Report No. MM-64-9
(Dept. 870)

DOCUMENTATION OF DIGITAL COMPUTER PROGRAMS FOR LUNAR LANDING DYNAMICS SYSTEM INVESTIGATION

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BENDIX PRODUCTS AEROSPACE DIVISION

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1. "Final Report of Lunar Landing Dynamics Systems Investigation," Bendix Products Aerospace Division, Report No. MM-64-8, October 1964.

INTRODUCTION

This report supplements the Final Report on Lunar Landing Dynamics Systems Investigation (Reference 1) and provides detailed information on the Digital Computer Programs involved in that study.

The information supplied herein should be sufficient to permit the use of any of the computer programs. All the programs were written in Fortran IV and will execute on a Univac 1107 Digital Computer.

This report includes, in addition to program flow diagrams and listings, a sample run for checkout purposes. This sample run may be used as an aid to the checkout of the programs on any other digital computer. The sample runs were performed using single precision on the Univac 1107 computer. Minor differences in computer results may be experienced when using these programs on other computers because of the differences in precision which may exist.

These programs have been checked out to the extent discussed in the particular section pertaining to that program and in Reference 1.

SECTION I

LANDING DYNAMICS COMPUTER PROGRAM

This program was written to study the detailed vehicle motions from the instant of touchdown until the vehicle comes to rest. The program will handle only planar motion although footpad motions and positions are determined in three dimensions. The general program flow is illustrated in Figure 1-1.

The basic mathematical approach used in this program is as follows:

1. Using the time history of the forces and torques acting on the vehicle center of gravity at the start of an interval ΔT, determine the c.g. motions during and at the end of the time interval.

2. Using the time history of the forces acting on the footpad masses at the start of the time interval, determine individual footpad motions during and at the end of the time interval.

3. Knowing the positions of the vehicle c.g. and all footpads at the end of a time interval ΔT, determine the lengths of all the landing gear struts and, knowing the strut lengths, determine the stroking forces developed by each individual strut.

4. Having determined the strut forces existing at the end of the time interval, bring the time history of the forces up to date and repeat the procedure for the next time interval.

A parabolic type of integration was used for the determination of both basic vehicle motion and footpad motion.

In general form, the force during the time interval t to $t + \Delta t$ can be expressed in the form

$$F(t) = f + a\,t + b\,t^2 \qquad (1)$$

let

f = general force at time t

f_{-1} = general force at time $t - \Delta t$

f_{-2} = general force at time $t - 2\Delta t$

then from (1)

$$F(o) = f$$

$$F(-\Delta t) = f_{-1} = f + a\,(-\Delta t) + b\,(-\Delta t)^2$$
$$= f - a\Delta t + b\Delta t^{\,2} \qquad (2)$$

$$F(-2\Delta t) = f_{-2} = f + a(-2\,\Delta t) + b\,(-2\,\Delta t)^2$$
$$= f - 2a\,\Delta t + 4\,b\Delta t^2 \qquad (3)$$

Solving equations (2) and (3) simultaneously for b gives:

$$b = \frac{f - 2f_{-1} + f_{-2}}{2\,\Delta t^2} \qquad (4)$$

and solving (2) and (3) for a gives:

$$a = \frac{3f - 4f_{-1} + f_{-2}}{2\,\Delta t} \qquad (5)$$

The general form for the equation of motion is:

$$M\ddot{q} = F\,(t)$$

or by substitution of equation (1)

$$\ddot{q} = \frac{1}{M}\left\{F\,(t)\right\} = \frac{1}{M}\left\{f + a\,t + b\,t^2\right\} \qquad (6)$$

Integrating to obtain velocity

$$\dot{q} = \frac{1}{M}\left\{f\,\Delta t + \frac{a\,\Delta t^2}{2} + \frac{b\,\Delta t^3}{3}\right\} + \dot{q}_o \qquad (7)$$

which, upon substitution for a and b from equations (4) and (5) gives

$$\dot{q} = \frac{\Delta t}{12M}\left\{23f - 16\,f_{-1} + 5\,f_{-2}\right\} + \dot{q}_o \qquad (8)$$

Integrating equation (7) to obtain displacement

$$q = \frac{1}{M}\left\{\frac{f\,\Delta t^2}{2} + \frac{a\Delta t^{\,3}}{6} + \frac{b\,\Delta t^4}{12}\right\} + \dot{q}_o\,\Delta t + q_o \qquad (9)$$

and substituting for a and b from equations (4) and (5) gives

$$q = \frac{\Delta t^2}{24M} \left\{ 19\,f - 10\,f_{-1} + 3\,f_{-2} \right\} + \dot{q}_0 \Delta t + q_0 \qquad (10)$$

A comparison of this force representation with simple rectangular integration shows the similarity

$$\dot{q} = \dot{q}_0 + \frac{\Delta t}{M} f \qquad \text{rectangular}$$

$$\dot{q} = \dot{q}_0 + \frac{\Delta t}{12M} \left\{ 23f - 16f_{-1} + 5\,f_{-2} \right\} \qquad \text{parabolic}$$

and

$$q = q_0 + \dot{q}_0 \, \Delta t + \frac{\Delta t^2}{2M} f \qquad \text{rectangular}$$

$$q = q_0 + \dot{q}_0 \, \Delta t + \frac{\Delta t^2}{24M} \left\{ 19\,f - 10\,f_{-1} + 3\,f_{-2} \right\} \qquad \text{parabolic}$$

Using this representation of the forces existent during the time interval t to $t + \Delta t$ gives a much better approximation to the closed form solution than could be obtained using rectangular integration.

These equations are used for determining the motions of both the main vehicle mass and the footpad masses.

Referring to Figure 1-1, the general flow through the computer program is as follows:

1. Input data is read in. The initial detailed vehicle geometry is determined and the input data printed for future reference.
2. The initial strut lengths of all the struts is determined from the input data.
3. The vehicle orientation relative to the ground surface is determined.
4. A test is performed to determine which footpads are in contact with the ground surface. If any footpads are not in contact with the ground, a further test is performed to determine if the footpad is moving relative to the vehicle. The strut force vs. strut length is illustrated in Figure 1-2. As is shown, the strut may develop an elastic force prior to actual plastic crushing of the honeycomb. Thus, the footpads may be off the ground but still possess both kinetic and potential energy relative to the vehicle itself. If this total energy is less than ten percent of the maximum possible potential energy due to the elasticity of the strut, the footpad is assumed to be fixed to the vehicle and its motions described by rigid body equations.

BENDIX COMPUTER PROGRAM FOR LUNAR LANDING STUDY

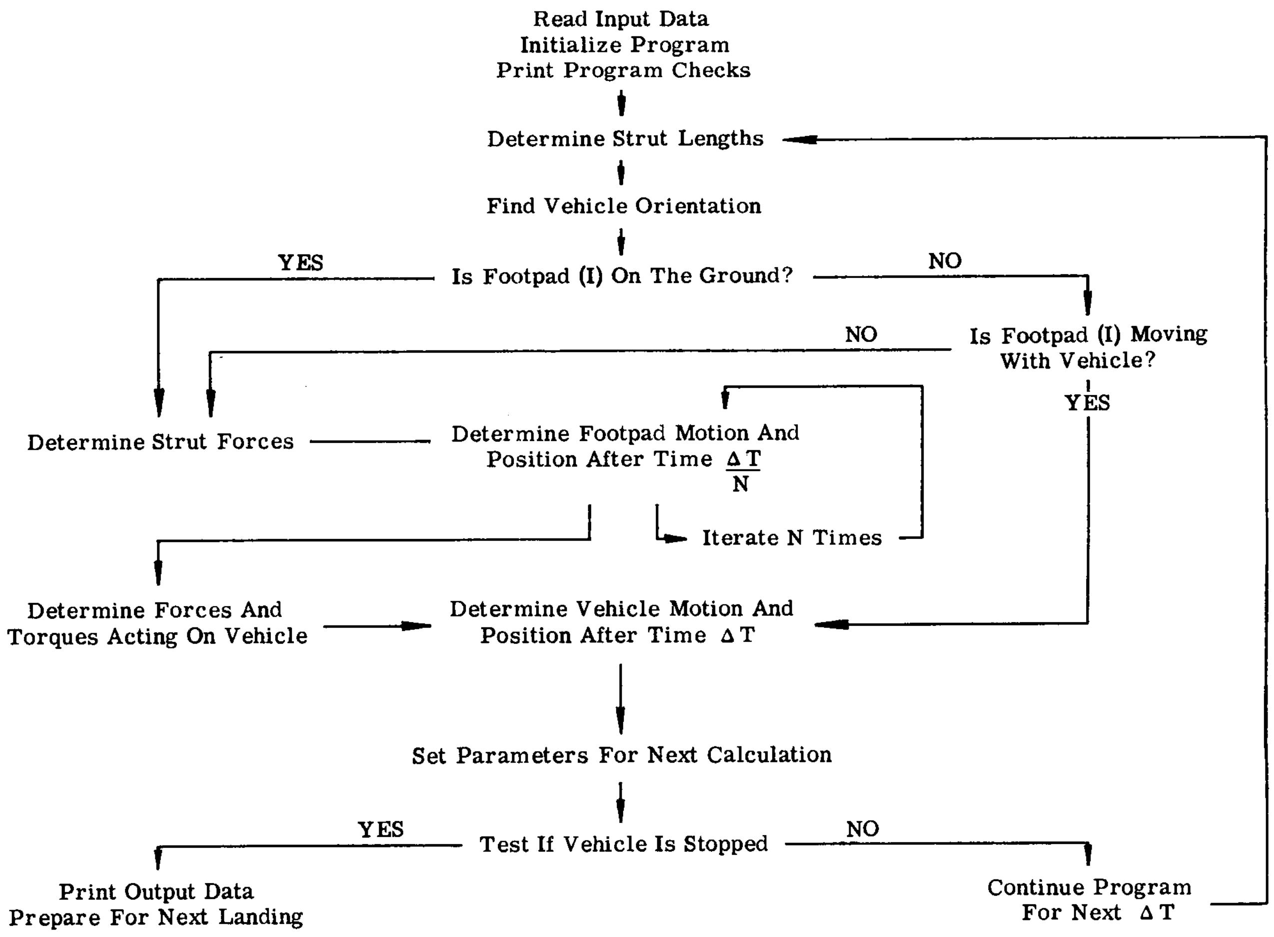

Figure 1-1. Landing Dynamics Computer Program Flow Diagram

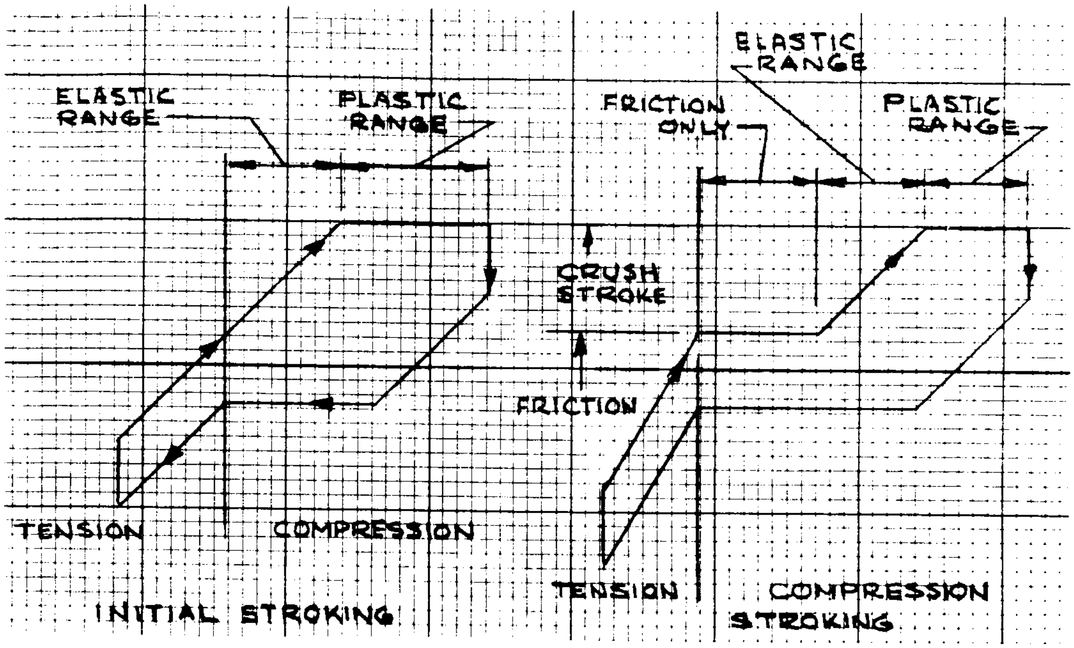

Figure 1-2. Strut Force Vs. Strut Length

5. If any footpads are on the ground or moving relative to the vehicle, the forces developed in the landing gear struts are determined using the force profile illustrated in Figure 1-2. The computer program is sufficiently general so that all parameters of stroke force (i.e. friction, spring rates, crush stroke force, etc.) may be varied from one strut to another as required.

6. The strut forces acting on each footpad and gravity, ground reaction forces and ground friction plus the time history of these forces are considered in determining the individual footpad motions. Since the footpad masses are usually small and the forces large, it is necessary to use a smaller time increment in integrating footpad motions. For this reason, an iteration loop is used at this step in the program so that time intervals of $\Delta T/N$ may be used. In practice, it has been determined that three iterations of footpad motion ($N = 3$) are sufficient to produce accurate results.

7. Using the strut forces determined in step 5, it is possible to define all forces acting on the vehicle c.g. Since geometry is known, torques can also be determined. Again, using these forces plus their time history, the c.g. motions can be determined during and at the end of the time interval Δ T. Parabolic integration is used for vehicle motion.

8. Next, all parameters are set for the start of the next time interval and tests are performed to determine if the vehicle is stopped. Here, all velocities $\dot{x}$, $\dot{y}$ and rotational velocity psi must be within epsilon's of zero. In addition,

all footpads must be either in contact with the ground or within a distance epsilon of the ground.

9. If all these tests can not be met simultaneously, the vehicle is still moving and the program is repeated for another iteration.

It has been determined that a time increment $\Delta T = 0.002$ seconds is sufficiently small to adequately describe the vehicle motions for reasonable values of all the parameters. If very small footpad masses (less than 0.5% of total vehicle mass) are used, a smaller time interval would be required. Since, depending on the accuracy of the particular computer used, smaller time increments may result in excessive computer round-off error; this is not recommended for the program described here.

Refer to Figure 7-1 for system nomenclature used in this program.

Figure 1-3 illustrates the input data format required for this program. The input variables are defined under "Input Definitions" in Figure 1-18.

When this program is used to define a complete stability profile as discussed in Reference 1, the following programming procedure should be followed.

In order to run a complete stability profile, an array of X and Y velocities is used. Both XVEL0 and YVEL0 are doubly subscripted variables where the subscripts NQ and NS represent the column and row of the velocity array. This velocity array must be rectangular (the same number of values in each row and the same number in each column). The starting point in the array is defined by setting the input parameters NS0 and NQ0. This permits starting anywhere in the velocity array and not just at (1, 1).

The computer program is designed to develop a stability profile in as few runs as possible. The following table illustrates a typical sequence of runs which the program will follow automatically in defining the stability profile. As is indicated, the choice of the velocities for succeeding runs is dependent upon the stability (or instability) of the preceding runs.

Assume NS = 1, NQ = 7 is stable, program sets NQ = 8
if NS = 1, NQ = 8 is unstable, program sets NS = 2
if NS = 2, NQ = 8 is stable, program sets NQ = 9
if NS = 2, NQ = 9 is unstable, program sets NS = 3
if NS = 3, NQ = 9 is unstable, program sets NQ = 8
if NS = 3, NQ = 8 is stable, program sets NS = 4
if NS = 4, NQ = 8 is stable, program sets NQ = 9
etc.

Figures 1-4 through 1-17 are flow diagrams for the Landing Dynamics Computer Program and its subroutines.

Figures 1-18 through 1-31 are complete program listings of the program and its subroutines.

Figures 1-32 illustrates the "on-line" printout of a typical program run. The initial printout is a summary of the input data for identification purposes. The following pages contain printout of pertinent information during the run. Following completion of the run, two additional outputs are printed. These include Figure 1-33 which is a summary of pertinent information concerning vehicle stability. This includes:

Line 1 - Identification and summary of input conditions

2 - Conversion of X and Y velocities to vertical and horizontal velocities

3 - Problem running time

4 - 6 Maximum stroke of all struts.

Note - When symmetry is used, results for struts 2 and 4 are identical to those for struts 1 and 3 respectively but the printout indicates zeros.

7 - 9 Self explanatory

10 - 12 Energy balance. If little or no sliding occurs, the "energy based on vehicle velocities and C.G. drop" should be approximately equal to the "energy dissipated" (lines 11 and 12).

13 - Angle between vehicle centerline and a normal to the ground surface

14 - Final stability angle and its rate of change

15 - Percentage of vehicle energy absorbed by each legset.

Figure 1-34 illustrates the printout of information stored during the program run and printed upon completion of the run.

C FOR COMMENT

STATEMENT NUMBER	Cont.		FORTRAN STATEMENT				
Identification		1	A(1)	A(2)	A(3)	A(4)	A(5)
		2	ALPHA(1)	ALPHA(2)	ALPHA(3)	ALPHA(4)	ALPHA(5)
		3	D(1)	D(2)	D(3)	D(4)	D(5)
		4	D11(1)	D11(2)	D11(3)	D11(4)	D11(5)
		5	F11(1)	F11(2)	F11(3)	F11(4)	F11(5)
		6	F22(1)	F22(2)	F22(3)	F22(4)	F22(5)
		7	F33(1)	F33(2)	F33(3)	F33(4)	F33(5)
		8	GRDMU(1)	GRDMU(2)	GRDMU(3)	GRDMU(4)	GRDMU(5)
		9	P1(1)	P1(2)	P1(3)	P1(4)	P1(5)
		10	P2(1)	P2(2)	P2(3)	P2(4)	P2(5)
		11	P3(1)	P3(2)	P3(3)	P3(4)	P3(5)
		12	R1(1)	R1(2)	R1(3)	R1(4)	R1(5)
		13	R2(1)	R2(2)	R2(3)	R2(4)	R2(5)
		14	RP(1)	RP(2)	RP(3)	RP(4)	RP(5)
		15	SKS(1)	SKS(2)	SKS(3)	SKS(4)	SKS(5)
		16	THETA(1)	THETA(2)	THETA(3)	THETA(4)	THETA(5)
		17	DELTAP	DELTAT	EPS2		
		18	EPS3	EPS4	EPS5		
		19	FINT	GRAV	HN		
		20	PMASS	PSIΦ	PSVELΦ		

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Figure 1-3. Input Data Format (Sheet 1 of 2)

C FOR COMMENT

STATEMENT NUMBER	Cont.	FORTRAN STATEMENT					
Identification	21	RMΦMI	RUNNΦΦ	RN			
(Cont.)	22	SK1	SK2	SK3			
	23	SKE1	SKE2	SKE3			
	24	SERNΦ	VMASS	YΦ			
	25	ZETA	H				
	26	II	JJ	J	K	KPRINT	LAND
	27	N	NSΦ	NQΦ	NSMAX	NQMAX	KCΦNMX
	28	INPLΦT	LΦTPRT				
	29	VVELΦ(1, 1)	HVELΦ(1, 1)	VVELΦ(2, 1)	HVELΦ(2, 1)	VVELΦ(3, 1)	HVELΦ(3, 1)
	30	VVELΦ(NQMAX,1)	HVELΦ(NQMAX, 1)	VVELΦ(1, 2)	HVELΦ(1, 2)	VVELΦ(2, 2)	HVELΦ(2, 2)
	31	ETC.	ETC.	VVELΦ(NQMAX, NSMAX)	HVELΦ(NQMAX, NSMAX)		

Figure 1-3. Input Data Format (Sheet 2 of 2)

MAIN LUNAR LANDING DYNAMICS PROGRAM

This program determines detailed planar motions from touchdown to rest or instability.

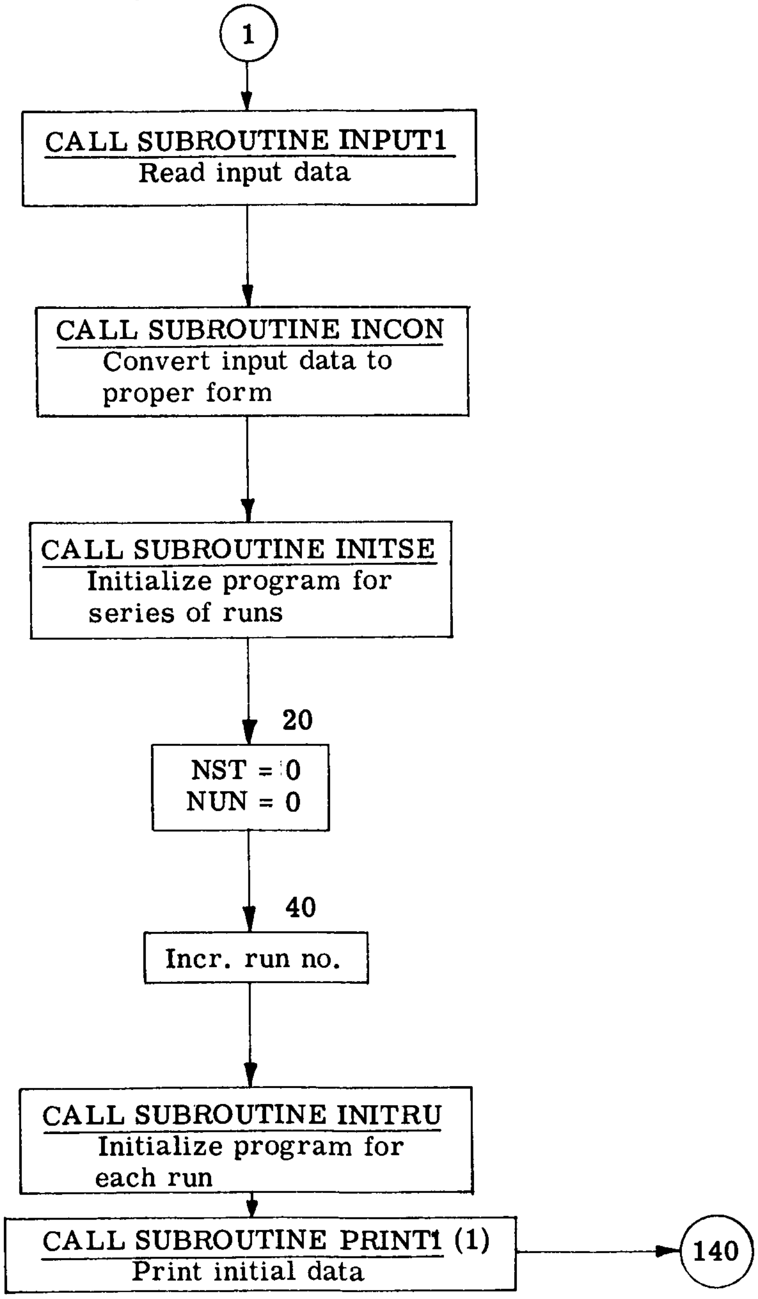

Figure 1-4. Main Lunar Landing Dynamics Program

MAIN LUNAR LANDING DYNAMICS PROGRAM

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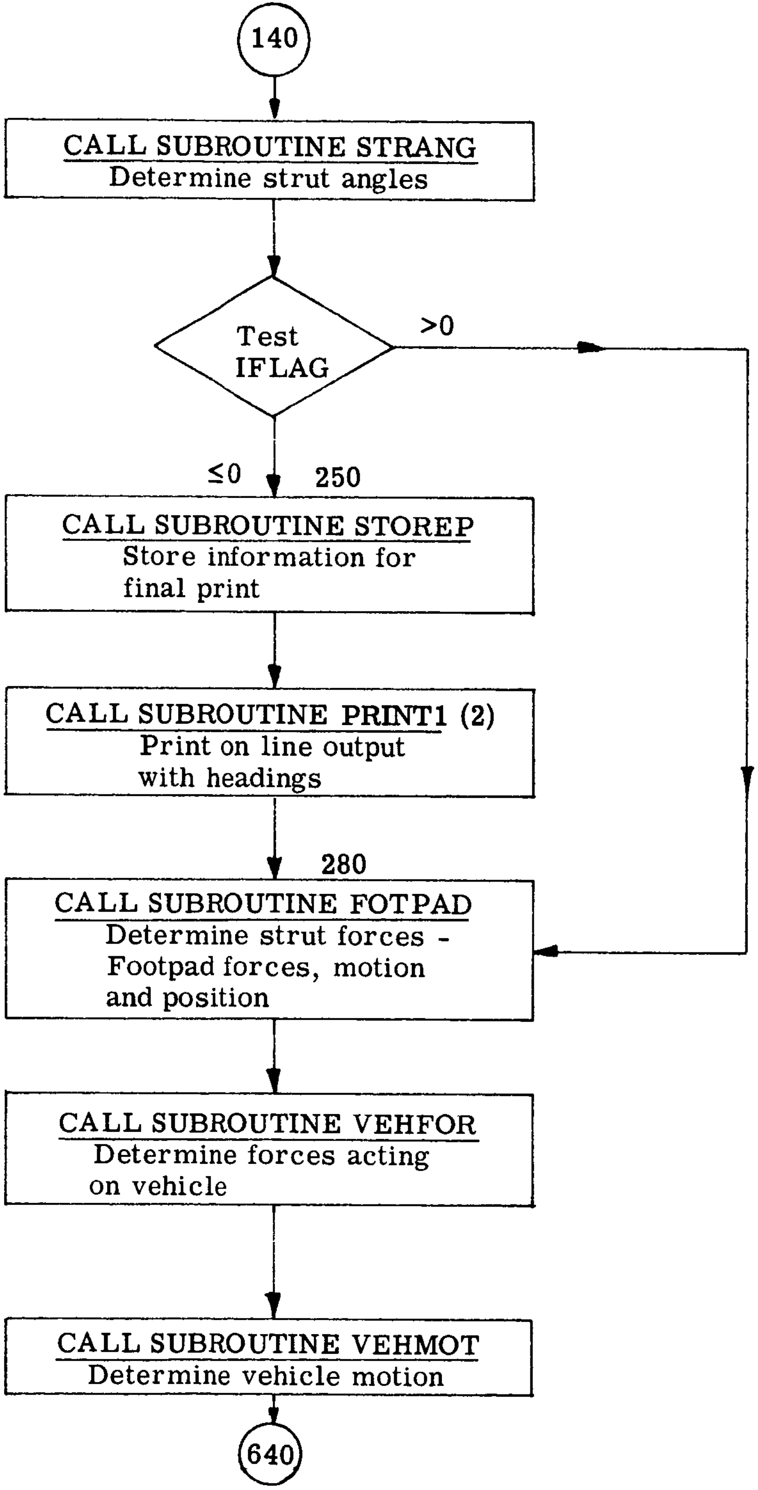

Figure 1-4. Main Lunar Landing Dynamics Program (Continued)

MAIN LUNAR LANDING DYNAMICS PROGRAM

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Page 3

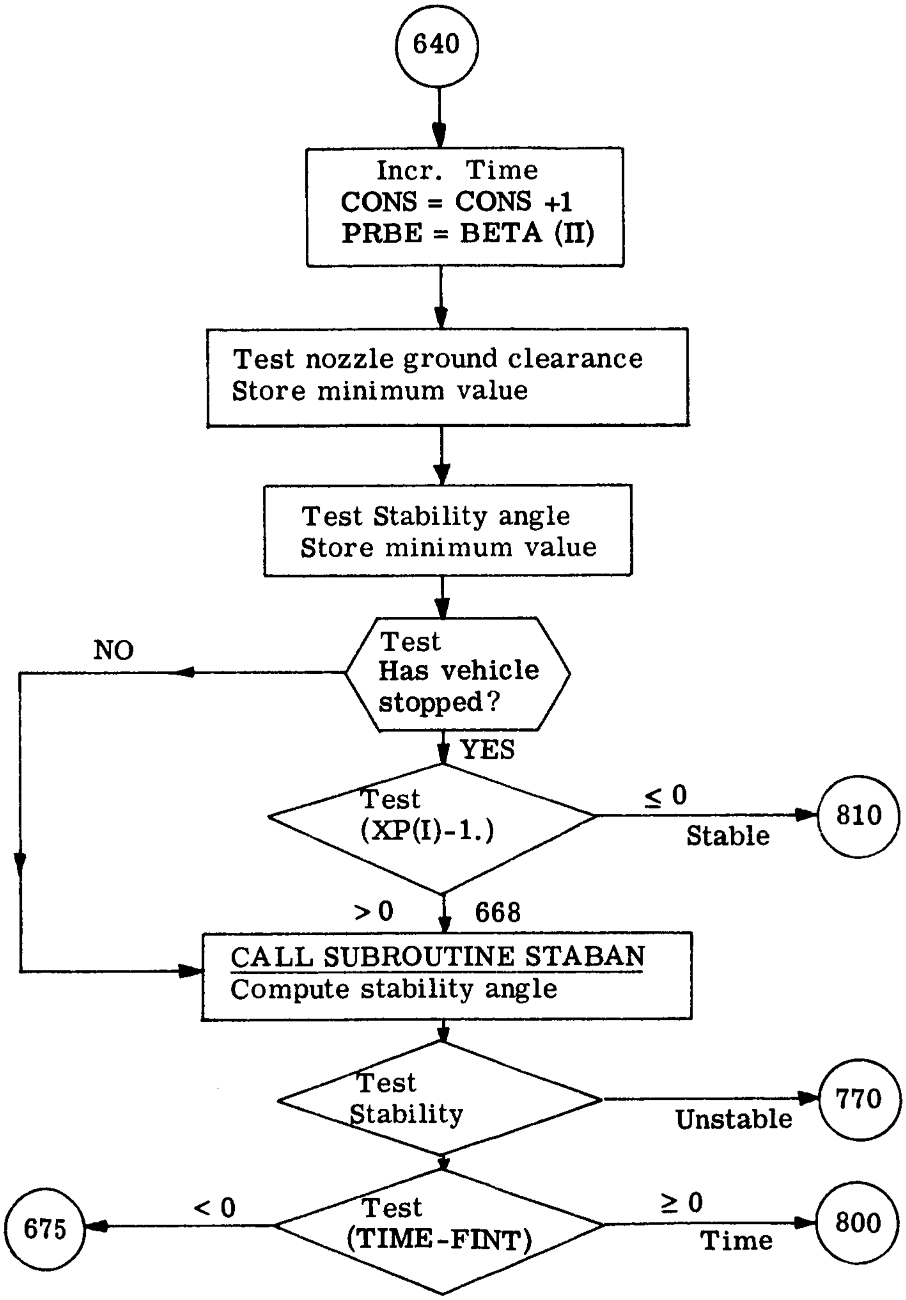

Figure 1-4. Main Lunar Landing Dynamics Program (Continued)

MAIN LUNAR LANDING DYNAMICS PROGRAM

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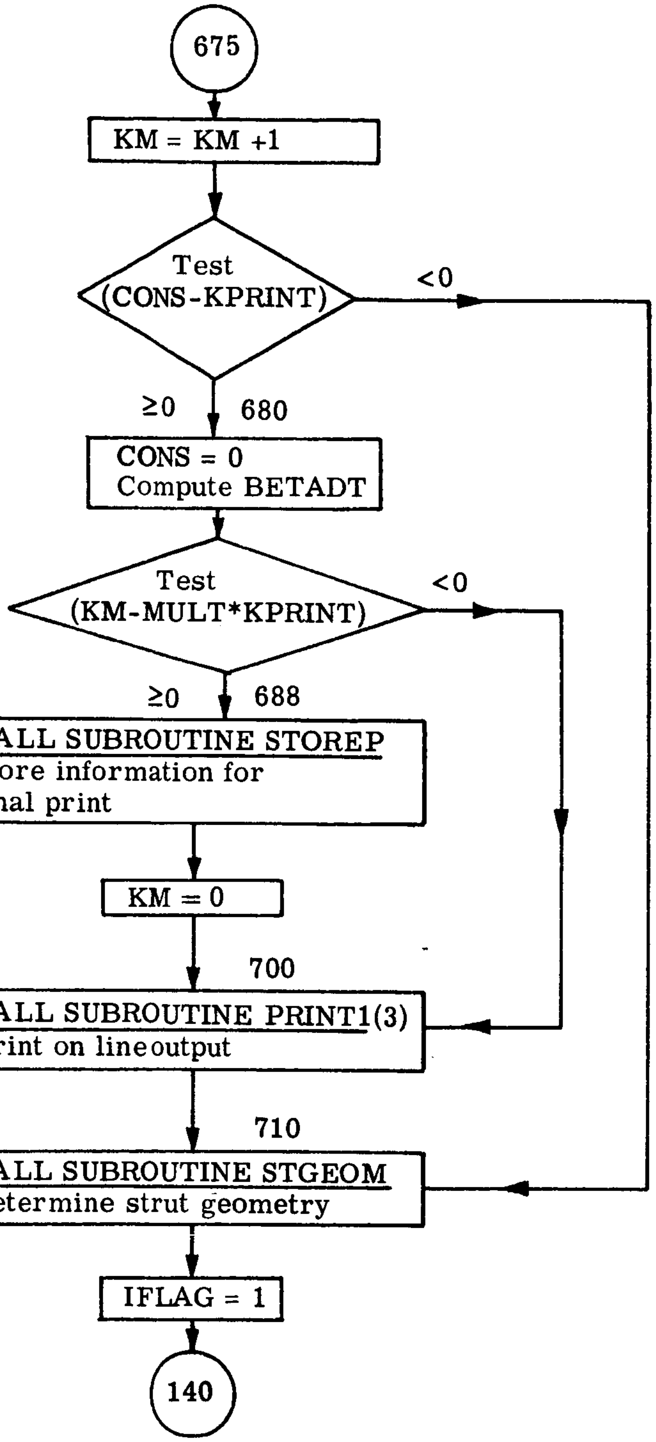

Figure 1-4. Main Lunar Landing Dynamics Program (Continued)

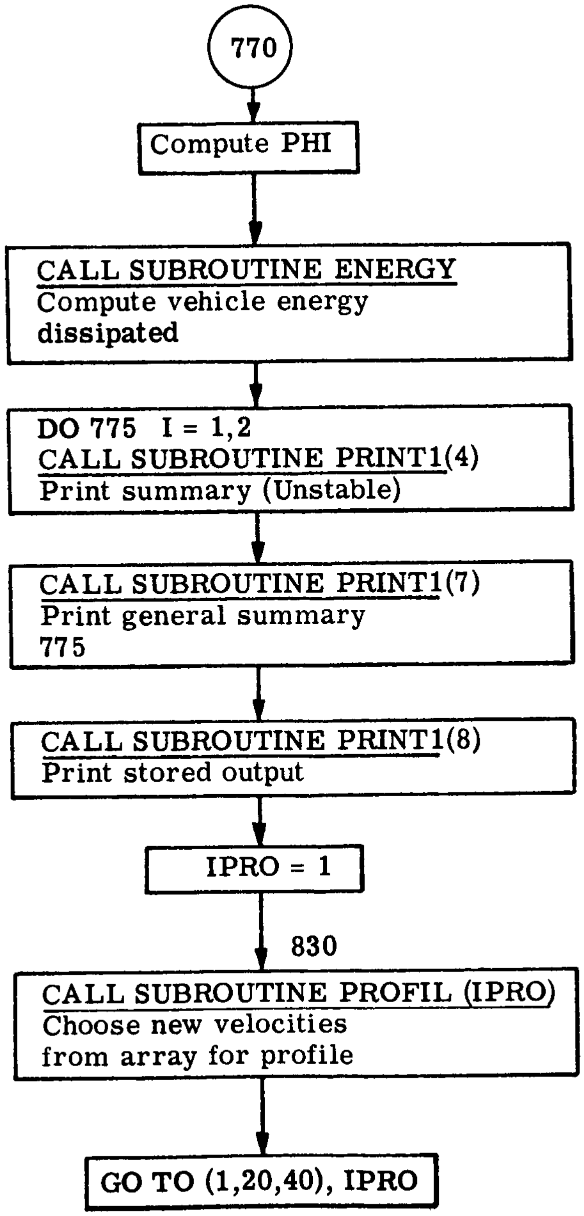

Figure 1-4. Main Lunar Landing Dynamics Program (Continued)

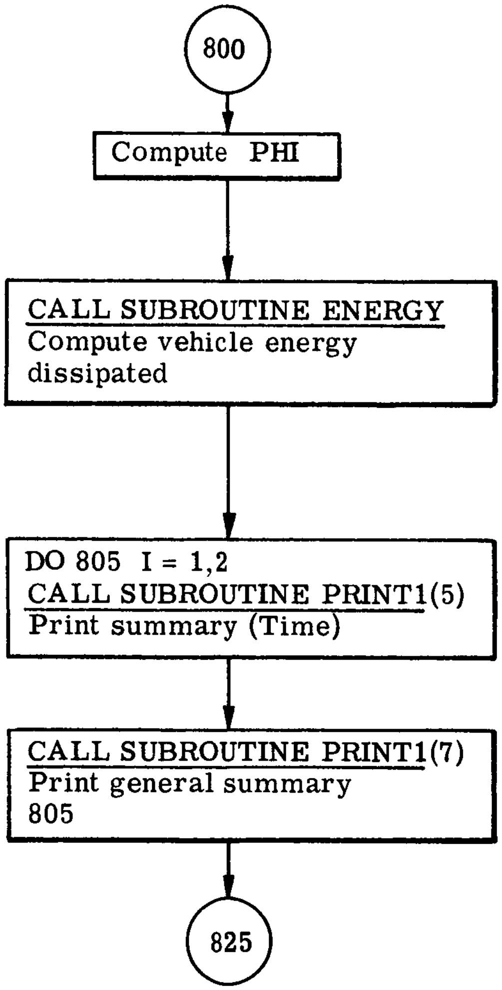

Figure 1-4. Main Lunar Landing Dynamics Program (Continued)

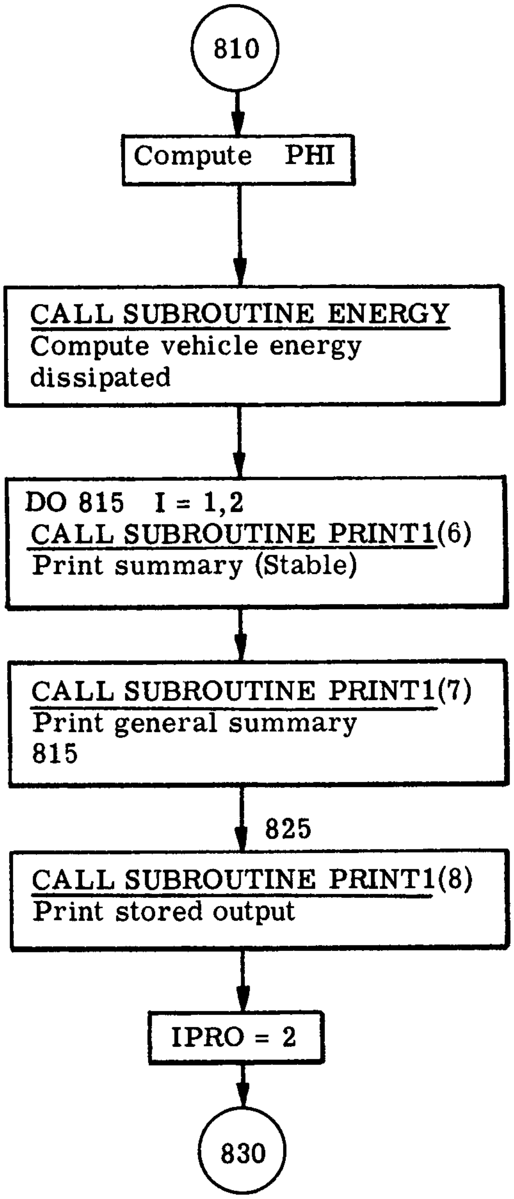

Figure 1-4. Main Lunar Landing Dynamics Program (Concluded)

This subroutine reads input data from cards.

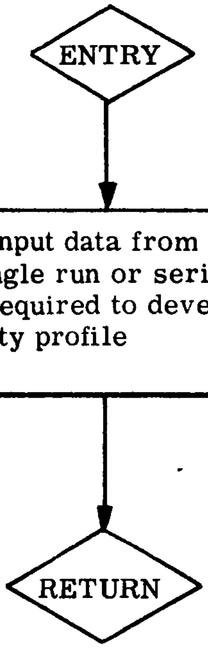

Figure 1-5. Subroutine-INPUT1

This subroutine converts the input data to a form that is used in the program.

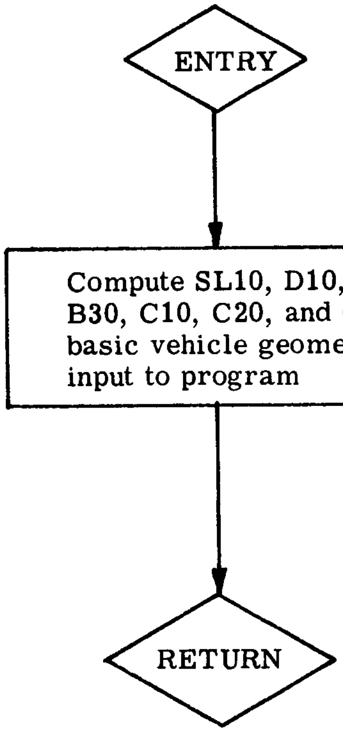

Figure 1-5A. Subroutine-INCON

This subroutine initializes the program for a series of runs used in determining a stability profile.

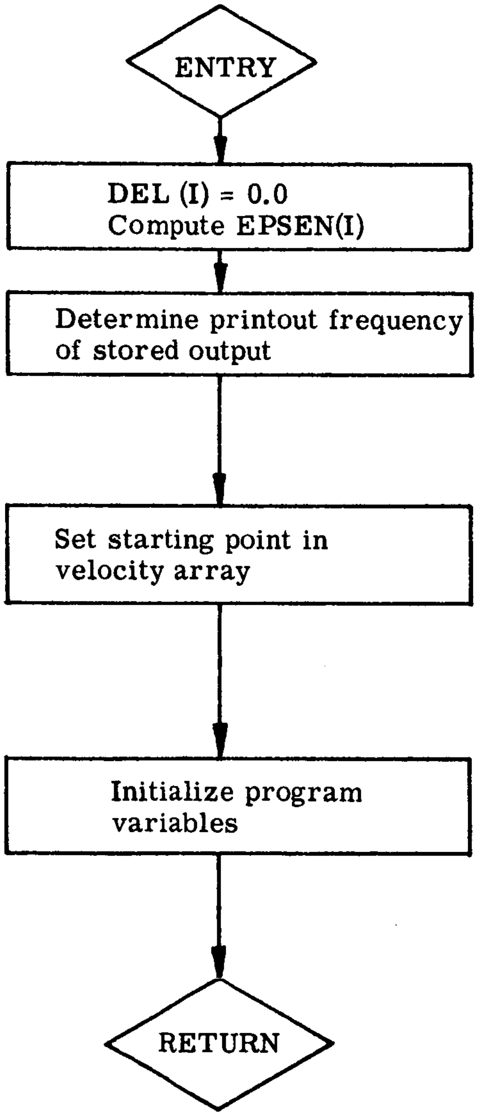

Figure 1-6. Subroutine-INITSE

This subroutine initializes program for each run.

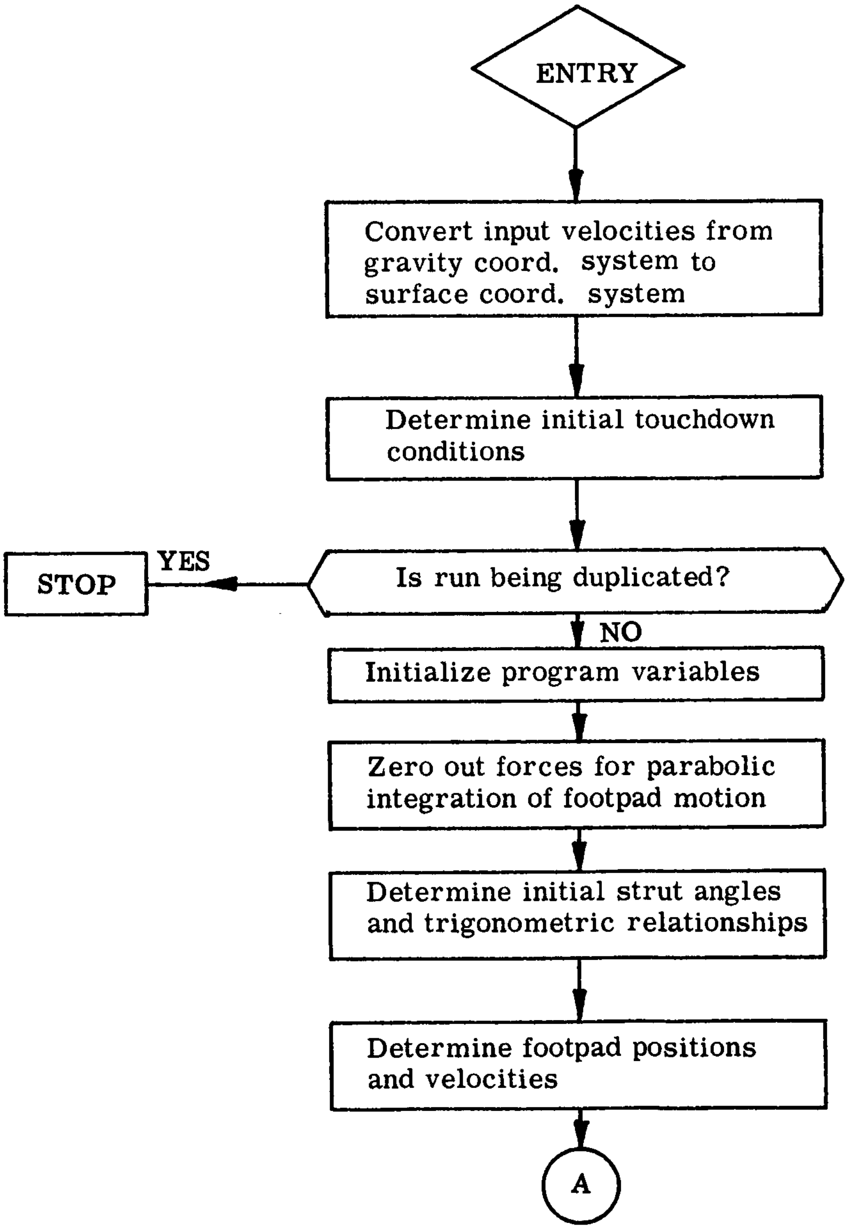

Figure 1-7. Subroutine-INITRU

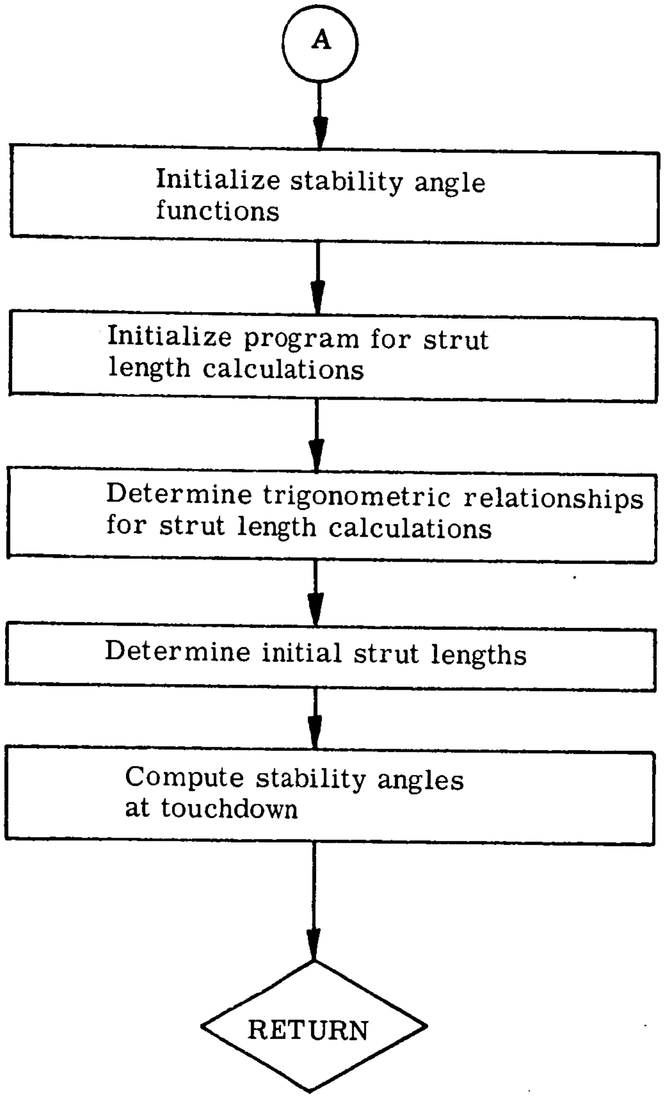

Figure 1-7. Subroutine-INITRU(Concluded)

STRANG-DETERMINE STRUT ANGLES

This subroutine determines new strut angles if footpad is on the ground.

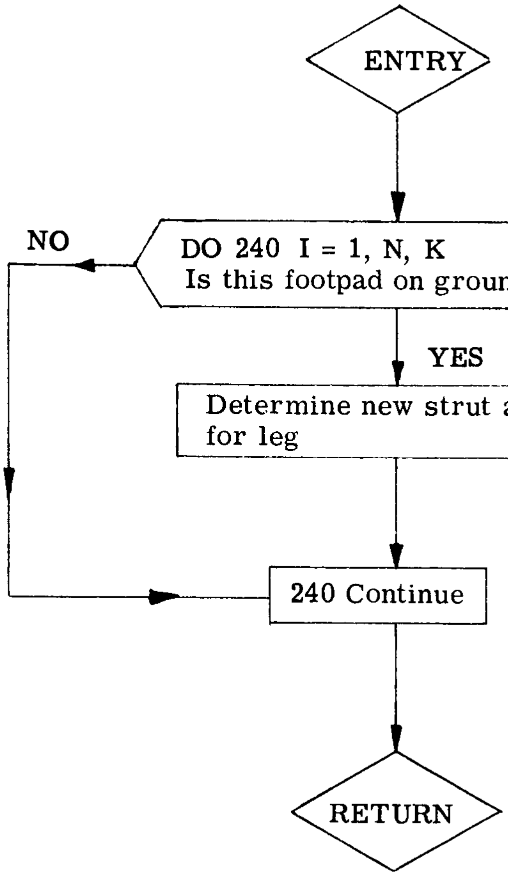

Figure 1-8. Subroutine-STRANG

This subroutine determines new strut geometry if footpad is on ground.

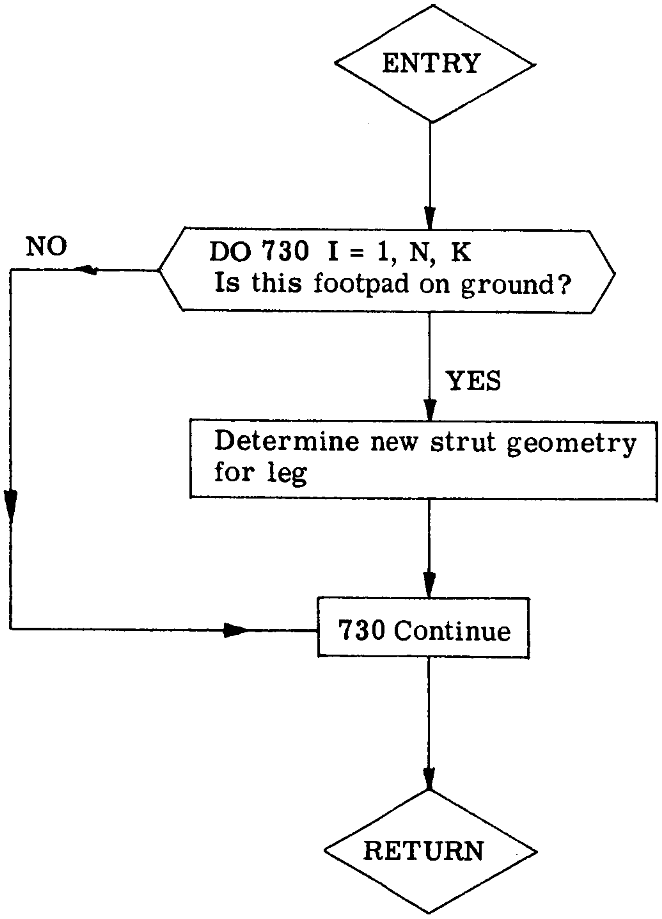

Figure 1-9. Subroutine-STGEOM

This subroutine determines strut forces and forces acting on footpads. It also obtains footpad position and motion using parabolic integration.

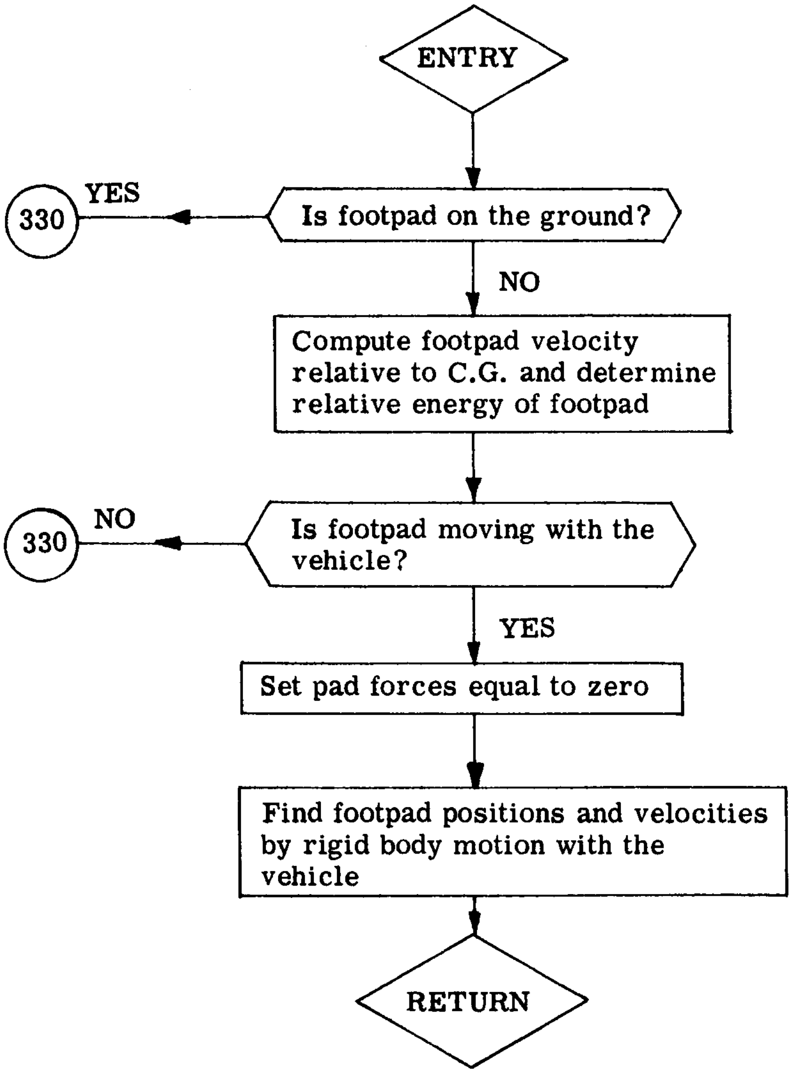

Figure 1-10. Subroutine-FOTPAD

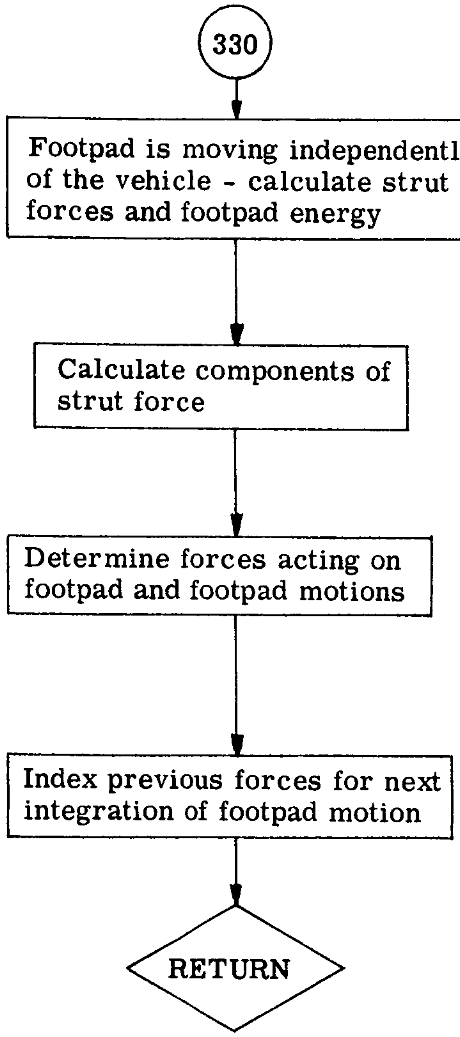

Figure 1-10. Subroutine-FOTPAD (Concluded)

This subroutine determines the forces at c.g. of vehicle to be used in determination of vehicle motion.

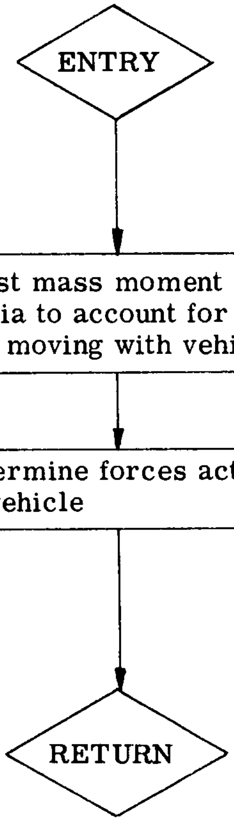

Figure 1-11. Subroutine-VEHFOR

This subroutine determines vehicle c.g. motion using parabolic integration.

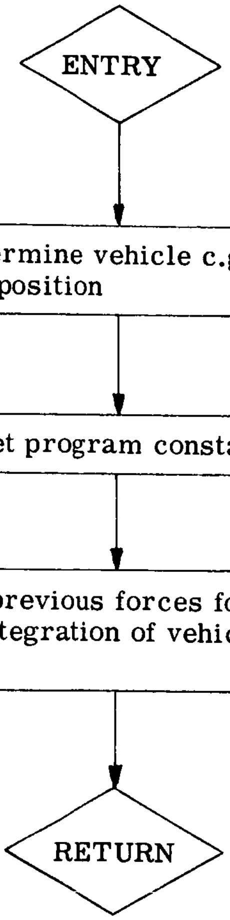

Figure 1-12. Subroutine-VEHMOT

This subroutine computes the stability angle and orients it in proper quadrant.

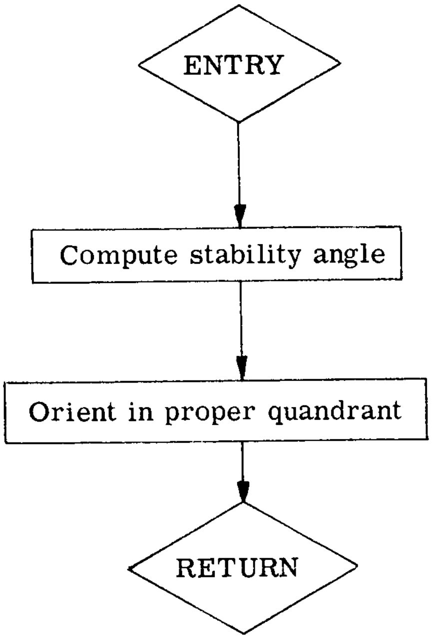

Figure 1-13. Subroutine-STABAN

STOREP-STORE INFORMATION FOR FINAL PRINT

This subroutine stores variables for print to be made at the end of the run.

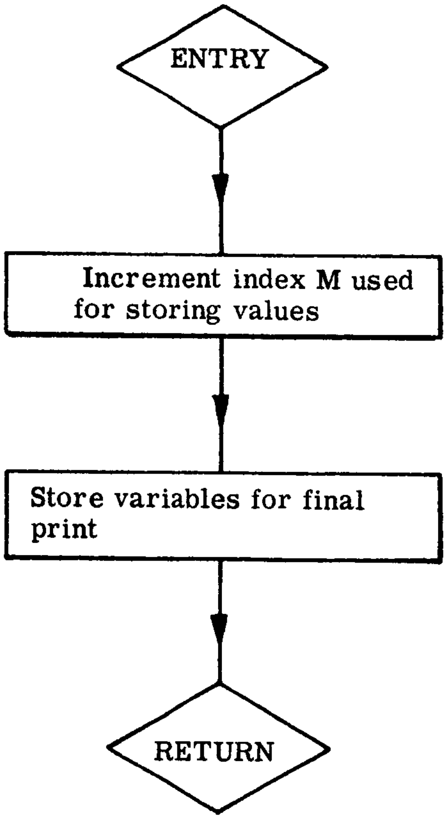

Figure 1-14. Subroutine-STOREP

This subroutine prints all output. Point of entry depends on value of IPR in call statement - CALL PRINT1 (IPR)

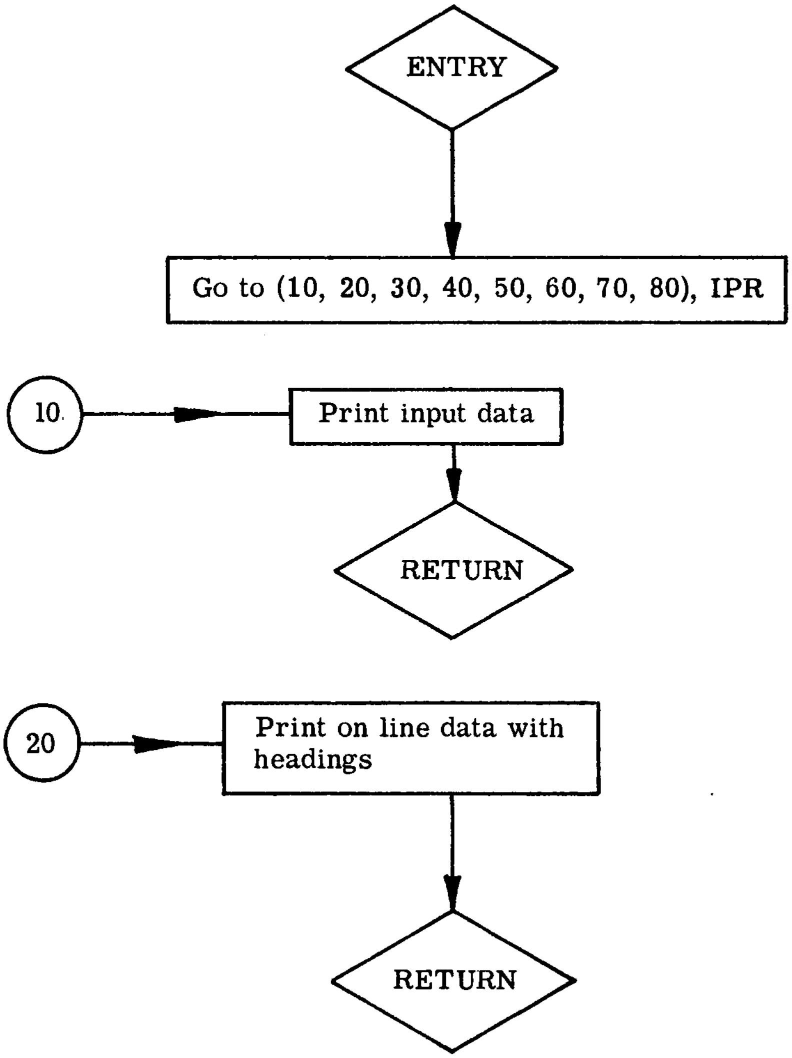

Figure 1-15. Subroutine-PRINT1

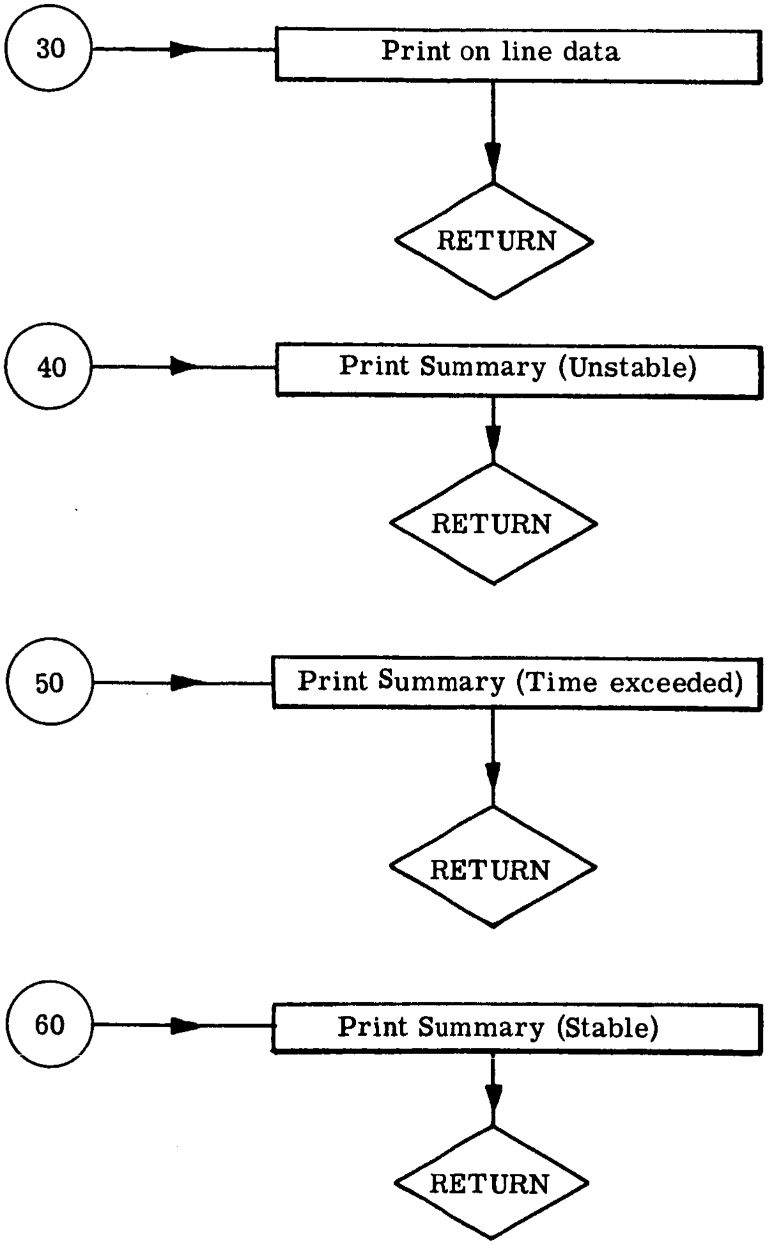

Figure 1-15. Subroutine-PRINT1 (Continued)

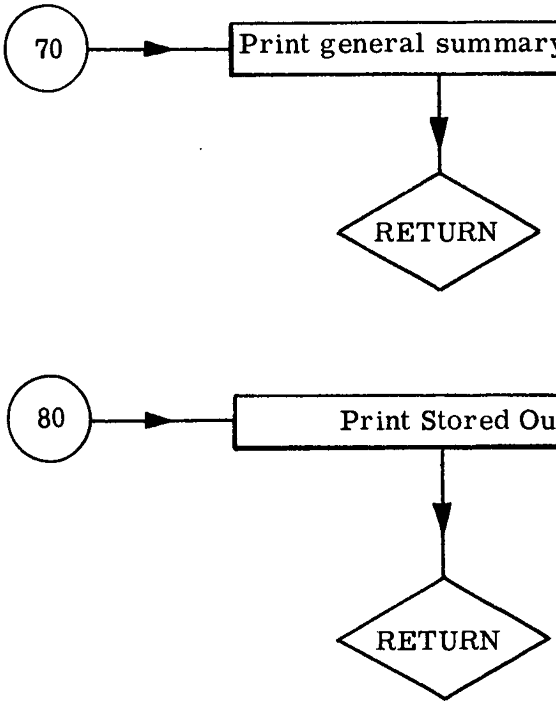

Figure 1-15. Subroutine-PRINT1 (Concluded)

This subroutine computes energy dissipated based on vehicle velocities and c.g. drop, based on plastic stroke and based on plastic and full elastic stroke.

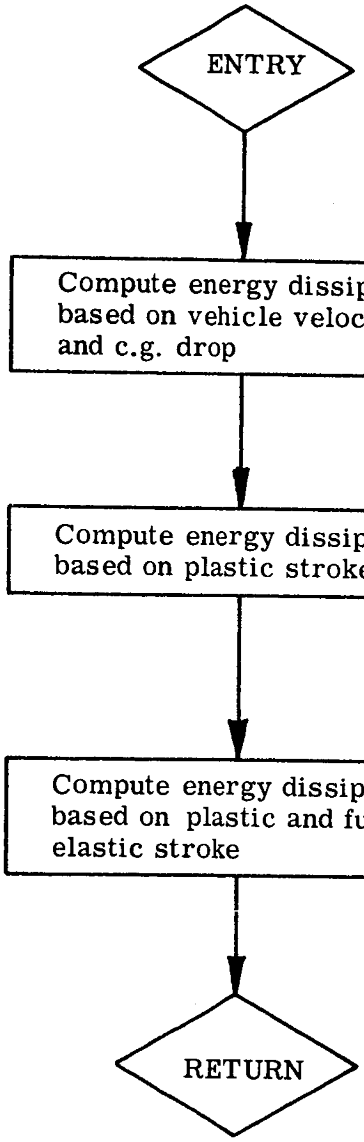

Figure 1-16. Subroutine-ENERGY

This subroutine determines new index values to choose new velocities from inputed array for the next run.

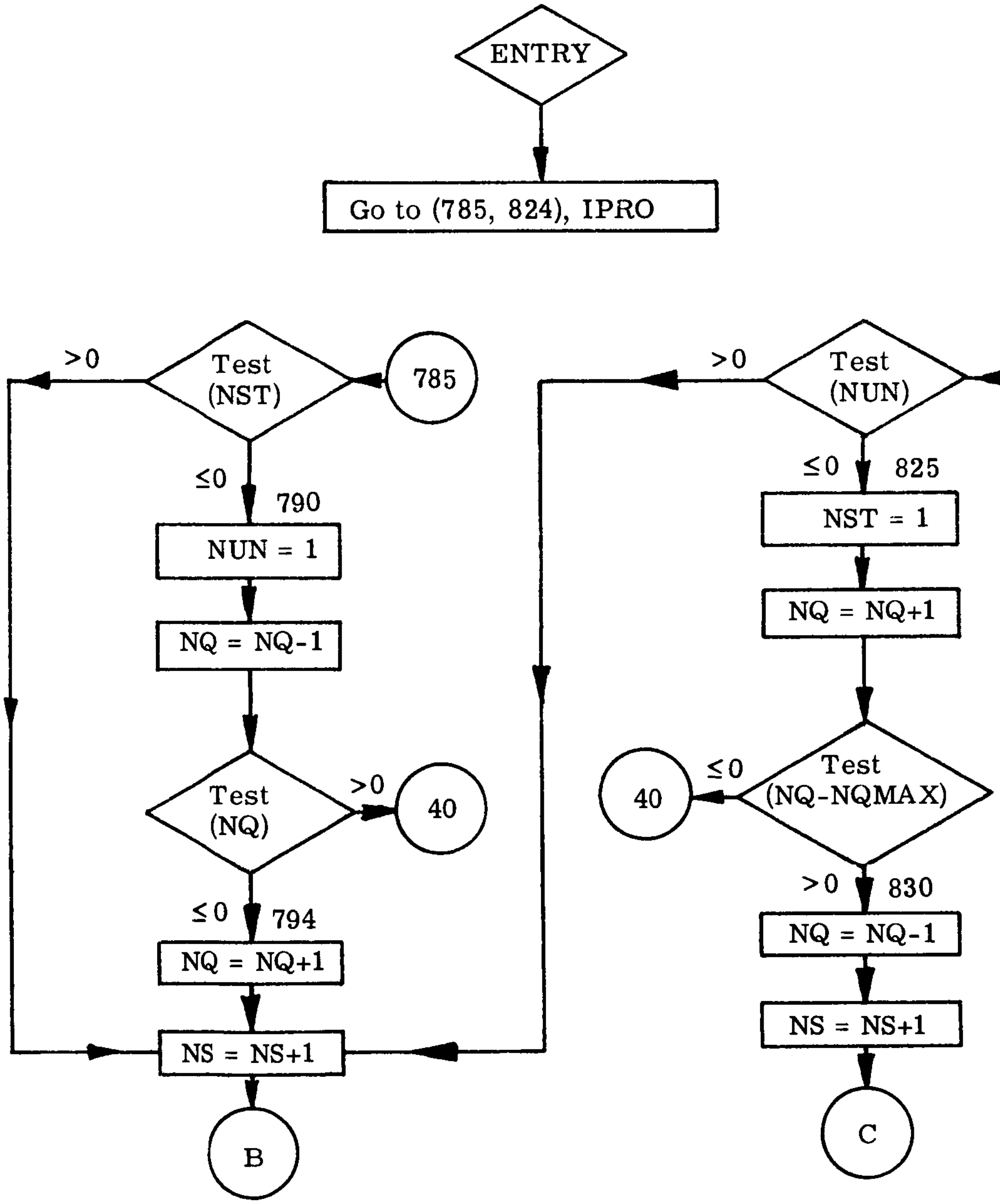

Figure 1-17. Subroutine-PROFIL

PROFIL-DETERMINE INDEX VALUES FOR VELOCITIES

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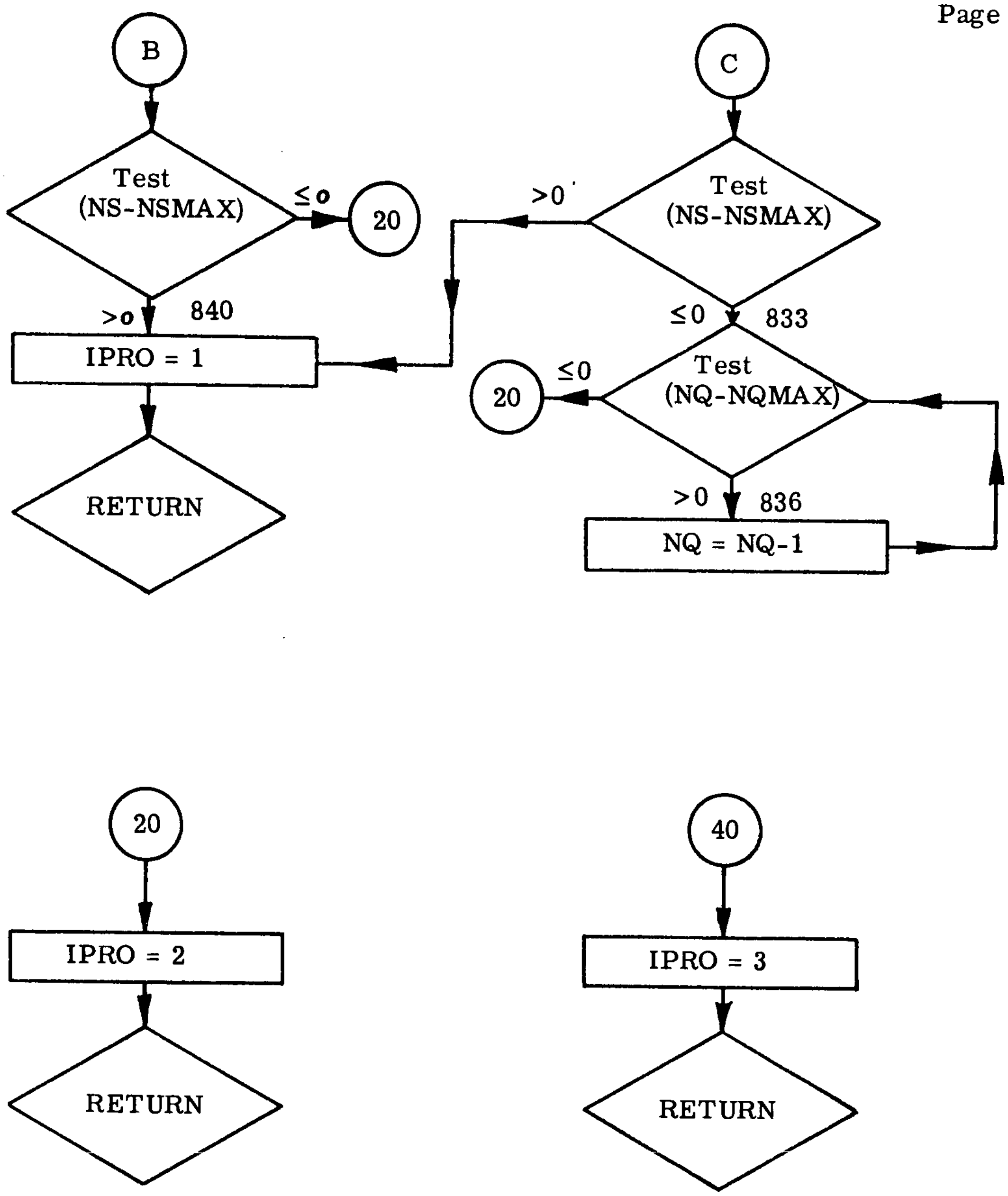

Figure 1-17. Subroutine-PROFIL (Concluded)

```
C TITLE       MAIN PROGRAM   LUNAR LANDING DYNAMICS COMPUTER PROGRAM
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C     PURPOSE   THIS PROGRAM COMPUTES THE DETAILED VEHICLE MOTIONS
C               FOR A PLANAR LANDING
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT       THROUGH LABELED COMMON
C
C OUTPUT      THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C               AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL    DEFINITION
C
C     A         SYMMETRY FACTOR -- IF TWO VEHICLE LEGS ARE SYMMETRIC,
C               SET A=2.0 FOR ONE OF THE SYMMETRIC PAIRS AND A=0.0 FOR
C               THE OTHER TO SAVE ON COMPUTER TIME    IE  FOR 22 LANDING
C               A=2,0,2,0          FOR A 121 LANDING  A= 1,2,1,0
C     ALPHA     ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C               SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     BEPR      VALUE OF BETA AT THE END OF THE PREVIOUS TIME INCREMENT.
C               USED TO ASSIGN BETA TO THE PROPER QUADRANT
C     BETA      VEHICLE STABILITY ANGLE
CC    BETADT    RATE OF CHANGE OF BETA WITH TIME
C     BETAPR    SIMILAR TO BEPR.  USED IN THE DETERMINATION OF VEHICLE
C               STABILITY
C     BIIMIN    MINIMUM STABILITY ANGLE FOR LEG SET II
C     BJJMIN    MINIMUM STABILITY ANGLE FOR LEG SET JJ
C     B10       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     B20       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B2PREV    VALUE OF B2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     B30       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     B3PREV    VALUE OF B3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     CONS      COUNTER FOR DETERMINING ON LINE PRINT FREQUENCY
C     COSA      COS(PSI)
C     COSB      COS(B1-PSI)
C     COSC      COS(THETA)
C     COSD      COS(B1)
C     COSE      COS(THETA-ALPHA/2.0)
C     COSG      COS(THETA+ALPHA/2.0)
C     C10,C20,C30      ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C               THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C               TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     C1PREV    VALUE OF C1 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C2PREV    VALUE OF C2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C3PREV    VALUE OF C3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     D         VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     DEL       PROGRAM CONSTANT EQUAL TO ZERO
```

Figure 1-18. Main Program

```
C     DELTAP    DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C               LEG STRUTS
C     DELTAT    TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     DELTTT    TIME INCREMENT USED IN THE INTEGRATION OF FOOTPAD
C               MOTION.   DELTTT= DELTAT/KCONMX
C     D10       INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C               OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C               TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     D11       VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     E1(I)     POTENTIAL ENERGY STORED IN STRUT NO.1 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     E2(I)     POTENTIAL ENERGY STORED IN STRUT NO.2 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     E3(I)     POTENTIAL ENERGY STORED IN STRUT NO. 3 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     EGBAL1    ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND C.G.
C               DROP
C     EGBAL2    ENERGY DISSIPATED BASED ON PLASTIC STROKE OF ALL STRUTS
C     EGBAL3    ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC
C               STROKE OF ALL STRUTS
C     ENPRO(I)  PERCENT OF TOTAL ENERGY ABSORBED BY  STROKING OF THE
C               STRUTS OF LEG SET I
C     EPSEN     PROGRAM CONSTANT EQUAL TO 10 PERCENT OF THE POSSIBLE
C               POTENTIAL ENERGY WHICH COULD BE STORED IN A FOOTPAD
C               AS THE RESULT OF ELASTIC STROKING OF  THE UPPER STRUT
C     EPS2      MINIMUM ALLOWABLE FOOTPAD SLIDING VELOCITY
C     EPS3      LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN X DIRECTION
C     EPS4      LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN Y DIRECTION
C     EPS5      LIMITING MINIMUM ANGULAR VELOCITY OF VEHICLE C. G.
C
C     NOTE      IF XVEL,YVEL AND PSIVEL ARE SIMULTANEOUSLY LESS THAN
C               EPS3,EPS4 AND EPS5 RESPECTIVELY AND THE FOOTPADS ARE ALL
C               LESS THAN 1 FT. FROM THE GROUND, THE PROGRAM TERMINATES
C
C     FA(I)     FORCE IN THE Z DIRECTION ACTING ON THE VEHICLE C.G. AS
C               THE RESULTANT OF THE STRUT FORCES IN THE THREE STRUTS
C               OF THE I TH LEG SET
C     FB(I)     FORCE, PARALLEL TO THE VEHICLE CENTERLINE  ACTING ON THE
C               VEHICLE C.G. AS THE RESULTANT OF THE STRUT FORCES IN
C               THE THREE STRUTS OF THE I TH LEG SET
C     FC(I)     FORCE, NORMAL TO VEHICLE CENTERLINE IN THE X-Y PLANE
C               ACTING ON THE VEHICLE C.G. AS THE RESULTANT OF THE STRUT
C               FORCES IN THE THREE STRUTS OF THE I TH LEG SET
C     FINT      MAXIMUM ALLOWABLE TIME FOR COMPUTER RUN
C     FLL       TOTAL FORCE ACTING ON THE VEHICLE IN THE LATERAL DIRECTION
C               (NORMAL TO THE VEHICLE CENTERLINE)
C     FVV       TOTAL FORCE ACTING ON THE VEHICLE IN THE VERTICAL
C               DIRECTION (  PARALLEL TO THE VEHICLE CENTERLINE)
C     FXP(I)    FORCE ON THE FOOTPAD I IN THE X DIRECTION IN THE FIXED
C               COORDINATE SYSTEM
C     FX        SAME AS FXP
C     FXPLG1    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG2    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FX1       FX     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FX3       FX     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FXPL31    FXPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FXPL33    FXPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
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Figure 1-18. Main Program (Continued)

```
C     FXX(3)    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(2)    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(1)    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG1    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG2    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG3    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPL33    FYPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FYPL31    FYPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FYY(3)    FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C               DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(2)    FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C               DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(1)    FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C               DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     F1(I)     PLASTIC STROKE FORCE IN STRUT NO.1 OF LEG I
C     F2(I)     PLASTIC STROKE FORCE IN STRUT NO.2 OF LEG I
C     F3(I)     PLASTIC STROKE FORCE IN STRUT NO.3 OF LEG I
C     F11       PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22       PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33       PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     FZPLG1    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG2    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG3    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG3    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPL31    FZPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FZPL33    FZPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     GRAV      LOCAL GRAVITY
C     GRDMU     COEFFICIENT OF FRICTION BETWEEN VEHICLE FOOTPADS AND GROUND
C     G1STR1    SL1T   VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1STR2    SL2T   VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1STR3    SL3T   VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G3STR1    SL1T   VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3STR2    SL2T   VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3STR3    SL3T   VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G1FRC1    F1     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1FRC2    F2     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1FRC3    F3     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G3FRC1    F1     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
```

Figure 1-18. Main Program (Continued)

```
C       G3FRC2     F2      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C       G3FRC3     F3      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C       H          DISTANCE FROM THE BOTTOM OF THE FOOTPAD TO THE VEHICLE
C                  CENTER OF GRAVITY
C       HN         VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND THE LOWEST
C                  POINT ON THE NOZZLE CONE
C       HVELO      HORIZONTAL VELOCITY PERPENDICULAR TO THE GRAVITATIONAL
C                  FIELD.
C       IFLAG      FLAG FOR INITIALIZING THE PROGRAM
C       II         PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                  PRINTED AS OUTPUT
C       IP         PRINT INDICATOR
C       IQ         PRINT INDICATOR
C       IR         PRINT INDICATOR
C       J          INDEX ASSOCIATED WITH FIRST LEG TO STRIKE GROUND DURING
C                  INITIAL IMPACT
C       JJ         SIMILAR TO II
C       K          FLAG FOR LANDING MODE    IF 1-2-1 LANDING , K=1    IF
C                  2-2 LANDING, K=2
CC      KCONMX     NUMBER OF ITERATIONS OF FOOTPAD CALCULATIONS PER  (DELTAT)
C                  TIME INTERVAL
C       KM         COUNTER FOR DETERMINING THE FREQUENCY OF THE STORED
C                  PRINTING
C       KPRINT     COMPUTATION INCREMENTS BETWEEN PRINTOUT INTERVALS
C       LAND       SIGNIFIES LANDING MODE  -  SET FOR 22 OR 121 LANDING
C       LINE       PRINTOUT LINE COUNTER
C       LOTPRT     FLAG TO DETERMINE IF COMPLETE SUMMARY PRINTING IS TO
C                  BE DESIRED.  COMPLETE OUTPUT PRINTING IS NOT NORMALLY
C                  USED THEREFORE SET LOTPRT=0  .   IF SET LOTPRT=1, THE
C                  COMPLETE HISTORY OF STRUT STROKES, AND STRUT FORCES WILL
C                  BE PRINTED.
C       M          INDEX USED TO STORE VARIABLES FOR PRINT AT END OF RUN
C       MULT       INDICATOR FLAG USED TO PRINT STORED OUTPUT DATA AT LESS
C                  FREQUENT INTERVALS IF FINT IS SUCH THAT THE DIMENSIONED
C                  STORAGE CAPACITY FOR THE STORED VARIABLES WILL BE EXCEEDED.
C       N          NUMBER OF LEGS ON THE VEHICLE
C       NOGR(I)    INDICATES IF FOOTPAD (I) IS MOVING WITH THE VEHICLE.  IF
C                  NOGR(I)=-1, FOOTPAD IS MOVING WITH THE VEHICLE.  IF
C                  NOGR(I) =+1, FOOTPAD IS MOVING INDEPENDENTLY
C       NQO        STARTING COLUMN IN VELOCITY INPUT ARRAY
C       NQMAX      ENDING COLUMN IN VELOCITY ARRAY
C       NSO        STARTING ROW IN VELOCITY INPUT ARRAY
C       NSMAX      ENDING ROW IN VELOCITY ARRAY
C
C       NOTE       SEE WRITEUP FOR DISCUSSION OF VELOCITY ARRAY
C
C       NST        FLAG FOR DETERMINING STABILITY PROFILE INPUT SEQUENCE
C       NUN        FLAG FOR DETERMINING STABILITY PROFILE INPUT SEQUENCE
C       PHI        ANGLE BETWEEN VEHICLE CENTERLINE AND GRAVITY VECTOR
C       PMASS      MASS OF EACH FOOTPAD
C       PRBE       SIMILAR TO BEPR.  USED IN THE DETERMINATION OF BETADT
C       PRXVEL     IN MULTIPLE RUNS, THIS IS THE INITIAL X VELOCITY OF THE
C                  PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C       PRYVEL     IN MULTIPLE RUNS, THIS IS THE INITIAL Y VELOCITY OF THE
C                  PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C       PSI        INSTANTANEOUS VALUE OF PSIO
C       PSIO       INITIAL PITCH ANGLE
C       PSIVEL     INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE C.G.
C       PSVELO     INITIAL VEHICLE PITCH RATE
C       P1         FRICTION FORCE IN STRUT NO. 1
C       P2         FRICTION FORCE IN STRUT NO. 2
```

Figure 1-18. Main Program (Continued)

