-1.761	0.035	0.724	-1.551
1.9428	0.177	0.935	-1.876	0.118	0.853	-1.530
1.9528	0.228	1.168	-2.814	0.128	0.998	-2.127
1.9608	0.177	1.127	-3.307	0.087	0.983	-2.628
1.9708	-0.694	0.803	-2.708	-0.822	0.595	-1.954
1.9808	-0.800	1.841	-4.443	-1.072	1.303	-1.746
1.9908	-1.245	0.792	-4.939	-1.270	0.832	-4.191
2.0008	-0.762	0.405	-6.588	-0.739	0.766	-10.631
2.0128	-1.437	1.276	-8.748	-1.706	1.011	-12.001
2.0228	-1.031	1.324	-9.572	-1.437	0.908	-14.729
2.0328	-0.688	1.100	-1.932	-1.040	0.759	-4.806

FIGURE 12

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

TIME SEC.	HORIZONTAL TIRE FORCES (POUNDS)							
	X' DIRECTION				Y' DIRECTION			
	RF	LF	RR	LR	RF	LF	RR	LR
1.5329	-292.8	-277.4	0.0	0.0	816.8	675.8	0.0	0.0
1.5429	-294.0	-269.7	0.0	0.0	810.3	642.4	0.0	0.0
1.5529	-296.0	-262.8	0.0	0.0	807.8	612.9	0.0	0.0
1.5629	-298.8	-257.4	0.0	0.0	808.7	589.0	0.0	0.0
1.5729	-302.1	-253.6	0.0	0.0	811.7	570.6	0.0	0.0
1.5829	-305.6	-251.0	0.0	0.0	814.3	556.5	0.0	0.0
1.5929	-308.5	-248.6	0.0	0.0	814.2	543.3	0.0	0.0
1.6029	-310.8	-246.0	0.0	0.0	810.1	529.8	0.0	0.0
1.6129	-312.7	-243.0	0.0	0.0	802.6	515.5	0.0	0.0
1.6229	-314.0	-239.9	0.0	0.0	792.1	501.1	0.0	0.0
1.6329	-315.1	-237.1	0.0	0.0	780.8	487.5	0.0	0.0
1.6429	-316.2	-235.5	0.0	0.0	769.9	477.5	0.0	0.0
1.6529	-317.4	-235.8	0.0	0.0	760.3	473.0	0.0	0.0
1.6629	-318.5	-238.2	0.0	0.0	751.4	473.8	0.0	0.0
1.6729	-319.4	-242.7	0.0	0.0	742.4	480.3	0.0	0.0
1.6829	-319.7	-248.9	0.0	0.0	731.8	491.2	0.0	0.0
1.6929	-319.1	-256.0	0.0	0.0	718.5	504.5	0.0	0.0
1.7029	-317.6	-264.4	0.0	0.0	702.4	521.1	0.0	0.0
1.7129	-315.2	-278.3	0.0	0.0	682.8	551.8	0.0	0.0
1.7229	-312.4	-296.3	0.0	0.0	661.9	594.6	0.0	0.0
1.7329	-309.1	-314.1	0.0	0.0	640.1	638.5	0.0	0.0
1.7429	-305.7	-328.9	0.0	0.0	619.1	674.6	0.0	0.0
1.7529	-301.8	-339.1	-153.9	-0.8	598.5	697.6	330.4	1.4
1.7629	-296.6	-344.8	-204.6	-211.9	576.8	708.9	491.5	534.8
1.7729	-289.7	-348.1	-237.3	-266.9	552.7	714.3	587.8	822.9
1.7829	-280.9	-351.3	-267.1	-277.8	525.1	721.8	643.7	985.0
1.7929	-269.8	-355.8	-295.9	-293.0	492.7	737.1	670.2	1063.3
1.8029	-256.5	-361.7	-318.3	-341.4	456.3	762.0	672.2	1098.5
1.8128	-241.6	-367.3	-329.5	-402.7	417.7	793.1	654.5	1088.8
1.8228	-226.1	-370.7	-330.9	-435.8	379.5	825.6	627.2	1022.7
1.8328	-211.2	-371.2	-330.1	-436.8	344.2	853.9	607.7	941.7
1.8428	-197.5	-368.8	-336.3	-438.5	313.5	875.6	612.2	922.1
1.8528	-185.0	-364.1	-353.9	-456.5	286.7	889.7	647.0	995.6
1.8628	-172.7	-357.8	-383.9	-463.0	261.5	898.3	712.8	1115.9
1.8728	-153.9	-350.1	-425.2	-415.4	225.7	903.6	804.7	1202.0
1.8828	-113.5	-341.4	-475.6	-303.1	158.8	908.6	916.3	1204.7
1.8928	-3.6	-332.2	-529.8	-236.0	5.0	915.7	1035.0	1227.6
1.9028	-464.4	-319.9	-577.0	-254.0	554.3	921.4	1139.3	1298.3
1.9128	-339.9	-301.9	-609.4	-269.2	406.5	921.1	1209.0	1311.9
1.9228	-245.4	-292.8	-618.6	-274.0	293.7	928.0	1226.7	1300.0
1.9328	-212.6	-288.7	-595.5	-261.3	254.7	928.5	1180.2	1394.9
1.9428	-367.0	-287.7	-615.0	-272.4	443.3	905.0	1173.0	2462.0
1.9528	-329.2	-286.2	-664.0	-299.0	403.2	846.4	1225.0	2293.0
1.9608	-470.5	-254.9	-634.8	-282.9	578.9	743.8	1194.2	2009.3
1.9708	-216.0	-384.7	-619.2	-274.3	266.9	464.6	1170.3	2676.4
1.9808	-116.4	-218.1	-650.3	-291.8	145.0	264.9	1203.7	2693.8
1.9908	-100.4	-135.6	-575.1	-253.4	126.1	165.9	1099.3	2356.8
2.0008	-63.4	-139.7	-525.8	-229.6	80.4	171.3	989.5	3430.0
2.0128	-44.6	-142.5	-567.5	-265.0	57.0	176.8	975.6	3353.4
2.0228	-52.6	-151.7	-859.2	-253.5	67.8	189.8	947.4	2463.4
2.0328	-63.8	-161.6	-452.9	-241.7	82.5	203.9	500.0	1980.7