```
C       P3          FRICTION FORCE IN STRUT NO. 3
C       RMOMGR      MOMENT OF INERTIA OF THE INDIVIDUAL VEHICLE FOOTPADS.
C                   THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C                   GROUND AT THE INSTANT UNDER INVESTIGATION
C       RMOMI       VEHICLE MOMENT OF INERTIA
C       RMOMIT      TOTAL MOMENT OF INERTIA OF THE VEHICLE MASS AND THOSE
C                   FOOTPADS WHICH ARE OFF THE GROUND
C       RMOO(3)     TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                   DURING THE CURRENT TIME INTERVAL.  THIS TORQUE IS USED
C                   IN THE PARABOLIC INTEGRATION PROCEDURE
C       RMOO(2)     TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                   DURING THE N-1 TIME INTERVAL.  THIS TORQUE IS USED
C                   IN THE PARABOLIC INTEGRATION PROCEDURE
C       RMOO(1)     TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                   DURING THE N-2 TIME INTERVAL.  THIS TORQUE IS USED
C                   IN THE PARABOLIC INTEGRATION PROCEDURE
C       RN          EXHAUST NOZZLE RADIUS
C       RP(I)       RADIUS OF FOOTPAD (I)
C       RUNNOO      RUN NUMBER  ( FOR IDENTIFICATION ONLY)
C       R1          RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C       R2          RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C       SERNO       SERIES NUMBER ( FOR IDENTIFICATION ONLY)
C       SINA        SIN(PSI)
C       SINB        SIN(B1-PSI)
C       SINC        SIN(THETA)
C       SIND        SIN(B1)
C       SING        SIN(C1)
C       SINI        SIN(C3)
C       SINJ        SIN(THETA-ALPHA/2.0)
C       SINK        SIN(THETA+ALPHA/2.0)
C       SINL        SIN(C2)
C       SKE1        TENSIL ELASTIC SPRINGRATE OF STRUT NO. 1 (UPPER)
C       SKE2        TENSIL ELASTIC SPRINGRATE OF STRUT NO. 2 (LOWER)
C       SKE3        TENSIL ELASTIC SPRINGRATE OF STRUT NO. 3 (LOWER)
C       SKS         SPRINGRATE UNDER VEHICLE FOOTPADS
C       SK1         COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C       SK2         COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C       SK3         COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C       SL1         PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C                   DIRECTION OF MOTION
C       SL1M        MINIMUM LENGTH TO WHICH STRUT NO.1 HAS BEEN COMPRESSED
C                   DURING THIS RUN
C       SL1O        INITIAL VALUE OF SL1
C       SL1PRE      LENGTH OF STRUT NO.1 AT THE END OF THE PREVIOUS TIME
C                   INCREMENT
C       SL1T        TRUE INSTANTANEOUS LENGTH OF STRUT NO.1
C       SL1TO       TRUE INITIAL LENGTH OF STRUT NO.1
C       SL2         INSTANTANEOUS LENGTH OF STRUT NO.2 ,PROJECTED IN A PLANE
C                   PARALLEL TO THE DIRECTION OF MOTION
C       SL2M        MINIMUM LENGTH TO WHICH STRUT NO.2 HAS BEEN COMPRESSED
C                   DURING THIS RUN
C       SL2PRE      LENGTH OF STRUT NO.2 AT THE END OF THE PREVIOUS TIME
C                   INCREMENT
C       SL2T        TRUE INSTANTANEOUS LENGTH OF STRUT NO.2
C       SL2TO       TRUE INITIAL LENGTH OF STRUT NO.2
C       SL3         INSTANTANEOUS LENGTH OF STRUT NO.3 ,PROJECTED IN A PLANE
C                   PARALLEL TO THE DIRECTION OF MOTION
C       SL3M        MINIMUM LENGTH TO WHICH STRUT NO.3 HAS BEEN COMPRESSED
C                   DURING THIS RUN
C       SL3PRE      LENGTH OF STRUT NO.3 AT THE END OF THE PREVIOUS TIME
C                   INCREMENT
```

Figure 1-18. Main Program (Continued)

```
C       SL3T       TRUE INSTANTANEOUS LENGTH OF STRUT NO.3
C       SL3TO      TRUE INITIAL LENGTH OF STRUT NO.3
C       THETA      ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C                  DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C                  CENTERLINE AND UPPER HARDPOINT
C       TMINBI     TIME WHEN MINIMUM STABILITY FOR LEG SET II OCCURS
C       TMINBJ     TIME WHEN MINIMUM STABILITY FOR LEG SET JJ OCCURS
C       TMINXN     TIME WHEN MINIMUM NOZZLE CLEARANCE OCCURS
C       VMASS      VEHICLE MASS
C       VVELO      INITIAL VEHICLE VELOCITY PARALLEL TO THE GRAVITATIONAL
C                  FIELD.   POSITIVE DOWNWARD
C       X          INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C       XP1        XP      VALUE FOR LEG II    STORED FOR FINAL PRINT
C       XN         INSTANTANEOUS NOZZLE CLEARANCE NORMAL TO THE SURFACE
C       XNMIN      MINIMUM VALUE OF NOZZLE CLEARANCE
C       XO         INITIAL X POSITION OF VEHICLE CENTER OF GRAVITY
C       XP(I)      X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C       XP3        XP      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C       XPVEL(I)   VELOCITY OF THE I TH FOOTPAD IN THE X DIRECTION IN THE
C                  FIXED COORDINATE SYSTEM
C       XVEL       INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C       XVELO      INITIAL VERTICAL VELOCITY OF VEHICLE C.G.
C       XVELOO     SAME AS XVELO
C       Y          INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C       YO         INITIAL HORIZONTAL POSITION OF VEHICLE C.G.
C       YP(I)      Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C       YP1        YP      VALUE FOR LEG II    STORED FOR FINAL PRINT
C       YP3        YP      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C       YPVEL(I)   VELOCITY OF THE I TH FOOTPAD IN THE Y DIRECTION IN THE
C                  FIXED COORDINATE SYSTEM
C       YVEL       INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C       YVELO      INITIAL HORIZONTAL VELOCITY OF VEHICLE C.G.
C       YVELOO     SAME AS YVELO
C       ZETA       GROUND SLOPE
C       ZP(I)      Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C       ZP1        ZP      VALUE FOR LEG II    STORED FOR FINAL PRINT
C       ZP3        ZP      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C       ZPVEL(I)   VELOCITY OF THE I TH FOOTPAD IN THE Z DIRECTION IN THE
C                  FIXED COORDINATE SYSTEM
C
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL1O(5),D1O(5),B1O(5),B2O(5),B3O(5),C1O(5),C2O(5),C3O(5)
      COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/EBLOCK/XP(5),YP(5),ZP(5),XPVEL(5),YPVEL(5),ZPVEL(5)
      COMMON/FBLOCK/FX(5),FXPLG3(5),FYPLG3(5),FZPLG3(5),FXPLG2(5),
     1 FYPLG2(5),FZPLG2(5),FXPLG1(5),FYPLG1(5),FZPLG1(5),
     1 F1(5),F2(5),F3(5),E1(5),E2(5),E3(5)
      COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
     1 SKE3
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
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Figure 1-18. Main Program (Continued)

```
     1 ENPRO(5)
      COMMON/IBLOCK/BETA(5),BEPR(5),BETAPR(5),LAND
      COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
      COMMON/KBLOCK/M,TIME,TME(402),XP1(402),YP1(402),ZP1(402),XP3(402),
     1 YP3(402),ZP3(402),FX1(402),FX3(402),FXPL31(402),FYPL31(402),
     1 FZPL31(402),FXPL33(402),FYPL33(402),FZPL33(402),G1STR1(402),
     1 G1STR2(402),G1STR3(402),G3STR1(402),G3STR2(402),G3STR3(402),
     1 G1FRC1(402),G1FRC2(402),G1FRC3(402),G3FRC1(402),G3FRC2(402),
     1 G3FRC3(402)
C
    1 CALL INPUT1
C
C     CONVERT INPUT DATA TO PROPER FORM TO BE USED BY THE PROGRAM
C
      CALL INCON
C
      CALL INITSE
C
   20 NST=0
      NUN=0
   40 RUNNO=RUNNO+1.0
C
      CALL INITRU
C
      CALL PRINT1(1)
C
  140 CALL STRANG
C
      IF(IFLAG)250,250,280
C
  250 CALL STOREP
C
      CALL PRINT1(2)
C
C
  280 CALL FOTPAD
C
      CALL VEHFOR
C
      CALL VEHMOT
C
C     INCREMENT TIME FOR NEXT CALCULATION
C
  640 TIME=TIME+DELTAT
      CONS=CONS+1.0
      PRBE=BETA(II)
C
C     TEST NOZZLE  =  GROUND CLEARANCE AND STORE MINIMUM VALUE
C
      XN=X-HN*COSA-RN*ABS (SINA)
      IF(XN-XNMIN)650,651,651
  650 XNMIN=XN
      TMINXN=TIME-DELTAT
      IF(TIME-2.0*DELTAT)653,653,651
C
C     TEST STABILITY ANGLE AND STORE MINIMUM VALUE
C
  651 IF(ABS (BETA(II))-ABS (BIIMIN))652,1653,1653
```

Figure 1-18. Main Program (Continued)

```
  652 BIIMIN=BETA(II)
      TMINBI=TIME-DELTAT
 1653 IF(ABS (BETA(JJ))-ABS (BJJMIN))1654,653,653
 1654 BJJMIN=BETA(JJ)
      TMINBJ=TIME-DELTAT
C
C     TEST IF VEHICLE IS STOPPED
C
  653 IF(ABS (XVEL)-EPS3)656,656,668
  656 IF(ABS (YVEL)-EPS4)660,660,668
  660 IF(ABS (PSIVEL)-EPS5)663,663,668
  663 DO 665 I=1,N,K
      IF(XP(I)-1.0)665,665,668
  665 CONTINUE
      GO TO 810
  668 CALL STABAN
C
C     TEST IF VEHICLE IS UNSTABLE
C
      DO 674 I=1,N,K
      PROD=BETA(I)*BETAPR(I)
      BETAPR(I)=BETA(I)
      IF(PROD)6732,674,674
C
C     TEST WHETHER LANDING IS 1=2=1 OR 2=2  .  IF IT IS 1=2=1 ,DISREGARD
C     STABILITY ANGLE DEFINED FOR MIDDLE LEGS
C
 6732 IF(LAND-100)770,770,6734
 6734 IF(I-1)770,770,6736
 6736 IF(I-3)674,770,674
  674 CONTINUE
      IF(TIME-FINT)675,800,800
C
C     SET LINE COUNT AND STORAGE FOR PLOT ROUTINE
C
  675 KM=KM+1
      IF(CONS-KPRINT)710,680,680
  680 CONS=0.0
      BETADT=(BETA(II)-PRBE)/DELTAT
  687 IF(KM-MULT*KPRINT)700,688,688
C
  688 CALL STOREP
C
      KM=0
C
  700 CALL PRINT1(3)
C
  710 CALL STGEOM
C
      IFLAG=1
      GO TO 140
C
C     VEHICLE IS UNSTABLE    PRINT OUTPUT DATA
C
  770 PHI=ZETA+PSI
C
      CALL ENERGY
C
      DO 775 I=1,2
C
      CALL PRINT1(4)
```

Figure 1-18. Main Program (Continued)

```
C
  775 CALL PRINT1(7)
C
      CALL PRINT1(8)
C
      IPRO=1
      GO TO 830
  800 PHI=ZETA+PSI
C
      CALL ENERGY
C
      DO 805 I=1,2
C
      CALL PRINT1(5)
C
  805 CALL PRINT1(7)
C
      GO TO 825
  810 PHI=ZETA+PSI
C
      CALL ENERGY
C
      DO 815 I=1,2
C
      CALL PRINT1(6)
C
  815 CALL PRINT1(7)
C
  825 CALL PRINT1(8)
C
      IPRO=2
C
  830 CALL PROFIL(IPRO)
C
      GO TO (1,20,40), IPRO
      END
```

Figure 1-18. Main Program (Concluded)

```
C TITLE       INPUT1
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C PURPOSE     READ INITIAL DATA
C
C CALL        INPUT1
C
C
C     NOTE        THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C     NOTE        THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C INPUT       CARD (FORMAT)
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C                 AS  B1O(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C                 IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL      DEFINITION
C
C     A           SYMMETRY FACTOR -- IF TWO VEHICLE LEGS ARE SYMMETRIC,
C                 SET A=2.0 FOR ONE OF THE SYMMETRIC PAIRS AND A=0.0 FOR
C                 THE OTHER TO SAVE ON COMPUTER TIME    IE  FOR 22 LANDING
C                 A=2,0,2,0         FOR A 121 LANDING  A= 1,2,1,0
C     ALPHA       ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C                 SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     D           VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     DELTAP      DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C                 LEG STRUTS
C     DELTAT      TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     D11         VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     EPS2        MINIMUM ALLOWABLE FOOTPAD SLIDING VELOCITY
C     EPS3        LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN X DIRECTION
C     EPS4        LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN Y DIRECTION
C     EPS5        LIMITING MINIMUM ANGULAR VELOCITY OF VEHICLE C. G.
C
C     NOTE        IF XVEL,YVEL AND PSIVEL ARE SIMULTANEOUSLY LESS THAN
C                 EPS3,EPS4 AND EPS5 RESPECTIVELY AND THE FOOTPADS ARE ALL
C                 LESS THAN 1 FT. FROM THE GROUND, THE PROGRAM TERMINATES
C
C     FINT        MAXIMUM ALLOWABLE TIME FOR COMPUTER RUN
C     F11         PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22         PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33         PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     GRAV        LOCAL GRAVITY
C     GRDMU       COEFFICIENT OF FRICTION BETWEEN VEHICLE FOOTPADS AND GROUND
C     H           DISTANCE FROM THE BOTTOM OF THE FOOTPAD TO THE VEHICLE
C                 CENTER OF GRAVITY
C     HN          VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND THE LOWEST
C                 POINT ON THE NOZZLE CONE
C     HVELO       HORIZONTAL VELOCITY PERPENDICULAR TO THE GRAVITATIONAL
C                 FIELD.
C     II          PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                 PRINTED AS OUTPUT
C     J           INDEX ASSOCIATED WITH FIRST LEG TO STRIKE GROUND DURING
C                 INITIAL IMPACT
C     JJ          SIMILAR TO II
```

Figure 1-19. Subroutine INPUT1

```
C     K          FLAG FOR LANDING MODE   IF 1-2-1 LANDING , K=1    IF
C                2-2 LANDING, K=2
CC    KCONMX     NUMBER OF ITERATIONS OF FOOTPAD CALCULATIONS PER  (DELTAT)
C                TIME INTERVAL
C     KPRINT     COMPUTATION INCREMENTS BETWEEN PRINTOUT INTERVALS
C     LAND       SIGNIFIES LANDING MODE  -  SET FOR 22 OR 121 LANDING
C     LOTPRT     FLAG TO DETERMINE IF COMPLETE SUMMARY PRINTING IS TO
C                BE DESIRED.  COMPLETE OUTPUT PRINTING IS NOT NORMALLY
C                USED THEREFORE SET LOTPRT=0  .   IF SET LOTPRT=1, THE
C                COMPLETE HISTORY OF STRUT STROKES, AND STRUT FORCES WILL
C                BE PRINTED.
C     N          NUMBER OF LEGS ON THE VEHICLE
C     NQO        STARTING COLUMN IN VELOCITY INPUT ARRAY
C     NQMAX      ENDING COLUMN IN VELOCITY ARRAY
C     NOTE       SEE WRITEUP FOR DISCUSSION OF VELOCITY ARRAY
C     NSO        STARTING ROW IN VELOCITY INPUT ARRAY
C     NSMAX      ENDING ROW IN VELOCITY ARRAY
C     PMASS      MASS OF EACH FOOTPAD
C     PSIO       INITIAL PITCH ANGLE
C     PSVELO     INITIAL VEHICLE PITCH RATE
C     P1         FRICTION FORCE IN STRUT NO. 1
C     P2         FRICTION FORCE IN STRUT NO. 2
C     P3         FRICTION FORCE IN STRUT NO. 3
C     RMOMI      VEHICLE MOMENT OF INERTIA
C     RN         EXHAUST NOZZLE RADIUS
C     RP(I)      RADIUS OF FOOTPAD (I)
C     RUNNOO     RUN NUMBER  ( FOR IDENTIFICATION ONLY)
C     R1         RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2         RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     SERNO      SERIES NUMBER ( FOR IDENTIFICATION ONLY)
C     SKE1       TENSIL ELASTIC SPRINGRATE OF STRUT NO. 1 (UPPER)
C     SKE2       TENSIL ELASTIC SPRINGRATE OF STRUT NO. 2 (LOWER)
C     SKE3       TENSIL ELASTIC SPRINGRATE OF STRUT NO. 3 (LOWER)
C     SKS        SPRINGRATE UNDER VEHICLE FOOTPADS
C     SK1        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C     SK2        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C     SK3        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C     THETA      ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C                DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C                CENTERLINE AND UPPER HARDPOINT
C     VMASS      VEHICLE MASS
C     VVELO      INITIAL VEHICLE VELOCITY PARALLEL TO THE GRAVITATIONAL
C                FIELD.   POSITIVE DOWNWARD
C     YO         INITIAL HORIZONTAL POSITION OF VEHICLE C.G.
C     ZETA       GROUND SLOPE
C
C OUTPUT       THROUGH LABELED COMMON
C
C
      SUBROUTINE INPUT1
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
     1 SKE3
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
```

Figure 1-19. Subroutine INPUT1 (Continued)

```
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      COMMON/IBLOCK/BETA(5),BEPR(5),BETAPR(5),LAND
      COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
C
C     READ INITIAL DATA
C
    1 READ 1000,(A(I),I=1,5),(ALPHA(I),I=1,5),(D(I),I=1,5),(D11(I),I=1,5
     1),(F11(I),I=1,5),(F22(I),I=1,5),(F33(I),I=1,5),(GRDMU(I),I=1,5),
     2(P1(I),I=1,5),(P2(I),I=1,5),(P3(I),I=1,5),(R1(I),I=1,5),(R2(I),I=1
     3,5),(RP(I),I=1,5),(SKS(I),I=1,5),(THETA(I),I=1,5)
    2 READ 1005,DELTAP,DELTAT,EPS2,EPS3,EPS4,EPS5,FINT,GRAV,HN,PMASS,
     1PSIO,PSVELO,RMOMI,RUNNOO,RN,SK1,SK2,SK3,SKE1,SKE2,SKE3,SERNO,
     2VMASS,YO,ZETA,H
    3 READ 1010,II,JJ,J,K,KPRINT,LAND,N,NSO,NQO,NSMAX,NQMAX,KCONMX,
     1LOTPRT
    4 READ 1015,((VVELO(ML,NL),HVELO(ML,NL),ML=1,NQMAX),NL=1,NSMAX)
      RETURN
 1000 FORMAT(10X,5F12.5)
 1005 FORMAT(10X,3F12.5)
 1010 FORMAT(10X,6I10)
 1015 FORMAT(10X,6F10.3)
      END
```

Figure 1-19. Subroutine INPUT1 (Concluded)

```
C TITLE       INCON
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C PURPOSE     CONVERT INPUT DATA TO PROPER FORM TO BE USED BY THE
C             PROGRAM
C
C CALL        INCON
C
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT       THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C               AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL    DEFINITION
C
C     ALPHA     ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C               SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     D         VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     DELTAP    DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C               LEG STRUTS
C     D11       VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     H         DISTANCE FROM THE BOTTOM OF THE FOOTPAD TO THE VEHICLE
C               CENTER OF GRAVITY
C     RP(I)     RADIUS OF FOOTPAD (I)
C     R1        RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2        RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     THETA     ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C               DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C               CENTERLINE AND UPPER HARDPOINT
C
C OUTPUT      THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     B10       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     B20       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B30       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     C10,C20,C30      ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C               THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C               TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     D10       INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C               OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C               TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     SL10      INITIAL VALUE OF SL1
C
C
      SUBROUTINE INCON
C
```

Figure 1-20. Subroutine INCON

```
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      DIMENSION C1ANG(5),C2ANG(5),C3ANG(5)
C     DETERMINE VEHICLE GEOMETRIC RELATIONSHIPS
    1 DO 100 I=1,N,K
      SL10(I)=SQRT((H-DELTAP-D11(I))*(H-DELTAP-D11(I))+((RP(I)-R1(I))*
     1COS(THETA(I))))*((RP(I)-R1(I))*COS(THETA(I))))
      D10(I)=(RP(I)-R1(I))*SIN(THETA(I))
      B10(I)=ATAN((RP(I)-R1(I))*COS(THETA(I))/(H-DELTAP-D11(I)))
      B20(I)=ATAN((RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)-ALPHA(I)/2.0
     1))/(H-DELTAP-D11(I)-D(I)))
      B30(I)=ATAN((RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)+ALPHA(I)/2.0
     1))/(H-DELTAP-D11(I)-D(I)))
   10 C1ANG(I)=ATAN(ABS(SL10(I)/D10(I)))
      S2X=RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)-ALPHA(I)/2.0)
      SL200=SQRT(S2X*S2X+(H-DELTAP-D11(I)-D(I))*(H-DELTAP-D11(I)-D(I)))
      C2ANG(I)=ATAN(ABS(SL200/(RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)-
     1ALPHA(I)/2.0))))
      S3X=RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)+ALPHA(I)/2.0)
      SL300=SQRT(S3X*S3X+(H-DELTAP-D11(I)-D(I))*(H-DELTAP-D11(I)-D(I)))
      C3ANG(I)=ATAN(ABS(SL300/(RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)+
     1ALPHA(I)/2.0))))
C     TEST WHICH QUADRANT CONTAINS THETA TO DETERMINE PROPER QUADRANT
C     FOR C10
   64 IF (THETA(I)) 68,70,72
   68 C10(I)=3.14159265359-C1ANG(I)
      GO TO 76
   70 C10(I)=1.5707963
      GO TO 76
   72 C10(I)=C1ANG(I)
   76 IF (RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)-ALPHA(I)/2.0)) 80,82,84
   80 C20(I)=3.14159265359-C2ANG(I)
      GO TO 88
   82 C20(I)=1.5707963
      GO TO 88
   84 C20(I)=C2ANG(I)
   88 IF (RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)+ALPHA(I)/2.0)) 92,94,96
   92 C30(I)=3.14159265359-C3ANG(I)
      GO TO 100
   94 C30(I)=1.5707963
      GO TO 100
   96 C30(I)=C3ANG(I)
  100 CONTINUE
      RETURN
      END
```

Figure 1-20. Subroutine INCON (Concluded)

```
C TITLE       INITSE
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C PURPOSE     INITIALIZE PROGRAM CONSTANTS AND VARIABLES FOR
C             SERIES OF RUNS
C
C CALL        INITSE
C
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT       THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C               AS  B1O(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL    DEFINITION
C
C     DELTAT    TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     FINT      MAXIMUM ALLOWABLE TIME FOR COMPUTER RUN
C     F11       PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     K         FLAG FOR LANDING MODE   IF 1-2-1 LANDING , K=1    IF
C               2-2 LANDING, K=2
C     KPRINT    COMPUTATION INCREMENTS BETWEEN PRINTOUT INTERVALS
C     N         NUMBER OF LEGS ON THE VEHICLE
C     RUNNOO    RUN NUMBER  ( FOR IDENTIFICATION ONLY)
C     SK1       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C
C OUTPUT      THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     EPSEN     PROGRAM CONSTANT EQUAL TO 10 PERCENT OF THE POSSIBLE
C               POTENTIAL ENERGY WHICH COULD BE STORED IN A FOOTPAD
C               AS THE RESULT OF ELASTIC STROKING OF  THE UPPER STRUT
C     MULT      INDICATOR FLAG USED TO PRINT STORED OUTPUT DATA AT LESS
C               FREQUENT INTERVALS IF FINT IS SUCH THAT THE DIMENSIONED
C               STORAGE CAPACITY FOR THE STORED VARIABLES WILL BE EXCEEDED.
C     NQO       STARTING COLUMN IN VELOCITY INPUT ARRAY
C     NSO       STARTING ROW IN VELOCITY INPUT ARRAY
C
C     NOTE      SEE WRITEUP FOR DISCUSSION OF VELOCITY ARRAY
C
C     PRXVEL    IN MULTIPLE RUNS, THIS IS THE INITIAL X VELOCITY OF THE
C               PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C     PRYVEL    IN MULTIPLE RUNS, THIS IS THE INITIAL Y VELOCITY OF THE
C               PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C
C
      SUBROUTINE INITSE
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
     1 SKE3
```

Figure 1-21. Subroutine INITSE

```
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
C     INITIALIZE PROGRAM CONSTANTS
C
      DO 5 I=1,N,K
    5 EPSEN(I)=F11(I)*F11(I)/(SK1*20.0)
C
C     DETERMINE PRINTOUT FREQUENCY OF STORED OUTPUT
C
      FACTOR=FINT/402.0
      IF(FACTOR-(DELTAT*KPRINT))7,8,8
    7 MULT=1
      GO TO 15
    8 IF(FACTOR-2.0*(DELTAT*KPRINT))9,12,12
    9 MULT=2
      GO TO 15
   12 MULT=5
C
C     SET STARTING POINT IN VELOCITY ARRAY
C
   15 NS=NSO
      NQ=NQO
C
C     INITIALIZE PROGRAM VARIABLES
C
      RUNNO=RUNNOO-1.0
      PRXVEL=100.0
      PRYVEL=100.0
      RETURN
      END
```

Figure 1-21. Subroutine INITSE (Concluded)

```
C TITLE        INITRU
C
C     AUTHORS    R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      INITIALIZE PROGRAM CONSTANTS AND VARIABLES FOR
C              EACH RUN
C
C CALL         INITRU
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C                AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C                IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL     DEFINITION
C
C     ALPHA      ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C                SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     B10        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     B20        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B30        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     COSA       COS(PSI)
C     C10,C20,C30      ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C                THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C                TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     DELTAP     DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C                LEG STRUTS
C     DELTAT     TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     D10        INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C                OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C                TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     D11        VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     FXP(I)     FORCE IN THE X DIRECTION ON THE FOOTPAD (I)
C     F11        PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22        PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33        PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     HVELO      HORIZONTAL VELOCITY PERPENDICULAR TO THE GRAVITATIONAL
C                FIELD.
CC    KCONMX     NUMBER OF ITERATIONS OF FOOTPAD CALCULATIONS PER  (DELTAT)
C                TIME INTERVAL
C     PRXVEL     IN MULTIPLE RUNS, THIS IS THE INITIAL X VELOCITY OF THE
C                PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C     PRYVEL     IN MULTIPLE RUNS, THIS IS THE INITIAL Y VELOCITY OF THE
C                PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C     PSIO       INITIAL PITCH ANGLE
C     PSVELO     INITIAL VEHICLE PITCH RATE
C     R1         RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2         RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     SINA       SIN(PSI)
C     SK1        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
```

Figure 1-22. Subroutine INITRU

```
C     SK2       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C     SK3       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C     SL10      INITIAL VALUE OF SL1
C     THETA     ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C               DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C               CENTERLINE AND UPPER HARDPOINT
C     TIME      TIME AFTER TOUCHDOWN
C     VVELO     INITIAL VEHICLE VELOCITY PARALLEL TO THE GRAVITATIONAL
C               FIELD.  POSITIVE DOWNWARD
C     YO        INITIAL HORIZONTAL POSITION OF VEHICLE C.G.
C     YVEL      INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C     ZETA      GROUND SLOPE
C
C OUTPUT      THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     BEPR      VALUE OF BETA AT THE END OF THE PREVIOUS TIME INCREMENT.
C               USED TO ASSIGN BETA TO THE PROPER QUADRANT
C     BETA      VEHICLE STABILITY ANGLE
CC    BETADT    RATE OF CHANGE OF BETA WITH TIME
C     BETAPR    SIMILAR TO BEPR.  USED IN THE DETERMINATION OF VEHICLE
C               STABILITY
C     BIIMIN    MINIMUM STABILITY ANGLE FOR LEG SET II
C     BJJMIN    MINIMUM STABILITY ANGLE FOR LEG SET JJ
C     B2PREV    VALUE OF B2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     B3PREV    VALUE OF B3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     CONS      COUNTER FOR DETERMINING ON LINE PRINT FREQUENCY
C     COSB      COS(B1-PSI)
C     COSC      COS(THETA)
C     COSD      COS(B1)
C     COSE      COS(THETA-ALPHA/2.0)
C     COSG      COS(THETA+ALPHA/2.0)
C     C1PREV    VALUE OF C1 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C2PREV    VALUE OF C2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C3PREV    VALUE OF C3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     DELTTT    TIME INCREMENT USED IN THE INTEGRATION OF FOOTPAD
C               MOTION.  DELTTT= DELTAT/KCONMX
C     E1(I)     POTENTIAL ENERGY STORED IN STRUT NO.1 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     E2(I)     POTENTIAL ENERGY STORED IN STRUT NO.2 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     E3(I)     POTENTIAL ENERGY STORED IN STRUT NO. 3 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     FLL       TOTAL FORCE ACTING ON THE VEHICLE IN THE LATERAL DIRECTION
C               (NORMAL TO THE VEHICLE CENTERLINE)
C     FVV       TOTAL FORCE ACTING ON THE VEHICLE IN THE VERTICAL
C               DIRECTION (  PARALLEL TO THE VEHICLE CENTERLINE)
C     FX        SAME AS FXP
C     FXP(I)    FORCE ON THE FOOTPAD I IN THE X DIRECTION IN THE FIXED
C               COORDINATE SYSTEM
C     FXPLG1    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG2    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG1    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG2    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 2
```

Figure 1-22. Subroutine INITRU (Continued)

```
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG3     AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO.3
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG1     AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.1
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG2     AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.2
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG3     AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.3
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG3     AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.3
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FZPL31     FZPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FXX(3)     FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C                DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(2)     FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(1)     FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(3)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(2)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(1)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     F1(I)      PLASTIC STROKE FORCE IN STRUT NO.1 OF LEG I
C     F2(I)      PLASTIC STROKE FORCE IN STRUT NO.2 OF LEG I
C     F3(I)      PLASTIC STROKE FORCE IN STRUT NO.3 OF LEG I
C     IFLAG      FLAG FOR INITIALIZING THE PROGRAM
C     KM         COUNTER FOR DETERMINING THE FREQUENCY OF THE STORED
C                PRINTING
C     LINE       PRINTOUT LINE COUNTER
C     M          INDEX USED TO STORE VARIABLES FOR PRINT AT END OF RUN
C     MULT       INDICATOR FLAG USED TO PRINT STORED OUTPUT DATA AT LESS
C                FREQUENT INTERVALS IF FINT IS SUCH THAT THE DIMENSIONED
C                STORAGE CAPACITY FOR THE STORED VARIABLES WILL BE EXCEEDED.
C     N          NUMBER OF LEGS ON THE VEHICLE
C     NOGR(I)    INDICATES IF FOOTPAD (I) IS MOVING WITH THE VEHICLE.  IF
C                NOGR(I)=-1, FOOTPAD IS MOVING WITH THE VEHICLE.  IF
C                NOGR(I) =+1, FOOTPAD IS MOVING INDEPENDENTLY
C     PSI        INSTANTANEOUS VALUE OF PSIO
C     PSIVEL     INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE C.G.
C     RMOMGR     MOMENT OF INERTIA OF THE INDIVIDUAL VEHICLE FOOTPADS.
C                THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C                GROUND AT THE INSTANT UNDER INVESTIGATION
C     RMOO(3)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE CURRENT TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(2)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-1 TIME INTERVAL.  THIS TORQUE IS USED
```

Figure 1-22. Subroutine INITRU (Continued)

```
C                   IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(1)       TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                   DURING THE N-2 TIME INTERVAL.  THIS TORQUE IS USED
C                   IN THE PARABOLIC INTEGRATION PROCEDURE
C     SINB          SIN(B1-PSI)
C     SINC          SIN(THETA)
C     SIND          SIN(B1)
C     SINJ          SIN(THETA-ALPHA/2.0)
C     SINK          SIN(THETA+ALPHA/2.0)
C     SL1           PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C                   DIRECTION OF MOTION
C     SL1M          MINIMUM LENGTH TO WHICH STRUT NO.1 HAS BEEN COMPRESSED
C                   DURING THIS RUN
C     SL1PRE        LENGTH OF STRUT NO.1 AT THE END OF THE PREVIOUS TIME
C                   INCREMENT
C     SL1T          TRUE INSTANTANEOUS LENGTH OF STRUT NO.1
C     SL1TO         TRUE INITIAL LENGTH OF STRUT NO.1
C     SL2           INSTANTANEOUS LENGTH OF STRUT NO.2 ,PROJECTED IN A PLANE
C                   PARALLEL TO THE DIRECTION OF MOTION
C     SL2M          MINIMUM LENGTH TO WHICH STRUT NO.2 HAS BEEN COMPRESSED
C                   DURING THIS RUN
C     SL2PRE        LENGTH OF STRUT NO.2 AT THE END OF THE PREVIOUS TIME
C                   INCREMENT
C     SL2T          TRUE INSTANTANEOUS LENGTH OF STRUT NO.2
C     SL2TO         TRUE INITIAL LENGTH OF STRUT NO.2
C     SL3           INSTANTANEOUS LENGTH OF STRUT NO.3 ,PROJECTED IN A PLANE
C                   PARALLEL TO THE DIRECTION OF MOTION
C     SL3M          MINIMUM LENGTH TO WHICH STRUT NO.3 HAS BEEN COMPRESSED
C                   DURING THIS RUN
C     SL3PRE        LENGTH OF STRUT NO.3 AT THE END OF THE PREVIOUS TIME
C                   INCREMENT
C     SL3T          TRUE INSTANTANEOUS LENGTH OF STRUT NO.3
C     SL3TO         TRUE INITIAL LENGTH OF STRUT NO.3
C     X             INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XNMIN         MINIMUM VALUE OF NOZZLE CLEARANCE
C     XO            INITIAL VERTICAL POSITION OF VEHICLE CENTER OF GRAVITY
C     XP(I)         X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     XPVEL(I)      VELOCITY OF THE I TH FOOTPAD IN THE X DIRECTION IN THE
C                   FIXED COORDINATE SYSTEM
C     XVELO         INITIAL VERTICAL VELOCITY OF VEHICLE C.G.
C     XVELOO        SAME AS XVELO
C     Y             INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YP(I)         Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     YPVEL(I)      VELOCITY OF THE I TH FOOTPAD IN THE Y DIRECTION IN THE
C                   FIXED COORDINATE SYSTEM
C     YVELO         INITIAL HORIZONTAL VELOCITY OF VEHICLE C.G.
C     ZP(I)         Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZPVEL(I)      VELOCITY OF THE I TH FOOTPAD IN THE Z DIRECTION IN THE
C                   FIXED COORDINATE SYSTEM
C
C
      SUBROUTINE  INITRU
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
```

Figure 1-22. Subroutine INITRU (Continued)

```
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/EBLOCK/XP(5),YP(5),ZP(5),XPVEL(5),YPVEL(5),ZPVEL(5)
      COMMON/FBLOCK/FX(5),FXPLG3(5),FYPLG3(5),FZPLG3(5),FXPLG2(5),
     1 FYPLG2(5),FZPLG2(5),FXPLG1(5),FYPLG1(5),FZPLG1(5),
     1 F1(5),F2(5),F3(5),E1(5),E2(5),E3(5)
      COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
     1 SKE3
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      COMMON/IBLOCK/BETA(5),BEPR(5),BETAPR(5),LAND
      COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
      COMMON/KBLOCK/M,TIME,TME(402),XP1(402),YP1(402),ZP1(402),XP3(402),
     1 YP3(402),ZP3(402),FX1(402),FX3(402),FXPL31(402),FYPL31(402),
     1 FZPL31(402),FXPL33(402),FYPL33(402),FZPL33(402),G1STR1(402),
     1 G1STR2(402),G1STR3(402),G3STR1(402),G3STR2(402),G3STR3(402),
     1 G1FRC1(402),G1FRC2(402),G1FRC3(402),G3FRC1(402),G3FRC2(402),
     1 G3FRC3(402)
C
C     CONVERT INPUT VELOCITIES FROM GRAVITY COORD. SYSTEM TO SURFACE
C     COORD. SYSTEM
C     CHOOSE INITIAL TOUCHDOWN CONDITIONS
C
      XVELO(NQ,NS)= HVELO(NQ,NS)*SIN(ZETA)-VVELO(NQ,NS)*COS(ZETA)
      YVELO(NQ,NS)=HVELO(NQ,NS)*COS(ZETA)+VVELO(NQ,NS)*SIN(ZETA)
      XVELOO=XVELO(NQ,NS)
      YVELOO=YVELO(NQ,NS)
      XVEL=XVELO(NQ,NS)
      YVEL=YVELO(NQ,NS)
      Y=YO
      X=SL10(J)*COS(B10(J)-PSIO)+R1(J)*COS(THETA(J))*SIN(PSIO)+D11(J)*
     1 COS(PSIO)+DELTAP
      XO=X
      PSI=PSIO
      PSIVEL=PSVELO
C
C     TEST IF TOUCHDOWN VELOCITIES DUPLICATE THOSE OF PREVIOUS RUN.
C     IF SO, STOP.  OTHERWISE CONTINUE
C
      IF(PRXVEL-XVELOO)44,43,44
   43 IF(PRYVEL-YVELOO)44,845,44
   44 PRXVEL=XVELOO
      PRYVEL=YVELOO
C
C     INITIALIZE PROGRAM VARIABLES
C
      TCONMX=KCONMX
      DELTTT=DELTAT/TCONMX
      SINA=SIN (PSIO)
      COSA=COS (PSIO)
      DO 45 I=1,2
      FXX(I)=0.0
      FYY(I)=0.0
   45 RMOO(I)=0.0
```

Figure 1-22. Subroutine INITRU (Continued)

```
C     ZERO OUT LINE COUNT
C
      LINE=0
      KM=0
C
C     ZERO OUT INITIAL FORCES FOR PARABOLIC INTEGRATION OF FOOTPAD
C     FORCES
C
      DO 70 I=1,N,K
      E1(I)=0.0
      E2(I)=0.0
      E3(I)=0.0
      F1(I)=0.0
      F2(I)=0.0
      F3(I)=0.0
      FX(I)=0.0
      FLL=0.0
      FVV=0.0
C
C     INITIALIZE FORCES FOR PARABOLIC INTEGRATION PROCEDURE
C
      FXPLG3(I)=0.0
      FYPLG3(I)=0.0
      FZPLG3(I)=0.0
      FXPLG1(I)=0.0
      FXPLG2(I)=0.0
      FYPLG1(I)=0.0
      FYPLG2(I)=0.0
      FZPLG1(I)=0.0
   48 FZPLG2(I)=0.0
C
C     DETERMINE INITIAL STRUT ANGLES AND TRIGONOMETRIC RELATIONSHIPS
C
      B1(I)=B10(I)
   60 COSB(I)=COS (B1(I)-PSI)
      COSC(I)=COS (THETA(I))
      SINB(I)=SIN (B1(I)-PSI)
      SINC(I)=SIN (THETA(I))
      SL1(I)=SL10(I)
      B2PREV(I)=B20(I)
      B3PREV(I)=B30(I)
      C1PREV(I)=C10(I)
      C2PREV(I)=C20(I)
      C3PREV(I)=C30(I)
   70 D1(I)=D10(I)
C     DETERMINE FOOTPAD POSITIONS AND VELOCITIES
C
      DO 100 I=1,N,K
      XP(I)=X-D11(I)*COSA-R1(I)*COSC(I)*SINA-SL1(I)*COSB(I)
      YP(I)=Y-D11(I)*SINA+R1(I)*COSC(I)*COSA+SL1(I)*SINB(I)
   80 ZP(I)=R1(I)*SINC(I)+D1(I)
      XPVEL(I)=X VEL+D11(I)*SINA*PSIVEL-R1(I)*COSC(I)*COSA*PSIVEL-
     1SL1(I)*SINB(I)*PSIVEL
      YPVEL(I)=YVEL-D11(I)*COSA*PSIVEL-R1(I)*COSC(I)*SINA*PSIVEL-SL1(I)*
     1COSB(I)*PSIVEL
      ZPVEL(I)=0.0
C
C     INITIALIZE STABILITY ANGLE FUNCTIONS
C
   90 BETA(I)=0.0
      BEPR(I)=ATAN ((YP(I)-Y)/(X-XP(I)))-ZETA
```

Figure 1-22. Subroutine INITRU (Continued)

```
      BETAPR(I)=0.0
      NOGR(I)=1
C
C     INITIALIZE PROGRAM FOR STRUT LENGTH CALCULATIONS
C
      SL1PRE(I)=0.0
      SL2PRE(I)=0.0
      SL3PRE(I)=0.0
      SL1M(I)=F11(I)/SK1
      SL2M(I)=F22(I)/SK2
  100 SL3M(I)=F33(I)/SK3
      TIME=0.0
      CONS=0.0
      XNMIN=100.0
      BIIMIN=10.0
      BJJMIN=-10.0
      IFLAG=-1
      BETADT=-PSVELO
      M=0
      RMOMGR=0.0
C
C     DETERMINE TRIGONOMETRIC RELATIONSHIPS FOR STRUT LENGTH
C     CALCULATIONS.
C
  110 DO 130 I=1,N,K
      SIND(I)=SIN (B1(I))
      COSD(I)=COS (B1(I))
      COSE(I)=COS (THETA(I)-ALPHA(I)/2.0)
      COSG(I)=COS (THETA(I)+ALPHA(I)/2.0)
  120 SINJ(I)=SIN (THETA(I)-ALPHA(I)/2.0)
      SINK(I)=SIN (THETA(I)+ALPHA(I)/2.0)
C
C     DETERMINE INITIAL STRUT LENGTHS
C
      SL1TO(I)=SQRT (SL1(I)*SL1(I)+D1(I)*D1(I))
      HALF3=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))*(SL1(I)*
     1SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))
      HALF4=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL2(I)=SQRT(HALF3+HALF4)
      SL2TO(I)=SQRT (SL2(I)*SL2(I)+(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I))*
     1(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I)))
      HALF1=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))*
     1(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))
      HALF2=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL3(I)=SQRT(HALF1+HALF2)
      SL3TO(I)=SQRT (SL3(I)*SL3(I)+(D1(I)-R2(I)*SINK(I)+R1(I)*SINC(I))*
     1(D1(I)-R2(I)*SINK(I)+R1(I)*SINC(I)))
      SL1T(I)=SL1TO(I)
      SL2T(I)=SL2TO(I)
  130 SL3T(I)=SL3TO(I)
C
C     COMPUTE STABILITY ANGLES AT TOUCHDOWN
C
  270 BETA(II)=ATAN ((YP(II)-Y)/(X-XP(II)))-ZETA
      BETA(JJ)=ATAN ((YP(JJ)-Y)/(X-XP(JJ)))-ZETA
      RETURN
  845 PRINT 950
      PRINT 935
      STOP
  935 FORMAT(98H  X AND Y VELOCITIES ARE IDENTICAL TO THOSE OF THE PREVI
     1OUS RUN.  CHECK THE INPUT DATA FOR ERRORS )
  950 FORMAT(1H1)
      END
```

Figure 1-22. Subroutine INITRU (Concluded)

```
C TITLE         STRANG
C
C     AUTHORS    R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE          10-25-64
C
C PURPOSE       DETERMINE STRUT ANGLES AND ASSIGN TO PROPER QUADRANTS
C
C CALL          STRANG
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT         THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A 0 IMPLIES THE INITIAL VALUE
C                AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C                IS DEFINED WITHOUT THE  0   AS B1(I).
C
C     SYMBOL     DEFINITION
C
C     B2PREV     VALUE OF B2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     B3PREV     VALUE OF B3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     COSC       COS(THETA)
C     COSD       COS(B1)
C     COSE       COS(THETA-ALPHA/2.0)
C     COSG       COS(THETA+ALPHA/2.0)
C     C1PREV     VALUE OF C1 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C2PREV     VALUE OF C2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C3PREV     VALUE OF C3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     D          VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     D10        INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C                OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C                TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     K          FLAG FOR LANDING MODE    IF 1-2-1 LANDING , K=1    IF
C                2-2 LANDING, K=2
C     N          NUMBER OF LEGS ON THE VEHICLE
C     NOGR(I)    INDICATES IF FOOTPAD (I) IS MOVING WITH THE VEHICLE.  IF
C                NOGR(I)=-1, FOOTPAD IS MOVING WITH THE VEHICLE.  IF
C                NOGR(I) =+1, FOOTPAD IS MOVING INDEPENDENTLY
C     R1         RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2         RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     SINC       SIN(THETA)
C     SIND       SIN(B1)
C     SINJ       SIN(THETA-ALPHA/2.0)
C     SINK       SIN(THETA+ALPHA/2.0)
C     SL1        PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C                DIRECTION OF MOTION
C     SL2        INSTANTANEOUS LENGTH OF STRUT NO.2 ,PROJECTED IN A PLANE
C                PARALLEL TO THE DIRECTION OF MOTION
C     SL3        INSTANTANEOUS LENGTH OF STRUT NO.3 ,PROJECTED IN A PLANE
C                PARALLEL TO THE DIRECTION OF MOTION
C
C OUTPUT        THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     B20        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
```

Figure 1-23. Subroutine STRANG

```
C     B30         ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                 BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     C10,C20,C30       ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C                 THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C                 TO THE VEHICLE CENTERLINE   -  FOR STRUTS 1,2,3 RESPECTIVELY
C
C
      SUBROUTINE  STRANG
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      DIMENSION B2MI(5),B2PL(5),B3MI(5),B3PL(5),C1MI(5),C1PL(5),
     1 C2MI(5),C2PL(5),C3MI(5),C3PL(5)
C
C     DETERMINE STRUT ANGLES AND ASSIGN TO PROPER QUADRANTS
C
C
C     TEST IF FOOTPAD (I) IS MOVING WITH THE VEHICLE
C
  140 DO 240 I=1,N,K
      IF(NOGR(I))240,240,145
C
C     DETERMINE  B2 ANGLE
C
  145 B2(I)=ATAN ((SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))/(SL1(I)*
     1COSD(I)-D(I)))
      B2MI(I)=B2(I)-3.14159265359
      B2PL(I)=B2(I)+3.14159265359
      DIFF1=ABS (B2MI(I)-B2PREV(I))
      DIFF2=ABS (B2(I)-B2PREV(I))
      DIFF3=ABS (B2PL(I)-B2PREV(I))
  148 IF(DIFF1-DIFF2)150,152,152
  150 IF(DIFF1-DIFF3)154,158,158
  152 IF(DIFF2-DIFF3)160,158,158
  154 B2(I)=B2MI(I)
      GO TO 160
  158 B2(I)=B2PL(I)
  160 B2PREV(I)=B2(I)
C
C     DETERMINE B3 ANGLE
C
      B3(I)=ATAN ((SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))/(SL1(I)*
     1COSD(I)-D(I)))
      B3MI(I)=B3(I)-3.14159265359
      B3PL(I)=B3(I)+3.14159265359
      DIFF1=ABS (B3MI(I)-B3PREV(I))
      DIFF2=ABS (B3(I)-B3PREV(I))
      DIFF3=ABS (B3PL(I)-B3PREV(I))
      IF(DIFF1-DIFF2)170,172,172
  170 IF(DIFF1-DIFF3)174,178,178
  172 IF(DIFF2-DIFF3)180,178,178
  174 B3(I)=B3MI(I)
      GO TO 180
  178 B3(I)=B3PL(I)
```

Figure 1-23. Subroutine STRANG (Continued)

```
  180 B3PREV(I)=B3(I)
      IF(D1(I))182,181,182
C
C     DETERMINE C1 ANGLE
C
  181 C1(I)=1.5708
      GO TO 183
  182 C1(I)=ATAN (SL1(I)/D1(I))
  183 C1MI(I)=C1(I)-3.14159265359
      C1PL(I)=C1(I)+3.14159265359
      DIFF1=ABS (C1MI(I)-C1PREV(I))
      DIFF2=ABS (C1(I)-C1PREV(I))
  186 DIFF3=ABS (C1PL(I)-C1PREV(I))
      IF(DIFF1-DIFF2)190,192,192
  190 IF(DIFF1-DIFF3)194,198,198
  192 IF(DIFF2-DIFF3)200,198,198
  194 C1(I)=C1MI(I)
      GO TO 200
  198 C1(I)=C1PL(I)
  200 C1PREV(I)=C1(I)
C
C     DETERMINE C2 ANGLE
C
      C2(I)=ATAN (SL2(I)/(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I)))
      C2MI(I)=C2(I)-3.14159265359
      C2PL(I)=C2(I)+3.14159265359
      DIFF1=ABS (C2MI(I)-C2PREV(I))
      DIFF2=ABS (C2(I)-C2PREV(I))
      DIFF3=ABS (C2PL(I)-C2PREV(I))
      IF(DIFF1-DIFF2)210,212,212
  210 IF(DIFF1-DIFF3)214,218,218
  212 IF(DIFF2-DIFF3)220,218,218
  214 C2(I)=C2MI(I)
      GO TO 220
  218 C2(I)=C2PL(I)
  220 C2PREV(I)=C2(I)
C
C     DETERMINE C3 ANGLE
C
      C3(I)=ATAN (SL3(I)/(D1(I)+R1(I)*SINC(I)-R2(I)*SINK(I)))
      C3MI(I)=C3(I)-3.14159265359
      C3PL(I)=C3(I)+3.14159265359
      DIFF1=ABS (C3MI(I)-C3PREV(I))
      DIFF2=ABS (C3(I)-C3PREV(I))
      DIFF3=ABS (C3PL(I)-C3PREV(I))
      IF(DIFF1-DIFF2)230,232,232
  230 IF(DIFF1-DIFF3)234,236,236
  232 IF(DIFF2-DIFF3)238,236,236
  234 C3(I)=C3MI(I)
      GO TO 238
  236 C3(I)=C3PL(I)
  238 C3PREV(I)=C3(I)
  240 CONTINUE
      RETURN
      END
```

Figure 1-23. Subroutine STRANG (Concluded)

```
C TITLE       STGEOM
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C PURPOSE     DETERMINE STRUT GEOMETRY
C
C CALL        STGEOM
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT       THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C               AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL    DEFINITION
C
C     COSA      COS(PSI)
C     COSC      COS(THETA)
C     COSE      COS(THETA-ALPHA/2.0)
C     COSG      COS(THETA+ALPHA/2.0)
C     D         VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     D10       INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C               OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C               TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     D11       VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     K         FLAG FOR LANDING MODE   IF 1-2-1 LANDING , K=1    IF
C               2-2 LANDING, K=2
C     N         NUMBER OF LEGS ON THE VEHICLE
C     NOGR(I)   INDICATES IF FOOTPAD (I) IS MOVING WITH THE VEHICLE.  IF
C               NOGR(I)=-1, FOOTPAD IS MOVING WITH THE VEHICLE.  IF
C               NOGR(I) =+1, FOOTPAD IS MOVING INDEPENDENTLY
C     PSI       INSTANTANEOUS VALUE OF PSIO
C     R1        RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2        RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     SINA      SIN(PSI)
C     SINC      SIN(THETA)
C     SINJ      SIN(THETA-ALPHA/2.0)
C     SINK      SIN(THETA+ALPHA/2.0)
C     X         INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XP(I)     X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     Y         INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YP(I)     Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZP(I)     Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C
C OUTPUT      THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     B10       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     COSB      COS(B1-PSI)
C     COSD      COS(B1)
C     SINB      SIN(B1-PSI)
C     SIND      SIN(B1)
```

Figure 1-24. Subroutine STGEOM

```
C     SL1         PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C                 DIRECTION OF MOTION
C     SL1T        TRUE INSTANTANEOUS LENGTH OF STRUT NO.1
C     SL2         INSTANTANEOUS LENGTH OF STRUT NO.2 ,PROJECTED IN A PLANE
C                 PARALLEL TO THE DIRECTION OF MOTION
C     SL2T        TRUE INSTANTANEOUS LENGTH OF STRUT NO.2
C     SL3         INSTANTANEOUS LENGTH OF STRUT NO.3 ,PROJECTED IN A PLANE
C                 PARALLEL TO THE DIRECTION OF MOTION
C     SL3T        TRUE INSTANTANEOUS LENGTH OF STRUT NO.3
C
C
      SUBROUTINE  STGEOM
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/EBLOCK/XP(5),YP(5),ZP(5),XPVEL(5),YPVEL(5),ZPVEL(5)
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      COMMON/KBLOCK/M,TIME,TME(402),XP1(402),YP1(402),ZP1(402),XP3(402),
     1 YP3(402),ZP3(402),FX1(402),FX3(402),FXPL31(402),FYPL31(402),
     1 FZPL31(402),FXPL33(402),FYPL33(402),FZPL33(402),G1STR1(402),
     1 G1STR2(402),G1STR3(402),G3STR1(402),G3STR2(402),G3STR3(402),
     1 G1FRC1(402),G1FRC2(402),G1FRC3(402),G3FRC1(402),G3FRC2(402),
     1 G3FRC3(402)
  710 DO 730 I=1,N,K
      IF(NOGR(I))730,730,715
C
C     IF FOOTPAD IS ON THE GROUND, DETERMINE STRUT GEOMETRY
C
  715 AA=Y+R1(I)*COSC(I)*COSA-D11(I)*SINA
      BB=X-R1(I)*COSC(I)*SINA-D11(I)*COSA
      SL1(I)=SQRT ((YP(I)-AA)*(YP(I)-AA)+(BB-XP(I))*(BB-XP(I)))
      B1(I)=ATAN ((YP(I)-AA)/(BB-XP(I)))+PSI
C
C     RESET PROGRAM CONSTANTS
C
      COSB(I)=COS (B1(I)-PSI)
      COSD(I)=COS (B1(I))
      SINB(I)=SIN (B1(I)-PSI)
      SIND(I)=SIN (B1(I))
C
C     CALCULATE NEW STRUT LENGTHS
C
  720 D1(I)=ZP(I)-R1(I)*SINC(I)
      SL1T(I)=SQRT (SL1(I)*SL1(I)+D1(I)*D1(I))
      HALF3=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))*(SL1(I)*
     1SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))
      HALF4=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL2(I)=SQRT(HALF3+HALF4)
      SL2T(I)=SQRT (SL2(I)*SL2(I)+(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I))*(
```

Figure 1-24. Subroutine STGEOM (Continued)

```
     1D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I)))
      HALF1=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))*
     1(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))
      HALF2=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL3(I)=SQRT(HALF1+HALF2)
      SL3T(I)=SQRT ((SL3(I)*SL3(I))+(D1(I)-R2(I)*SINK(I)+R1(I)*
     1SINC(I))*(D1(I)-R2(I)*SINK(I)+R1(I)*SINC(I)))
  730 CONTINUE
      RETURN
      END
```

Figure 1-24. Subroutine STGEOM (Concluded)

```
C TITLE        FOTPAD
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      COMPUTE STRUT FORCES AND FORCES ACTING ON FOOTPADS
C              DETERMINE FOOTPAD POSITION AND MOTION
C
C METHOD       PARABOLIC INTEGRATION USED IN DETERMINING FOOTPAD MOTION
C
C CALL         FOTPAD
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C                AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C                IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL     DEFINITION
C
C     B20        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B30        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     COSA       COS(PSI)
C     COSB       COS(B1-PSI)
C     COSC       COS(THETA)
C     COSD       COS(B1)
C     C10,C20,C30       ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C                THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C                TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     DELTAP     DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C                LEG STRUTS
C     DELTTT     TIME INCREMENT USED IN THE INTEGRATION OF FOOTPAD
C                MOTION.   DELTTT= DELTAT/KCONMX
C     D10        INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C                OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C                TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     D11        VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     EPSEN      PROGRAM CONSTANT EQUAL TO 10 PERCENT OF THE POSSIBLE
C                POTENTIAL ENERGY WHICH COULD BE STORED IN A FOOTPAD
C                AS THE RESULT OF ELASTIC STROKING OF  THE UPPER STRUT
C     EPS2       MINIMUM ALLOWABLE FOOTPAD SLIDING VELOCITY
C     F11        PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22        PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33        PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     GRAV       LOCAL GRAVITY
C     GRDMU      COEFFICIENT OF FRICTION BETWEEN VEHICLE FOOTPADS AND GROUND
C     K          FLAG FOR LANDING MODE   IF 1-2-1 LANDING , K=1    IF
C                2-2 LANDING, K=2
CC    KCONMX     NUMBER OF ITERATIONS OF FOOTPAD CALCULATIONS PER  (DELTAT)
C                TIME INTERVAL
C     N          NUMBER OF LEGS ON THE VEHICLE
C     PMASS      MASS OF EACH FOOTPAD
C     PSIVEL     INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE C.G.
```

Figure 1-25. Subroutine FOTPAD

```
C      P1        FRICTION FORCE IN STRUT NO. 1
C      P2        FRICTION FORCE IN STRUT NO. 2
C      P3        FRICTION FORCE IN STRUT NO. 3
C      R1        RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C      SINA      SIN(PSI)
C      SINB      SIN(B1-PSI)
C      SIND      SIN(B1)
C      SKE1      TENSIL ELASTIC SPRINGRATE OF STRUT NO. 1 (UPPER)
C      SKE2      TENSIL ELASTIC SPRINGRATE OF STRUT NO. 2 (LOWER)
C      SKE3      TENSIL ELASTIC SPRINGRATE OF STRUT NO. 3 (LOWER)
C      SKS       SPRINGRATE UNDER VEHICLE FOOTPADS
C      SK1       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C      SK2       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C      SK3       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C      SL1       PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C                DIRECTION OF MOTION
C      SL1M      MINIMUM LENGTH TO WHICH STRUT NO.1 HAS BEEN COMPRESSED
C                DURING THIS RUN
C      SL1PRE    LENGTH OF STRUT NO.1 AT THE END OF THE PREVIOUS TIME
C                INCREMENT
C      SL1T      TRUE INSTANTANEOUS LENGTH OF STRUT NO.1
C      SL1TO     TRUE INITIAL LENGTH OF STRUT NO.1
C      SL2M      MINIMUM LENGTH TO WHICH STRUT NO.2 HAS BEEN COMPRESSED
C                DURING THIS RUN
C      SL2PRE    LENGTH OF STRUT NO.2 AT THE END OF THE PREVIOUS TIME
C                INCREMENT
C      SL2T      TRUE INSTANTANEOUS LENGTH OF STRUT NO.2
C      SL2TO     TRUE INITIAL LENGTH OF STRUT NO.2
C      SL3M      MINIMUM LENGTH TO WHICH STRUT NO.3 HAS BEEN COMPRESSED
C                DURING THIS RUN
C      SL3PRE    LENGTH OF STRUT NO.3 AT THE END OF THE PREVIOUS TIME
C                INCREMENT
C      SL3T      TRUE INSTANTANEOUS LENGTH OF STRUT NO.3
C      SL3TO     TRUE INITIAL LENGTH OF STRUT NO.3
C      X         INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C      XVEL      INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C      Y         INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C      YVEL      INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C      ZETA      GROUND SLOPE
C
C OUTPUT        THROUGH LABELED COMMON
C
C      SYMBOL    DEFINITION
C
C      E3(I)     POTENTIAL ENERGY STORED IN STRUT NO. 3 OF LEG I DUE TO
C                COMPRESSION OR EXTENSION OF THE LEG
C      E2(I)     POTENTIAL ENERGY STORED IN STRUT NO.2 OF LEG I DUE TO
C                COMPRESSION OR EXTENSION OF THE LEG
C      E3(I)     POTENTIAL ENERGY STORED IN STRUT NO .3 OF LEG I DUE TO
C                COMPRESSION OR EXTENSION OF THE LEG
C      FA(I)     FORCE IN THE Z DIRECTION ACTING ON THE VEHICLE C.G. AS
C                THE RESULTANT OF THE STRUT FORCES IN THE THREE STRUTS
C                OF THE I TH LEG SET
C      FB(I)     FORCE, PARALLEL TO THE VEHICLE CENTERLINE  ACTING ON THE
C                VEHICLE C.G. AS THE RESULTANT OF THE STRUT FORCES IN
C                THE THREE STRUTS OF THE I TH LEG SET
C      FC(I)     FORCE, NORMAL TO VEHICLE CENTERLINE IN THE X-Y PLANE
C                ACTING ON THE VEHICLE C.G. AS THE RESULTANT OF THE STRUT
C                FORCES IN THE THREE STRUTS OF THE I TH LEG SET
C      FX        SAME AS FXP
C      FXP(I)    FORCE IN THE X DIRECTION ON THE FOOTPAD (I)
```

Figure 1-25. Subroutine FOTPAD (Continued)

```
C     FXPLG1    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG2    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG3    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG1    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG2    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG3    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     F1(I)     PLASTIC STROKE FORCE IN STRUT NO.1 OF LEG I
C     F2(I)     PLASTIC STROKE FORCE IN STRUT NO.2 OF LEG I
C     F3(I)     PLASTIC STROKE FORCE IN STRUT NO.3 OF LEG I
C     FZPLG1    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG2    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG3    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     NOGR(I)   INDICATES IF FOOTPAD (I) IS MOVING WITH THE VEHICLE.  IF
C               NOGR(I)=-1, FOOTPAD IS MOVING WITH THE VEHICLE.  IF
C               NOGR(I) =+1, FOOTPAD IS MOVING INDEPENDENTLY
C     RMOMGR    MOMENT OF INERTIA OF THE INDIVIDUAL VEHICLE FOOTPADS.
C               THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C               GROUND AT THE INSTANT UNDER INVESTIGATION
C     XP(I)     X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     XPVEL(I)  VELOCITY OF THE I TH FOOTPAD IN THE X DIRECTION IN THE
C               FIXED COORDINATE SYSTEM
C     YP(I)     Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     YPVEL(I)  VELOCITY OF THE I TH FOOTPAD IN THE Y DIRECTION IN THE
C               FIXED COORDINATE SYSTEM
C     ZP(I)     Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZPVEL(I)  VELOCITY OF THE I TH FOOTPAD IN THE Z DIRECTION IN THE
C               FIXED COORDINATE SYSTEM
C
C
      SUBROUTINE  FOTPAD
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/EBLOCK/XP(5),YP(5),ZP(5),XPVEL(5),YPVEL(5),ZPVEL(5)
      COMMON/FBLOCK/FX(5),FXPLG3(5),FYPLG3(5),FZPLG3(5),FXPLG2(5),
     1 FYPLG2(5),FZPLG2(5),FXPLG1(5),FYPLG1(5),FZPLG1(5),
```

Figure 1-25. Subroutine FOTPAD (Continued)

```
     1 F1(5),F2(5),F3(5),E1(5),E2(5),E3(5)
      COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
     1 SKE3
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      DIMENSION PADENG(5),FXP(5)
  280 DO 600 I=1,N,K
C
C     TEST IF FOOTPAD IS ON THE GROUND
C
      IF(XP(I)-DELTAP)330,330,290
C
C     COMPUTE FOOTPAD VELOCITY RELATIVE TO C.G. AND DETERMINE RELATIVE
C     ENERGY OF FOOTPAD
C
  290 XPVELR=XVEL+D11(I)*SINA*PSIVEL-R1(I)*COSC(I)*COSA*PSIVEL-SL1(I)*
     1SINB(I)*PSIVEL
      YPVELR=YVEL-D11(I)*COSA*PSIVEL-R1(I)*COSC(I)*SINA*PSIVEL-SL1(I)*
     1COSB(I)*PSIVEL
      PADENG(I)=PMASS/2.0*((XPVELR-XPVEL(I))*(XPVELR-XPVEL(I))+(YPVELR-
     1YPVEL(I))*(YPVELR-YPVEL(I))+(ZPVEL(I))*(ZPVEL(I)))+E1(I)+E2(I)+
     1E3(I)
C
C     TEST IF FOOTPAD IS MOVING WITH THE VEHICLE
C
      IF(PADENG(I)-EPSEN(I))300,300,330
C
C     FOOTPAD IS MOVING WITH THE VEHICLE.  SET FORCES EQUAL TO ZERO
C
  300 FA(I)=0.0
      FB(I)=0.0
      FC(I)=0.0
      FXPLG1(I)=0.0
      FXPLG2(I)=0.0
      FXPLG3(I)=0.0
      FYPLG1(I)=0.0
      FYPLG2(I)=0.0
      FYPLG3(I)=0.0
      FZPLG1(I)=0.0
      FZPLG2(I)=0.0
      FZPLG3(I)=0.0
      RMOMGR=RMOMGR+2.0*PMASS*((X-XP(I))*(X-XP(I))+(Y-YP(I))*(Y-YP(I)))
      NOGR(I)=-1
C
C     FIND FOOTPAD POSITIONS AND VELOCITY BY RIGID BODY MOTION WITH
C     THE VEHICLE
C
  310 XP(I)=X-D11(I)*COSA-R1(I)*COSC(I)*SINA-SL1(I)*COSB(I)
      YP(I)=Y-D11(I)*SINA+R1(I)*COSC(I)*COSA+SL1(I)*SINB(I)
      ZP(I)=R1(I)*SINC(I)+D1(I)
      XPVEL(I)=XVEL+D11(I)*SINA*PSIVEL-R1(I)*COSC(I)*COSA*PSIVEL-
     1SL1(I)*SINB(I)*PSIVEL
  320 YPVEL(I)=YVEL-D11(I)*COSA*PSIVEL-R1(I)*COSC(I)*SINA*PSIVEL-
     1SL1(I)*COSB(I)*PSIVEL
      ZPVEL(I)=0.0
      FX(I)=0.0
      GO TO 600
```

Figure 1-25. Subroutine FOTPAD (Continued)

```
C       FOOTPAD IS MOVING INDEPENDENTLY OF THE VEHICLE , CALCULATE STRUT
C       FORCES AND FOOTPAD ENERGY
C
  330 SL=SL1TO(I)-SL1T(I)
      NOGR(I)=1
      IF(SL-SL1M(I)+F11(I)/SK1)334,334,375
  334 IF(SL)340,367,367
  340 IF(SL-SL1PRE(I))343,360,360
  343 F1(I)=SKE1*SL-P1(I)
      E1(I)=SKE1*SL*SL/2.0
      GO TO 393
  350 F1(I)=-P1(I)
      E1(I)=0.0
      GO TO 393
  360 F1(I)=SKE1*SL+P1(I)
      E1(I)=SKE1*SL*SL/2.0
      GO TO 393
  367 IF(SL-SL1PRE(I))350,370,370
  370 F1(I)=P1(I)
      E1(I)=0.0
      GO TO 393
  375 IF(SL-SL1M(I))378,390,390
  378 IF(SL-SL1PRE(I))385,380,380
  380 F1(I)=SK1*(SL-SL1M(I)+F11(I)/SK1)+P1(I)
      E1(I)=(SK1/2.0)*(SL-SL1M(I)+F11(I)/SK1)*(SL-SL1M(I)+F11(I)/SK1)
      GO TO 393
  385 F1(I)=SK1*(SL-SL1M(I)+F11(I)/SK1)-P1(I)
      E1(I)=(SK1/2.0)*(SL-SL1M(I)+F11(I)/SK1)*(SL-SL1M(I)+F11(I)/SK1)
      GO TO 393
  390 F1(I)=F11(I)+P1(I)
      E1(I)=(SK1/2.0)*(SL-SL1M(I)+F11(I)/SK1)*(SL-SL1M(I)+F11(I)/SK1)
  393 IF(SL-SL1M(I))400,400,396
  396 SL1M(I)=SL
  400 SL1PRE(I)=SL
      SL=SL2TO(I)-SL2T(I)
      IF(SL-SL2M(I)+F22(I)/SK2)403,403,433
  403 IF(SL)406,425,425
  406 IF(SL-SL2PRE(I))410,420,420
  410 F2(I)=SKE2*SL-P2(I)
      E2(I)=SKE2*SL*SL/2.0
      GO TO 450
  412 F2(I)=-P2(I)
      E2(I)=0.0
      GO TO 450
  420 F2(I)=SKE2*SL+P2(I)
      E2(I)=SKE2*SL*SL/2.0
      GO TO 450
  425 IF(SL-SL2PRE(I))412,430,430
  430 F2(I)=P2(I)
      E2(I)=0.0
      GO TO 450
  433 IF(SL-SL2M(I))436,446,446
  436 IF(SL-SL2PRE(I))443,440,440
  440 F2(I)=SK2*(SL-SL2M(I)+F22(I)/SK2)+P2(I)
      E2(I)=(SK2/2.0)*(SL-SL2M(I)+F22(I)/SK2)*(SL-SL2M(I)+F22(I)/SK2)
      GO TO 450
  443 F2(I)=SK2*(SL-SL2M(I)+F22(I)/SK2)-P2(I)
      E2(I)=(SK2/2.0)*(SL-SL2M(I)+F22(I)/SK2)*(SL-SL2M(I)+F22(I)/SK2)
      GO TO 450
  446 F2(I)=F22(I)+P2(I)
```

Figure 1-25. Subroutine FOTPAD (Continued)

```
      E2(I)=(SK2/2.0)*(SL-SL2M(I)+F22(I)/SK2)*(SL-SL2M(I)+F22(I)/SK2)
  450 IF(SL-SL2M(I))454,454,452
  452 SL2M(I)=SL
  454 SL2PRE(I)=SL
      SL=SL3TO(I)-SL3T(I)
      IF(SL-SL3M(I)+F33(I)/SK3)458,458,486
  458 IF(SL)460,480,480
  460 IF(SL-SL3PRE(I))465,475,475
  465 F3(I)=SKE3*SL-P3(I)
      E3(I)=SKE3*SL*SL/2.0
      GO TO 505
  470 F3(I)=-P3(I)
      E3(I)=0.0
      GO TO 505
  475 F3(I)=SKE3*SL+P3(I)
      E3(I)=SKE3*SL*SL/2.0
      GO TO 505
  480 IF(SL-SL3PRE(I))470,483,483
  483 F3(I)=P3(I)
      E3(I)=0.0
      GO TO 505
  486 IF(SL-SL3M(I))490,500,500
  490 IF(SL-SL3PRE(I))496,493,493
  493 F3(I)=SK3*(SL-SL3M(I)+F33(I)/SK3)+P3(I)
      E3(I)=SK3/2.0 *(SL-SL3M(I)+F33(I)/SK3)*(SL-SL3M(I)+F33(I)/SK3)
      GO TO 505
  496 F3(I)=SK3*(SL-SL3M(I)+F33(I)/SK3)-P3(I)
      E3(I)=SK3/2.0 *(SL-SL3M(I)+F33(I)/SK3)*(SL-SL3M(I)+F33(I)/SK3)
      GO TO 505
  500 F3(I)=F33(I)+P3(I)
      E3(I)=SK3/2.0 *(SL-SL3M(I)+F33(I)/SK3)*(SL-SL3M(I)+F33(I)/SK3)
  505 IF(SL-SL3M(I))510,510,507
  507 SL3M(I)=SL
  510 SL3PRE(I)=SL
C
C     CALCULATE COMPONENTS OF STRUT FORCE
C
      SING(I)=SIN (C1(I))
      SINL(I)=SIN (C2(I))
      SINI(I)=SIN (C3(I))
      FA(I)=F1(I)*COS (C1(I))+F2(I)*COS (C2(I))+F3(I)*COS (C3(I))
      FB(I)=F1(I)*SING(I)*COSD(I)+F2(I)*SINL(I)*COS (B2(I))+F3(I)*
     1SINI(I)*COS (B3(I))
      FC(I)=F1(I)*SING(I)*SIND(I)+F2(I)*SINL(I)*SIN (B2(I))+F3(I)*
     1SINI(I)*SIN (B3(I))
C
C     DETERMINE FORCES ACTING ON FOOTPAD AND FOOTPAD MOTIONS
C
  514 KCON=0
  515 KCON=KCON+1
      SLVEL=SQRT ((YPVEL(I))*(YPVEL(I))+(ZPVEL(I))*(ZPVEL(I)))
      IF(SLVEL-EPS2)530,535,535
  530 SLVEL=EPS2
  535 FXP(I)=SKS(I)*(DELTAP-XP(I))
      IF (FXP(I)) 540,540,545
  540 FX(I)=0.0
      GO TO 550
  545 FX(I)=FXP(I)
  550 TEMP2=GRDMU(I)*FX(I)/(PMASS*SLVEL)
      FYPLG3(I)=((FC(I) *COSA-FB(I)*SINA)/PMASS+GRAV*SIN (ZETA))*PMASS
      YP(I)=YP(I)+YPVEL(I)*DELTTT+(19.0*FYPLG3(I)-10.0*FYPLG2(I)+3.0*
```

Figure 1-25. Subroutine FOTPAD (Continued)

```
     1FYPLG1(I))*DELTTT*DELTTT/(24.0*PMASS)-TEMP2*YPVEL(I)*DELTTT*
     2DELTTT/2.0
      YPVEL(I)=YPVEL(I)+(23.0*FYPLG3(I)-16.0*FYPLG2(I)+5.0*FYPLG1(I))*
     1DELTTT/(12.0*PMASS)-TEMP2*YPVEL(I)*DELTTT
      FZPLG3(I)=FA(I)
  580 ZP(I)=ZP(I)+ZPVEL(I)*DELTTT+(19.0*FZPLG3(I)-10.0*FZPLG2(I)+3.0*
     1FZPLG1(I))*DELTTT*DELTTT/(24.0*PMASS)-TEMP2*ZPVEL(I)*DELTTT*
     2DELTTT/2.0
      ZPVEL(I)=ZPVEL(I)+(23.0*FZPLG3(I)-16.0*FZPLG2(I)+5.0*FZPLG1(I))*
     1DELTTT/(12.0*PMASS)-TEMP2*ZPVEL(I)*DELTTT
      FXPLG3(I)=-FB(I)*COSA-FC(I)*SINA-GRAV*COS (ZETA)*PMASS
      XP(I)=XP(I)+XPVEL(I)*DELTAT+(19.0*FXPLG3(I)-10.0*FX PLG2(I)+3.0*
     1FXPLG1(I))*DELTTT*DELTTT/(24.0*PMASS)+FX(I)*DELTTT*DELTTT/
     2(2.0*PMASS)
      XPVEL(I)=XPVEL(I)+(23.0*FXPLG3(I)-16.0*FXPLG2(I)+5.0*FXPLG1(I))*
     1DELTTT/(12.0*PMASS)+FX(I)*DELTTT/PMASS
  590 IF(KCON-KCONMX)  515,600,600
  600 CONTINUE
C
C     INDEX PREVIOUS FORCES FOR THE NEXT  INTEGRATION OF FOOTPAD MOTION
C
      DO 639 I=1,N,K
      IF(NOGR(I))639,639,638
  638 FXPLG1(I)=FXPLG2(I)
      FXPLG2(I)=FXPLG3(I)
      FYPLG1(I)=FYPLG2(I)
      FYPLG2(I)=FYPLG3(I)
      FZPLG1(I)=FZPLG2(I)
      FZPLG2(I)=FZPLG3(I)
  639 CONTINUE
      RETURN
      END
```

Figure 1-25. Subroutine FOTPAD (Concluded)

```
C TITLE        VEHFOR
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      DETERMINE FORCES ACTING ON VEHICLE
C
C CALL         VEHFOR
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     A         SYMMETRY FACTOR -- IF TWO VEHICLE LEGS ARE SYMMETRIC,
C               SET A=2.0 FOR ONE OF THE SYMMETRIC PAIRS AND A=0.0 FOR
C               THE OTHER TO SAVE ON COMPUTER TIME    IE  FOR 22 LANDING
C               A=2,0,2,0         FOR A 121 LANDING  A= 1,2,1,0
C     COSA      COS(PSI)
C     COSC      COS(THETA)
C     COSD      COS(B1)
C     D11       VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     FB(I)     FORCE, PARALLEL TO THE VEHICLE CENTERLINE  ACTING ON THE
C               VEHICLE C.G. AS THE RESULTANT OF THE STRUT FORCES IN
C               THE THREE STRUTS OF THE I TH LEG SET
C     FC(I)     FORCE, NORMAL TO VEHICLE CENTERLINE IN THE X-Y PLANE
C               ACTING ON THE VEHICLE C.G. AS THE RESULTANT OF THE STRUT
C               FORCES IN THE THREE STRUTS OF THE I TH LEG SET
C     GRAV      LOCAL GRAVITY
C     RMOMI     VEHICLE MOMENT OF INERTIA
C     RMOMGR    MOMENT OF INERTIA OF THE INDIVIDUAL VEHICLE FOOTPADS.
C               THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C               GROUND AT THE INSTANT UNDER INVESTIGATION
C     R1        RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     SINA      SIN(PSI)
C     SIND      SIN(B1)
C     SL1       PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C               DIRECTION OF MOTION
C     VMASS     VEHICLE MASS
C     ZETA      GROUND SLOPE
C
C OUTPUT       THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     FXX(3)    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(2)    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(1)    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C               IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(3)    FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C               DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
```

Figure 1-26. Subroutine VEHFOR

```
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(2)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(1)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(3)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE CURRENT TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(2)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-1 TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(1)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-2 TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOMIT     TOTAL MOMENT OF INERTIA OF THE VEHICLE MASS AND THOSE
C                FOOTPADS WHICH ARE OFF THE GROUND
C
C
      SUBROUTINE  VEHFOR
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
     1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
      COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
C
C     DETERMINE FORCES ACTING ON THE VEHICLE
C
      FXX(3)=0.0
      FYY(3)=0.0
      RMOO(3)=0.0
      RMOMIT=RMOMI+RMOMGR
  610 RMOMGR=0.0
      DO 620 I=1,N,K
      FXX(3)=FXX(3)+A(I)*FB(I)*COSA+A(I)*FC(I)*SINA
      FYY(3)=FYY(3)+A(I)*FB(I)*SINA-A(I)*FC(I)*COSA
  620 RMOO(3)=RMOO(3)+A(I)*FC(I)*(D11(I)+SL1(I)*COSD(I))-A(I)*FB(I)*
     1(R1(I)*COSC(I)+SL1(I)*SIND(I))
      FXX(3)=FXX(3)-VMASS*GRAV*COS (ZETA)
      FYY(3)=FYY(3)+VMASS*GRAV*SIN (ZETA)
      RETURN
      END
```

Figure 1-26. Subroutine VEHFOR (Concluded)

```
C TITLE        VEHMOT
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      DETERMINE VEHICLE C.G. MOTUON
C
C METHOD       PARABOLIC INTEGRATION USED IN DETERMINING VEHICLE MOTION
C
C CALL         VEHMOT
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     B1         ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     DELTAT     TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     FXX(3)     FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C                DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(2)     FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FXX(1)     FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(3)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE CURRENT TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(2)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-1 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     FYY(1)     FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C                DURING THE N-2 TIME INTERVAL.  THIS FORCE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     PSI        INSTANTANEOUS VALUE OF PSIO
C     PSIVEL     INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE C.G.
C     RMOO(3)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE CURRENT TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(2)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-1 TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(1)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-2 TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOMIT     TOTAL MOMENT OF INERTIA OF THE VEHICLE MASS AND THOSE
C                FOOTPADS WHICH ARE OFF THE GROUND
C     X          INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XVEL       INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C     Y          INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YVEL       INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C     VMASS      VEHICLE MASS
C
```

Figure 1-27. Subroutine VEHMOT

```
C OUTPUT       THROUGH LABELED COMMON
C
C      SYMBOL     DEFINITION
C
C      COSA       COS(PSI)
C      COSB       COS(B1-PSI)
C      FLL        TOTAL FORCE ACTING ON THE VEHICLE IN THE LATERAL DIRECTION
C                 (NORMAL TO THE VEHICLE CENTERLINE)
C      FVV        TOTAL FORCE ACTING ON THE VEHICLE IN THE VERTICAL
C                 DIRECTION (  PARALLEL TO THE VEHICLE CENTERLINE)
C      SINA       SIN(PSI)
C      SINB       SIN(B1-PSI)
C
C
       SUBROUTINE  VEHMOT
C
       COMMON/ABLOCK/N,K,NOGR(5)
       COMMON/CBLOCK/SIND(5),COSC(5),COSE(5),COSD(5),SINC(5),SINJ(5),
     1 COSG(5),SINK(5),COSB(5),SINB(5),SING(5),SINL(5),SINI(5),COSA,SINA
       COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
       COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
       COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
C
C      DETERMINE VEHICLE C.G. MOTIONS
C
       X=X+XVEL*DELTAT+(19.0*FXX(3)-10.0*FXX(2)+3.0*FXX(1))*DELTAT*
     1DELTAT/(24.0*VMASS)
       XVEL=XVEL+(23.0*FXX(3)-16.0*FXX(2)+5.0*FXX(1))*DELTAT/(12.0*VMASS)
   630 Y=Y+YVEL*DELTAT+(19.0*FYY(3)-10.0*FYY(2)+3.0*FYY(1))*DELTAT*
     1DELTAT/(24.0*VMASS)
       YVEL=YVEL+(23.0*FYY(3)-16.0*FYY(2)+5.0*FYY(1))*DELTAT/(12.0*VMASS)
       PSI=PSI+PSIVEL*DELTAT+(19.0*RMOO(3)-10.0*RMOO(2)+3.0*RMOO(1))*
     1DELTAT*DELTAT/(24.0*RMOMIT)
       PSIVEL=PSIVEL+(23.0*RMOO(3)-16.0*RMOO(2)+5.0*RMOO(1))*DELTAT/
     1(12.0*RMOMIT)
C
C      RESET PROGRAM CONSTANTS
C
       COSA=COS (PSI)
       SINA=SIN (PSI)
       DO 635 I=1,N,K
   633 COSB(I)=COS (B1(I)-PSI)
   635 SINB(I)=SIN (B1(I)-PSI)
C
C      DETERMINE HORIZONTAL AND VERTICAL FORCES AT THE VEHICLE C.G.
C
       FVV=FXX(3)*COSA+FYY(3)*SINA
       FLL=FYY(3)*COSA-FXX(3)*SINA
C
C      INDEX PREVIOUS FORCES FOR THE NEXT INTEGRATION OF VEHICLE MOTION
```

Figure 1-27. Subroutine · VEHMOT (Continued)

```
C
      DO 637 I=1,2
      FXX(I)=FXX(I+1)
      FYY(I)=FYY(I+1)
  637 RMOO(I)=RMOO(I+1)
      RETURN
      END
```

Figure 1-27. Subroutine VEHMOT (Concluded)

```
C TITLE        STABAN
C
C     AUTHORS    R.BLACK,J.CADORET,J.GIBSON     THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      COMPUTE STABILITY ANGLE AND ORIENT IN PROPER QUADRANT
C
C CALL         STABAN
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     BEPR       VALUE OF BETA AT THE END OF THE PREVIOUS TIME INCREMENT.
C                USED TO ASSIGN BETA TO THE PROPER QUADRANT
C     X          INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XP(I)      X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     Y          INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YP(I)      Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZETA       GROUND SLOPE
C
C OUTPUT       THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     BETA       VEHICLE STABILITY ANGLE
C
      SUBROUTINE STABAN
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/EBLOCK/XP(5),YP(5),ZP(5),XPVEL(5),YPVEL(5),ZPVEL(5)
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      COMMON/IBLOCK/BETA(5),BEPR(5),BETAPR(5),LAND
      DIMENSION BEMI(5),BEPL(5)
C
C     ORIENT STABILITY ANGLE IN PROPER QUADRANT
C
      DO 673 I=1,N,K
      BETA(I)=ATAN ((YP(I)-Y)/(X-XP(I)))-ZETA
      BEMI(I)=BETA(I)-3.14159265359
      BEPL(I)=BETA(I)+3.14159265359
      DIFF1=ABS (BEMI(I)-BEPR(I))
      DIFF2=ABS (BETA(I)-BEPR(I))
      DIFF3=ABS (BEPL(I)-BEPR(I))
      IF(DIFF1-DIFF2)669,670,670
  669 IF(DIFF1-DIFF3)672,671,671
  670 IF(DIFF2-DIFF3)673,671,671
  671 BETA(I)=BEPL(I)
      GO TO 673
  672 BETA(I)=BEMI(I)
```

Figure 1-28. Subroutine STABAN

```
C
C     RESET BEPR FOR NEXT ITERATION STEP
C
  673 BEPR(I)=BETA(I)
      RETURN
      END
```

Figure 1-28. Subroutine STABAN (Concluded)

```
C TITLE        STOREP
C
C     AUTHORS    R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      STORE INFORMATION FOR FINAL PRINTOUT
C
C CALL         STOREP
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     FX         SAME AS FXP
C     FXP(I)     FORCE ON THE FOOTPAD I IN THE X DIRECTION IN THE FIXED
C                COORDINATE SYSTEM
C     FXPLG3     AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.3
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG3     AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO.3
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG3     AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.3
C                DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C                THE PARABOLIC INTEGRATION PROCEDURE
C     F1(I)      PLASTIC STROKE FORCE IN STRUT NO.1 OF LEG I
C     F2(I)      PLASTIC STROKE FORCE IN STRUT NO.2 OF LEG I
C     F3(I)      PLASTIC STROKE FORCE IN STRUT NO.3 OF LEG I
C     M          INDEX USED TO STORE VARIABLES FOR PRINT AT END OF RUN
C     SL1T       TRUE INSTANTANEOUS LENGTH OF STRUT NO.1
C     SL2T       TRUE INSTANTANEOUS LENGTH OF STRUT NO.2
C     SL3T       TRUE INSTANTANEOUS LENGTH OF STRUT NO.3
C     TIME       TIME AFTER TOUCHDOWN
C     XP(I)      X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     YP(I)      Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZP(I)      Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C
C OUTPUT       THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     FXPL31     FXPLG3 VALUE FOR LEG II     STORED FOR FINAL PRINT
C     FXPL33     FXPLG3 VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C     FYPL31     FYPLG3 VALUE FOR LEG II     STORED FOR FINAL PRINT
C     FYPL33     FYPLG3 VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C     FZPL31     FZPLG3 VALUE FOR LEG II     STORED FOR FINAL PRINT
C     FZPL33     FZPLG3 VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C     FX1        FX     VALUE FOR LEG II     STORED FOR FINAL PRINT
C     FX3        FX     VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C     G1STR1     SL1T   VALUE FOR LEG II     STORED FOR FINAL PRINT
C     G1STR2     SL2T   VALUE FOR LEG II     STORED FOR FINAL PRINT
C     G1STR3     SL3T   VALUE FOR LEG II     STORED FOR FINAL PRINT
C     G3STR1     SL1T   VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C     G3STR2     SL2T   VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C     G3STR3     SL3T   VALUE FOR LEG JJ     STORED FOR FINAL PRINT
```

Figure 1-29. Subroutine **STOREP**

```
C     G1FRC1    F1      VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1FRC2    F2      VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1FRC3    F3      VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G3FRC1    F1      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3FRC2    F2      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3FRC3    F3      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     TME       TIME    STORED FOR FINAL PRINT
C     XP1       XP      VALUE FOR LEG II    STORED FOR FINAL PRINT
C     XP3       XP      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     YP1       YP      VALUE FOR LEG II    STORED FOR FINAL PRINT
C     YP3       YP      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     ZP1       ZP      VALUE FOR LEG II    STORED FOR FINAL PRINT
C     ZP3       ZP      VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C
C
      SUBROUTINE  STOREP
C
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/EBLOCK/XP(5),YP(5),ZP(5),XPVEL(5),YPVEL(5),ZPVEL(5)
      COMMON/FBLOCK/FX(5),FXPLG3(5),FYPLG3(5),FZPLG3(5),FXPLG2(5),
     1 FYPLG2(5),FZPLG2(5),FXPLG1(5),FYPLG1(5),FZPLG1(5),
     1 F1(5),F2(5),F3(5),E1(5),E2(5),E3(5)
      COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
      COMMON/KBLOCK/M,TIME,TME(402),XP1(402),YP1(402),ZP1(402),XP3(402),
     1 YP3(402),ZP3(402),FX1(402),FX3(402),FXPL31(402),FYPL31(402),
     1 FZPL31(402),FXPL33(402),FYPL33(402),FZPL33(402),G1STR1(402),
     1 G1STR2(402),G1STR3(402),G3STR1(402),G3STR2(402),G3STR3(402),
     1 G1FRC1(402),G1FRC2(402),G1FRC3(402),G3FRC1(402),G3FRC2(402),
     1 G3FRC3(402)
C
C     STORE VARIABLES FOR THE PRINT TO BE MADE AT THE END OF THE RUN
C
  688 M=M+1
      TME(M)=TIME
      XP1(M)=XP(II)
      YP1(M)=YP(II)
      ZP1(M)=ZP(II)
      XP3(M)=XP(JJ)
      YP3(M)=YP(JJ)
      ZP3(M)=ZP(JJ)
      FX1(M)=FX(II)
      FX3(M)=FX(JJ)
      FXPL31(M)=FXPLG3(II)
      FYPL31(M)=FYPLG3(II)
      FZPL31(M)=FZPLG3(II)
      FXPL33(M)=FXPLG3(JJ)
      FYPL33(M)=FYPLG3(JJ)
      FZPL33(M)=FZPLG3(JJ)
      G1STR1(M)=SL1T(II)
      G1STR2(M)=SL2T(II)
      G1STR3(M)=SL3T(II)
      G3STR1(M)=SL1T(JJ)
      G3STR2(M)=SL2T(JJ)
      G3STR3(M)=SL3T(JJ)
      G1FRC1(M)=F1(II)
```

Figure 1-29. Subroutine STOREP (Continued)

```
G1FRC2(M)=F2(II)
G1FRC3(M)=F3(II)
G3FRC1(M)=F1(JJ)
G3FRC2(M)=F2(JJ)
G3FRC3(M)=F3(JJ)
RETURN
END
```

Figure 1-29. Subroutine STOREP (Concluded)

```
C TITLE       PRINT1
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C     PURPOSE   TO PRINT THE OUTPUT DATA
C
C CALL        PRINT1 (IPR)
C             IPR=1 ---  PRINT INITIAL DATA
C             IPR=2 ---  PRINT ON LINE OUTPUT WITH HEADINGS
C             IPR=3 ---  PRINT ON LINE OUTPUT
C             IPR=4 ---  PRINT SUMMARY (UNSTABLE RUN)
C             IPR=5 ---  PRINT SUMMARY (TIME EXCEEDED)
C             IPR=6 ---  PRINT SUMMARY (STABLE RUN)
C             IPR=7 ---  PRINT GENERAL SUMMARY
C             IPR=8 ---  PRINT STORED OUTPUT
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT       THROUGH LABELED COMMON
C
C     SYMBOL    DEFINITION
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A 0 IMPLIES THE INITIAL VALUE
C               AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  0   AS B1(I).
C     A         SYMMETRY FACTOR -- IF TWO VEHICLE LEGS ARE SYMMETRIC,
C               SET A=2.0 FOR ONE OF THE SYMMETRIC PAIRS AND A=0.0 FOR
C               THE OTHER TO SAVE ON COMPUTER TIME    IE  FOR 22 LANDING
C               A=2,0,2,0         FOR A 121 LANDING  A= 1,2,1,0
C     ALPHA     ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C               SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     BETA      VEHICLE STABILITY ANGLE
CC    BETADT    RATE OF CHANGE OF BETA WITH TIME
C     BIIMIN    MINIMUM STABILITY ANGLE FOR LEG SET II
C     BJJMIN    MINIMUM STABILITY ANGLE FOR LEG SET JJ
C     B10       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     B20       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B30       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     C10,C20,C30      ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C               THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C               TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     D         VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     DELTAP    DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C               LEG STRUTS
C     DELTAT    TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     D10       INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C               OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C               TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     D11       VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     EGBAL1    ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND C.G.
C               DROP
C     EGBAL2    ENERGY DISSIPATED BASED ON PLASTIC STROKE OF ALL STRUTS
C     EGBAL3    ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC
```

Figure 1-30. Subroutine PRINT1

```
C                 STROKE OF ALL STRUTS
C     ENPRO(I)    PERCENT OF TOTAL ENERGY ABSORBED BY  STROKING OF THE
C                 STRUTS OF LEG SET I
C     EPS2        MINIMUM ALLOWABLE FOOTPAD SLIDING VELOCITY
C     EPS3        LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN X DIRECTION
C     EPS4        LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN Y DIRECTION
C     EPS5        LIMITING MINIMUM ANGULAR VELOCITY OF VEHICLE C. G.
C
C     NOTE        IF XVEL,YVEL AND PSIVEL ARE SIMULTANEOUSLY LESS THAN
C                 EPS3,EPS4 AND EPS5 RESPECTIVELY AND THE FOOTPADS ARE ALL
C                 LESS THAN 1 FT. FROM THE GROUND, THE PROGRAM TERMINATES
C
C     FINT        MAXIMUM ALLOWABLE TIME FOR COMPUTER RUN
C     FLL         TOTAL FORCE ACTING ON THE VEHICLE IN THE LATERAL DIRECTION
C                 (NORMAL TO THE VEHICLE CENTERLINE)
C     FVV         TOTAL FORCE ACTING ON THE VEHICLE IN THE VERTICAL
C                 DIRECTION (  PARALLEL TO THE VEHICLE CENTERLINE)
C     FX1         FX     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FX3         FX     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FXPL31      FXPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FXPL33      FXPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FYPL31      FYPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FYPL33      FYPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     F11         PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22         PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33         PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     FZPL31      FZPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FZPL33      FZPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     GRAV        LOCAL GRAVITY
C     GRDMU       COEFFICIENT OF FRICTION BETWEEN VEHICLE FOOTPADS AND GROUND
C     G1FRC1      F1     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1FRC2      F2     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1FRC3      F3     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G3FRC1      F1     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3FRC2      F2     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3FRC3      F3     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G1STR1      SL1T   VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1STR2      SL2T   VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G1STR3      SL3T   VALUE FOR LEG II    STORED FOR FINAL PRINT
C     G3STR1      SL1T   VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3STR2      SL2T   VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     G3STR3      SL3T   VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     H           DISTANCE FROM THE BOTTOM OF THE FOOTPAD TO THE VEHICLE
C                 CENTER OF GRAVITY
C     HN          VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND THE LOWEST
C                 POINT ON THE NOZZLE CONE
C     HVELO       HORIZONTAL VELOCITY PERPENDICULAR TO THE GRAVITATIONAL
C                 FIELD.
C     II          PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                 PRINTED AS OUTPUT
C     IP          PRINT INDICATOR
C     IQ          PRINT INDICATOR
C     IR          PRINT INDICATOR
C     J           INDEX ASSOCIATED WITH FIRST LEG TO STRIKE GROUND DURING
C                 INITIAL IMPACT
C     JJ          SIMILAR TO II
C     K           FLAG FOR LANDING MODE   IF 1-2-1 LANDING , K=1    IF
C                 2-2 LANDING, K=2
CC    KCONMX      NUMBER OF ITERATIONS OF FOOTPAD CALCULATIONS PER  (DELTAT)
C                 TIME INTERVAL
C     KPRINT      COMPUTATION INCREMENTS BETWEEN PRINTOUT INTERVALS
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
C     LAND       SIGNIFIES LANDING MODE  -  SET FOR 22 OR 121 LANDING
C     LINE       PRINTOUT LINE COUNTER
C     LOTPRT     FLAG TO DETERMINE IF COMPLETE SUMMARY PRINTING IS TO
C                BE DESIRED.  COMPLETE OUTPUT PRINTING IS NOT NORMALLY
C                USED THEREFORE SET LOTPRT=0  .   IF SET LOTPRT=1, THE
C                COMPLETE HISTORY OF STRUT STROKES, AND STRUT FORCES WILL
C                BE PRINTED.
C     M          INDEX USED TO STORE VARIABLES FOR PRINT AT END OF RUN
C     N          NUMBER OF LEGS ON THE VEHICLE
C     NQO        STARTING COLUMN IN VELOCITY INPUT ARRAY
C     NQMAX      ENDING COLUMN IN VELOCITY ARRAY
C     NOTE       SEE WRITEUP FOR DISCUSSION OF VELOCITY ARRAY
C     NSO        STARTING ROW IN VELOCITY INPUT ARRAY
C     NSMAX      ENDING ROW IN VELOCITY ARRAY
C     PHI        ANGLE BETWEEN VEHICLE CENTERLINE AND GRAVITY VECTOR
C     PMASS      MASS OF EACH FOOTPAD
C     PSIO       INITIAL PITCH ANGLE
C     PSVELO     INITIAL VEHICLE PITCH RATE
C     P1         FRICTION FORCE IN STRUT NO. 1
C     P2         FRICTION FORCE IN STRUT NO. 2
C     P3         FRICTION FORCE IN STRUT NO. 3
C     RMOMI      VEHICLE MOMENT OF INERTIA
C     RMOO(3)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE CURRENT TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(2)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-1 TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RMOO(1)    TORQUE ACTING ON THE VEHICLE C.G. IN THE X-Y PLANE
C                DURING THE N-2 TIME INTERVAL.  THIS TORQUE IS USED
C                IN THE PARABOLIC INTEGRATION PROCEDURE
C     RN         EXHAUST NOZZLE RADIUS
C     RP(I)      RADIUS OF FOOTPAD (I)
C     PSI        INSTANTANEOUS VALUE OF PSIO
C     PSIVEL     INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE C.G.
C     RUNNOO     RUN NUMBER  ( FOR IDENTIFICATION ONLY)
C     R1         RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2         RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     SERNO      SERIES NUMBER ( FOR IDENTIFICATION ONLY)
C     SKE1       TENSIL ELASTIC SPRINGRATE OF STRUT NO. 1 (UPPER)
C     SKE2       TENSIL ELASTIC SPRINGRATE OF STRUT NO. 2 (LOWER)
C     SKE3       TENSIL ELASTIC SPRINGRATE OF STRUT NO. 3 (LOWER)
C     SKS        SPRINGRATE UNDER VEHICLE FOOTPADS
C     SK1        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C     SK2        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C     SK3        COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C     SL1M       MINIMUM LENGTH TO WHICH STRUT NO.1 HAS BEEN COMPRESSED
C                DURING THIS RUN
C     SL10       INITIAL VALUE OF SL1
C     SL2M       MINIMUM LENGTH TO WHICH STRUT NO.2 HAS BEEN COMPRESSED
C                DURING THIS RUN
C     SL3M       MINIMUM LENGTH TO WHICH STRUT NO.3 HAS BEEN COMPRESSED
C                DURING THIS RUN
C     THETA      ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C                DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C                CENTERLINE AND UPPER HARDPOINT
C     TIME       TIME AFTER TOUCHDOWN
C     TME        TIME   STORED FOR FINAL PRINT
C     TMINBI     TIME WHEN MINIMUM STABILITY FOR LEG SET II OCCURS
C     TMINBJ     TIME WHEN MINIMUM STABILITY FOR LEG SET JJ OCCURS
C     TMINXN     TIME WHEN MINIMUM NOZZLE CLEARANCE OCCURS
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
C      VMASS      VEHICLE MASS
C      VVELO      INITIAL VEHICLE VELOCITY PARALLEL TO THE GRAVITATIONAL
C                 FIELD.   POSITIVE DOWNWARD
C      X          INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C      XP1        XP      VALUE FOR LEG II     STORED FOR FINAL PRINT
C      XNMIN      MINIMUM VALUE OF NOZZLE CLEARANCE
C      XP3        XP      VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C      XVEL       INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C      XVELO      INITIAL VERTICAL VELOCITY OF VEHICLE C.G.
C      XVELOO     SAME AS XVELO
C      Y          INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C      YO         INITIAL HORIZONTAL POSITION OF VEHICLE C.G.
C      YP1        YP      VALUE FOR LEG II     STORED FOR FINAL PRINT
C      YP3        YP      VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C      YVEL       INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C      YVELO      INITIAL HORIZONTAL VELOCITY OF VEHICLE C.G.
C      YVELOO     SAME AS YVELO
C      ZETA       GROUND SLOPE
C      ZP1        ZP      VALUE FOR LEG II     STORED FOR FINAL PRINT
C      ZP3        ZP      VALUE FOR LEG JJ     STORED FOR FINAL PRINT
C
C      OUTPUT     PRINTED OUTPUT
C
C
       SUBROUTINE  PRINT1(IPR)
       COMMON/ABLOCK/N,K,NOGR(5)
       COMMON/BBLOCK/H,DELTAP,D11(5),R1(5),R2(5),RP(5),THETA(5),ALPHA(5),
      1 D(5),SL10(5),D10(5),B10(5),B20(5),B30(5),C10(5),C20(5),C30(5)
       COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
      1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
      1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
      1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
       COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
      1 SKE3
       COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
      1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
      1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOO(3),
      1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
      1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
      1 ENPRO(5)
       COMMON/IBLOCK/BETA(5),BEPR(5),BETAPR(5),LAND
       COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
      1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
      1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
      1 MULT,PRXVEL,PRYVEL
       COMMON/KBLOCK/M,TIME,TME(402),XP1(402),YP1(402),ZP1(402),XP3(402),
      1 YP3(402),ZP3(402),FX1(402),FX3(402),FXPL31(402),FYPL31(402),
      1 FZPL31(402),FXPL33(402),FYPL33(402),FZPL33(402),G1STR1(402),
      1 G1STR2(402),G1STR3(402),G3STR1(402),G3STR2(402),G3STR3(402),
      1 G1FRC1(402),G1FRC2(402),G1FRC3(402),G3FRC1(402),G3FRC2(402),
      1 G3FRC3(402)
       GO TO (10,20,30,40,50,60,70,80), IPR
C
C      PRINT INPUT DATA
C
    10 DO 3042 KKK=1,2
       PRINT 950
       PRINT 1050,(A(I),I=1,5)
       PRINT 1061,(ALPHA(I),I=1,5)
       PRINT 1062,(D(I),I=1,5)
       PRINT 1063,(D11(I),I=1,5)
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
      PRINT 1064,(F11(I),I=1,5)
      PRINT 1065,(F22(I),I=1,5)
      PRINT 1066,(F33(I),I=1,5)
      PRINT 1058,(GRDMU(I),I=1,5)
      PRINT 1067,(P1(I),I=1,5)
      PRINT 1068,(P2(I),I=1,5)
      PRINT 1069,(P3(I),I=1,5)
      PRINT 1070,(R1(I),I=1,5)
      PRINT 1071,(R2(I),I=1,5)
      PRINT 1090,(RP(I),I=1,5)
      PRINT 1091,(SKS(I),I=1,5)
      PRINT 1060,(THETA(I),I=1,5)
      PRINT 1072,DELTAP,DELTAT,EPS2
      PRINT 1073,EPS3,EPS4,EPS5
      PRINT 1074,FINT,GRAV,HN
      PRINT 1075,PMASS,PSIO,PSVELO
      PRINT 1076,RMOMI,RUNNOO,RN
      PRINT 1077,SK1,SK2
      PRINT 1078,SK3,SKE1,SKE2
      PRINT 1079,SKE3,SERNO,VMASS
      PRINT 1080,YO,ZETA,H
      PRINT 1081,II,JJ,J,K,KPRINT,LAND
      PRINT 1082,N,NSO,NQO,NSMAX,NQMAX,KCONMX
      PRINT 1089,LOTPRT
      PRINT 1083 ((VVELO(ML,NL),HVELO(ML,NL),ML=1,NQMAX),NL=1,NSMAX)
      PRINT 1059,(SL10(I),I=1,5)
      PRINT 1057,(D10(I),I=1,5)
      PRINT 1051,(B10(I),I=1,5)
      PRINT 1052,(B20(I),I=1,5)
      PRINT 1053,(B30(I),I=1,5)
      PRINT 1054,(C10(I),I=1,5)
      PRINT 1055,(C20(I),I=1,5)
      PRINT 1056,(C30(I),I=1,5)
      PRINT 1092,XVELOO,YVELOO
 3042 CONTINUE
      RETURN
C
C     PRINT  ON  LINE  DATA
C
   20 PRINT 950
      PRINT 850,SERNO,RUNNO,XVELOO,YVELOO,ZETA,PSIO,PSVELO
      PRINT 851,VVELO(NQ,NS),HVELO(NQ,NS)
      PRINT 902,II,JJ
      PRINT 903,TIME,X,Y,PSI,XVEL,YVEL,PSIVEL,BETADT,BETA(II),
     1 BETA(JJ),FLL,FVV,RMOO(3)
      RETURN
C
C     RECORD LINE COUNT FOR PRINT HEADINGS
C
   30 LINE=LINE+1
      IF(LINE-49)705,705,707
  705 PRINT 903,TIME,X,Y,PSI,XVEL,YVEL,PSIVEL,BETADT,BETA(II),
     1 BETA(JJ),FLL,FVV,RMOO(3)
      RETURN
  707 PRINT 950
      PRINT 902,II,JJ
      LINE=0
      PRINT 903,TIME,X,Y,PSI,XVEL,YVEL,PSIVEL,BETADT,BETA(II),
     1 BETA(JJ),FLL,FVV,RMOO(3)
      RETURN
   40 PRINT 950
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
C
C      PRINT PAGE TITLES
C
       PRINT 850,SERNO,RUNNO,XVELOO,YVELOO,ZETA,PSIO,PSVELO
       PRINT 851,VVELO(NQ,NS),HVELO(NQ,NS)
       PRINT 905,TIME
       RETURN
    50 PRINT 950
       PRINT 850,SERNO,RUNNO,XVELOO,YVELOO,ZETA,PSIO,PSVELO
       PRINT 851,VVELO(NQ,NS),HVELO(NQ,NS)
       PRINT 906,TIME
       RETURN
C
C      VEHICLE IS STABLE AND HAS STOPPED .  PRINT OUTPUT DATA
C
    60 PRINT 950
       PRINT 850,SERNO,RUNNO,XVELOO,YVELOO,ZETA,PSIO,PSVELO
       PRINT 851,VVELO(NQ,NS),HVELO(NQ,NS)
       PRINT 904,TIME
       RETURN
C
C      PRINT SUMMARY OUTPUT
C
    70 PRINT 907,(SL1M(I),I=1,N)
       PRINT 908,(SL2M(I),I=1,N)
       PRINT 909,(SL3M(I),I=1,N)
       PRINT 910,XNMIN,TMINXN
       PRINT 936,II,BIIMIN,TMINBI
       PRINT 937,JJ,BJJMIN,TMINBJ
       PRINT 917,EGBAL1
       PRINT 918,EGBAL2
       PRINT 934,EGBAL3
       PRINT 913,PHI
       PRINT 938,II,BETA(II),II,BETADT
       PRINT 939,(ENPRO(I),I=1,N)
       RETURN
    80 IP=1
       IQ=50
       IR=-1
  1822 IF(M-IQ)1823,1823,1824
  1823 IQ=M
       IR=1
C
C      PRINT STORED OUTPUT INFORMATION
C
  1824 PRINT 950
       PRINT 930,II,II,II,JJ,JJ,JJ,II,JJ
       PRINT 931,(TME(I),XP1(I),YP1(I),ZP1(I),XP3(I),YP3(I),ZP3(I),
      1FX1(I),FX3(I),I=IP,IQ)
       IF(IR)1825,1825,1826
  1825 IP=IP+50
       IQ=IG+50
       GO TO 1822
C
C      TEST FLAG  LOTPRT  TO SEE IF COMPLETE PRINTOUT IS DESIRED
C
  1826 IF (LOTPRT) 1836,1836,2826
  2826 IP=1
       IQ=50
       IR=-1
  1827 IF(M-IQ)1828,1828,1829
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
1828 IQ=M
     IR=1
1829 PRINT 950
     PRINT 932,II,II,II,JJ,JJ,JJ
     PRINT 933,(TME(I),FXPL31(I),FYPL31(I),FZPL31(I),FXPL33(I),
    1FYPL33(I),FZPL33(I),I=IP,IQ)
     IF(IR)1830,1830,1831
1830 IP=IP+50
     IQ=IQ+50
     GO TO 1827
1831 IP=1
     IQ=50
     IR=-1
1832 IF (M-IQ) 1833,1833,1834
1833 IQ=M
     IR=1
1834 PRINT 950
     PRINT 960,II,JJ
     PRINT 961
     PRINT 962,(TME(I),G1STR1(I),G1FRC1(I),G1STR2(I),G1FRC2(I),G1STR3(I
    1),G1FRC3(I),G3STR1(I),G3FRC1(I),G3STR2(I),G3FRC2(I),G3STR3(I),
    2G3FRC3(I),I=IP,IQ)
     IF (IR) 1835,1835,1836
1835 IP=IP+50
     IQ=IQ+50
     GO TO 1832
1836 RETURN
C
C
C     FORMAT STATEMENTS FOR OUTPUT INFORMATION
C
  850 FORMAT(11H SERIES NO., F7.2,9H  RUN NO.,F6.2,     14H        XVELO
     1=,F6.2,11H      YVELO=,F6.2,10H     ZETA=,F5.3,10H      PSIO=,F6.4,1
     12H      PSVELO=,F6.4/)
  851 FORMAT(47H                                              VVELO=,F6.2,11H
     1      HVELO=,F6.2/)
  902 FORMAT(78H     TIME       X         Y        PSI      XVEL       YVEL     P
     1SIVEL    BETAVEL    BETA,I1,6H  BETA,I1,30H          FL           FV
     2    TQ/)
  903 FORMAT(F8.3,F10.3,F9.3,2F8.3,2F9.3,F10.3,F7.3,F8.3,3F10.1)
  904 FORMAT(11H      STABLE,F7.3,5HSECS.///)
  905 FORMAT(13H      UNSTABLE,F7.3,5HSECS.///)
  906 FORMAT(9H      TIME,F7.3,5HSECS.///)
  907 FORMAT(32H      MAXIMUM STROKE  NO. 1 STRUT,5F12.3//)
  908 FORMAT(32H                      NO. 2 STRUT,5F12.3//)
  909 FORMAT(32H                      NO. 3 STRUT,5F12.3///)
  910 FORMAT(///32H    MINIMUM CLEARANCE OF NOZZLE=,F7.3,55H
     1TIME WHEN THE MINIMUM CLEARANCE OCCURS     =,F7.3///)
  911 FORMAT(54H      MINIMUM CLEARANCE BETWEEN SHOCK STRUT AND FRAME =)
  912 FORMAT(32H                                   ,5F12.3///)
  913 FORMAT(43H      FINAL ANGULAR ORIENTATION OF VEHICLE =,F7.4///)
  914 FORMAT(32H      MAXIMUM STROKE  NO. 1 STRUT,4F12.3//)
  915 FORMAT(32H                      NO. 2 STRUT,4F12.3//)
  916 FORMAT(32H                      NO. 3 STRUT,4F12.3//)
  917 FORMAT(66H      ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND
     1C.G. DROP=,F11.3///)
  918 FORMAT(48H      ENERGY DISSIPATED BASED ON PLASTIC STROKE =,F11.3//
     1/)
  930 FORMAT(21H       TIME       XP(,I1,11H)       YP(,I1,11H)       ZP
     1(,I1,12H)       XP(,I1,11H)       YP(,I1,11H)       ZP(,I1,13H)
     1       FX(,I1,14H)          FX(,I1,1H)/)
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
  931 FORMAT(7F12.3,2F14.1)
  932 FORMAT(24H       TIME      FXPLG3(,I1,13H)     FYPLG3(,I1,13H)
     1 FZPLG3(,I1,13H)     FXPLG3(,I1,13H)     FYPLG3(,I1,13H)     FZPLG
     13(,I1,1H)/)
  933 FORMAT(F12.3,6F14.1)
  934 FORMAT(65H     ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC
     1 STROKE =,F11.3///)
  936 FORMAT(29H    MINIMUM STABILITY ANGLE B,I1,1H=,F7.3,55H
     1 TIME WHEN THIS STABILITY ANGLE OCCURS      =,F7.3///)
  937 FORMAT(29H    MINIMUM STABILITY ANGLE B,I1,1H=,F7.3,55H
     1 TIME WHEN THIS STABILITY ANGLE OCCURS      =,F7.3///)
  938 FORMAT(27H    FINAL STABILITY ANGLE B,I1,2H =,F7.3,30H
     1        FINAL BETA,I1,17H RATE OF CHANGE =,F7.3///)
  939 FORMAT(48H    ENERGY DISTRIBUTION BETWEEN LEGS - PERCENT =,5F8.3//
     1/)
  950 FORMAT(1H1)
  960 FORMAT(37H                             LEG SET NO.,I1,56H
     1                                 LEG SET NO.,I1/)
  961 FORMAT(117H   TIME  LENGTH1  FORCE1   LENGTH2  FORCE2   LENGTH3  F
     1ORCE3      LENGTH1  FORCE1   LENGTH2  FORCE2   LENGTH3  FORCE3/)
  962 FORMAT(F7.3,F9.3,F10.2,F8.3,F10.2,F8.3,F10.2,F11.3,F10.2,F8.3,F10.
     12,F8.3,F10.2)
 1050 FORMAT(10X,10HA         =,5F15.5)
 1051 FORMAT(10X,10HB10       =,5F15.5)
 1052 FORMAT(10X,10HB20       =,5F15.5)
 1053 FORMAT(10X,10HB30       =,5F15.5)
 1054 FORMAT(10X,10HC10       =,5F15.5)
 1055 FORMAT(10X,10HC20       =,5F15.5)
 1056 FORMAT(10X,10HC30       =,5F15.5)
 1057 FORMAT(10X,10HD10       =,5F15.5)
 1058 FORMAT(10X,10HGRDMU     =,5F15.5)
 1059 FORMAT(/10X,10HSL10      =,5F15.5)
 1060 FORMAT(10X,10HTHETA     =,5F15.5)
 1061 FORMAT(10X,10HALPHA     =,5F15.5)
 1062 FORMAT(10X,10HD         =,5F15.5)
 1063 FORMAT(10X,10HD11       =,5F15.5)
 1064 FORMAT(10X,10HF11       =,5F15.5)
 1065 FORMAT(10X,10HF22       =,5F15.5)
 1066 FORMAT(10X,10HF33       =,5F15.5)
 1067 FORMAT(10X,10HP1        =,5F15.5)
 1068 FORMAT(10X,10HP2        =,5F15.5)
 1069 FORMAT(10X,10HP3        =,5F15.5)
 1070 FORMAT(10X,10HR1        =,5F15.5)
 1071 FORMAT(10X,10HR2        =,5F15.5)
 1072 FORMAT(10X,10HDELTAP    =,F15.5,10H  DELTAT =,F15.5,10H  EPS2   =,F
     115.5)
 1073 FORMAT(10X,10HEPS3      =,F15.5,10H  EPS4   =,F15.5,10H  EPS5   =,F
     115.5)
 1074 FORMAT(10X,10HFINT      =,F15.5,10H  GRAV   =,F15.5,10H  HN     =,F
     115.5)
 1075 FORMAT(10X,10HPMASS     =,F15.5,10H  PSIO   =,F15.5,10H  PSVELO =,F
     115.5)
 1076 FORMAT(10X,10HRMOMI     =,F15.5,10H  RUNNOO =,F15.5,10H  RN     =,F
     115.5)
 1077 FORMAT(10X,10HSK1       =,F15.5,10H  SK2    =,F15.5)
 1078 FORMAT(10X,10HSK3       =,F15.5,10H  SKE1   =,F15.5,10H  SKE2   =,F
     115.5)
 1079 FORMAT(10X,10HSKE3      =,F15.5,10H  SERNO  =,F15.5,10H  VMASS  =,F
     115.5)
 1080 FORMAT(10X,10HYO        =,F15.5,10H  ZETA   =,F15.5,10H  H      =,F
     115.5)
```

Figure 1-30. Subroutine PRINT1 (Continued)

```
1081 FORMAT(10X,8H    II =,I5,8H    JJ =,I5,8H     J =,I5,8H     K =,I5
    1,8HKPRINT =,I5,8H  LAND =,I5)
1082 FORMAT(10X,8H     N =,I5,8H   NSO =,I5,8H   NQO =,I5,8H NSMAX =,I5
    1,8H NQMAX =,I5,8HKCONMX =,I5)
1083 FORMAT(15H          VVELO,15H          HVELO,15H          VVELO,15
    1H          HVELO,15H          VVELO,15H          HVELO/(F17.4,5F15
    1.4))
1089 FORMAT(10X,8HLOTPRT =,I5/)
1090 FORMAT(10X,10HRP       =,5F15.5)
1091 FORMAT(10X,10HSKS      =,5F15.5)
1092 FORMAT(10X,10HXVELO    =,F15.5,15H      YVELO   =,F15.5)
     END
```

Figure 1-30. Subroutine PRINT1 (Concluded)

```
C TITLE       ENERGY
C
C     AUTHORS   R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE        10-25-64
C
C PURPOSE     COMPUTE ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES
C             AND C.G. DROP , BASED ON PLASTIC STROKE AND BASED ON
C             PLASTIC AND FULL ELASTIC STROKE
C
C CALL        ENERGY
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT       THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A 0 IMPLIES THE INITIAL VALUE
C               AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  0   AS B1(I).
C
C     SYMBOL    DEFINITION
C
C     A         SYMMETRY FACTOR -- IF TWO VEHICLE LEGS ARE SYMMETRIC,
C               SET A=2.0 FOR ONE OF THE SYMMETRIC PAIRS AND A=0.0 FOR
C               THE OTHER TO SAVE ON COMPUTER TIME    IE  FOR 22 LANDING
C               A=2,0,2,0         FOR A 121 LANDING  A= 1,2,1,0
C     F11       PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22       PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33       PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     GRAV      LOCAL GRAVITY
C     PSIVEL    INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE C.G.
C     PSVELO    INITIAL VEHICLE PITCH RATE
C     P1        FRICTION FORCE IN STRUT NO. 1
C     P2        FRICTION FORCE IN STRUT NO. 2
C     P3        FRICTION FORCE IN STRUT NO. 3
C     RMOMIT    TOTAL MOMENT OF INERTIA OF THE VEHICLE MASS AND THOSE
C               FOOTPADS WHICH ARE OFF THE GROUND
C     SK1       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C     SK2       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C     SK3       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C     SL1M      MINIMUM LENGTH TO WHICH STRUT NO.1 HAS BEEN COMPRESSED
C               DURING THIS RUN
C     SL2M      MINIMUM LENGTH TO WHICH STRUT NO.2 HAS BEEN COMPRESSED
C               DURING THIS RUN
C     SL3M      MINIMUM LENGTH TO WHICH STRUT NO.3 HAS BEEN COMPRESSED
C               DURING THIS RUN
C     VMASS     VEHICLE MASS
C     X         INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XVEL      INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C     XVELO     INITIAL VERTICAL VELOCITY OF VEHICLE C.G.
C     XVELOO    SAME AS XVELO
C     Y         INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YVEL      INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C     YVELO     INITIAL HORIZONTAL VELOCITY OF VEHICLE C.G.
C     YVELOO    SAME AS YVELO
C     ZETA      GROUND SLOPE
C
C OUTPUT      THROUGH LABELED COMMON
```

Figure 1-31. Subroutine ENERGY

```
C
C     SYMBOL    DEFINITION
C
C     EGBAL1    ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND C.G.
C               DROP
C     EGBAL2    ENERGY DISSIPATED BASED ON PLASTIC STROKE OF ALL STRUTS
C     EGBAL3    ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC
C               STROKE OF ALL STRUTS
C     ENPRO(I)  PERCENT OF TOTAL ENERGY ABSORBED BY  STROKING OF THE
C               STRUTS OF LEG SET I
C
C
      SUBROUTINE  ENERGY
C
      COMMON/ABLOCK/N,K,NOGR(5)
      COMMON/DBLOCK/D1(5),B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1(5),
     1 SL2(5),SL3(5),SL1T(5),SL2T(5),SL3T(5),SL1TO(5),SL2TO(5),SL3TO(5),
     1 SL1M(5),SL2M(5),SL3M(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),B2PREV(5),
     1 B3PREV(5),C1PREV(5),C2PREV(5),C3PREV(5),EPS2,EPS3,EPS4,EPS5
      COMMON/GBLOCK/F11(5),F22(5),F33(5),SKS(5),SK1,SK2,SK3,SKE1,SKE2,
     1 SKE3
      COMMON/HBLOCK/VVELO(14,8),HVELO(14,8),XVELO(14,8),YVELO(14,8),
     1 XVELOO,YVELOO,PSI,PSIO,PSVELO,X,XO,Y,YO,XVEL,YVEL,PSIVEL,GRAV,
     1 ZETA,KCONMX,DELTTT,DELTAT,GRDMU(5),A(5),FXX(3),FYY(3),RMOC(3),
     1 VMASS,PMASS,RMOMIT,RMOMGR,RMOMI,FA(5),FB(5),FC(5),IP,IQ,IR,
     1 EGBAL1,EGBAL2,EGBAL3,P1(5),P2(5),P3(5),DEL(5),EPSEN(5),PHI,
     1 ENPRO(5)
      DIMENSION ENGY(5)
C
C
C     COMPUTE ENERGY TERMS FOR PRINTOUT PURPOSES ONLY
C
      EGBAL1=VMASS*XVELOO*XVELOO/2.0+VMASS*YVELOO*YVELOO/2.0+RMOMIT*
     1PSVELO*PSVELO/2.0+((XO-X)*COS (ZETA)+Y*SIN (ZETA))*VMASS*GRAV-
     1(VMASS*XVEL*XVEL/2.0+VMASS*YVEL*YVEL/2.0+RMOMIT*PSIVEL*PSIVEL/
     12.0)
      EGBAL2=0.0
      EGBAL3=0.0
      DO 821 I=1,N
  821 ENGY(I)=0.0
      DO 822 I=1,N,K
      ENGY(I)=A(I)*((F11(I)+P1(I))*(SL1M(I)-F11(I)/SK1)+(F22(I)+P2(I))*(
     1SL2M(I)-F22(I)/SK2)+(F33(I)+P3(I))*(SL3M(I)-F33(I)/SK3))
      EGBAL2=EGBAL2+ENGY(I)
  822 EGBAL3=EGBAL3+A(I)*((F11(I)+P1(I))*(SL1M(I)-F11(I)/(2.0*SK1))+(
     1F22(I)+P2(I))*(SL2M(I)-F22(I)/(2.0*SK2))+(F33(I)+P3(I))*(SL3M(I)-
     2F33(I)/(2.0*SK3)))
      DO 2822 I=1,N
C
C     DETERMINE ENERGY ABSORPTION DISTRIBUTION BETWEEN LEG SETS
C
 2822 ENPRO(I)=(ENGY(I)/EGBAL2)*100.0
      RETURN
      END
```

Figure 1-31. Subroutine ENERGY (Concluded)

```
C TITLE        PROFIL
C
C     AUTHORS    R.BLACK,J.CADORET,J.GIBSON    THE BENDIX CORPORATION
C
C DATE         10-25-64
C
C PURPOSE      DETERMINE NEW INDEX VALUES TO CHOOSE NEW VELOCITY
C              CONDITIONS FROM INPUTED ARRAY FOR NEXT RUN
C
C CALL         PROFIL (IPRO)
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM EXECUTES ON THE UNIVAC 1107 COMPUTER
C
C INPUT        THROUGH LABELED COMMON
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A O IMPLIES THE INITIAL VALUE
C                AS  B1O(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C                IS DEFINED WITHOUT THE  O   AS B1(I).
C
C     SYMBOL     DEFINITION
C
C     IPRO       FLAG USED TO INDICATE ENTRANCE POINT
C     NQO        STARTING COLUMN IN VELOCITY INPUT ARRAY
C     NQMAX      ENDING COLUMN IN VELOCITY ARRAY
C     NSO        STARTING ROW IN VELOCITY INPUT ARRAY
C     NSMAX      ENDING ROW IN VELOCITY ARRAY
C
C     NOTE       SEE WRITEUP FOR DISCUSSION OF VELOCITY ARRAY
C
C     NST        FLAG FOR DETERMINING STABILITY PROFILE INPUT SEQUENCE
C     NUN        FLAG FOR DETERMINING STABILITY PROFILE INPUT SEQUENCE
C
C OUTPUT       THROUGH LABELED COMMON
C
C
      SUBROUTINE PROFIL(IPRO)
C
      COMMON/JBLOCK/BETADT,FLL,FVV,LINE,FINT,RUNNO,RUNNOO,SERNO,XN,
     1 XNMIN,TMINXN,BIIMIN,BJJMIN,TMINBI,TMINBJ,HN,RN,KPRINT,NSO,NQO,
     1 NS,NQ,NSMAX,NQMAX,LOTPRT,NST,NUN,II,JJ,J,CONS,IFLAG,PRBE,KM,
     1 MULT,PRXVEL,PRYVEL
C
C     DETERMINE NEW INDEX VALUES TO CHOOSE NEW VELOCITY CONDITIONS
C      FROM INPUTED ARRAY FOR NEXT RUN
C
      GO TO (785,824), IPRO
  785 IF(NST) 790,790,796
  790 NUN=1
      NQ=NQ-1
      IF(NQ)794,794,40
  794 NQ=NQ+1
  796 NS=NS+1
      IF(NS-NSMAX)20,20,840
C
  824 IF(NUN) 825,825,796
  825 NST=1
      NQ=NQ+1
      IF(NQ-NQMAX     )40,40,830
```

Figure 1-31A. Subroutine PROFIL

```
830 NQ=NQ-1
    NS=NS+1
    IF(NS-NSMAX)833,833,840
833 IF(NQ-NQMAX     )20,20,836
836 NQ=NQ-1
    GO TO 833
840 PRINT 950
    IPRO=1
    RETURN
 20 IPRO=2
    RETURN
 40 IPRO=3
    RETURN
950 FORMAT(1H1)
    END
```

Figure 1-31A. Subroutine PROFIL (Concluded)

```
A       =      2.00000         .00000        2.00000         .00000         .00000
ALPHA   =      1.49200        1.49200        1.49200        1.49200         .00000
D       =      5.25000        5.25000        5.25000        5.25000         .00000
D11     =      1.50000        1.50000        1.50000        1.50000         .00000
F11     =   5411.00000     5411.00000     5411.00000     5411.00000         .00000
F22     =   1737.00000     1737.00000     1737.00000     1737.00000         .00000
F33     =   1737.00000     1737.00000     1737.00000     1737.00000         .00000
GRDMU   =      2.00000        2.00000        2.00000        2.00000         .00000
P1      =    100.00000      100.00000      100.00000      100.00000         .00000
P2      =    100.00000      100.00000      100.00000      100.00000         .00000
P3      =    100.00000      100.00000      100.00000      100.00000         .00000
R1      =      6.00000        6.00000        6.00000        6.00000         .00000
R2      =      6.00000        6.00000        6.00000        6.00000         .00000
RP      =     12.08000       12.08000       12.08000       12.06000         .00000
SKS     = 125000.00000   125000.00000   125000.00000   125000.00000         .00000
THETA   =       .78540        2.35620       -2.35620        -.78540         .00000
DELTAP  =       .25000  DELTAT =          .00200  EPS2   =        .05000
EPS3    =       .40000  EPS4   =          .40000  EPS5   =        .01000
FINT    =      2.00000  GRAV   =         5.32000  HN     =       6.58300
PMASS   =      4.00000  FSIO   =         -.22685  PSVELO =        .00000
RHOMI   =  11873.00000  PUNNOO =         1.00000  RN     =       1.87500
SK1     = 125000.00000  SK2    =    125000.00000
SK3     = 125000.00000  SKE1   =    125000.00000  SKE2   =  125000.00000
SKE3    = 125000.00000  SERNO  =      1608.00000  VMASS  =     400.00000
YO      =       .00000  ZETA   =          .22685  H      =      12.83000
     II =      1     JJ =      3      J =      3     K =     2KPRINT =     10  LAND =     22
      N =      4    NSO =      1    NQO =      1 NSMAX =     1 NQMAX =     1KCONMX =      3
LOTPRT =       1

VVELO          HVELO          VVELO          HVELO          VVELO          HVELO
10.0000         .0000

SL10    =     11.88484         .00000       11.88486         .00000         .00000
D10     =      4.29922         .00000       -4.29919         .00000         .00000
B10     =       .37013         .00000        -.37013         .00000         .00000
B20     =       .41182         .00000        -.41182         .00000         .00000
B30     =       .95877         .00000        -.95877         .00000         .00000
C10     =      1.22370         .00000        1.91789         .00000         .00000
C20     =       .65365         .00000        2.48794         .00000         .00000
C30     =      1.32492         .00000        1.81666         .00000         .00000
XVELO   =     -9.74380     YVELO   =         2.24909
```

Figure 1-32. Data Printout and "On-Line" Printout

```
SERIES EC.1699.09  RUN NO.  1.00       XVELO = -9.74     YVELO=  2.25     ZETA= .227     PSIO=-.2268     PSVELO= .0000
                                       VVELO= 10.00      HVELO=   .00

 TIME      X        Y      PSI     XVEL     YVEL   PSIVEL  DETAVEL  BETA1  BETA3       FL        FV        TQ

 .000   14.429    .000   -.227   -9.744    2.249    .000   -.000    .596  -.596        .0        .0        .0
 .020   14.233    .045   -.227   -9.714    2.292    .016   -.017    .597  -.606    -278.9   -2519.5     104.9
 .040   14.040    .092   -.225   -9.335    2.434    .047   -.043    .597  -.614    6371.1   10194.4   28046.0
 .060   13.851    .143   -.225   -8.733    2.675    .076   -.076    .595  -.623    7656.0   11183.5   19770.5
 .080   13.692    .192   -.223   -8.158    2.910    .107   -.107    .593  -.631    7940.6   11046.7   18994.1
 .100   13.535    .260   -.221   -7.574    3.155    .136   -.136    .591  -.639    8014.7   10925.2   18315.6
 .120   13.382    .325   -.216   -6.995    3.408    .165   -.165    .588  -.648    8084.9   10808.5   17674.2
 .140   13.255    .396   -.214   -6.415    3.671    .192   -.192    .584  -.657    8153.3   10700.1   17075.6
 .160   13.133    .472   -.210   -5.841    3.936    .219   -.220    .580  -.666    8219.4   10600.9   16523.4
 .180   13.022    .554   -.205   -5.267    4.212    .246   -.247    .576  -.675    8284.4   10509.6   16008.7
 .200   12.922    .641   -.200   -4.694    4.495    .272   -.273    .570  -.684    8344.5   10433.4   15569.5
 .220   12.838    .733   -.194   -4.122    4.786    .297   -.298    .565  -.693    8398.4   10375.6   15220.4
 .240   12.757    .832   -.185   -3.571    5.063    .326   -.326    .558  -.702    7185.4    9501.1   21885.7
 .260   12.690    .935   -.181   -3.080    5.286    .366   -.362    .551  -.712    5232.6    8141.8   32393.2
 .280   12.633   1.043   -.173   -2.664    5.451    .416   -.412    .544  -.721    4568.9    7504.4   34546.7
 .300   12.587   1.153   -.165   -2.321    5.595    .460   -.457    .535  -.730    3623.6    5653.6   29118.1
 .320   12.539   1.266   -.155   -2.083    5.710    .496   -.493    .525  -.739    2565.1    3354.1   20980.8
 .340   12.499   1.382   -.145   -1.966    5.766    .518   -.516    .515  -.748    1263.0     527.9   10977.1
 .360   12.459   1.498   -.134   -2.086    5.819    .524   -.524    .505  -.757     196.3   -2116.9        .0
 .380   12.417   1.614   -.124   -2.150    5.843    .524   -.524    .494  -.767     218.4   -2116.8        .0
 .400   12.373   1.731   -.114   -2.254    5.867    .524   -.524    .484  -.778     240.6   -2114.4        .0
 .420   12.327   1.849   -.103   -2.357    5.891    .524   -.524    .473  -.788     262.7   -2111.7        .0
 .440   12.279   1.967   -.093   -2.461    5.915    .524   -.524    .463  -.799     284.8   -2108.9        .0
 .460   12.229   2.086   -.082   -2.565    5.939    .524   -.524    .452  -.809     306.9   -2105.8        .0
 .480   12.176   2.205   -.072   -2.669    5.962    .524   -.524    .442  -.820     328.9   -2102.4        .0
 .500   12.123   2.323   -.061   -2.540    5.852    .507   -.490    .438  -.830   -1451.3    2742.3  -19198.6
 .520   12.074   2.439   -.051   -2.287    5.660    .477   -.066    .435  -.840   -2308.2    4210.6  -21401.1
 .540   12.038   2.549   -.042   -1.755    5.303    .445    .056    .431  -.849   -7453.2   11333.9  -20301.8
 .560   12.008   2.651   -.034   -1.248    4.940    .415    .002    .428  -.858   -7504.7   11241.7  -19714.1
 .580   11.984   2.766   -.026    -.738    4.580    .365   -.009    .425  -.866   -7548.4   11158.7  -19191.8
 .600   11.975   2.874   -.018    -.216    4.212    .356   -.067    .421  -.873   -7565.4   11087.6  -18741.6
 .620   11.976   2.915   -.011     .312    3.842    .327   -.098    .417  -.880   -7611.8   11032.9  -18391.5
 .640   11.987   2.966   -.005     .841    3.473    .299   -.120    .413  -.886   -7633.9   10996.9  -18092.9
 .660   12.009   3.058    .001    1.363    3.118    .259   -.180    .410  -.892   -7650.7   10950.9  -17853.4
 .680   12.041   3.113    .006    1.832    2.820    .235   -.221    .406  -.897   -5482.3    8684.1  -23715.2
 .700   12.082   3.167    .010    2.220    2.598    .195   -.199    .402  -.901   -4366.3    7570.0  -26819.0
 .720   12.129   3.217    .013    2.507    2.453    .155   -.217    .396  -.905   -2367.2    4764.6  -25905.8
 .740   12.181   3.265    .016    2.683    2.358    .126   -.213    .394  -.908   -1410.5    2390.1  -16232.8
 .760   12.236   3.312    .019    2.727    2.305    .116   -.209    .389  -.910    -718.3    -256.2   -1156.0
 .780   12.290   3.358    .021    2.646    2.304    .119   -.119    .386  -.912     522.0   -2063.0        .0
 .800   12.341   3.408    .023    2.542    2.328    .119   -.119    .383  -.915     526.9   -2061.7        .0
 .820   12.391   3.451    .026    2.438    2.352    .119   -.119    .381  -.917     531.8   -2060.5        .0
 .840   12.439   3.498    .028    2.335    2.376    .119   -.119    .379  -.919     536.7   -2059.2        .0
 .860   12.485   3.546    .030    2.231    2.399    .119   -.119    .376  -.922     541.6   -2057.9        .0
 .880   12.529   3.594    .033    2.127    2.423    .119   -.119    .374  -.924     546.5   -2056.6        .0
 .900   12.575   3.647    .035    2.024    2.447    .119   -.119    .372  -.927     551.4   -2055.3        .0
 .920   12.612   3.692    .038    1.920    2.471    .119   -.119    .369  -.929     556.3   -2054.0        .0
 .940   12.647   3.737    .040    1.816    2.495    .119   -.119    .367  -.931     561.2   -2052.7        .0
 .960   12.683   3.782    .042    1.713    2.519    .119   -.119    .364  -.934     566.0   -2051.3        .0
 .980   12.715   3.827    .045    1.609    2.543    .119   -.119    .362  -.936     570.9   -2050.0        .0
```

Figure 1-32. Data Printout and "On-Line Printout" (Continued)

```
 TIME      X        Y      PSI     XVEL     YVEL    PSIVEL   DETAVEL   BETA1   BETA3        FL        FV         TQ

1.000   12.746    3.894    .047    1.505    2.567     .119     -.119    .360    -.939     575.8   -2046.6         .0
1.020   12.779    3.946    .050    1.402    2.591     .119     -.119    .357    -.941     580.7   -2047.2         .0
1.040   12.804    3.997    .052    1.298    2.615     .119     -.119    .355    -.943     585.5   -2045.9         .0
1.060   12.827    4.050    .054    1.194    2.639     .119     -.119    .353    -.946     590.4   -2044.5         .0
1.080   12.850    4.103    .057    1.091    2.663     .119     -.119    .350    -.948     595.3   -2043.1         .0
1.100   12.871    4.156    .059     .987    2.687     .119     -.119    .348    -.950     600.1   -2041.6         .0
1.120   12.889    4.210    .061     .883    2.711     .119     -.119    .345    -.953     605.0   -2040.2         .0
1.140   12.906    4.265    .064     .780    2.734     .119     -.119    .343    -.955     609.8   -2036.8         .0
1.160   12.921    4.320    .066     .676    2.758     .119     -.119    .341    -.958     614.7   -2037.3         .0
1.180   12.933    4.375    .069     .572    2.782     .119     -.119    .338    -.960     619.5   -2035.8         .0
1.200   12.944    4.431    .071     .469    2.806     .119     -.119    .336    -.962     624.4   -2034.3         .0
1.220   12.952    4.487    .073     .365    2.830     .119     -.119    .334    -.965     629.2   -2032.9         .0
1.240   12.959    4.544    .076     .261    2.854     .119     -.119    .331    -.967     634.0   -2031.4         .0
1.260   12.962    4.602    .078     .158    2.878     .119     -.119    .329    -.970     638.9   -2029.8         .0
1.280   12.964    4.659    .080     .054    2.902     .119     -.119    .326    -.972     643.7   -2028.3         .0
1.300   12.965    4.718    .083    -.050    2.926     .119     -.119    .324    -.974     648.5   -2026.8         .0
1.320   12.963    4.776    .085    -.153    2.950     .119     -.119    .322    -.977     653.3   -2025.2         .0
1.340   12.958    4.836    .088    -.257    2.974     .119     -.119    .319    -.979     658.1   -2023.7         .0
1.360   12.952    4.895    .090    -.361    2.998     .119     -.119    .317    -.982     663.0   -2022.1         .0
1.380   12.944    4.956    .092    -.464    3.022     .119     -.119    .315    -.984     607.8   -2020.5         .0
1.400   12.934    5.016    .095    -.568    3.046     .119     -.119    .312    -.986     672.6   -2016.9         .0
1.420   12.921    5.077    .097    -.672    3.069     .119     -.119    .310    -.989     677.4   -2017.3         .0
1.440   12.907    5.139    .099    -.775    3.093     .119     -.119    .307    -.991     682.2   -2015.7         .0
1.460   12.891    5.201    .102    -.771    3.031     .128     -.204    .305    -.994   -4238.6    4172.1     4466.6
1.480   12.877    5.260    .105    -.561    2.864     .130     -.174    .301    -.996   -3442.9    3957.3    -2846.3
1.500   12.870    5.315    .107    -.132    2.620     .115     -.076    .298    -.999   -6411.0    9326.2   -14108.8
1.520   12.872    5.364    .109     .373    2.350     .093     -.140    .295   -1.001   -6747.6   10012.4   -15837.7
1.540   12.885    5.409    .111     .879    2.060     .072     -.124    .293   -1.002   -6263.2    9057.2   -13079.5
1.560   12.907    5.448    .112    1.332    1.831     .055     -.101    .290   -1.003   -5754.5    7983.1    -9563.4
1.580   12.937    5.482    .113    1.695    1.612     .047     -.112    .288   -1.004   -4446.9    5599.0    -4313.5
1.600   12.974    5.513    .114    1.912    1.453     .048     -.126    .286   -1.005   -3210.4    2852.0     4781.8
1.620   13.013    5.541    .115    1.951    1.367     .059     -.059    .283   -1.006   -1414.2    -453.1    11940.5
1.640   13.051    5.568    .116    1.859    1.367     .066     -.066    .281   -1.008     716.0   -2003.9         .0
1.660   13.087    5.595    .118    1.755    1.391     .066     -.066    .280   -1.009     718.6   -2003.0         .0
1.680   13.121    5.624    .119    1.652    1.415     .066     -.066    .279   -1.010     721.3   -2002.0         .0
1.700   13.153    5.652    .120    1.548    1.439     .066     -.066    .277   -1.012     723.9   -2001.1         .0
1.720   13.183    5.681    .122    1.444    1.462     .066     -.066    .276   -1.013     726.5   -2000.1         .0
1.740   13.211    5.711    .123    1.341    1.486     .066     -.066    .275   -1.014     729.2   -1999.2         .0
1.760   13.237    5.740    .124    1.237    1.510     .066     -.066    .273   -1.016     731.8   -1998.2         .0
1.780   13.260    5.771    .126    1.133    1.534     .066     -.066    .272   -1.017     734.4   -1997.2         .0
1.800   13.282    5.802    .127    1.030    1.558     .066     -.066    .271   -1.018     737.1   -1996.3         .0
1.820   13.302    5.833    .128     .926    1.582     .066     -.066    .269   -1.020     739.7   -1995.3         .0
1.840   13.319    5.865    .129     .822    1.606     .066     -.066    .268   -1.021     742.3   -1994.3         .0
1.860   13.334    5.898    .131     .719    1.630     .066     -.066    .267   -1.022     744.9   -1993.4         .0
1.880   13.349    5.930    .132     .615    1.654     .066     -.066    .265   -1.024     747.6   -1992.4         .0
1.900   13.359    5.964    .133     .511    1.678     .066     -.066    .264   -1.025     750.2   -1991.4         .0
1.920   13.368    5.997    .135     .408    1.702     .066     -.066    .263   -1.026     752.8   -1990.4         .0
1.940   13.375    6.032    .136     .304    1.726     .066     -.066    .261   -1.028     755.4   -1989.4         .0
1.960   13.380    6.066    .137     .200    1.750     .066     -.066    .260   -1.029     758.1   -1998.4         .0
1.980   13.383    6.102    .139     .097    1.774     .066     -.066    .259   -1.030     760.7   -1987.4         .0
```

Figure 1-32. Data Printout and "On-Line" Printout (Concluded)

```
SERIES NO.1608.00  RUN NO.  1.00       XVELO = -9.74     YVELO=  2.25      ZETA= .227      PSIO=-.2268      PSVELO= .0000
                                        VVELO= 10.00      HVELO=   .00

   TIME  2.002SECS.

   MAXIMUM STROKE  NO. 1 STRUT        .581        .000        1.123        .000
                   NO. 2 STRUT        .246        .000         .500        .000
                   NO. 3 STRUT        .314        .000         .546        .000

  MINIMUM CLEARANCE OF NOZZLE=  [illegible]       TIME WHEN THE MINIMUM CLEARANCE OCCURS    =   .562

  MINIMUM STABILITY ANGLE B1=   .25[illegible]     TIME WHEN THIS STABILITY ANGLE OCCURS     =  2.000

  MINIMUM STABILITY ANGLE B7=  -.596              TIME WHEN THIS STABILITY ANGLE OCCURS     =   .004

   ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND  C.G. DROP=  24424.271

   ENERGY DISSIPATED BASED ON PLASTIC STROKE =  23536.649

   ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC STROKE =  24115.877

   FINAL ANGULAR ORIENTATION OF VEHICLE =  .367[illegible]

  FINAL STABILITY ANGLE B1 =   .257                    FINAL BETA1 RATE OF CHANGE =  -.066

  ENERGY DISTRIBUTION BETWEEN LEGS - PERCENT =  33.553    .000  66.447    .000
```

Figure 1-33. Summary Data Printout

```
TIME      XF(1)      YF(1)      ZF(1)      XF(3)      YF(3)      ZF(3)       FX(1)       FX(3)

 .000     4.092     11.152      8.542      .250     -5.494     -6.542         .0          .0
 .020     3.918     11.192      8.542      .185     -5.549     -6.634         .0      7460.5
 .040     3.717     11.237      8.542      .196     -5.560     -6.652         .0      7369.9
 .060     3.522     11.272      8.542      .193     -5.567     -6.664         .0      7901.3
 .080     3.333     11.305      8.542      .200     -5.572     -6.671         .0      6630.6
 .100     3.148     11.344      8.542      .202     -5.577     -6.678         .0      6542.6
 .120     2.968     11.375      8.542      .204     -5.583     -6.692         .0      6186.8
 .140     2.794     11.412      8.542      .205     -5.589     -6.704         .0      5652.3
 .160     2.626     11.445      8.542      .207     -5.597     -6.717         .0      5609.7
 .180     2.463     11.477      8.542      .206     -5.606     -6.731         .0      5528.4
 .200     2.306     11.506      8.542      .203     -5.615     -6.745         .0      5781.7
 .220     2.156     11.541      8.542      .199     -5.619     -6.753         .0      6367.3
 .240     2.011     11.573      8.542      .197     -5.628     -6.768         .0      6585.8
 .260     1.871     11.602      8.542      .207     -5.640     -6.764         .0      5411.9
 .280     1.736     11.626      8.542      .210     -5.642     -6.790         .0      4972.2
 .300     1.598     11.641      8.542      .215     -5.645     -6.796         .0      4064.7
 .320     1.445     11.649      8.542      .225     -5.646     -6.796         .0      2647.2
 .340     1.299     11.651      8.542      .241     -5.649     -6.800         .0      1223.4
 .360     1.153     11.649      8.542      .257     -5.651     -6.800         .0          .0
 .380     1.008     11.647      8.542      .291     -5.662     -6.800         .0          .0
 .400      .857     11.646      8.542      .324     -5.672     -6.800         .0          .0
 .420      .707     11.644      8.542      .356     -5.680     -6.800         .0          .0
 .440      .557     11.636      8.542      .387     -5.687     -6.800         .0          .0
 .460      .407     11.631      8.542      .416     -5.693     -6.800         .0          .0
 .480      .255     11.626      8.542      .448     -5.697     -6.800         .0          .0
 .500      .204     11.667      8.561      .477     -5.700     -6.800     4637.0          .0
 .520      .194     11.693      8.588      .506     -5.695     -6.800     7419.3          .0
 .540      .192     11.707      8.614      .542     -5.696     -6.800     7758.3          .0
 .560      .198     11.715      8.623      .583     -5.692     -6.800     6923.3          .0
 .580      .202     11.728      8.630      .630     -5.688     -6.800     6288.5          .0
 .600      .204     11.740      8.646      .683     -5.684     -6.800     5996.8          .0
 .620      .201     11.752      8.658      .741     -5.680     -6.800     6273.2          .0
 .640      .202     11.768      8.671      .808     -5.677     -6.800     6141.1          .0
 .660      .208     11.777      8.687      .877     -5.675     -6.800     5755.7          .0
 .680      .208     11.789      8.695      .953     -5.672     -6.800     5453.1          .0
 .700      .214     11.797      8.707     1.032     -5.665     -6.800     4527.6          .0
 .720      .222     11.803      8.707     1.110     -5.654     -6.800     3482.7          .0
 .740      .233     11.805      8.708     1.187     -5.637     -6.800     2231.5          .0
 .760      .244     11.807      8.710     1.263     -5.617     -6.800      825.4          .0
 .780      .258     11.812      8.710     1.336     -5.597     -6.800         .0          .0
 .800      .292     11.830      8.710     1.411     -5.576     -6.800         .0          .0
 .820      .322     11.848      8.710     1.483     -5.556     -6.800         .0          .0
 .840      .350     11.857      8.710     1.552     -5.534     -6.800         .0          .0
 .860      .376     11.868      8.710     1.619     -5.512     -6.800         .0          .0
 .880      .400     11.905      8.710     1.685     -5.490     -6.800         .0          .0
 .900      .422     11.925      8.710     1.748     -5.467     -6.800         .0          .0
 .920      .442     11.945      8.710     1.809     -5.444     -6.800         .0          .0
 .940      .456     11.956      8.710     1.869     -5.420     -6.800         .0          .0
 .960      .476     11.967      8.710     1.926     -5.395     -6.800         .0          .0
 .980      .495     12.005      8.710     1.981     -5.370     -6.800         .0          .0
```

Figure 1-34. Final Data Printout (Part 1)

```
TIME      XP(1)     YP(1)     ZP(1)     XP(3)     YP(3)     ZP(3)      FX(1)      FX(3)

1.000      .502    12.030     8.710     2.035    -5.345    -8.800         .0         .0
1.020      .512    12.053     8.710     2.086    -5.319    -8.800         .0         .0
1.040      .520    12.075     8.710     2.135    -5.292    -8.800         .0         .0
1.060      .526    12.099     8.710     2.182    -5.265    -8.800         .0         .0
1.080      .530    12.122     8.710     2.226    -5.237    -8.800         .0         .0
1.100      .532    12.146     8.710     2.271    -5.209    -8.800         .0         .0
1.120      .532    12.171     8.710     2.312    -5.180    -8.800         .0         .0
1.140      .529    12.196     8.710     2.351    -5.151    -8.800         .0         .0
1.160      .525    12.221     8.710     2.386    -5.121    -8.800         .0         .0
1.180      .519    12.247     8.710     2.424    -5.091    -8.800         .0         .0
1.200      .511    12.274     8.710     2.457    -5.060    -8.800         .0         .0
1.220      .501    12.300     8.710     2.488    -5.029    -8.800         .0         .0
1.240      .489    12.327     8.710     2.517    -4.997    -8.800         .0         .0
1.260      .475    12.355     8.710     2.544    -4.964    -8.800         .0         .0
1.280      .459    12.383     8.710     2.569    -4.931    -8.800         .0         .0
1.300      .441    12.411     8.710     2.592    -4.898    -8.800         .0         .0
1.320      .421    12.440     8.710     2.613    -4.864    -8.800         .0         .0
1.340      .399    12.470     8.710     2.632    -4.829    -8.800         .0         .0
1.360      .374    12.499     8.710     2.649    -4.794    -8.800         .0         .0
1.380      .348    12.530     8.710     2.664    -4.758    -8.800         .0         .0
1.400      .320    12.560     8.710     2.677    -4.722    -8.800         .0         .0
1.420      .290    12.591     8.710     2.688    -4.685    -8.800         .0         .0
1.440      .258    12.623     8.710     2.697    -4.646    -8.800         .0         .0
1.460      .238    12.639     8.712     2.705    -4.611    -8.800     1201.4         .0
1.480      .206    12.644     8.715     2.717    -4.576    -8.800     5429.5         .0
1.500      .206    12.649     8.719     2.733    -4.548    -8.800     5551.6         .0
1.520      .201    12.656     8.724     2.756    -4.520    -8.800     6069.5         .0
1.540      .202    12.662     8.733     2.784    -4.492    -8.800     5950.9         .0
1.560      .208    12.668     8.737     2.816    -4.465    -8.800     5259.6         .0
1.580      .218    12.675     8.743     2.858    -4.441    -8.800     4113.5         .0
1.600      .232    12.683     8.749     2.903    -4.420    -8.800     2325.6         .0
1.620      .246    12.687     8.751     2.952    -4.404    -8.800      540.2         .0
1.640      .254    12.693     8.752     3.003    -4.387    -8.800         .0         .0
1.660      .281    12.704     8.752     3.053    -4.373    -8.800         .0         .0
1.680      .306    12.715     8.752     3.100    -4.358    -8.800         .0         .0
1.700      .328    12.727     8.752     3.145    -4.343    -8.800         .0         .0
1.720      .349    12.739     8.752     3.189    -4.327    -8.800         .0         .0
1.740      .358    12.751     8.752     3.230    -4.311    -8.800         .0         .0
1.760      .385    12.764     8.752     3.269    -4.294    -8.800         .0         .0
1.780      .399    12.778     8.752     3.306    -4.277    -8.800         .0         .0
1.800      .412    12.792     8.752     3.341    -4.259    -8.800         .0         .0
1.820      .423    12.806     8.752     3.374    -4.241    -8.800         .0         .0
1.840      .431    12.821     8.752     3.405    -4.222    -8.800         .0         .0
1.860      .438    12.836     8.752     3.434    -4.203    -8.800         .0         .0
1.880      .442    12.852     8.752     3.461    -4.183    -8.800         .0         .0
1.900      .444    12.868     8.752     3.486    -4.163    -8.800         .0         .0
1.920      .445    12.885     8.752     3.509    -4.142    -8.800         .0         .0
1.940      .443    12.902     8.752     3.529    -4.121    -8.800         .0         .0
1.960      .439    12.920     8.752     3.546    -4.099    -8.800         .0         .0
1.980      .433    12.938     8.752     3.565    -4.077    -8.800         .0         .0
```

Figure 1-34. Final Data Printout (Part 1 - Continued)

```
 TIME     FXFLG3(1)    FYFLG3(1)    FZFLG3(1)    FXFLG3(3)    FYFLG3(3)    FZFLG3(3)

  .000          .0           .0           .0           .0           .0           .0
  .020          .0           .0           .0        201.4         96.8        140.3
  .040          .0           .0           .0      -6739.1      -1717.6      -3487.4
  .060          .0           .0           .0      -7364.4      -2337.9      -3961.1
  .080          .0           .0           .0      -7322.5      -2405.9      -4008.0
  .100          .0           .0           .0      -7264.7      -2470.6      -4049.2
  .120          .0           .0           .0      -7207.1      -2536.1      -4090.2
  .140          .0           .0           .0      -7151.4      -2603.0      -4127.3
  .160          .0           .0           .0      -7098.0      -2670.7      -4160.5
  .180          .0           .0           .0      -7046.3      -2739.9      -4191.0
  .200          .0           .0           .0      -6999.4      -2807.9      -4215.2
  .220          .0           .0           .0      -6958.6      -2873.5      -4231.7
  .240          .0           .0           .0      -6396.2      -2396.5      -3832.1
  .260          .0           .0           .0      -5533.4      -1595.8      -3143.6
  .280          .0           .0           .0      -5147.7      -1356.5      -2662.7
  .300          .0           .0           .0      -4143.0      -1079.9      -1774.1
  .320          .0           .0           .0      -2912.5       -764.0      -1226.9
  .340          .0           .0           .0      -1469.9       -342.7       -555.2
  .360          .0           .0           .0           .0           .0           .0
  .380          .0           .0           .0           .0           .0           .0
  .400          .0           .0           .0           .0           .0           .0
  .420          .0           .0           .0           .0           .0           .0
  .440          .0           .0           .0           .0           .0           .0
  .460          .0           .0           .0           .0           .0           .0
  .480          .0           .0           .0           .0           .0           .0
  .500     -2351.6       1057.4        895.5           .0           .0           .0
  .520     -5100.7       1508.8       1329.3           .0           .0           .0
  .540     -6552.2       4206.4       3891.1           .0           .0           .0
  .560     -6549.1       4187.1       3921.1           .0           .0           .0
  .580     -6538.4       4158.8       3949.0           .0           .0           .0
  .600     -6531.4       4136.9       3975.0           .0           .0           .0
  .620     -6530.4       4112.3       3994.7           .0           .0           .0
  .640     -6531.5       4088.9       4011.6           .0           .0           .0
  .660     -6535.7       4066.1       4025.5           .0           .0           .0
  .680     -5415.0       2960.6       2955.9           .0           .0           .0
  .700     -4864.2       2309.4       2322.9           .0           .0           .0
  .720     -3458.5       1795.5       1616.2           .0           .0           .0
  .740     -2263.8        959.8        903.7           .0           .0           .0
  .760      -936.1        665.6        348.6           .0           .0           .0
  .780          .0           .0           .0           .0           .0           .0
  .800          .0           .0           .0           .0           .0           .0
  .820          .0           .0           .0           .0           .0           .0
  .840          .0           .0           .0           .0           .0           .0
  .860          .0           .0           .0           .0           .0           .0
  .880          .0           .0           .0           .0           .0           .0
  .900          .0           .0           .0           .0           .0           .0
  .920          .0           .0           .0           .0           .0           .0
  .940          .0           .0           .0           .0           .0           .0
  .960          .0           .0           .0           .0           .0           .0
  .980          .0           .0           .0           .0           .0           .0
```

Figure 1-34. Final Data Printout (Part 2)

```
 TIME     FXFLG3(1)    FYFLG3(1)    FZFLG3(1)    FXFLG3(3)    FYFLG3(3)    FZFLG3(3)

 1.000          .0           .0           .0           .0           .0           .0
 1.020          .0           .0           .0           .0           .0           .0
 1.040          .0           .0           .0           .0           .0           .0
 1.060          .0           .0           .0           .0           .0           .0
 1.080          .0           .0           .0           .0           .0           .0
 1.100          .0           .0           .0           .0           .0           .0
 1.120          .0           .0           .0           .0           .0           .0
 1.140          .0           .0           .0           .0           .0           .0
 1.160          .0           .0           .0           .0           .0           .0
 1.180          .0           .0           .0           .0           .0           .0
 1.200          .0           .0           .0           .0           .0           .0
 1.220          .0           .0           .0           .0           .0           .0
 1.240          .0           .0           .0           .0           .0           .0
 1.260          .0           .0           .0           .0           .0           .0
 1.280          .0           .0           .0           .0           .0           .0
 1.300          .0           .0           .0           .0           .0           .0
 1.320          .0           .0           .0           .0           .0           .0
 1.340          .0           .0           .0           .0           .0           .0
 1.360          .0           .0           .0           .0           .0           .0
 1.380          .0           .0           .0           .0           .0           .0
 1.400          .0           .0           .0           .0           .0           .0
 1.420          .0           .0           .0           .0           .0           .0
 1.440          .0           .0           .0           .0           .0           .0
 1.460     -3348.3       2140.1       1492.8           .0           .0           .0
 1.480     -3204.9       1749.7       1297.1           .0           .0           .0
 1.500     -6036.3       2933.2       2617.4           .0           .0           .0
 1.520     -6401.3       3652.7       3197.7           .0           .0           .0
 1.540     -5904.4       2866.0       2632.8           .0           .0           .0
 1.560     -5345.6       2657.1       2213.2           .0           .0           .0
 1.580     -4089.5       2137.6       1660.7           .0           .0           .0
 1.600     -2656.8       1876.7       1078.7           .0           .0           .0
 1.620      -913.0        977.5        340.2           .0           .0           .0
 1.640          .0           .0           .0           .0           .0           .0
 1.660          .0           .0           .0           .0           .0           .0
 1.680          .0           .0           .0           .0           .0           .0
 1.700          .0           .0           .0           .0           .0           .0
 1.720          .0           .0           .0           .0           .0           .0
 1.740          .0           .0           .0           .0           .0           .0
 1.760          .0           .0           .0           .0           .0           .0
 1.780          .0           .0           .0           .0           .0           .0
 1.800          .0           .0           .0           .0           .0           .0
 1.820          .0           .0           .0           .0           .0           .0
 1.840          .0           .0           .0           .0           .0           .0
 1.860          .0           .0           .0           .0           .0           .0
 1.880          .0           .0           .0           .0           .0           .0
 1.900          .0           .0           .0           .0           .0           .0
 1.920          .0           .0           .0           .0           .0           .0
 1.940          .0           .0           .0           .0           .0           .0
 1.960          .0           .0           .0           .0           .0           .0
 1.980          .0           .0           .0           .0           .0           .0
```

Figure 1-34. Final Data Printout (Part 2 - Continued)

```
                            LEG SET NO.1                                                      LEG SET NO.3

TIME   LENGTH1    FORCE1   LENGTH2    FORCE2   LENGTH3    FORCE3       LENGTH1    FORCE1   LENGTH2    FORCE2   LENGTH3    FORCE3

.000   12.639        .00   10.462        .00   10.462        .00       12.629        .00   10.462        .00   10.462        .00
.020   12.639        .00   10.462        .00   10.462        .00       12.557    -100.00   10.460    -100.00   10.446    -100.00
.040   12.639        .00   10.462        .00   10.462        .00       12.423    5511.00   10.393    1558.99   10.374    1055.73
.060   12.639        .00   10.462        .00   10.462        .00       12.275    5511.00   10.311    1837.00   10.265    1837.00
.080   12.639        .00   10.462        .00   10.462        .00       12.149    5511.00   10.229    1837.00   10.199    1837.00
.100   12.639        .00   10.462        .00   10.462        .00       12.002    5511.00   10.160    1837.00   10.125    1837.00
.120   12.639        .00   10.462        .00   10.462        .00       11.890    5511.00   10.103    1837.00   10.062    1837.00
.140   12.639        .00   10.462        .00   10.462        .00       11.793    5511.00   10.057    1837.00   10.011    1837.00
.160   12.639        .00   10.462        .00   10.462        .00       11.710    5511.00   10.019    1837.00    9.970    1837.00
.180   12.639        .00   10.462        .00   10.462        .00       11.643    5511.00    9.994    1837.00    9.943    1837.00
.200   12.639        .00   10.462        .00   10.462        .00       11.592    5511.00    9.975    1837.00    9.925    1837.00
.220   12.639        .00   10.462        .00   10.462        .00       11.556    5511.00    9.963    1837.00    9.916    1837.00
.240   12.639        .00   10.462        .00   10.462        .00       11.535    5511.00    9.962    1566.40    9.920    1178.55
.260   12.639        .00   10.462        .00   10.462        .00       11.530    5511.00    9.966    1080.95    9.928     159.65
.280   12.639        .00   10.462        .00   10.462        .00       11.516    5511.00    9.970     623.18    9.934    -100.00
.300   12.639        .00   10.462        .00   10.462        .00       11.520    4777.73    9.976    -100.00    9.940    -100.00
.320   12.639        .00   10.462        .00   10.462        .00       11.531    3394.40    9.983    -100.00    9.946    -100.00
.340   12.639        .00   10.462        .00   10.462        .00       11.545    1695.02    9.991    -100.00    9.950    -100.00
.360   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.380   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.400   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.420   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.440   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.460   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.480   12.639        .00   10.462        .00   10.462        .00       11.557     359.81    9.997    -100.00    9.952    -100.00
.500   12.553    2900.42   10.427    -100.00   10.435    -100.00       11.557     359.61    9.997    -100.00    9.952    -100.00
.520   12.500    3506.44   10.415     100.00   10.429     100.00       11.557     359.81    9.997    -100.00    9.952    -100.00
.540   12.404    5511.00   10.361    1837.00   10.360    1837.00       11.557     359.61    9.997    -100.00    9.952    -100.00
.560   12.310    5511.00   10.309    1837.00   10.332    1837.00       11.557     359.81    9.997    -100.00    9.952    -100.00
.580   12.234    5511.00   10.271    1837.00   10.295    1837.00       11.557     359.81    9.997    -100.00    9.952    -100.00
.600   12.175    5511.00   10.248    1837.00   10.270    1837.00       11.557     359.81    9.997    -100.00    9.952    -100.00
.620   12.133    5511.00   10.227    1837.00   10.253    1837.00       11.557     359.61    9.997    -100.00    9.952    -100.00
.640   12.101    5511.00   10.217    1837.00   10.243    1837.00       11.557     359.81    9.997    -100.00    9.952    -100.00
.660   12.092    5511.00   10.214    1837.00   10.241    1837.00       11.557     359.81    9.997    -100.00    9.952    -100.00
.680   12.077    5224.06   10.219     944.19   10.246     943.62       11.557     359.81    9.997    -100.00    9.952    -100.00
.700   12.075    5177.62   10.226     335.57   10.251     505.12       11.557     359.81    9.997    -100.00    9.952    -100.00
.720   12.085    4121.6    10.232    -100.00   10.254     -88.24       11.557     359.81    9.997    -100.00    9.952    -100.00
.740   12.097    2077.79   10.240    -100.00   10.254      -8.06       11.557     359.81    9.997    -100.00    9.952    -100.00
.760   12.111     -99.38   10.249    -100.00   10.252     376.79       11.557     359.81    9.997    -100.00    9.952    -100.00
.780   12.121    -100.00   10.253    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.800   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.820   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.840   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.860   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.880   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.900   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.920   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.940   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.960   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
.980   12.121    -100.00   10.252    -100.00   10.251     514.92       11.557     359.81    9.997    -100.00    9.952    -100.00
```

Figure 1-34. Final Data Printout (Part 3)

```
                         LEG SET NO.1                                                              LEG SET NO.3

 TIME   LENGTH1   FORCE1    LENGTH2   FORCE2    LENGTH3   FORCE3       LENGTH1   FORCE1   LENGTH2   FORCE2    LENGTH3   FORCE3

1.000   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.020   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.040   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.060   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.080   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.100   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.120   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.140   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.160   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.180   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.200   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.220   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.240   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.260   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.280   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.300   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.320   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.340   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.360   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.380   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.400   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.420   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.440   12.121   -100.00   10.257   -100.00   10.251    514.92       11.557   359.81   9.997   -100.00   9.952   -100.00
1.460   12.100   2497.58   10.240    100.00   10.228   1837.00       11.557   359.81   9.997   -100.00   9.952   -100.00
1.480   12.095   2799.29   10.240   -100.00   10.213   1294.71       11.557   359.81   9.997   -100.00   9.952   -100.00
1.500   12.074   5511.00   10.228    100.00   10.186   1837.00       11.557   359.81   9.997   -100.00   9.952   -100.00
1.520   12.060   5511.00   10.222    751.04   10.167   1837.00       11.557   359.81   9.997   -100.00   9.952   -100.00
1.540   12.057   5289.30   10.225    212.42   10.157   1837.00       11.557   359.81   9.997   -100.00   9.952   -100.00
1.560   12.061   4429.51   10.230   -100.00   10.149   1837.00       11.557   359.81   9.997   -100.00   9.952   -100.00
1.580   12.071   3564.32   10.238   -100.00   10.148   1606.56       11.557   359.81   9.997   -100.00   9.952   -100.00
1.600   12.084   1987.59   10.249   -100.00   10.150   1550.12       11.557   359.81   9.997   -100.00   9.952   -100.00
1.620   12.098    247.50   10.258   -100.00   10.153   1219.47       11.557   359.81   9.997   -100.00   9.952   -100.00
1.640   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.660   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.680   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.700   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.720   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.740   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.760   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.780   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.800   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.820   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.840   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.860   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.880   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.900   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.920   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.940   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
1.960   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.61   9.997   -100.00   9.952   -100.00
1.980   12.115   -100.00   10.268   -100.00   10.162    -50.48       11.557   359.81   9.997   -100.00   9.952   -100.00
```

Figure 1-34. Final Data Printout (Part 3 - Concluded)

SECTION II

DIGITAL COMPUTER PROGRAM FOR THE APPROXIMATE DETERMINATION OF NOZZLE CLEARANCE

This digital computer program was written to provide a simple means for determining final nozzle clearance as a function of initial vehicle C.G. height and upper strut stroke load.

In addition to this information, the program also defines additional vehicle geometrical dimensions required for the landing dynamics computer program (Section I) and the stowability index (STOW).

A DIGITAL COMPUTER PROGRAM FOR THE APPROXIMATE DETERMINATION OF NOZZLE CLEARANCE

The mathematical model used in this program is illustrated in Figure 2-1. In determining the approximate relationship between vehicle geometry, upper strut stroke force and nozzle clearance, it is assumed that total vehicle energy, both kinetic and potential, is absorbed by stroking of the upper struts only. Further, it is assumed that all upper struts, both on the front and rear legs, stroke equal amounts. This assumption approximates the real vehicle by one in which the lower struts are rigid or non-strokable, and the coefficient of friction is zero.

The kinetic energy of the vehicle is given by the equation

$$KE = 1/2\ M\ V^2$$

where M is the total vehicle mass and V may be assumed to be the vehicle vertical velocity. (This assumes the vehicle comes to rest.)

The potential energy of the vehicle may be broken into two parts:

1. The potential energy loss resulting from the vehicle tipping from its initial contact configuration through an angle until all feet contact the ground. The potential energy loss for this phase of landing is approximated by

   $$P\ E_1 = MGH_1$$

   Where M is the mass of the vehicle c.g. only, and H_1 is the vertical distance the c.g. drops.

2. The potential energy loss resulting from stroking of the upper struts. This energy term is a function of the final allowable nozzle clearance (FNC) and is given by the equation.

   $$P\ E_2 = MGH_2$$

UPPER STRUT STROKE FORCE DETERMINATION

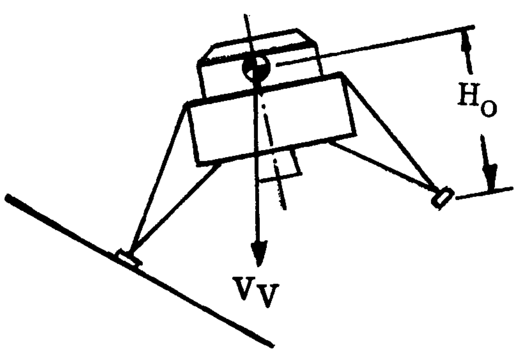
Assume: Vehicle Energy = E = KE + PE1 + PE2

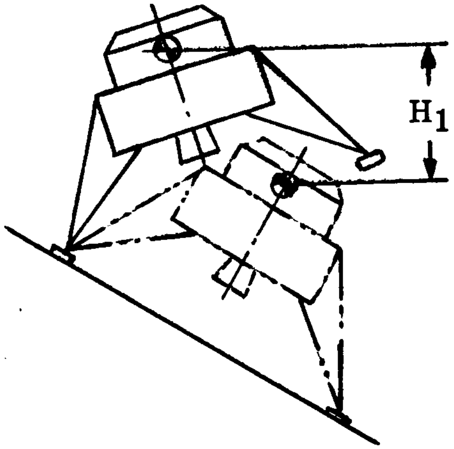
Where:

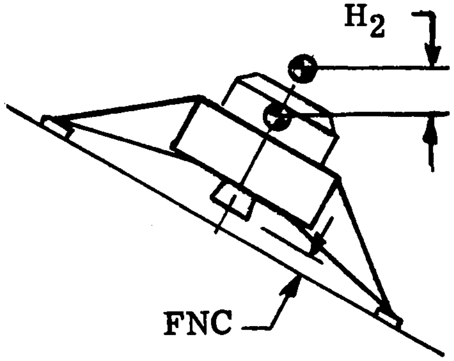
$KE = 1/2\ M_T V_V^2$

$PE1 = M_{CG} G H_1$

$PE2 = M_{CG} G H_2\ (FNC)$







Assume: Energy Absorbed by Upper Struts Only

$E = 4 \times F_{11} \times (LO-LF)$

Therefore:

$$F11 = \frac{E}{4\ (LO-LF)}$$

or

$H = f\ (F_{11}, FNC, Etc.)$

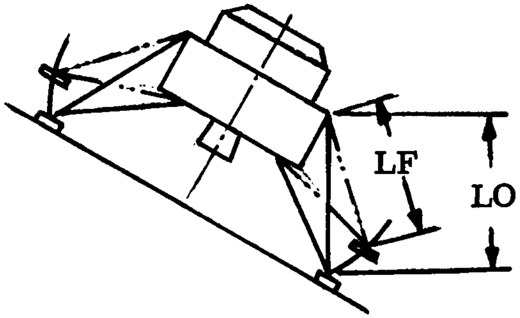


Figure 2-1. Geometric Computer Program

where M is again the mass of the vehicle c.g. only, and H_2 is the vertical distance the c.g. drops.

Here, the distance H_2 is a function of FNC.

This total vehicle energy (which must be absorbed to bring the vehicle to rest) $E = KE + PE_1 + PE_2$ is equated to the energy absorbed by stroking of the upper struts. The initial strut length is given by L_o and its final length by L_f as indicated in the lower right of Figure 2-1.

Equating the energy terms by the equation

$$E = 4 \times F11 \times (L_o - L_f)$$

permits a solution for the required upper strut stroke load F11 as a function of initial c.g. Height and final required nozzle clearance or, as was used for the parametric study, the initial c.g. height, H_o, required to result in the proper nozzle clearance for a given F11. Thus:

H_o = function of F11, FNC and overall vehicle geometry.

This computer program was also used to compute various geometric quantities for the vehicle which are required inputs to the landing dynamics and weight analysis programs. In addition to these parameters, the stowability for the vehicle is also determined.

It has been determined that a 2-2 landing configuration having infinite friction on the rear legs and zero friction on the front legs with V_V and V_H the maximum values defined by the landing specification set produces the most critical nozzle clearance conditions. Repeated comparisons between the results of the geometric program and complete dynamic landing studies have shown good agreement.

Although not rigorous, this geometric computer program provided a consistent basis for the determination of R and H for any given ratio of R/H during the parameter variation studies. This approximate relationship between R and H for a given R/H, final nozzle clearance and F11 provided a convenient means of systematizing the choice of R and H during the parametric variation study.

Figure 2-2 illustrates the input data format required for use of the program. The input quantities are defined in Figure 2-7 under "input definitions."

The program has two modes of operation defined by the input parameter "IFLAG." If this flag is set equal to -1, the program will compute the upper strut stroke force F11 necessary to produce a given final nozzle clearance for a given initial vehicle c.g. height.

If the flag is set equal to +1, the program will compute the vehicle c.g. height necessary to produce the required final nozzle clearance for a given upper strut stroke load.

Figures 2-3 through 2-6 are a flow diagram of the program and Figures 2-7 through 2-10 are complete listings of the program and its subroutines.

Figures 2-11 and 2-12 are summaries of the output data for a typical run. As is illustrated, the input data is printed as part of the output record. The first sample run has IFLAG = -1 as shown on card No. 8 of the input data. The output data is immediately after the input data.

The sample data of Figure 2-12 is a run for control mode IFLAG = +1. Again, the input data is printed out first. Since, in this mode, the vehicle c.g. height is interpolated to converge on the desired value of F11, namely FΦΦ, the output data is printed during the convergence process for each new H (I) chosen by the computer. The final output is the desired information and includes computation of the stowability index (STOW).

This program was written in Fortran IV and is currently being used on a Univac 1107 digital computer.

C FOR COMMENT STATEMENT NUMBER 1 2 3 4 5	Cont. 6	FORTRAN STATEMENT 7 8 9 10	11–25	26–40	41–55	56–72
		1	THETA	PSI	ZETA	
		2	RH	V MASS	P MASS	
		3	AN	XVEL	YVEL	
IDENTIFICATION		4	G	HN	FNC	
		5	DELTAP	D11	D	
		6	Z	GAMMA	DELTA	
		7	FOO	SERNO		
		8	NOH	IFLAG		
		9	H(1)	H(2)	H (NOH)	

Figure 2-2. Geometry Program

This program computes stroke force F11 vs vehicle C.G. height H(I) and final nozzle clearance FNC.