FIGURE 13

PROGRAM 2140 3:1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

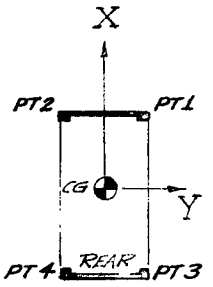
TIME	STEERING TORQUES		TERRAIN SLOPES				TIRE ROLLING RADIUS			
SEC.	T1PSI LB.-IN.	T2PSI LB.-IN.	PHIG1 DEGREES	PHIG2 DEGREES	PHIG3 DEGREES	PHIG4 DEGREES	H1 INCHES	H2 INCHES	H3 INCHES	H4 INCHES
1.5329	-600.0	0.0	18.0	18.0	18.0	18.0	12.8	13.2	14.0	14.0
1.5429	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.2	14.0	14.0
1.5529	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.3	14.0	14.0
1.5629	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.3	14.0	14.0
1.5729	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.4	14.0	14.0
1.5829	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.4	14.0	14.0
1.5929	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.4	14.0	14.0
1.6029	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.4	14.0	14.0
1.6129	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.4	14.0	14.0
1.6229	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.5	14.0	14.0
1.6329	-600.0	0.0	18.0	18.0	18.0	18.0	12.9	13.5	14.0	14.0
1.6429	-600.0	0.0	18.0	18.0	18.0	18.0	13.0	13.5	14.0	14.0
1.6529	-600.0	0.0	18.0	18.0	18.0	18.0	13.0	13.5	14.0	14.0
1.6629	-600.0	0.0	18.0	18.0	18.0	18.0	13.0	13.5	14.0	14.0
1.6729	-600.0	0.0	18.0	18.0	18.0	18.0	13.0	13.5	14.0	14.0
1.6829	-600.0	0.0	18.0	18.0	18.0	18.0	13.1	13.5	14.0	14.0
1.6929	-600.0	0.0	18.0	18.0	18.0	18.0	13.1	13.5	14.0	14.0
1.7029	-600.0	0.0	18.0	18.0	18.0	18.0	13.1	13.5	14.0	14.0
1.7129	-600.0	0.0	18.0	18.0	18.0	18.0	13.2	13.4	14.0	14.0
1.7229	-600.0	0.0	18.0	18.0	18.0	18.0	13.2	13.3	14.0	14.0
1.7329	-600.0	0.0	18.0	18.0	18.0	18.0	13.3	13.3	14.0	14.0
1.7429	-600.0	0.0	18.0	18.0	18.0	18.0	13.3	13.2	14.0	14.0
1.7529	-600.0	0.0	18.0	18.0	18.0	18.0	13.3	13.2	13.7	14.0
1.7629	-600.0	0.0	18.0	18.0	18.0	18.0	13.4	13.1	13.4	13.3
1.7729	-600.0	0.0	18.0	18.0	18.0	18.0	13.4	13.1	13.3	12.7
1.7829	-600.0	0.0	18.0	18.0	18.0	18.0	13.5	13.1	13.2	12.2
1.7929	-600.0	0.0	18.0	18.0	18.0	18.0	13.5	13.1	13.2	12.1
1.8029	-600.0	0.0	18.0	18.0	18.0	18.0	13.6	13.0	13.3	12.1
1.8128	-600.0	0.0	18.0	18.0	18.0	18.0	13.6	13.0	13.4	12.4
1.8228	-600.0	0.0	18.0	18.0	18.0	18.0	13.7	12.9	13.4	12.7
1.8328	-600.0	0.0	18.0	18.0	18.0	18.0	13.7	12.8	13.5	12.9
1.8428	-600.0	0.0	18.0	18.0	18.0	18.0	13.8	12.7	13.5	13.0
1.8528	-600.0	0.0	18.0	18.0	18.0	18.0	13.8	12.7	13.4	12.8
1.8628	-600.0	0.0	18.0	18.0	18.0	18.0	13.8	12.6	13.3	12.4
1.8728	-600.0	0.0	18.0	18.0	18.0	18.0	13.9	12.6	13.2	12.0
1.8828	-600.0	0.0	18.0	18.0	18.0	18.0	13.9	12.5	13.0	11.6
1.8928	-600.0	0.0	18.0	18.0	18.0	18.0	14.0	12.5	12.9	11.2
1.9028	-600.0	0.0	0.0	18.0	18.0	18.0	13.1	12.4	12.7	11.1
1.9128	-600.0	0.0	0.0	18.0	18.0	18.0	11.5	12.4	12.6	11.1
1.9228	-600.0	0.0	0.0	18.0	18.0	18.0	10.6	12.3	12.6	11.1
1.9328	-600.0	0.0	0.0	18.0	18.0	18.0	11.3	12.3	12.6	11.0
1.9428	-600.0	0.0	0.0	18.0	18.0	18.0	12.4	12.4	12.7	10.7
1.9528	-600.0	0.0	0.0	18.0	18.0	18.0	13.1	12.5	12.7	10.7
1.9608	-600.0	0.0	0.0	18.0	18.0	18.0	12.3	12.7	12.6	10.8
1.9708	-600.0	0.0	0.0	0.0	18.0	18.0	9.8	13.2	12.6	10.6
1.9808	-600.0	0.0	0.0	0.0	18.0	18.0	9.8	11.3	12.6	10.6
1.9908	-600.0	0.0	0.0	0.0	18.0	18.0	9.5	10.3	12.7	10.7
2.0008	-600.0	0.0	0.0	0.0	18.0	18.0	9.4	11.2	12.8	10.4
2.0128	-600.0	0.0	0.0	0.0	18.0	18.0	9.8	9.7	13.0	10.4
2.0228	-600.0	0.0	0.0	0.0	0.0	18.0	10.3	9.6	12.3	10.7
2.0328	-600.0	0.0	0.0	0.0	0.0	18.0	10.8	9.9	10.7	10.8