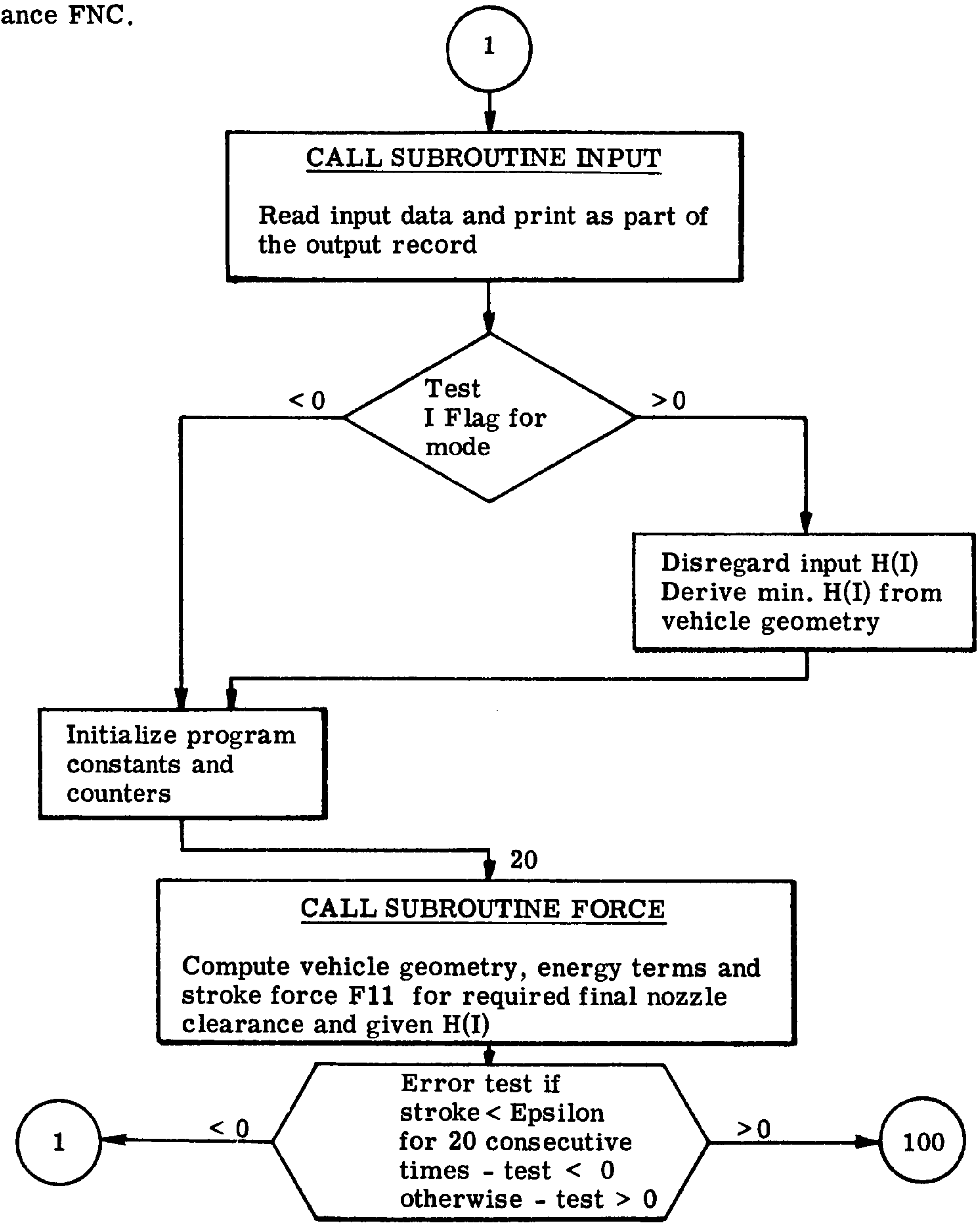


Figure 2-3. Geometry Program

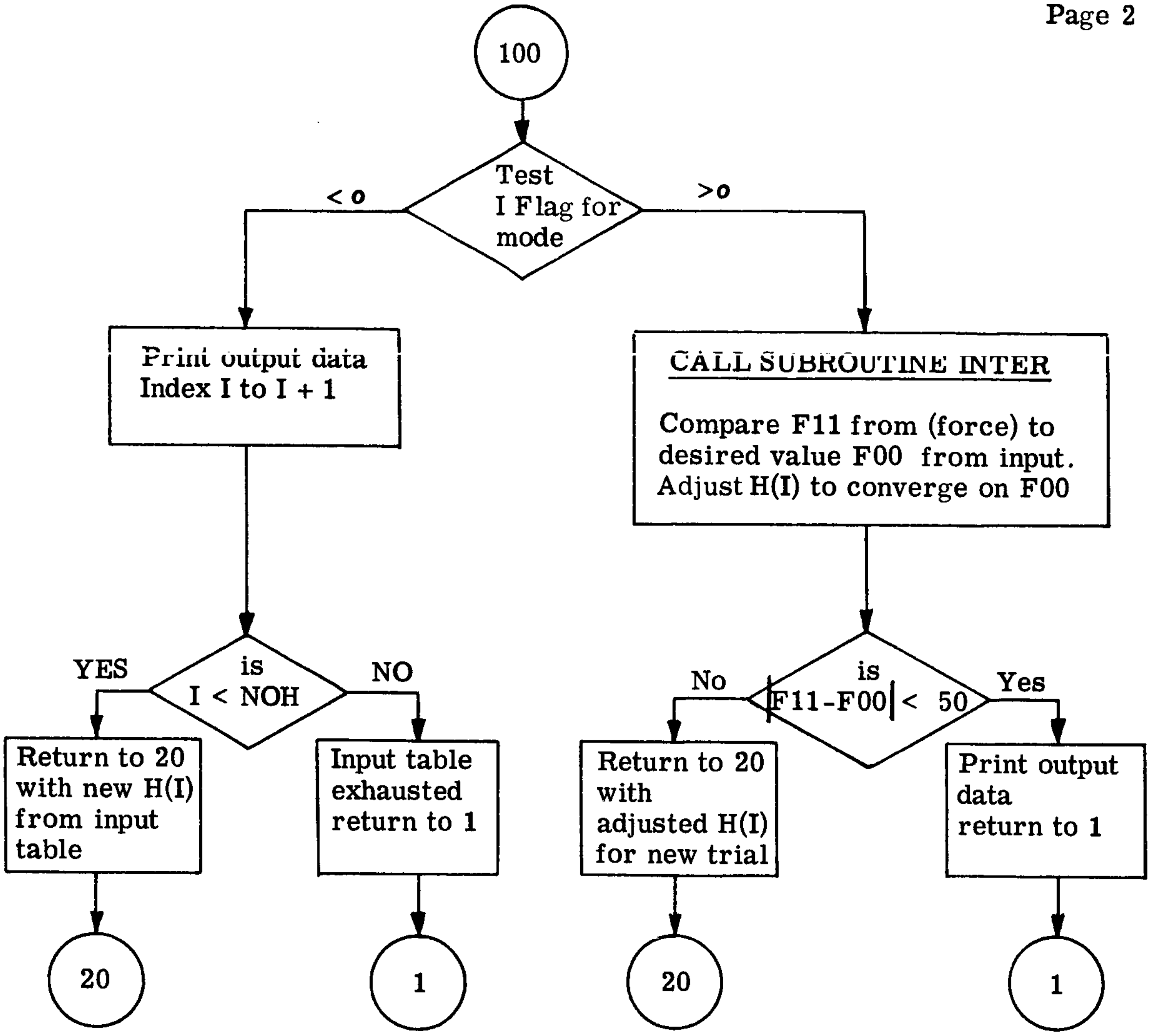


Figure 2-3. Geometry Program (Continued)

This subroutine reads the input data cards and prints data as part of the output record.

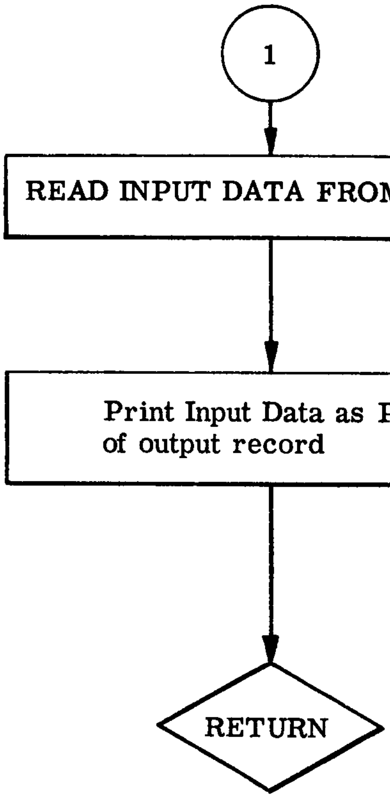


Figure 2-4. Subroutine To Geometry Program

This subroutine computes the stroke force F11 as a function of vehicle geometry.

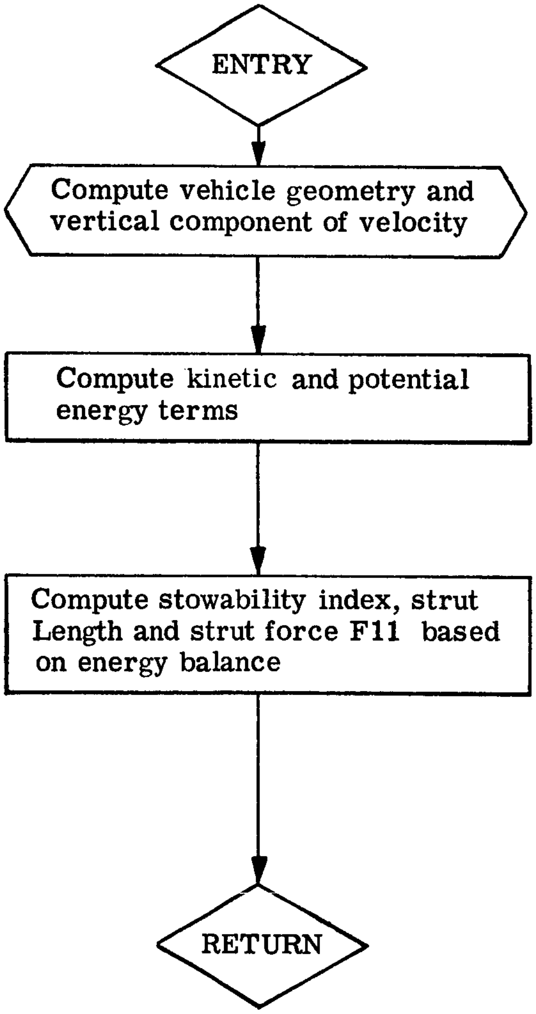


Figure 2-5. Subroutine To Geometry Program

This subroutine determines by interpolation the H(I) required to produce a given F11 and FNC.

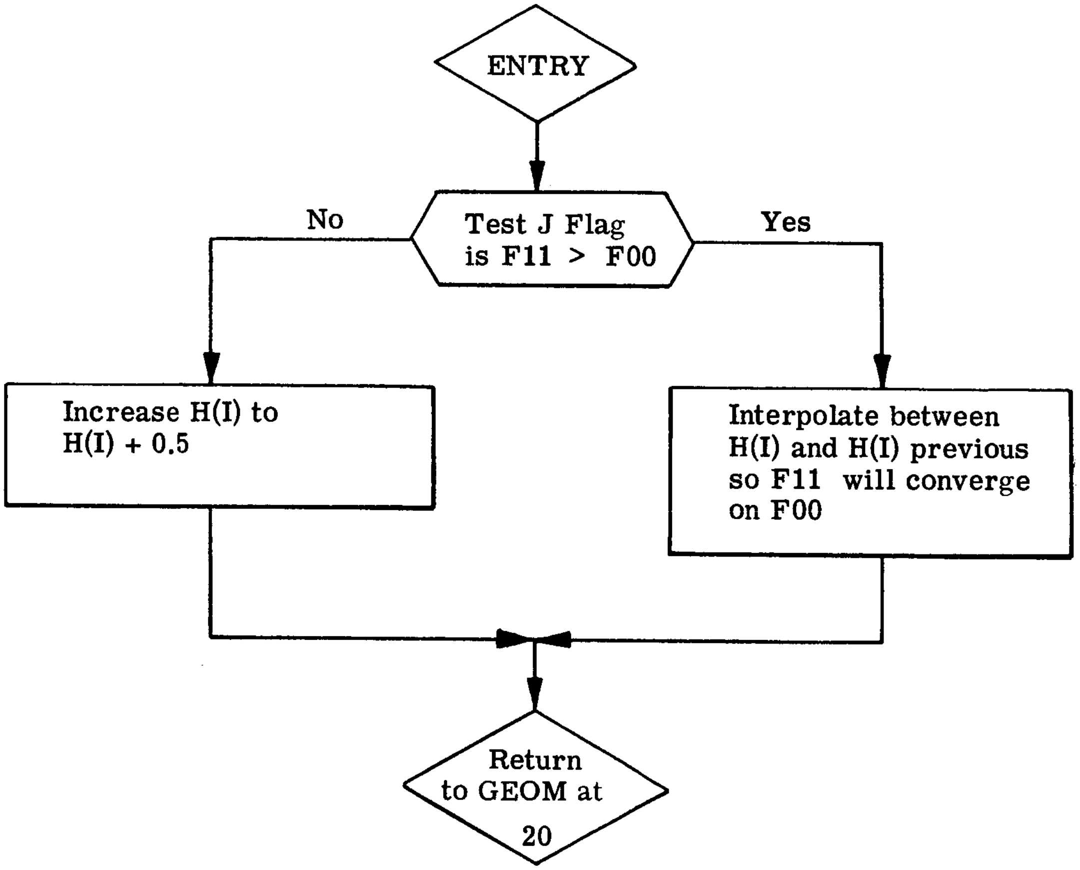


Figure 2-6. Subroutine To Geometry Program

```
-I FOR FORCE
C
C     TITLE     FORCE  -  STRUT FORCE PROGRAM
C
C     AUTHOR    BENDIX PRODUCTS AEROSPACE DIVISION - SOUTH BEND,INDIANA
C               J.C.GIBSON
C
C     DATE      AUGUST 3,1964
C
C     PURPOSE   LUNAR LANDING DYNAMICS SYSTEM INVESTIGATION - THIS
C               PROGRAM RELATES VEHICLE C.G.HEIGHT AND STRUT STROKE
C               FORCE TO FINAL NOZZLE CLEARANCE, COMPUTES THE
C               STOWABILITY INDEX AND BASIC GEOMETRIC INPUTS FOR THE
C               LANDING DYNAMICS AND WEIGHT PROGRAMS.  REF. BENDIX REPORT
C               NO MM-64-9       NOV.,1964
C
C     METHOD    PROGRAM RELATES LANDING VEHICLE NCOMING KENETIC AND
C               POTENTIAL ENERGY TO ENERGY ABSORBED IN STROKING MAIN
C               SHOCK STRUT. THIS ENERGY BALANCE ALLOWS DETERMINATION OF
C               FINAL C.G.HEIGHT AS FUNCTION OF GEOMETRY AND STROKE
C               FORCE.ALSO COMPUTES SUPPLEMENTAL GEOMETRIC DATA BY
C               TRIGOMETRIC RELATIONSHIPS
C
C     NOTE      IF(IFLAG)=+,PROGRAM COMPUTES C.G.HEIGHT FOR A GIVEN
C               NOZZLE CLEARANCE AND STROKE FORCE
C               IF(IFLAG)=-,PROGRAM COMPUTES NOZZLE CLEARANCE FOR A
C               GIVEN C.G.HEIGHT AND STROKE FORCE
C
C     INPUT     BY PUNCH CARD
C
C
C     NOTE      INPUTS DEFINED FOR VEHICLE ORIENTED WITH ITS CENTERLINE
C               VERTICAL
C
C               ALL INPUTS REQUIRED REGARDLESS OF IFLAG CONTROL MODE
C
C               ALL UNITS ARE SLUG,FT,SEC,RADIAUS
C
C
C     INPUT DEFINITIONS
C
C
C               AN      =NUMBER OF LEGS ON VEHICLE (USUALLY 4)
C               D       =VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARD-
C                         POINTS
C               D11     =VERTICAL DISTANCE BETWEEN VEHICLE C.G.AND
C                         UPPER HARDPOINT
C               DELTA   = ANGLE,PROJECTED IN PLANE PARALLEL TO DIRECTION
C                         OF MOTION FOR 1-2-1 LANDING,BETWEEN LOWER
C                         STRUTS AND VEHICLE CENTERLINE
C               DELTAP  = VERTICAL THICKNESS OF FOOTPAD (FROM BOTTOM
C                         SURFACE TO STRUT ATTACH POINT)
C               FNC     = FINAL DESIRED NOZZLE CLEARANCE
C               FOO     = REQUIRED UPPER STRUT STROKE FORCE
C               G       = ACCELERATION OF LOCAL GRAVITY AT LANDING SITE
C               GAMMA   = TRUE ANGLE BETWEEN UPPER (MAIN) STRUT AND
C                         VEHICLE CENTERLINE
C               HN      = VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND
C                         LOWEST POINT ON NOZZLE CONE
C               PMASS   = MASS OF ONE VEHICLE FOOTPAD
C               PSI     = INITIAL VEHICLE PITCH ANGLE.  ANGLE BETWEEN
```

Figure 2-7. Nozzle Clearance Program

```
C                       LOCAL VERTICAL NAD VEHICLE CENTERLINE
C             RH      = R/H RATIO WHERE R = RADIUS OF VEHICLE FOOTPADS
C                                       H = DEFINED BELOW
C             SERNO   = IDENT. NO. COMPUTER RUN
C             THETA   = ANGLE BETWEEN VERTICAL PLANE IN DIRECTION OF
C                       MOTION AND VERTICAL PLANE THROUGH VEHICLE C.G.
C                       AND UPPER HARDPOINT
C             VMASS   = PRIMARY VEHICLE MASS CONCENTRATED AT VEHICLE
C                       C.G.
C             XVEL    = VELOCITY NORMAL TO GROUND SURFACE. POSITIVE
C                       AWAY FROM SURFACE
C             YVEL    = VELOCITY PARALLEL TO GROUND SURFACE
C             Z       = WIDTH OF BASIC ATTACH POINTS ON VEHICLE FOR
C                       STRUTS ON NARROW TRACK VEHICLE OR TRUSSWORK ON
C                       WIDETRACK VEHICLE.  THIS IS A PROGRAM CONSTANT
C                       WITH VALUE = 5.0
C             ZETA    = GROUND SLOPE ANGLE
C             IFLAG   = FLAG TO DETERMIN PROGRAM MODE. IF +, CALCULATE
C                       C.G.HEIGHT FOR GIVEN STRUT FORCE AND FNC.  IF-,
C                       CALCULATE STRUT FORCE FOR GIVEN C.G.HEIGHT AND
C                       FNC.
C             NOH     = NUMBER OF H(I) VALUES IN INPUT LIST. PERMITS
C                       MULTIPLE RUNS UNDER IFLAG = -  CONTROL
C             H(I)    = INITIAL VEHICLE C.G. HEIGHT.  INPUT AS LIST FOR
C                       MULTIPLE RUNS UNDER IFLAG = - CONTROL
C
C
C     OUTPUT  PRINTED OUTPUT
C
C     OUTPUT  BY EQUIVALENCE TO COMMON STORAGE
C
C
C     OUTPUT DEFINITIONS
C
C             RP      = FOOTPAD RADIUS
C             F11     = UPPER STRUT STROKE FORCE
C             ALPHA   = ANGLE BETWEEN LOWER HARDPOINTS
C             SLO     = INITIAL UPPER STRUT LENGTH
C             E       = TOTAL VEHICLE ENERGY
C             SL      = FINAL UPPER STRUT LENGTH
C             EKE     = VEHICLE INCOMING KENETIC ENERGY
C             PE1     = POTENTIAL ENERGY RESULTING FROM C G DROP FROM
C                       INITIAL ORIENTATION  TO ALL FOOTPADS ON SURFACE
C             PE2     = POTENTIAL ENERGY RESULTING FROM C G DROP
C                       RESULTING FROM STROKING OF UPPER STRUT
C             R1      = UPPER HARDPOINT RADIUS
C             R2      = LOWER HARDPOINT RADIUS
C             STOW    = STOWABILITY INDEX
C
C
C
      COMMON AN,ALPHA,D,D11,DELTA,DELTAP,DIFF,E,EKE,F11,FNC,FOO,
     1G,GAMMA,H1PRE,H(20),HN,I,IFLAG,IJK,JFLAG,LL,NOH,PE1,PE2,PMASS,PSI,
     2R1,R2,RH,RP,SL,SLO,STOW,THETA,VMASS,XVEL,YVEL,Z,ZETA
C
    1 CALL INPUT
C
      IJK=1
      I=1
C
C     TEST PROGRAM MODE
```

Figure 2-7. Nozzle Clearance Program (Continued)

```
C
      IF (IFLAG) 20,20,15
C
C     COMPUTE H(I) MINIMUM BASED ON VEHICLE GEOMETRY
C
   15 H(I)=1.01*(FNC+HN+DELTAP)
      H1PREV=FNC+HN+DELTAP
      JFLAG=1
C
   20 CALL GEOM
C
      GO TO (20,1,100),LL
C
C     TEST PROGRAM MODE
C
  100 IF (IFLAG) 110,110,120
C
C     PRINT OUTPUT DATA
C
  110 PRINT 610,H(I),RP    ,F11    ,ALPHA
      PRINT 611,SLO,E,SL,EKE
      PRINT 612,PE1,PE2,R1,R2
      PRINT 618,STOW
      PRINT 530
C
C     IF STROKE FORCE IS NEGATIVE, INCREASE H(I)
C
      IF(F11)200,200,112
  112 IF (IFLAG)115,1,1
C
C     CHOOSE NEW I INDEX AND RETURN TO 20 IF A MULTIPLE LIST OF H(I) IS
C     PRESENT
C
  115 I=I+1
      IF (I-NOH) 20,20,1
C
C     TEST DIFFERENCE OF F11 FROM F00 UNDER IFLAG = -  MODE
C
  120 DIFF=(F11   -F00)
C
C     IF DIFFERENCE IS LESS THAN 50 LBS, STOP AND PRINT OUTPUT DATA
C
      IF(ABS(DIFF)- 50.0)110,110,125
  125 PRINT 610,H(I),RP,F11,ALPHA
      PRINT 611,SLO,E,SL,EKE
      PRINT 612,PE1,PE2,R1,R2
      PRINT 617
C
  130 CALL INTER
C
      GO TO 20
  200 PRINT 616,F11
      H(I)=H(I)+0.5
      GO TO 20
  530 FORMAT(1H1)
  610 FORMAT(18H             H       =,F15.5,13H      RP      =,F15.5,12H
     1F11    =,F15.5,12H       ALPHA =,F15.5)
  611 FORMAT(18H             SLO     =,F15.5,13H      E       =,F15.5,12H
     1SL     =,F15.5,12H       KE    =,F15.5)
  612 FORMAT(18H             PE1     =,F15.5,13H      PE2     =,F15.5,12H
     1R1     =,F15.5,12H       R2    =,F15.5)
```

Figure 2-7. Nozzle Clearance Program (Continued)

```
616 FORMAT(61H   THE FORCE F11 IS NEGATIVE  REPEAT USING A LARGER H
   1 F11=,F15.5//)
617 FORMAT(1H0)
618 FORMAT(18H          STOW   =,F15.5)
    END
```

Figure 2-7. Nozzle Clearance Program (Concluded)

```
-I FOR INPUT
C
C      TITLE     INPUT
C
C      AUTHOR    BENDIX PRODUCTS AEROSPACE DIVISION - SOUTH BEND,INDIANA
C                J.C.GIBSON
C
C      DATE      AUGUST 3,1964
C
C                INPUT DATA AS PART OF THE OUTPUT RECORD
C      PURPOSE   THIS SUBROUTINE READS THE INPUT CARDS AND PRINTS THE
C
C
C      CALL      CALL INPUT
C
C      INPUT     BY PUNCH CARD
C
C
C      INPUT DEFINITIONS
C
C                AN      =NUMBER OF LEGS ON VEHICLE (USUALLY 4)
C                D       =VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARD-
C                          POINTS
C                D11     =VERTICAL DISTANCE BETWEEN VEHICLE C.G.AND
C                          UPPER HARDPOINT
C                DELTA   = ANGLE,PROJECTED IN PLANE PARALLEL TO DIRECTION
C                          OF MOTION FOR 1-2-1 LANDING,BETWEEN LOWER
C                          STRUTS AND VEHICLE CENTERLINE
C                DELTAP  = VERTICAL THICKNESS OF FOOTPAD (FROM BOTTOM
C                          SURFACE TO STRUT ATTACH POINT)
C                FNC     = FINAL DESIRED NOZZLE CLEARANCE
C                FCC     = REQUIRED UPPER STRUT STROKE FORCE
C                G       = ACCELERATION OF LOCAL GRAVITY AT LANDING SITE
C                GAMMA   = TRUE ANGLE BETWEEN UPPER (MAIN) STRUT AND
C                          VEHICLE CENTERLINE
C                HN      = VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND
C                          LOWEST POINT ON NOZZLE CONE
C                PMASS   = MASS OF ONE VEHICLE FOOTPAD
C                PSI     = INITIAL VEHICLE PITCH ANGLE.  ANGLE BETWEEN
C                          LOCAL VERTICAL NAD VEHICLE CENTERLINE
C                RH      = R/H RATIO WHERE R = RADIUS OF VEHICLE FOOTPADS
C                                            H = DEFINED BELOW
C                SERNO   = IDENT. NO. COMPUTER RUN
C                THETA   = ANGLE BETWEEN VERTICAL PLANE IN DIRECTION OF
C                          MOTION AND VERTICAL PLANE THROUGH VEHICLE C.G.
C                          AND UPPER HARDPOINT
C                VMASS   = PRIMARY VEHICLE MASS CONCENTRATED AT VEHICLE
C                VMASS   = PRIMARY VEHICLE MASS CONCENTRATED AT VEHICLE
C                          C.G.
C                XVEL    = VELOCITY NORMAL TO GROUND SURFACE. POSITIVE
C                          AWAY FROM SURFACE
C                YVEL    = VELOCITY PARALLEL TO GROUND SURFACE
C                Z       = WIDTH OF BASIC ATTACH POINTS ON VEHICLE FOR
C                          STRUTS ON NARROW TRACK VEHICLE OR TRUSSWORK ON
C                          WIDETRACK VEHICLE.  THIS IS A PROGRAM CONSTANT
C                          WITH VALUE = 5.0
C                ZETA    = GROUND SLOPE ANGLE
C                IFLAG   = FLAG TO DETERMIN PROGRAM MODE. IF +, CALCULATE
C                          C.G.HEIGHT FOR GIVEN STRUT FORCE AND FNC.  IF-,
C                          CALCULATE STRUT FORCE FOR GIVEN C.G.HEIGHT AND
C                          FNC.
```

Figure 2-8. Subroutine INPUT

```
C               NOH    = NUMBER OF H(I) VALUES IN INPUT LIST. PERMITS
C                        MULTIPLE RUNS UNDER IFLAG = -  CONTROL
C               H(I)   = INITIAL VEHICLE C.G. HEIGHT.  INPUT AS LIST FOR
C                        MULTIPLE RUNS UNDER IFLAG = - CONTROL
C     OUTPUT    BY EQUIVALENCE TO COMMON STORAGE
C
C
      SUBROUTINE INPUT
      COMMON AN,ALPHA,D,D11,DELTA,DELTAP,DIFF,E,EKE,F11,FNC,FOO,
     1G,GAMMA,H1PRE,H(20),HN,I,IFLAG,IJK,JFLAG,LL,NOH,PE1,PE2,PMASS,PSI,
     2R1,R2,RH,RP,SL,SLO,STOW,THETA,VMASS,XVEL,YVEL,Z,ZETA
    1 READ 500 ,THETA,PSI,ZETA,RH,VMASS,PMASS,AN,XVEL,YVEL,G,HN,FNC,
     1DELTAP,D11,D,Z,GAMVA,DELTA,FOO,SERNO
      READ 510,NOH,IFLAG
      READ 520,(H(K),K=1,NOH)
      PRINT 613,SERNO
   10 PRINT 600,THETA,PSI,ZETA,RH
      PRINT 601,VMASS,PMASS,AN,XVEL
      PRINT 602,YVEL,G,HN,FNC
      PRINT 603,DELTAP,D11,D,Z
      PRINT 604,GAMMA,DELTA,FOO
      PRINT 614,NOH,IFLAG
      RETURN
 500  FORMAT(10X,3F15.5)
 510  FORMAT(10X,3I10)
 520  FORMAT(10X,6F10.5)
 613  FORMAT(21H          SERIES NO =,F10.3//)
 600  FORMAT(18H          THETA  =,F15.5,13H     PSI    =,F15.5,12H
     1ZETA   =,F15.5,12H    R/H   =,F15.5)
 601  FORMAT(18H          VMASS  =,F15.5,13H     PMASS  =,F15.5,12H
     1AN     =,F15.5,12H    XVEL  =,F15.5)
 602  FORMAT(18H          YVEL   =,F15.5,13H     G      =,F15.5,12H
     1HN     =,F15.5,12H    FNC   =,F15.5)
 603  FORMAT(18H          DELTAP =,F15.5,13H     D11    =,F15.5,12H
     1D      =,F15.5,12H    Z     =,F15.5)
 604  FORMAT(18H          GAMMA  =,F15.5,13H     DELTA  =,F15.5,12H
     1FOO    =,F15.5)
 614  FORMAT(18H          NHO    =,I15,13H     IFLAG  =,I15///)
      END
```

Figure 2-8. Subroutine INPUT (Concluded)

```
-I FOR GEOM
C
C     TITLE       GEOM  - GEOMETRY
C
C     AUTHOR      BENDIX PRODUCTS AEROSPACE DIVISION - SOUTH BEND,INDIANA
C                 J.C.GIBSON
C
C     DATE        AUGUST 3,1964
C
C     PURPOSE     THIS SUBROUTINE COMPUTES THE BASIC GEOMETRY OF THE
C                 VEHICLE
C
C
C     CALL        CALL GEOM
C
C     INPUT       BY EQUIVALENCE TO COMMON STORAGE
C
C
C     INPUT DEFINITIONS
C
C                 AN      =NUMBER OF LEGS ON VEHICLE (USUALLY 4)
C                 D       =VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARD-
C                            POINTS
C                 D11     =VERTICAL DISTANCE BETWEEN VEHICLE C.G.AND
C                            UPPER HARDPOINT
C                 DELTA   = ANGLE,PROJECTED IN PLANE PARALLEL TO DIRECTION
C                           OF MOTION FOR 1-2-1 LANDING,BETWEEN LOWER
C                           STRUTS AND VEHICLE CENTERLINE
C                 DELTAP  = VERTICAL THICKNESS OF FOOTPAD (FROM BOTTOM
C                           SURFACE TO STRUT ATTACH POINT)
C                 FNC     = FINAL DESIRED NOZZLE CLEARANCE
C                 FOO     = REQUIRED UPPER STRUT STROKE FORCE
C                 G       = ACCELERATION OF LOCAL GRAVITY AT LANDING SITE
C                 GAMMA   = TRUE ANGLE BETWEEN UPPER (MAIN) STRUT AND
C                           VEHICLE CENTERLINE
C                 HN      = VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND
C                           LOWEST POINT ON NOZZLE CONE
C                 PMASS   = MASS OF ONE VEHICLE FOOTPAD
C                 PSI     = INITIAL VEHICLE PITCH ANGLE.  ANGLE BETWEEN
C                           LOCAL VERTICAL NAD VEHICLE CENTERLINE
C                 RH      = R/H RATIO WHERE R = RADIUS OF VEHICLE FOOTPADS
C                                           H = DEFINED BELOW
C                 SERNO   = IDENT. NO. COMPUTER RUN
C                 THETA   = ANGLE BETWEEN VERTICAL PLANE IN DIRECTION OF
C                           MOTION AND VERTICAL PLANE THROUGH VEHICLE C.G.
C                           AND UPPER HARDPOINT
C                 VMASS   = PRIMARY VEHICLE MASS CONCENTRATED AT VEHICLE
C                 VMASS   = PRIMARY VEHICLE MASS CONCENTRATED AT VEHICLE
C                           C.G.
C                 XVEL    = VELOCITY NORMAL TO GROUND SURFACE. POSITIVE
C                           AWAY FROM SURFACE
C                 YVEL    = VELOCITY PARALLEL TO GROUND SURFACE
C                 Z       = WIDTH OF BASIC ATTACH POINTS ON VEHICLE FOR
C                           STRUTS ON NARROW TRACK VEHICLE OR TRUSSWORK ON
C                           WIDETRACK VEHICLE.  THIS IS A PROGRAM CONSTANT
C                           WITH VALUE = 5.0
C                 ZETA    = GROUND SLOPE ANGLE
C                 IFLAG   = FLAG TO DETERMIN PROGRAM MODE. IF +, CALCULATE
C                           C.G.HEIGHT FOR GIVEN STRUT FORCE AND FNC.  IF-,
C                           CALCULATE STRUT FORCE FOR GIVEN C.G.HEIGHT AND
C                           FNC.
```

Figure 2-9. Subroutine GEOM

```
C               NCH    = NUMBER OF H(I) VALUES IN INPUT LIST. PERMITS
C                        MULTIPLE RUNS UNDER IFLAG = -  CONTROL
C               H(I)   = INITIAL VEHICLE C.G. HEIGHT.  INPUT AS LIST FOR
C                        MULTIPLE RUNS UNDER IFLAG = - CONTROL
C
C
C     OUTPUT    BY EQUIVALENCE TO COMMON STORAGE
C
C     OUTPUT DEFINITIONS
C
C               RP     = FOOTPAD RADIUS
C               F11    = UPPER STRUT STROKE FORCE
C               ALPHA  = ANGLE BETWEEN LOWER HARDPOINTS
C               SLO    = INITIAL UPPER STRUT LENGTH
C               E      = TOTAL VEHICLE ENERGY
C               SL     = FINAL UPPER STRUT LENGTH
C               EKE    = VEHICLE INCOMING KENETIC ENERGY
C               PE1    = POTENTIAL ENERGY RESULTING FROM C G DROP FROM
C                        INITIAL ORIENTATION  TO ALL FOOTPADS ON SURFACE
C               PE2    = POTENTIAL ENERGY RESULTING FROM C G DROP
C                        RESULTING FROM STROKING OF UPPER STRUT
C               R1     = UPPER HARDPOINT RADIUS
C               R2     = LOWER HARDPOINT RADIUS
C               STOW   = STOWABILITY INDEX
C
C
      SUBROUTINE GEOM
C
      COMMON AN,ALPHA,D,D11,DELTA,DELTAP,DIFF,E,EKE,F11,FNC,FOO,
     1G,GAMMA,H1PRE,H(20),HN,I,IFLAG,IJK,JFLAG,LL,NCH,PE1,PE2,PMASS,PSI,
     2R1,R2,RH,RP,SL,SLO,STOW,THETA,VMASS,XVEL,YVEL,Z,ZETA
C
C     DETERMINE VEHICLE GEOMETRY
C
    1 RP=RH*H(I)
      A=RP*COS(THETA)
      VV=XVEL*COS(ZETA)
      VH=YVEL*SIN(ZETA)
C
C     DETERMINE KENETIC ENERGY
C
   30 EKE=0.5*(VMASS+AN*PMASS)*(VH-VV)*(VH-VV)
C
C     DETERMINE PE1
C
      B1=H(I)*COS(PSI+ZETA)
      C1=A*SIN(PSI+ZETA)
      B2=H(I)*COS(ZETA)
      C2=A*SIN(ZETA)
   40 PE1    =VMASS*G*(B1-C1-B2+C2)
      DHS=(H(I)-HN-FNC)
C
C     DETERMINE PE2
C
      PL2    =VMASS*G*COS(ZETA)*DHS
      R4=(H(I)-DELTAP-D11-D)*TAN(DELTA)
      R3=RP-R4
C
C     DETERMINE ANGLE BETWEEN LOWER HARDPOINTS
C
   50 ALPHA=2.0*ATAN(Z/R3)
```

Figure 2-9. Subroutine GEOM (Continued)

```
      IF(ALPHA-1.5708)57,57,53
   53 ALPHA=1.5708
C
C     DETERMINE LOWER HARDPOINT RADIUS
C
   57 R2=R3/COS(ALPHA/2.0)
   60 UO=SQRT(R4*R4+(H(I)-DELTAP-D11-D)*(H(I)-DELTAP-D11-D))
      R5=(H(I)-DELTAP-D11)*TAN(GAMMA)
C
C     DETERMINE RADIUS OF UPPER HARDPOINT
C
      R1=RP-R5
C
C     COMPUTE STOWABILITY INDEX
C
      STOW=SQRT(RP*RP+(H(I)-DELTAP-D11)*(H(I)-DELTAP-D11))
C
C     FIND INITIAL LENGTH OF UPPER STRUT
C
   70 SLO=(H(I)-DELTAP-D11)/COS(GAMMA)
C
C     FIND TOTAL VEHICLE ENERGY
C
      E=SQRT(UO*UO-(H(I)-D11-D-DHS)*(H(I)-D11-D-DHS))
   80 SL=SQRT((E+R3-R1)*(E+R3-R1)+(H(I)-D11-DHS)*(H(I)-D11-DHS))
      DS=SLO-SL
      IF(DS-0.005)85,85,90
   85 PRINT 615,DS
      H(I)=H(I)+0.1
      IJK=IJK+1
      IF(IJK-20)100,100,95
C
C     FIND UPPER STRUT STROKE LOAD
C
   90 F11=(EKE+PE1+PE2)/(AN*DS)
      LL=3
      RETURN
   95 LL=2
      RETURN
  100 LL=1
      RETURN
  615 FORMAT(70H   THE DIFFERENCE SLO-SL IS TOO SMALL,REPEAT USING H=H+0
     1.1      SLO-SL =,F15.5//)
      END
```

Figure 2-9. Subroutine GEOM (Concluded)

```
-I FOR INTER
C
C      TITLE INTER   -  INTERPOLATE
C
C      AUTHOR    BENDIX PRODUCTS AEROSPACE DIVISION - SOUTH BEND,INDIANA
C                J.C.GIBSON
C
C      DATE      AUGUST 3,1964
C
C      PURPOSE   THIS SUBROUTINE INTERPOLATES THE VEHICLE HEIGHT H(I)
C                TO CAUSE F11 TO CONVERGE ON THE DESIRED UPPER STRUT
C                STROKE LOAD  FOO
C
C
C      CALL      CALL INTER
C
C
C      INPUT     BY EQUIVALENCE TO COMMON STORAGE
C
C      INPUT DEFINITIONS
C
C                H(I)   = INITIAL VEHICLE C.G. HEIGHT.  INPUT AS LIST FOR
C                         MULTIPLE RUNS UNDER IFLAG = - CONTROL
C
C      OUTPUT    BY EQUIVALENCE TO COMMON STORAGE
C
C
       SUBROUTINE INTER
C
       COMMON AN,ALPHA,D,D11,DELTA,DELTAP,DIFF,E,EKE,F11,FNC,FOO,
      1G,GAMMA,H1PRE,H(20),HN,I,IFLAG,IJK,JFLAG,LL,NOH,PE1,PE2,PMASS,PSI,
      2R1,R2,RH,RP,SL,SLO,STOW,THETA,VMASS,XVEL,YVEL,Z,ZETA
   130 IF (JFLAG) 170,140,140
   140 IF(DIFF)145,145,160
   145 IF(F11)147,147,150
   147 H(I)=H(I)+0.1
       PRINT 616,F11
       RETURN
   150 JFLAG=-1
       H2PREV=H(I)
       H(I)=(H1PREV+H(I))/2.0
       RETURN
   160 H1PREV=H(I)
       H(I)=H(I)+0.5
       RETURN
   170 IF (DIFF) 180,180,190
   180 H2PREV=H(I)
       H(I)=(H1PREV+H(I))/2.0
       RETURN
   190 H1PREV=H(I)
       H(I)=(H2PREV+H(I))/2.0
       RETURN
   200 PRINT 616,F11
       H(I)=H(I)+0.5
       RETURN
   616 FORMAT(61H   THE FORCE F11 IS NEGATIVE  REPEAT USING A LARGER H
      1 F11=,F15.5//)
       END
C
C
```

Figure 2-10. Subroutine INTER

```
- XQT FORCE
R THE30   1 0.7854        -0.34907       0.2618
R RH 30   2 1.20          400.0          4.0
R AN 30   3 4.0           -8.35                7.4
R G  30   4 5.32          10.5                2.0
R DEL30   5 0.25          1.915          5.41
R Z  30   6 5.0           0.34907        0.894
R FOO30   7 7000.0           2126.0
R NOH30   8         1        1
R H  30   9 14.10
R THE30   1 0.7854        -0.34907       0.2618
R RH 30   2 1.20          400.0          4.0
R AN 30   3 4.0           -8.35                7.4
R G  30   4 5.32          10.5                2.0
R DEL30   5 0.25          1.915          5.41
R Z  30   6 5.0           0.34907        0.894
R FOO30   7 7000.0           2126.0
R NOH30   8         1       -1
R H  30   9 14.10
- FIN
```

Figure 2-10. Subroutine INTER (Concluded)

```
SERIES NO =  2126.000

THETA   =         .78540     PSI     =        -.34907     ZETA    =        .26180     R/H     =         1.20000
VMASS   =      400.00000     PMASS   =        4.00000     AN      =       4.00000     XVEL    =        -8.35000
YVEL    =        7.40000     G       =        5.32000     HN      =      10.50000     FNC     =         2.00000
DELTAP  =         .25000     F11     =        1.91500     D       =       5.41000     Z       =         5.00000
GAMMA   =         .34907     DELTA   =         .89400     FOO     =    7000.00000
RHO     =              1     IFLAG   =             -1


H       =       14.10000     RF      =       16.92000     F11     =    9589.96400     ALPHA   =         1.03358
SLO     =       12.70098     E       =        9.04220     SL      =      11.62179     KE      =     20719.97300
PE1     =     9716.78450     PE2     =     3288.76370     R1      =      12.57596     R2      =        10.11955
STOW    =       20.70581
```

Figure 2-11. Output Data for Mode IFLAG = -1

```
SERIES NO =  2126.000

THETA  =       .78540   FSI    =     -.34907   ZETA  =       .26180   R/H   =       1.20000
VMASS  =    400.00000   FMASS  =     4.00000   AN    =      4.00000   XVEL  =      -8.35000
YVEL   =      7.40000   G      =     5.32000   HN    =     10.50000   FNC   =       2.00000
DELTAP =       .25000   C11    =     1.91500   D     =      5.41000   Z     =       5.00000
GAMMA  =       .34907   DELTA  =      .89400   FUO   =   7000.00000
NMO    =            1   IFLAG  =           1


H      =     12.87750   RF     =    15.45300   F11   =  89727.38000   ALPHA =       1.02827
SLO    =     11.40002   E      =     6.70070   SL    =     11.31540   KE    =   20719.97300
PE.    =   8674.31860   PE2    =   775.94701   R1    =     11.55392   R2    =      10.16715


H      =     13.37750   RF     =    16.05300   F11   =  19199.46700   ALPHA =       1.03043
SLO    =     11.93211   E      =     7.56472   SL    =     11.51879   KE    =   20719.97300
PE.    =   9218.88500   PE2    =  1803.69180   R1    =     11.97193   R2    =      10.14767


H      =     13.87750   RF     =    16.65300   F11   =  11234.63170   ALPHA =       1.03261
SLO    =     12.46420   E      =     8.53048   SL    =     11.72731   KE    =   20719.97300
PE.    =   9563.45190   PE2    =  2831.43680   R1    =     12.38994   R2    =      10.12821


H      =     14.37750   RF     =    17.25300   F11   =   6170.87970   ALPHA =       1.03480
SLO    =     12.99629   E      =     9.54935   SL    =     11.94111   KE    =   20719.97300
PE.    =   9908.01860   PE2    =  3859.18160   R1    =     12.80796   R2    =      10.10876


H      =     14.87750   RF     =    17.85300   F11   =   6552.47060   ALPHA =       1.03699
SLO    =     13.52838   E      =    10.44843   SL    =     12.16021   KE    =   20719.97300
PE.    =  10252.58540   PE2    =  4886.92650   R1    =     13.22597   R2    =      10.08932


H      =     14.62750   RF     =    17.55300   F11   =   7253.19420   ALPHA =       1.03589
SLO    =     13.26234   E      =    10.00103   SL    =     12.05000   KE    =   20719.97300
PE.    =  10080.30190   PE2    =  4373.05410   R1    =     13.01696   R2    =      10.09904


H      =     14.75250   RF     =    17.70300   F11   =   6680.79230   ALPHA =       1.03644
SLO    =     13.39536   E      =    10.22523   SL    =     12.10494   KE    =   20719.97300
PE.    =  10166.44370   PE2    =  4629.99020   R1    =     13.12147   R2    =      10.09418


H      =     14.69000   RF     =    17.62800   F11   =   7060.95030   ALPHA =       1.03617
SLO    =     13.32885   E      =    10.11325   SL    =     12.07743   KE    =   20719.97300
PE.    =  10123.37310   PE2    =  4501.52220   R1    =     13.06921   R2    =      10.09661


H      =     14.72125   RF     =    17.66550   F11   =   6969.43310   ALPHA =       1.03630
SLO    =     13.36210   E      =    10.16927   SL    =     12.09117   KE    =   20719.97300
PE.    =  10144.90860   PE2    =  4565.75620   R1    =     13.09534   R2    =      10.09539
STAW   =     21.67324
```

Figure 2-12. Output Data for Mode IFLAG = +1

SECTION III

WEIGHT ANALYSIS DIGITAL COMPUTER PROGRAM

This computer program determines a gear system weight as a function of five landing gear parameters R, H, α , β, and stroke loads F11 in member 1-4 and F22 in members 1-2 and 1-3 which are input data to the program.

The program will handle five different structural configurations referred to as Cases A, B, C, D, and E. See pages 3-1 through 3-5 in Section III of Reference 1

NOTE

All references to page numbers in this write-up refer to pages in Section III of Reference 1.

The computer program first optimizes the design of the stroking members 1-2 and 1-4 (see pages 3-5 through 3-21), and second it optimizes the design of the truss members (see pages 3-22 through 3-28).

Please note that Case A has no truss structure. Case E has a modified truss which differs from Cases B, C, and D, and will require separate equilibrium equations.

The computer input data card consists of one set of the five basic parameters, a Flag B to designate the particular Case in question, and a serial number.

INPUT DATA	COLUMNS IN CARD
Serial Nos.	1 through 10
R	11 through 19
H	20 through 28
ALPHA	29 through 37
BETA	38 through 46
F(1) = F22	47 through 55
F(2) = F11	56 through 64
FLAGB	65 through 72

Note 1. Serial No. may be numeric and (or) alphabetic. Alphabetic is used for the five test sets of parameters only.

Note 2. Flag B = + 2.0 for Case A
Flag B = + 1.0 for Cases B, C, D
Flag B = - 1.0 for Case E

Note 3. If material other than aluminum is studied, then the five cards FTU(1), FTU(2), FTU(3), E, and DENS in the subroutine INPUT must be changed (see page 3-28 of Reference 1).

Note 4. See computer program listing (Figure 3-9) for identification of symbols.

COMPUTER OUTPUT DATA

1. The input data is printed first and then the density of the material.
2. A table of leg radius, wall thickness, and the product of the two is now printed as the program searches for the minimum point on the curve (see Figure 3-16) for member 1-2.
3. Then the weight, length, radius, wall thickness is printed for member 1-2.
4. Steps (2) and (3) are now printed for member 1-4.
5. For Case A only, a total leg weight, final total weight, weight of honeycomb, and weight of one footpad is now printed and program returns to read next set of data.
6. For the other four cases, the program now designs the truss members and prints the weight, force, length, radius, and wall thickness of each truss member for the particular case in question.
7. Then (5) is repeated for Case B, C, D, or E.

Note 1. The computer sample solution that follows gives the solution to a set of parameters for each of the five cases. The serial number is replaced by the words Test A, Test B, etc.

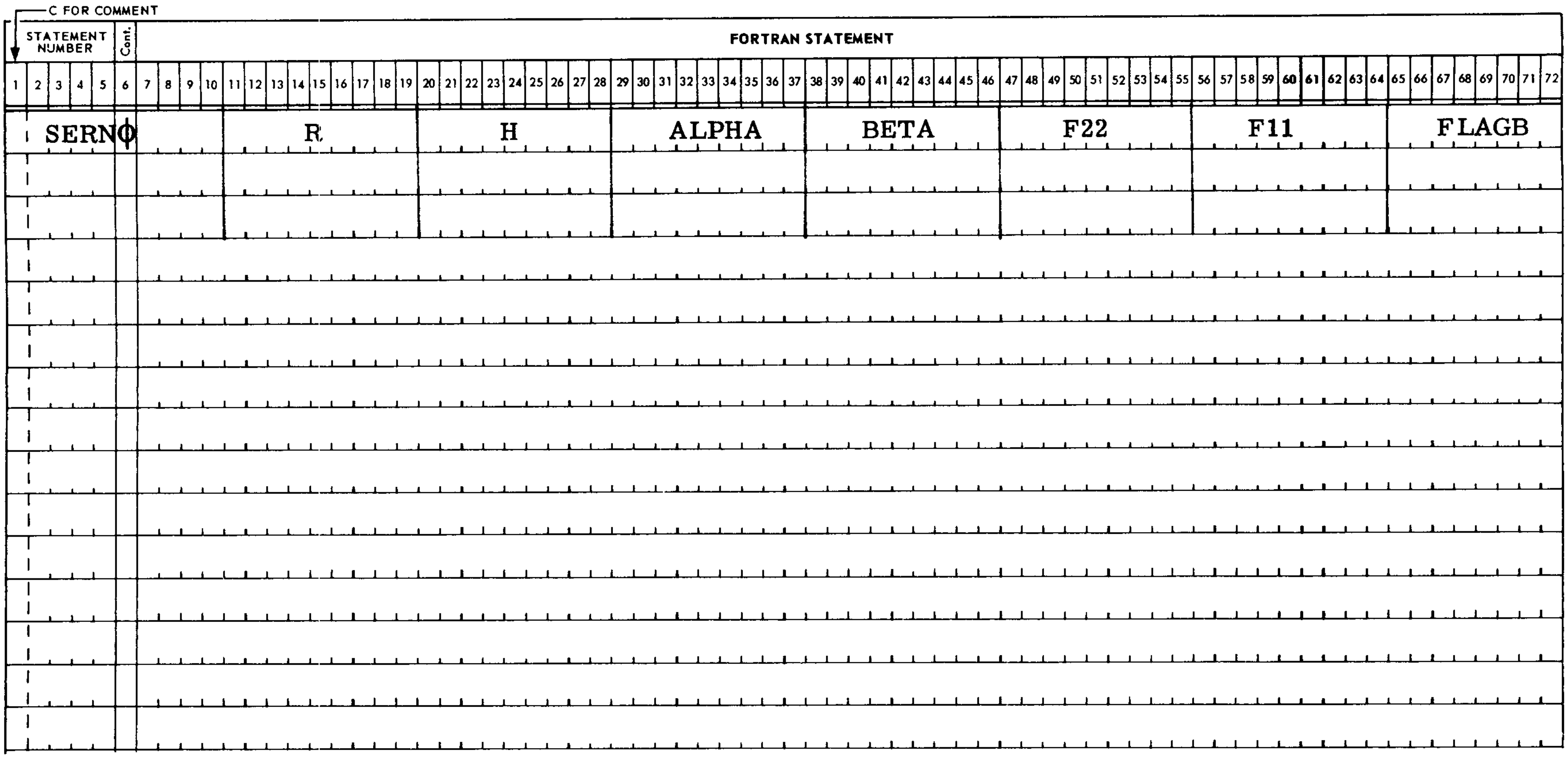


Figure 3-1. Input Data Format

This program minimizes the leg weight based upon a given leg configuration and also calculates total leg weight including honeycomb and footpads. (See Reference 1.)

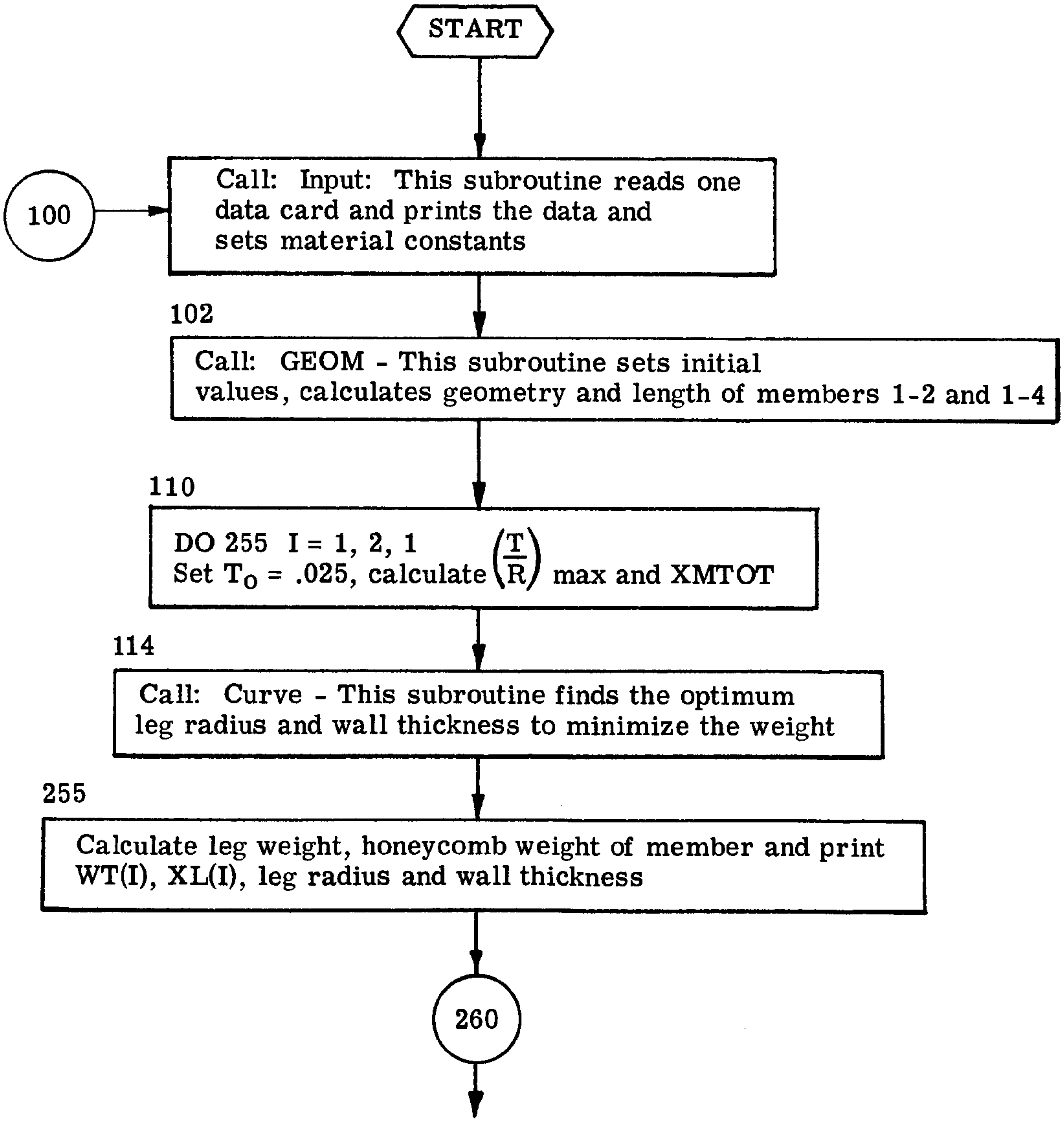


Figure 3-2. Computer Program: Design of Legs to Minimize Weight

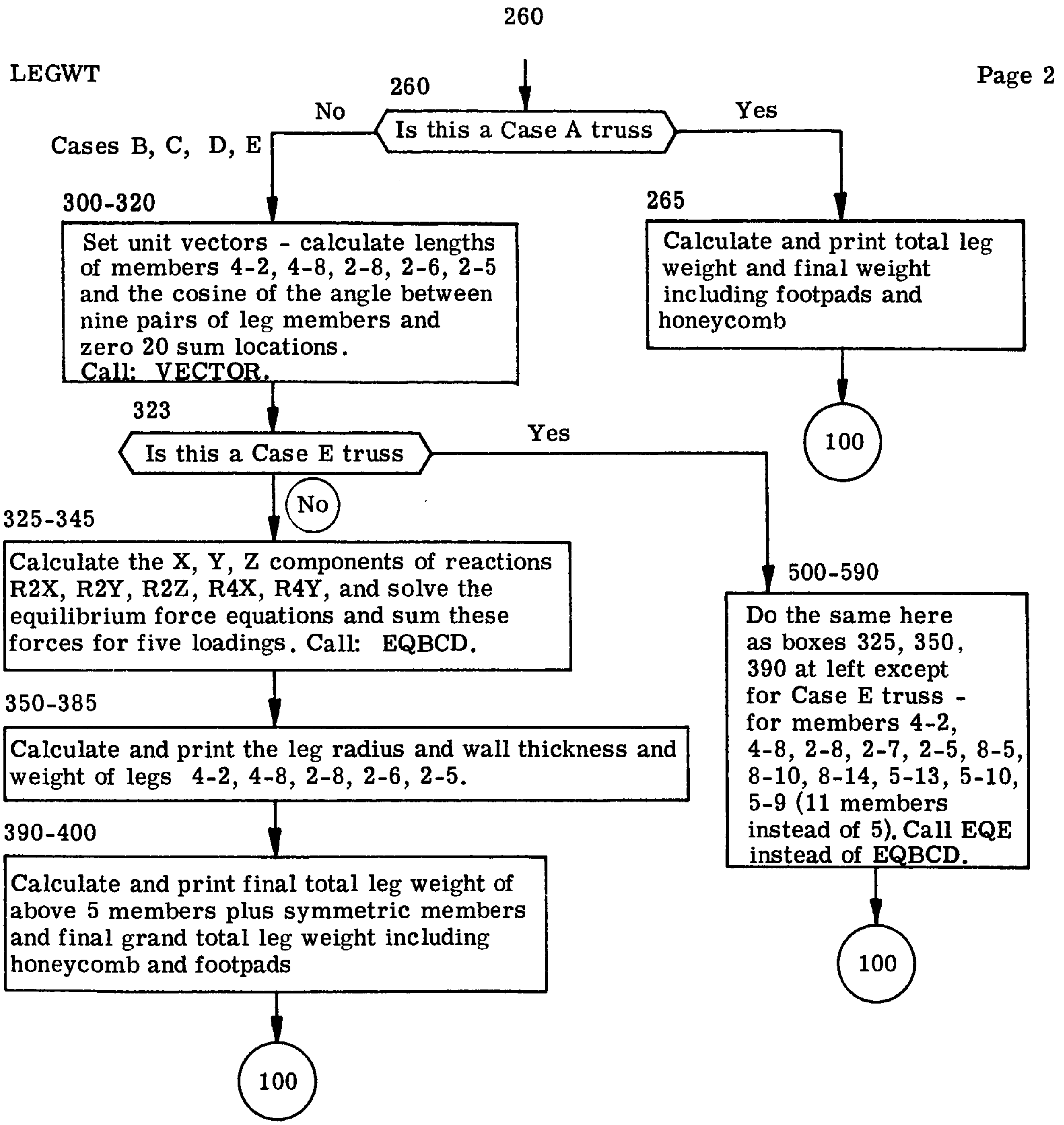


Figure 3-2. Computer Program: Design of Legs to Minimize Weight (Concluded)

This subroutine reads and prints one data card and sets material constants

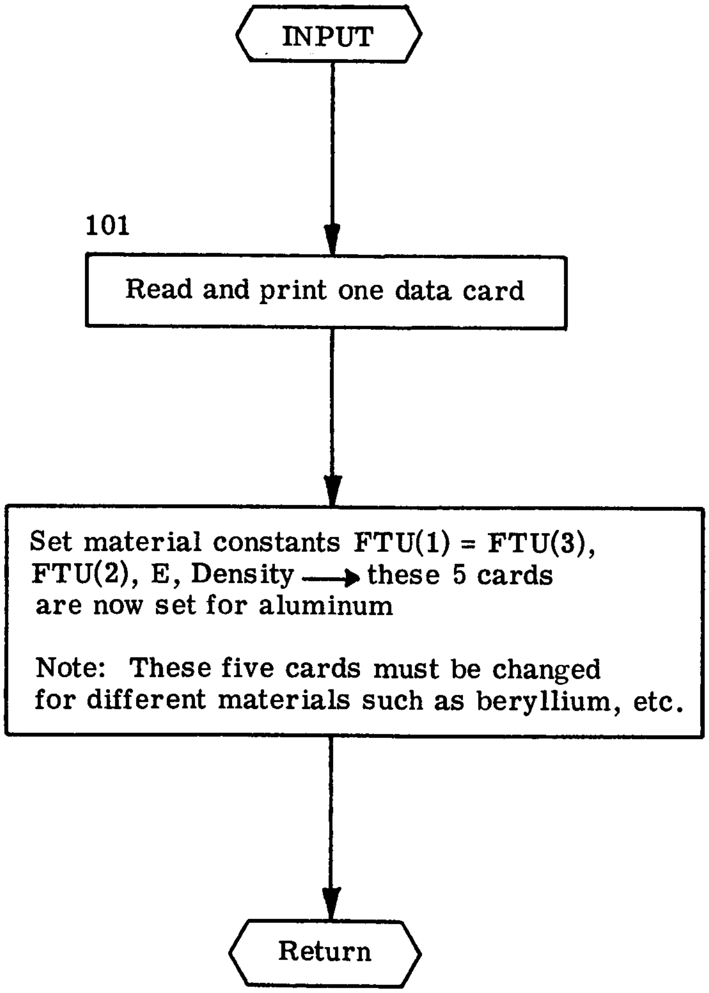


Figure 3-3. Subroutine Input

This subroutine initializes geometric constants, calculates lengths of members 1-2 and 1-4 and the weight of one footpad.

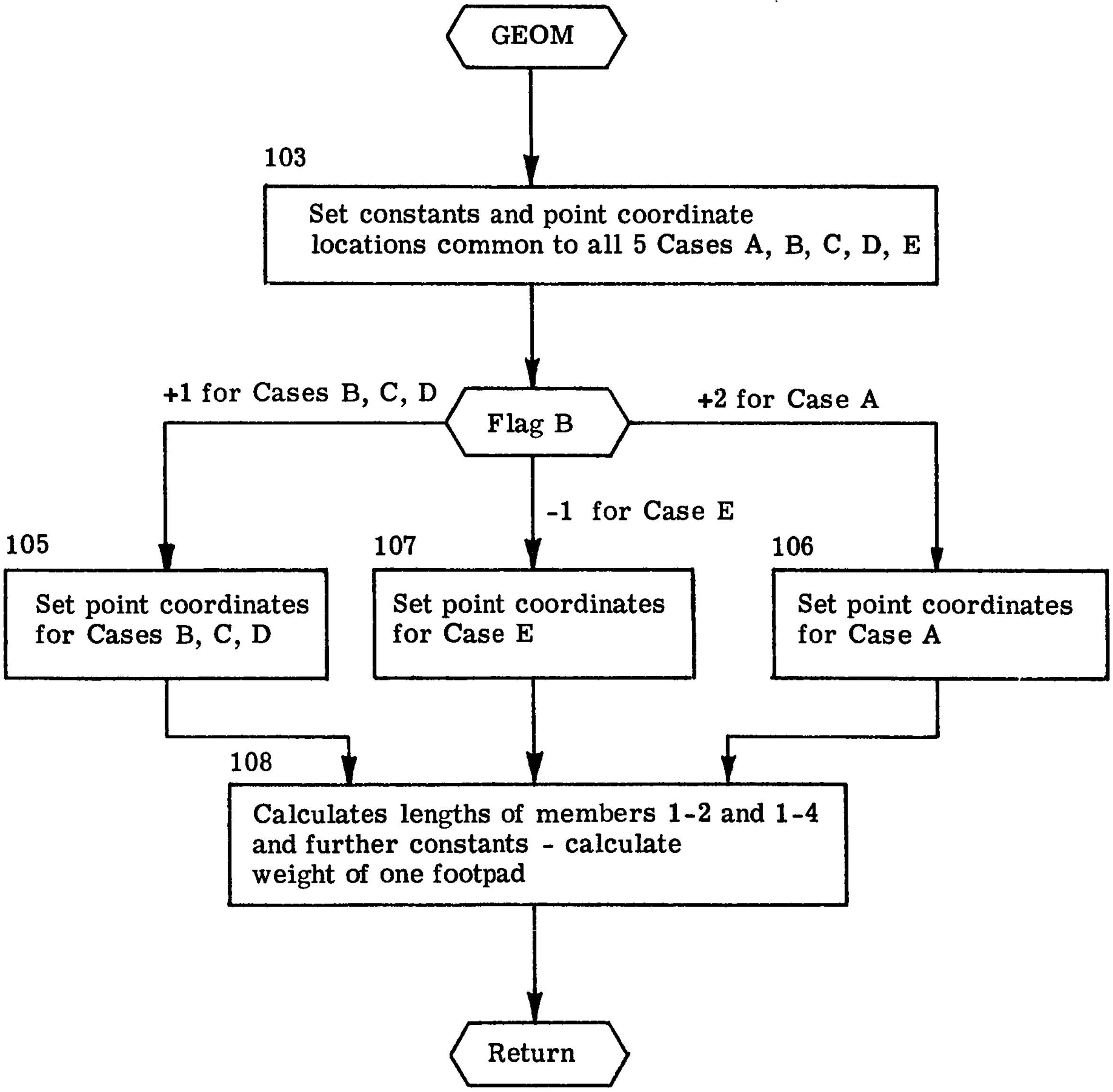


Figure 3-4. Subroutine GEDM

SUBROUTINE: CURVE

This subroutine finds the optimum leg radius and wall thickness to minimize leg weight.

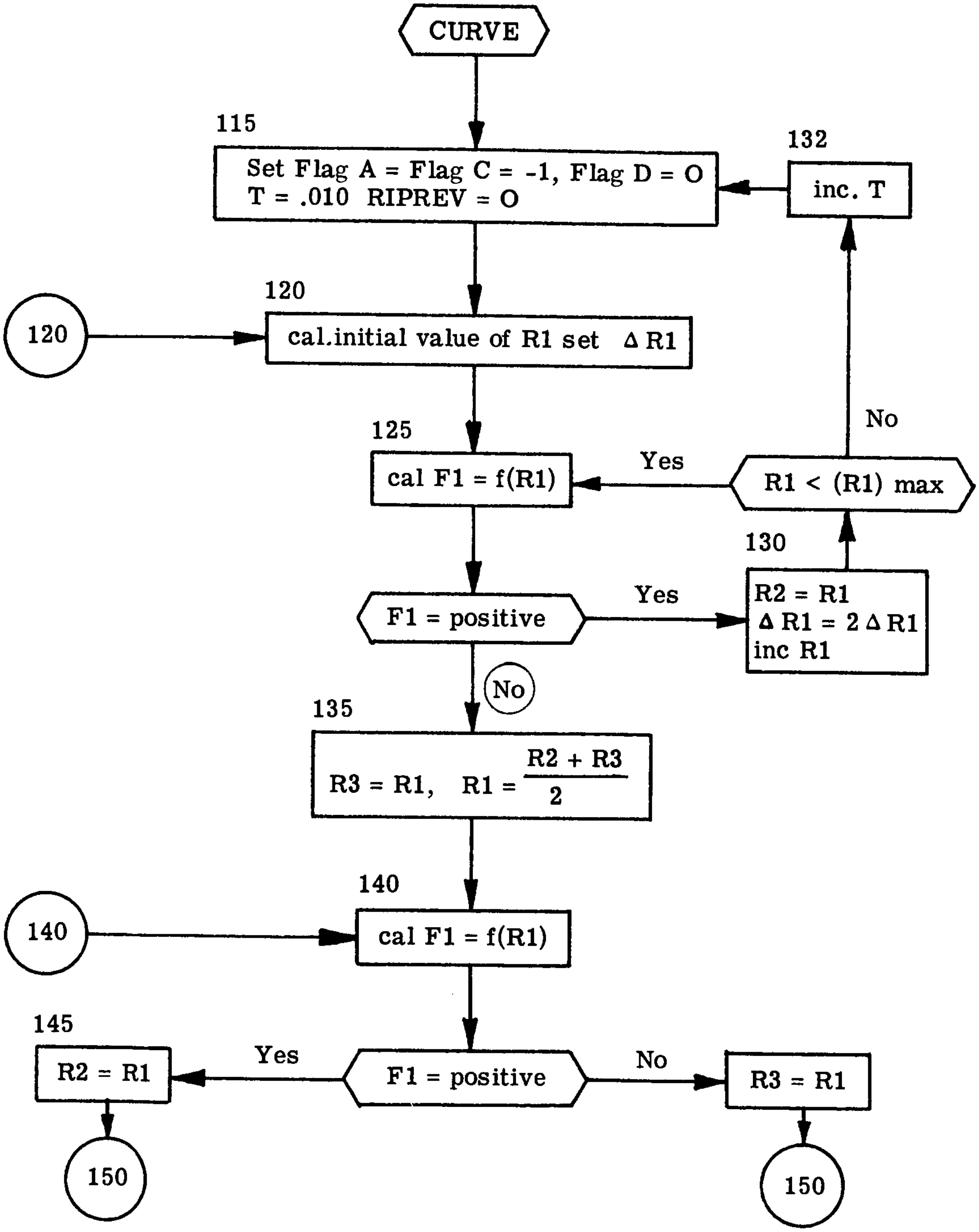


Figure 3-5. Subroutine CURVE

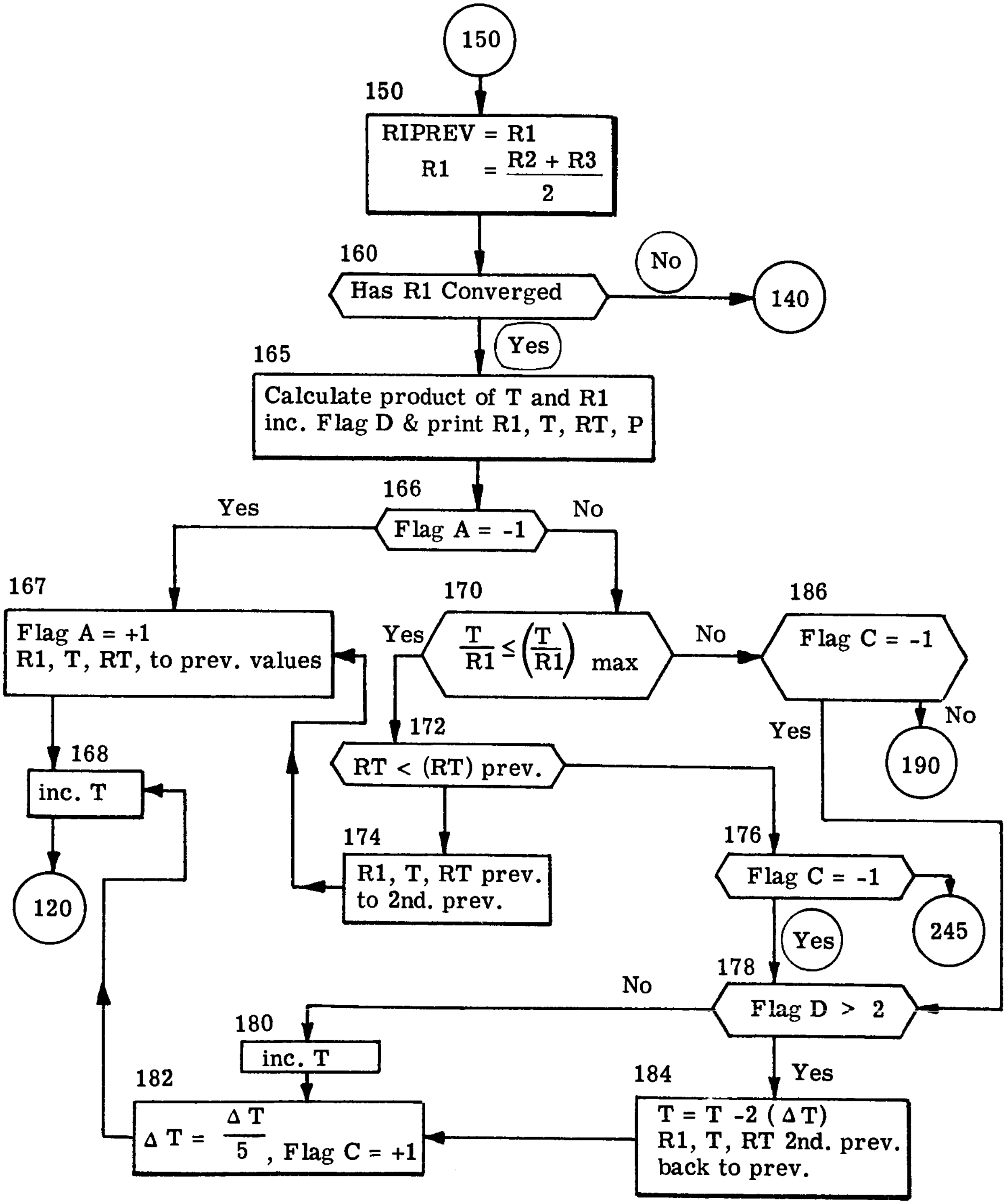


Figure 3-5. Subroutine CURVE (Continued)

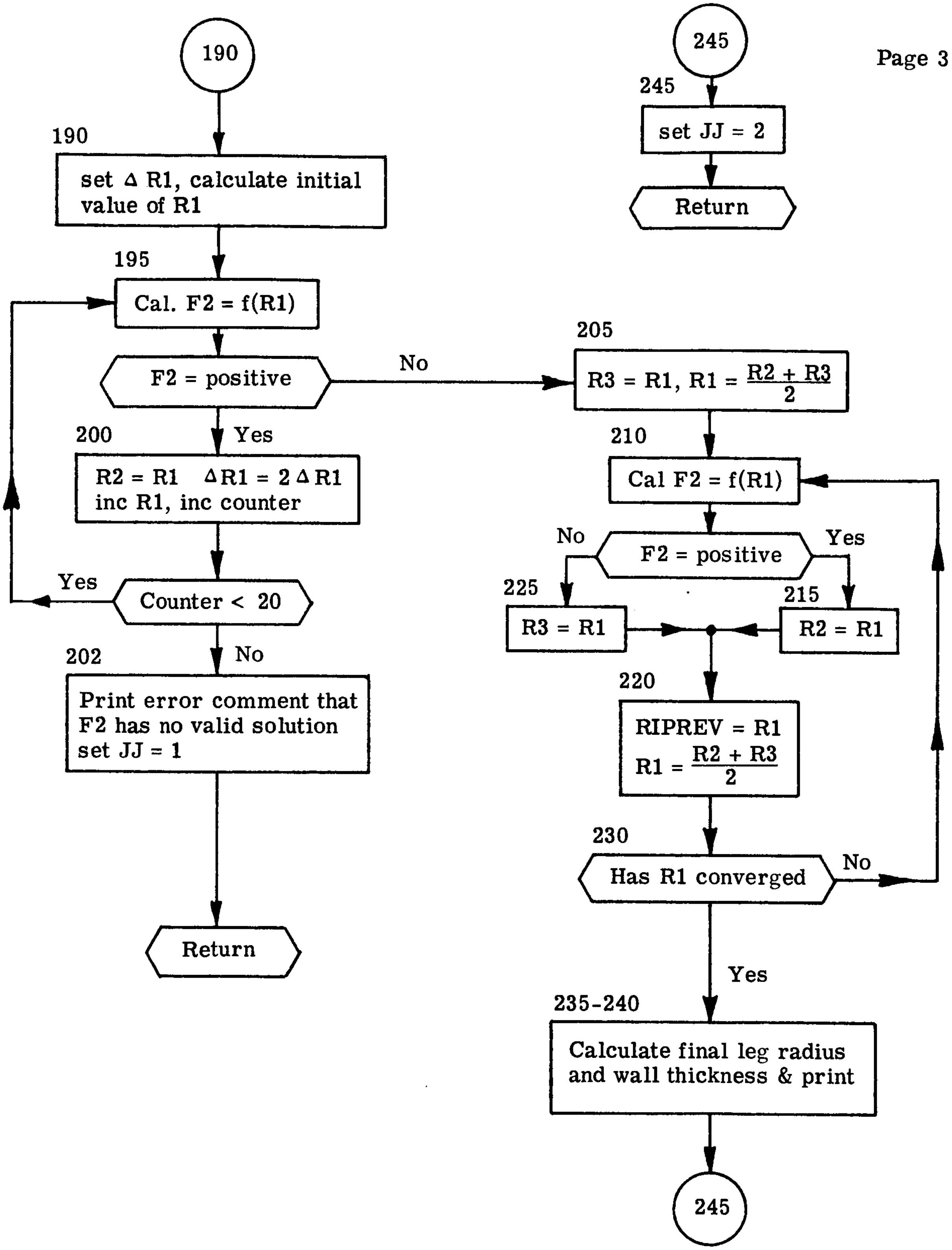


Figure 3-5. Subroutine CURVE (Concluded

This subroutine finds the cosine of the angle between any two leg members. Before entering this subroutine N must be set between 1 and 33 so as to pick up the proper set of 5 nos. in the data table that determines the 2 leg member in question.

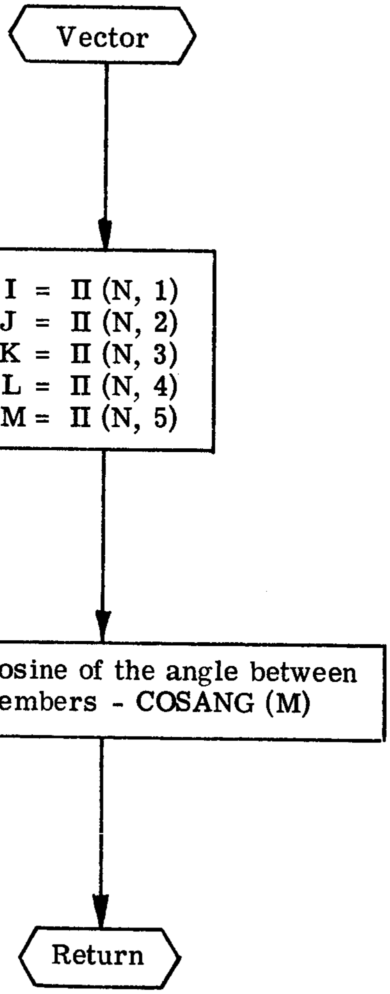


Figure 3-6. Subroutine VECTOR

This subroutine solves a set of simultaneous equilibrium force equations for cases B or C or D. They are solved for forces in members 4-2, 4-8, 2-8, 2-6, 2-5. Sum locations are zeroed before 1st entry.

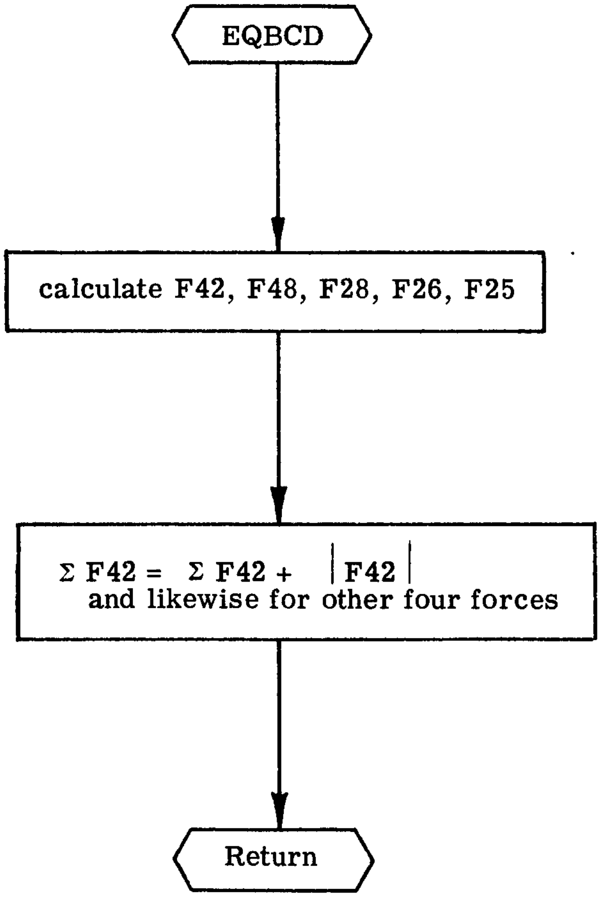


Figure 3-7. Subroutine EQBCD

This subroutine solves a set of simultaneous equilibrium force equations for Case E only. They are solved for forces in members 4-2, 4-8, 2-8, 2-7, 3-5, 2-5, 8-5, 8-10, 8-14, 5-13, and 5-10. The sum locations are zeroed before the 1st entry.