FIGURE 14

PROGRAM 2140 3 1 SIDE SLOPE SPEED = 60 MPH ANGLE = 25 DEG
3.16 SEC RUN DSN = JN31 (RUN NO 5)

(BUMPERS)

TIME SEC.	WHEEL POSITIONS (INCHES) (* INDICATES LOSS OF CONTACT)								REFERENCE PT. CONTACT WITH TERRAIN SURFACE (PENETRATION, IN.)			
	RF WHEEL		LF WHEEL		RR WHEEL		LR WHEEL					
	X'	Y'	X'	Y'	X'	Y'	X'	Y'	PT1	PT2	PT3	PT4
1.5329	1742.93	873.25	1771.24	821.95	1637.70*	820.97*	1665.62*	771.15*	0.0	0.0	0.0	0.0
1.5429	1752.37	878.51	1780.86	827.31	1647.34*	825.97*	1675.46*	776.46*	0.0	0.0	0.0	0.0
1.5529	1761.80	883.79	1790.48	832.69	1656.97*	830.97*	1685.29*	781.74*	0.0	0.0	0.0	0.0
1.5629	1771.23	889.09	1800.09	838.10	1666.59*	835.97*	1695.11*	787.00*	0.0	0.0	0.0	0.0
1.5729	1780.64	894.42	1809.70	843.54	1676.22*	840.96*	1704.94*	792.22*	0.0	0.0	0.0	0.0
1.5829	1790.04	899.77	1819.30	849.01	1685.84*	845.95*	1714.76*	797.41*	0.0	0.0	0.0	0.0
1.5929	1799.43	905.16	1828.90	854.50	1695.46*	850.95*	1724.58*	802.56*	0.0	0.0	0.0	0.0
1.6029	1808.81	910.57	1838.50	860.02	1705.08*	855.96*	1734.40*	807.70*	0.0	0.0	0.0	0.0
1.6129	1818.18	916.01	1848.09	865.58	1714.69*	860.99*	1744.22*	812.82*	0.0	0.0	0.0	0.0
1.6229	1827.55	921.48	1857.68	871.16	1724.31*	866.03*	1754.05*	817.92*	0.0	0.0	0.0	0.0
1.6329	1836.90	926.97	1867.26	876.78	1733.92*	871.08*	1763.87*	823.02*	0.0	0.0	0.0	0.0
1.6429	1846.24	932.50	1876.83	882.43	1743.53*	876.15*	1773.70*	828.11*	0.0	0.0	0.0	0.0
1.6529	1855.57	938.05	1886.40	888.11	1753.14*	881.24*	1783.53*	833.20*	0.0	0.0	0.0	0.0
1.6629	1864.90	943.62	1895.97	893.81	1762.75*	886.34*	1793.36*	838.30*	0.0	0.0	0.0	0.0
1.6729	1874.21	949.22	1905.52	899.55	1772.35*	891.45*	1803.20*	843.41*	0.0	0.0	0.0	0.0
1.6829	1883.50	954.85	1915.07	905.31	1781.95*	896.57*	1813.03*	848.53*	0.0	0.0	0.0	0.0
1.6929	1892.79	960.51	1924.61	911.11	1791.54*	901.71*	1822.87*	853.68*	0.0	0.0	0.0	0.0
1.7029	1902.06	966.20	1934.15	916.94	1801.13*	906.84*	1832.71*	858.86*	0.0	0.0	0.0	0.0
1.7129	1911.33	971.92	1943.68	922.79	1810.71*	911.99*	1842.55*	864.06*	0.0	0.0	0.0	0.0
1.7229	1920.57	977.66	1953.19	928.67	1820.29*	917.15*	1852.39*	869.29*	0.0	0.0	0.0	0.0
1.7329	1929.81	983.43	1962.70	934.57	1829.87*	922.31*	1862.23*	874.54*	0.0	0.0	0.0	0.0
1.7429	1939.03	989.23	1972.21	940.51	1839.44*	927.48*	1872.08*	879.79*	0.0	0.0	0.0	0.0
1.7529	1948.24	995.05	1981.70	946.49	1849.01	932.66	1881.93	885.05	0.0	0.0	0.0	0.0