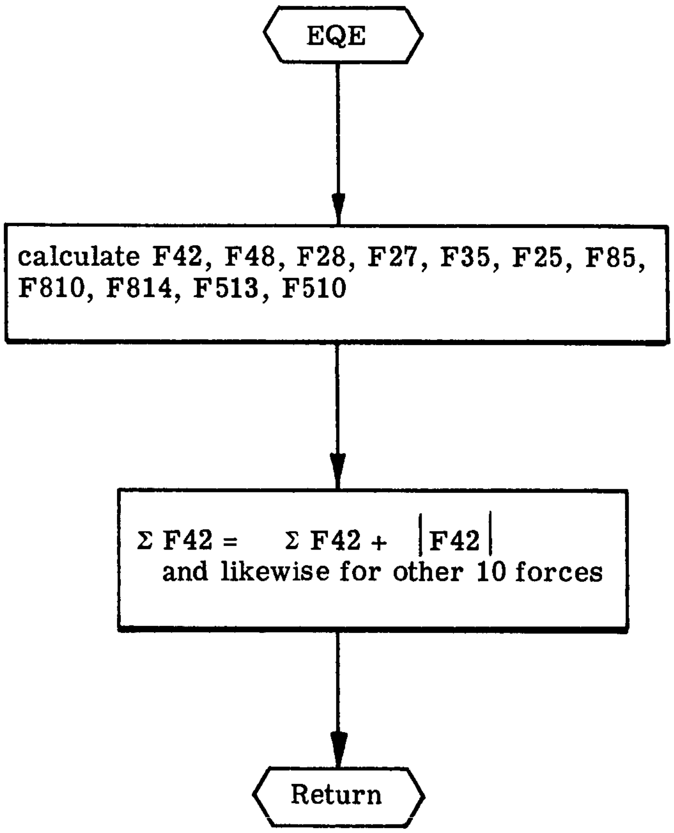


Figure 3-8. Subroutine EQE

```
C
C
C  TITLE OF MAIN PROGRAM     DESIGN OF LEGS TO MINIMIZE WEIGHT
C
C  AUTHOR            H. C. CARR
C
C  DATE              09-1-64
C
C CALL                   LEGWT
C
C  PURPOSE           TO MINIMIZE LEG WEIGHT BASED UPON A GIVEN INPUT
C                    GEOMETRIC CONFIGURATION  AND THEN TO CALULATE TOTAL LEG
C                    WEIGHT INCLUDING WEIGHT OF HONEYCOMB WITHIN EACH LEG
C                    AND THE WEIGHT OF ALL FOUR FOOTPADS.
C
C
C
C                        SEE BENDIX REPORT MM-8-64
C                        SEE FIGURES 3-1, 3-5, 3-9, 3-11, 3-13, 3-14, 3-16
C
C
C                    THIS PROGRAM WILL HANDLE FIVE DIFFERENT LEG TRUSS
C                    DESIGNS AS FOLLOWS.
C
C                CASE      SERIAL NO. RANGE        SEE DRAWING NO     FLAG B
C                 A        22,000 TO 22,999               A              +2.0
C                 B        21,000 TO 21,999               B              +1.0
C                 C        23,000 TO 23,999               C              +1.0
C                 D        24,000 TO 24,999               D              +1.0
C                 E        25,000 TO 25,000               E              -1.0
C
C
C
C
C      INPUT DATA CARD ( ONE CARD ONLY )
C
C      SYMBOL               COLUMNS USED
C
C      SERIAL NO.             1  THRU   10
C      R                      11  THRU  19
C      H                      20  THRU  28
C      ALPHA                  29  THRU  37
C      BETA                   38  THRU  46
C      F(1) = F22             47  THRU  55
C      F(2) = F11             56  THRU  64
C      FLAGB                  65  THRU  72
C
C
C
C      LIST OF SYMBOLS FOLLOWS.              DEFINITIONS
C
C       X(N),Y(N),Z(N)           COORINATE LOCATIONS OF LEG JOINTS
C       FOR N=1 THRU 14
C
C      SERIAL(1)                 INPUT CARD SERIAL NO
C      SERIAL(2)                 INPUT CARD SERIAL NO
C       R                  INPUT GEOMETRIC  DATA - SEE DRAWINGS
C       H                        SAME
C       ALPHA                    SAME  (IN DEGREES)
C       BETA                     SAME  (IN DEGREES)
```

Figure 3-9. Main Program

```
C     F22                               STROKE LOAD IN MEMBER 1-4
C     F11                               STROKE LOAD IN MEMBER 1-2 AND 1-3
C     FLAG B                          DEFINED  ABOVE
C
C
C
C    FURTHER SYMBOLS                             DEFINITIONS
C
C     ALPRD                            ALPHA IN RADIANS
C     BETRD                            BETA  IN RADIANS
C     PHI                              TRUSS  ANGLE - SEE DRAWING FOR CASE NO.
C     RONE                             GEOMETRIC DIMENSION - SEE DRAWING
C     RTWO                             SAME
C     GAMMA                            SAME
C     XL(1)                            LENGTH OF MEMBER 1-2
C     XL(2)                            LENGTH OF MEMBER 1-4
C     PBAR                             VERTICAL REACTION ON THE FOOTPAD
C     A1                               DECELERATION FACTOR
C     A2                               SAME
C     A4                               SAME
C     RBAR                             RADIUS OF FOOTPAD IN INCHES
C     XM(1)                            BEAM MASS
C     XM(2)                            SAME
C     TMIN                             MINIMUM WALL THICKNESS OF LEGS
C     UM1(1)                           ALPRD (SEE ABOVE)
C     UM1(2)                           BETRD (SEE ABOVE)
C     UM2(1)                           ALPRD (SEE ABOVE)
C     UM2(2)                           PI/2 RADIANS
C     XK1 =.65                         DYNAMIC TRANSIENT FACTOR FOR MEMBER 1-2
C     XK2 = 2.0                        SAME  FOR MEMBER 1-4
C
C
C     WFP                              WEIGHT OF ONE FOOTPAD
C
C     FTU(1)                           ULTIMATE TENSILE STRENGTH IN MEMBER 1-2
C     FTU(2)                           SAME IN MEMBER  1-4
C     FTU(3)                           SAME IN MEMBER  1-2
C     DENS                             DENSITY OF MATERIAL
C     E                                MODULUS OF ELASTICITY
C
C     RIPREV                       FINAL RADIUS FOR MEMBERS  1-2 AND 1-4
C     TPREV                        FINAL WALL THICKNESS FOR SAME MEMBERS
C
C     XL(I)                        LENGTH OF MEMBERS  1-2 AND 1-4 FOR I = 1,2
C
C     F(I)                         STROKE LOAD IN MEMBERS 1-2 AND 1-4
C                                  F(I) = F22 FOR I =1  AND F11 FOR I=2
C     XMTOT                        TOTAL STRUT MOMENT
C
C     TRMAX                        MAXIMUM VALUE OF THE QUOTIENT OF WALL
C                                  THICKNESS TO RADIUS
C
C    COSANG(M)                     COSINE OF THE ANGLE BETWEEN TWO VECTORS IN
C                                  SPACE (FOR THE TRUSS LOADINGS)
C
C    R2X,R2Y,R2Z                   THE X,Y,Z COMPONENTS OF THE REACTIONS
C    R4X,R4Y                       AT JOINTS  2 AND 4.
C
C
C    F42,F48,F28,F26,F25               FORCE IN MEMBERS 4-2,4-8,2-8,2-6,2-5
C                                      FOR CASES  B,C,D
```

Figure 3-9. Main Program (Continued)

```
C
C      F27,F35,F25,F85,F610        ADDITIONAL FORCES FOR CASE E ONLY FOR
C      F814,F513,F510,F59          MEMBERS 2-7,3-5,2-5,8-5,6-10,8-14,5-13,
C                                  5-10, AND 5-9.
C
C      SF(I)                       SUM OF THE ABSOLUTE VALUES OF THE ABOVE
C                                  FORCES FOR FIVE DIFFERENT LOADINGS
C
C      WT(I)                       WEIGHT OF MEMBERS 1-2 AND 1-4
C      WHC(I)                      WEIGHT OF HONEYCOMB IN SAME MEMBERS
C      WTTOT                       TOTAL LEG WEIGHT
C      DL(I),I=1,5                 LENGTH OF MEMBERS FOR CASES B,C,D
C      RR                          RADIUS OF SAME MEMBERS
C      XLEN(I),I=1=11              LENGTH OF MEMBERS FOR CASE E ONLY
C      FINWT                       FINAL TOTAL WEIGHT INCLUDING ALL MEMBERS,
C                                  HONEYCOMB,AND FOOTPADS OF ALL 4 LEGS.
C      WTT(I),I=1,5                WEIGHT OF FIVE MEMBERS   (CASES B,C,D)
C      WTTT(I),I=1,11              WEIGHT OF ELEVEN MEMBERS (CASE E)
C
       DIMENSION L2(2), L3(5), L4(11)
       DATA (L2(I),I=1,2) /  3H1-2,3H1-4 /
       DATA (L3(I),I=1,5) /  3H4-2,3H4-8,3H2-8,3H2-6,3H2-5 /
       DATA (L4(I),I=1,11) / 3H4-2,3H4-8,3H2-8,3H2-7,3H2-5,3H8-5,4H8-10,
      14H8-14,4H5-13,4H5-10,3H5-9 /
       DIMENSION II(33,5)
       COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
       COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
      1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
       COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
      1RTPREV,JJ,J,K,L,M,COSANG(30)
       COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
      1F610,F814,F513,F510,F59,SF(30),II
       COMMON/S5/WTT(14),WTTT(11),WT(2),WHC(2),DL(14),XLEN(11)
       COMMON/S6/N
       COMMON/S7/ALPRD,BETRD
C
C
C              THE FOLLOWING DATA STATEMENT CONTAINS ALL THE JOINT
C              ENDPOINT NOS. REQUIRED TO CALCULATE THE COSINE OF THE
C              ANGLE BETWEEN ALL THE NECESSARY MEMBERS FOR ALL FIVE
C              CONFIGURATIONS.
C
C              A SET OF FIVE NOS. IS REQUIRED FOR EACH CALCULATION IN
C              THE SUBROUTINE VECTOR.   THE FIRST SET (2.4,4,8,1 ) FOR
C              EXAMPLE MEANS  --- THE ANGLE BETWEEN MEMBERS 2-4 AND 4-6
C              AND STORE IT AS COSANG(1)
C
       DATA((II(N,M),M=1,5),N=1,33)/2,4,4,8,1,8,2,2,5,2,6,2,2,5,3,4,2,2,
      15,4,4,2,27,29,5,8,2,27,29,6,4,2,27,30,7,8,2,27,30,8,6,2,27,30,9,7,
      22,27,30,10,7,2,2,5,11,5,8,27,29,12,10,8,27,29,13,2,8,8,4,14,10,8,2
      3 7,28,15,14,8,27,28,16,13,5,27,29,17,3,5,5,7,18,8,5,5,7,19,13,5,5,
      47,20,10,5,5,7,21,3,5,27,28,22,10,5,5,9,23,13,5,5,9,24,2,4,4,8,1,
      58,2,2,5,2,6,2,2,5,3,4,2,2,5,4,4,2,27,29,5,8,2,27,29,6,4,2,27,30,7,
      68,2,27,30,8,6,2,27,30,9/
C
C               CALL  SUBROUTINE (INPUT)  WHICH READS ONE DATA CARD
C               AND THEN PRINTS  THIS DATA.
C
C
  100 CALL  INPUT
C
```

Figure 3-9. Main Program (Continued)

```
C                 THE NEXT SUBROUTINE  (GEOM)  SETS UP INITIAL VALUES,
C                 CALCULATES GEOMETRIC CONSTANTS FOR LEG CONFIGURATION
C                 CASE A OR B OR C OR D OR E, CALCULATES LENGTH OF MEMBER
C                 1-2 AND 1-4  AND CALCULATES WEIGHT OF ONE FOOTPAD
C
C

  102 CALL GEOM
  110 DO 255 I=1,2,1
      PRINT 902
      T=0.025
      TRMAX=FTU(I)/(.15*E)
      XM1=XM(I)/12.0*(12.0*XL(I))**2/16.0*(A1+A2)*COS(UM1(I))*XK2
      IF (I-2) 113,112,112
  112 XMTOT=XM1
      GO TO 114
  113 UU=ATAN(5.0/(R-(RTWO*COS(PHI))))
      SINLAM=(H-7.575)/XL(I)
      COSLAM=5.0/(XL(I)*SIN(UU))
      XM2=0.20/3.1416*PBAR*RBAR*COSLAM*(TAN(GAMMA)+1.0/TAN(GAMMA))*XK2
      XMY2=0.60*RBAR/(3.0*3.1416)*PBAR*SINLAM*XK2
      ETA=ATAN((XM1+XM2)/XMY2)
      XMTOT=(XM1+XM2)/SIN(ETA)
      GO TO 114
C
C                 THE NEXT SUBROUTINE ( RTMIN)  FINDS THE  OPTIMUM LEG
C                 RADIUS  R1 = RIPREV  AND WALL THICKNESS  T = TPREV
C
C

  114 CALL CURVE
      GO TO (100,250),JJ
C
C
C                 NOW CALCULATE WEIGHT  OF LEG  (1-2 FOR I=1 AND 1-4 FOR
C                 I=2), WEIGHT OF  HONEYCOMB  AND PRINT  WEIGHT OF LEG,
C                 LENGTH, RADIUS =RIPREV , WALL THICKNESS = TPREV
C
C

  250 WT(I)=(DENS)*2.0*R1PREV*TPREV*12.0*XL(I)*3.1416
      WHC(I)=1.0*3.1416*R1PREV*R1PREV/1728.0*0.45*12.0*XL(I)/0.75/127.3
     1*(F(I)/(1.0*3.1416*R1PREV*R1PREV)+300.0)
      PRINT 930,L2(I)
  255 PRINT 904,WT(I),XL(I),R1PREV,TPREV,P
C
C                 NOW IF THIS IS A CASE A  RUN  THEN  PRINT TOTAL LEG
C                 WEIGHT AND  THEN GO TO 100 TO READ NEXT DATA CARD
C                 CASE A HAS NO  TRUSS  STRUCTURE
C
C                 DUE TO SYMMETRY THERE ARE 8 MEMBERS LIKE 1-2 AND 4
C                 MEMBERS LIKE  1-4  INCLUDING ALL FOUR LEGS
C
C
C                 FOR  CASES B,C,D,E, GO ON TO PART TWO  TO CALCULATE
C                 THE TRUSS LOADS  AND LEG SIZES
C

  260 IF (FLAGB-2.) 300,265,265
  265 WTTOT=8.0*WT(1)+4.0*WT(2)
      PRINT 907,WTTOT
      FINWT=WTTOT+4.0*WFP+4.0*WHC(2)+8.0*WHC(1)
      PRINT 908,FINWT,WFP,WHC(1),WHC(2)
      PRINT 1500
  907 FORMAT(24H0      TOTAL LEG WEIGHT =,F10.5/)
```

Figure 3-9. Main Program (Continued)

```
  908 FORMAT(6H0 FINWT=,F10.5,7H  WFP =,F10.5,9H  WHC(1)=,F10.5,6H WHC(2
     1)=,F10.5//)
 1500 FORMAT(1H1)
      GO TO 100
C
C     SETUP  POINTS 27,28,29,30 TO GIVE UNIT  VECTORS
C
  300 X(27)=0.0
      Y(27)=0.0
      Z(27)=0.0
      X(28)=1.0
      Y(28)=0.0
      Z(28)=0.0
      X(29)=0.0
      Y(29)=1.0
      Z(29)=0.0
      X(30)=0.0
      Y(30)=0.0
      Z(30)=1.0
C
C
C                                      MEMBER     SYMBOL
C     CALCULATE LEG LENGTHS             4-2   =   DL(1)
C     FOR CASES B OR C OR D.            4-8   =   DL(2)
C                                       2-8   =   DL(3)
C                                       2-6   =   DL(4)
C                                       2-5   =   DL(5)
C
  305 DL(1)=SQRT((X(4)-X(2))**2+(Y(4)-Y(2))**2+(Z(4)-Z(2))**2)
      DL(2)=SQRT((X(4)-X(8))**2+(Y(4)-Y(8))**2+(Z(4)-Z(8))**2)
      DL(3)=SQRT((X(2)-X(8))**2+(Y(2)-Y(8))**2+(Z(2)-Z(8))**2)
      DL(4)=SQRT((X(2)-X(6))**2+(Y(2)-Y(6))**2+(Z(2)-Z(6))**2)
      DL(5)=SQRT((X(2)-X(5))**2+(Y(2)-Y(5))**2+(Z(2)-Z(5))**2)
C
C     NOW CALCULATE  THE COSINE OF THE ANGLE  BETWEEN  9 PAIRS OF
C     VECTORS IN SPACE (LEG MEMBERS)
C
  310 N=1
      CALL VECTOR
      N=2
      CALL VECTOR
      N=3
      CALL VECTOR
      N=4
      CALL VECTOR
      N=5
      CALL VECTOR
      N=6
      CALL VECTOR
      N=7
      CALL VECTOR
      N=8
      CALL VECTOR
      N=9
      CALL VECTOR
C
C     SET  20 LOCATIONS FOR SUM OF FORCES   SF(N) EQUAL TO ZERO
C     FOR CASES B,C,D THE SUM SF(N) FOR N=1 THRU 5  EQUALS FORCES F42,
C     F48, F28, F26, F25  FOR LEG MEMBERS  4-2, 4-8, 2-8, 2-6, AND 2-5
C
C     FOR CASE E  THE SUM  SF(N)  FOR N=1  THRU 11  EQUALS FORCES
```

Figure 3-9. Main Program (Continued)

```
C      F42, F48, F28 , F27, F35, F25, F65, F810, F814, F513, F510, F59
C      FOR LEG MEMBERS 4-2, 4-8, 2-8, 2-7, 3-5, 2-5, 6-5, 8-10, 8-14,
C      5-13, 5-10, 5-9  RESPECTIVELY
C
C      THESE  FORCES ARE  THEN  SUMMED  FOR  5  DIFFERENT  LOADINGS
C      ON  THE  TRUSS.
C
  315 DO 320 I=1,20,1
  320 SF(I)=0.0
C
C
C         FLAG B EQUAL TO  -1 IMPLIES  CASE E  ONLY
C
  323 IF (FLAGB) 500,500,325
C
C      NOW  CALCULATE THE  X,Y,Z  COMPONENTS OF REACTIONS R2X,R2Y,R2Z,
C      R4X, AND R4Y  FOR   JOINTS  TWO  AND FOUR  FOR  LOADINGS (1) UPPER
C      LEG STROKE, (2) UPPER LEG BEAM ACTION, (3) LOWER LEG STROKES,
C      (4) LOWER LEG BEAM ACTION, AND (5)  ECCENTRIC  IMPACT  AND THEN
C      ENTER   SUBROUTINE  EQBCD   TO  CALULATE  SUM OF  FORCES
C
C
  325 R2X=0.0
      R2Y=0.0
      R2Z=0.0
      R4X=-F(2)*COS(BETRD)
      R4Y=F(2)*SIN(BETRD)
      CALL EQBCD
  330 R2X=0.0
      R2Y=0.0
      R2Z=0.0
      R4X = -XM(2)*XL(2)*COS(BETRD)*SIN(BETRD)*XK2/3.0*(A1/2.0+A4)
      R4Y = -XM(2)*XL(2)*(COS(BETRD))**2*XK2/3.0*(A1/2.0+A4)
      CALL EQBCD
  335 R4X=0.0
      R4Y=0.0
      R2X=-F(1)*COS(ALPRD)*COS(GAMMA)
      R2Y=F(1)*COS(GAMMA)*SIN(ALPRD)
      R2Z=F(1)*COS(ALPRD)*SIN(GAMMA)
      CALL EQBCD
  340 R4X=0.0
      R4Y=0.0
      R2Z=0.0
      R2X = -XM(1)*XL(1)*COS(ALPRD)*SIN(ALPRD)*XK2/3.0*(A1/2.0+A2)
      R2Y = -XM(1)*XL(1)*(COS(ALPRD))**2*XK2/3.0*(A1/2.0+A2)
      CALL EQBCD
  345 R4X=0.0
      R4Y=0.0
      R2Z=0.0
      R2X=PBAR*RBAR/(2.0*12.0*XL(1))*(COS(ALPRD)*SIN(ALPRD)*(TAN(GAMMA)+
     11.0/(TAN(GAMMA)))*XK2)
      R2Y=PBAR*RBAR/(2.0*12.0*XL(1))*((COS(ALPRD))**2*(TAN(GAMMA)+
     11.0/(TAN(GAMMA)))*XK2)
      CALL EQBCD
C
C         THIS SUM OF FORCES FOR EACH MEMBER  4-2, 4-8, 2-8, 2-6, AND
C         2-5  IS NOW USED  TO  DESIGN EACH MEMBER  BY  EQUATING
C         ULTIMATE  STRESS  TO  LOCAL BUCKLING  ALLOWABLE  STRESS TO
C         FIND  WALL  THICKNESS  T   AND  RADIUS RR
C
C
```

Figure 3-9. Main Program (Continued)

```
 350 DO 385 I=1,5,1
     RTMIN=1.5*SF(I)/(2.0*3.1416*FTU(3))
     TMIN=SQRT(1.5*SF(I)/(.30*3.1416*E))
 355 IF (TMIN-.025) 360,365,365
 360 TMIN=.025
 365 RR=((1.5*SF(I)*(12.0*DL(I))**2)/(E*TMIN*(3.1416)**3))**(1.0/3.0)
 370 IF (RR*TMIN-RTMIN) 375,380,380
 375 TPRIME=RTMIN/RR
     TMIN=TPRIME
C
C            NOW CALCULATE AND PRINT WEIGHT OF MEMBER, FORCE IN MEMBER,
C            LENGTH, RADIUS, AND WALL THICKNESS FOR THE FIVE TIMES THRU
C            THE DO LOOP.
C            CALCULATE AND PRINT  TOTAL LEG WEIGHT (DUE TO SYMMETRY
C            MEMBER 2-5 = 3-7, 2-6 = 3-6, AND 2-8 = 3-8) OF ALL FOUR LEGS.
C            THEN PRINT FINAL WEIGHT INCLUDING TOTAL LEG WEIGHT, TOTAL
C            HONEYCOMP WEIGHT, AND FOOTPAD WEIGHT
C
 380 WTT(I)=DENS*2.0*3.1416*RR*TMIN*12.0*DL(I)
     PRINT 930,L3(I)
 385 PRINT 906,WTT(I),SF(I),DL(I),RR,TMIN
 390 WTTOT=4.0*(2.0*(WT(1)+WTT(1)+WTT(3)+WTT(4)+WTT(5))+WT(2)+WTT(2))
 391 PRINT 907,WTTOT
     FINWT=WTTOT+4.0*(WFP+WHC(2)+2.0*WHC(1))
     PRINT 908,FINWT,WFP,WHC(1),WHC(2)
     PRINT 1500
 400 GO TO 100
C
C
C      CALCULATE  MEMBER LENGTHS FOR  CASE E MEMBERS ONLY
C                        MEMBER         SYMBOL
C
C                        4-2             XLEN(1)
C                        4-8             XLEN(2)
C                        2-8             XLEN(3)
C                        2-7             XLEN(4)
C                        2-5             XLEN(5)
C                        8-5             XLEN(6)
C                        8-10            XLEN(7)
C                        8-14            XLEN(8)
C                        5-13            XLEN(9)
C                        5-10            XLEN(10)
C                        5-9             XLEN(11)
C
 500 XLEN(1)=SQRT((X(4)-X(2))**2+(Y(4)-Y(2))**2+(Z(4)-Z(2))**2)
     XLEN(2)=SQRT((X(4)-X(8))**2+(Y(4)-Y(8))**2+(Z(4)-Z(8))**2)
     XLEN(3)=SQRT((X(2)-X(8))**2+(Y(2)-Y(8))**2+(Z(2)-Z(8))**2)
     XLEN(4)=SQRT((X(2)-X(7))**2+(Y(2)-Y(7))**2+(Z(2)-Z(7))**2)
     XLEN(5)=SQRT((X(2)-X(5))**2+(Y(2)-Y(5))**2+(Z(2)-Z(5))**2)
     XLEN(6)=SQRT((X(8)-X(5))**2+(Y(8)-Y(5))**2+(Z(8)-Z(5))**2)
     XLEN(11)=SQRT((X(5)-X(9))**2+(Y(5)-Y(9))**2+(Z(5)-Z(9))**2)
     XLEN(7)=SQRT((X(8)-X(10))**2+(Y(8)-Y(10))**2+(Z(8)-Z(10))**2)
     XLEN(8)=SQRT((X(8)-X(14))**2+(Y(8)-Y(14))**2+(Z(8)-Z(14))**2)
     XLEN(9)=SQRT((X(5)-X(13))**2+(Y(5)-Y(13))**2+(Z(5)-Z(13))**2)
     XLEN(10)=SQRT((X(5)-X(10))**2+(Y(5)-Y(10))**2+(Z(5)-Z(10))**2)
C
C            NOW CALCULATE THE COSINE OF THE ANGLE BETWEEN 11 PAIRS  OF
C
C
C            VECTORS (LEG MEMBERS) IN SPACE.
 505 N=10
```

Figure 3-9. Main Program (Continued)

```
      CALL VECTOR
      N=11
      CALL VECTOR
      N=12
      CALL VECTOR
      N=13
      CALL VECTOR
      N=14
      CALL VECTOR
      N=15
      CALL VECTOR
      N = 16
      CALL VECTOR
      N=17
      CALL VECTOR
      N=18
      CALL VECTOR
      N = 19
      CALL VECTOR
      N=20
      CALL VECTOR
      N=21
      CALL VECTOR
      N=22
      CALL VECTOR
      N=23
      CALL VECTOR
      N=24
      CALL VECTOR
      N=25
      CALL VECTOR
      N=26
      CALL VECTOR
      N=27
      CALL VECTOR
      N=28
      CALL VECTOR
      N=29
      CALL VECTOR
      N=30
      CALL VECTOR
      N=31
      CALL VECTOR
      N=32
      CALL VECTOR
      N=33
      CALL VECTOR
C
C
C
C     NOW  CALCULATE THE  X,Y,Z  COMPONENTS OF REACTIONS R2X,R2Y,R2Z,
C     R4X, AND R4Y  FOR   JOINTS  TWO  AND FOUR  FOR  LOADINGS (1) UPPER
C     LEG STROKE, (2) UPPER LEG BEAM ACTION, (3) LOWER LEG STROKES,
C     (4) LOWER LEG BEAM ACTION, AND (5)  ECCENTRIC  IMPACT  AND THEN
C     ENTER   SUBROUTINE  EQBCD   TO  CALULATE  SUM OF  FORCES
C
C
C
  510 R2X=0.0
      R2Y=0.0
      R2Z=0.0
```

Figure 3-9. Main Program (Continued)

```
      R4X=-F(2)*COS(BETRD)
      R4Y=F(2)*SIN(BETRD)
      CALL EQE
  515 R2X=0.0
      R2Y=0.0
      R2Z=0.0
      R4X = -XM(2)*XL(2)*COS(BETRD)*SIN(BETRD)*XK2/3.0*(A1/2.0+A4)
      R4Y = -XM(2)*XL(2)*(COS(BETRD))**2*XK2/3.0*(A1/2.0+A4)
      CALL EQE
  520 R4X=0.0
      R4Y=0.0
      R2X=-F(1)*COS(ALPRD)*COS(GAMMA)
      R2Y=F(1)*COS(GAMMA)*SIN(ALPRD)
      R2Z=F(1)*COS(ALPRD)*SIN(GAMMA)
      CALL EQE
  525 R4X=0.0
      R4Y=0.0
      R2Z=0.0
      R2X = -XM(1)*XL(1)*COS(ALPRD)*SIN(ALPRD)*XK2/3.0*(A1/2.0+A2)
      R2Y = -XM(1)*XL(1)*(COS(ALPRD))**2*XK2/3.0*(A1/2.0+A2)
      CALL EQE
  530 R4X=0.0
      R4Y=0.0
      R2Z=0.0
      R2X=PBAR*RBAR/(2.0*12.0*XL(1))*(COS(ALPRD)*SIN(ALPRD)*(TAN(GAMMA)+
     11.0/(TAN(GAMMA)))*XK2)
      R2Y=PBAR*RBAR/(2.0*12.0*XL(1))*((COS(ALPRD))**2*(TAN(GAMMA)+
     11.0/(TAN(GAMMA)))*XK2)
      CALL EQE
C
C           THIS SUM OF FORCES FOR EACH MEMBER  4-2,4-8, 2-8, 2-7, 2-5,
C           8-5, 8-10, 8-14, 5-13, 5-10, AND  5-9  IS NOW USED TO DESIGN
C           EACH MEMBER BY EQUATING ULTIMATE STRESS TO LOCAL BUCKLING
C           ALLOWABLE STRESS TO FIND WALL THICKNESS  T AND RADIUS RR
C
  540 DO 575 I=1,11,1
      J=I+5
      RTMIN=1.5*SF(J)/(2.0*3.1416*FTU(3))
      TMIN=SQRT(1.5*SF(J)/(.30*3.1416*E))
  545 IF (TMIN-.025) 550,555,555
  550 TMIN=.025
  555 RR=((1.5*SF(J)*(12.0*XLEN(I))**2)/(E*TMIN*(3.1416)**3))**(1.0/3.)
  560 IF (RR*TMIN-RTMIN) 565,570,570
  565 TPRIME=RTMIN/RR
      TMIN=TPRIME
C
C           NOW  CALCULATE AND PRINT WEIGHT OF MEMBER, FORCE IN MEMBER,
C           LENGTH, RADIUS, AND WALL THICKNESS FOR EACH OF THE ELEVEN
C           TIMES THRU THIS DO LOOP.
C
C           CALCULATE AND PRINT TOTAL LEG WEIGHT OF ALL FOUR LEGS. THEN
C           PRINT  FINAL WEIGHT INCLUDING TOTAL LEG WEIGHT, TOTAL
C           HONEYCOMB WEIGHT, AND TOTAL FOOTPAD WEIGHT
C
C
  570 WTTT(I)=DENS*2.0*3.1416*RR*TMIN*12.0*XLEN(I)
      PRINT 930,L4(I)
  575 PRINT 906,WTTT(I),SF(J),XLEN(I),RR,TMIN
  580 WTTOT=4.0*(2.0*(WT(1)+WTTT(1)+WTTT(3)+WTTT(5)+WTTT(4)+WTTT(6)+
     1WTTT(11)+WTTT(10)+WTTT(9)+WTTT(8))+WT(2)+WTTT(2)+WTTT(7))
  585 PRINT 907,WTTOT
```

Figure 3-9. Main Program (Continued)

```
      FINWT=WTTOT+4.0*(WFP+WHC(2)+2.0*WHC(1))
      PRINT 908,FINWT,WFP,WHC(1),WHC(2)
      PRINT 1500
  590 GO TO 100
 1001 FORMAT(6F20.10)
  900 FORMAT(A6,A4,F9.5,F9.5,F9.5,F9.5,F9.1,F9.1,F7.1)
  901 FORMAT(5H    R=,F9.5,4X,2HH=,F8.4,4X,6HALPHA=,F7.3,4X,5HBETA=,F7.3,
     14X,4HF22=,F7.1,4X,4HF11=,F7.1,4X,6HFLAGB=,F4.1,4X,8HDENSITY=,F8.4/
     2/)
  902 FORMAT(44H           R1           T                   RT            P/)
  903 FORMAT(F12.5,F11.5,F13.5,F12.5)
  904 FORMAT(10H0  WEIGHT=,F10.5,12H      LENGTH=,F9.5,10H    R1PREV=,F9.5
     1,10H     TPREV=,F9.5,7H     P=,F9.5///)
  906 FORMAT(10H   WEIGHT=,F10.5,11H      FORCE=,F8.1,12H      LENGTH=,F9.
     15,7H      R=,F9.5,10H      TMIN=,F9.5)
  909 FORMAT(5X,8HFUNCTION,2X,3HNOT,2X,8HNEGATIVE,2X,3HYET)
  910 FORMAT(13H  SERIAL NO =,A6,A4//)
  930 FORMAT(6H0  LEG,2X,A6)
      END
```

Figure 3-9. Main Program (Concluded)

```
C
C
C  TITLE OF SUBROUTINE.         INPUT
C  AUTHOR         H. C. CARR
C
C  DATE           09-1-64
C
C  CALL           INPUT
C
C  PURPOSE        TO READ ONE DATA CARD AND THEN INITIALIZE MATERIAL
C                 CONSTANTS FTU(1),FTU(2),FTU(3),E, AND DENSITY (THESE
C                 FIVE CONSTANTS MUST BE CHANGED FOR DIFFERENT MATERIALS
C                 SUCH AS ALUMINUM,BERYLLIUM,ETC.) AND THEN PRINT THE
C                 DATA CARD
C
C
C       SYMBOLS                       DEFINITION OF INPUT DATA
C
C      SERIAL(1)                 SERIAL NO OF DATA
C      SERIAL(2)                 SAME
C      R                         GEOMETRIC PARAMETER
C      H                         SAME
C      ALPHA                     SAME  ( IN DEGREES)
C      BETA                      SAME  ( IN DEGREES)
C      F(1)                 F22= STROKE LOAD IN MEMBER  1-4
C      F(2)                 F11= STROKE LOAD IN MEMBER  1-2 AND 1-3
C      FLAGB                     FLAG B DEFINES THE LEG CONFIGURATION
C                                IN QUESTION. FOR CASES B,C,D FLAG B =+1.0
C                                FOR CASE A  FLAG B = +2.0
C                                FOR CASE E  FLAG B = -1.0
C
C
C     OTHER  SYMBOLS                  DEFINITION
C
C     FTU(1)                     ULTIMATE TENSILE STRENGTH IN MEMBER 1-2
C     FTU(2)                     SAME IN MEMBER  1-4
C     FTU(3)                     REPEAT OF MEMBER 1-2
C     DENS                       DENSITY OF MATERIAL
C     E                          MODULUS OF ELASTICITY
C
C
C
C
C
      SUBROUTINE  INPUT
      COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
      COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
     1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
      COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
     1RTPREV,JJ,J,K,L,M,COSANG(30)
      COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
     1F810,F814,F513,F510,F59,SF(30),II
      COMMON/S5/WTT(14),WTTT(11),WT(2),WHC(2),DL(14),XLEN(11)
      COMMON/S7/ALPRD,BETRD
  101 READ 900,SERIAL(1),SERIAL(2),R,H,ALPHA,BETA,(F(I),I=1,2),FLAGB
      FTU(1) = 61500.0
      FTU(2) = 53000.0
      FTU(3) = 61500.0
      E = 10000000.
```

Figure 3-10. Subroutine INPUT

```
      DENS = .102
      PRINT 910, SERIAL(1),SERIAL(2)
      PRINT 901,R,H,ALPHA,BETA,(F(I),I=1,2),FLAGB,DENS
  900 FORMAT(A6,A4,4F9.5,F9.1,F9.1,F7.1)
  901 FORMAT(5H    R=,F9.5,4X,2HH=,F8.4,4X,6HALPHA=,F7.3,4X,5HBETA=,F7.3,
     14X,4HF22=,F7.1,4X,4HF11=,F7.1,4X,6HFLAGB=,F4.1,4X,8HDENSITY=,F8.4/
     2/)
  910 FORMAT(13H  SERIAL NO =,A6,A4//)
      RETURN
      END
```

Figure 3-10. Subroutine INPUT (Concluded)

```
C
C TITLE OF SUBROUTINE       GEOM
C
C AUTHOR               H. O. CARR
C
C CALL                 GEOM
C
C
C PURPOSE              TO INITIALIZE GEOMETRIC CONSTANTS FOR CASE A OR B
C                      OR C OR D OR E.
C
C                      TO CALCULATE LENGTH OF MEMBERS 1-2 AND 1-4
C                      TO CALCULATE WEIGHT OF ONE  FOOTPAD
C
C
C       SYMBOLS                                  DEFINITIONS
C
C      X(N),Y(N),Z(N)              COORDINATE  LOCATIONS OF LEG JOINTS
C      FOR N=1 THRU 14
C      ALPRD               ALPHA IN RADIANS
C      BETRD               BETA  IN RADIANS
C      PHI                 TRUSS ANGLE - SEE DRAWING  FOR CASE NO.
C      RONE                GEOMETRIC DIMENSION  - SEE DRAWING
C      RTWO                SAME
C      GAMMA               SAME
C
C      XL(1)               LENGTH OF MEMBER  1-2
C      XL(2)               LENGTH OF MEMBER  1-4
C
C      PBAR                VERTICAL REACTION ON THE FOOTPAD
C
C      A1                  DECELERATION FACTOR
C      A2                  SAME
C      A4                  SAME
C
C      RBAR                RADIUS OF FOOTPAD
C      XM(1)               BEAM MASS
C      XM(2)               SAME
C      TMIN                MINIMUM WALL THICKNESS OF LEGS
C
C      UM1(1)              ALPRD
C      UM1(2)              BETRD
C      UM2(1)              ALPRD
C      UM2(2)              PI/2 RADIANS
C
C      XK1                 DYNAMIC  TRANSIENT FACTOR FOR MEMBER  1-2
C      XK2                 SAME  FOR MEMBER  1-4
C
C      WFP                 WEIGHT OF FOOTPAD
C
C
C
C
C
      SUBROUTINE GEOM
      COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
      COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
     1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
      COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
```

Figure 3-11. Subroutine GEOM

```
     1RTPREV,JJ,J,K,L,M,COSANG(30)
      COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
     1F810,F814,F513,F510,F59,SF(30),II
      COMMON/S5/WTT(14),WTTT(11),WT(2),WHC(2),DL(14),XLEN(11)
      COMMON/S7/ALPRD,BETRD
C
C     THE FOLLOWING GEOMETRY IS THE SAME FOR CASES A,B,C,D,E
C
  103 X(1) = R
      Y(1) = .250-H
      Z(1) = 0.0
      ALPRD =ALPHA*3.1416/180.0
      BETRD = BETA*3.1416/180.0
      PHI   = ATAN(5.00/(R-COS(ALPRD)/SIN(ALPRD)*(H-7.575)))
      RONE = R-(H-2.165)*COS(BETRD)/SIN(BETRD)
      RTWO = (R-(H-7.575)*COS(ALPRD)/SIN(ALPRD))/COS(PHI)
      X(2) = RTWO*COS(PHI)
      Y(2) = -7.325
      Z(2) = 5.0
      X(3) = RTWO*COS(PHI)
      Y(3) = -7.325
      Z(3) = -5.0
      X(4) = RONE
      Y(4) = -1.915
      Z(4) = 0.0
      X(6) = 7.08
      Y(6) = -7.325
      Z(6) = 0.0
  104 IF(FLAGB-1.0)107,105,106
C
C     THESE POINTS ARE FOR CASES B,C,D ONLY
C
  105 X(5) =   5.0
      Y(5) = -7.325
      Z(5) =   5.0
      X(7) =   5.0
      Y(7) =  -7.325
      Z(7) =   -5.0
      X(8) =     7.08
      Y(8) =   -1.915
      Z(8) =     0.0
      A1  = 225.4
      A2  = 115.92
      A4  = 115.92
      GO  TO 108
C
C     THESE POINTS ARE FOR CASE A ONLY.
C
  106 X(5) =   5.0
      Y(5) = -7.325
      Z(5) =   5.0
      X(7) =   5.0
      Y(7) = -7.325
      Z(7) = -5.0
      X(8) =   7.08
      Y(8) = -1.915
      Z(8) = 0.0
      A1  = 225.4
      A2  =   70.84
      A4  =   70.84
      GO  TO 108
```

Figure 3-11. Subroutine GEOM (Continued)

```
C
C     THESE POINTS ARE FOR CASE  E  ONLY.
C
C
  107 X(5) =  14.58
      Y(5) =  -7.325
      Z(5) =   4.81
      X(7) = 14.58
      Y(7) = -7.325
      Z(7) =  -4.81
      X(8) =  14.58
      Y(8) =  -1.915
      Z(8) =   0.0
      X(9) =  5.0
      Y(9) = -7.325
      Z(9) =  5.0
      X(10) =  7.08
      Y(10) = -7.325
      Z(10) =  0.0
      X(11) =   5.0
      Y(11) =  -7.325
      Z(11) =  -5.0
      X(12) =  5.0
      Y(12) = -1.915
      Z(12) =  5.0
      X(13) =  7.08
      Y(13) = -1.915
      Z(13) =  0.0
      X(14) =  5.0
      Y(14) = -1.915
      Z(14) = -5.0
      A1 = 225.4
      A2 = 144.9
      A4 = 144.9
      GO TO 108
C
C     CONTINUE GEOMETRY CALCULATIONS COMMON TO ALL FIVE CASES.
C
  108 GAMMA = ATAN(ABS(5.0/(X(1)-X(2))))
      XL(1)=SQRT((X(1)-X(2))**2+(Y(1)-Y(2))**2+(Z(1)-Z(2))**2)
      XL(2)=SQRT((X(1)-X(4))**2+(Y(1)-Y(4))**2+(Z(1)-Z(4))**2)
      PBAR = F(2)*SIN(BETRD)+2.0*F(1)*COS(GAMMA)*SIN(ALPRD)
      XM(1) = .0930
      XM(2) = .0930
      RBAR  = 18.0
      TMIN  =.025
      UM1(1) =ALPRD
      UM1(2) =BETRD
      UM2(1) =ALPRD
      UM2(2) = 3.14159265/2.0
      XK1 =.65
      XK2 = 2.0
C
C     CALCULATE WEIGHT OF ONE  FOOTPAD  WFP
C
C
      WFP =  1.0/1728.0*3.1416*RBAR**2*6.0/127.3*(1.20*PBAR/(1.0*RBAR**2
     1*3.1416) + 300.0)
      RETURN
      END
```

Figure 3-11. Subroutine GEOM (Concluded)

```
C
C TITLE OF SUBROUTINE      CURVE
C
C AUTHOR                 H. O. CARR
C
C CALL                   CURVE
C
C
C PURPOSE          TO DETERMINE  THE OPTIMUM  LEG CROSS SECTION
C                  CONFIGURATION OF WALL THICKNESS  T  AND  RADIUS  R1 TO
C                  GIVE THE  MINIMUM WEIGHT.
C
C
C
C
C
C
C
C METHOD           THIS IS FOUND  BY EQUATING ULTIMATE  STRESS TO THE
C                  CRITICAL ALLOWABLE STRESS  AND THEN BY INCREMENTING
C                  WALL THICKNESS T  UNTIL THE MINIMUM POINT IS FOUND ON
C                  THE CURVE  T   V.S. RT  WHERE RT IS THE  PRODUCT OF T
C                  AND R1 THE LEG RADIUS
C
C                  THIS FUNCTION OF R1 IS BEST SOLVED BY THE NORMAL
C                  ITERATION PROCESS. INCREASE R1 UNTIL THE VALUE OF THE
C                  FUNCTION CHANGES SIGN AND THEN HALF THE INTERVAL UNTIL
C                  THE VALUE OF THE FUNCTION APPROACHES ZERO. CONVERGENCE
C                  IS SATISFIED  WHEN  TWO SUCCESSIVE VALUES OF THE
C                  VARIABLE MEET A PERCENT ERROR TEST.
C
C
C
C OUTPUT           VALUES OF R1 V.S. T  ARE PRINTED  UNTIL THE MINIMUM
C                  POINT ON THE  T  V.S.  RT  CURVE  IS FOUND
C
C
C
C
C
C      SYMBOLS                          DEFINITION
C
C      R1                CURRENT  LEG RADIUS
C      T                 CURRENT  WALL  THICKNESS
C      RIPREV            PREVIOUS LEG  RADIUS
C      RIPR              SECOND  PREVIOUS LEG RADIUS
C
C      TPREV             PREVIOUS  WALL THICKNESS
C      TPR               SECOND PREVIOUS WALL THICKNESS
C
C      XL(I)             LENGTH OF MEMBER 1-2 FOR I=1 AND 1-4 FOR I=2
C      XK1               DYNAMIC TRANSIENT FACTOR
C      XMTOT             TOTAL STRUT MOMENT
C
C      R2                LAST VALUE  OF VARIABLE THAT GAVE A POSITIVE VALUE
C                        TO FUNCTION BEING SOLVED BY ITERATION.
C      R3                SAME AS ABOVE EXCEPT THE FUNCTION VALUE IS NEGATIVE
C
C      RT                CURRENT  PRODUCT  OF R1 AND  T
C      RTPREV            PREVIOUS   PRODUCT
```

Figure 3-12. Subroutine CURVE

```
C      RTPR                 SECOND  PREVIOUS  PRODUCT
C      COUNT                THIS IS A COUNTER THAT LIMITS THE NO. OF TIMES
C                           THIS LOOP IS GONE THRU.
C      FLAGA                THESE THREE FLAGS (FLAG A , FLAG C , FLAG D )
C      FLAGC                CONTROL THE LOGICAL FLOW NECESSARY TO DETERMINE
C      FLAGD                THE MINIMUM POINT  ON THE   RT  CURVE.
C
C
       SUBROUTINE CURVE
       COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
       COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
      1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
       COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
      1RTPREV,JJ,J,K,L,M,COSANG(30)
       COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
      1F810,F814,F513,F510,F59,SF(30),II
       COMMON/S5/WTT(14),WITT(11),WT(2),WHC(2),DL(14),XLEN(11)
       COMMON/S7/ALPRD,BETRD
C
   115 FLAGA=-1.0
       FLAGC=-1.0
       FLAGD=0.0
       R1PREV=0.0
       TPREV=0.0
       RTPREV=0.0
       R1PR=0.0
       TPR=0.0
       RTPR=0.0
       TDEL=0.010
C
C      TO FIND THE DESIRED ROOT OF THIS FUNCTION F1  BY ITERATION A
C      STARTING VALUE  OF R1 IS NOW  COMPUTED.
C
   120 RC1=(1.5*F(I)*(12.0*XL(I))**2/(3.1416**3*T*E*XK1))**(1.0/3.0)
       R1PRE=0.0
       R1=RC1+.001
       R1DEL=R1 *5.0
C
C      NOW SOLVE F1  WHEN  VARIABLE HAS VALUE  R1
C
   125 A          =2.0*3.1416*R1*T
       P          =1.5*F(I)*(12.0*XL(I))**2/(3.1416**3*E*XK1*T*(R1**3))
       F1=-.15*E*T/R1+1.5/A*(F(I)+2.0/R1*XMTOT*(1.0/(1.0-P)))
       IF (F1) 135,135,130
C
C      IF F1 IS POSITIVE  INCREMENT R1 TO GET F1 TO APPROACH ZERO
C
   130 R2=R1
       R1DEL=R1DEL*2.0
       R1=R1+R1DEL
       IF (R1-1000.0) 125,132,132
C
C      R1 GREATER THAN  1000  IMPLIES WALL  THICKNESS  T  IS  TOO SMALL
C      SO INCREMENT  T  AND  RESTART  ITERATION
C
   132 T=T+TDEL
       GO TO 115
C
C      F1  IS NOW NEGATIVE.  NOW KEEP HALVING  THE INTERVAL  UNTIL  F1
C      CONVERGES AND  STAISFIES A .01 OF ONE PERCENT  TEST.
C
```

Figure 3-12. Subroutine CURVE (Continued)

```
 135 R3=R1
     R1=(R2+R3)/2.0
 140 A          =2.0*3.1416*R1*T
     P          =1.5*F(I)*(12.0*XL(I))**2/(3.1416**3*E*XK1*T*(R1**3))
     F1=-.15*E*T/R1+1.5/A*(F(I)+2.0/R1*XMTOT*(1.0/(1.0-P)))
     IF (F1) 155,155,145
 145 R2=R1
 150 R1PRE=R1
     R1=(R2+R3)/2.0
     GO TO 160
 155 R3=R1
     GO TO 150
 160 RFIN=ABS((R1-R1PRE)/R1)-0.0001
1000 FORMAT(8F20.10)
     IF (RFIN) 165,165,140
C
C    NOW COMPUTE  THE  PRODUCT  R1 TIMES T  WHICH EQUALS A POINT (T,RT)
C       ON THE   T  V.S. RT  CURVE.  WE  NOW  INCREMENT  T  AND REPEAT
C    THE  ITERATION  PROCESS  UNTIL  WE FIND A  MINIMUM POINT  ON THIS
C    CURVE   WE PRINT  THE  POINTS ON THIS CURVE  TO SEE HOW WE ARE
C    PROGRESSING  STEP BY STEP.
C
 165 RT=R1*T
     FLAGD=FLAGD+1.0
     PRINT 903,R1,T,RT,P
 166 IF(FLAGA)167,170,170
 167 FLAGA=1.0
     R1PREV=R1
     TPREV=T
     RTPREV=RT
 168 T=T+TDEL
     GO TO 120
C
C    IF THE QUOTIENT  T/R1 EXCEEDS A  T/R1 MAXIMUM FOR THE SECOND
C    TIME (AS CONTROLLED BY FLAG C ) THEN  WE GO TO STATEMENT 190  AND
C    FIND   R1  BY ITERATION  OF  A  SECOND FUNCTION  F2
C
 170 IF(T/R1-TRMAX)172,172,186
 172 IF(RT-RTPREV)174,176,176
 174 R1PR=R1PREV
     TPR=TPREV
     RTPR=RTPREV
     GO TO 167
 176 IF(FLAGC)178,245,245
 178 IF(FLAGD-2.0)180,180,184
 180 T=T-TDEL
 182 FLAGC=1.0
     TDEL=TDEL/5.0
     GO TO 168
 184 T=T-(2.0*TDEL)
     R1PREV=R1PR
     TPREV=TPR
     RTPREV=RTPR
     GO TO 182
 186 IF(FLAGC)178,190,190
C
C    STATEMENTS 190  THRU 240  NOW  FIND  A LEG RADIUS R1 BY KEEPING
C    THE RATIO  T/R1 FIXED  AND  ITERATING UPON A SECOND FUNCTION F2
C    WHICH IS SIMILAR  TO  F1
C
 190 RC2=(1.5*F(I)*(12.0*XL(I))**2/(3.1416**3*E*XK1*TRMAX))**(1.0/4.)
```

Figure 3-12. Subroutine CURVE (Continued)

```
      COUNT=0.0
      R1PRE=0.0
      R1PREV=0.0
      R1=RC2+.001
      R1DEL=R1*5.0
  195 A          =2.0*3.1416*R1**2*TRMAX
      P          =1.5*F(I)*(12.0*XL(I))**2/(3.1416**3*E*XK1*TRMAX*R1**4)
      F2=-FTU(I)+1.5/A*(F(I)+2.0/R1*XMTOT*(1.0/(1.0-P)))
      IF (F2) 205,205,200
  200 R2=R1
      R1DEL=R1DEL*2.0
      R1=R1+R1DEL
      COUNT=COUNT+1.0
      IF (COUNT-40.0) 195,202,202
  202 PRINT 909
      PRINT 1500
      JJ = 1
      RETURN
  205 R3=R1
      R1=(R2+R3)/2.0
  210 A          =2.0*3.1416*R1**2*TRMAX
      P          =1.5*F(I)*(12.0*XL(I))**2/(3.1416**3*E*XK1*TRMAX*R1**4)
      F2=-FTU(I)+1.5/A*(F(I)+2.0/R1*XMTOT*(1.0/(1.0-P)))
      IF (F2) 225,225,215
  215 R2=R1
  220 R1PRE=R1
      R1=(R2+R3)/2.0
      GO TO 230
  225 R3=R1
      GO TO 220
  230 RFIN=ABS((R1-R1PRE)/R1)-0.0001
      IF (RFIN) 235,235,210
  235 T=R1*TRMAX
      RT=R1*T
      PRINT 903,R1,T,RT,P
  240 R1PREV=R1
      RTPREV=RT
      TPREV=T
C
C     SINCE  MINIMUM  POINT ON   T  V.S. RT  CURVE  IS REACHED  AT NEXT
C     TO  LAST VALUES  OF  R1 AND T, THEN  FINAL VALUES  NEEDED FOR
C     CALCULATING  LEG WEIGHT  ARE  THE PREVIOUS  SET  RIPREV AND TPREV
  245 FLAGC = -1.0
  903 FORMAT(F12.5,F11.5,F13.5,F12.5)
  909 FORMAT(5X,8HFUNCTION,2X,3HNOT,2X,8HNEGATIVE,2X,3HYET)
 1500 FORMAT(1H1)
      JJ = 2
      RETURN
      END
```

Figure 3-12. Subroutine CURVE (Concluded)

```
C
C TITLE OF SUBROUTINE     VECTOR
C
C AUTHOR          H. C. CARR
C
C CALL            VECTOR
C
C
C PURPOSE         TO FIND THE COSINE OF THE ANGLE BETWEEN ANY TWO LEG
C                 MEMBERS CALLED  COSANG
C
C METHOD          BY TAKING THE DOT PRODUCT BETWEEN TWO VECTORS IN
C                 THREE DIMENSIONAL SPACE
C
C                 BEFORE CALLING THIS SUBROUTINE  N  MUST BE SET BETWEEN
C                 THE NUMBERS 1 AND 33 SO AS TO PICK UP THE PROPER SET OF
C                 FIVE NUMBERS IN THE DATA TABLE FOR THE TWO LEG MEMBERS
C                 IN QUESTION.  THIS DATA STATEMENT OCCURS AT THE
C                 BEGINNING OF THE MAIN PROGRAM.
C
C
C
C     SYMBOLS                       DEFINITION
C
C     X(N),Y(N),Z(N)                COORDINATES IN SPACE
C     WHERE N CAN EQUAL
C     I OR J OR K OR L
C     N= 1 THRU 30
C
C     COSANG(M)                     COSINE OF THE ANGLE  BETWEEN TWO
C                                   VECTORS IN  SPACE
C
C
C
C
C
      SUBROUTINE VECTOR
      DIMENSION  II(33,5)
      COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
      COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
     1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
      COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
     1RTPREV,JJ,J,K,L,M,COSANG(30)
      COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
     1F810,F814,F513,F510,F59,SF(30),II
      COMMON/S5/WTT(14),WTTT(11),WT(2),WHC(2),DL(14),XLEN(11)
      COMMON/S6/N
      COMMON/S7/ALPRD,BETRD
C
C
      I = II(N,1)
      J = II(N,2)
      K = II(N,3)
      L = II(N,4)
      M = II(N,5)
C
      AA1 = X(I) - X(J)
      BB1= Y(I)-Y(J)
      CC1= Z(I)-Z(J)
```

Figure 3-13. Subroutine VECTOR

```
AA2= X(K)-X(L)
BB2= Y(K)-Y(L)
CC2= Z(K)-Z(L)
AB  = AA1*AA2+BB1*BB2+CC1*CC2
AABS = SQRT(AA1**2+BB1**2+CC1**2)
BABS = SQRT(AA2**2+BB2**2+CC2**2)
COSANG(M) = ABS(AB)/(AABS*BABS)
RETURN
END
```

Figure 3-13. Subroutine VECTOR (Concluded)

```
C
C
C TITLE OF SUBROUTINE     EQBCD
C
C AUTHOR          H. O. CARR
C
C DATE            09-1-64
C
C CALL            EQBCD
C
C PURPOSE         TO SOLVE A SET OF SIMULTANEOUS EQUILIBRIUM FORCE
C                 EQUATIONS  FOR  FORCES  IN MEMBERS 4-2, 4-8, 2-8, 2-6,
C                 AND 2-5 FOR CASES B,C,D
C
C METHOD          THE ABSOLUTE VALUE OF THE FORCES ARE SUMMED FOR EACH
C                 OF THE FIVE SEPARATE LOADINGS ON THE TRUSS
C
C
C
C
C
C     SYMBOLS                          DEFINITIONS
C
C     R2X,R2Y,R2Z,R4X,R4Y         THE X,Y,Z COMPONENTS AT JOINTS 2 + 4
C
C     COSANG(M)                   THE COSINE OF THE ANGLE BETWEEN THE
C                                 DESIRED TWO VECTORS IN SPACE
C
C     F42,F48,F28,F26,F25         FORCE  IN MEMBER 4-2, 4-8, 2-8, 2-6, 2-5
C                                 FOR EACH SEPARATE  LOADING
C
C     SF(1)                       ABSOLUTE SUM OF FORCE  F42 FOR FIVE LOADS
C     SF(2)                       SAME FOR F48
C     SF(3)                       SAME FOR F28
C     SF(4)                       SAME FOR F26
C     SF(5)                       SAME FOR F25
C
C
      SUBROUTINE EQBCD
      COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
      COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
     1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
      COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
     1RTPREV,JJ,J,K,L,M,COSANG(30)
      COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
     1F810,F814,F513,F510,F59,SF(30),II
      COMMON/S5/WTT(14),WTTT(11),WT(2),WHC(2),DL(14),XLEN(11)
      COMMON/S7/ALPRD,BETRD
      F42 = R4Y/(2.0*COSANG(5))
      SF(1) = SF(1)+ABS(F42)
      F48 = R4X - 2.0*F42*COSANG(1)
      SF(2) = SF(2)+ABS(F48)
      F28 = (-R2Y-F42*COSANG(5))/COSANG(6)
      SF(3) = SF(3)+ABS(F28)
      F26 = (R2Z-F42*COSANG(7)-F28*COSANG(8))/COSANG(9)
      SF(4) = SF(4)+ABS(F26)
      F25 = R2X-F28*COSANG(2)-F26*COSANG(3)+F42*COSANG(4)
      SF(5) = SF(5)+ABS(F25)
      RETURN
      END
```

Figure 3-14. Subroutine EQBCD

```
C
C
C TITLE OF SUBROUTINE     EQE
C
C AUTHOR        H. O. CARR
C
C DATE          09-1-64
C
C CALL          EQE
C
C PURPOSE       TO SOLVE A SET OF SIMULTANEOUS EQUILIBRIUM FORCE
C               EQUATIONS  FOR FORCES IN MEMBERS 4-2, 4-8, 2-8, 2-7,2-5,
C               8-5,8-10, 8-14, 5-13, 5-10, AND 5-9  FOR CASE  E ONLY.
C
C METHOD        THE ABSOLUTE VALUE OF THE FORCES ARE SUMMED  FOR EACH
C               OF THE FIVE SEPARATE LOADINGS ON THE TRUSS.
C
C
C
C
C     SYMBOLS                         DEFINITIONS
C
C     R2X,R2Y,R2Z,R4X,R4Y      THE X,Y,Z COMPONENTS AT JOINTS 2 + 4
C
C     COSANG(M)       THE COSINE OF THE ANGLE BETWEEN THE
C                              DESIRED TWO VECTORS IN SPACE
C
C     F42,F48,F28,F27          FORCE IN MEMBERS 4-2, 4-8, 2-8, 2-7,
C     F35,F25,F85,F810         3-5, 2-5, 8-5, 8-10,8-14, 5-13, 5-10,
C     F814,F513,F510,F59       AND 5-9 FOR EACH SEPARATE LOADING.
C
C     SF(6)                    ABSOLUTE SUM OF FORCE F42 FOR FIVE LOADS
C     SF(7)                    SAME FOR  4-8
C     SF(8)                    SAME FOR  2-8
C     SF(9)                    SAME FOR  2-7
C     SF(10)                   SAME FOR  3-5
C     SF(11)                   SAME FOR  2-5
C     SF(12)                   SAME FOR  8-5
C     SF(13)                   SAME FOR  8-10
C     SF(14)                   SAME FOR  8-14
C     SF(15)                   SAME FOR  5-13
C     SF(16)                   SAME FOR 5-10
C
C
C
C
C
C
      SUBROUTINE EQE
      COMMON/S1/ SERIAL(2),R,H,ALPHA,BETA,F(2),FLAGB,FTU(3),E,DENS
      COMMON/S2/X(30),Y(30),Z(30),PHI,RONE,RTWO,A1,A2,A4,GAMMA,XL1,XL2,
     1PBAR,XM(2),RBAR,TMIN,UM1(2),UM2(2),XK1,XK2,WFP
      COMMON/S3/I,R1 PREV,TPREV,T,TDEL,XL(2),R1,XMTOT,A,P,RT,TRMAX,
     1RTPRFV,JJ,J,K,L,M,COSANG(30)
      COMMON/S4/R4Y,R4X,R2Y,R2Z,R2X,F42,F48,F28,F26,F25,F27,F35,F85,
     1F810,F814,F513,F510,F59,SF(30),II
      COMMON/S5/WTT(14),WTTT(11),WT(2),WHC(2),DL(14),XLEN(11)
      COMMON/S7/ALPRD,BETRD
      F42 = R4Y/(2.0*COSANG(5))
```

Figure 3-15. Subroutine EQE

```
 SF(6) = SF(6)+ABS(F42)
 F48 = R4X -2.0*F42*COSANG(1)
 SF(7) = SF(7)+ABS(F48)
 F28 = (-R2Y-F42*COSANG(5))/COSANG(6)
 SF(8) = SF(8)+ABS(F28)
 F27 =  (R2Z-F42*COSANG(7)-F28*COSANG(8))/COSANG(10)
 SF(9) = SF(9)+ABS(F27)
 F35 = F27
 F25 = R2X+F42*COSANG(4)-F28*COSANG(2)-F27*COSANG(11)
 SF(10) = SF(10)+ABS(F25)
 F85 = ( -.40*F28*COSANG(6))/COSANG(12)
 SF(11) = SF(11)+ABS(F85)
 F810 = -.60*2.0*F28*COSANG(6)/COSANG(13)
 SF(12) = SF(12)+ABS(F810)
 F814 =  (F48 + 2.0*F28*COSANG(14)-F810*COSANG(15))/(2.0*COSANG(16)
1)
 SF(13) = SF(13)+ABS(F814)
 F513 =  -F85*COSANG(12)/COSANG(17)
 SF(14) = SF(14)+ABS(F513)
 F510 = (-F35*COSANG(18)-F85*COSANG(19)-F513*COSANG(20))/COSANG(21)
 SF(15) = SF(15)+ABS(F510)
 F59 = F25 +F35*COSANG(22)-F510*COSANG(23)-F513*COSANG(24)
 SF(16) = SF(16) +ABS(F59)
 RETURN
 END
```

Figure 3-15. Subroutine EQE (Concluded)

```
SERIAL NO = TEST A

R= 13.62690    H= 14.4200    ALPHA= 38.437    BETA= 61.885    F22=  600.0    F11= 7100.0    FLAGB= 2.0    DENSITY=   .1020

   R1          T           RT          P

 23.62572    .02500      .59064      .00038
 10.73897    .03500      .37586      .00289
  6.26462    .04500      .28191      .01133
  4.18585    .05500      .23022      .03107
  3.07249    .06500      .19971      .06649
  2.42271    .07500      .18170      .11754
  2.01817    .08500      .17154      .17950
  2.91480    .06700      .19529      .07558
  2.77270    .06900      .19132      .08523
  2.64455    .07100      .18776      .09546
  2.52802    .07300      .18455      .10629
  2.42271    .07500      .18170      .11754
  2.32647    .07700      .17914      .12935
  2.23899    .07900      .17688      .14144
  2.15894    .08100      .17487      .15387
  2.08540    .08300      .17309      .16661
  2.01817    .08500      .17154      .17950
  2.04977    .08404      .17226      .17317

LEG  1-2

WEIGHT=  16.02106     LENGTH= 12.09300    R1PREV=  2.04977     TPREV=    .08404      P=    .17317


   R1          T           RT          P

 12.85118    .03500      .44979      .01977
  3.70945    .04500      .16693      .63944
  3.21538    .05500      .17685      .80365
  6.06109    .03700      .22500      .17651
  4.73843    .03900      .18480      .35411
  4.20171    .04100      .17227      .48294
  3.90475    .04300      .16790      .57372
  3.70945    .04500      .16693      .63944
  3.56666    .04700      .16763      .68875

LEG  1-4

WEIGHT=  17.83722     LENGTH= 13.69448    R1PREV=  3.70945     TPREV=    .04500      P=    .68875


   TOTAL LEG WEIGHT = 199.51732

FINWT= 285.34571  *FP =    8.56220  WHC(1)=    1.88405 WHC(2)=    9.12661
```

Figure 3-16. Sample Output - Case A

```
SERIAL NO = TEST B

R= 19.79000    H= 14.3900    ALPHA= 28.754    BETA= 62.037    F22= 2750.0    F11=10400.0    FLAGB= 1.0    DENSITY=   .1020

     R1            T             RT            P

101.69332      .02500       2.54233       .00002
 24.21635      .03500        .84757       .00065
 12.06633      .04500        .54296       .00535
  7.49984      .05500        .41249       .01824
  5.26477      .06500        .34221       .04459
  4.02120      .07500        .30159       .08676
  3.27152      .08500        .27808       .14210
  2.79031      .09500        .26508       .20502
  2.46315      .10500        .25863       .26950
  3.15884      .08700        .27482       .15430
  3.05492      .08900        .27189       .16675
  2.95954      .09100        .26932       .17928
  2.87137      .09300        .26704       .19208
  2.79031      .09500        .26508       .20502
  2.71513      .09700        .26337       .21793
  2.64520      .09900        .26187       .23092
  2.56038      .10100        .26062       .24384
  2.51957      .10300        .25952       .25684
  2.46315      .10500        .25863       .26950
  2.51572      .10314        .25948       .25753

LEG  1-2

WEIGHT=  23.90764    LENGTH= 11.98022    R1PREV=  2.51572    TPREV=   .10314    P=   .25753


     R1            T             RT            P

  5.34339      .04500        .24045       .31097
  3.75169      .05500        .20634       .73535
  3.38918      .06500        .22030       .84400
  4.60263      .04700        .21632       .46603
  4.24428      .04900        .20797       .56985
  4.02430      .05100        .20524       .64253
  3.86997      .05300        .20511       .69497
  3.75169      .05500        .20634       .73535

LEG  1-4

WEIGHT=  21.83283    LENGTH= 13.64090    R1PREV=  3.86997    TPREV=   .05300    P=   .73535



LEG  4-2
WEIGHT=   3.81234    FORCE=  6510.9    LENGTH=  7.63338    R=  2.01735    TMIN=   .03219

LEG  4-6
```

Figure 3-17. Sample Output - Case B

```
WEIGHT=   3.19589     FORCE=  8337.9     LENGTH=  6.22001     R=  1.63401     TMIN=   .03643

LEG  2-8
WEIGHT=   7.23624     FORCE= 13052.0     LENGTH=  8.48975     R=  2.43168     TMIN=   .04558

LEG  2-6
WEIGHT=   2.76172     FORCE=  5902.2     LENGTH=  6.54277     R=  1.79077     TMIN=   .03065

LEG  2-5
WEIGHT=   3.64909     FORCE=  9853.4     LENGTH=  6.29993     R=  1.90189     TMIN=   .03960

   TOTAL LEG WFIGHT = 431.05107

FINWT= 537.72108  WFP =   8.72683  WHC(1)=   3.41731 WHC(2)=  11.10606
```

Figure 3-17. Sample Output - Case B (Concluded)

```
SERIAL NO = TEST C

R= 22.70100    H= 15.4500    ALPHA= 38.775    BETA= 62.080    F22= 2900.0    F11=10900.0    FLAGB= 1.0    DENSITY=   .1020

      R1           T            RT          P

144.49286      .02500      3.61232      .00001
 30.95624      .03500      1.08347      .00068
 15.17332      .04500       .68280      .00447
  9.35500      .05500       .51474      .01556
  6.52852      .06500       .42435      .03881
  4.95511      .07500       .37163      .07691
  4.00599      .08500       .34051      .12841
  3.39760      .09500       .32277      .18832
  2.98536      .10500       .31346      .25131
  2.69242      .11500       .30963      .31265
  3.30264      .09700       .32036      .20092
  3.21456      .09900       .31824      .21349
  3.13262      .10100       .31639      .22612
  3.05665      .10300       .31483      .23868
  2.98536      .10500       .31346      .25131
  2.91921      .10700       .31236      .26360
  2.85695      .10900       .31141      .27606
  2.79862      .11100       .31065      .28852
  2.74385      .11300       .31005      .30072
  2.75039      .11277       .31015      .29922
LEG  1-2

WEIGHT=  35.84443     LENGTH= 15.02752    R1PREV=  2.75039     TPREV=   .11277     P=   .29922


      R1           T            RT          P

  7.57376      .04500       .34062      .15614
  4.35926      .05500       .23976      .67026
  3.87430      .06500       .25183      .80791
  5.82570      .04700       .27381      .32861
  5.14146      .04900       .25193      .45854
  4.77127      .05100       .24333      .55128
  4.53189      .05300       .24019      .61881
  4.35926      .05500       .23976      .67026
  4.22541      .05700       .24085      .70989
LEG  1-4

WEIGHT=  29.80994     LENGTH= 16.16675    R1PREV=  4.35926     TPREV=   .05500     P=   .70989



LEG  4-2
WEIGHT=   4.58127     FORCE=  7289.4     LENGTH=  8.14655     R=  2.14682     TMIN=   .03406
```

Figure 3-18. Sample Output - Case C

```
LEG  4-8
WEIGHT=   6.03781     FORCE= 11356.5     LENGTH=  8.05114     R=  2.29345     TMIN=   .04252

LEG  2-8
WEIGHT=   7.84139     FORCE= 13967.3     LENGTH=  8.67061     R=  2.49411     TMIN=   .04715

LEG  2-6
WEIGHT=   2.99767     FORCE=  6115.4     LENGTH=  6.77579     R=  1.64392     TMIN=   .03120

LEG  2-5
WEIGHT=   4.53175     FORCE= 11899.2     LENGTH=  6.65289     R=  2.03528     TMIN=   .04352
   TOTAL LEG WEIGHT = 589.76302

FINWT= 725.21915  WFP =   8.75262  WHC(1)=   4.93319 WHC(2)=  15.24503
```

Figure 3-18. Sample Output - Case C (Concluded)

```
SERIAL NO = TEST D

R= 18.47560     H= 12.9200     ALPHA= 39.060     BETA= 62.119     F22= 2700.0     F11= 9900.0     FLAGB= 1.0     DENSITY=    .1020

     R1            T            RT           P

  83.77090      .02500       2.09427      .00002
  20.58727      .03500        .72055      .00092
  10.31324      .04500        .46410      .00568
   6.42699      .05500        .35348      .01920
   4.52102      .06500        .29387      .04667
   3.46079      .07500        .25956      .09020
   2.82170      .08500        .23984      .14678
   2.41113      .09500        .22906      .21060
   2.13167      .10500        .22383      .27558
   2.72505      .08700        .23706      .15921
   2.63690      .08900        .23468      .17185
   2.55524      .09100        .23253      .18471
   2.48033      .09300        .23067      .19762
   2.41113      .09500        .22906      .21060
   2.34660      .09700        .22762      .22374
   2.35743      .09665        .22786      .22135
LEG  1-2

WEIGHT=  17.24883     LENGTH=  9.64316    R1PREV=  2.35743     TPREV=   .09665      P=    .22135


     R1            T            RT           P

   4.25909      .04500        .19166      .45173
   3.31827      .05500        .18251      .78150
   3.02916      .06500        .19690      .86925
   3.87824      .04700        .18228      .57284
   3.66184      .04900        .17943      .65274
   3.51526      .05100        .17928      .70919
   3.40578      .05300        .18051      .75008
LEG  1-4

WEIGHT=  16.77599     LENGTH= 12.16741    R1PREV=  3.51526     TPREV=   .05100      P=    .75008



LEG  4-2
WEIGHT=    3.45435     FORCE=  6027.2      LENGTH=  7.42046      R=  1.95436     TMIN=    .03097

LEG  4-8
WEIGHT=    2.25623     FORCE=  6137.1      LENGTH=  5.70562      R=  1.64523     TMIN=    .03125

LEG  2-8
WEIGHT=    7.67911     FORCE= 13043.5      LENGTH=  8.80010      R=  2.49032     TMIN=    .04556
```

Figure 3-19. Sample Output - Case D

```
LEG  2-6
WEIGHT=   3.21968     FORCE=  6409.9     LENGTH=  6.94073     R=  1.88847     TMIN=   .03194

LEG  2-5
WEIGHT=   4.09955     FORCE=  9366.7     LENGTH=  6.89391     R=  2.00265     TMIN=   .03861

   TOTAL LEG WEIGHT = 361.74097

FINWT= 451.34034  WFP =   8.70421  WHC(1)=   2.55739 WHC(2)=   8.56086
```

Figure 3-19. Sample Output - Case D (Concluded)

```
SERIAL NO = TEST E

R= 30.59000     H= 15.3200    ALPHA= 38.348    BETA= 62.026    F22= 3000.0    F11=14400.0    FLAGB=-1.0    DENSITY=    .1020

    R1           T           RT           P

181.63735      .02500      4.54093      .00000
 35.85834      .03500      1.25504      .00036
 17.35897      .04500       .78115      .00247
 10.61240      .05500       .58368      .00884
  7.31763      .06500       .47565      .02282
  5.46532      .07500       .40990      .04749
  4.33503      .08500       .36848      .08394
  3.60597      .09500       .34257      .13055
  3.11228      .10500       .32679      .18363
  2.76414      .11500       .31788      .23945
  3.49173      .09700       .33870      .14076
  3.36598      .09900       .33521      .15132
  3.28798      .10100       .33209      .16199
  3.19698      .10300       .32929      .17279
  3.11228      .10500       .32679      .18363
  3.03319      .10700       .32455      .19476
  2.95905      .10900       .32254      .20593
  2.88974      .11100       .32076      .21700
  2.82463      .11300       .31918      .22837
  2.76414      .11500       .31788      .23945
  2.78661      .11425       .31837      .23512
LEG  1-2

WEIGHT=  32.92549    LENGTH= 13.44725   R1PREV=  2.78661    TPREV=   .11425     P=   .23512


    R1           T           RT           P

  4.91316      .05500       .27022      .52464
  4.06809      .06500       .26443      .78230
  3.75373      .07500       .28153      .86337
  4.61174      .05700       .26287      .61259
  4.41545      .05900       .26051      .67404
  4.27258      .06100       .26063      .71985
LEG  1-4

WEIGHT=  29.84280    LENGTH= 14.69535   R1PREV=  4.41545    TPREV=   .05900     P=   .71985



LEG  4-2
WEIGHT=    5.10137     FORCE=  9302.4     LENGTH=  7.88195      R=  2.18718     TMIN=   .03848

LEG  4-8
WEIGHT=    8.157       FORCE= 13415.2     LENGTH=  9.02306      R=  2.54409     TMIN=   .04621
```

Figure 3-20. Sample Output - Case E

```
LEG  2-8
WEIGHT=  11.65351     FORCE= 19407.9     LENGTH=  9.64142     R=  2.62784     TMIN=   .05558

LEG  2-7
WEIGHT=   7.42650     FORCE=  6197.4     LENGTH= 11.61572     R=  2.64705     TMIN=   .03141

LEG  2-5
WEIGHT=   5.01562     FORCE= 16373.7     LENGTH=  6.22293     R=  2.05298     TMIN=   .05105

LEG  8-5
WEIGHT=   3.24162     FORCE=  5826.8     LENGTH=  7.23907     R=  1.91168     TMIN=   .03046

LEG  8-10
WEIGHT=  11.93942     FORCE= 22336.2     LENGTH=  9.24760     R=  2.61552     TMIN=   .05963

LEG  6-14
WEIGHT=  19.59881     FORCE= 31827.1     LENGTH= 10.80631     R=  3.31346     TMIN=   .07117

LEG  5-13
WEIGHT=   7.58966     FORCE=  8393.1     LENGTH= 10.42373     R=  2.59040     TMIN=   .03655

LEG  5-10
WEIGHT=   6.43272     FORCE=  9695.2     LENGTH=  8.90989     R=  2.38986     TMIN=   .03928

LEG  5-9
WEIGHT=  15.40726     FORCE= 29964.5     LENGTH=  9.58188     R=  3.02760     TMIN=   .06906
   TOTAL LEG WEIGHT =1114.89930

FINWT=1250.56380  WFP =   8.85384  WHC(1)=   4.54164 WHC(2)=  15.97903
```

Figure 3-20. Sample Output - Case E (Concluded)

SECTION IV

DIGITAL COMPUTER PROGRAMS FOR THE CONDENSED ANALYSIS OF REAR LEG TOUCHDOWN AND FREE FLIGHT

DESCRIPTION

This computer program solves for the kinematical conditions involving the rear leg touchdown period and free flight to front leg touchdown.

The two main parameters in this study are the "coefficients of restitution" EX and EY. The values of EX and EY that lead to a reasonable solution depend upon the other input parameters in a very complex way. To avoid this complexity, ranges of EX and EY are set up with eleven increments of each one. Then a solution is attempted for all the 121 possible combinations of EX and EY. This program can be used to investigate the effect of EX and EY on the landing.

A valid solution may not exist for two reasons. First, XN(30) and XN(44) may not converge in the valid range of PS2 (-20° to 0°), and second, the function FF may have no solution within this range. In either case, a comment is made accordingly, the present values of EX and EY are printed, and then the problem continues with the next combination until all 121 combinations are exhausted.

COMPUTER INPUT DATA

The input data requires two cards. For identification of the input data, see Figure 4-7.

INPUT DATA (CARD 1)	DEFINITIONS	COLUMNS USED
RUNNO	See Figure 4-7	1 through 5
EXX	Ref. 1, Section 6, Eq. 33 $(EX)_o$	6 through 10
EXDEL	See Figure 4-7	11 through 15
EXMAX	See Figure 4-7	16 through 20
EYY	Ref. 1, Section 6, Eq. 36 $(EY)_o$	21 through 25
EYDEL	See Figure 4-7	26 through 30
EYMAX	See Figure 4-7	31 through 35

INPUT DATA (CARD 2)	DEFINITIONS	COLUMNS USED
RUNNO	See Figure 4-7	1 through 5
XDOT1	Ref. 1, Section 6, Eq. 1 $\dot{X}_1$	6 through 10
YDOT1	Ref. 1, Section 6, Eq. 1 $\dot{Y}_1$	11 through 15
WONE	Ref. 1, Section 6, Eq. 1 ω_1	16 through 20
XKX	Ref. 1, Section 6, Eq. 30 K_X	21 through 25
XKY	Ref. 1, Section 6, Eq. 39 K_Y	26 through 30
XKXP	Ref. 1, Section 6, Eq. 31 K'_X	31 through 35
XKYP	Ref. 1, Section 6, Eq. 40 K'_Y	36 through 40
XKXDP	Ref. 1, Section 6, Eq. 32 K''_X	41 through 45
XKYDP	Ref. 1, Section 6, Eq. 41 K''_Y	46 through 50

NOTE

For identification of symbols, see Section VI of Reference 1 and computer program comments, Figure 4-7, as indicated above.

COMPUTER OUTPUT DATA

1. The input data is printed first as part of the output record.

2. For every valid solution, the following is printed for that combination of EX and EY:

    a. FF, XN(30), XN(44), PS2, XN(42), EX, EY where XN(30) and XN(44) have converged and FF is close to zero.

    b. The function FFF = f(T) is now solved by iteration and the values of FFF and T are printed for every 10th iteration. The final line is the last value of FFF and T which meets the percent error test.

    c. Now solve and print:
    XN(30), XN(31), XN(32), XN(33), XN(34)
    XN(35), XN(44), Δ T, $\dot{X}_3$, $\dot{y}_3$, $(PSI)_3$, X_3, Y_3, β_3.

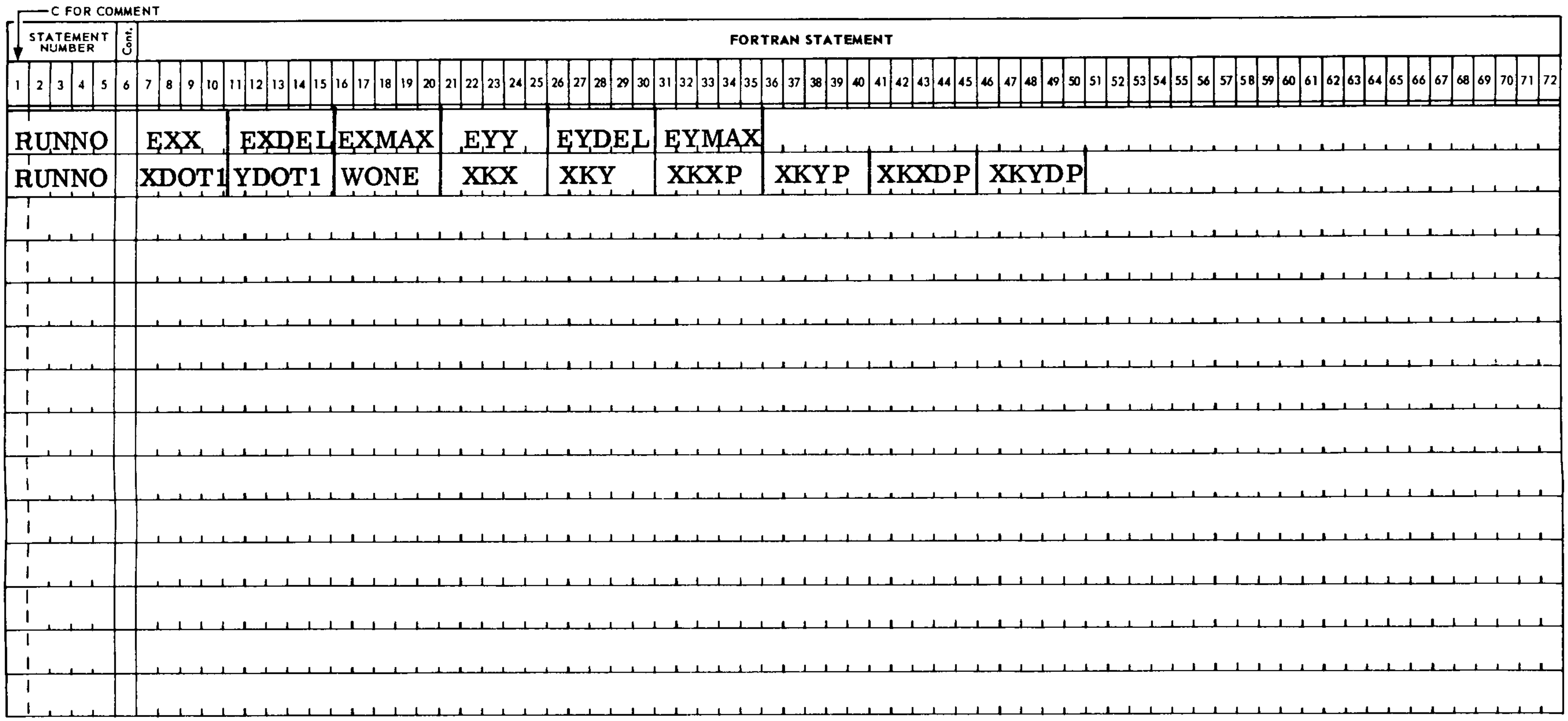
3. For every non-valid combination of EX and EY one of two error statements is printed and then EX is incremented and program continues with the next combination of EX and EY.

NOTE

The sample computer solution that follows gives the solution for one set of input parameters. For this example, there are only 18 valid solutions out of the 121 possible combinations of EX and EY. Only the first 15 solutions are shown in Figure 4-12, although a complete output would include all 121 trials.

Since the EX, EY combination which corresponds to the detailed digital computer solution cannot be analytically determined, the solution which compares most favorably is selected by visual inspection.

The first four lines of printed output consist of input data. The next 7 lines are invalid cases and then three valid cases occur. The last four lines are also invalid cases. This output is typical of the printout for the remaining 106 cases.



STATEMENT NUMBER 1–5	Cont. 6	7–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50
RUNNO		EXX	EXDEL	EXMAX	EYY	EYDEL	EYMAX			
RUNNO		XDOT1	YDOT1	WONE	XKX	XKY	XKXP	XKYP	XKXDP	XKYDP

Figure 4-1. Input Data Format

This program solves for the kinematical conditions involving the rear leg touchdown period, and free flight to front leg touchdown, as described in Reference 1.

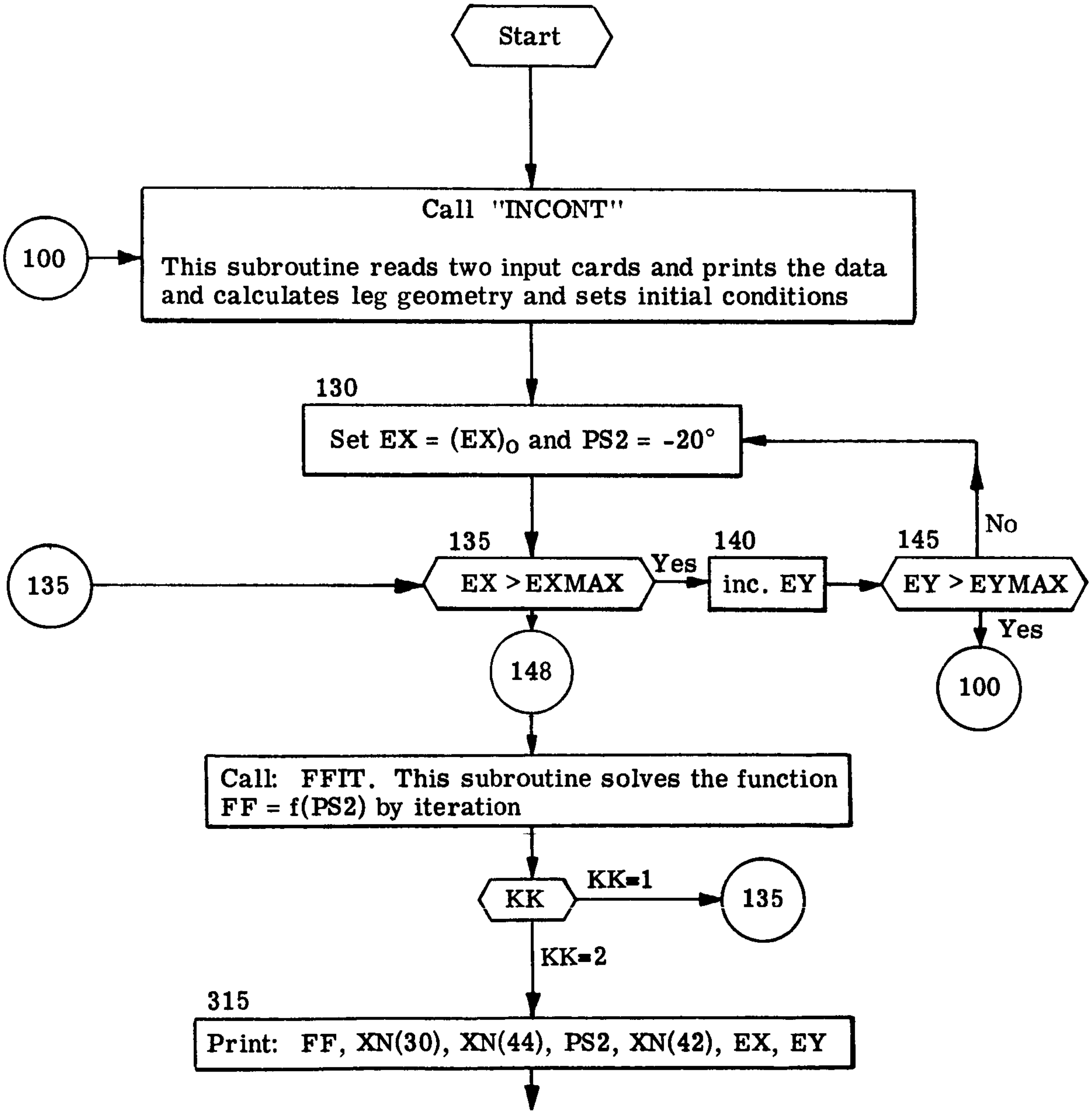


Figure 4-2. Computer Program - Condensed Analysis for Downhill Landing Dynamics

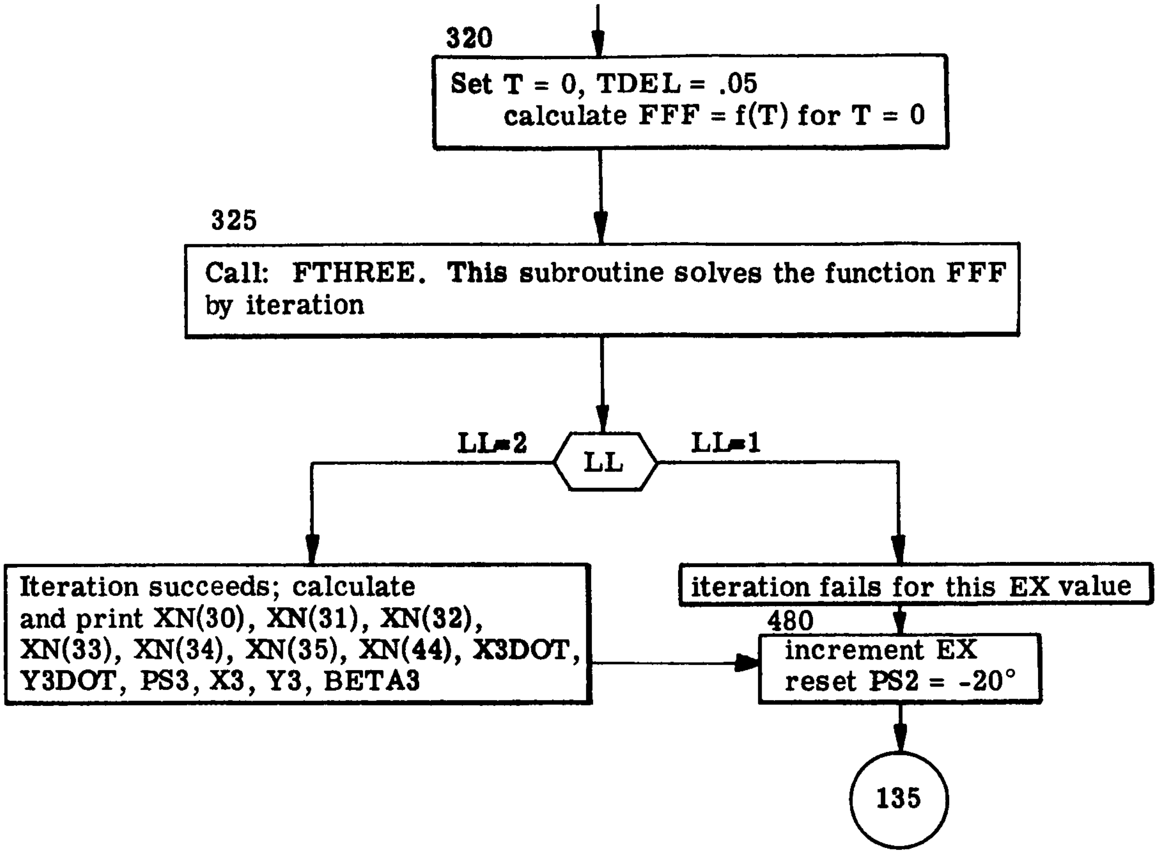


Figure 4-2. Computer Program - Condensed Analysis for Downhill Landing Dynamics (Concluded)

This subroutine reads two data cards, prints this data, initializes and sets basic constants.

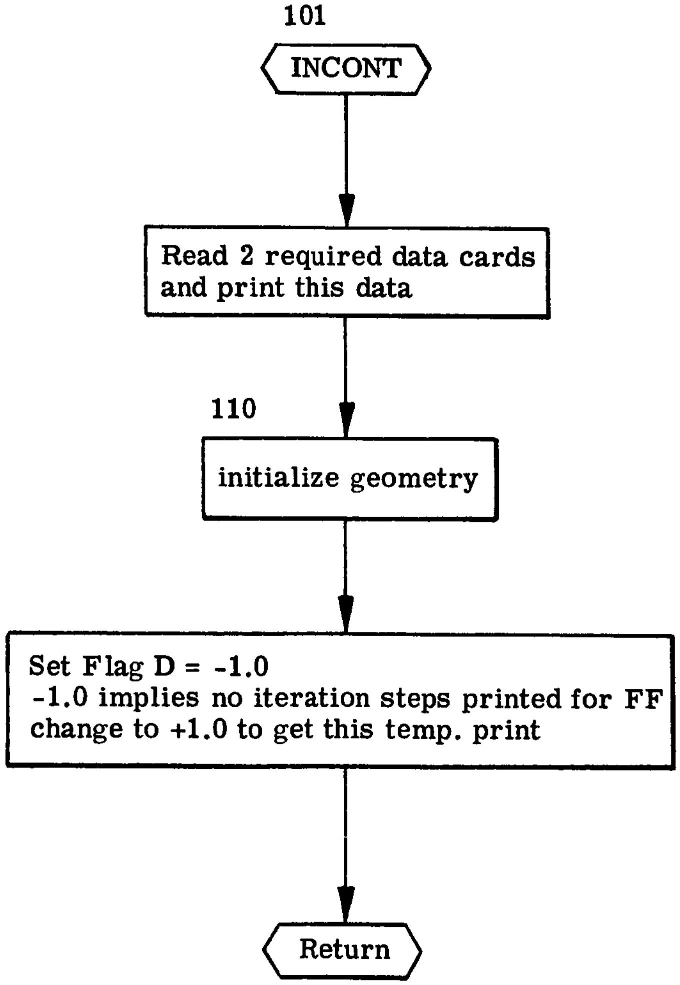


Figure 4-3. Subroutine INCONT

This subroutine solves the equation FF = f(PS2) by iteration. PS2 is set initially to -20 degrees before entry.