1.7629	1957.43	1000.89	1991.18	952.50	1858.58	937.88	1891.78	890.32	0.0	0.0	0.0	0.0
1.7729	1966.61	1006.76	2000.65	958.54	1868.14	943.16	1901.62	895.64	0.0	0.0	0.0	0.0
1.7829	1975.78	1012.66	2010.11	964.60	1877.69	948.50	1911.45	901.04	0.0	0.0	0.0	0.0
1.7929	1984.93	1018.59	2019.55	970.68	1887.23	953.89	1921.27	906.56	0.0	0.0	0.0	0.0
1.8029	1994.07	1024.54	2028.98	976.78	1896.75	959.32	1931.08	912.17	0.0	0.0	0.0	0.0
1.8128	2003.19	1030.51	2038.39	982.89	1906.25	964.78	1940.87	917.85	0.0	0.0	0.0	0.0
1.8228	2012.31	1036.50	2047.78	989.02	1915.75	970.26	1950.64	923.56	0.0	0.0	0.0	0.0
1.8328	2021.41	1042.51	2057.16	995.17	1925.23	975.75	1960.40	929.26	0.0	0.0	0.0	0.0
1.8428	2030.50	1048.54	2066.53	1001.33	1934.70	981.25	1970.15	934.93	0.0	0.0	0.0	0.0
1.8528	2039.58	1054.58	2075.88	1007.51	1944.16	986.75	1979.88	940.56	0.0	0.0	0.0	0.0
1.8628	2048.64	1060.64	2085.22	1013.70	1953.62	992.26	1989.60	946.16	0.0	0.0	0.0	0.0
1.8728	2057.70	1066.71	2094.54	1019.91	1963.06	997.79	1999.30	951.77	0.0	0.0	0.0	0.0
1.8828	2066.76	1072.80	2103.86	1026.13	1972.50	1003.33	2008.98	957.40	0.0	0.0	0.0	0.0
1.8928	2075.81	1078.90	2113.16	1032.35	1981.92	1008.89	2018.66	963.08	0.0	0.0	0.0	0.0
1.9028	2084.85	1085.00	2122.46	1038.58	1991.33	1014.49	2028.32	968.82	0.0	0.0	0.0	0.0
1.9128	2093.90	1091.17	2131.74	1044.83	2000.73	1020.11	2037.96	974.61	0.0	0.0	0.0	0.0
1.9228	2102.97	1097.50	2141.01	1051.08	2010.12	1025.77	2047.60	980.44	0.0	0.0	0.0	0.0
1.9328	2112.09	1104.10	2150.27	1057.34	2019.51	1031.46	2057.21	986.23	0.0	0.0	0.0	0.0
1.9428	2121.23	1110.76	2159.51	1063.62	2028.88	1037.17	2066.79	992.02	0.0	0.0	0.0	0.0
1.9528	2130.36	1117.36	2168.75	1069.94	2038.23	1042.92	2076.36	997.92	0.0	0.0	0.0	0.0
1.9608	2137.62	1122.41	2176.13	1075.01	2045.68	1047.55	2083.99	1002.67	0.0	0.0	0.0	0.0
1.9708	2146.61	1128.48	2185.33	1081.38	2054.98	1053.38	2093.49	1008.59	1.5	0.0	0.0	0.0
1.9808	2155.70	1134.97	2194.49	1087.74	2064.22	1059.27	2102.95	1014.56	2.9	0.0	0.0	0.0
1.9908	2164.76	1141.39	2203.63	1094.26	2073.35	1065.29	2112.33	1020.58	3.2	0.0	0.0	0.0
2.0008	2173.79	1147.80	2212.87	1100.99	2082.39	1071.40	2121.61	1026.54	2.9	0.0	0.0	0.4
2.0128	2184.63	1155.51	2223.74	1108.70	2093.17	1078.83	2132.70	1033.79	1.7	1.1	0.0	1.5
2.0228	2193.67	1161.91	2232.86	1115.16	2102.13	1085.07	2141.86	1039.87	0.4	1.4	0.0	2.1
2.0328	2202.70	1168.25	2241.98	1121.58	2111.15	1091.31	2150.93	1045.97	0.0	0.9	0.0	2.1