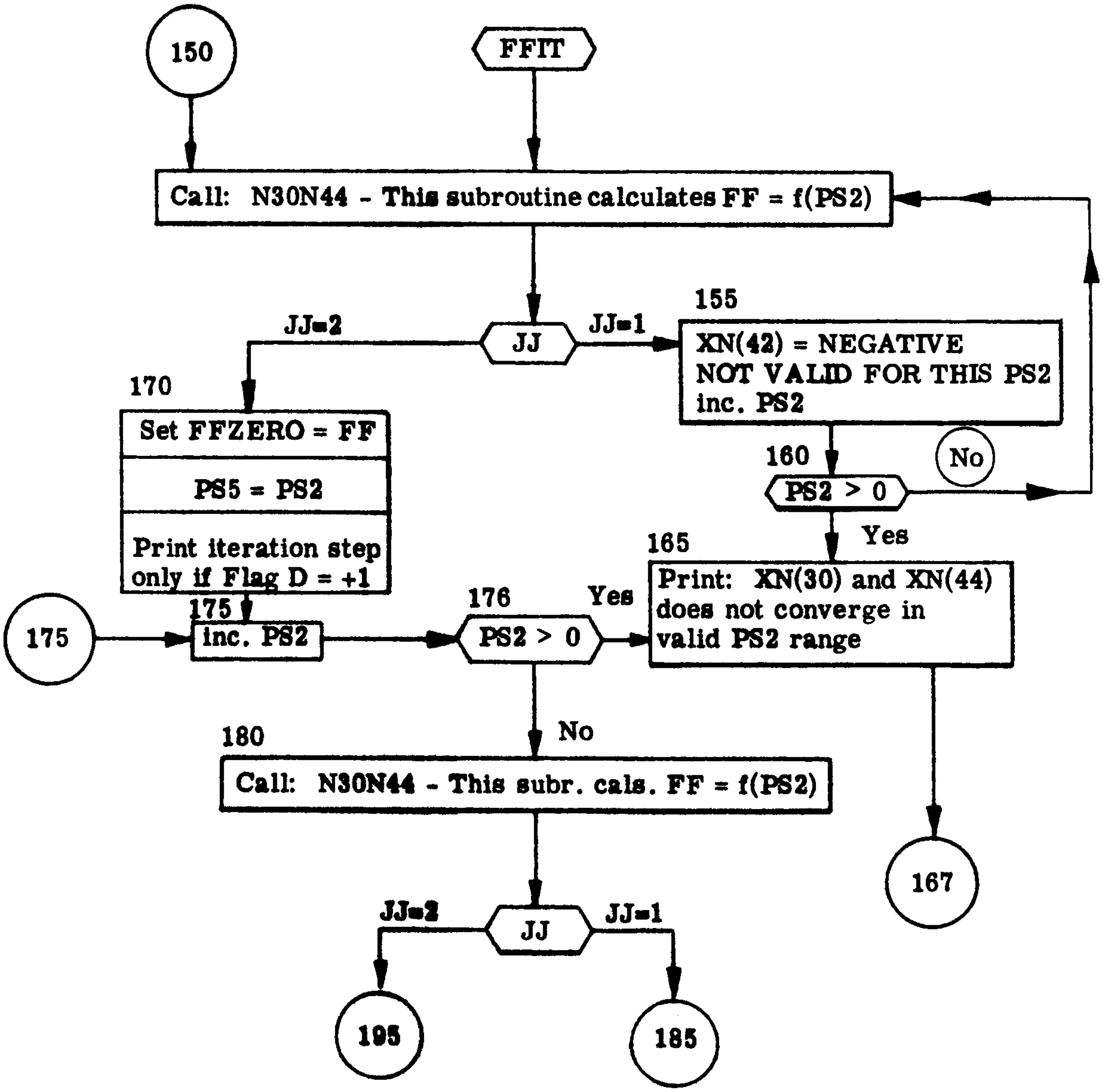


Figure 4-4. Subroutine FFIT

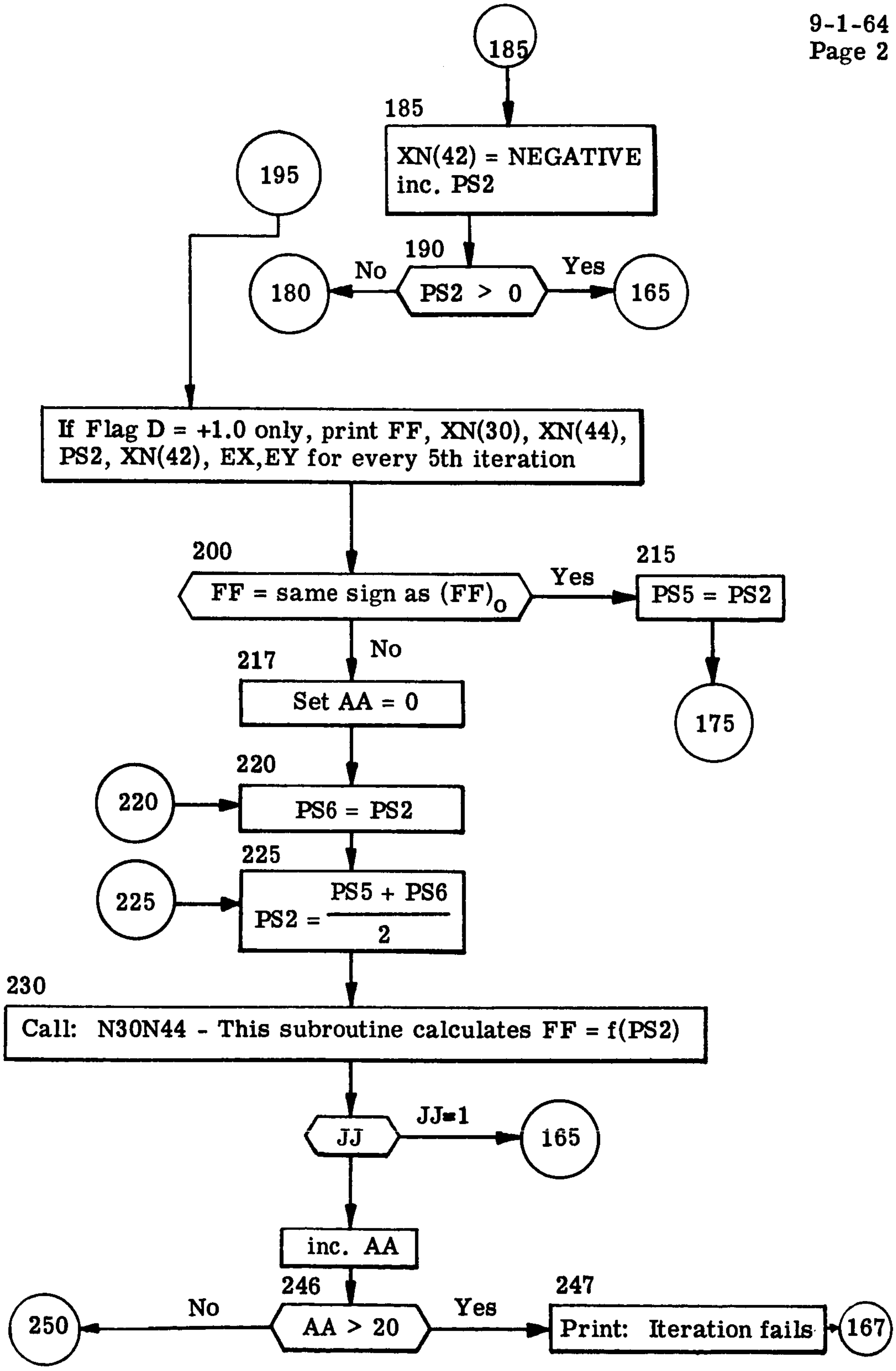


Figure 4-4. Subroutine FFIT (Continued)

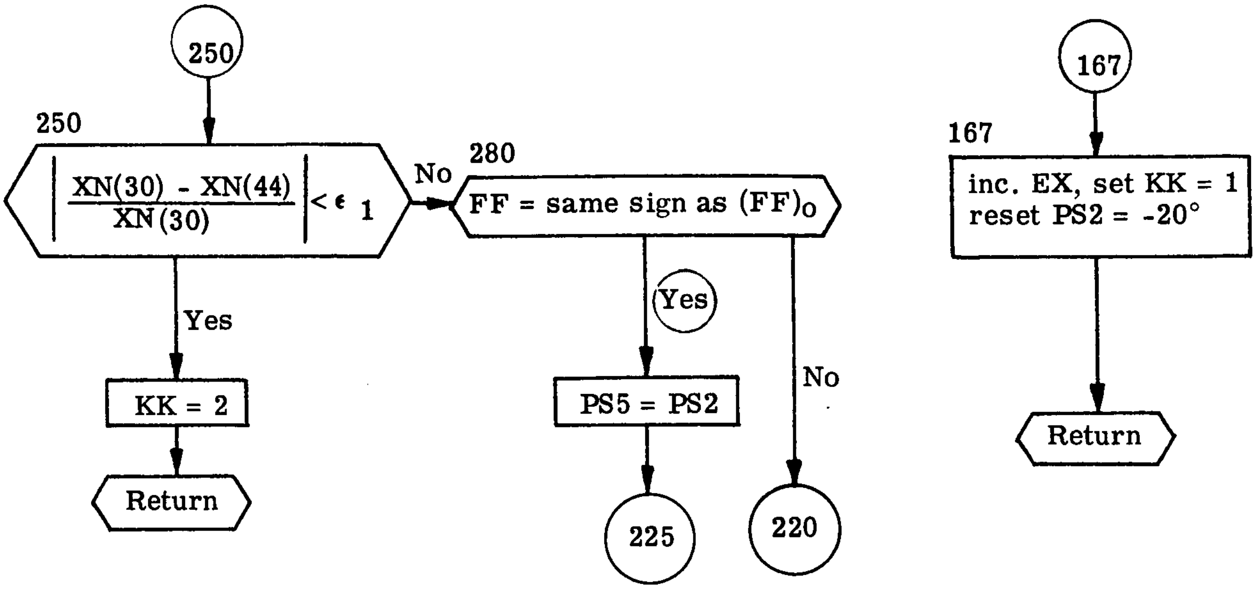


Figure 4-4. Subroutine FFIT (Concluded)

SUBROUTINE: FTHREE

This subroutine solves the equation FFF = f(T) by iteration FFF = f(To) is calculated before entry.

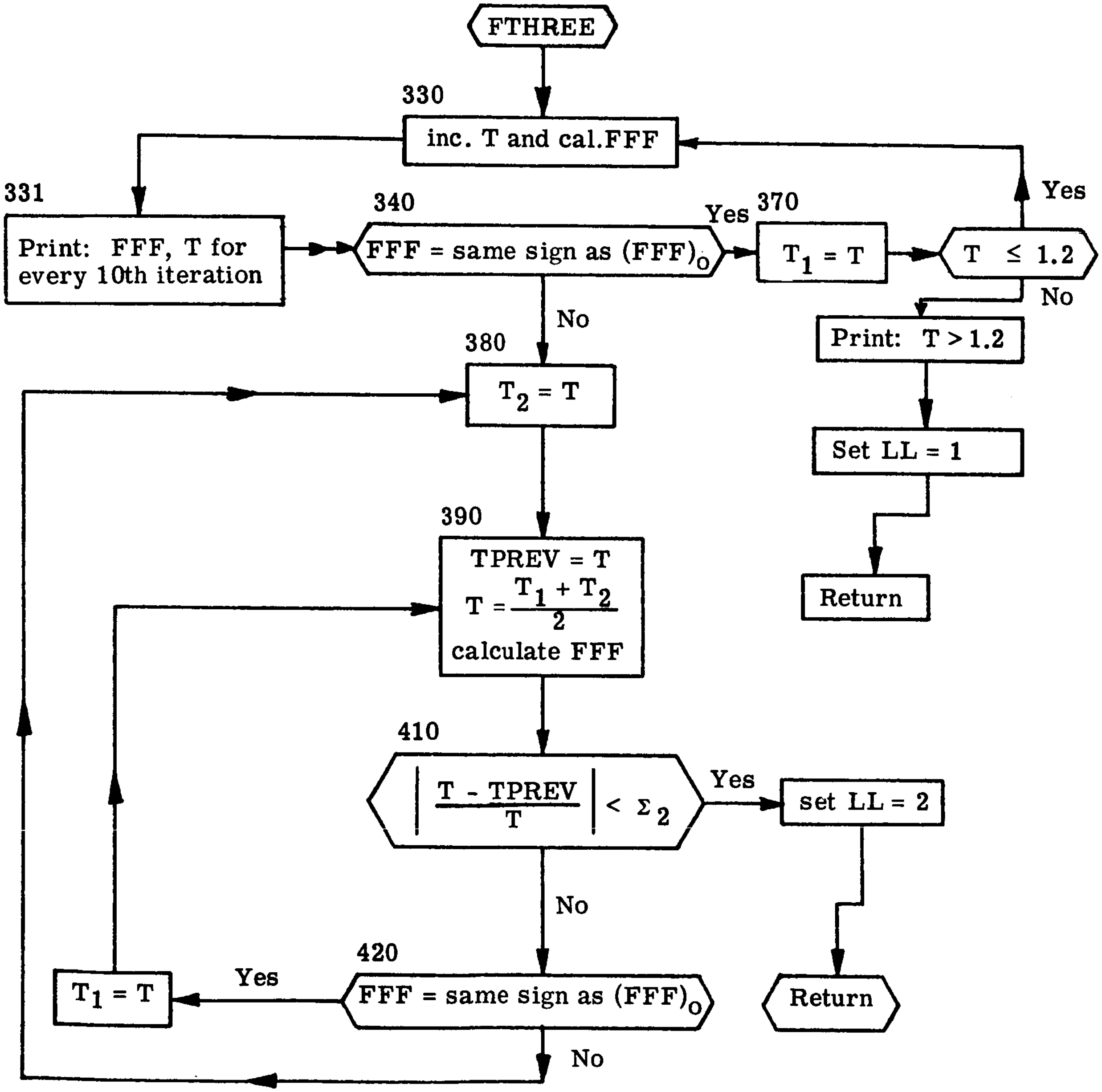


Figure 4-5. Subroutine FTHREE

This subroutine calculates the value of FF which equals XN(30 - XN(44) where FF is a function of PS2 and WTWO.

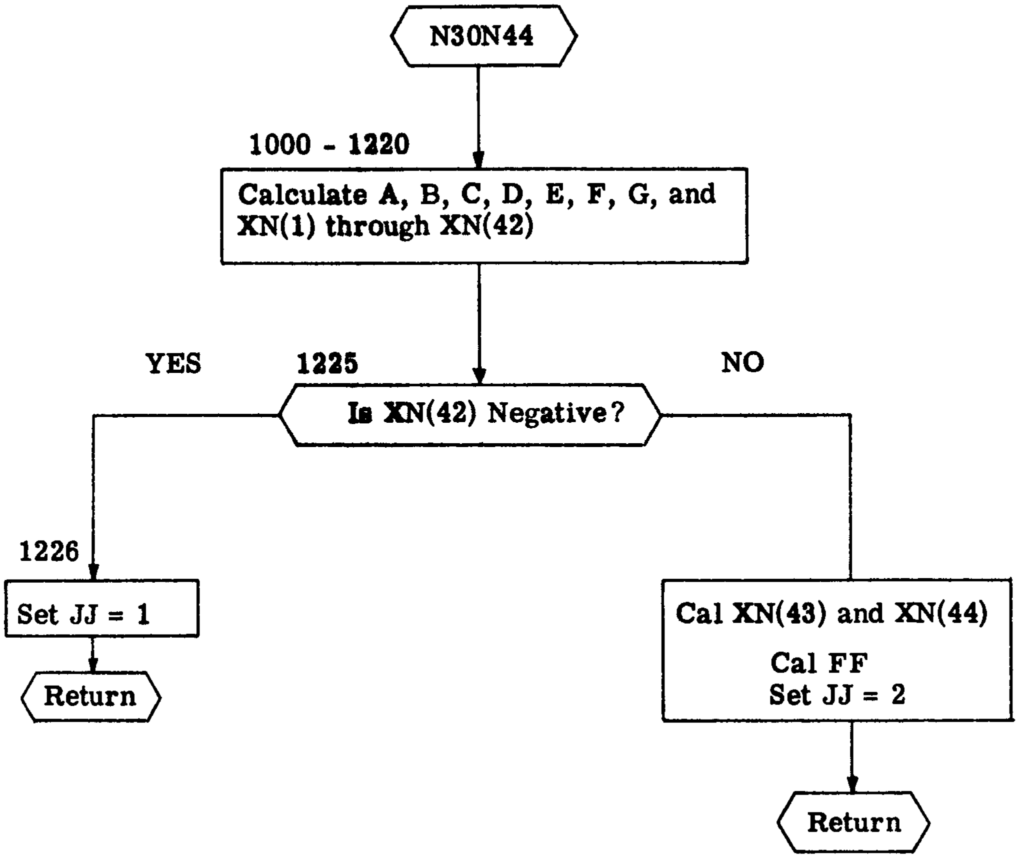


Figure 4-6. Subroutine N30N44

```
- RUN CARR,ZZ0610,3,40
- FOR LEM
C
C
C
C
C
C      MAIN PROGRAM TITLE          CONDENSED ANALYSIS FOR DOWNHILL LANDING
C                                  DYNAMICS
C
C      AUTHOR                      H. O. CARR
C
C      DATE                        09-1-64
C
C
C      CALL                        LEM
C
C      PURPOSE                     TO SOLVE FOR THE KINEMATICAL CONDITIONS
C                                  INVOLVING REAR LEG TOUCHDOWN PERIOD,FREE
C                                  FLIGHT TO FRONT LEG TOUCHDOWN.
C
C
C                                  SEE FIGURES 6-3,6-4,6-5,AND 6-6 IN
C                                  MAIN REPORT FOR VEHICLE GEOMETRY.
C      BENDIX REPORT MM- 8-64
C
C
C      INPUT DATA            COLUMNS USED
C
C      CARD 1.
C
C      RUNNO                 1    THRU  5
C      EXX                   6    THRU  10
C      EXDEL                 11   THRU  15
C      EXMAX                 16   THRU  20
C      EYY                   21   THRU  25
C      EYDEL                 26   THRU  30
C      EYMAX                 31   THRU  35
C
C
C      CARD 2.
C
C      RUNNO                 1    THRU  5
C      XDOT1                 6    THRU  10
C      YDOT1                 11   THRU  15
C      WONE                  16   THRU  20
C      XKX                   21   THRU  25
C      XKY                   26   THRU  30
C      XKXP                  31   THRU  35
C      XKYP                  36   THRU  40
C      XKXDP                 41   THRU  45
C      XKYDP                 46   THRU  50
C
C
C
C      SYMBOL                      DEFINITION
C
C      EX                    COEFFICIENT OF RESTITUTION IN X DIRECTION
C      EY                    SAME BUT IN Y DIRECTION
C      EXX                   INITIAL VALUE OF EX     (INPUT DATA)
C      EYY                   INITIAL VALUE OF EX     (INPUT DATA)
```

Figure 4-7. Main Program

```
C     EXDEL                EX RANGE                (INPUT DATA)
C     EYDEL                EY RANGE               (INPUT DATA)
C     EXMAX                EX MAXIMUM             (INPUT DATA)
C     EYMAX                EY MAXIMUM             (INPUT DATA)
C
C     XDOT1     (INPUT)    INITIAL VELOCITY COMPONENT OF REAR FOOTPAD
C     YDOT1     (INPUT)    INITIAL VELOCITY COMPONENT OF REAR FOOTPAD
C     WONE      (INPUT)    INITIAL ANGULAR VELOCITY   OF REAR FOOTPAD
C     XKX                  THESE SIX VARIABLES
C     XKY                  ARE FUNCTIONS
C     XKXP                 OF  MASS
C     XKYP                 AND VELOCITIES
C     XKXDP                (SEE EQS. 30-31-32-
C     XKYDP                39-40-41)
C
C     PSI                  VEHICLE INTIIAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     XI                   LEG GEOMETRY ANGLE (FIGURE 6-5) IN RADIANS
C     ZETA                 SLOPE OF LUNAR SURFACE (FIG.6-6) IN RADIANS
C     XM                   MASS OF FOOTPADS
C     XMM                  MASS OF VEHICLE EXCLUDING FOOTPADS
C     XII                  MOMENT OF INERTIA
C     XG                   GRAVITY FORCE
C     XL1                  LENGTH OF LEG ONE (FIGURE 6-5)
C     XL2
C     EPONE                CONVERGENCE ERROR TEST FOR XN(30) AND XN(44)
C     EPTWO                CONVERGENCE ERROR TEST FOR  T AND TPREV.
C
C     FF                   FF = XN(30)-XN(44)
C     FFZERO               FFZERO EQUALS INITIAL VALUE OF FF
C     TPREV                PREV VALUE OF TIME
C     FFF                  FUNCTION OF   T (SOLVED BY ITERATION)
C     FZERO                INITIAL VALUE OF FFF
C
C     PS2                  VEHICLE FINAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     PS2DEG               SAME AS PS2 BUT IN DEGREES
C     PS2DEL               INCREMENT OF PS2
C     FLAGD                TO PRINT OR NOT PRINT CONVERGENCE STEPS OF XN(30)
C     JJ                   CONTROLS LOGICAL EXIT FROM SUBROUTINE  N30N44
C     KK                   CONTROLS LOGICAL EXIT FROM SUBROUTINE FFIT
C     LL                   CONTROLS LOGICAL EXIT FROM SUBROUTINE  FTHREE
C     RR
C     RUNNO                IDENTIFICATION  OF RUN NUMBER
C
C     PS5                  EQUALS PS2 VALUE WHEN FF OF PS2 HAS SAME SIGN AS
C                          FFZERO.
C
C     PS6                  EQUALS PS2 WHEN FF OF PS2 HAS OPPISITE SIGN FFZERO
C     AA                   TO PRINT EVERY FIFTH VALUE OF FF, XN(30),XN(44),PS1
C                          IF CONVERGENCE  STEPS ARE DESIRED
C     AA2                  IF CONVERGENCE OF FF DOESN-T DUCCEED WITHIN 20
C                          ITERATIONS THEN ON TO NEXT EX VALUE
C     ALPHA1               A FUNCTION OF PS1,PS2,XI,ZETA (SEE EQ.46)
C     ALPHA2               SAME AS ABOVE (SEE EQ.26)
C     BETA1                SAME AS ABOVE (SEE EQ.47)
C     GAMMA                SAME AS ABOVE (SEE EQ.88)
C
C     A                    A FUNCTION OF INITIAL AND FINAL CONDITIONS.
C     B                    FOR A SEE EQ. 34, FOR B SEE EQ. 35, FOR C SEE EQ.
C     C                    37, FOR D SEE EQ. 38.
C     D
C     E                    A FUNCTION OF THE INTIIAL CONDITIONS
```

Figure 4-7. Main Program (Continued)

```
C     F                   FOR E SEE EQ. 12-FOR F SEE EQ.13
C     G                   AND FOR G SEE EQ. 14.
C
C     XN(1) THRU          XN(1) THRU XN(44) ARE FUNCTIONS OF VEHICLE MASS,
C     XN(44)              INITIAL AND FINAL VELOCITIES, ETC. (SEE EQS. 51-99)
C     X3DOT               VELOCITY COMPONENT WHEN FRONT FOOTPAD TOUCHES
C     Y3DOT               VELOCITY COMPONENT WHEN FRONT FOOTPAD TOUCHES
C     PS3                 ATTITUDE WHEN FRONT FOOTPAD TOUCHES -EQ. 110
C     W3                  ANGULAR VELOCITY WHEN FRONT FOOTPAD TOUCHES -EQ.109
C     X3                  X DISTANCE FROM AXES AT C.G. AS FOOTPAD TOUCHES
C     Y3                  Y DISTANCE FROM AXES AT C.G. AS FOOTPAD TOUCHES
C     BETA3               FUNCTION OF PS3
C
C     PS1D                SAME AS PS1 BUT IN DEGREES
C     XID                 SAME AS XI BUT IN DEGREES
C     ZETAD               SAME AS ZETA BUT IN DEGREES
C     PS2D                SAME AS PS2  BUT IN DEGREES
C     PS2DEG              SAME AS PS2D
C     T                   TIME INTERVAL FOR REAR LEG TOUCHDOWN (SEE EQ. 69)
C     TDEL                INCREMENTS OF T.    (T=DELTA T SUB 2)
C     T1                  EQUALS T WHEN FFF OF T HAS SAME SIGN AS FZERO
C     FZERO               INITIAL VALUE OF FFF
C
C
C
C

      COMMON/C1/RUNNO,EXX,EXDEL,EXMAX,EYY,EYDEL,EYMAX,EX,EY,XN(50)
      COMMON/C2/XDOT1,YDOT1,WONE,XKX,XKY,XKXP,XKYP,XKXDP,XKYDP
      COMMON/C3/PS1,XI,ZETA,PS2DEL,XM,XMM,XII,XG,XL1,XL2,EPONE,EPTWO
      COMMON/C4/FF,FFZERO,T,TDEL,FFF,FZERO,TPREV, PS2,PS2DEG
      COMMON/C5/FLAGD,JJ,LL,KK,BB
C
C                         CALL SUBROUTINE INCONT WHICH READS TWO DATA
C                         CARDS AND SETS UP INITIAL CONDITIONS AND BASIC
C                         GEOMETRY.
C
C

  100 CALL INCONT
  130 EX = EXX
      PS2D=-20.0
      PS2=PS2D*3.14159265/180.0
      PS2DEG=PS2D
  135 IF(EX-EXMAX)148,148,140
  140 EY=EY+EYDEL
  145 IF(EY-EYMAX)130,130,146
  146 PRINT 912
  147 GO TO 100
C
C                         CALL SUBROUTINE FFIT WHICH SOLVES THE FUNCTION
C                         FF BY ITERATION. FF=XN(30)-XN(44).
C
C

  148 CALL FFIT
      GO TO (135,315),KK
C
C                         A VALID SOLUTION IS REACHED FOR FF SO FINAL
C                         VALUES OF FF, XN(30),XN(44),ETC. ARE PRINTED
C
C

  315 PRINT 901,FF,XN(30),XN(44),PS2DEG,XN(42),EX,EY
      PRINT 913
```

Figure 4-7. Main Program (Continued)

```
  316 GO TO 320
C
C                              THIS IS THE START OF THE SECOND PART OF THE
C                              PROGRAM THAT SOLVES A SECOND FUNCTION FFF
C                              BY ITERATION. AN INITIAL VALUE IS CALCULATED
C                              FOR AN INITIAL VALUE OF T.
C
C
  320 T = 0.0
      BB=10.0
      TDEL = 0.05
      PRINT 913
      PRINT 903
      FFF = -XL2*SIN(PS2) +XN(31)*T - XG/2.0*T*T*COS(ZETA) -XL1*SIN(XI+
     1PS2+XN(30)*T)+ XL1*SIN(XI+PS2)
      FZERO=FFF
      PRINT 902,FFF,T
C
C                              CALL SUBROUTINE FTHREE WHICH THEN SOLVES THE
C                              FUNCTION FFF BY ITERATION. THE ONLY VALID
C                              SOLUTIONS ARE FOR T BETWEEN ZERO AND 1.2
C
C
  325 CALL FTHREE
      GO TO (480,455),LL
  455 PRINT 902,FFF,T
      PRINT 913
C
C
C                              CALCULATE FINAL VELOCITIES AND LENGTHS AND
C                              PRINT THEM FOR THIS SET OF VALUES OF THE TWO
C                              PARAMETERS EX AND EY.
C
  460 X3DOT = XN(31) -XG*T*COS(ZETA)
      Y3DOT = XN(32) +XG*T*SIN(ZETA)
      PS3 = PS2+XN(30)*T
      W3 = XN(30)
      X3 = -XL1*SIN(XI +PS3)
      Y3 = XL1*COS(XI+PS3)
      BETA3 = -3.14159265/2.0 +XI+PS3+ZETA
      PRINT 909,XN(30),XN(31),XN(32),XN(33),XN(34)
      PRINT 910,XN(35),XN(44),T,X3DOT,Y3DOT
      PRINT 911,PS3,X3,Y3,BETA3
  470 PRINT 913
      PRINT 913
      GO TO 480
C
C
C                              INCREMENT EX TO NEXT VALUE AND RESET PS2D TO
C                              -20 DEGREES AND LOOP BACK TO STATEMENT 135.
C
  480 EX = EX + EXDEL
      PS2D = -20.0
      PS2 = PS2D*3.14159265/180.0
      PS2DEG = PS2D
      PRINT 913
      GO TO 135
  901 FORMAT(5H  FF=,F8.4,11H    XN(30)=,F8.4,11H    XN(44)=,F7.4,8H
     1PS2=,F8.2,11H    XN(42)=,F16.2,7H    EX=,F6.3,7H    EY=,F6.3)
  902 FORMAT(F15.4,F15.4)
  903 FORMAT(29H          FFF              T    //)
```

Figure 4-7. Main Program (Continued)

```
  909 FORMAT(10HO    N(30)=,F9.4,10H     N(31)=,F9.4,10H     N(32)=,F9.4,10
     1H     N(33)=,F9.4,10H     N(34)=,F9.4 )
  910 FORMAT(10HO    N(35)=,F9.4,10H     N(44)=,F9.4,10H DEL T 2 =,F9.4,10
     1H  X3 DOT =,F9.4,10H  Y3 DOT =,F9.4 )
  911 FORMAT(10HO  PSI 3 =,F9.4,10H      X3  =,F9.4,10H      Y3  =,F9.4,10
     1H BETA 3  =,F9.4 )
  912 FORMAT(1H1)
  913 FORMAT(1H )
C
C
      END
```

Figure 4-7. Main Program (Concluded)

```
C
C FOR INCONT
C
C
C
C     SUBROUTINE TITLE         INCONT
C
C     AUTHOR                   H. O. CARR
C
C     DATE                     09-1-64
C
C     CALL                     INCONT
C
C
C
C     PURPOSE               TO READ TWO DATA CARDS AND PRINT THIS DATA
C                           AND THEN TO INITIALIZE AND SET BASIC CONSTANTS
C
C     NOTE                  FLAG D IS SET TO MINUS ONE HERE. CHANGE THIS
C                           TO +1 IF INTERMEDIATE CONVERGENCE STEPS OF
C                           XN(30) AND XN(44) ARE DESIRED
C
C
C     SYMBOL                   DEFINITION
C
C     EX                    COEFFICIENT OF RESTITUTION IN X DIRECTION
C     EY                    SAME BUT IN Y DIRECTION
C     EXX                   INITIAL VALUE OF EX     (INPUT DATA)
C     EYY                   INITIAL VALUE OF EX     (INPUT DATA)
C     EXDEL                 EX RANGE                (INPUT DATA)
C     EYDEL                 EY RANGE               (INPUT DATA)
C     EXMAX                 EX MAXIMUM             (INPUT DATA)
C     EYMAX                 EY MAXIMUM             (INPUT DATA)
C     XDOT1     (INPUT)     INITIAL VELOCITY COMPONENT OF REAR FOOTPAD
C     YDOT1     (INPUT)     INITIAL VELOCITY COMPONENT OF REAR FOOTPAD
C     WONE      (INPUT)     INITIAL ANGULAR VELOCITY   OF REAR FOOTPAD
C     XKX                   THESE SIX VARIABLES
C     XKY                   ARE FUNCTIONS
C     XKXP                  OF  MASS
C     XKYP                  AND VELOCITIES
C     XKXDP                 (SEE EQS. 30-31-32-
C     XKYDP                 39-40-41)
C     PSI                   VEHICLE INTIIAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     XI                    LEG GEOMETRY ANGLE (FIGURE 6-5) IN RADIANS
C     ZETA                  SLOPE OF LUNAR SURFACE (FIG.6-6) IN RADIANS
C     XM                    MASS OF FOOTPADS
C     XMM                   MASS OF VEHICLE EXCLUDING FOOTPADS
C     XII                   MOMENT OF INERTIA
C     XG                    GRAVITY FORCE
C     XL1                   LENGTH OF LEG ONE (FIGURE 6-5)
C     XL2
C     EPONE                 CONVERGENCE ERROR TEST FOR XN(30) AND XN(44)
C     EPTWO                 CONVERGENCE ERROR TEST FOR  T AND TPREV.
C     PS2DEG                SAME AS PS2 BUT IN DEGREES
C     PS2DEL                INCREMENT OF PS2
C     FLAGD                 TO PRINT OR NOT PRINT CONVERGENCE STEPS OF XN(30)
C     RUNNC                 IDENTIFICATION  OF RUN NUMBER
C     PS1D                  SAME AS PS1 BUT IN DEGREES
C     XID                   SAME AS XI BUT IN DEGREES
C     PS2D                  SAME AS PS2  BUT IN DEGREES
C     PS2DEG                SAME AS PS2D
```

Figure 4-8. Subroutine INCONT

```
C
C
C
      SUBROUTINE INCONT
      COMMON/C1/RUNNO,EXX,EXDEL,EXMAX,EYY,EYDEL,EYMAX,EX,EY,XN(50)
      COMMON/C2/XDOT1,YDOT1,WONE,XKX,XKY,XKXP,XKYP,XKXDP,XKYDP
      COMMON/C3/PS1,XI,ZETA,PS2DEL,XM,XMM,XII,XG,XL1,XL2,EPONE,EPTWO
      COMMON/C4/FF,FFZERO,T,TDEL,FFF,FZERO,TPREV, PS2,PS2DEG
      COMMON/C5/FLAGD,JJ,LL,KK,BB
  101 READ 920,RUNNO,EXX,EXDEL,EXMAX,EYY,EYDEL,EYMAX
      READ 921,RUNNO,XDOT1,YDOT1,WONE,XKX,XKY,XKXP,XKYP,XKXDP,XKYDP
  105 PRINT 906,RUNNO
      PRINT 924,EXX,EXDEL,EXMAX
      PRINT 925,EYY,EYDEL,EYMAX
      PRINT 926,XDOT1,YDOT1,WONE,XKX,XKY ,  XKXP,XKYP,XKXDP,XKYDP
  110 PS1D=-20.0
      PS1=PS1D*3.14159265/180.0
      XID=45.0
      XI=XID*3.14159265/180.0
      ZETAD=15.0
      ZETA=ZETAD*3.14159265/180.0
      PS2DEL = 1.0*3.14159265/180.0
  115 XM=8.0
      XMM=400.0
      XII=7960.0
      XG=5.32
      XL1=20.0
      XL2=28.28
  120 EPONE=0.0001
      EPTWO=0.0001
      PS2D=-20.0
      PS2=PS2D*3.14159265/180.0
      PS2DEG=PS2D
      EY = EYY
      FLAGD = -1.0
  906 FORMAT(17H0    RUN NUMBER  =,F5.0//)
  920 FORMAT(F5.0,6F5.3)
  921 FORMAT(F5.0,2F5.1,7F5.3)
  924 FORMAT(7H0    EX=,F6.3,9H  EXDEL =,F6.2,9H EXMAX  =,F6.3//)
  925 FORMAT(7H0    EY=,F6.3,9H  EYDEL =,F6.2,9H EYMAX  =,F6.3//)
  926 FORMAT(9H0 XDOT1 =,F5.2,9H  YDOT1 =,F5.2,9H  W ONE =,F4.2,7H  XKX
     1=,F4.2,7H  XKY =,F4.2,8H  XKXP =,F4.2,8H  XKYP =,F4.2,9H  XKXDP =,
     2F4.2,9H  XKYDP =,F4.2///)
      RETURN
      END
```

Figure 4-8. Subroutine INCONT (Concluded)

```
- FOR FFIT
C
C
C     SUBROUTINE TITLE          FFIT
C
C     AUTHOR                    H. O. CARR
C
C     DATE                      09-1-64
C
C     CALL                      FFIT
C
C
C     PURPOSE                   SOLVE EQUATION FF BY ITERATION IN TERMS
C                               OF THE VARIABLE PS2. FF IS SATISFIED
C                               WHEN XN(30) DIFFERS FROM XN(44) BY A
C                               SMALL PERCENT DIFFERENCE.
C
C
C     METHOD                    INCREMENT PS2 UNTIL VALUE OF FF CHANGES
C                               SIGN AND THEN HALF INTERVAL UNTIL
C                               CONVERGENCE OCCURS.
C
C     NOTE 1.                   IF THE CONVERGENCE TEST FAICS AFTER
C                               HALVING THE INTERVAL 20 TIMES, THEN
C                               INCREMENT EX AND EXIT FROM SUBROUTINE
C
C     NOTE 2.                   IF CONVERGENCE DOES NOT OCCUR FOR
C                               VALUES OF PS2 BETWEEN -20 DEGREES AND
C                               ZERO DEGREES, THEN INCREMENT EX AND EXIT
C                               FROM SUBROUTINE
C
C
C     SYMBOL                    DEFINITION
C
C     EX                    COEFFICIENT OF RESTITUTION IN X DIRECTION
C     EY                    SAME BUT IN Y DIRECTION
C     EXDEL                 EX RANGE                 (INPUT DATA)
C     ERCNF                 CONVERGENCE ERROR TEST FOR XN(30) AND XN(44)
C     FF                    FF = XN(30)-XN(44)
C     FFZERO                FFZERO EQUALS INITIAL VALUE OF FF
C     PS2                   VEHICLE FINAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     PS2DEG                SAME AS PS2 BUT IN DEGREES
C     PS2DEL                INCREMENT OF PS2
C     FLAGD                 TO PRINT OR NOT PRINT CONVERGENCE STEPS OF XN(30)
C     JJ                    CONTROLS LOGICAL EXIT FROM SUBROUTINE  N30N44
C     KK                    CONTROLS LOGICAL EXIT FROM SUBROUTINE FFIT
C     PS5                   EQUALS PS2 VALUE WHEN FF OF PS2 HAS SAME SIGN AS
C     PS6                   EQUALS PS2 WHEN FF OF PS2 HAS OPPISITE SIGN FFZERO
C     AA                    TO PRINT EVERY FIFTH VALUE OF FF, XN(30),XN(44),PS1
C                           IF CONVERGENCE  STEPS ARE DESIRED
C     AA2                   IF CONVERGENCE OF FF DOESN-T DUCCEED WITHIN 20
C                           ITERATIONS  THEN ON TO NEXT EX VALUE
C     XN(1) THRU            XN(1) THRU XN(44) ARE FUNCTIONS OF VEHICLE MASS,
C     XN(44)                INITIAL AND FINAL VELOCITIES, ETC. (SEE EQS. 51-99)
C     PS2D                  SAME AS PS2  BUT IN DEGREES
C     PS2DEG                SAME AS PS2D
C
C
C
```

Figure 4-9. Subroutine FFIT

```
      SUBROUTINE FFIT
      COMMON/C1/RUNNO,EXX,EXDEL,EXMAX,EYY,EYDEL,EYMAX,EX,EY,XN(50)
      COMMON/C2/XDOT1,YDOT1,WONE,XKX,XKY,XKXP,XKYP,XKXDP,XKYDP
      COMMON/C3/PS1,XI,ZETA,PS2DEL,XM,XMM,XII,XG,XL1,XL2,EPONE,EPTWO
      COMMON/C4/FF,FFZERO,T,TDEL,FFF,FZERO,TPREV, PS2,PS2DEG
      COMMON/C5/FLAGD,JJ,LL,KK,BB
C
C
C                               CALL SUBROUTINE N30N44 AND CALCULATE XN(30) AND
C                               XN(44) AND FF
C                               SUBROUTINE SETS JJ=2 FOR NORMAT EXIT
C                               AND IT SETS JJ=1 FOR ABNORMAL EXIT WHEN
C                               XN(42) IS NEGATIVE
C
  150 CALL N30N44
      GO TO (155,170),JJ
  155 PS2=PS2+PS2DEL
      PS2DEG=PS2*180.0/3.14159265
  160 IF (PS2) 150,150,165
  165 PRINT 927,EX,EY
      GO TO 167
  167 EX = EX +EXDEL
      PS2D=-20.0
      PS2=PS2D*3.14159265/180.0
      PS2DEG=PS2D
      PRINT 913
C
C
C                               SUBROUTINE SETS KK=2 FOR NORMAL EXIT
C                               AND SETS KK=1 WHEN ITERATION FAILS OR CONVERGENCE
C                               DOESN-T OCCUR WITHIN PS2 RANGE
C
      KK = 1
      RETURN
  170 FFZERO=FF
      PS5 = PS2
C
C
C                               AA IS A COUNTER THAT ALLOWS A TEMP PRINT EVERY
C                               FIVE TIMES THRU THIS LOOP (NOTE. THIS PRINT ONLY
C                               OCCURS WHEN FLAGD IS SET TO +1.0)
C
      AA=0.0
      IF(FLAGD)175,173,173
  173 PRINT 901,FF,XN(30),XN(44),PS2DEG,XN(42),EX,EY
  175 PS2=PS2+PS2DEL
      PS2DEG=PS2*180.0/3.14159265
  176 IF (PS2) 180,180,165
  180 CALL N30N44
      GO TO (185,195),JJ
  185 PS2=PS2+PS2DEL
      PS2DEG=PS2*180.0/3.14159265
  190 IF (PS2) 180,180,165
  195 AA=AA+1.0
  196 IF (AA-4.0) 200,200,197
  197 AA=0.0
      IF(FLAGD)200,198,198
  198 PRINT 901,FF,XN(30),XN(44),PS2DEG,XN(42),EX,EY
      GO TO 200
C
C
```

Figure 4-9. Subroutine FFIT (Continued)

```
C                                             IF FF HAS SAME SIGN AS FFZERO THEN VALUE OF
C                                             FUNCTION HAS NOT CROSSED OVER ZERO POINT.
C                                             IF SIGNS ARE DIFFERENT, THEN HALF INTERVAL UNTIL
C                                             CONVERGENCE OCCURS.
C
  200 IF(FFZERO)205,210,210
  205 IF(FF)215,217,217
  210 IF(FF)217,215,215
  215 PS5=PS2
      GO TO 175
  217 AA2=0.0
  218 GO TO 220
  220 PS6=PS2
  225 PS2=(PS5+PS6)/2.0
      PS2DEG=PS2*180.0/3.14159265
  230 CALL N30N44
      GO TO (235,240),JJ
  235 GO TO 165
  240 GO TO 245
  245 AA2=AA2+1.0
  246 IF(AA2-20.0)250,250,247
  247 PRINT 914
      GO TO 167
C
C
C                                             PERCENT CONVERGENCE TEST
C
  250 IF(ABS((XN(30)-XN(44))/XN(30))-EPONE)255,255,280
  280 IF(FFZERO)290,300,300
  290 IF(FF)310,220,220
  300 IF(FF)220,310,310
  310 PS5=PS2
      GO TO 225
  255 KK = 2
  901 FORMAT(5H  FF=,F8.4,11H     XN(30)=,F8.4,11H     XN(44)=,F7.4,8H
     1PS2=,F8.2,11H     XN(42)=,F16.2,7H     EX=,F6.3,7H     EY=,F6.3)
  913 FORMAT(1H )
  914 FORMAT(51H0     FF ITERATION FAILS. INCREMENT EX AND CONTINUE.//)
  927 FORMAT(99H XN(30) + XN(44) DO NOT CONV. IN VALID PS2 INTERVAL (-20
     1 TO 0 DEGREES)---THIS VOIDED CASE HAS    EX=,F6.3,7H     EY=,F6.3)
      RETURN
      END
```

Figure 4-9. Subroutine FFIT (Concluded)

```
C
- FOR FTHREE
C
C
C
C     SUBROUTINE TITLE               FTHREE
C
C     AUTHOR                         H. O. CARR
C
C
C     DATE                           09-1-64
C
C     CALL                           FTHREE
C
C     PURPOSE                        SOLVE EQUATION FFF BY ITERATION IN
C                                    TERMS OF THE VARIABLE T=DELTA T SUB 2.
C
C     METHOD                         INCREMENT T UNTIL VALUE OF FFF CHANGES
C                                    SIGN AND THEN HALF INTERVAL UNTIL
C                                    CONVERGENCE OCCURS
C
C     NOTE 1.                        MAXIMUM T VALUE IS 1.20.
C                                    IF CONVERGENCE DOES NOT OCCUR BEFORE
C                                    THIS MAXIMUM T VALUE THEN EXIT FROM
C                                    SUBROUTINE.
C
C
C     SYMBOL                         DEFINITION
C     ZETA                      SLOPE OF LUNAR SURFACE (FIG.6-6) IN RADIANS
C     XL1                       LENGTH OF LEG ONE (FIGURE 6-5)
C     XL2
C     EPTWO                     CONVERGENCE ERROR TEST FOR  T AND TPREV.
C     TPREV                     PREV VALUE OF TIME
C     FZERO                     INITIAL VALUE OF FFF
C     PS2                       VEHICLE FINAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     LL                        CONTROLS LOGICAL EXIT FROM SUBROUTINE  FTHREE
C     XN(1) THRU                XN(1) THRU XN(44) ARE FUNCTIONS OF VEHICLE MASS,
C     XN(44)                    INITIAL AND FINAL VELOCITIES, ETC. (SEE EQS. 51-99)
C     ZETAD                     SAME AS ZETA BUT IN DEGREES
C     PS2D                      SAME AS PS2  BUT IN DEGREES
C     PS2DEG                    SAME AS PS2D
C     T                         TIME INTERVAL FOR REAR LEG TOUCHDOWN (SEE EQ. 69)
C     TDEL                      INCREMENTS OF T.    (T=DELTA T SUB 2)
C     T1                        EQUALS T WHEN FFF OF T HAS SAME SIGN AS FZERO
C     FZERO                     INITIAL VALUE OF FFF
C
C
C
      SUBROUTINE FTHREE
      COMMON/C1/RUNNO,EXX,EXDEL,EXMAX,EYY,EYDEL,EYMAX,EX,EY,XN(50)
      COMMON/C2/XDOT1,YDOT1,WONE,XKX,XKY,XKXP,XKYP,XKXDP,XKYDP
      COMMON/C3/PS1,XI,ZETA,PS2DEL,XM,XMM,XII,XG,XL1,XL2,EPONE,EPTWO
      COMMON/C4/FF,FFZERO,T,TDEL,FFF,FZERO,TPREV, PS2,PS2DEG
      COMMON/C5/FLAGD,JJ,LL,KK,BB
C
C
C                               JUST BEFORE ENTERING THIS SUBROUTINE,THE MAIN
C                               PROGRAM SET T=0 AND CALCULATED FFF FOR T=0.
C
C                               NOW T IS INCREMENTED AND THE FUNCTION FFF IS
C                               SOLVED BY ITERATION
```

Figure 4-10. Subroutine FTHREE

```
C
  330 T = T + TDEL
      FFF = -XL2*SIN(PS2) +XN(31)*T - XG/2.0*T*T*COS(ZETA)-XL1*SIN(XI+
     1PS2 +XN(30)*T) +XL1*SIN(XI+PS2)
C
C
C                            BB IS USED AS A COUNTER SO AS TO PRINT THE
C                            VALUES OF FFF AND T FOR EVERY TENTH
C                            ITERATION STEP
C
  331 BB=BB+1.0
  332 IF(BB-10.0)340,340,333
  333 BB=0.0
      PRINT 902,FFF,T
      GO TO 340
  340 IF(FZERO)350,360,360
  350 IF(FFF)370,380,380
  360 IF(FFF)380,370,370
  370 TONE=T
  371 IF(T-1.2)330,330,372
  372 PRINT 915
      LL = 1
      RETURN
C                            SUBROUTINE SETS LL=1 FOR ABNORMAL EXIT WHEN
C                            T IS INCREMENTED BEYOND 1.2 BEFORE VALUE OF
C                            FUNCTION FFF CHANGES SIGN FROM VALE AT T =0.
C
  380 TTWO=T
  390 TPREV =T
      T=(TONE+TTWO)/2.0
  400 FFF = -XL2*SIN(PS2) +XN(31)*T-XG/2.0*T*T*COS(ZETA)-XL1*SIN(XI+
     1PS2 +XN(30)*T) +XL1*SIN(XI+PS2)
  410 IF(ABS((T-TPREV)/T)-EPTWO)452,452,420
  420 IF(FZERO)430,440,440
  430 IF(FFF)450,380,380
  440 IF(FFF)380,450,450
  450 TONE=T
      GO TO 390
C
C
C                            SUBROUTINE SETS LL=2 FOR NORMAL EXIT WHEN
C                            ITERATION SUCCEEDS FOR T LESS THAN 1.2
C
  452 LL = 2
  902 FORMAT(F15.4,F15.4)
  915 FORMAT( 35H    DELTA T 2  GREATER  THAN  1.25. )
      RETURN
      END
```

Figure 4-10. Subroutine FTHREE (Concluded)

```
- FOR N30N44
C
C
C
C     SUBROUTINE TITLE          N30N44
C
C     AUTHOR                    H. O. CARR
C
C     DATE                      09-1-64
C
C     CALL                      N30N44
C
C
C     PURPOSE                   CALCULATE THE VALUE OF FF WHICH EQUALS
C                               XN(30)-XN(44). FF IS A FUNCTION OF PS2
C                               AND WTWO
C
C     METHOD                    PS2 IS THE VARIABLE IN THIS SET OF
C                               EQUATIONS. THE ONLY VALID VALUES OF PS2
C                               ARE FROM -20 DEGREES TO ZERO DEGREES.
C
C                               FOR SOME VALUES OF PS2 THE VALUE OF
C                               XN(42) IS NEGATIVE. WHEN THIS OCCURS EXIT
C                               FROM THE SUBROUTINE , GET A NEW VALUE OF
C                               PS2 AND RE-ENTER SUBROUTINE
C
C
C     SYMBOL                    DEFINITION
C
C     EX                   COEFFICIENT OF RESTITUTION IN X DIRECTION
C     EY                   SAME BUT IN Y DIRECTION
C     XDOT1     (INPUT)    INITIAL VELOCITY COMPONENT OF REAR FOOTPAD
C     YDOT1     (INPUT)    INITIAL VELOCITY COMPONENT OF REAR FOOTPAD
C     WONE      (INPUT)    INITIAL ANGULAR VELOCITY   OF REAR FOOTPAD
C     XKX                  THESE SIX VARIABLES
C     XKY                  ARE FUNCTIONS
C     XKXP                 OF  MASS
C     XKYP                 AND VELOCITIES
C     XKXDP                (SEE EQS. 30-31-32-
C     XKYDP                39-40-41)
C     PSI                  VEHICLE INTIIAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     XI                   LEG GEOMETRY ANGLE (FIGURE 6-5) IN RADIANS
C     XM                   MASS OF FOOTPADS
C     XMM                  MASS OF VEHICLE EXCLUDING FOOTPADS
C     XII                  MOMENT OF INERTIA
C     XG                   GRAVITY FORCE
C     XL1                  LENGTH OF LEG ONE (FIGURE 6-5)
C     XL2
C     FF                   FF = XN(30)-XN(44)
C     FFZERO               FFZERO EQUALS INITIAL VALUE OF FF
C     PS2                  VEHICLE FINAL PITCH ANGLE (FIGURE 6-6) IN RADIANS
C     JJ                   CONTROLS LOGICAL EXIT FROM SUBROUTINE  N30N44
C     ALPHA1               A FUNCTION OF PS1,PS2,XI,ZETA (SEE EQ.46)
C     ALPHA2               SAME AS ABOVE (SEE EQ.26)
C     BETA1                SAME AS ABOVE (SEE EQ.47)
C     GAMMA                SAME AS ABOVE (SEE EQ.88)
C     A                    A FUNCTION OF INITIAL AND FINAL CONDITIONS.
C     B                    FOR A SEE EQ. 34, FOR B SEE EQ. 35, FOR C SEE EQ.
C     C                    37, FOR D SEE EQ. 38.
C     D
```

Figure 4-11. Subroutine N30N44

```
C      E                             A FUNCTION OF THE INITIAL CONDITIONS
C      F                             FOR E SEE EQ. 12-FOR F SEE EQ.13
C      G                             AND FOR G SEE EQ. 14.
C      XN(1) THRU                    XN(1) THRU XN(44) ARE FUNCTIONS OF VEHICLE MASS,
C      XN(44)                        INITIAL AND FINAL VELOCITIES, ETC. (SEE EQS. 51-99)
C
C
C

      SUBROUTINE N30N44
      COMMON/C1/RUNNO,EXX,EXDEL,EXMAX,EYY,EYDEL,EYMAX,EX,EY,XN(50)
      COMMON/C2/XDOT1,YDOT1,WONE,XKY,XKY,XKXP,XKYP,XKXDP,XKYDP
      COMMON/C3/PS1,XI,ZETA,PS2DEL,XM,XMM,XII,XG,XL1,XL2,EPONE,EPTWO
      COMMON/C4/FF,FFZERO,T,TDEL,FFF,FZERO,TPREV, PS2,PS2DEG
      COMMON/C5/FLAGD,JJ,LL,KK,BB
 1000 ALPHA1=XI-ZETA-(PS1+PS2)/2.0
      ALPHA2=XI+ZETA+(PS1+PS2)/2.0
      BETA1=ZETA+(PS1+PS2)/2.0
      GAMMA=XI-1.0/2.0*(PS1+PS2)
 1010 A=(XMM*XKX+XM*(XKXP+XKXDP))*XDOT1+XM*XL1*WONE*(XKXP*COS(XI-PS1)-
     1XKXDP*COS(XI+PS1))
      B=(XMM*(1.0-XKX)+XM*(1.0-XKXP)+XM*(1.0-XKXDP))*XDOT1+XM*XL1*WONE*
     1((1.0-XKXP)*COS(XI-PS1)+(1.0-XKXDP)*COS(XI+PS1))
      C=(XMM*XKY+XM*(XKYP+XKYDP))*YDOT1-XM*XL1*WONE*(XKYP*SIN(XI-PS1
     1)+XKYDP*SIN(XI+PS1))
 1020 D=(XMM*(1.0-XKY)+XM*(1.0-XKYP)+XM*(1.0-XKYDP))*YDOT1-XM*XL1*WONE*
     1((1.0-XKYP)*SIN(XI-PS1)+(1.0-XKYDP)*SIN(XI+PS1))
      E=(XMM+2.0*XM)*XDOT1+XM*XL1*WONE*(COS(XI-PS1)-COS(XI+PS1))
 1030 F=(XMM+2.0*XM)*YDOT1-XM*XL1*WONE*(SIN(XI-PS1)+SIN(XI+PS1))
      G=(XII+2.0*XM*XL1**2)*WONE+XM*XL1*(XDOT1*(COS(XI-PS1)-COS(XI+
     1PS1))-YDOT1*(SIN(XI-PS1) +SIN(XI+PS1)))
 1040 XN(1)= (XMM+2.0*XM) -(1.0+EX)*(XMM*XKX+XM*(XKXP+XKXDP))
      XN(2)=XM*XL1*(-(1.-(1.+EX)*XKXP)*COS(XI-PS2)+(1.-(1.+EX)*XKXDP)*
     1COS(XI+PS2))
      XN(3)= A-EX*B
 1050 XN(4)=(XMM+2.0*XM)-(1.0+EY)*(XMM*XKY+XM*(XKYP+XKYDP))
      XN(5)=XM*XL1*((1.-(1.+EY)*XKYP)*SIN(XI-PS2)+(1.-(1.+EY)*XKYDP)*
     1SIN(XI+PS2))
      XN(6)=C-EY*D
      XN(7)= XN(2)/XN(1)
 1060 XN(8) = XN(3)/XN(1)
      XN(9) = XN(5)/XN(4)
      XN(10) = XN(6)/XN(4)
      XN(11) = XN(7) +XL1*COS(XI-PS2)
 1070 XN(12) = XN(9) -XL1*SIN(XI-PS2)
      XN(13) = XN(7) -XL1*COS(XI+PS2)
      XN(14) = XN(9) -XL1*SIN(XI+PS2)
 1080 XN(15) = XII+XMM*XL1*(XN(9)*SIN(XI-PS2) -XN(7)*COS(XI-PS2))-XM*
     1XL2*(XN(14)*SIN(PS2) +XN(13)*COS(PS2))
 1090 XN(16) = -XII*WONE+XMM*XL1*(XN(10)*SIN(XI-PS2) -XN(8)*COS(XI-PS2)
     1-YDOT1* SIN(XI-PS1) +XDOT1*COS(XI-PS1)) -XM*XL2* (XN(10)*SIN(PS2)+
     1XN(8)*COS(PS2) - (YDOT1 -XL1*WONE*SIN(XI+PS1))*SIN(PS1) -(XDOT1-
     1XL1*WONE*COS(XI+PS1))*COS(PS1))
 1100 XN(17) = XMM*XG*XL1*COS(ALPHA1) +XM*XG*XL2*COS(BETA1)
      XN(18) = XN(15)/XN(17)
      XN(19) = XN(16)/XN(17)
 1110 XN(20) = XM*(XN(11)+XN(13))+XMM*XN(7)+(XMM+2.0*XM)*XG*XN(18)*
     1COS(ZETA)
      XN(21) = (XMM+2.0*XM)*XN(8) -E +(XMM+2.0*XM) *XG*XN(19)*COS(ZETA)
 1120 XN(22) = XM*(XN(12)+XN(14)) +XMM*XN(9) -(XMM+2.0*XM)*XG*XN(18)*
     1SIN(ZETA)
      XN(23) = (XMM+2.0*XM)*XN(10) -F -(XMM+2.0*XM)*XG*XN(19)*SIN(ZETA)
```

Figure 4-11. Subroutine N30N44 (Continued)

```
1130 XN(24) = XII+XM*XL1*(XN(11)*COS(XI-PS2) -XN(12)*SIN(XI-PS2)-
    1XN(13)*SIN(XI+PS2) -XN(14)*COS(XI+PS2))
     XN(25) = XM*XL1*(XN(8)*COS(XI-PS2) -XN(10)*SIN(XI-PS2) -XN(8)*
    1COS(XI+PS2) -XN(10)*SIN(XI+PS2))
1140 XN(26) = XL1*(XN(20)*COS(GAMMA) -XN(22)*SIN(GAMMA)+XM*XG*XN(18)*
    1(COS(ALPHA2) -COS(ALPHA1)))
     XN(27) = XL1*(XN(21)*COS(GAMMA) -XN(23)*SIN(GAMMA)+XM*XG*XN(19)*
    1(COS(ALPHA2)-COS(ALPHA1)))
1150 XN(28) = G +XN(27) -XN(25)
     XN(29) = XN(24)-XN(26)
1160 XN(30) = XN(28)/XN(29)
     XN(31) = XN(7)*XN(30)+XN(8)
1170 XN(32) = XN(9)*XN(30)+XN(10)
     XN(33) = XN(18)*XN(30)+XN(19)
1180 XN(34) = XN(20)*XN(30)+XN(21)
1190 XN(35) = XN(22)*XN(30)+XN(23)
     XN(36) = XMM*XG*XL1* (SIN(XI-ZETA-PS1) -SIN(XI-ZETA-PS2)) -XM*XG*
    1XL2*(SIN(ZETA+PS1)-SIN(ZETA+PS2))
1200 XN(37) = 1.0/2.0*XM* ((XDOT1+XL1*WONE*COS(XI-PS1))**2 +(YDOT1-XL1*
    1WONE*SIN(XI-PS1))**2)  +1.0/2.0*XM* ((XDOT1-XL1*WONE*COS(XI+PS1))*
    1*2 +(YDOT1 -XL1*WONE*SIN(XI+PS1))**2)  +1.0/2.0*XMM*(XDOT1**2+
    1YDOT1**2) +1.0/2.0*XII*WONE**2
     XN(38) = (1.0/2.0*XMM+XM)*(XN(8)*XN(8)+XN(10)*XN(10)) -XN(37)
1210 XN(39) =XM*(XN(5)*(XN(11)+XN(13)) +XN(10)*(XN(12)+XN(14))) +
    1XMM*(XN(7)*XN(8)+XN(9)*XN(10))
     XN(40) = 1.0/2.0*XM*(XN(11)**2+XN(12)**2+XN(13)**2+XN(14)**2)
    1+1.0/2.0*XMM*(XN(7)**2 +XN(9)**2) +1.0/2.0*XII
1220 XN(41) = XN(38)-XN(36)
     XN(42) = XN(39)**2 -4.0*XN(40)*XN(41)
C
C
C                               THE VALUE OF XN(42) MAY BE NEGATIVE FOR SOME
C                               VALUES OF PS2. IF SO SET JJ=1 AND EXIT
C                               AND INCREMENT PS2 AND RE-ENTER. FOR POSITIVE
C                               VALUES OF XN(42) CONTINUE AND CALCULATE VALUE
C                               OF FF. SET JJ=2 AND EXIT NORMALLY.
C
1225 IF(XN(42))1226,1230,1230
1226 JJ = 1
     RETURN
1230 XN(43) = -XN(39) +SQRT(XN(42))
1240 XN(44) = XN(43)/(2.0*XN(40))
1250 FF = XN(30)-XN(44)
1260 JJ = 2
     RETURN
     END
```

Figure 4-11. Subroutine N30N44 (Concluded)

```
RUN NUMBER  =  66.

EX= 1.000  EXDEL =   .01 EXMAX  = 1.100

EY=  .950  EYDEL =   .01 EYMAX  = 1.050

XDOT1 =-5.00  YDOT1 = 0.00  A ONE = .10  XKX = .50  XKY = .50  XKXP = .00  XKYP = .00  XKXDP = .50  XKYDP = .50

XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.000   EY=  .950
XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.010   EY=  .950
XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.020   EY=  .950
XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.030   EY=  .950
XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.040   EY=  .950
XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.050   EY=  .950
XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.060   EY=  .950
 FF=   .0001    XN(30)=   .8661    XN(44)=  .8660    PS2=  -15.04    XN(42)=    383304570.00   EX= 1.070   EY=  .950

        FFF              T

        7.3380           .0000
        6.4432           .0500
        -.0001           .4283

  N(30)=    .8661    N(31)=  -2.9535    N(32)=   6.5819    N(33)=    .1466   N(34)=1121.4655
  N(35)=  -9.8834    N(44)=    .6660 DEL T 2 =   .4283  X3 DOT =  -5.1547  Y3 DOT =   9.1717
 PSI 3 =    .1085    X3  = -15.5695    Y3  =  12.5282 BETA 3  =   -.4151

 FF=   .0000    XN(30)=   .6864    XN(44)=  .6683    PS2=  -14.03    XN(42)=    565222340.00   EX= 1.080   EY=  .950

        FFF              T

        6.6556           .0000
```

Figure 4-12. Sample Output

```
        5.9512          .0500
        -.0002          .3968

  N(30)=     .5584    N(31)=  -2.9325     N(32)=   6.6872     N(33)=     .1651    N(34)=1172.0113

  N(35)=  17.5680     N(44)=     .6667 DEL T 2 =     .3968  X3 DOT =  -4.9715  Y3 DOT =    9.2536

  PSI 3 =     .1076     X3  = -15.5796      Y3  =  12.5409 BETA 3  =   -.4160


 FF=  -.0001     XN(30)=    .9022    XN(44)=  .9023     PS2=  -13.24      XN(42)=     670157160.00    EX= 1.090    EY=  .950


        FFF                T


        6.4762          .0000
        5.5622          .0500
         .0001          .3708

  N(30)=     .9022    N(31)=  -3.0275     N(32)=   8.7368     N(33)=     .1863    N(34)=1179.8967

  N(35)=  23.1257     N(44)=     .9023 DEL T 2 =     .3708  X3 DOT =  -4.9331  Y3 DOT =    9.2494

  PSI 3 =     .1075     X3  = -15.5278      Y3  =  12.6051 BETA 3  =   -.4201


  FF    ITERATION FAILS.  INCREMENT  EX  AND CONTINUE. THIS VOIDED CASE HAS                   EX= 1.100    EY=  .950


XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.000    EY=  .960

XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.010    EY=  .960

XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.020    EY=  .960

XN(30) + XN(44) DO NOT CONV. IN VALID FS2 INTERVAL (-20 TO 0 DEGREES)---THIS VOIDED CASE HAS   EX= 1.030    EY=  .960
```

Figure 4-12. Sample Output (Concluded)

SECTION V

PROGRAM FOR COMPUTER SOLUTION OF EQUATIONS FROM CONDENSED ANALYSIS OF FRONT LEG IMPACT

A set of non-linear, algebraic equations has been derived in the Final Report. These equations, based upon rational analysis together with certain reasonable, simplifying assumptions, describe the behavior of the vehicle during stroking of the landing gear. This condensed analysis technique has been applied to examine vehicle motion during the first forward leg impact for a downhill landing, 2-2 footpad orientation, with the rear legs sustaining the initial ground contact. The applicability of the technique is not limited to this specific situation, but the 2-2, back-pitched, downhill landing is likely to be the critical landing configuration.

Due to the complexity of the set of non-linear equations describing the front leg impact, a numerical method has been utilized for simultaneous solution of the equations. The set of equations comprises three primary equations which must be solved simultaneously, and a number of auxiliary equations which can be substituted directly in the primary equations. The primary equations, derived in the previous section, are:

$$\dot{\beta}_f = \frac{1}{I+M\ell_f^2}\left\{M\ell_o V_{ot} + I\dot{\psi}_o + M\left[\ell_o t_f \sin\beta_o + \frac{(7V_{oh}+3V_{fh})t_f^2}{20} + \frac{(3\ddot{\eta}_o-2\ddot{\eta}_f)t_f^2}{60}\right]\right\} \tag{1}$$

$$\beta_f = \beta_o + \frac{(\dot{\beta}_o+\dot{\beta}_f)t_f}{2} + \frac{(\ddot{\beta}_o-\ddot{\beta}_f)t_f^2}{12} \tag{2}$$

$$\frac{1}{2}(I\dot{\psi}_o^2 + MV_o^2) - \frac{1}{2}(I+M\ell_f^2)\dot{\beta}_f^2 + Mg(\ell_o\cos\beta_o - \ell_f\cos\beta_f) = \sum_i F_i\delta_i \tag{3}$$

The unknowns in the primary equations, describing vehicle orientation and motion at the completion of front leg stroking, are the stability angle (β_f), time rate of change of stability angle ($\dot{\beta}_f$) and the distance in the plane of motion from the vehicle c.g. to the forward footpads (ℓ_f). Parameters used in these equations are defined in Table 5-1. Once the set of equations is solved, the ultimate stability of the vehicle is predicted based upon considerations of potential and kinetic energies.

The numerical procedure used is an adaptation of Newton's method for solving a set of non-linear algebraic equations. The procedure is an automatized trial and error method in which values of the unknowns are sought which simultaneously satisfy the three primary equations. To facilitate the search for a solution, Equations (1), (2), and (3) are each rewritten in terms of a difference function:

Table 5-1. Summary of Important Parameters Used In Condensed Analysis of Front Leg Impact

M	Mass (Vehicle and Pads)
I	Mass Moment of Inertia (Vehicle and Pads)
g	Gravitational Acceleration
F_i (i=1, 2, 3)	Crushing Force in ith Strut
δ i (i=1, 2, 3)	Total Stroking of ith Strut
A, B, C, D, E	Hardpoint Coordinates Relative to C.G.
α	Ground Slope
x, y, z	Initial Vehicle C.G. Coordinates (Ground Coordinate Axes)
$\dot{X}_o$, $\dot{Y}_o$	Initial Vehicle C.G. Velocities (Ground Coordinate Axes)
x_p, y_p, z_p	Initial Pad Coordinates (Vehicle Coordinate Axes)
ψ_o	Initial Pitch Attitude
ψ_f	Final Pitch Attitude
$\dot{\psi}_o$	Initial Pitch Rate
$\ddot{\psi}_o$	Initial Pitch Acceleration
β_o	Initial Stability Angle
β_f	Final Stability Angle
$\dot{\beta}_o$	Initial Stability Angular Rate
$\dot{\beta}_f$	Final Stability Angular Rate
$\ddot{\beta}_o$	Initial Stability Angular Acceleration
$\ddot{\beta}_f$	Final Stability Angular Acceleration
ℓ_o	Initial Effective Leg Length
ℓ_f	Final Effective Leg Length
t_f	Duration of Front Leg Stroking
V_{oh}	Initial Horizontal Velocity of C.G.
V_{fh}	Final Horizontal Velocity of C.G.
$\ddot{\eta}_o$	Initial Horizontal Acceleration of C.G.
$\ddot{\eta}_f$	Final Horizontal Acceleration of C.G.
V_{ot}	Initial Tangential Velocity of C.G.
a_{ot}	Initial Tangential Acceleration of C.G.
F_{ot}	Initial Tangential Force on C.G.
m_o	Initial Torque About C.G.
F_{oh}	Initial Horizontal Force on C.G.
γ_o	Initial Angle (in plane of motion) Included Between Footpad, C.G., and Vehicle Longitudinal Axis
γ_f	Final Angle (in plane of motion) Included Between Footpad, C.G., and Vehicle Longitudinal Axis

"Initial" and "Final" Respectively Refer to Conditions at Front Leg Impact and at the Completion of Front Leg Stroking.

$$F(\beta_f,\dot{\beta}_f,\ell_f)=\beta_o+\frac{\dot{\beta}_o+\dot{\beta}_{ft}}{2}t_f+\frac{\ddot{\beta}_o-\ddot{\beta}_f}{12}t_f^2-\beta_{ft} \tag{4}$$

$$G(\beta_f,\dot{\beta}_f,\ell_f)=\frac{1}{I+M\ell_{f_t}^2}\left\{M\ell_o V_{ot}+I\dot{\psi}_o+M\left[\ell_o t_f \sin\beta_o+\frac{(7V_{oh}+3V_{fh})}{20}t_f^2+\frac{(3\ddot{\eta}_o-2\ddot{\eta}_f)}{60}t_f^3\right]\right\}-\dot{\beta}_{f_t} \tag{5}$$

$$H(\beta_f,\dot{\beta}_f,\ell_f)=\frac{1}{2}\left(I\dot{\psi}_o^2+MV_o^2\right)-\frac{1}{2}\dot{\beta}_{f_t}^2(I+M\ell_{f_t}^2)+Mg(\ell_o\cos\beta_o-\ell_{f_t}\cos\beta_{f_t})-2\sum_i F_{ii}\delta_i \tag{6}$$

(The work done to crush the honeycomb is written $2\sum_i F_{ii}\delta_i$ to take advantage of the symmetry of a 2-2 landing.)

β_{ft}, $\dot{\beta}_{ft}$, and ℓ_{ft} are trial values of the unknowns. Successive sets of trial values are substituted until F, G, and H are sufficiently small.

Since F, G, and H are complicated functions, it is preferred to initiate the search for a solution by choosing a set of trial values close to the trial solution. An acceptable initial set of trial values is sought by choosing the "best" set of trial values for a large number of combinations of arbitrary values of β_f, $\dot{\beta}_f$, and ℓ_f. These arbitrary values are:

$(\beta_{ft})_j = a_j\beta_o$ (a_j = .6, .75, .8, .85, .9, .95)

$(\dot{\beta}_{ft})_k = b_k\dot{\beta}_o$ (b_k = .6, .7, .8, .9, .95, 1.0, 1.05, 1.1, 1.15, 1.20, 1.30, 1.40)

$(\ell_{ft})_n = c_n\ell_o$ (c_n = .75, .775, .8, .825, .875, .95)

where β_o, $\dot{\beta}_o$, and ℓ_o are the known values of β, $\dot{\beta}$, and ℓ at the time of front leg impact. A total of 432 combinations are thus defined. The "best" combination is chosen by defining:

$$\text{Index} = F^2 + G^2 + H^2 \tag{7}$$

Equation (7) is evaluated for each of the 432 combinations, and the set of trial values which results in the minimum value of Index is used as the starting point in the search for a solution.

To obtain subsequent sets of trial solutions, an extrapolation technique is used. Ignoring terms of second order and above, F, G, and H can each be expanded in a truncated Taylor's Series:

$$F(\beta_f, \dot{\beta}_f, \ell_f) = F_t(\beta_{f_t}, \dot{\beta}_{f_t}, \ell_{f_t}) + \left[\frac{\partial F}{\partial \beta_f} \delta\beta_f + \frac{\partial F}{\partial \dot{\beta}_f} \delta\dot{\beta}_f + \frac{\partial F}{\partial \ell_f} \delta\ell_f \right]_t + \dots \quad (8)$$

$$G(\beta_f, \dot{\beta}_f, \ell_f) = G_t(\beta_{f_t}, \dot{\beta}_{f_t}, \ell_{f_t}) + \left[\frac{\partial G}{\partial \beta_f} \delta\beta_f + \frac{\partial G}{\partial \dot{\beta}_f} \delta\dot{\beta}_f + \frac{\partial G}{\partial \ell_f} \delta\ell_f \right]_t + \dots \quad (9)$$

$$H(\beta_f, \dot{\beta}_f, \ell_f) = H_t(\beta_{f_t}, \dot{\beta}_{f_t}, \ell_{f_t}) + \left[\frac{\partial H}{\partial \beta_f} \delta\beta_f + \frac{\partial H}{\partial \dot{\beta}_f} \delta\dot{\beta}_f + \frac{\partial H}{\partial \ell_f} \delta\ell_f \right]_t + \dots \quad (10)$$

where the subscript "t" denotes that functions and partial derivatives are evaluated using the trial solution. It should be noted that the partial derivatives as well as the functions are available in analytical form.

Since the objective of the extrapolation is to determine values of $\beta_f, \dot{\beta}_f$, and ℓ_f which drive F, G, and H simultaneously toward zero, Equations (8), (9), and (10) are solved for $\delta\beta_f$, $\delta\dot{\beta}_f$, and $\delta\ell_f$ by setting F, G, and H all equal to zero. This result is

$$\delta\beta_f = \frac{1}{\Delta} x \left\{ -F_t \left[\frac{\partial G}{\partial \dot{\beta}_f} \frac{\partial H}{\partial \ell_f} - \frac{\partial G}{\partial \ell_f} \frac{\partial H}{\partial \dot{\beta}_f} \right]_t - \left[\frac{\partial F}{\partial \dot{\beta}_f} \left(-G_t \frac{\partial H}{\partial \ell_f} + H_t \frac{\partial G}{\partial \ell_f} \right) \right]_t + \left[\frac{\partial F}{\partial \ell_f} \left(-G_t \frac{\partial H}{\partial \dot{\beta}_f} + H_t \frac{\partial G}{\partial \dot{\beta}_f} \right) \right]_t \right\} \quad (11)$$

$$\delta\dot{\beta}_f = \frac{1}{\Delta} x \left\{ \left[\frac{\partial F}{\partial \beta_f} \left(-G_t \frac{\partial H}{\partial \ell_f} + H_t \frac{\partial G}{\partial \ell_f} \right) \right]_t + F_t \left[\frac{\partial G}{\partial \beta_f} \frac{\partial H}{\partial \ell_f} - \frac{\partial G}{\partial \ell_f} \frac{\partial H}{\partial \beta_f} \right]_t + \left[\frac{\partial F}{\partial \ell_f} \left(-H_t \frac{\partial G}{\partial \beta_f} + G_t \frac{\partial H}{\partial \beta_f} \right) \right]_t \right\} \quad (12)$$

$$\delta\ell_f = \frac{1}{\Delta} x \left\{ \left[\frac{\partial F}{\partial \beta_f} \left(-H_t \frac{\partial G}{\partial \dot{\beta}_f} + G_t \frac{\partial H}{\partial \dot{\beta}_f} \right) \right]_t - \left[\frac{\partial F}{\partial \dot{\beta}_f} \left(-H_t \frac{\partial G}{\partial \beta_f} + G_t \frac{\partial H}{\partial \beta_f} \right) \right]_t - F_t \left[\frac{\partial G}{\partial \beta_f} \frac{\partial H}{\partial \dot{\beta}_f} - \frac{\partial G}{\partial \dot{\beta}_f} \frac{\partial H}{\partial \beta_f} \right]_t \right\} \quad (13)$$

where

$$\Delta = \left[\frac{\partial F}{\partial \beta_f} \left(\frac{\partial G}{\partial \dot{\beta}_f} \frac{\partial H}{\partial \ell_f} - \frac{\partial G}{\partial \ell_f} \frac{\partial H}{\partial \dot{\beta}_f} \right) - \frac{\partial F}{\partial \dot{\beta}_f} \left(\frac{\partial G}{\partial \beta_f} \frac{\partial H}{\partial \ell_f} - \frac{\partial G}{\partial \ell_f} \frac{\partial H}{\partial \beta_f} \right) + \frac{\partial F}{\partial \ell_f} \left(\frac{\partial G}{\partial \beta_f} \frac{\partial H}{\partial \dot{\beta}_f} - \frac{\partial G}{\partial \dot{\beta}_f} \frac{\partial H}{\partial \beta_f} \right) \right]_t$$

The next set of trial solutions is obtained from:

$$\beta_{f_{t+1}} = \beta_{f_t} + \delta\beta_f \tag{14}$$

$$\dot{\beta}_{f_{t+1}} = \dot{\beta}_{f_t} + \delta\dot{\beta}_f \tag{15}$$

$$\ell_{f_{t+1}} = \ell_{f_t} + \delta\ell_f \tag{16}$$

The process is repeated until $\delta\beta_f$, $\delta\dot{\beta}_f$, and $\delta\ell_f$ simultaneously satisfy some predetermined error criteria.

Details of the computer program are presented in Figures 5-1 through 5-14. Figure 5-1 is a sample of the input data used in this program. The FORTRAN nomenclature is defined in the program and subroutine listings, Figure 5-8. Flow diagrams for the program are presented in the following order:

Figure 5-2	Flow Diagram of Main Program
Figure 5-3	Flow Diagram of Subroutine INCOND
Figure 5-4	Flow Diagram of Subroutine GUESS
Figure 5-5	Flow Diagram of Subroutine FEVAL
Figure 5-6	Flow Diagram of Subroutine SOLN
Figure 5-7	Flow Diagram of Subroutine DEVAL

INCOND calculate various initial conditions of geometry and motion from the input data. GUESS computes arbitrary trial solutions, from which will be determined a "best" set from which to initiate the extrapolation procedure. FEVAL evaluates the difference functions for a particular set of trial solutions. SOLN conducts the extrapolation procedure which should result in the final solution. DEVAL computes derivatives of the difference functions with respect to the independent variables.

The program listings are presented in the following order:

Figure 5-8	Listing of Main Program
Figure 5-9	Listing of Subroutine INCOND
Figure 5-10	Listing of Subroutine GUESS
Figure 5-11	Listing of Subroutine FEVAL
Figure 5-12	Listing of Subroutine SOLN
Figure 5-13	Listing of Subroutine DEVAL

A sample of the output data is presented in Figure 5-14.

IDENTIFICATION	1	I	M	GRAV
	2	F11	F22	F33
	3	X	Y	Z
	4	XPAD	YPAD	ZPAD
	5	PSO	PSOVEL	BETO
	6	ERRBF	ERRBFV	ERRLF
	7	ALPHA	R	RUN
	8	A	B	C
	9	D	E	
	10	XVEL	YVEL	

Figure 5-1. Sample Input Data

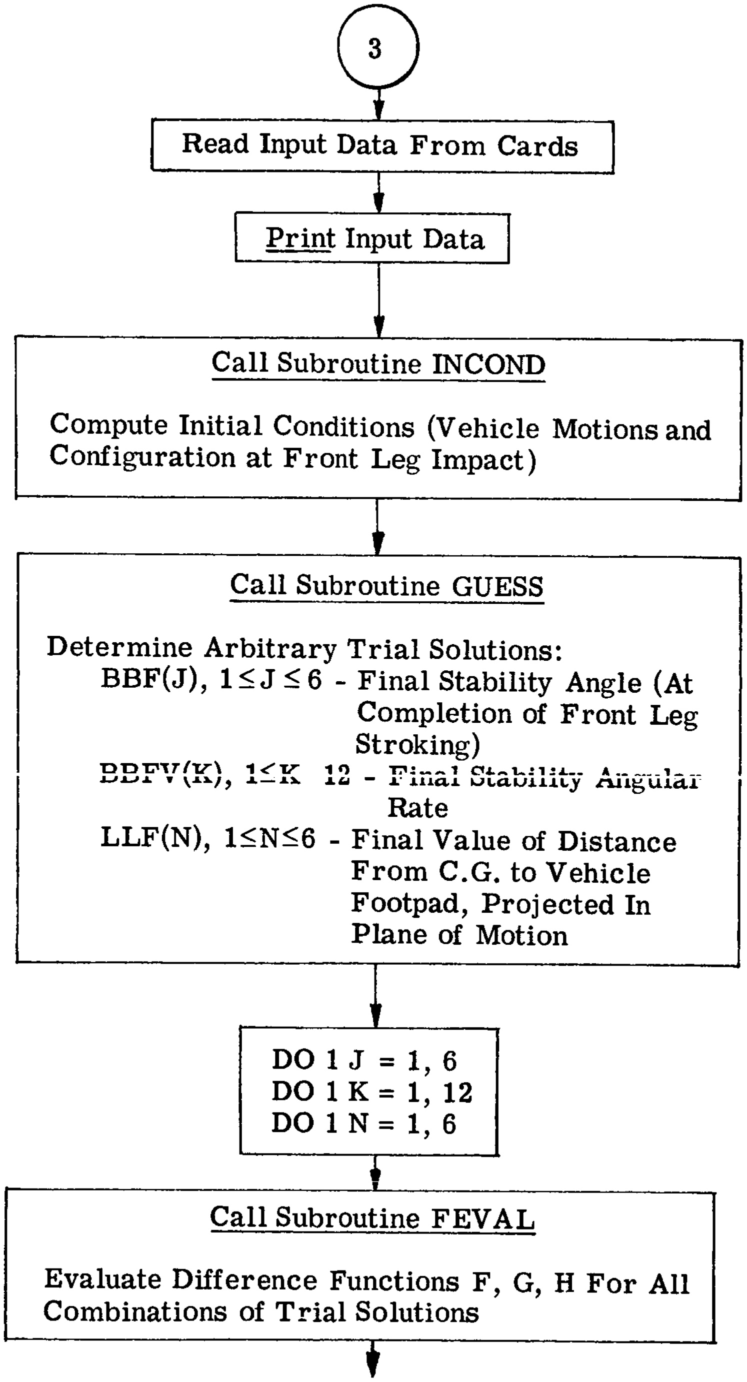


Figure 5-2. Flow Diagram of Main Program

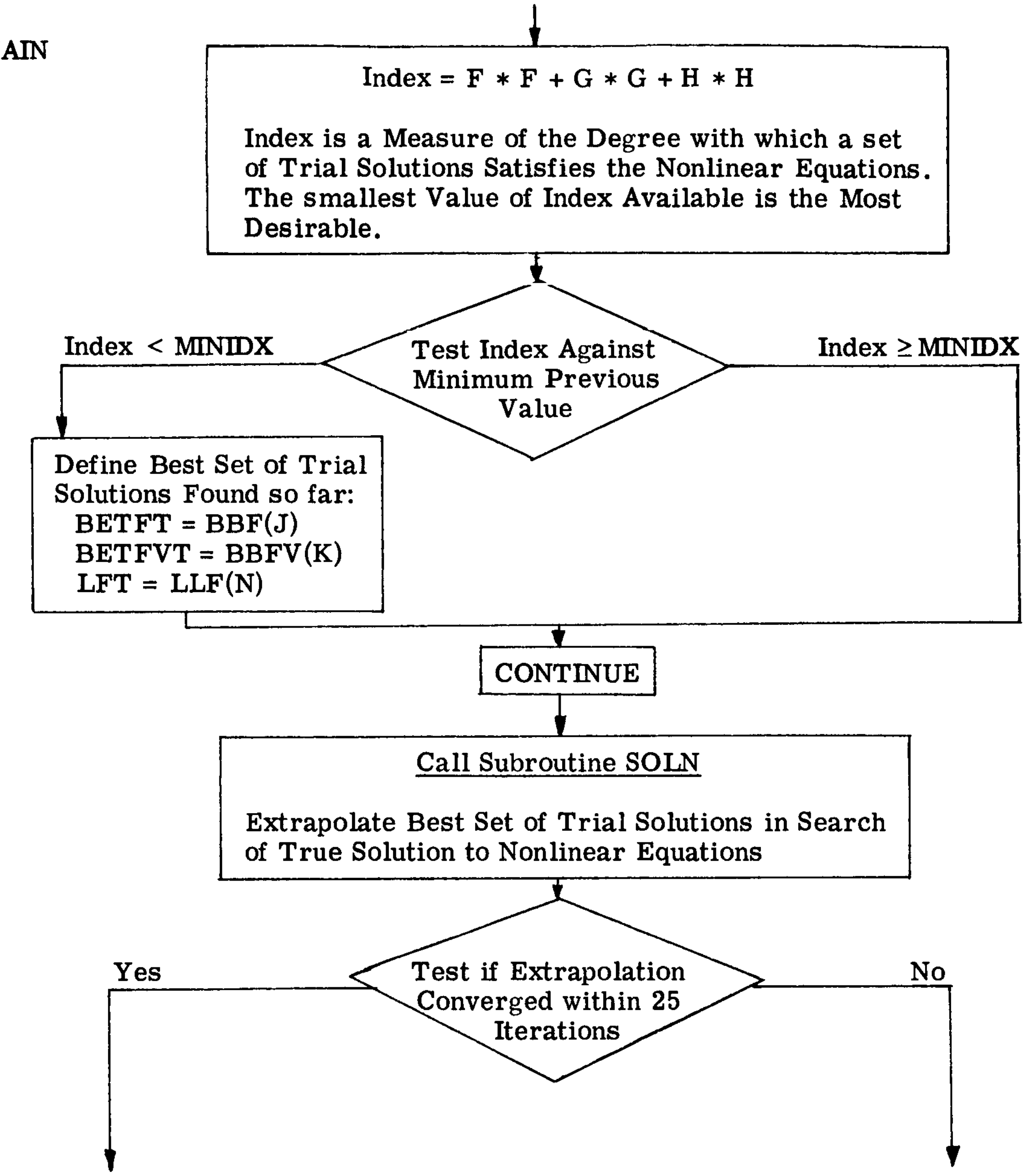


Figure 5-2. Flow Diagram of Main Program (Continued)

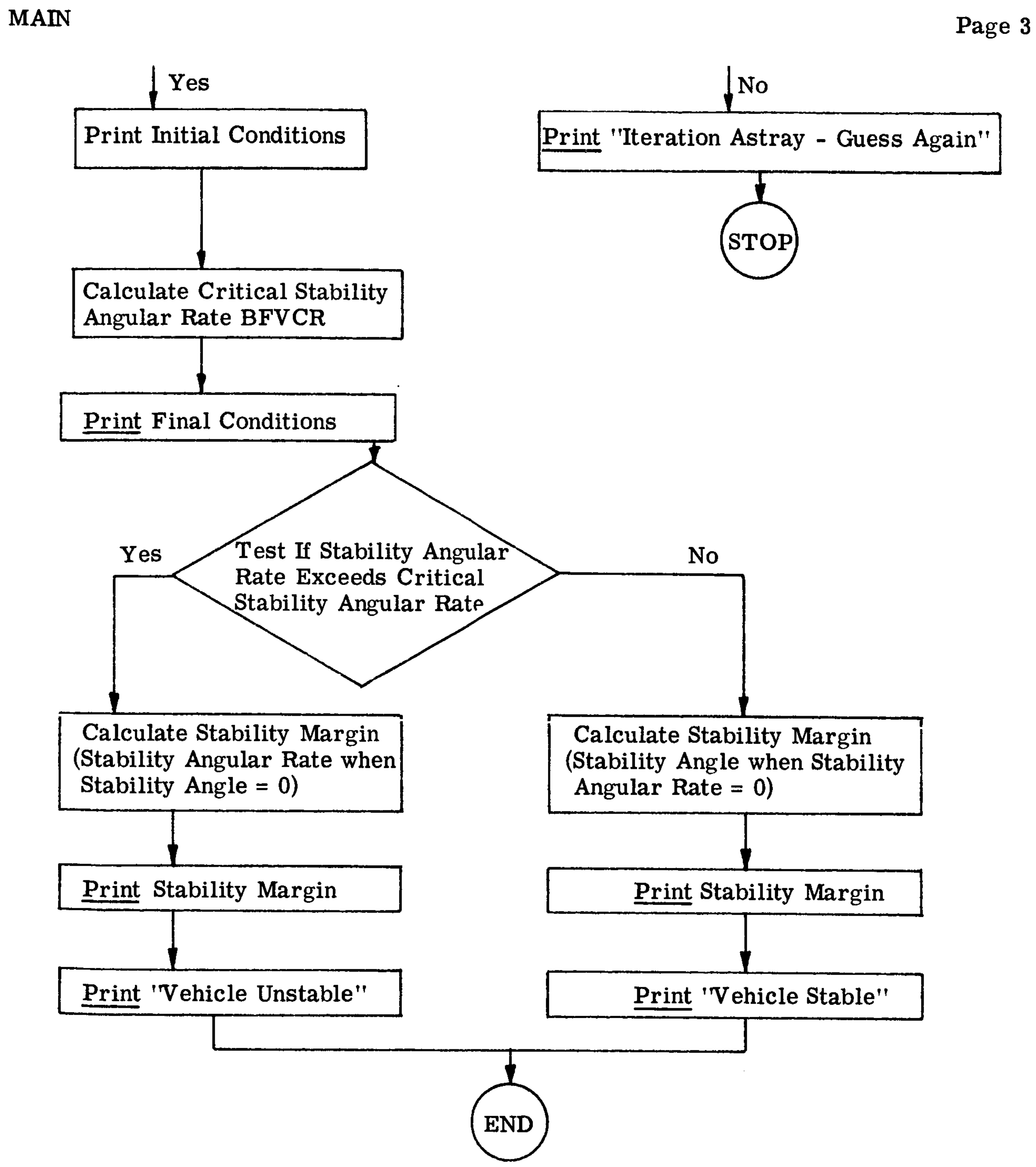


Figure 5-2. Flow Diagram of Main Program (Continued)