Note that simultaneous front and rear bumper contact occurred during time interval used for computing Severity-Index in Figure 5

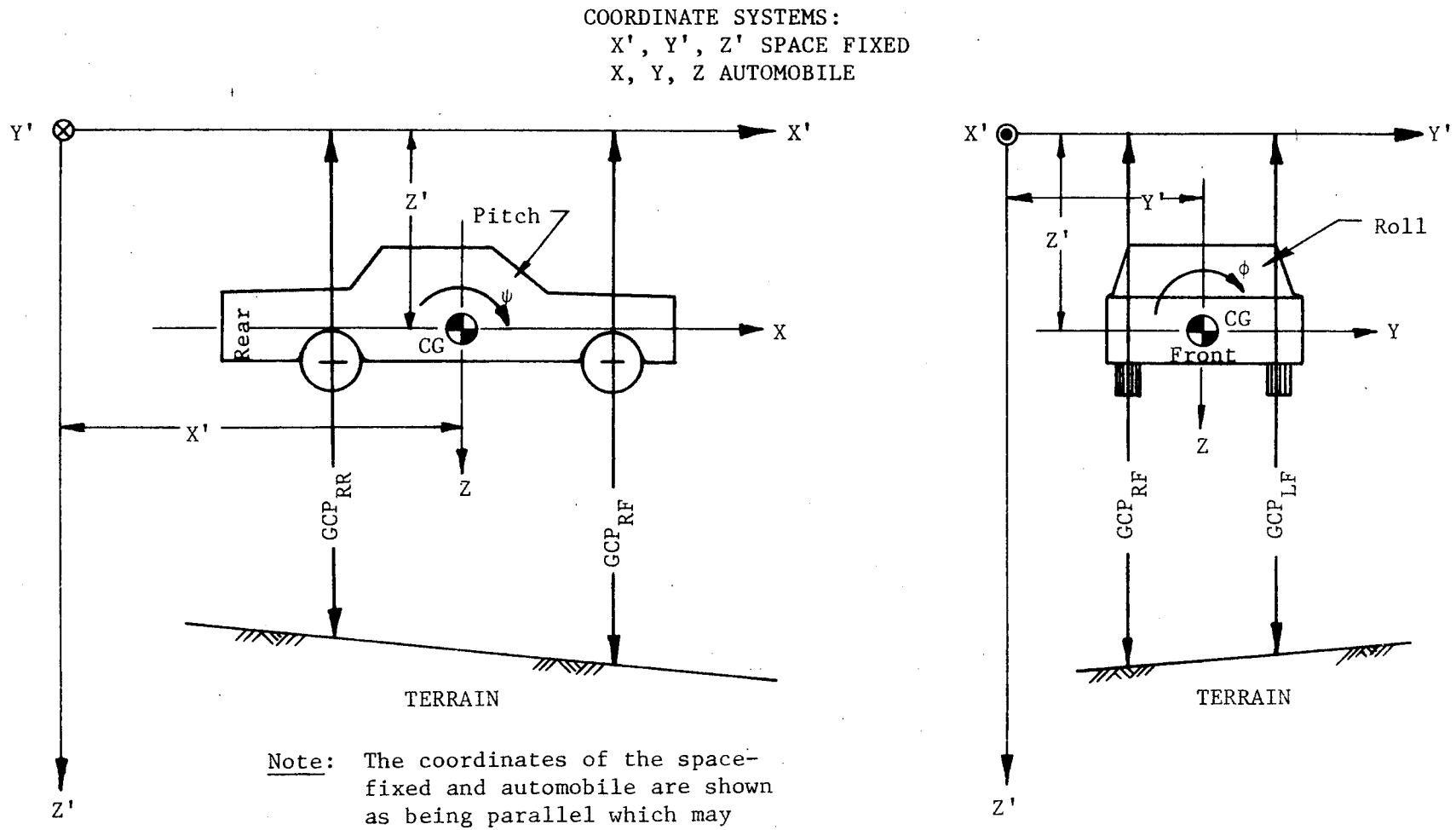


FIGURE 15 LOCATION OF SPRUNG MASS CG AND TERRAIN ELEVATIONS THROUGH WHEEL CENTERS WITH REFERENCE TO SPACE-FIXED COORDINATE SYSTEM

APPENDIX A

SUSPENSION BUMPER INPUT

INPUT FORMAT FOR SUSPENSION BUMPER DATA

26TH SERIES OF CARDS

Front wheels' nonlinear suspension bumper data (always included)

One Card, Format(9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKFC	K_{FC}	*	lb/in.
9-16	AKFCP	K'_{FC}	*	$lb/in.^3$
17-24	OMEGFC	Ω_{FC}	*	in.
25-32	AKFE	K_{FE}	*	lb/in.
33-40	AKFEP	K'_{FE}	*	$lb/in.^3$
41-48	OMEGFE	Ω_{FE}	*	in.
49-78			leave blank	
79-80	ICARD		= 26	

*See page 29.

27TH SERIES OF CARDS

Rear wheels' nonlinear suspension bumper data (always included)

One Card, Format(9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKRC	K_{RC}	*	lb/in.
9-16	AKRCP	K'_{RC}	*	$lb/in.^3$
17-24	OMEGRC	K_{RC}	*	in.
25-32	AKRE	K'_{RC}	*	lb/in.
33-40	AKREP	Ω_{RC}	*	$lb/in.^3$
41-48	OMEGRE	K_{RE}	*	in.
49-78		K'_{RE}	leave blank	
79-80	ICARD	Ω_{RE}	= 27	

*See page 29.

DEFINITIONS

FOR

ICARDS 26 and 27

K_{FC}, K_{FE} = coefficients of the complete suspension bumper terms,
K_{RC}, K_{RE} for compression and extension bumpers at the front and rear suspensions. These coefficients correspond to forces effective at the wheel in the front and at the spring in the rear suspension.

K'_{FC}, K'_{FE} = coefficients of the cubic terms within the suspension
K'_{RC}, K'_{RE} bumper force expressions, for compression and extension at the front and rear suspensions.

Ω_{FC}, Ω_{FE} = suspension deflections at which the bumpers, compression (jounce) and extension (rebound) at the front and
Ω_{RC}, Ω_{RE} rear, respectively, are contacted. These items are measured at the wheel in the front and at the spring in the rear suspension, inches.