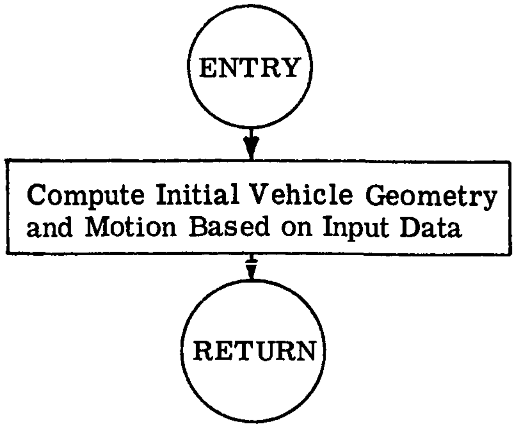


Figure 5-3. Flow Diagram of Subroutine INCOND

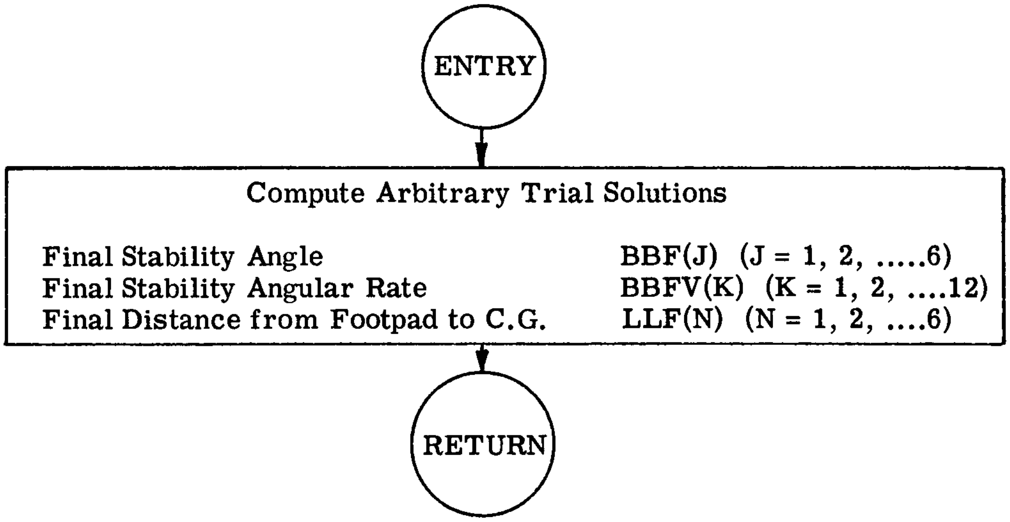


Figure 5-4. Flow Diagram of Subroutine GUESS

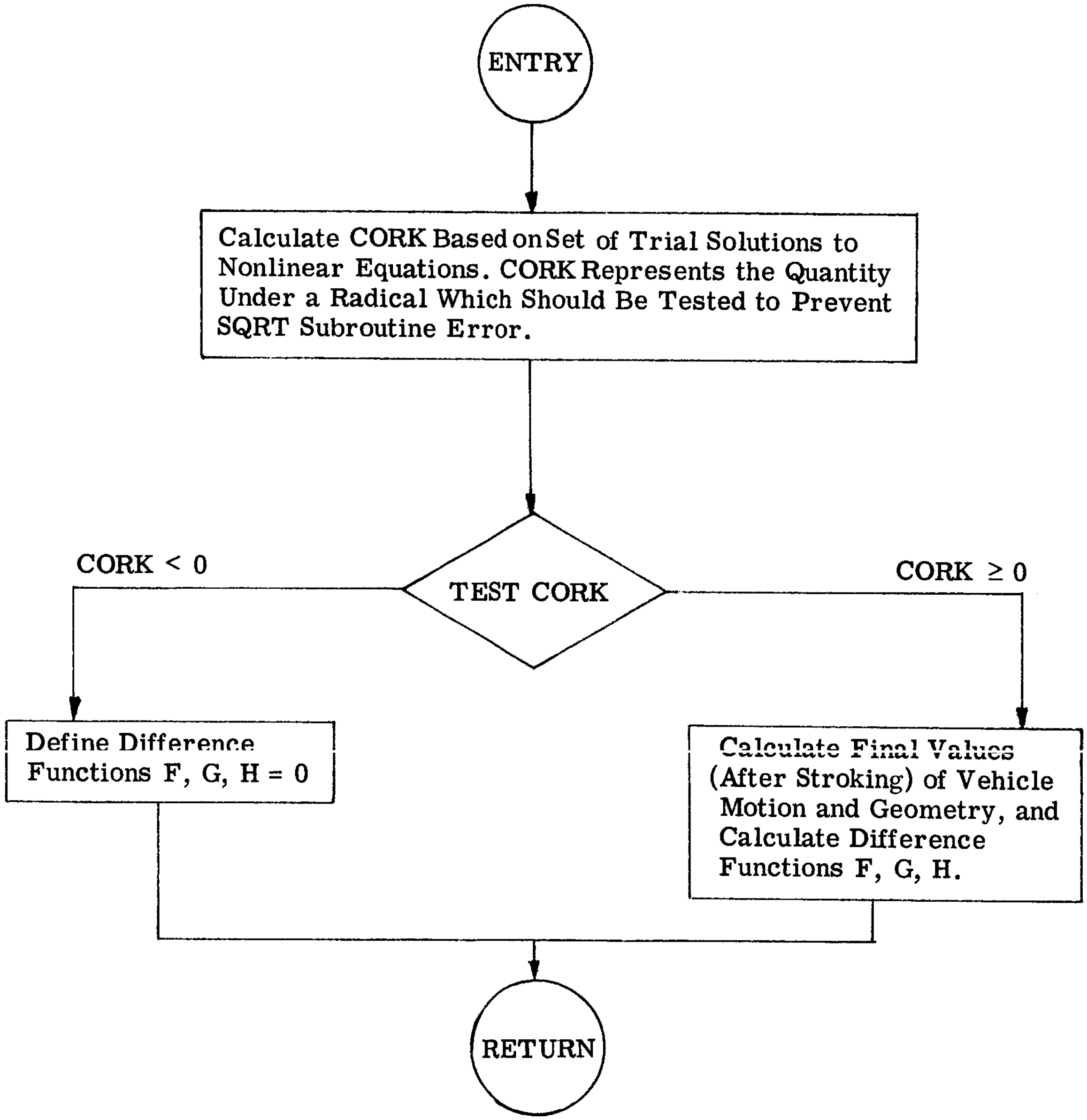


Figure 5-5. Flow Diagram of Subroutine FEVAL

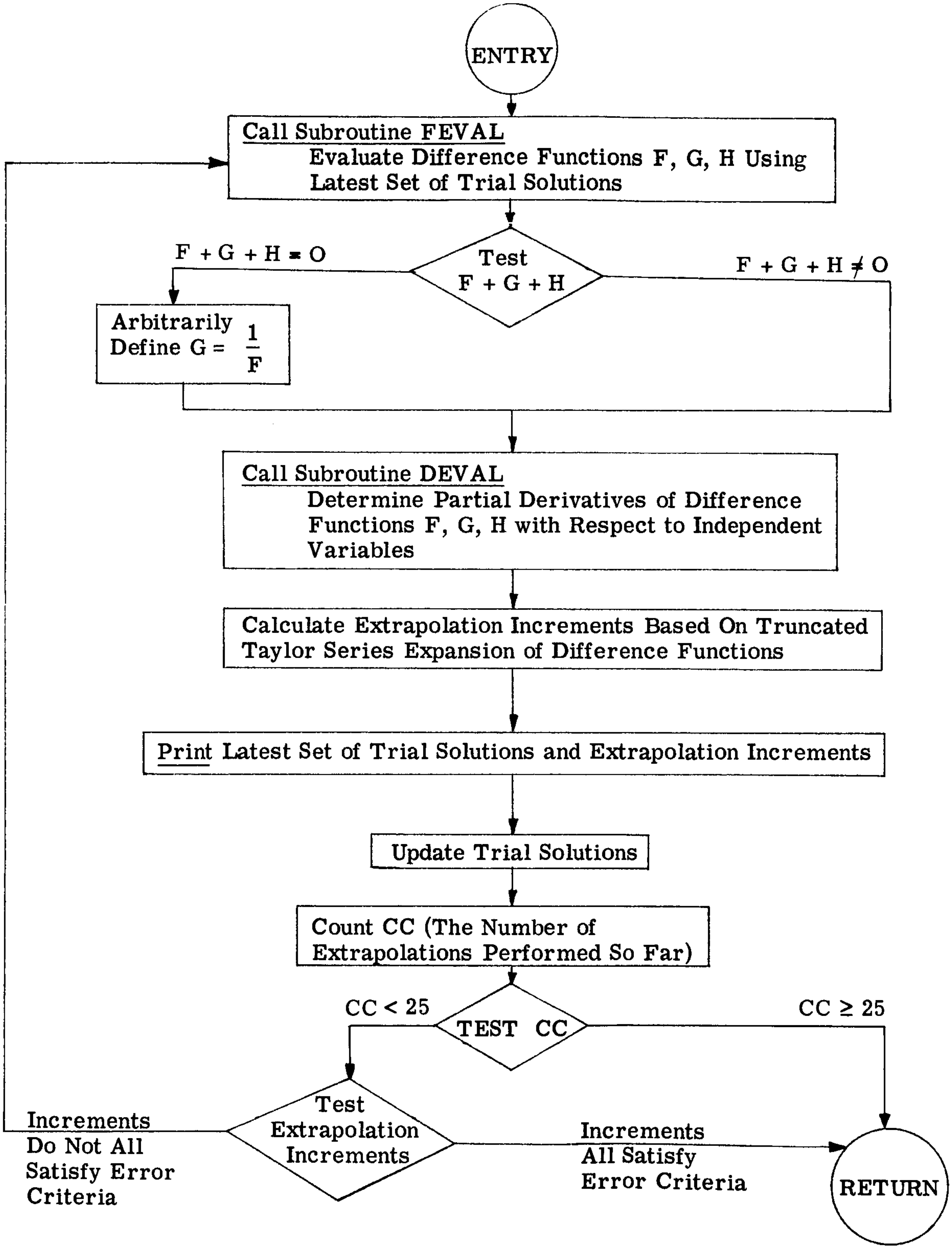


Figure 5-6. Flow Diagram of Subroutine SOLN

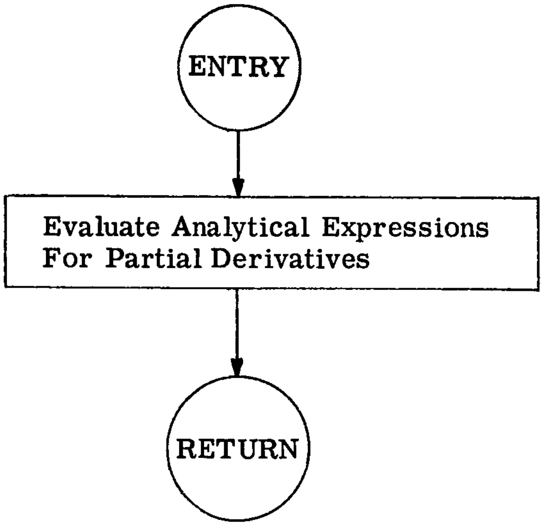


Figure 5-7. Flow Diagram of Subroutine DEVAL

```
C TITLE         LUNAR LANDING DYNAMICS STUDY
C               CONDENSED ANALYSIS OF FRONT LEG IMPACT
C
C AUTHORS       R.G.ALDERSON AND L.L.ANDERSON   BENDIX MISHAWAKA DIVISION
C
C DATE          10-31-64
C
C PURPOSE       TO PREDICT THE STABILITY AND MOTION OF THE LUNAR VEHICLE
C               AS A FUNCTION OF CONDITIONS AT FRONT LEG IMPACT
C
C INPUT         FROM PUNCHED CARDS
C
C               FOR DEFINITION OF THE GEOMETRY USED IN THIS PROGRAM
C               REFER TO SECTION VI-B OF THE BXAERO FINAL REPORT
C
C               SYMBOL         DEFINITION
C               I          MASS MOMENT OF INERTIA (FT*LB*SEC*SEC)
C               M          MASS (LB*SEC*SEC/FT)
C               GRAV       GRAVITATIONAL ACCELERATION (FT/SEC/SEC)
C               F11        STROKE FORCE IN MAIN STRUT (LB)
C               F22,F33    STROKE FORCE IN LOWER STRUTS (LB)
C               A          THESE QUANTITIES LOCATE THE UPPER AND LOWER
C               B          HARD POINTS RELATIVE TO THE VEHICLE C.G.
C               C          A IS POSITIVE IF UPPER HARD POINT IS ABOVE THE
C               D          C.G.- B IS POSITIVE IF LOWER HARD POINTS ARE
C               E          BELOW THE C.G.- C,D,E ARE POSITIVE. UNITS (FT)
C               ALPHA      GROUND SLOPE (RAD)
C               X          X-COMP. OF C.G. INITIALLY (GROUND AXES) (FT)
C               Y          Y-COMP. OF C.G. INITIALLY (GROUND AXES) (FT)
C               Z          Z-COMP. OF C.G. INITIALLY (GROUND AXES) (FT)
C               XVEL       X-COMP. OF C.G. INITIAL VELOCITY (GROUND
C                          AXES) (FT/SEC)
C               YVEL       Y-COMP. OF C.G. INITIAL VELOCITY (GROUND
C                          AXES) (FT/SEC)
C               XPAD       X-COMP. OF FOOTPAD (GROUND AXES) (FT)
C               YPAD       Y-COMP. OF FOOTPAD (GROUND AXES) (FT)
C               ZPAD       Z-COMP. OF FOOTPAD (GROUND AXES) (FT)
C               PSO        INITIAL PITCH ATTITUDE (RAD)
C               PSOVEL     INITIAL PITCH RATE (RAD/SEC)
C               PSOVV      INITIAL PITCH ACCELERATION (RAD/SEC/SEC)
C               PSF        FINAL PITCH ATTITUDE (RAD)
C               BETO       INITIAL STABILITY ANGLE (RAD)
C               BETOV      INITIAL STABILITY ANGULAR RATE (RAD/SEC)
C               BETOVV     INITIAL STABILITY ANGULAR ACC. (RAD/SEC/SEC)
C               BETAF      FINAL VALUE OF STABILITY ANGLE (RAD)
C               BETAFV     FINAL VALUE OF STABILITY ANGULAR RATE (RAD/SEC)
C
C               INITIAL AND FINAL REFER TO STATES BEFORE AND AFTER
C               STROKING OF THE FRONT LEGS
C
C               GAMMO      INITIAL ANGLE INCLUDED BETWEEN FOOTPAD,C.G.
C                          AND VEHICLE LONGITUDINAL AXIS (RAD)
C               GAMMF      FINAL VALUE OF GAMMO
C               VOH        HORIZONTAL COMP. OF C.G. INITIAL VEL. (FT/SEC)
C               VOT        TANGENTIAL COMP. OF C.G. INITIAL VEL  (FT/SEC)
C               VFH        HORIZONTAL COMP. OF C.G. FINAL VEL. (FT/SEC)
C               AOT        TANGENTIAL COMP. OF C.G. INIT. ACC.(FT/SEC/SEC)
C               VO         ABSOLUTE VELOCITY OF C.G. INITIALLY (FT/SEC)
C               XDOP       X-COMP. OF FOOTPAD RELATIVE TO C.G.
C                          (GROUND AXES) (FT)
```

Figure 5-8. Main Program Listing

```
C                   YDOP       Y-COMP. OF FOOTPAD RELATIVE TO C.G.
C                              (GROUND AXES) (FT)
C                   XDO        X-COMP. OF FOOTPAD RELATIVE TO C.G.
C                              (VEHICLE AXES) (FT)
C                   YDO        Y-COMP. OF FOOTPAD RELATIVE TO C.G.
C                              (VEHICLE AXES) (FT)
C                   ZDO        Z-COMP. OF FOOTPAD RELATIVE TO C.G.
C                              (EITHER VEHICLE OR GROUND AXES) (FT)
C                   L1         LENGTH OF NO.1 STRUT (FT)
C                   L2         LENGTH OF NO.2 STRUT (FT)
C                   L3         LENGTH OF NO.3 STRUT (FT)
C                   LO         INITIAL DISTANCE FROM FOOTPAD TO C.G.
C                              (MEASURED IN PLANE OF MOTION) (FT)
C                   LF         FINAL DISTANCE FROM FOOTPAD TO C.G.
C                              MEASURED IN PLANE OF MOTION (FT)
C                   LOVEL      TIME RATE OF CHANGE OF LO (FT/SEC)
C                   FX         X-COMP. OF INITIAL STROKING FORCES
C                              (VEHICLE AXES) (LB)
C                   FY         Y-COMP. OF INITIAL STROKING FORCES
C                              (VEHICLE AXES) (LB)
C                   TG         TORQUE INDUCED BY INITIAL STROKE FORCES (FT*LB)
C                   FOH        HORIZI. COMP. OF INITIAL STROKE FORCES (LB)
C                   FOT        TANGENTIAL COMP. OF INITIAL STROKE FORCES (LB)
C                   TF         DURATION OF STROKING (SEC)
C                   DEL1       STROKING OF NO.1 STRUT (FT)
C                   DEL2       STROKING OF NO.2 STRUT (FT)
C                   DEL3       STROKING OF NO.3 STRUT (FT)
C                   W          WORK DONE AGAINST STROKING FORCES (FT*LB)
C                   BFVCR      CRITICAL VALUE OF FINAL STABILITY ANGULAR RATE
C                              (RAD/SEC)
C                   BFMIN      STABILITY INDEX FOR STABLE VEHICLE. THIS IS
C                              THE MINIMUM STABILITY ANGLE EXPERIENCED BASED
C                              UPON RIGID BODY ROTATION AFTER STROKING. (RAD)
C                   BFVMIN     STABILITY INDEX FOR UNSTABLE VEHICLE. THIS IS
C                              THE STABILITY ANGULAR RATE WHEN THE STABILITY
C                              ANGLE IS ZERO BASED UPON RIGID BODY ROTATION
C                              AFTER STROKING. (RAD/SEC)
C                   ERRBF      ERROR STANDARD FOR BETAF
C                   ERRBFV     ERROR STANDARD FOR BETAFV
C                   ERRLF      ERROR STANDARD FOR LF
C                   RUN        RUN NUMBER
C                   R          MULTIPLIER FOR NORMAL FORCE,USUALLY SET=2
C                   BETFT      TRIAL SOLUTION FOR FINAL STABILITY ANGLE (RAD)
C                   BETFVT     TRIAL SOLUTION FOR FINAL STABILITY ANGULAR
C                              RATE (RAD/SEC)
C                   LFT        TRIAL SOLUTION FOR FINAL DISTANCE FROM FOOTPAD
C                              TO CG (PROJECTED IN PLANE OF MOTION) (FT)
C                   F,G,H,     DIFFERENCE FUNCTIONS DENOTING DIFFERENCES
C                              BETWEEN LEFT AND RIGHT SIDES OF PRIMARY
C                              EQUATIONS AFTER SUBSTITUTION OF TRIAL SOLUTIONS
C                   INDEX      DIFFERENCE FUNCTION DENOTING QUALITY OF SET OF
C                              TRIAL SOLUTIONS
C                   MINIDX     MINIMUM PREVIOUS VALUE OF INDEX
C
C OUTPUT            PRINT SUMMARY OF INITIAL AND FINAL VALUES OF PARAMETERS
C
C METHOD            SOLUTION OF THREE SIMULTANEOUS NONLINEAR ALGEBRAIC
C                   EQUATIONS IS ACCOMPLISHED BY A MODIFICATION OF
C                   NEWTONS METHOD
C
      REAL LLF,I,M,LO,LFT,L1,L2,L3,LOVEL,LF,MINIDX,LFQ,INDEX
```

Figure 5-8. Main Program Listing (Continued)

```
      COMMON ALPHA,XVEL,YVEL,BETO,PSO,X,Y,Z,XPAD,YPAD,ZPAD,I,M,A,B,C,D,
     1E,F11,F22,F33,PSOVEL,GRAV,SINA,COSA,VOH,GAMMO,PGO,COSPGO,SINPGO,
     2VOT,ZDO,COSPO,SINPO,L1,L2,L3,PSOVV,FOH,SNBETO,CSBETO,FOT,AOT,
     3ETAOVV,LO,BETOV,LOVEL,BETOVV,VO,FSUBX,FSUBY,BETFQ,BETFVQ,LFQ,R,
     4ETAFVV,TERMA,TERMB,SINB,COSB,VFH,TF,BETFVV,BETAF,BETAFV,PSF,SINGF,
     5COSGF,DEL1,DEL2,DEL3,W,CC,F,G,H,FX,FY,FZ,GX,GY,GZ,HX,HY,HZ,PAO,LF,
     6ERRBF,ERRBFV,ERRLF,BBF(6),BBFV(12),LLF(6),XDO,YDO,XDOP,YDOP,FB,
     7FBV,FL,GB,GBV,GL,HB,HBV,HL
C
C                 PART 1    CALCULATION OF INITIAL CONDITIONS
C
    3 READ 1000,I,M,GRAV,F11,F22,F33,X,Y,Z,XPAD,YPAD,ZPAD,PSO,PSOVEL,
     1BETO,ERRBF,ERRBFV,ERRLF,ALPHA,R,RUN,A,B,C
 1000 FORMAT(20X,3F17.5)
      RLAD 1002,D,E,XVEL,YVEL
 1002 FORMAT(20X,2F17.5)
      PRINT 951
      PRINT 3059
 3059 FORMAT(11H INPUT DATA)
      PRINT 3060,I,M,GRAV,F11,F22,F33
 3060 FORMAT(8H       I=,E11.5,9H          M=,E11.5,9H     GRAV=,E11.5,9H
     1 F11=,E11.5,9H      F22=,E11.5,9H      F33=,E11.5)
      PRINT 3061,X,Y,Z,XPAD,YPAD,ZPAD
 3061 FORMAT(8H       X=,E11.5,9H          Y=,E11.5,9H          Z=,E11.5,9H
     1XPAD=,E11.5,9H     YPAD=,E11.5,9H     ZPAD=,E11.5)
      PRINT 3062,PSO,PSOVEL,BETO,ERRBF,ERRBFV,ERRLF
 3062 FORMAT(8H     PSO=,E11.5,9H  PSOVEL=,E11.5,9H     BETO=,E11.5,9H    E
     1RRBF=,E11.5,9H  ERRBFV=,E11.5,9H    ERRLF=,E11.5)
      PRINT 3063,A,B,C,D,E,R
 3063 FORMAT(8H       A=,E11.5,9H          B=,E11.5,9H          C=,E11.5,9H
     1    D=,E11.5,9H         E=,E11.5,9H         R=,E11.5)
      PRINT 3064,ALPHA,XVEL,YVEL,RUN
 3064 FORMAT(8H  ALPHA=,E11.5,9H     XVEL=,E11.5,      YVEL=,E11.5,9H
     1 RUN=,E11.5)
      CALL INCOND
      CALL GUESS
C
C                 PART 2    OBTAIN STARTING POINT FOR EXTRAPOLATION
C     CHOOSE BEST GUESS SET OF TRIAL SOLUTIONS. DECISION BASED ON
C     MINIMIZATION OF INDEX, A DIFFERENCE FUNCTION. INDEX=F*F+G*G+H*H
C     WHERE F,G,H ARE DIFFERENCES BETWEEN RIGHT AND LEFT SIDES OF
C     PRIMARY EQUATIONS (AFTER SUBSTITUTION OF TRIAL SOLUTIONS).
C
C          INITIALIZE MINIDX (MINIMUM PREVIOUS VALUE OF INDEX)
C
      MINIDX=1E20
      DO 1 J=1,6
      DO 1 K=1,12
      DO 1 N=1,6
      BETFQ=BBF(J)
      BETFVQ=BBFV(K)
      LFQ=LLF(N)
      CALL FEVAL
      INDEX=F*F+G*G+H*H
      IF(INDEX) 10,1,10
C
C     NOTE      THE ABOVE TEST IS NECESSITATED BY A FEATURE OF THE FEVAL
C     SUBROUTINE. THIS FEATURE PREVENTS PROGRAM STOPPAGE DUE TO SQUARE
C     ROOT SUBROUTINE ERROR DURING THE SEARCH FOR THE BEST SET OF TRIAL
C     SOLUTIONS. WHEN THIS FEATURE FUNCTIONS F,G,H ARE ARBITRARILY SET
C     EQUAL TO ZERO. THE RESULTING ZERO VALUE OF INDEX MUST THEN BE
```

Figure 5-8. Main Program Listing (Continued)

```
C      EXCLUDED FROM CONSIDERATION.
C
C      CHECK INDEX AGAINST MINIMUM PREVIOUS VALUE
C
   10 IF(INDEX-MINIDX) 2,1,1
C
C      RESET MINIDX AND DEFINE BEST SET OF TRIAL SOLUTIONS FOUND SO FAR.
C
    2 MINIDX=INDEX
      BETFT=BBF(J)
      BETFVT=BBFV(K)
      LFT=LLF(N)
    1 CONTINUE
      BETFQ=BETFT
      BETFVQ=BETFVT
      LFQ=LFT
C
C                PART 3    SOLVING EQUATIONS
C
      CALL SOLN
      IF(CC-25) 6,7,7
C
C      THIS IS A TEST TO DETERMINE IF 25 ITERATIONS HAVE OCCURRED. IF
C      YES, THE METHOD IS NOT CONVERGING AND PROGRAM IS TERMINATED. IT IS
C      POSSIBLE THAT CONVERGENCE CAN BE OBTAINED BY GUESSING A DIFFERENT
C      SET OF TRIAL SOLUTIONS
C
    7 PRINT 500
  500 FORMAT(31H ITERATION ASTRAY - GUESS AGAIN    )
      STOP
C
C                PART 4    OUTPUT RESULTS
C
    6 PRINT 950
  950 FORMAT(1H1)
      PRINT 100
  100 FORMAT(19H INITIAL CONDITIONS  )
      PRINT 951
      PRINT 2000,VOH,VOT,FSUBX,FSUBY,FOH,FOT
 2000 FORMAT(8H     VOH=,E11.5,9H      VOT=,E11.5,9H     FSUBX=,E11.5,9H     F
     1SUBY=,E11.5,9H      FOH=,E11.5,9H      FOT=,E11.5)
      PRINT 2001,LO,SINA,COSA,GAMMO,PGO,XDOP
 2001 FORMAT(8H      LO=,E11.5,9H     SINA=,E11.5,9H     COSA=,E11.5,9H     G
     1AMMO=,E11.5,9H      PGO=,E11.5,9H     XDOP=,E11.5)
      PRINT 2002,YDOP,ZDO,COSPO,SINPO,XDO,YDO
 2002 FORMAT(8H    YDOP=,E11.5,9H      ZDO=,E11.5,9H    COSPO=,E11.5,9H     S
     1INPO=,E11.5,9H      XDO=,E11.5,9H      YDO=,E11.5)
      PRINT 2003,L1,L2,L3,PSOVV,PAO,SNBETO
 2003 FORMAT(8H      L1=,E11.5,9H       L2=,E11.5,9H       L3=,E11.5,9H     P
     1SOVV=,E11.5,9H      PAO=,E11.5,9H   SNBETO=,E11.5)
      PRINT 2004,CSBETO,AOT,ETAOVV,BETOV,LOVEL,BETOVV
 2004 FORMAT(8H CSBETO=,E11.5,9H      AOT=,E11.5,9H   ETAOVV=,E11.5,9H     B
     1ETOV=,E11.5,9H    LOVEL=,E11.5,9H   BETOVV=,E11.5)
      PRINT 951
      PRINT 951
      PRINT 200
  200 FORMAT(17H FINAL CONDITIONS  )
      PRINT 951
C
C      CALCULATE CRITICAL STABILITY ANGULAR RATE
C
```

Figure 5-8. Main Program Listing (Continued)

```
      BFVCR=SQRT(2.0*M*GRAV*LF*(1-COS(BETAF))/(I+M*LF*LF))
      BETFQ=BETAF
      BETFVQ=BETAFV
      LFQ=LF
      CALL FEVAL
      PRINT 2005,BETFT,BETFVT,LFT,BETAF,BETAFV,LF
 2005 FORMAT(8H  BETFT=,E11.5,9H  BETFVT=,E11.5,9H     LFT=,E11.5,9H     B
     1ETAF=,E11.5,9H  BETAFV=,E11.5,9H      LF=,E11.5)
      PRINT 2006,F,G,H,TF,VFH,PSF
 2006 FORMAT(8H       F=,E11.5,9H       G=,E11.5,9H       H=,E11.5,9H
     1  TF=,E11.5,9H     VFH=,E11.5,9H     PSF=,E11.5)
      PRINT 2007,DEL1,DEL2,DEL3,W,VO,BFVCR
 2007 FORMAT(8H   DEL1=,E11.5,9H    DEL2=,E11.5,9H    DEL3=,E11.5,9H
     1   W=,E11.5,9H      VO=,E11.5,9H   BFVCR=,E11.5)
      PRINT 951
      PRINT 951
  951 FORMAT(1H0)
C
C     TEST VEHICLE STABILITY BY COMPARING STABILITY ANGULAR RATE WITH
C     CRITICAL STABILITY ANGULAR RATE
C
      IF (BETAFV-BFVCR) 4,5,5
C
C     DETERMINE MINIMUM STABILITY ANGLE IF VEHICLE STABLE
C
    4 BFMIN=-1.5707963+ASIN((I+M*LF*LF)*BETAFV*BETAFV/(2*M*GRAV*LF)
     1+COS(BETAF))
      PRINT 300,BFMIN
  300 FORMAT(30H VEHICLE STABLE       BFMIN = F10.7)
      GO TO 3
C
C     DETERMINE MINIMUM STABILITY ANGULAR RATE IF VEHICLE UNSTABLE
C
    5 BFVMIN=SQRT(BETAFV*BETAFV-2.0*M*GRAV*LF*(1-COS(BETAF))/
     1          (I+M*LF*LF))
      PRINT 400,BFVMIN
  400 FORMAT(33H VEHICLE UNSTABLE       BFVMIN = F10.7)
      GO TO 3
      END
```

Figure 5-8. Main Program Listing (Concluded)

```
C TITLE         INCOND
C
C AUTHORS       R.G.ALDERSON AND L.E.ANDERSON  BENDIX MISHAWAKA DIVISION
C
C DATE          10-31-64
C
C PURPOSE       TO COMPUTE INITIAL CONDITIONS. THESE CONDITIONS ARE THE
C               VEHICLE MOTIONS AND CONFIGURATION AT FRONT LEG IMPACT
C
C CALL          INCOND
C
C INPUT         FROM INPUT DATA TO MAIN PROGRAM
C
C               SYMBOL          DEFINITION
C
C               VOH       INITIAL HORIZONTAL CG VELOCITY (FT/SEC)
C               GAMMO     INITIAL ANGLE (PROJECTED IN PLANE OF MOTION)
C                         INCLUDED BETWEEN FOOTPAD, CG AND VEHICLE
C                         LONGITUDINAL AXIS (RAD)
C               VOT       INITIAL TANGENTIAL CG VELOCITY (FT/SEC)
C               XDOP      X-COMPONENT OF FOOTPAD RELATIVE TO CG
C                         (GROUND AXES) (FT)
C               YDOP      Y-COMPONENT OF FOOTPAD RELATIVE TO CG
C                         (GROUND AXES) (FT)
C               XDO       X-COMPONENT OF FOOTPAD RELATIVE TO CG
C                         (VEHICLE AXES) (FT)
C               YDO       Y-COMPONENT OF FOOTPAD RELATIVE TO CG
C                         (VEHICLE AXES) (FT)
C               ZDO       Z-COMPONENT OF FOOTPAD RELATIVE TO CG
C                         (VEHICLE OR GROUND AXES) (FT)
C               L1        LENGTH OF NO.1 STRUT (FT)
C               L2        LENGTH OF NO.2 STRUT (FT)
C               L3        LENGTH OF NO.3 STRUT (FT)
C               FSUBX     X-COMPONENT OF INITIAL STROKING FORCES
C                         (VEHICLE AXES) (LB)
C               FSUBY     Y-COMPONENT OF INITIAL STROKING FORCES
C                         (VEHICLE AXES) (LB)
C               TQ        TORQUE ABOUT Z-AXIS INDUCED BY INITIAL STROKING
C                         FORCES (FT-LB)
C               PSOVV     INITIAL PITCH ANGULAR ACCELERATION(RAD/SEC/SEC)
C               FOH       HORIZ. COMP. OF INITIAL STROKING FORCES (LB)
C               FOT       TANGENT. COMP. OF INITIAL STROKING FORCES (LB)
C               AOT       INITIAL TANGENTIAL COMPONENT OF CG ACCELERATION
C                         (FT/SEC/SEC)
C               ETAOVV    INITIAL HORIZONTAL COMPONENT OF CG ACCELERATION
C                         (FT/SEC/SEC)
C               LO        INITIAL LENGTH FROM FOOTPAD TO CG (PROJECTED IN
C                         PLANE OF MOTION) (FT)
C               BETOV     INITIAL STABILITY ANGULAR VELOCITY (RAD/SEC)
C               LOVEL     INITIAL TIME RATE OF CHANGE OF LENGTH FROM
C                         FOOTPAD TO CG (PROJECTED IN PLANE OF MOTION)
C                         (FT/SEC)
C               BETOVV    INITIAL STABILITY ANGULAR ACCELERATION
C                         (RAD/SEC/SEC)
C               VO        INITIAL MAGNITUDE OF CG VELOCITY (FT/SEC)
C               GRAV      GRAVITATIONAL ACCELERATION (FT/SEC/SEC)
C OUTPUT        THESE PARAMETERS USED FOR CALCULATIONS ELSEWHERE IN
C               PROGRAM. VALUES OF SELECTED PARAMETERS ARE PRINTED VIA
C               PRINT STATEMENT IN MAIN PROGRAM
C
```

Figure 5-9. Subroutine INCOND

```
      SUBROUTINE INCOND
      REAL LLF,I,M,LO,LFT,L1,L2,L3,LOVEL,LF,MINIDX,LFG,INDEX
      COMMON ALPHA,XVEL,YVEL,BETO,PSO,X,Y,Z,XPAD,YPAD,ZPAD,I,M,A,B,C,D,
     1E,F11,F22,F33,PSOVEL,GRAV,SINA,COSA,VOH,GAMMO,PGO,COSPGO,SINPGO,
     2VOT,ZDO,COSPO,SINPO,L1,L2,L3,PSOVV,FOH,SNBETO,CSBETO,FOT,AOT,
     3ETAOVV,LO,BETOV,LOVEL,BETOVV,VO,FSUBX,FSUBY,BETFQ,BETFVQ,LFQ,R,
     4ETAFVV,TERMA,TERMB,SINB,COSB,VFH,TF,BETFVV,BETAF,BETAFV,PSF,SINGF,
     5COSGF,DEL1,DEL2,DEL3,W,CC,F,G,H,FX,FY,FZ,GX,GY,GZ,HX,HY,HZ,PAO,LF,
     6ERRBF,ERRBFV,ERRLF,BBF(6),BBFV(12),LLF(6),XDO,YDO,XDOP,YDOP,FB,
     7FBV,FL,GB,GBV,GL,HB,HBV,HL
      SINA=SIN(ALPHA)
      COSA=COS(ALPHA)
      VOH=XVEL*SINA+YVEL*COSA
      GAMMO=1.5708-ALPHA+BETO-PSO
      PGO=PSO+GAMMO
      COSPGO=COS(PGO)
      SINPGO=SIN(PGO)
      VOT=XVEL*COSPGO+YVEL*SINPGO
      XDOP=XPAD-X
      YDOP=YPAD-Y
      ZDO=ZPAD-Z
      COSPO=COS(PSO)
      SINPO=SIN(PSO)
      XDO=XDOP*COSPO+YDOP*SINPO
      YDO=YDOP*COSPO-XDOP*SINPO
      L1=SQRT((A-XDO)*(A-XDO)+(E-YDO)*(E-YDO)+(E-ZDO)*(E-ZDO))
      L2=SQRT((-B-XDO)*(-B-XDO)+(D-YDO)*(D-YDO)+(C-ZDO)*(C-ZDO))
      L3=SQRT((-B-XDO)*(-B-XDO)+(C-YDO)*(C-YDO)+(D-ZDO)*(D-ZDO))
      FSUBX=2.0*F11/L1*(A-XDO)+2.0*F22/L2*(-B-XDO)+2.0*F33/L3*(-B-XDO)
      FSUBY=2.0*F11/L1*(E-YDO)+2.0*F22/L2*(C-YDO)+2.0*F33/L3*(D-YDO)
      TQ=XDO*FSUBY-YDO*FSUBX
      PSOVV=TQ/I
      PAO=PSO+ALPHA
      SINPAO=SIN(PAO)
      COSPAO=COS(PAO)
      FOH=FSUBX*SINPAO+FSUBY*COSPAO
      SINGO=SIN(GAMMO)
      COSGO=COS(GAMMO)
      SNBETO=SIN(BETO)
      CSBETO=COS(BETO)
      FOT=FSUBX*COSGO+FSUBY*SINGO+M*GRAV*SNBETO
      AOT=FOT/M
      ETAOVV=FOH/M
      LO=SQRT((XPAD-X)*(XPAD-X)+(YPAD-Y)*(YPAD-Y))
      BETOV=VOT/LO
      LOVEL=XVEL*SINPGO-YVEL*COSPGO
      BETOVV=(AOT-2.0*LOVEL*BETOV)/LO
      VO=SQRT(XVEL*XVEL+YVEL*YVEL)
      RETURN
      END
```

Figure 5-9. Subroutine INCOND (Concluded)

```
C TITLE         GUESS
C
C AUTHORS       R.G.ALDERSON AND L.E.ANDERSON BENDIX MISHAWAKA DIVISION
C
C DATE          10-31-64
C
C PURPOSE       TO GUESS TRIAL SOLUTIONS TO THE NONLINEAR EQUATIONS SO
C               THAT THE EXTRAPOLATION WILL COMMENCE IN THE VICINITY OF
C               THE TRUE SOLUTION
C
C CALL          GUESS
C
C INPUT         FROM INPUT DATA TO MAIN PROGRAM
C
C               SYMBOL         DEFINITION
C
C               BBF(I)     ARBITRARILY SELECTED TRIAL SOLUTION OF THE
C                          NONLINEAR EQUATIONS FOR THE STABILITY ANGLE
C                          AT THE COMPLETION OF FRONT LEG STROKING. (RAD)
C                          (VALUES OF PARAMETERS AT THIS INSTANT ARE
C                          REFERRED TO AS FINAL VALUES)
C               BBFV(I)    ARBITRARILY SELECTED TRIAL SOLUTION FOR FINAL
C                          STABILITY ANGULAR VELOCITY (RAD/SEC)
C               LLF(I)     ARBITRARILY SELECTED TRIAL SOLUTION FOR FINAL
C                          LENGTH FROM FOOTPAD TO CG (PROJECTED IN PLANE
C                          OF MOTION) (FT)
C
C OUTPUT        THESE QUANTITIES ARE USED ELSEWHERE IN THE PROGRAM TO
C               DETERMINE THE BEST SET OF TRIAL SOLUTIONS WITH WHICH TO
C               BEGIN THE EXTRAPOLATION PROCESS
C
      SUBROUTINE GUESS
      REAL LLF,I,M,LO,LFT,L1,L2,L3,LOVEL,LF,MINIDX,LFQ,INDEX
      COMMON ALPHA,XVEL,YVEL,BETO,PSO,X,Y,Z,XPAD,YPAD,ZPAD,I,M,A,B,C,D,
     1E,F11,F22,F33,PSOVFL,GRAV,SINA,COSA,VOH,GAMMO,PGO,COSPGO,SINPGO,
     2VOT,ZDO,COSPO,SINPO,L1,L2,L3,PSOVV,FOH,SNBETO,CSBETO,FOT,AOT,
     3ETAOVV,LO,BETOV,LOVEL,BETOVV,VO,FSUBX,FSUBY,BETFQ,BETFVQ,LFQ,R,
     4ETAFVV,TERMA,TERMB,SINB,COSB,VFH,TF,BETFVV,BETAF,BETAFV,PSF,SINGF,
     5COSGF,DEL1,DEL2,DEL3,W,CC,F,G,H,FX,FY,FZ,GX,GY,GZ,HX,HY,HZ,PAO,LF,
     6ERRBF,ERRBFV,ERRLF,BBF(6),BBFV(12),LLF(6),XDO,YDO,XDOP,YDOP,FB,
     7FBV,FL,GB,GBV,GL,HB,HBV,HL
      BBF(1)=.6*BETO
      BBF(2)=.75*BETO
      BBF(3)=.8*BETO
      BBF(4)=.85*BETO
      BBF(5)=.9*BETO
      BBF(6)=.95*BETO
      BBFV(1)=.6*BETOV
      BBFV(2)=.7*BETOV
      BBFV(3)=.8*BETOV
      BBFV(4)=.9*BETOV
      BBFV(5)=.95*BETOV
      BBFV(6)=1*BETOV
      BBFV(7)=1.05*BETOV
      BBFV(8)=1.1*BETOV
      BBFV(9)=1.15*BETOV
      BBFV(10)=1.20*BETOV
      BBFV(11)=1.3*BETOV
      BBFV(12)=1.4*BETOV
      LLF(1)=.75*LO
```

Figure 5-10. Subroutine GUESS

```
LLF(2)=.775*LO
LLF(3)=.8*LO
LLF(4)=.825*LO
LLF(5)=.875*LO
LLF(6)=.95*LO
RETURN
END
```

Figure 5-10. Subroutine - GUESS (Concluded)

```
C
C TITLE        FEVAL
C
C AUTHORS      R.G. ALDERSON AND L.E.ANDERSON
C
C DATE         10-31-64
C
C PURPOSE      TO DETERMINE VALUES OF THE DIFFERENCE FUNCTIONS FOR
C              VARIOUS SETS OF TRIAL SOLUTIONS
C
C CALL         FEVAL
C
C INPUT        EITHER FROM TRIAL SET OF SOLUTIONS (SUBROUTINE GUESS OR
C              SOLN) OR FROM FINAL SOLUTION
C
C              SYMBOL         DEFINITION
C
C              BETFT     TRIAL SOLUTION FOR FINAL STABILITY ANGLE (RAD)
C              BETFVT    TRIAL SOLUTION FOR FINAL STABILITY ANGULAR
C                        RATE (RAD/SEC)
C              LFT       TRIAL SOLUTION FOR FINAL DISTANCE FROM FOOTPAD
C                        TO CG (PROJECTED IN PLANE OF MOTION) (FT)
C              BETFQ     THESE QUANTITIES ARE
C              BETFVQ         DUMMY VARIABLES TO ALLOW ENTRY
C              LFQ                 TO SUBROUTINE FROM DIFFERENT POINTS
C              TERMA     THESE QUANTITIES ARE CONVENIENT
C              TERMB          GROUPINGS OF PARAMETERS
C              ETAFVV    FINAL HORIZONTAL ACCELERATION OF CG(FT/SEC/SEC)
C              R         MULTIPLIER FOR NORMAL FORCE,USUALLY =2
C              VFH       FINAL HORIZONTAL VELOCITY OF CG (FT/SEC)
C              CORK      ARTIFICIAL PARAMETER DEFINED TO ALLOW A TEST OF
C                        A QUANTITY UNDER A RADICAL
C              F,G,H,    DIFFERENCE FUNCTIONS DENOTING DIFFERENCES
C                        BETWEEN LEFT AND RIGHT SIDES OF PRIMARY
C                        EQUATIONS AFTER SUBSTITUTION OF TRIAL SOLUTIONS
C              BETFVV    FINAL STABILITY ANGULAR ACC(RAD/SEC/SEC)
C              TF        DURATION OF STROKING PERIOD (SEC)
C              BETAF     FINAL STABILITY ANGLE (RAD)
C              BETAFV    FINAL STABILITY ANGULAR RATE (RAD/SEC)
C              PSF       FINAL PITCH ANGLE (RAD)
C              GAMMF     FINAL VALUE OF ANGLE (PROJECTED IN PLANE OF
C                        MOTION) OF ANGLE INCLUDED BETWEEN FOOTPAD,CG
C                        AND VEHICLE LONGITUDINAL AXIS (RAD)
C              XD        X-COMPONENT OF FOOTPAD RELATIVE TO CG
C                        (VEHICLE AXES) (FT)
C              YD         Y-COMPONENT OF FOOTPAD RELATIVE TO CG
C                        (VEHICLE AXES) (FT)
C              DEL1      SHORTENING OF
C              DEL2           NOS. 1,2,3 STRUTS,
C              DEL3                RESPECTIVELY (FT)
C              W         WORK DONE IN STROKING (FT-LB)
C
C OUTPUT       F,G,H ARE USED IN THE EXTRAPOLATION PROCESS. VALUES OF
C              SELECTED PARAMETERS ARE PRINTED VIA PRINT STATEMENT IN
C              MAIN PROGRAM.
C
      SUBROUTINE FEVAL
      REAL LLF,I,M,LO,LFT,L1,L2,L3,LOVEL,LF,MINIDX,LFQ,INDEX
      COMMON ALPHA,XVEL,YVEL,BETO,PSO,X,Y,Z,XPAD,YPAD,ZPAD,I,M,A,B,C,D,
     1E,F11,F22,F33,PSOVEL,GRAV,SINA,COSA,VOH,GAMMO,PGO,COSPGO,SINPGO,
```

Figure 5-11. Subroutine FEVAL

```
     2VOT,ZDO,COSPO,SINPO,L1,L2,L3,PSOVV,FOH,SNBETO,CSBETO,FOT,AOT,
     3ETAOVV,LO,BETOV,LOVEL,BETOVV,VO,FSUBX,FSUBY,BETFQ,BETFVQ,LFQ,R,
     4ETAFVV,TERMA,TERMB,SINB,COSB,VFH,TF,BETFVV,BETAF,BETAFV,PSF,SINGF,
     5COSGF,DEL1,DEL2,DEL3,W,CC,F,G,H,FX,FY,FZ,GX,GY,GZ,HX,HY,HZ,PAO,LF,
     6ERRBF,ERRBFV,ERRLF,BBF(6),BBFV(12),LLF(6),XDO,YDO,XDOP,YDOP,FB,
     7FBV,FL,GB,GBV,GL,HB,HBV,HL
      BETFT=BETFQ
      BETFVT=BETFVQ
      LFT=LFQ
      SINB=SIN(BETFT)
      COSB=COS(BETFT)
      TERMA=1.0/(I+M*LFT*LFT)
      ETAFVV=( R  -I*TERMA)*GRAV*SINB*COSB
      VFH=LFT*BETFVT*COSB
      TERMB=3.0*(VOH+VFH)/(ETAOVV-ETAFVV)
C
C     DEFINE AND TEST CORK. THIS IS A TEST OF THE QUANTITY WHICH APPEARS
C     UNDER THE RADICAL IN THE CALCULATION OF TF. THIS TEST HAS BEEN
C     INCLUDED TO ASSURE PROGRAM CONTINUITY IN THE EVENT THAT ONE OF THE
C     SETS OF TRIAL SOLUTIONS (SUBROUTINE GUESS) SHOULD PRODUCE A
C     NEGATIVE QUANTITY AT THIS POINT (THIS IS NOT UNUSUAL). THIS
C     FEATURE PERMITS AUTOMATIC REJECTION OF THAT SET OF TRIAL SOLUTIONS
C     BEFORE A SQRT SUBROUTINE ERROR IS ENCOUNTERED. HOWEVER, IF THE
C     QUANTITY UNDER THE RADICAL SHOULD BECOME NEGATIVE DURING THE
C     EXTRAPOLATION (AS CAN HAPPEN IF THE PROCESS IS NOT CONVERGENT)
C     THEN THE PROCESS WILL CAUSE OVERFLOW.
C
      CORK=TERMB*TERMB-12.0*(LO*SNBETO-LFT*SINB)/(ETAOVV-ETAFVV)
      IF(CORK) 1,2,2
    1 F=0
      G=0
      H=0
      GO TO 3
    2 TF=-TERMB-SQRT(CORK)
      BETFVV=TERMA*M*GRAV*LFT*SINB
      BETAF=BETO+(BETOV+BETFVT)/2.0*TF
     1      +(BETOVV-BETFVV)/12.0*TF*TF
      BETAFV=TERMA*(M*LO*VOT+I*PSOVEL+M*GRAV*(LO*TF*SNBETO
     1      +(7.0*VOH+3.0*VFH)/20.0*TF*TF+(3.0*ETAOVV-2.0*ETAFVV)/
     1      60.0*TF*TF*TF))
      F=BETAF-BETFT
      G=BETAFV-BETFVT
      PSF=PSO+(PSOVEL+BET FVT)/2.0*TF
     1      +(PSOVV-BETFVV)/12.0*TF*TF
      GAMMF=1.5708-ALPHA+BETFT-PSF
      SINGF=SIN(GAMMF)
      COSGF=COS(GAMMF)
      XD=-LFT*SINGF
      YD=LFT*COSGF
      DEL1=L1-SQRT((XD-A)*(XD-A)+(YD-E)*(YD-E)+(ZDO-E)*(ZDO-E))
      DEL2=L2-SQRT((XD+B)*(XD+B)+(YD-D)*(YD-D)+(ZDO-C)*(ZDO-C))
      DEL3=L3-SQRT((XD+B)*(XD+B)+(YD-C)*(YD-C)+(ZDO-D)*(ZDO-D))
      W=2.0*(F11*DEL1+F22*DEL2+F33*DEL3)
      H=1/2.0*(I*PSOVEL*PSOVEL+M*VO*VO)-BETFVT*BETFVT/(2.0*
     1      TERMA)+M*GRAV*(LO*CSBETO-LFT*COSB)-W
    3 RETURN
      END
```

Figure 5-11. Subroutine FEVAL (Concluded)

```
C TITLE          SOLN
C
C AUTHORS        R.G.ALDERSON AND L.E.ANDERSON
C
C DATE           10-31-64
C
C PURPOSE        TO EXTRAPOLATE TRIAL SOLUTIONS TO TRUE SOLUTIONS
C
C CALL           SOLN
C
C INPUT          FROM BEST SET OF TRIAL SOLUTIONS AND FROM INPUT DATA
C                TO MAIN PROGRAM
C
C                SYMBOL         DEFINITION
C
C                BETFT      BEST TRIAL VALUE OF FINAL STABILITY ANGLE (RAD)
C                BETFVT     BEST TRIAL VALUE OF FINAL STABILITY ANGULAR
C                           RATE (RAD/SEC)
C                LFT        BEST TRIAL VALUE OF DISTANCE FROM FOOTPAD TO
C                           VEHICLE CG (PROJECTED IN PLANE OF MOTION) (FT)
C                CC        COUNT OF NUMBER OF EXTRAPOLATIONS
C                BETFQ      THESE QUANTITIES ARE
C                BETFVQ          DUMMY VARIABLES DEFINED
C                LFQ                  FOR ENTRY INTO FEVAL SUBROUTINE
C                F,G,H      DIFFERENCE FUNCTIONS CALCULATED BY FEVAL
C
C                FB   FBV   FL     THESE QUANTITIES ARE THE PARTIAL
C                GB GBV   GL     DERIVATIVES OF F,G,H WITH RESPECT TO
C                HB   HBV   HL     BETFT,BETFVT,LFT
C
C                FX FY FZ  REDEFINITION OF
C                GX GY GZ       PARTIAL DERIVATIVES
C                HX HY HZ            FOR CONVENIENCE
C
C               XF.YF.ZF   REDEFINITION OF BETFT;BETFVT;LFT FOR
C                          CONVENIENCE
C               DX,DY,DZ   INCREMENTAL CHANGE IN BETFT,BETFVT,LFT FOR USE
C                          IN THE EXTRAPOLATION
C               ERRBF      THESE QUANTITIES
C               ERRBFV          ARE ERROR CRITERIA
C               ERRLF                FOR THE EXTRAPOLATION
C
C OUTPUT        SOLUTIONS TO SIMULTANEOUS SET OF EQUATIONS ARE PRINTED AND
C               ALSO USED LATER IN THE MAIN PROGRAM
C
      SUBROUTINE SOLN
      REAL LLF,I,M,LO,LFT,L1,L2,L3,LOVEL,LF,MINIDX,LFQ,INDEX
      COMMON ALPHA,XVEL,YVEL,BETO,PSO,X,Y,Z,XPAD,YPAD,ZPAD,I,M,A,B,C,D,
     1E,F11,F22,F33,PSOVEL,GRAV,SINA,COSA,VOH,GAMMO,PGO,COSPGO,SINPGO,
     2VOT,ZDO,COSPO,SINPO,L1,L2,L3,PSOVV,FOH,SNBETO,CSBETO,FOT,AOT,
     3ETAOVV,LO,BETOV,LOVEL,BETOVV,VO,FSUBX,FSUBY,BETFQ,BETFVQ,LFQ,R,
     4ETAFVV,TERMA,TERMB,SINB,COSB,VFH,TF,BETFVV,BETAF,BETAFV,PSF,SINGF,
     5COSGF,DEL1,DEL2,DEL3,W,CC,F,G,H,FX,FY,FZ,GX,GY,GZ,HX,HY,HZ,PAO,LF,
     6ERRBF,ERRBFV,ERRLF,BBF(6),BBFV(12),LLF(6),XDO,YDO,XDOP,YDOP,FB,
     7FBV,FL,GB,GBV,GL,HB,HBV,HL
C
C     INITIALIZE CC,THE NUMBER OF EXTRAPOLATIONS WHICH HAVE BEEN
C     PERFORMED
C
      CC=0
```

Figure 5-12. Subroutine SOLN

```
C
C     REDEFINE PARAMETERS FOR CONVENIENCE IN PRINTING
C
      XF=BETFQ
      YF=BETFVQ
      ZF=LFQ
      PRINT 951
      PRINT 951
      PRINT 77
   77 FORMAT(15H ITERATION DATA    )
      GO TO 8
    1 BETFQ=XF
      BETFVQ=YF
      LFQ=ZF
    8 CALL FEVAL
C
C     TEST OF (F+G+H) TO PREVENT OVERFLOW IF THIS QUANTITY =0 EXACTLY
C
      IF (F+G+H) 5,6,5
    6 G=1.0/F
    5 CALL DEVAL
C
C     DETERMINE EXTRAPOLATION INCREMENTS
C
      DEL=FX*GY*HZ+FY*GZ*HX+FZ*GX*HY-FZ*GY*HX-FY*GX*HZ-FX*GZ*HY
      DX=(-F*GY*HZ-FY*GZ*H-FZ*G*HY+FZ*GY*H+FY*G*HZ+F*GZ*HY)/DEL
      DY=(-FX*G*HZ-F*GZ*HX-FZ*GX*H+FZ*G*HX+F*GX*HZ+FX*GZ*H)/DEL
      DZ=(-FX*GY*H-FY*G*HX-F*GX*HY+F*GY*HX+FY*GX*H+FX*G*HY)/DEL
      PRINT 951
  951 FORMAT(1H0)
      PRINT 2008,XF,YF,ZF,DX,DY,DZ
 2008 FORMAT(8H     XF=,E11.5,9H      YF=,E11.5,9H      ZF=,E11.5,9H
     1  DX=,E11.5,9H      DY=,E11.5,9H      DZ=,E11.5)
      PRINT 2009,F,G,H
 2009 FORMAT(8H      F=,E11.5,9H       G=,E11.5,9H       H=,E11.5)
C
C     DETERMINE NEW VALUE OF VARIABLES BASED ON HALF THE INCREMENT. THE
C     FACTOR OF A HALF IS INTRODUCED ARBITRARILY FOR STABILIZATION OF
C     THE EXTRAPOLATION PROCEDURE
C
      XF=XF+DX*.5
      YF=YF+DY*.5
      ZF=ZF+DZ*.5
      BETAF=XF
      BETAFV=YF
      LF=ZF
C
C     COUNT NUMBER OF EXTRAPOLATIONS AND STOP PROGRAM IF CONVERGENCE
C     DOES NOT OCCUR IN 25 STEPS
C
      CC=CC+1
      IF(CC-25) 7,4,4
    7 IF(ABS(DX)-ERRBF) 2,2,1
    2 IF(ABS(DY)-ERRBFV) 3,3,1
    3 IF(ABS(DZ)-ERRLF) 4,4,1
    4 RETURN
      END
```

Figure 5-12. Subroutine SOLN (Concluded)

```
C TITLE          DEVAL
C
C AUTHORS        R.G.ALDERSON AND L.E.ANDERSON
C
C DATE           10-31-64
C
C PURPOSE        TO DETERMINE VARIOUS PARTIAL DERIVATIVES OF THE THREE
C                DIFFERENCE FUNCTIONS WITH RESPECT TO INDEPENDENT
C                VARIABLES
C
C CALL           DEVAL
C
C INPUT          FROM BEST SET OF TRIAL SOLUTIONS AND FROM QUANTITIES
C                EVALUATED IN MAIN PROGRAM
C
C      NOTE      ONLY PREVIOUSLY UNDEFINED TERMS WILL BE DEFINED HERE
C
C                SYMBOL        DEFINITION
C
C                TERMC     THESE QUANTITIES
C                TERMD
C                TERME       ARE CONVENIENT
C                TERMF
C                TERMG          GROUPINGS OF
C                TERM1
C                TERM2             PARAMETERS
C                TERM3
C
C                TFBV      PARTIAL TF WITH RESPECT TO BETFVT
C                TFB               TF                 BETFT
C                VFHBV             VFH                BETFVT
C                VFHL              VFH                LFT
C                VFHB              VFH                BETFT
C                ETVVB             ETAFVV             BETFT
C                ETVVL             ETAFVV             LFT
C                BVVB              BETFVV             BETFT
C                BVVL              BETFVV             LFT
C                TFL               TF                 LFT
C                FBV               F                  BETFVT
C                FB                F                  BETFT
C                FL                F                  LFT
C                GBV               G                  BETFVT
C                GB                G                  BETFT
C                GL                G                  LFT
C                GAMBV             GAMMF              BETFVT
C                GAMB              GAMMF              BETFT
C                GAML              GAMMF              LFT
C                DEL1BV            DEL1               BETFVT
C                DEL2BV            DEL2               BETFVT
C                DEL3BV            DEL3               BETFVT
C                HBV               H                  BETFVT
C                DEL1B             DEL1               BETAF
C                DEL2B             DEL2               BETAF
C                DEL3B             DEL3               BETAF
C                HB                H                  BETAF
C                DEL1L             DEL1               LFT
C                DEL2L             DEL2               LFT
C                DEL3L             DEL3               LFT
C                HL                H                  LFT
```

Figure 5-13. Subroutine DEVAL

```
C OUTPUT         PARTIAL DERIVATIVES USED IN SUBROUTINE SOLN
C
      SUBROUTINE DEVAL
      REAL LLF,I,M,LO,LFT,L1,L2,L3,LOVEL,LF,MINIDX,LFQ,INDEX
      COMMON ALPHA,XVEL,YVEL,BETO,PSO,X,Y,Z,XPAD,YPAD,ZPAD,I,M,A,B,C,D,
     1E,F11,F22,F33,PSOVEL,GRAV,SINA,COSA,VOH,GAMMO,PGO,COSPGO,SINPGO,
     2VOT,ZDO,COSPO,SINPO,L1,L2,L3,PSOVV,FOH,SNBETO,CSBETO,FOT,AOT,
     3ETAOVV,LO,BETOV,LOVEL,BETOVV,VO,FSUBX,FSUBY,BETFQ,BETFVQ,LFQ,R,
     4ETAFVV,TERMA,TERMB,SINB,COSB,VFH,TF,BETFVV,BETAF,BETAFV,PSF,SINGF,
     5COSGF,DEL1,DEL2,DEL3,W,CC,F,G,H,FX,FY,FZ,GX,GY,GZ,HX,HY,HZ,PAO,LF,
     6ERRBF,ERRBFV,ERRLF,BBF(6),BBFV(12),LLF(6),XDO,YDO,XDOP,YDOP,FB,
     7FBV,FL,GB,GBV,GL,HB,HBV,HL
      BETFT=BETFQ
      BETFVT=BETFVQ
      LFT=LFQ
      TERMC=LO*SNBETO-LFT*SINB
      TERMD=ETAOVV-ETAFVV
      TFBV=-3.0*LFT*COSB/TERMD-3.0*TERMB*LFT*COSB/
     1(TERMD*SQRT(TERMB*TERMB-12.0*TERMC/TERMD))
      TERMF=COSB*COSB-SINB*SINB
      TFB=3.0*LFT*BETFVT*SINB/TERMD-TERMB/TERMD*
     1GRAV*TERME*( R -I*TERMA)-(2.0*TERMB*(-3.0*LFT*BETFVT*SINB/
     1TERMD+TERMB/TERMD*GRAV*TERME*( R -I*TERMA))+12.0*LFT*
     1COSB/TERMD-12.0*TERMC/(TERMD*TERMD)*GRAV*( R -I*TERMA)*
     1TERME)/(2.0*SQRT(TERMB*TERMB-12.0*TERMC/TERMD))
      VFHBV=LFT*COSB
      VFHL=BETFVT*COSB
      VFHB=-LFT*BETFVT*SINB
      ETVVB=GRAV*( R -I*TERMA)*TERME
      ETVVL=2.0*M*GRAV*I*LFT*TERMA*TERMA*SINB*COSB
      BVVB=M*GRAV*LFT*COSB*TERMA
      BVVL=M*GRAV*SINB*TERMA-2.0*M*M*LFT*LFT*GRAV*SINB*TERMA*
     1TERMA
      TFL=-3.0/TERMD*VFHL-TERMB/TERMD*ETVVL-
     1(2.0*TERMB*(3.0/TERMD*VFHL+TERMB/TERMD*ETVVL)+12.0/
     1TERMD*SINB-12.0*TERMC/(TERMD*TERMD)*ETVVL)/(2.0*
     1SQRT(TERMB*TERMB-12.0*TERMC/TERMD))
      TERMF=(BETOV+BETFVT)/2.0+(BETOVV-BETFVV)*TF/6.0
      FBV=TERMF*TFBV+TF/2.0
      FB=-1+TERMF*TFB-TF*TF/12.0*BVVB
      FL=TERMF*TFL-TF*TF/12.0*BVVL
      GBV=-1.0+M*GRAV*TERMA*((LO*SNBETO+(7.0*VOH+3.0*VFH)/10.0*
     1TF+(3.0*ETAOVV-2.0*ETAFVV)/20.0*TF*TF)*TFBV+3.0*TF*TF/
     120.0*VFHBV)
      GB=M*GRAV*TERMA*((LO*SNBETO+(7.0*VOH+3.0*VFH)/10.0*TF+
     1(3.0*ETAOVV-2.0*ETAFVV)/20.0*TF*TF)*TFB+3.0*TF*TF/20.0*
     1VFHB-TF*TF*TF/30.0*ETVVB)
C
C     THE FOLLOWING DETERMINATION OF GL HAS BEEN SPLIT DUE TO COMPUTER
C     LIMITATIONS. HODGE AND PODGE ARE DUMMY VARIABLES
C
      HODGE=M*GRAV*TERMA*((LO*SNBETO+(7.0*VOH+3.0*VFH)/10.0*TF+(3.0*
     1ETAOVV-2.0*ETAFVV)/20.0*TF*TF)*TFL+3.0*TF*TF/20.0*VFHL-TF*TF*TF/
     230.0*ETVVL)
      PODGE=2.0*M*LFT*TERMA*TERMA*(M*LO*VOT+I*PSOVEL+M*GRAV*(LO*TF*
     1SNBETO+(7.0*VOH+3.0*VFH)/20.0*TF*TF+(3.0*ETAOVV-2.0*ETAFVV)/60.0*
     2TF*TF*TF))
      GL=HODGE-PODGE
      TERMG=(PSOVEL+BETFVT)/2.0+(PSOVV-BETFVV)/6.0*TF
      GAMBV=-TERMG*TFBV-TF/2.0
      GAMB=1-TERMG*TFB+TF*TF/12.0*BVVB
```

Figure 5-13. Subroutine DEVAL (Continued)

```
      GAML=-TERMG*TFL+TF*TF/12.0*BVVL                                   ALDERSON
      TERM3=SQRT((LFT*SINGF-B)**2+(LFT*COSGF-C)**2+(ZDO-D)**2)          ALDERSON
      TERM2=SQRT((LFT*SINGF-B)**2+(LFT*COSGF-D)**2+(ZDO-C)**2)          ALDERSON
      TERM1=SQRT((LFT*SINGF+A)**2+(LFT*COSGF-E)**2+(ZDO-E)**2)          ALDERSON
      DEL1BV=-(A*LFT*COSGF+E*LFT*SINGF)*GAMBV/TERM1                     ALDERSON
      DEL2BV=-(-B*LFT*COSGF+D*LFT*SINGF)*GAMBV/TERM2                    ALDERSON
      DEL3BV=-(-B*LFT*COSGF+C*LFT*SINGF)*GAMBV/TERM3                    ALDERSON
      HBV=-BETFVT/TERMA-2.0*(F11*DEL1BV+F22*DEL2BV+                     ALDERSON
     1F33*DEL3BV)                                                       ALDERSON
      DEL1B=-LFT*(A*COSGF+E*SINGF)*GAMB/TERM1                           ALDERSON
      DEL2B=-LFT*(-B*COSGF+D*SINGF)*GAMB/TERM2                          ALDERSON
      DEL3B=-LFT*(-B*COSGF+C*SINGF)*GAMB/TERM3                          ALDERSON
      HB=M*GRAV*LFT*SINB -2.0*(F11*DEL1B+F22*DEL2B+F33*DEL3B)           ALDERSON
      DEL1L=-(LFT*(A*COSGF+E*SINGF)*GAML+LFT+A*SINGF-                   ALDERSON
     1E*COSGF)/TERM1                                                    ALDERSON
      DEL2L=-(LFT*(-B*COSGF+D*SINGF)*GAML+LFT-B*SINGF-D*COSGF)/         ALDERSON
     1TERM2                                                             ALDERSON
      DEL3L=-(LFT*(-B*COSGF+C*SINGF)*GAML+LFT-B*SINGF-C*COSGF)/         ALDERSON
     1TERM3                                                             ALDERSON
      HL=-M*LFT*BETFVT*BETFVT-M*GRAV*COSB-2.0*(F11*DEL1L+               ALDERSON
     1F22*DEL2L+F33*DEL3L)                                              ALDERSON
      FX=FB                                                             ALDERSON
      FY=FBV                                                            ALDERSON
      FZ=FL                                                             ALDERSON
      GX=GB                                                             ALDERSON
      GY=GBV                                                            ALDERSON
      GZ=GL                                                             ALDERSON
      HX=HB                                                             ALDERSON
      HY=HBV                                                            ALDERSON
      HZ=HL                                                             ALDERSON
      RETURN                                                            ANDERSON
      END                                                               ANDERSON
```

Figure 5-13. Subroutine DEVAL (Concluded)

```
INPUT DATA
     I=  .11160+05        H=  .40800+03     GRAV=  .53200+01      F11=  .10500+05      F22=  .28500+04      F33=  .28500+04
     X=  .15453+02        Y=  .49200+01        Z=  .00000        XPAD=  .23400-00     YPAD=  .17381+02     ZPAD=  .14025+02
   PSC=  .11100+00   PSOVEL=  .92500-00     BETO= -.42400-00    ERRBF=  .10000-04   ERRBFV=  .10000-04    ERRLF=  .10000-02
     A= -.19150+01        B=  .73250+01        C=  .11240+02        D=  .47700+01        E=  .94000+01        R=  .20000+01
 ALPHA=  .26130-00     XVEL= -.60550+01   .10160+02       RUN=  .10300+03


ITERATION DATA

    XF= -.40290-00       YF=  .22533-00       ZF=  .18683+02       DX=  .26906-01       DY=  .30935-01       DZ=  .19258-01
     F=  .79705-02        G=  .36571-01        H=  .22327+02

    XF= -.36935-00       YF=  .24079-00       ZF=  .18692+02       DX=  .18088-01       DY=  .15236-01       DZ= -.25092-01
     F=  .42197-02        G=  .19416-01        H=  .21030+03

    XF= -.36930-00       YF=  .24841-00       ZF=  .18660+02       DX=  .11694-01       DY=  .74887-02       DZ= -.35161-01
     F=  .22030-02        G=  .97576-02        H=  .21314+03

    XF= -.37446-00       YF=  .25216-00       ZF=  .18662+02       DX=  .72224-02       DY=  .30786-02       DZ= -.30133-01
     F=  .11438-02        G=  .48973-02        H=  .15865+03

    XF= -.37084-00       YF=  .25400-00       ZF=  .18647+02       DX=  .42329-02       DY=  .16100-02       DZ= -.20929-01
     F=  .58697-03        G=  .24552-02        H=  .10134+03

    XF= -.36873-00       YF=  .25490-00       ZF=  .18637+02       DX=  .23566-02       DY=  .89373-03       DZ= -.12768-01
     F=  .29869-03        G=  .12296-02        H=  .56756+02

    XF= -.36755-00       YF=  .25535-00       ZF=  .18630+02       DX=  .12583-02       DY=  .44314-03       DZ= -.71562-02
     F=  .15096-03        G=  .61554-03        H=  .31991+02

    XF= -.36692-00       YF=  .25557-00       ZF=  .18627+02       DX=  .65294-03       DY=  .22046-03       DZ= -.38108-02
     F=  .75940-04        G=  .30795-03        H=  .16765+02

    XF= -.36659-00       YF=  .25568-00       ZF=  .18625+02       DX=  .33301-03       DY=  .10993-03       DZ= -.19694-02
     F=  .36091-04        G=  .15402-03        H=  .85964+01

    XF= -.36643-00       YF=  .25573-00       ZF=  .18624+02       DX=  .16819-03       DY=  .54891-04       DZ= -.10012-02
     F=  .19075-04        G=  .77024-04        H=  .43516+01

    XF= -.36634-00       YF=  .25576-00       ZF=  .18623+02       DX=  .84555-04       DY=  .27418-04       DZ= -.50503-03
     F=  .95479-05        G=  .38512-04        H=  .21892+01
```

Figure 5-14. Output Data

```
     XF= -.30630-00      YF=  .25576-00      ZF=  .18623+02      DX=  .42563-04      DY=  .13676-04      DZ= -.25483-03
      F=  .47944-05       G=  .19252-04       H=  .11023+01

     XF= -.30628-00      YF=  .25578-00      ZF=  .18623+02      DX=  .21127-04      DY=  .68737-05      DZ= -.12671-03
      F=  .23730-05       G=  .96336-05       H=  .55516-00

     XF= -.30627-00      YF=  .25579-00      ZF=  .18623+02      DX=  .10548-04      DY=  .34431-05      DZ= -.63442-04
      F=  .11809-05       G=  .48168-05       H=  .26174-00

     XF= -.30626-00      YF=  .25579-00      ZF=  .18623+02      DX=  .51646-05      DY=  .17424-05      DZ= -.31027-04
      F=  .57742-06       G=  .24140-05       H=  .14014-00


INITIAL CONDITIONS

    VCH=  .62457+01     VCT=  .40264+01   FSUBX=  .24657+05   FSUBY= -.13184+05     FOH= -.32976+04      FOT=  .75242+04
     LO=  .19656+02    SINA=  .25882-00    COSA=  .96593-00   GAMMO=  .77400-00     PGO=  .88500-00     XDOP= -.15219+02
   YDCP=  .12855+02     ZDD=  .14025+02   COSPO=  .99385-00   SINPO=  .11077+00     XDO= -.13746+02      YDO=  .14064+02
     L1=  .13532+02      L2=  .11635+02      L3=  .11613+02   PSUVV= -.14835+02     PAO=  .37280-00   SNBETO= -.41141-00
 CSBETO=  .91145-00     ACT=  .18442+02  ETAUVV= -.60824+01   BETOV=  .20484-00   LOVEL= -.11120+02   BETOVV=  .11694+01


FINAL CONDITIONS

  BETFT= -.40290-00  BETFVT=  .22553-00     LFT=  .18683+02   BETAF= -.36626-00  BETAFV=  .25579-00       LF=  .18623+02
      F=  .31292-06       G=  .12033-05       H=  .71533-01      TF=  .22710-00     VFH=  .44475+01      PSF=  .18173-00
   DEL1=  .98166-00    DEL2=  .94978-00    DEL3=  .60606-00       W=  .29483+05      VO=  .11827+02    BFVCR=  .18742-00


VEHICLE UNSTABLE        DFVMIN =   .1740775



EXECUTION TERMINATED BY AN ATTEMPT TO READ THRU AN END OF FILE
10 NOV 64   08:43:13   IDENT 50E      ACCOUNT 270610   CARDS IN  861   CARDS OUT    0   PAGES   30   ELAPSED TIME  0: 0:46
```

Figure 5-14. Output Data (Concluded)

SECTION VI

LANDING DYNAMICS COMPUTER PROGRAM FOR NON-PLANAR LANDINGS WITH INFINITE GROUND COEFFICIENT OF FRICTION AND ZERO FOOTPAD MASS

THEORETICAL ANALYSIS OF NON-PLANAR MOTION

This section describes a six degree of freedom mathematical model for prediction of motion and stability for the case of infinite friction between the feet and the lunar surface. Sufficient runs have been made with this program to provide a comparison between a theoretical and experimental stability profile. It is emphasized, however, that detailed comparative studies of vehicle motion during the landing have not been carried out at this time. Several areas in the program such as strut re-extension and foot contact conditions are open to question and will have to be more thoroughly investigated before this program could be used extensively. Results to date do indicate a reasonable correlation with drop test results from the standpoint of gross stability predictions.

Discussion of Mathematical Model

The following is a brief discussion of the six degree of freedom computer program which is fully discussed along with definition of terms, flow diagram, and sample input and output in the documentation of computer programs report.

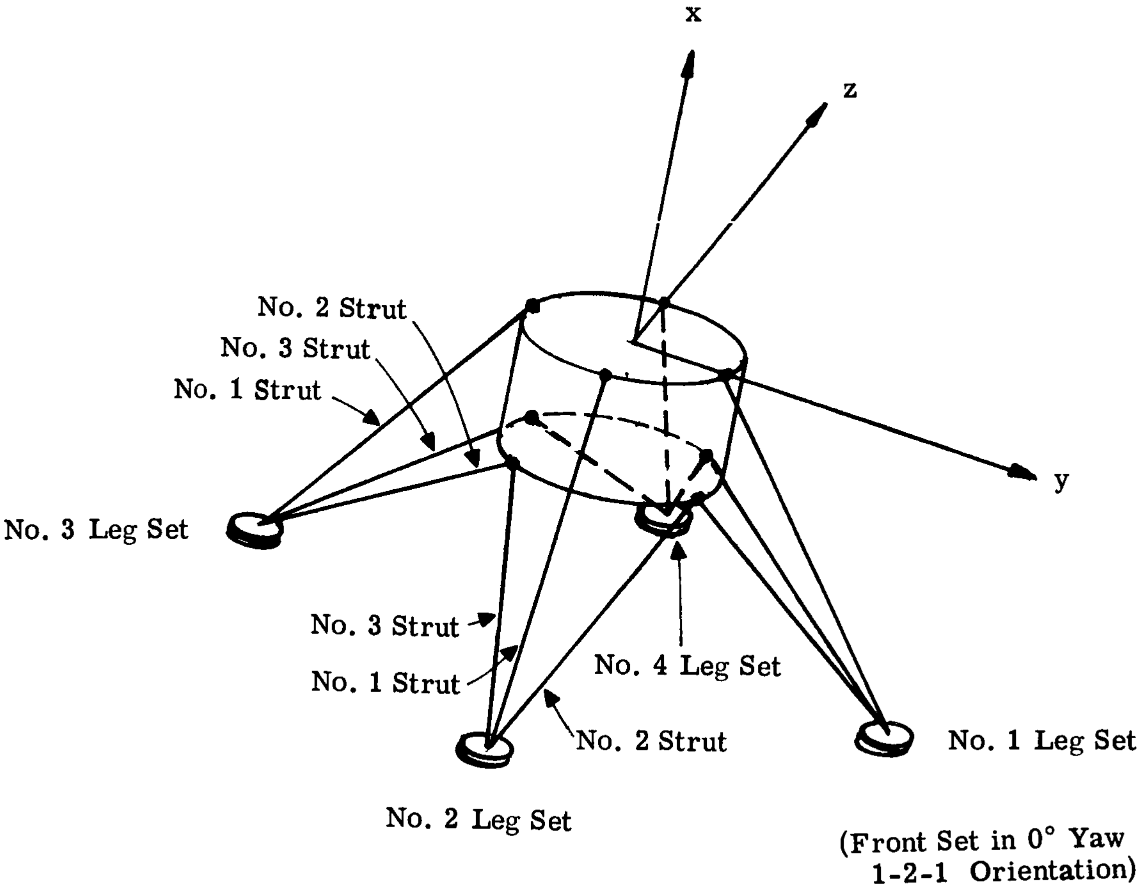
The moving (vehicle) coordinate system and leg numbering system is as shown in Figure 6-1.

The x axis is a line from the c.g. on the vehicle centerline. The y axis is a line through the c.g., perpendicular to the x axis and in the direction and plane of the number one leg of the number one leg set. The z axis passes through the c.g. and is perpendicular to both the x and y axis and in the direction of the number 4 leg set. The struts are numbered clockwise from the y axis as shown in Figure 6-1.

The fixed (ground) coordinate system and output variables are shown in Figure 6-2. The X axis is perpendicular to the slope, the Y axis is parallel to the slope and in the direction of the principal slope. The Z axis is perpendicular to both the X and Y axis (i.e., across the slope). The variables are defined as follows:

Input Variables

X B (i, j) = x of the ith strut of the jth leg set body attachment (hardpoint) in feet
Y B (i, j) = y of the ith strut of the jth leg set body attachment (hardpoint) in feet



(Front Set in 0° Yaw
1-2-1 Orientation)

Figure 6-1. Moving (Vehicle) Coordinate System and Leg Numbering System

Z B (i, j) = z of the ith strut of the jth leg set body attachment (hardpoint) in feet. x, y, and z are in terms of the vehicle coordinate system and relative to this system.

Numbering of Leg Sets, Hardpoints, and Struts - See Figure 6-1

TYPE (i) = Type of strut i (e.g. Strut No. 1 is of Type 1, Strut Nos. 2 and 3 are Type 2 on each leg set).
VASLUG = Mass of Vehicle in slugs.
U1 = Mass moment of inertia of vehicle about vertical, x-axis (yaw), vehicle coordinate system, in slug ft^2.
U2 = Mass moment of inertia of vehicle about the y-axis (roll), vehicle coordinate system, in slug ft^2.
U3 = Mass moment of inertia of vehicle about the z-axis (pitch), vehicle coordinate system, in slug ft^2.

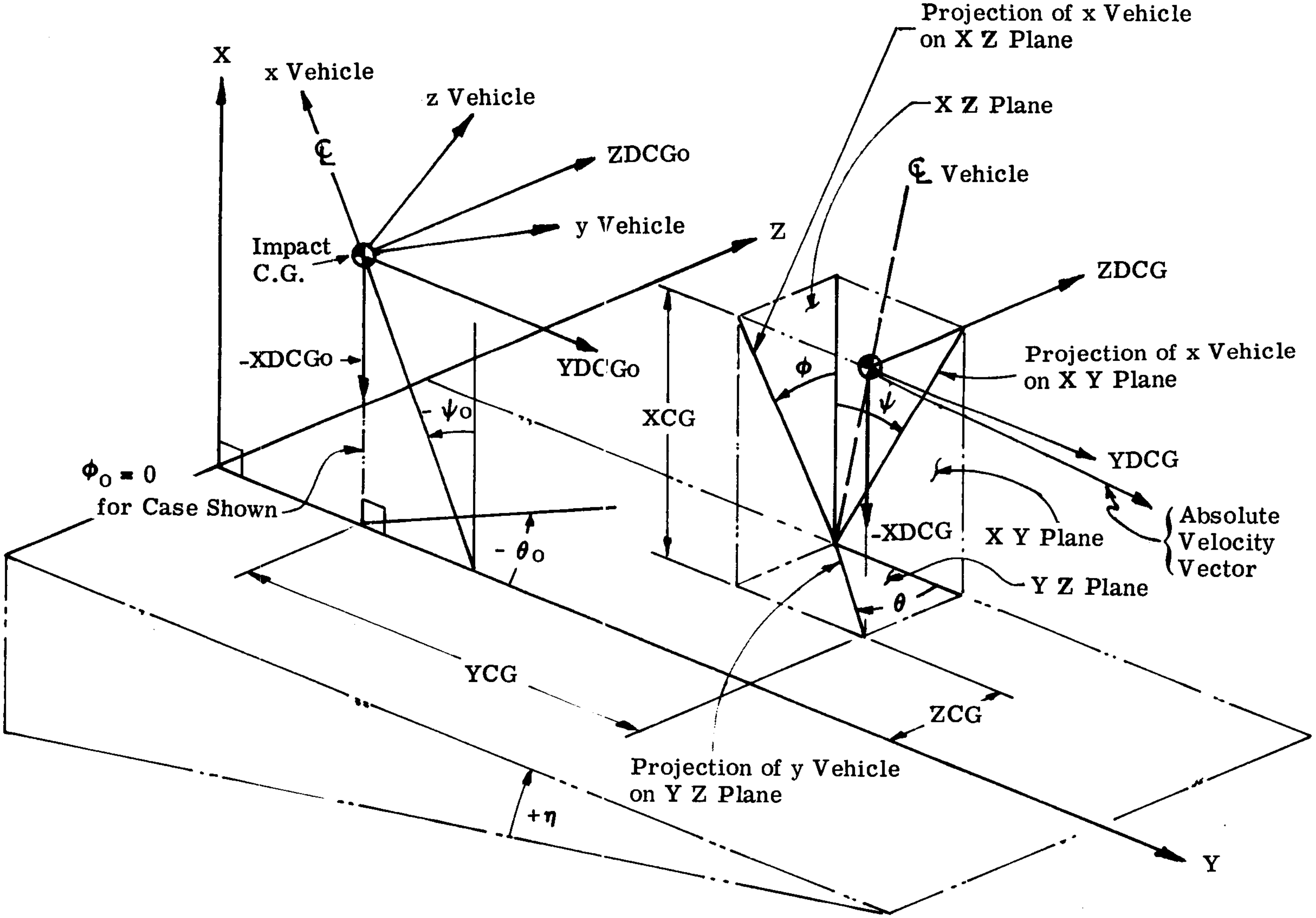


Figure 6-2. Fixed (Ground) Coordinate System and Output Variables

FOTAC or FOTAC 1(i) = Mode of action of the ith footpad where value
(*See note below)
1 Corresponds to sliding on surface
2 Corresponds to stationary on surface
3 Corresponds to off surface and thus moving with the vehicle.

V FOT (j, i) = ith component of the vector position of the jth footpad in terms of vehicle coordinates and relative to this system.
i = 1 is x component (in feet).
i = 2 is y component (in feet).
i = 3 is z component (in feet).

XCG or XCG1
YCG or YCG1
ZCG or ZCG1
= Position of vehicle center of gravity in fixed (ground) coordinate system and relative to this system, in feet.

V VEL = Initial vertical velocity of vehicle center of gravity parallel to gravity vector, in ft./sec.

H VEL = Initial horizontal velocity of vehicle center of gravity, perpendicular to gravity vector and in the direction of the principal slope in ft./sec.

ZDCG or ZDCG1 = Horizontal velocity of the vehicle center of gravity across the slope, in ft./sec.

W1E or W1E1
W2E or W2E1
W3E or W3E1
= Angular velocity components about the x, y, and z vehicle axes respectively and expressed in terms of vehicle coordinate system in Rads/sec.

PITCH or PITCH 1
YAW or YAW 1
ROLL or ROLL 1
= Initial vehicle orientation, in radians. See text on initial orientation of vehicle.

ETA or ETA1 = Ground slope, positive for downhill in positive X direction (fixed coordinate system) in radians.

Output Variables

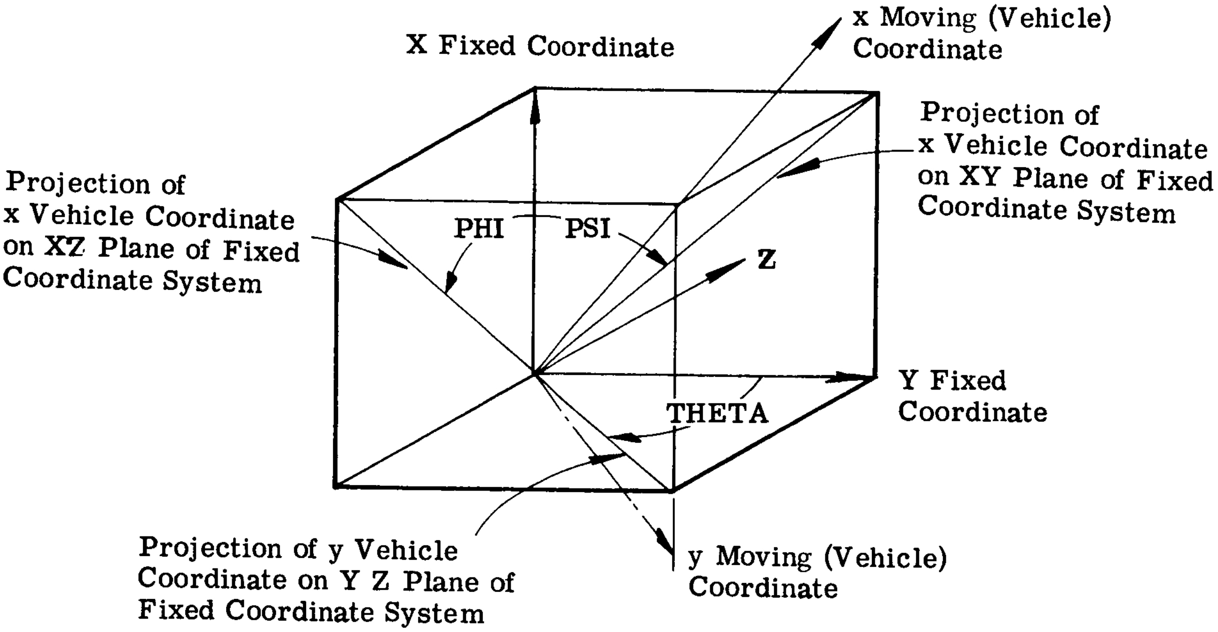
TIME = Time after touchdown in seconds.

XCG
YCG
ZCG
= Position of vehicle center of gravity in fixed ground coordinates, in ft.

PHI
PSI
THETA
= Angular orientation of the vehicle relative to the fixed coordinates system, in terms of the projections of the x and y vehicle axis on the XY, XZ, and YZ fixed (ground) coordinate system planes, in radians (see Figure 6-2 and sketch on the following page).

---

* Appearance of "1" after any variable indicates the initial value of the variable. Absence of the "1" indicates instantaneous values.



Analytically

$$\psi = \tan^{-1}\left(\frac{\ell_{21}}{\ell_{11}}\right)$$

$$\phi = \tan^{-1}\left(\frac{-\ell_{31}}{\ell_{11}}\right)$$

$$\theta = \tan^{-1}\left(\frac{-\ell_{32}}{\ell_{22}}\right)$$

XDCG, YDCG, ZDCG = Velocity of vehicle center of gravity in terms of the fixed coordinate system, feet/second.

FORCE X = Net force acting on vehicle center of gravity in direction of X of the fixed coordinate system, in pounds. (Includes gravity and footpad action.)

TORQZ = Component, parallel to fixed coordinate Z-axis, of torque acting about c.g.

BETA = Stability angle. See text on stability angle.

PX1, PX2, PX3, PX4 = Height above surface of footpads one through four respectively, in feet.

FX1, FX2, FX3, FX4 = Force acting perpendicular to the surface on footpads one through four, respectively, in pounds.

XBFT1, XBFT2, XBFT3, XBFT4 = x component of VFOT for footpads one through four, respectively, in feet. Or the component of the distance from the vehicle center of gravity to four footpads in the direction parallel to the vehicle axis of symmetry.

ON MOON = Four digits representing FOTAC of footpads one through four, respectively.

THEDT, PHIDOT, PSIDOT = Components of vehicle angular velocity in the X, Y, and Z directions for the fixed coordinate system. NOTE: These are NOT the rate of change of THETA, PHI, and PSI previously defined except in the 1-2-1 landing configuration.

BETADT = Rate of change of BETA.

CRUSH = Twelve digits representing the force causing mechanism in the twelve leg struts in the order

Leg Set No.1	Leg Set No.2	Leg Set No.3	Leg Set No.4
Strut No.1,No.2,No.3	Strut No.1,No.2,No.3	Strut No.1,No.2,No.3	Strut No.1,No.2,No.3

The digit code is as follows:

0 = No force because the footpad is off the surface.
1 = Elastic compression in strut.
2 = Plastic compression in strut.
3 = Strut re-extended from previously crushed position but is still shorter than the original length.
8 = Strut streched beyond original length, but less than 10,000 lb. force.
9 = Strut in tension more than 10,000 lbs.

The basic computational flow required to determine the trajectory of a non-planar lunar landing is as follows:

1. From the geometry of the leg sets, calculate the forces in each leg set (see subroutine FORCE) and lift from the surface any footpad with negative ground force.

2. From these forces, at the footpads and center of gravity, calculate the forces and torques acting on the vehicle and convert to moving (vehicle) coordinate system.

3. Integrate (see subroutine INTEQM) the Euler and Newton equations to find the new vehicle positions expressed in terms of center of gravity translation and vehicle orientation, by direction cosines. (Δ t is determined by the rate of change of the torques and later checked in INTEQ.)

4. Check to see if any footpads have just contacted the surface and compute geometry of all the leg sets in contact with the surface.

5. Check stability and print sufficient information to reveal trajectory details for analysis.

6. Return to 1.

The infinite surface - footpad coefficient of friction used in the calculations significantly simplified the process. No slip of any footpad on the surface is allowed. Footpads are removed from the surface if the contact force between the surface and the footpad becomes negative. Any footpad not on the surface is assumed to move in rigid body rotation with the vehicle.

Finite friction coefficient simulations have not been conducted as yet, because of the difficulty of finding the pad motions satisfying the requirements or the constraints:

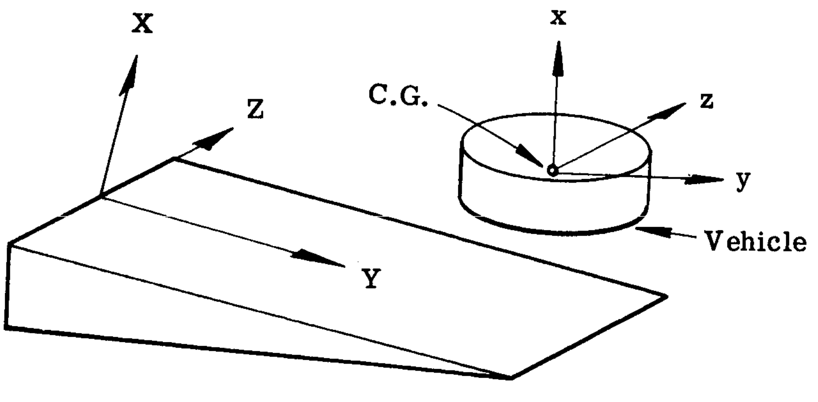
1. $\left| F_{\text{friction}} \right| = \mu \left| F_{\text{normal}} \right|$

2 Direction of friction force = opposite to direction of motion.

Infinite surface friction, generally, is the most stringent (de-stabilizing) case and best simulates the spike footpad experimental work.