APPENDIX B

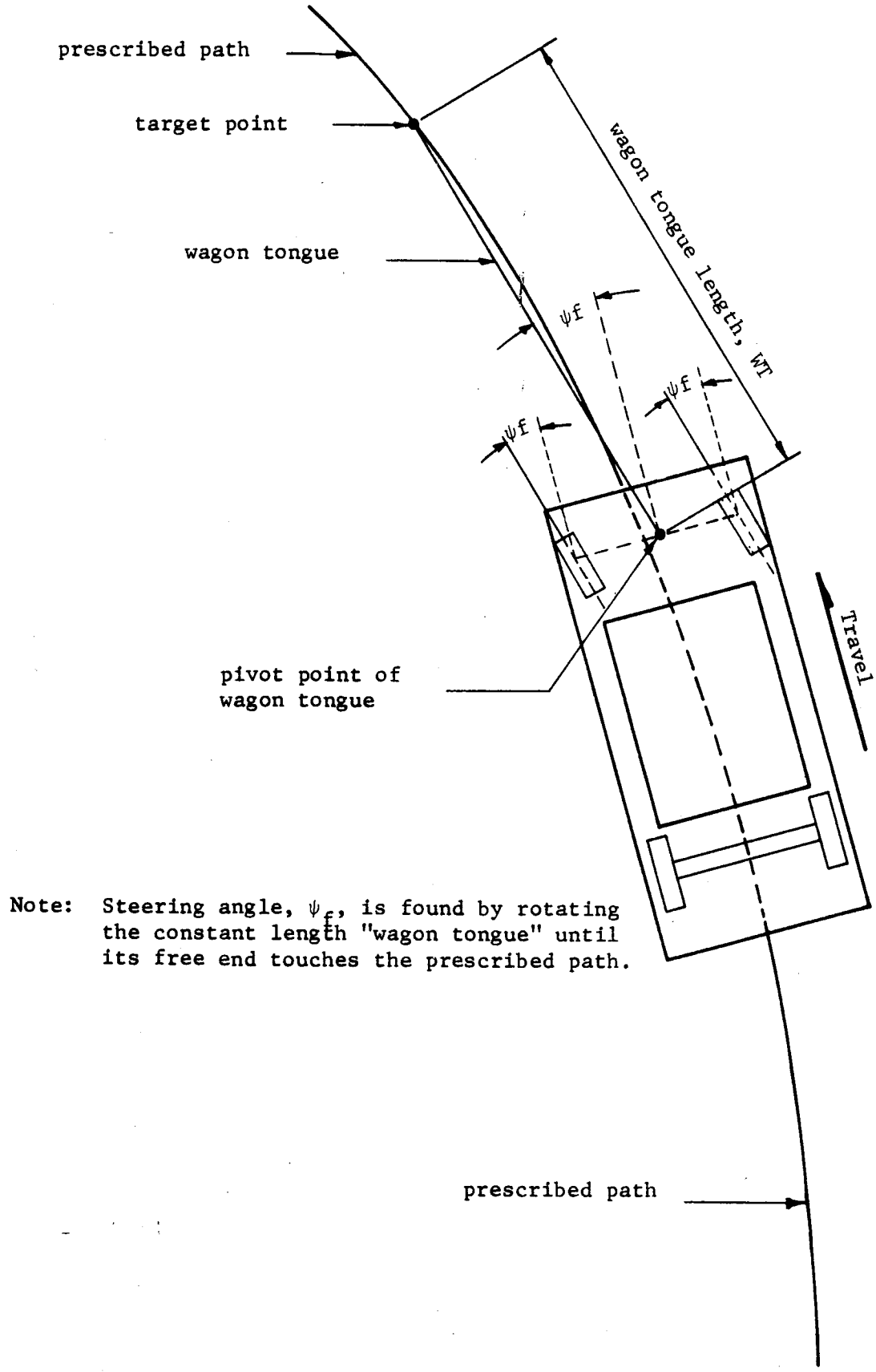
WAGON TONGUE DEVICE

DESCRIPTION

The mechanism used to compute the instantaneous steering angle as the vehicle travels along its prescribed path is depicted in Figure 16. The steering angle is estimated by pointing the front wheels in the direction of a "target point" on the desired path some distance ahead of the vehicle. This is achieved using a rod of constant length (called the "wagon tongue") one end of which is fixed at a point midway between the front wheels. The wagon tongue, which has no physical restraint capabilities, is rotated in a horizontal plane until its free end coincides with the prescribed path of the vehicle. The angle defined by the x-axis of the vehicle and the wagon tongue is used instantaneously as the steering angle.

This method of estimating the steering angle is similar to that employed by an actual driver who estimates the steering angle of his vehicle by looking some distance down the roadway. The driver depends on his experience in handling his car to estimate the turn of the steering wheel, whereas the success of the steering mechanism used in HVOSM depends on the length of the steering pointer. It was found that a wagon tongue length of 20 ft produces good tracking for the curvature (875 ft.) and speed (60 mph) evaluated in this study.

For the runs, the vehicle is placed on a tangent to the spiral (see Figure 17) such that the free end of the wagon tongue touches the point of tangency (with zero steering). The vehicle is then given a forward speed and was allowed to coast through the curve.



Note: Steering angle, ψ_f, is found by rotating the constant length "wagon tongue" until its free end touches the prescribed path.

FIGURE 16. SCHEMATIC OF STEERING MECHANISM FOR FOLLOWING PRESCRIBED PATH

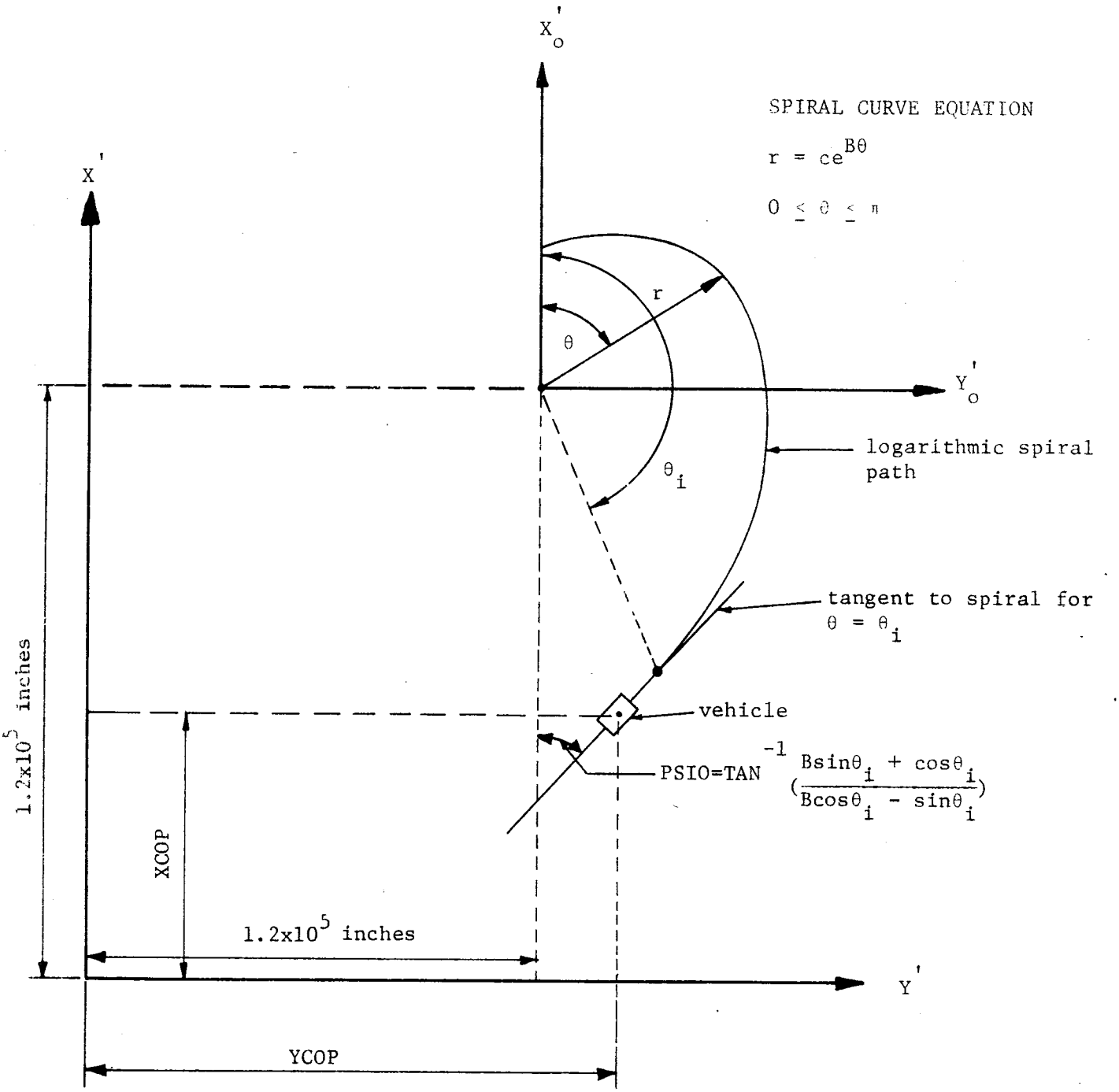


FIGURE 17. THE LOGARITHMIC SPIRAL

24th Series of Cards

Definition of logarithmic spiral which vehicle is to follow.

One Card, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	WT	WT	length of wagon tongue	Inches
9-16	C	C	*	Inches
17-24	BM	B	*	
25-32	JWT		=1.0	
33-78			leave blank	
79-80	ICARD		=24	

*See Figure 17.

Comments on 24th Series

1. This series is left out unless the logarithmic spiral path is desired.
2. Whenever this series is included, the following must be done:
   a. Set INDCRB=0.0 on third card (ICARD=1)
   b. Compute PSIO=$(B \sin\theta_i + \cos\theta_i)/(B \cos\theta_i - \sin\theta_i)$ as shown in Fig. 2-4, and enter on tenth card (ICARD=8)
   c. Set PSIFIO=0.0 and PSIFDO=0.0 on tenth card (ICARD=8)
   d. Compute XCOP and YCOP as shown in Fig. 17, and enter these on eleventh card (ICARD=9)
   e. Put in large enough terrain template in sixteenth series of cards (ICARD=14)