Coordinate Transformations

Using the direction cosines which describe the relative position of the two coordinate systems, X, Y, and Z fixed (ground) coordinates and x, y, and z moving (fixed in vehicle) coordinates as shown below (see also Figures 6-2 and 6-1, respectively), we can convert quantities expressed in terms of one coordinate system to the other coordinate system.



Fixed (Ground) and Moving (Vehicle) Coordinate Systems

The equations are in matrix form

$$\left\{ X_i \right\} = \left[\ell_{ij} \right] \left\{ x_{ij} \right\} + \left\{ v_{i,\,c.g.} \right\} \qquad (1)$$

for conversion from vehicle to ground coordinate systems

and

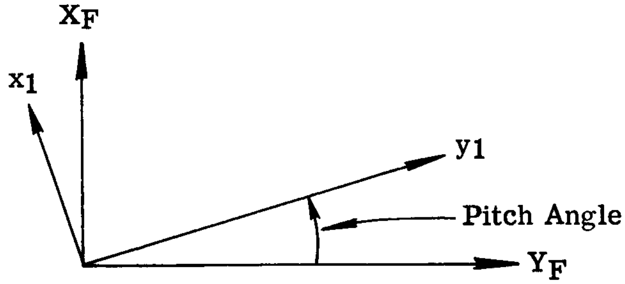
$$\left\{ x_j \right\} = \left[\ell_{ij} \right]^T \left\{ X_i - v_{i,\,c.g.} \right\} \qquad (2)$$

for conversion from ground to vehicle coordinate systems. The first equation is used to find hardpoint and footpad positions in the ground coordinate system and the second to convert footpad positions and torques into the vehicle coordinate system.

Initial Orientation of the Vehicle

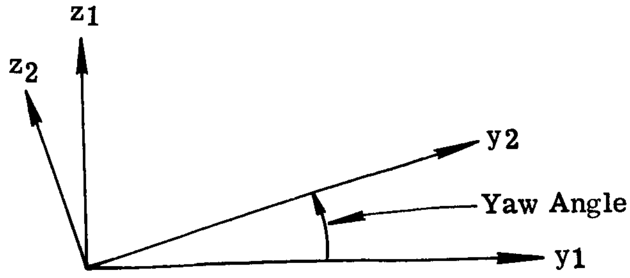
Although direction cosines are used to define vehicle orientation throughout the computer program, it was felt that a simpler input form would be preferable. Accordingly, the vehicle initial orientation is specified by starting with the vehicle in a 1-2-1 position, resting on the surface and with the number one leg set in the direction of the principal slope. The vehicle is then rotated as follows:

1. A pitch rotation from X_F, Y_F (fixed coordinate system),to a x_1, y_1 position, as shown below.



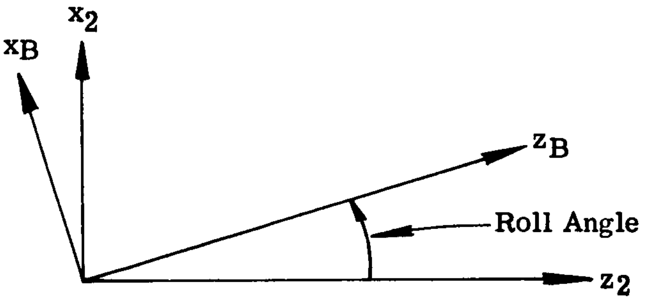
Pitch Rotation

2. A yaw from x_1, y_1, z_1, to x_2, y_2, z_2



Yaw Rotation

3. A roll from x_2, y_2, z_2 to vehicle coordinate final positions of x_B, y_B, z_B.



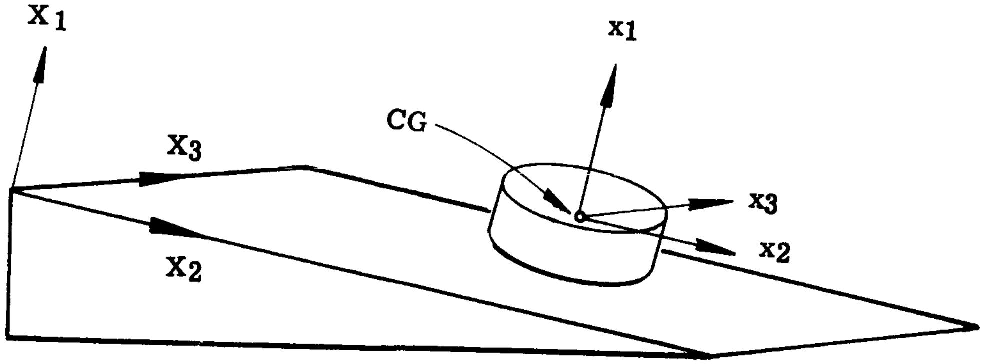
Roll Rotation

The preceding specification of the initial position is easier to visualize than the Euler angles would be. The calculation of the initial direction cosines from the pitch, roll, and yaw angles is easily carried out. The resulting formulas appear in the computer program.

Description of Subroutine INTEQM

This subroutine basically integrates the equations for motion of a six degree of freedom (3 translational, 3 rotational) system to find the x_K, y_K, z_K, θ_K, ϕ_K, ψ_K position from the previous position and the forces and torques acting during a time increment dt. The angular position is actually stated in terms of the direction cosines between a triad fixed in the moving system and a triad fixed in the "ground" rather than in terms of the Euler angles.

The following figure depicts the fixed coordinate system (X_1, X_2, X_3) and the "vehicle" coordinate system (x_1, x_2, x_3). Both are right-handed triads and unit vectors ($\vec{i}$, $\vec{j}$, $\vec{k}$) and ($\vec{I}$, $\vec{J}$, $\vec{K}$) will be used to indicate direction in the vehicle and fixed systems, respectively.



For computing translation of the vehicle, the forces will be expressed in terms of the fixed coordinate system and the equations which are integrated are simply

$$\ddot{X}_{CG} = \Sigma F_X/m \tag{3}$$

$$\ddot{Y}_{CG} = \Sigma F_Y/m \tag{4}$$

$$\ddot{Z}_{CG} = \Sigma F_Z/m \tag{5}$$

For rotation, the equations are more complex. First, note that it is desirable to find torques and rotations in terms of the vehicle coordinate system so that the moments of inertia remain constant in the direction of the applied torques.

With this done these torques G_1, G_2, G_3 which are the torques about the x_1, x_2, and x_3 axes (positive clockwise looking at the origin) respectively, give rise to angular velocity changes according to the Euler equations

$$\dot{\omega}_1 = G_1/U_1 + \frac{U_2 - U_3}{U_1} (\omega_2 \omega_3) \tag{6}$$

$$\dot{\omega}_2 = \frac{1}{U_2} (G_2 + (U_3 - U_1) \omega_1 \omega_3) \tag{7}$$

$$\dot{\omega}_3 = \frac{1}{U_3} (G_3 + (U_1 - U_2) \omega_1 \omega_2) \tag{8}$$

where $U_1, U_2,$ and U_3 are the moments of inertia of the vehicle body about its x_1, x_2, and x_3 axes and ω_1, ω_2, and ω_3 are the angular velocities around these axes (positive clockwise looking at the origin).

In Equation (6) the term $\frac{U_2 - U_3}{U_1} (\omega_2 \omega_3)$ is zero if x_1 is an axis of symmetry. The difficulty in transforming the torques to the vehicle coordinate system and the new position resulting from the integration back into terms of the fixed coordinate system is resolved by the use of the direction cosines, $\ell(i, j)$. Here, $\ell(i, j)$ is the cosine of the angle between the positive ith axis of the fixed coordinate system and the positive jth axis of the vehicle coordinate system when the vehicle system is translated so that the origins of the two systems coincide.

If the $(\vec{i}, \vec{j}, \vec{k})$ triad is expressed in terms of the fixed triad $(\vec{I}, \vec{J}, \vec{K})$ with components expressed as $\vec{i}\,(\vec{I})$, $\vec{i}\,(\vec{J})$, etc., where $\vec{i}\,(\vec{I})$ is the $\vec{I}$ - component of $\vec{i}$, etc., thus for $\ell(i, j)$:

$$\begin{array}{lll}
\ell(1,1) = i\,(I) & \ell(1,2) = j\,(I) & \ell(1,3) = k\,(I) \\
\ell(2,1) = i\,(J) & \ell(2,2) = j\,(J) & \ell(2,3) = k\,(J) \\
\ell(3,1) = i\,(K) & \ell(3,2) = j\,(K) & \ell(3,3) = k\,(K)
\end{array}$$

In the program the motion of the vehicle body during one time step is expressed in terms of the (i, j, k) triad as oriented at the beginning of the time step. Then the acceleration of any point in the vehicle body is given by:

$$\ddot{\vec{r}} = \underbrace{\vec{\omega} \times (\vec{\omega} \times \vec{r})}_{\substack{\text{Radial}\\ \text{Component}}} + \underbrace{\dot{\vec{\omega}} \times \vec{r}}_{\substack{\text{Tangential}\\ \text{Component}}}$$

$\vec{r}$ is where a vector originates at the C.G.

If we let $\vec{r}$ be, in turn, the $\vec{i}$, $\vec{j}$, and $\vec{k}$ vectors we can, by integrating, find the position of the $\vec{i}$, $\vec{j}$, and $\vec{k}$ vectors at the end of the iteration interval. This is an especially convenient choice of $\vec{r}$ because we can, from the new $(\vec{i}, \vec{j}, \vec{k})$, easily find the new ℓ(i, j) and thus any point on the body can be located in the fixed coordinate system from its known position on the vehicle body. (For example, the hardpoints can be found quickly.)

Considering that $\vec{r}$ is any vector expressed in terms of the vehicle coordinates, we have

$$\vec{r}_{new} = \left\{ (\vec{\omega}_{avg} \times (\vec{\omega}_{avg} \times \vec{r}_{old}) + \dot{\vec{\omega}} \times \vec{r}_{old} \right\} \frac{(\Delta t)^2}{2} + \dot{\vec{r}}_{old} \ \Delta t + \vec{r}_{old} \qquad (9)$$

The symbol V (m, n) is introduced to denote the nth component in the $(\vec{i}, \vec{j}, \vec{k})$ triad $(\vec{i} = 1, \vec{j} = 2, \vec{k} = 3)$ of the new position of the mth vector where m = 1 denotes the $\vec{i}$ vector, etc.

For $\underline{\underline{\text{V (1, n)}}}$: $\vec{\omega} \times (\vec{\omega} \times \vec{i}) = \vec{\omega} \times (\omega_2 \vec{j} + \omega_3 \vec{k}) \times \vec{i}$

$$= \vec{\omega} \times (-\omega_2 \vec{k} + \omega_3 \vec{j}) = (\omega_1 \vec{i} + \omega_2 \vec{j} + \omega_3 \vec{k}) \times (-\omega_2 \vec{k} + \omega_3 \vec{j})$$

$$= \omega_1 \omega_2 \vec{j} + \omega_1 \omega_3 \vec{k} - (\omega_2^2 + \omega_3^2) \vec{i}$$

Similarly, for $\underline{\underline{\text{V (2, n)}}}$:

$$\vec{\omega} \times (\vec{\omega} \times \vec{j}) = - (\omega_1^2 + \omega_3^2) \vec{j} + \omega_2 \omega_3 \vec{k} + \omega_1 \omega_2 \vec{i}$$

and

for $\underline{\underline{\text{V (3, n)}}}$:

$$\vec{\omega} \times (\vec{\omega} \times \vec{k}) = \omega_2 \omega_3 \vec{j} - (\omega_1^2 + \omega_2^2) \vec{k} + \omega_1 \omega_3 \vec{i}$$

for V (1, n):

$$\dot{\vec{\omega}} \times \vec{i} = - \dot{\omega}_2 \vec{k} + \dot{\omega}_3 \vec{j}$$

for V (2, n):

$$\dot{\vec{\omega}} \times \vec{j} = \dot{\omega}_1 \vec{k} - \dot{\omega}_3 \vec{i}$$

for V (3, n):

$$\vec{\omega} \times \vec{k} = -\dot{\omega}_1 \vec{j} + \dot{\omega}_2 \vec{i}$$

Also for V (1, n):

$$\dot{\vec{r}}_{old} = \dot{\vec{i}}_{old} = - \omega_{3} \vec{j} + \omega_2 \vec{k}$$

and for V (2, n):

$$\dot{\vec{j}}_{old} = \omega_3 \vec{i} - \omega_1 \vec{k}$$

for V (3, n):

$$\dot{\vec{k}}_{old} = -\omega_2 \vec{i} + \omega_1 \vec{j}$$

All of these quantities are combined to give the values of $\vec{r}_{new}$ (denoted by V (m, n)) using Equation (9).

The new $\vec{r}$ (that is, new $\vec{i}$, $\vec{j}$, and $\vec{k}$) are expressed in terms of the old ($\vec{i}$, $\vec{j}$, $\vec{k}$) triad and, thus, can be expressed in terms of the fixed coordinate system by means of the old direction cosines, $\ell(i, j)$. First, it should be noted that the components of the new $\vec{i}$, $\vec{j}$, and $\vec{k}$ in terms of the fixed coordinate system are exactly the direction cosines relating the two systems when the origins are brought together by translation without rotation. Thus

$$\ell(i, j)_{new} = \sum_{k=1}^{3} \ell(i, k)_{old} \cdot V(j, k) \qquad (10)$$

This equation states that the direction cosine between the ith fixed axis and the jth vehicle body axis after an iteration interval, that is the new jth axis, is the sum of three terms which are old direction cosines and the new $\vec{i}$, $\vec{j}$, or $\vec{k}$ vector, which is the desired result. The direction cosines relating the "new" vehicle position, the fixed axes, and the new position of the center of gravity are based on integration of F = ma by the equations:

$$X_{CG} = X_{CG}\,(prev) + \dot{X}_{CG} \;\Delta t + F_X \frac{\Delta t^2}{2 \text{ VASLUG}} \qquad (11)$$

$$Y_{CG} = Y_{CG}\,(prev) + \dot{Y}_{CG} \;\Delta t + F_Y \frac{\Delta t^2}{2 \text{ VASLUG}} \qquad (12)$$

$$Z_{CG} = Z_{CG}\,(prev) + \dot{Z}_{CG} \;\Delta t + F_Z \frac{\Delta t^2}{2 \text{ VASLUG}} \qquad (13)$$

These constitute the INTEQM Subroutine Outputs.

An error check on the 3rd term in the Taylor series for the position change from the previous position is made based on the torque equations.

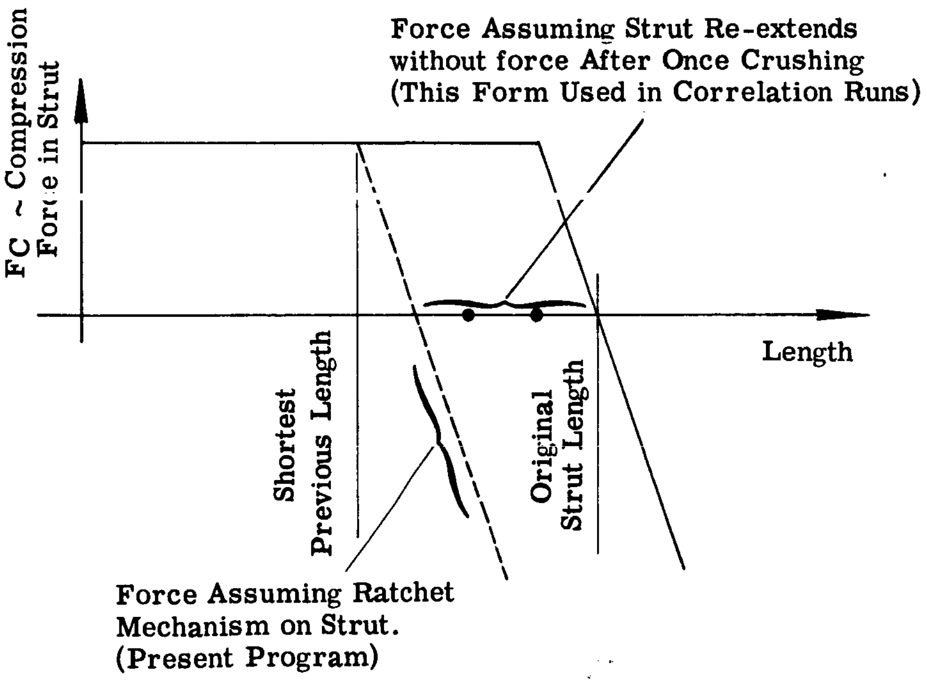
$$\vec{V}_{new} = \vec{V}_{old} + \underbrace{\left.\frac{\partial \vec{V}}{\partial t}\right|_{old} dt}_{\substack{\text{terms of the} \\ \text{form } \dot{\vec{r}}}} + \underbrace{\left.\frac{\partial^2 V}{\partial t^2}\right|_{old} \frac{dt^2}{2}}_{\substack{\text{terms of the} \\ \text{form } \vec{\omega} \text{ x } \vec{\omega} \text{ x } \vec{r} \\ \text{and } \dot{\vec{\omega}} \text{ x } \vec{r}}} + \underbrace{\left.\frac{\partial^3 V}{\partial t^3}\right|_{old} \frac{dt^3}{6}}_{\substack{\text{differences in } \frac{\partial^2 V}{\partial t^2} \\ \text{from present and previous} \\ \text{time increments divided} \\ \text{by } \Delta t.}} + \dots \tag{14}$$

The error check was set up so that a total error of .1° per second was allowed.

Description of Subroutine FORCE

This subroutine requires as input the positions of the vehicle hardpoints in terms of the ground (fixed) coordinate system, the footpad position, the just previous length, and previous shortest length, of all the struts. It provides, as output, the net force acting between the footpad and the surface in terms of the fixed (ground) coordinate system and the strut lengths.

For each strut a static force vs. length relationship, as shown below, is assumed. To this force is added a friction (Coulomb) force depending on the direction of the strut length change in the previous interval.



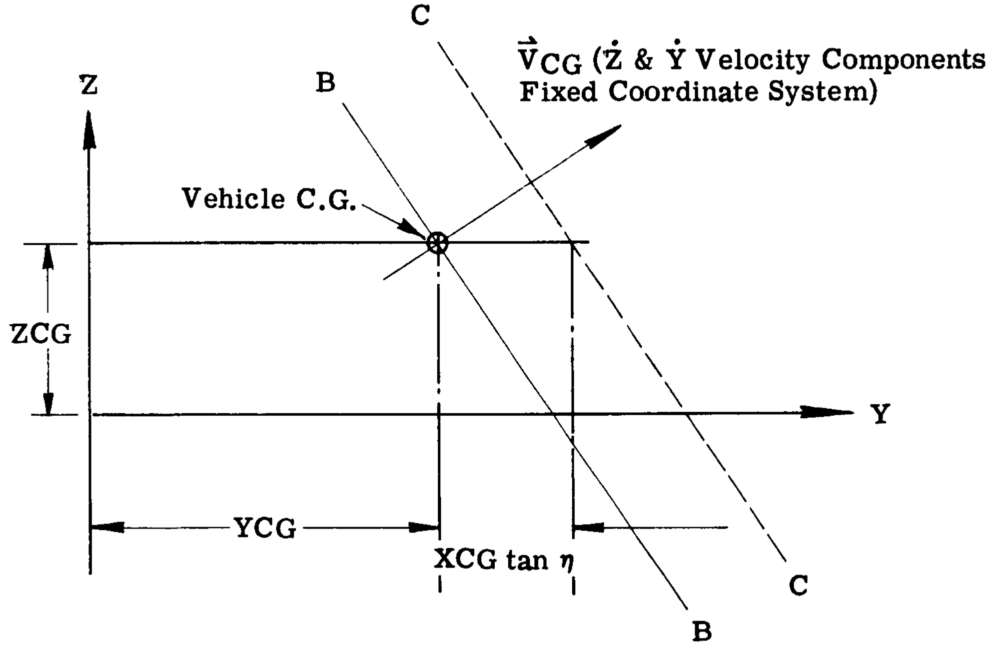
Static Force Vs. Length Relationship

The subroutine calculates forces in only one leg set at a time. The first step in the program is the calculation of the three strut lengths and direction cosines for the leg set under consideration. Then the preceding curve is used to determine the strut forces. Finally, these forces are summed to find the vertical, horizontal, and lateral components in the fixed coordinate system.

Stability Determination

The basic idea of the instability check is simply that, if there are no footpads "in front of" the vehicle center of gravity, then the motion is unstable. "In front of" means ahead of the vehicle center of gravity in the direction of its motion. As presently written, only instability in the generally downhill direction is provided for an all-directional instability check could be provided by simply adding an uphill stability criteria essentially identical to the present downhill case described below.

The BETA value is derived as follows: (See Figure 6-3 for nomenclature.)



View Looking Down on X Axis - Fixed (Ground) Coordinate System

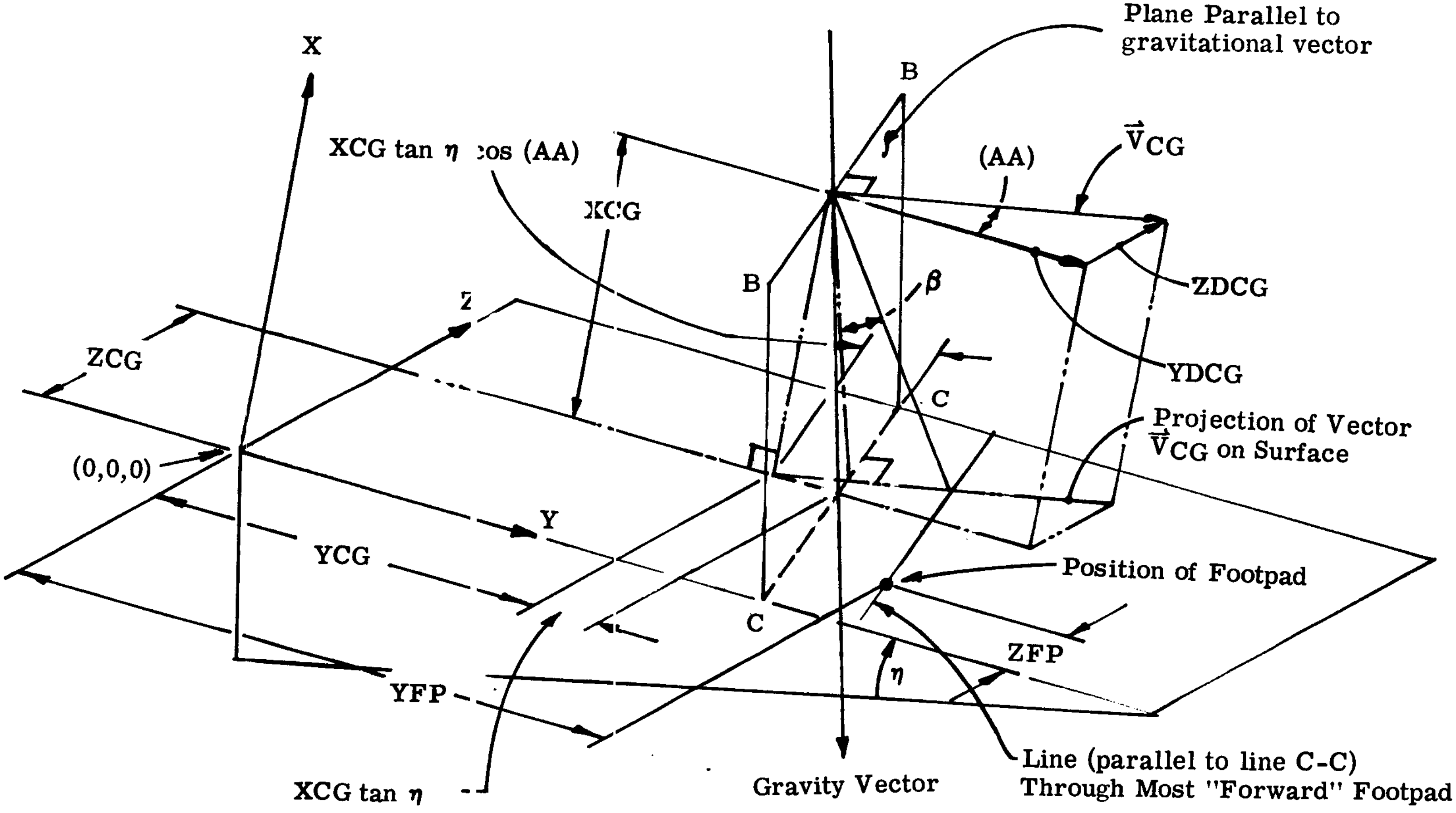
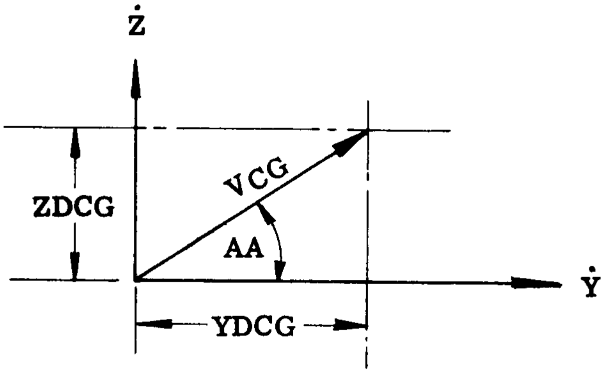


Figure 5-3. Nomenclature for Stability Determination

B-B is a line perpendicular to the vector $\vec{V}_{CG}$ and through the vehicle center of gravity. C-C is the projection of the line B-B onto the Y Z plane in the gravity direction. AA is defined as

$$AA = \arctan\left(\frac{ZDCG}{YDCG}\right) \tag{15}$$



Now we can write an equation for the line B-B

$$Y = C_1 + C_2 Z \tag{16}$$

$$C_2 = - \tan(AA) \tag{17}$$

$$YCG = C_1 - \tan(AA) \cdot ZCG \tag{18}$$

$$\therefore C_1 = YCG + \tan(AA)\, ZCG \tag{19}$$

$$Y = YCG + ZCG \tan(AA) - Z \tan(AA) \tag{20}$$

Using $AAA = \left(\frac{ZDCG}{YDCG}\right) = \tan(AA)$ and rearranging, we have the Equation of B-B;

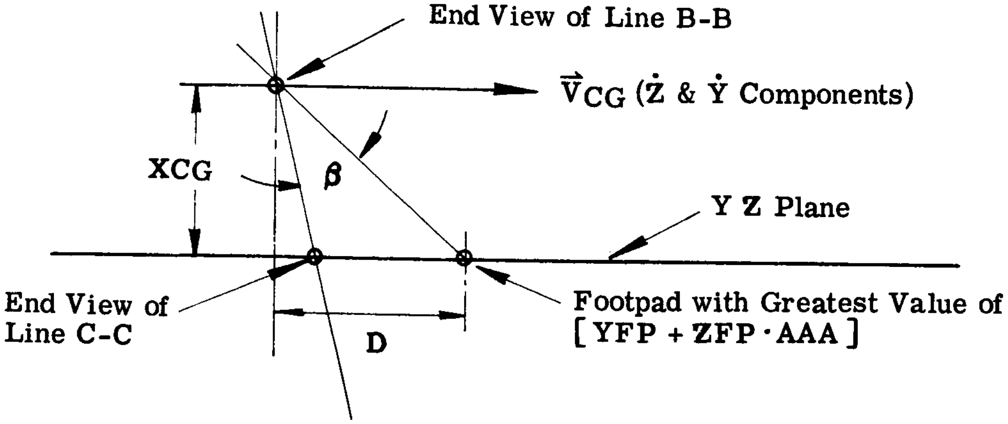
$$Y = YCG + (ZCG - Z) \cdot AAA \tag{21}$$

Then the amount by which the Y-coordinate of a footpad with coordinates VFP and ZFP exceeds the Y-coordinate of the plane through line B-B and perpendicular to plane Y Z is given by

$$YFP - Y = YFP - [\,YCG + (ZCG - ZFP)\, AAA\,] \tag{22}$$

$$YFP - Y = YFP + ZFP \cdot AAA - (YCG + ZCG \cdot AAA) \tag{23}$$

If gravity were acting perpendicular to the YZ plane, then this quantity would be the stability test. However, because the YZ plane is tilted with respect to gravity, we must make a correction.



$$D = [YFP + ZFP \cdot AAA - YCG - ZCG \cdot AAA] \operatorname{Cos}(AA) \tag{24}$$

$$D = FPTEST \cdot \operatorname{Cos}(AA) \tag{25}$$

$$BETA = \beta = \arctan\left[\frac{D}{XCG}\right] - \arctan\left[\tan \zeta \operatorname{Cos}(AA)\right] \tag{26}$$

If BETA becomes negative the calculation of vehicle motion is stopped, instability being evident.

Figure 6-4 illustrates the input data format required for use of the program. The input quantities are defined in Figure 6-14 under "input definitions."

Figures 6-4 through 6-13 are flow diagrams of the main program and its subroutines. Figures 6-14 through 6-22 are complete listings of the program and its subroutines.

The output data for a sample run is shown in Figure 6-24. The input data is printed as part of the output as shown in Figure 6-23. This is followed by "on line" printing of pertinent information. At the completion of the run, additional stored output is printed as illustrated in Figure 6-25.

C FOR COMMENT

STATEMENT NUMBER	Cont.	FORTRAN STATEMENT						
Identification		1	XB(1, 1)	XB(2, 1)	XB(3, 1)	XB(1,2)	XB(2, 2)	XB(3, 2)
		2	XB (1, 3)	XB(2, 3)	XB(3, 3)	XB(1, 4)	XB(2, 4)	XB(4, 4)
		3	YB(1, 1)	YB(2, 1)	YB(3, 1)	YB(1, 2)	YB(2, 2)	YB(3, 2)
		4	YB(1, 3)	YB(2, 3)	YB(3, 3)	YB(1, 4)	YB(2, 4)	YB(3, 4)
		5	ZB(1, 1)	ZB(2, 1)	ZB(3, 1)	ZB(1, 2)	ZB(2, 2)	ZB(3, 2)
		6	ZB(1, 3)	ZB(2, 3)	ZB(3, 3)	ZB(1, 4)	ZB(2, 4)	ZB(3, 4)
		7	VFΦT1(1, 1)	VFΦT1(2, 1)	VFΦT1(3, 1)	VFΦT1(4, 1)	VFDT1(1, 2)	VFΦT1(2, 2)
		8	VFΦT1(3, 2)	VFΦT1(4, 2)	VFΦT1(1, 3)	VFΦT1(2, 3)	VFΦT1(3, 3)	VFΦT1(4, 3)
		9	FΦTAC1(1)	FΦTAC1(2)	FΦTAC1(3)	FΦTAC1(4)	VVEL	HVEL
		10	U1	U2	U3	XCG1	YCG1	ZCG1
		11	W1E1	W2E1	W3E1	PITCH1	YAW1	RΦLL1
		12	TYPE (1)	TYPE (2)	TYPE (3)	VASLUG	ZDCG1	ETA1

Figure 6-4. Input Data Format

This program determines the detailed vehicle motions in three dimensions for a lunar landing vehicle having four tripodal type legs as described in Reference 1.

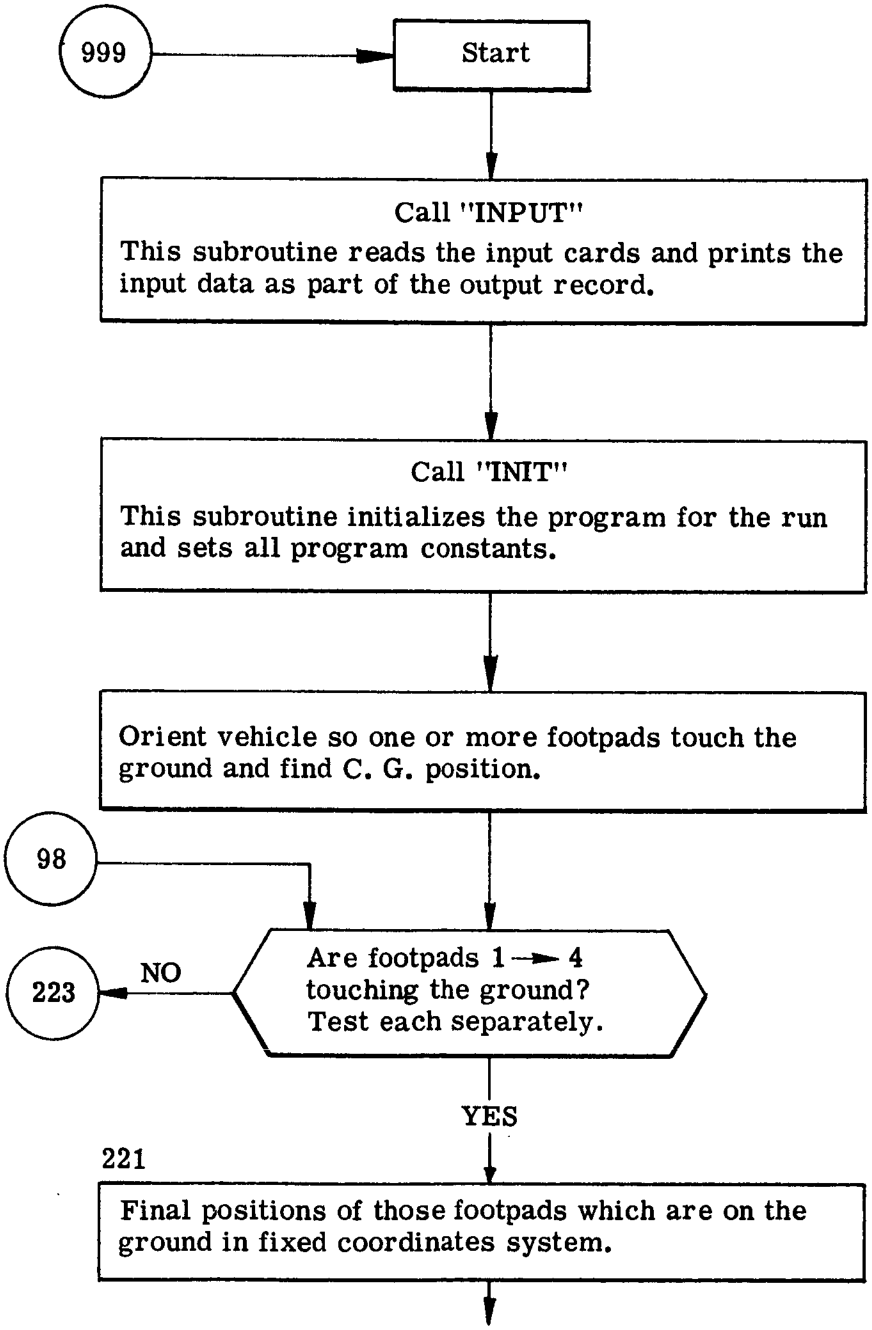


Figure 6-5. Three Dimensional Landing Dynamics

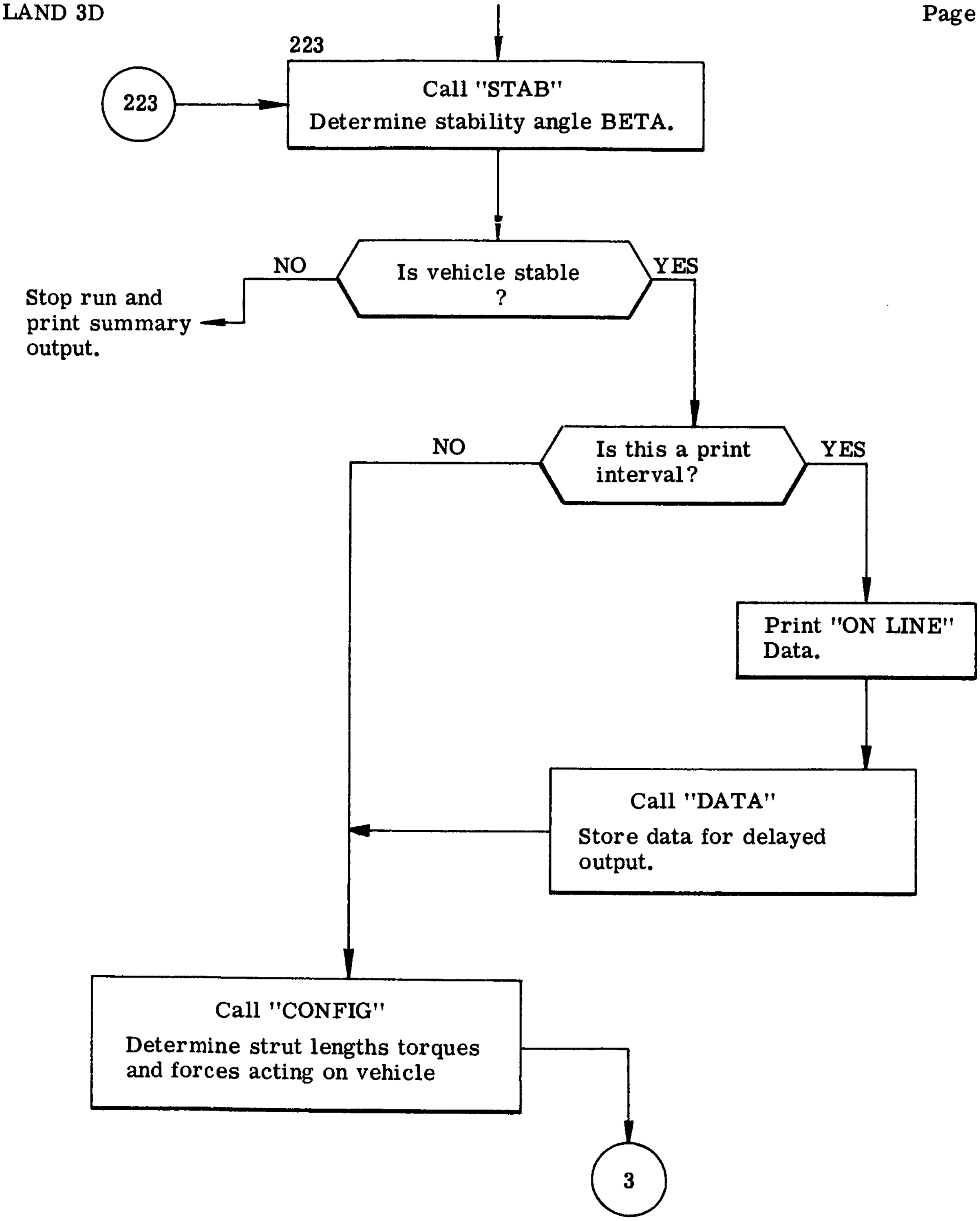


Figure 6-5. Three Dimensional Landing Dynamics (Continued)

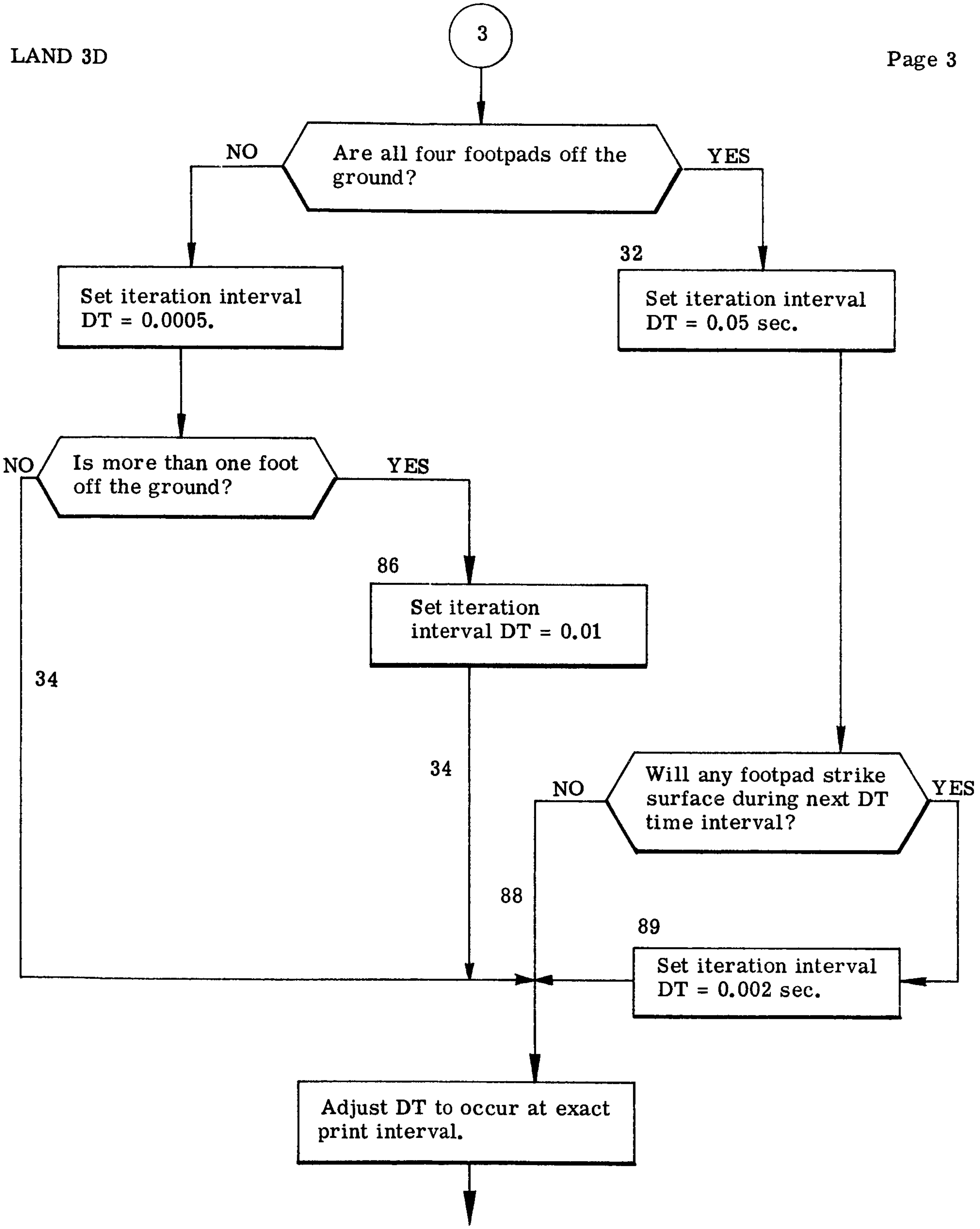


Figure 6-5. Three Dimensional Landing Dynamics (Continued)

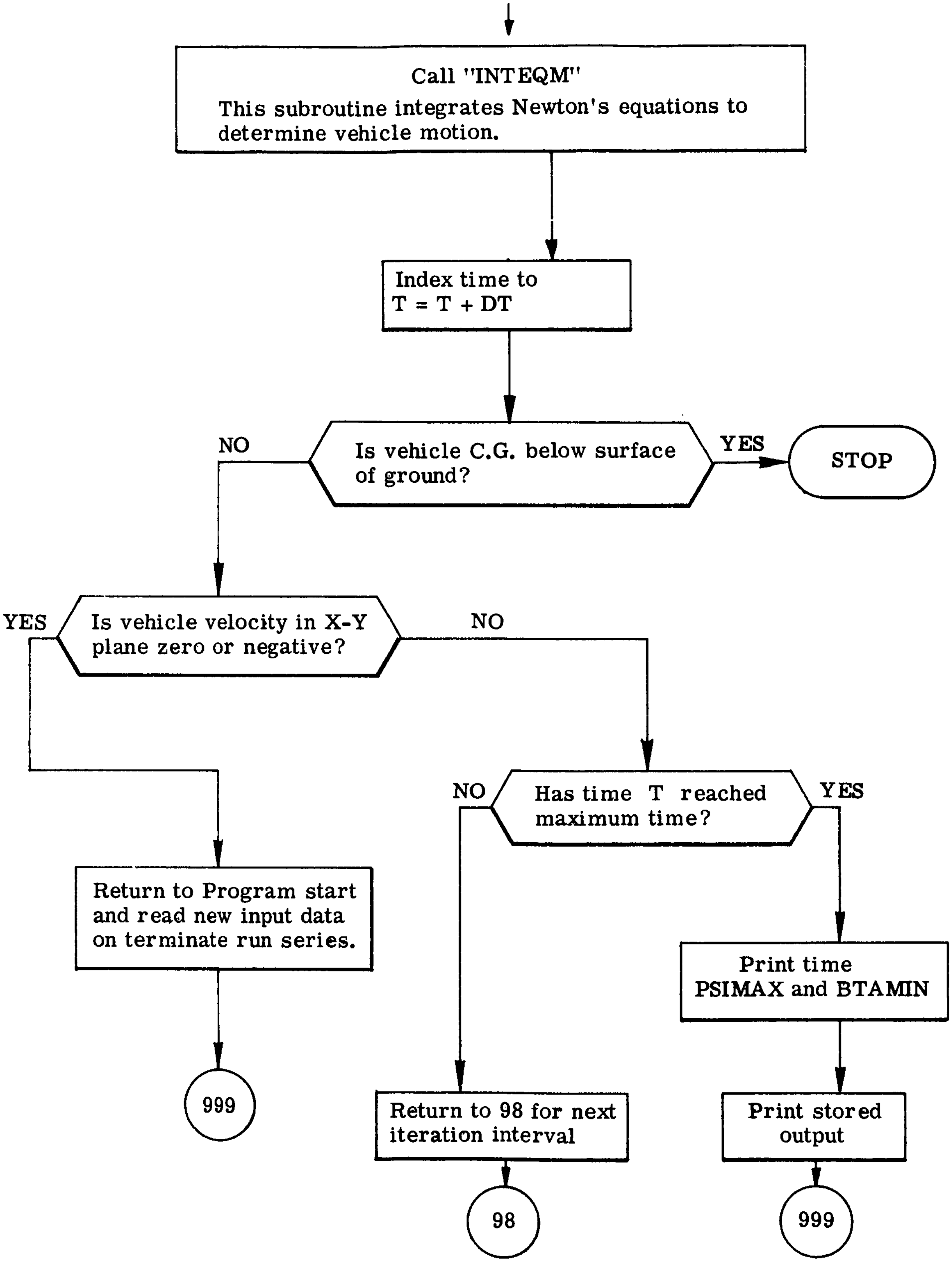


Figure 6-5. Three Dimensional Landing Dynamics (Concluded)

This subroutine reads the input data cards and prints this data as part of the output record

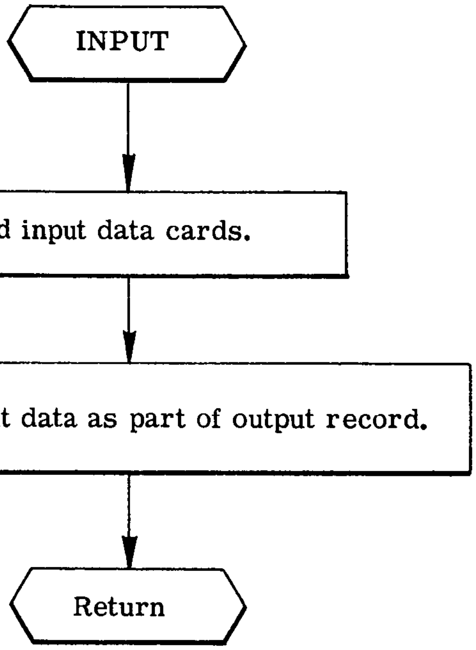


Figure 6-6. Subroutine - INPUT

This subroutine initializes the LAND 3D program and sets program constants.

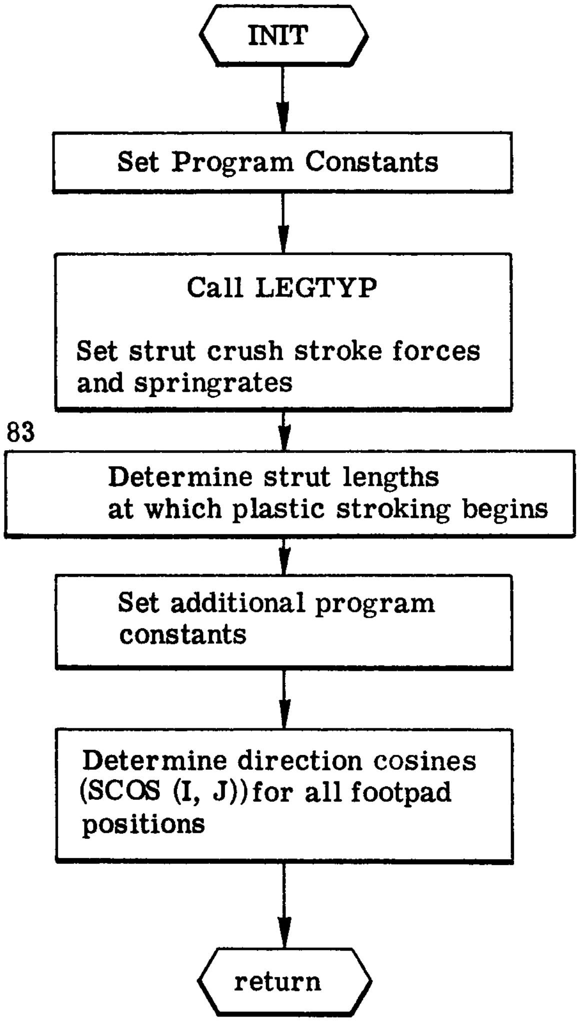


Figure 6-7. Subroutine - INIT

This subroutine sets crush stroke loads and springrates for the struts.

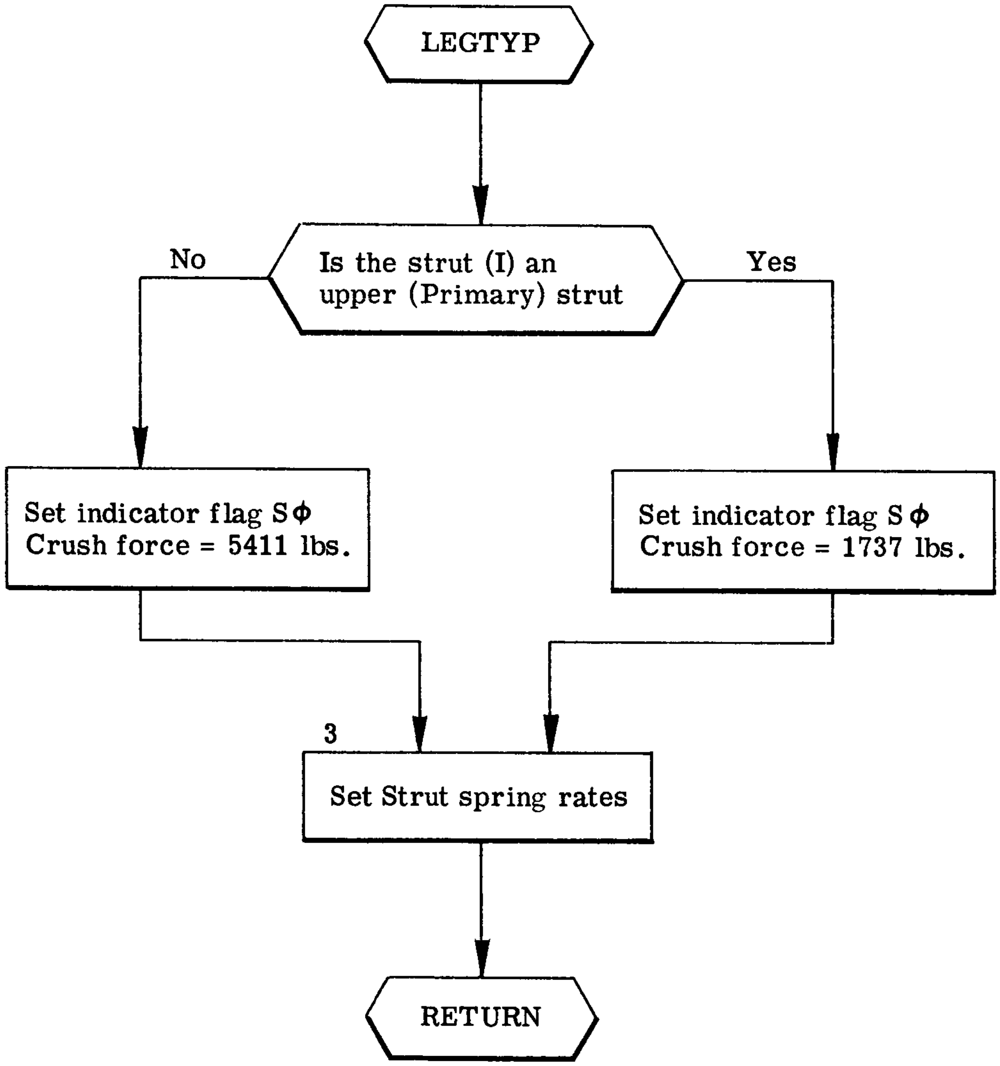


Figure 6-8. Subroutine - LEGTYP

This subroutine defines the stability angle BETA.

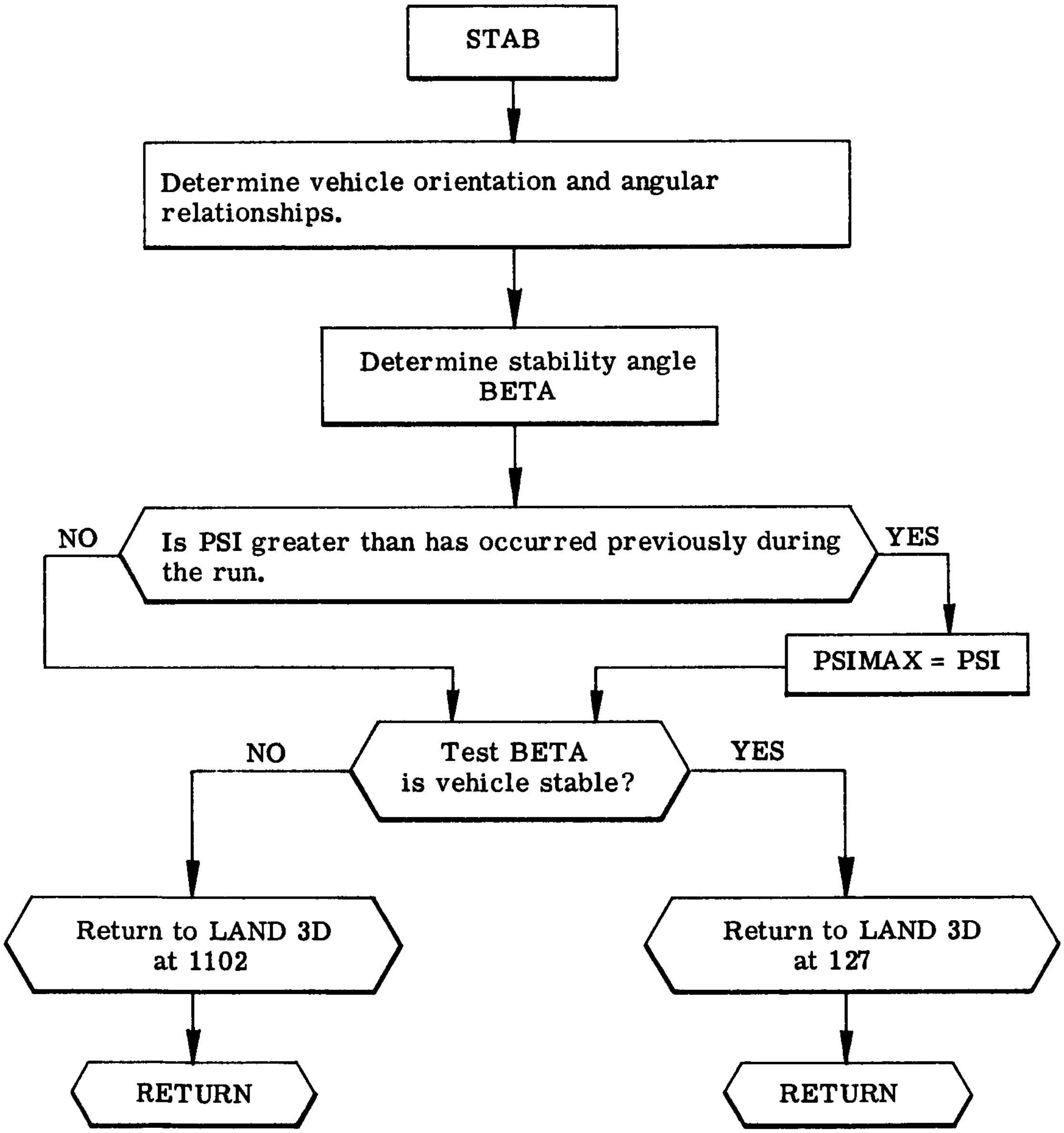


Figure 6-9. Subroutine - STAB

This subroutine stores output data for printing at the end of the run.

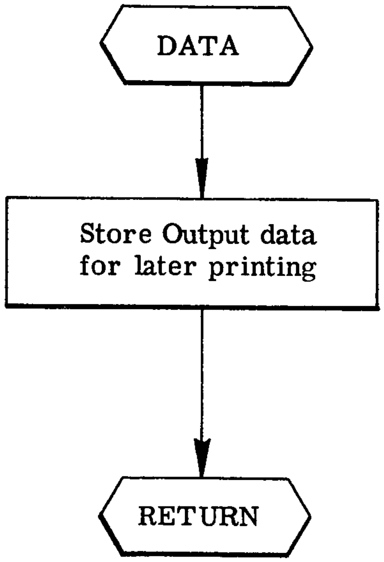


Figure 6-10. Subroutine - DATA

This subroutine determines the vehicle geometry in space.

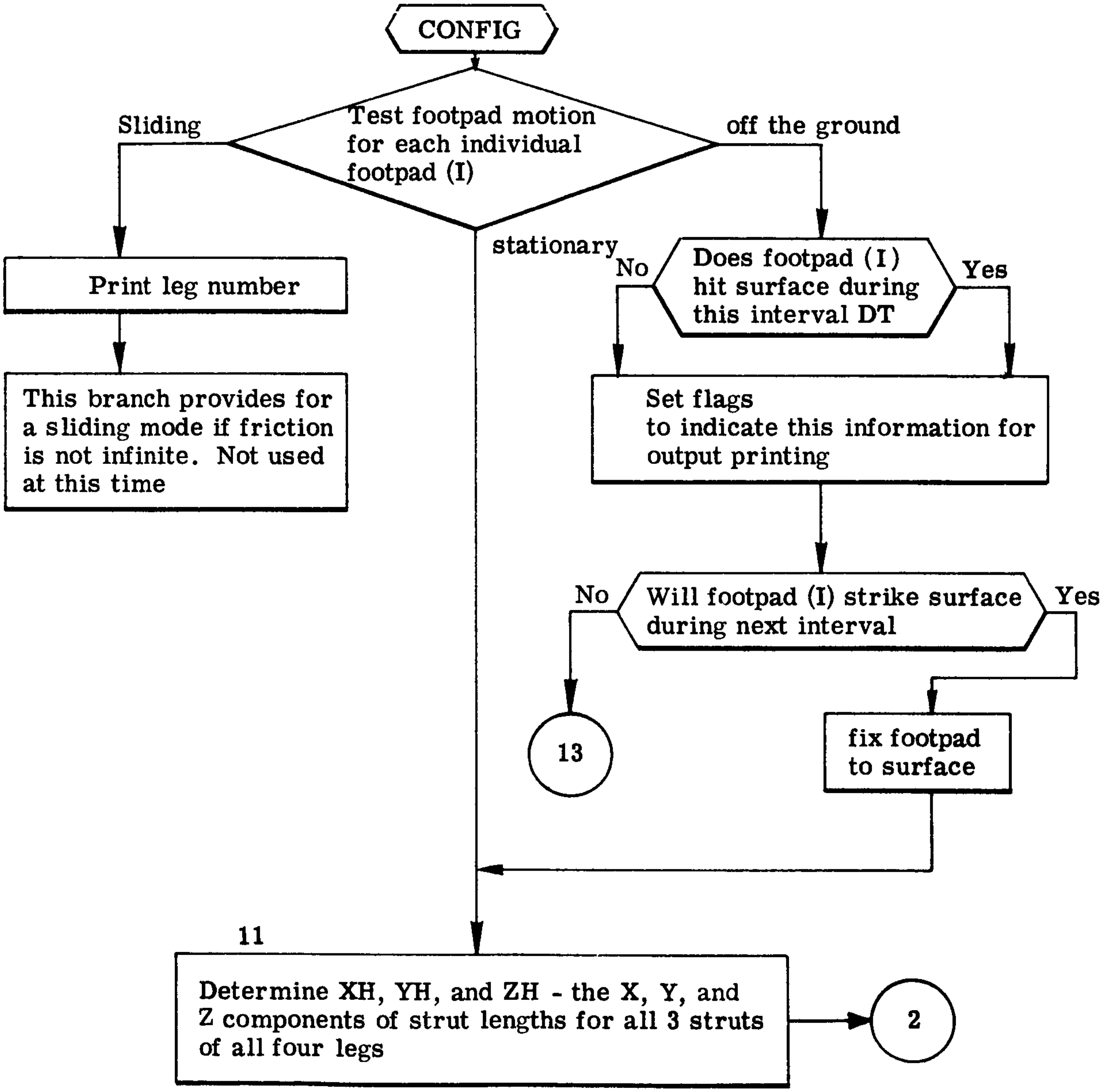


Figure 6-11. Subroutine - CONFIG

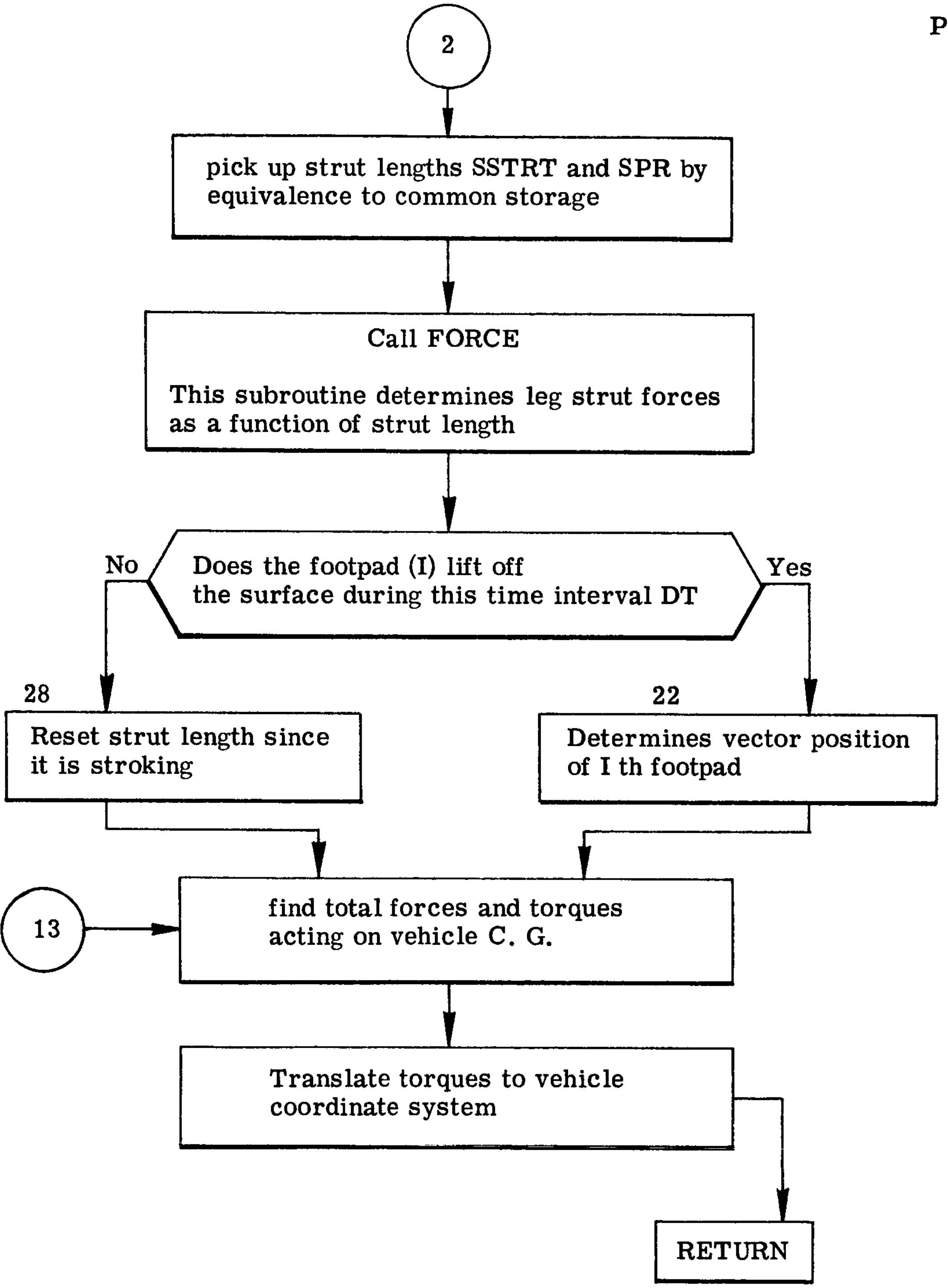


Figure 6-11. Subroutine - CONFIG (Concluded)

This subroutine determines strut stroke forces as a function of strut length.

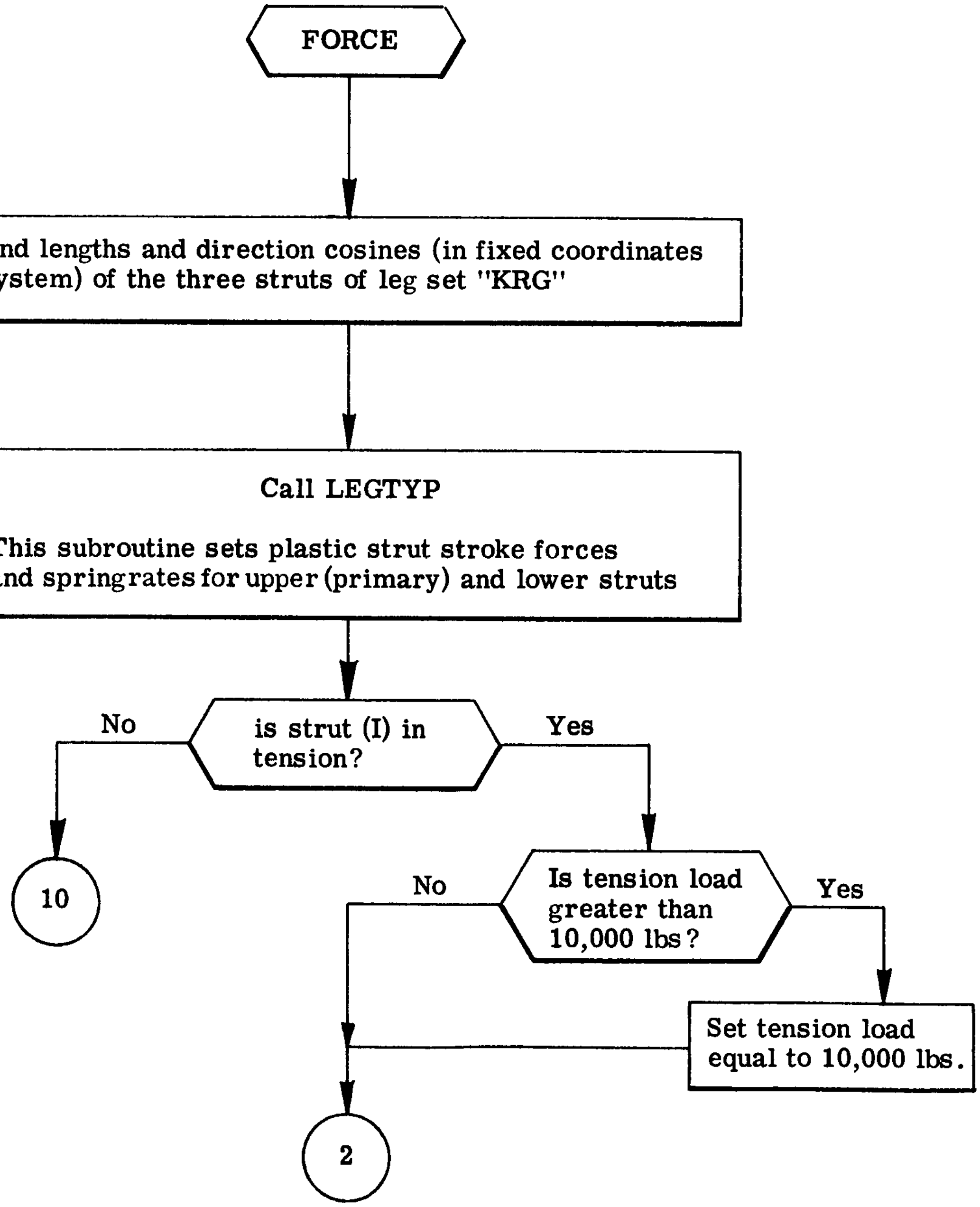


Figure 6-12. Subroutine - FORCE

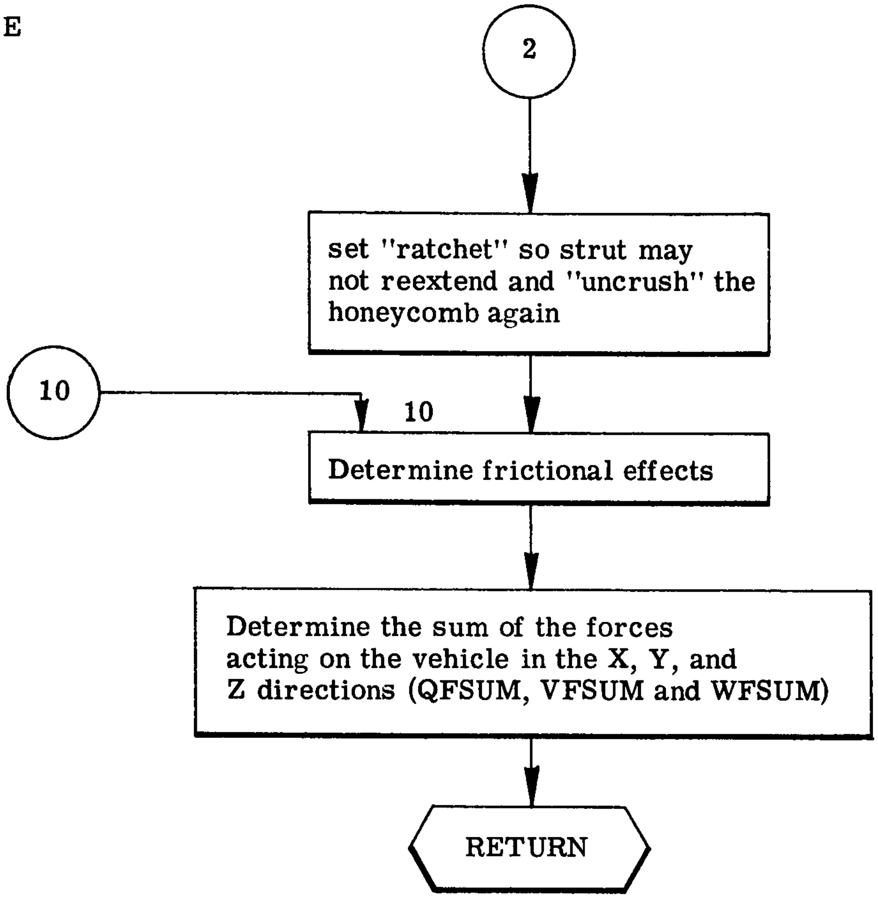


Figure 6-12. Subroutine - FORCE (Concluded)

This subroutine integrates the equations of motion for the vehicle.

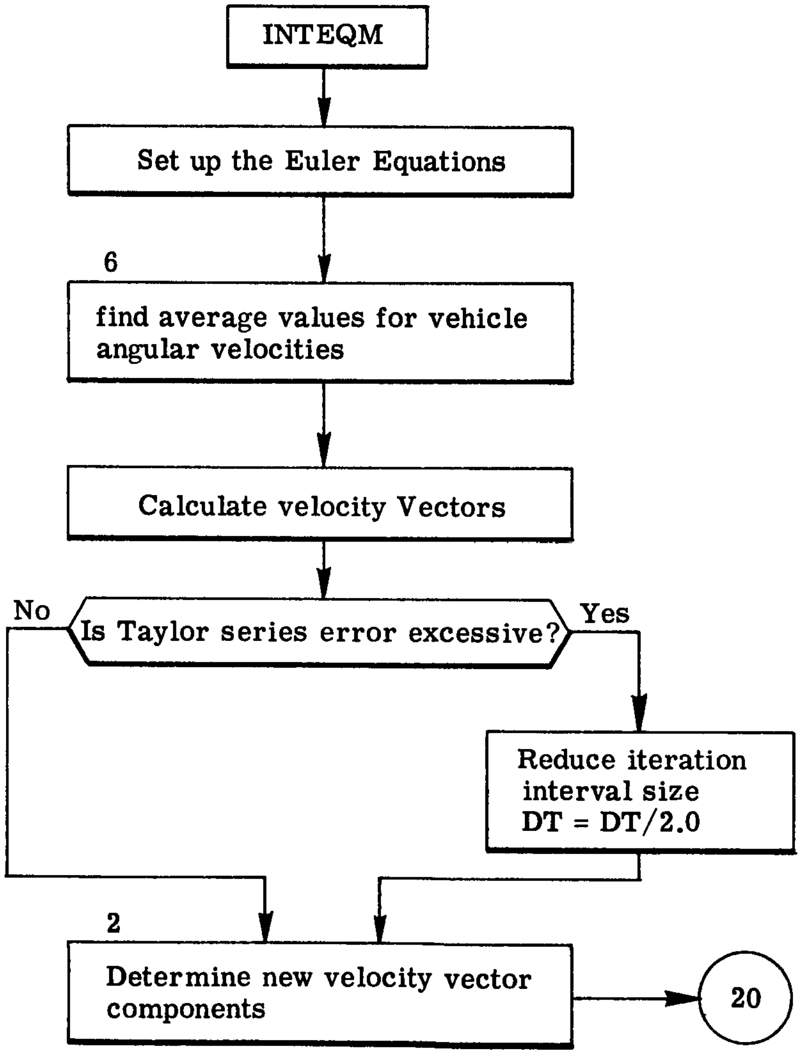


Figure 6-13. Subroutine - INTEQM

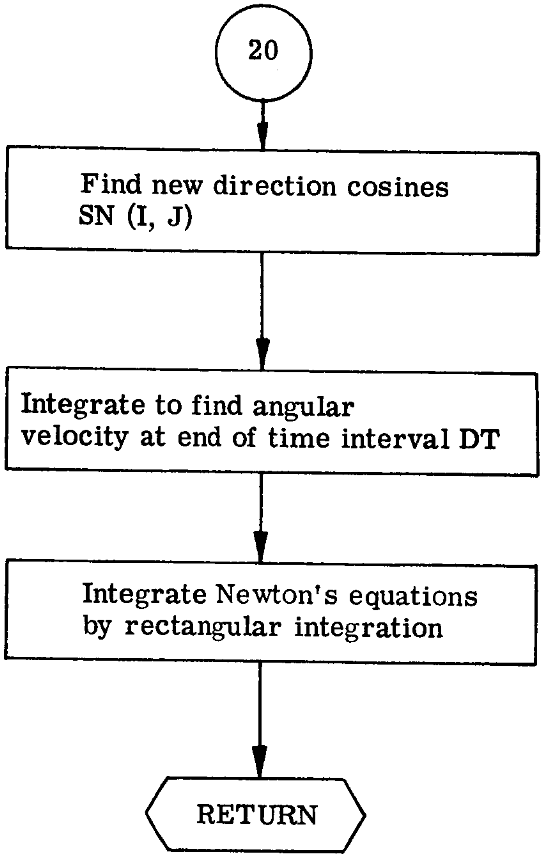


Figure 6-13. Subroutine - INTEQM (Concluded)

```
-I FOR LAND3D
C
C     TITLE       LAND3D  THREE DIMENSIONAL LANDING DYNAMICS COMPUTER
C                         PROGRAM
C
C     AUTHOR      DR.R. DIX   THE BENDIX CORPORATION
C
C     DATE        NOVEMBER, 1964
C
C     PURPOSE     THIS PROGRAM DETERMINES THE DETAILED VEHICLE MOTIONS
C                 IN THREE DIMENSIONS FOR A LUNAR LANDING VEHICLE HAVING
C                 FOUR TRIPODAL TYPE LEGS AS ILLUSTRATED IN BENDIX REPORT
C                 NO. MM 64 - 9
C
C     METHOD      THE PROGRAM DETERMINES LEG STRUT FORCES AS A FUNCTION
C                 OF STRUT LENGTH.  THESE FORCES PLUS GRAVITY DETERMINE
C                 VEHICLE MOTIONS BY INTEGRATION USING VARIABLE TIME
C                 INCREMENTS DETERMINED BY ALLOWABLE ERROR TESTS
C
C     NOTES       PROGRAM WRITTEN IN FORTRAN IV
C
C                 EXECUTES ON UNIVAC  1107 COMPUTER
C
C                 THIS PROGRAM ASSUMES ZERO FOOTPAD MASS AND AN INFINITE
C                 GROUND COEFFICIENT OF FRICTION
C
C                 THE PROGRAM WILL NOT OPERATE IF VVEL AND HVEL  ARE
C                 INITIALLY ZERO SIMULTANEOUSLY
C
C                 THIS PROGRAM WILL NOT OPERATE FOR UPHILL LANDINGS
C
C                 THIS PROGRAM HAS BEEN CHECKED OUT TO A LIMITED EXTENT
C                 ONLY.  FURTHER CHECK OUT AND CORRELATION WITH A PHYSICAL
C                 DROP TEST MODEL ARE CURRENTLY IN PROGRESS.  AS THE
C                 RESULT OF THIS LIMITED CHECKOUT, THE RESULTS OF THIS
C                 PROGRAM SHOULD BE USED WITH CAUTION
C
C     NOTE        ALL UNITS ARE FEET, SECONDS,RADIANS AND SLUGS
C
C                 (M) DENOTES COORDINATE SYSTEM MOVING WITH THE VEHICLE
C                 (F)  DENOTES COORDINATE SYSTEM FIXED IN SPACE
C
C                 APPEARANCE OF  1  AFTER ANY VARIABLE INDICATES THE
C                 INITIAL VALUE OF THAT VARIABLE.
C                 ABSENCE OF THE  1  INDICATES THE INSTANTANEOUS VALUE .
C
C
C     SUBROUTINES USED
C
C                 INPUT  - READS INPUT CARDS AND PRINTS DATA AS PART OF
C                          THE OUTPUT RECORD
C
C                 INIT   - INITIALIZES LAND3D AND SETS PROGRAM CONSTANTS
C
C                 STAB   - DETERMINES STABILITY ANGLE BETA FOR THREE
C                        DIMENSIONAL VEHICLE
C
C                 DATA   - STORES OUTPUT DATA FOR PRINTING AT THE END OF
C                          THE RUN
C
C                 CONFIG - DETERMINES VEHICLE ORIENTATION IN THREE
```

Figure 6-14. Main Program

```
C                        DIMENSIONS
C
C               LEGTYP - SETS SPRING RATES AND PLASTIC STRUT FORCE
C                        MAGNITUDE FOR ALL LEG STRUTS
C
C               FORCE  - DETERMINES LEG STRUT FORCES AS FUNCTION OF STRUT
C                      LENGTH AND SPRINGRATES , ETC.
C
C               INTEQM - INTEGRATES EQUATIONS OF MOTION OF VEHICLE
C
C
C     INPUT     INPUT BY PUNCH CARD
C              INPUT FORMAT IS ILLUSTRATED IN BENDIX REPORT MM 64 - 9
C
C     INPUT DEFINITIONS
C
C     ETA1 (OR ETA)  ANGLE OF SLOPE IN PRINCIPLE DIRECTION
C
C     FOTAC1(I) OR (FOTAC(I))    MODE OF ACTION OF THE I TH FOOTPAD
C               I = 1 CORRESPONDS TO SLIDING ON THE SURFACE
C               I = 2 CORRESPONDS TO THE FOOTPAD STATIONARY ON THE SURFACE
C               I = 3 CORRESPONDS TO THE FOOTPAD OFF THE SURFACE
C            NOTE FOTAC1(I) ARE PROGRAM INPUT CONSTANTS.  SET THEM EQUAL
C               TO 3.0 FOR ALL RUNS
C
C     PITCH1  (OR PITCH ) INITIAL VEHICLE ORIENTATION  - SEE BENDIX
C               REPORT  MM-64-9
C     YAW1 (OR YAW)       INITIAL VEHICLE ORIENTATION  - SEE BENDIX
C               REPORT  MM-64-9
C     ROLL1 (OR ROLL)     INITIAL VEHICLE ORIENTATION  - SEE BENDIX
C               REPORT  MM-64-9
C     H VEL     HORIZONTAL VELOCITY OF THE VEHICLE C.G. ( NORMAL TO
C               THE GRAVITY VECTOR) AND IN THE DIRECTION OF THE PRINCIPLE
C               SLOPE. (IN THE Y DIRECTION IN (F) COORDINATE SYSTEM)
C     U1        MASS MOMENT OF INERTIA OF VEHICLE ABOUT X AXIS IN (M)
C               COORDINATE SYSTEM
C     U2        MASS MOMENT OF INERTIA OF VEHICLE ABOUT Y AXIS IN (M)
C               COORDINATE SYSTEM
C     U3        MASS MOMENT OF INERTIA OF VEHICLE ABOUT Z AXIS IN (M)
C               COORDINATE SYSTEM
C     VASLUG    VEHICLE MASS
C     VVEL      VERTICAL VELOCITY OF THE VEHICLE C.G. ( PARALLEL TO THE
C               GRAVITY VECTOR)
C     VFOT1(I,J)  (OR VFOT(I,J))    I TH COMPONENT OF THE VECTOR POSITION
C               OF THE J TH FOOTPAD IN (M) COORDINATE SYSTEM
C               I = 1 IS X COMPONENT
C               I = 2 IS THE Y COMPONENT
C               I = 3 IS THE Z COMPONENT
C     W1E1 (OR W1E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE X AXIS IN THE
C               (M) COORDINATE SYSTEM
C     W2E1 (OR W2E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Y AXIS IN THE
C               (M) COORDINATE SYSTEM
C     W3E1 (OR W3E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Z AXIS IN THE
C               (M) COORDINATE SYSTEM
C     XB(2,4)   X COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C               BODY ATTACH POINT (HARDPOINT)
C     YB(2,4)   Y COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C               BODY ATTACH POINT (HARDPOINT)
C     ZB(2,4)   Z COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C               BODY ATTACH POINT (HARDPOINT)
C     XCG       X POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
```

Figure 6-14. Main Program (Continued)

```
C      YCG          Y POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C      ZCG          Z POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C      ZDCG1 (OR ZDCG) HORIZONTAL VELOCITY OF VEHICLE C.G. (NORMAL TO
C                   GRAVITY VECTOR) NORMAL TO THE PRINCIPLE DIRECTION OF
C                   THE SLOPE  ( IN Z DIRECTION IN (F) COORDINATE SYSTEM)
C
C
C      OUTPUT       PRINTED OUTPUT
C
C      OUTPUT DEFINITIONS
C
C      BETA         STABILITY ANGLE    SEE TEXT BENDIX REPORT  MM-64-9
C      BETADT       RATE OF CHANGE OF THE STABILITY ANGLE BETA
C      BETAP        PREVIOUS VALUE OF BETA AT LAST ITERATION INTERVAL
C      BETAMIN      MINIMUM BETA ANGLE REACHED DURING THE COMPUTER RUN
C
C      CRUSH        OUTPUT INDICATOR  -  TWELVE DIGITS , ONE FOR EACH STRUT,
C                   REPRESENTING THE FORCE CAUSING MECHANISM IN EACH STRUT
C             ORDER OF OUTPUT    1         2         3         4
C                   STRUT        1 2 3     1 2 3     1 2 3     1 2 3
C                      THE DIGITAL CODE IS AS FOLLOWS
C                            0    NO FORCE BECAUSE FOOTPAD IS OFF SURFACE
C                            1    ELASTIC COMPRESSION IN STRUT
C                            2    PLASTIC COMPRESSION IN STRUT
C                            3    STRUT RE-EXTENDED FROM PREVIOUSLY CRUSHED
C                                 POSITION BUT IS STILL SHORTER THAN ORIGINAL
C                                 LENGTH
C                            8    STRUT STRETCHED BEYOND ORIGINAL LENGTH BUT
C                                 LESS THAN 10000 LBS FORCE
C                            9    STRUT IN TENSION MORE THAN 10000 LBS
C
C      DT            ITERATION TIME INTERVAL
C      E             OUTPUT INDICATOR   E=0 IF LEG IS NOT COMPRESSING OR THE
C                       FORCE IN LEG IS LESS THAN 10000 LBS.   E=1 IF AT LEAST
C                       ONE LEG IS IN TENSION GREATER THAN 10000 LBS
C      IE           SAME AS E
C      FC            STRUT PLASTIC STROKE FORCE
C      FSUMX         SAME AS FXP
C      FSUMY         SAME AS FYP
C      FSUMZ         SAME AS FZP
C      FYGRAV        GRAVITY FORCE IN Y DIRECTION IN (F) COORDINATE SYSTEM
C      FXP           FORCE IN THE X DIRECTION ON THE FOOTPAD
C      FYP           FORCE IN THE Y DIRECTION ON THE FOOTPAD
C      FZP           FORCE IN THE Z DIRECTION ON THE FOOTPAD
C      FORCEX        NET FORCE ACTING ON THE VEHICLE C.G. IN THE X DIRECTION
C                    IN THE (F) COORDINATE SYSTEM
C      FORCEY        NET FORCE ACTING ON THE VEHICLE C.G. IN THE Y DIRECTION
C                    IN THE (F) COORDINATE SYSTEM
C      FORCEZ        NET FORCE ACTING ON THE VEHICLE C.G. IN THE Z DIRECTION
C                    IN THE (F) COORDINATE SYSTEM
C      IFORCX        SAME AS FORCEX
C      IFORCY        SAME AS FORCEY
C      IFORCZ        SAME AS FORCEZ
C      TORQZ         COMPONENT OF TORQUE ACTING ON THE VEHICLE C.G. IN THE
C                    X-Y PLANE
C      ITORQ         SAME AS TORQZ
C      FX1           GROUND REACTION FORCE PERPENDICULAR TO GROUND FOR FOOTPAD
C                    NO. 1
C      FX2           GROUND REACTION FORCE PERPENDICULAR TO GROUND FOR FOOTPAD
C                    NO. 2
C      FX3           GROUND REACTION FORCE PERPENDICULAR TO GROUND FOR FOOTPAD
```

Figure 6-14. Main Program (Continued)

```
C               NO. 3
C     FX4       GROUND REACTION FORCE PERPENDICULAR TO GROUND FOR FOOTPAD
C               NO. 4
C     IX1       SAME AS FX1
C     IX2       SAME AS FX2
C     IX3       SAME AS FX3
C     IX4       SAME AS FX4
C     GSUM      SUM OF THE TORQUES.  USED TO CONTROL DT  ( USED TO FIND IF
C               THE TORQUE IS CHANGING.  IF THE DIFFERENCE BETWEEN GSUM
C               AND GSUMP IS LARGE , TAKE SMALL DT TIME INCREMENTS
C               IF THE DIFFERENCE IS SMALL   TAKE LARGE DT TIME INCREMENTS
C     GSUMP     PREVIOUS VALUE OF GSUM
C     GND       INDICATES IF ANY FOOTPAD IS ON THE GROUND
C               GND = 1  -- ONE OR MORE FEET ARE ON THE GROUND
C               GND  = 0   ALL FEET ARE OFF THE GROUND
C     IFLAG     INDICATOR FOR CONDITIONAL RETURN TO MAIN PROGRAM
C     ITORE     STORAGE INDEX FOR FINAL OUTPUT PRINTING
C     LINE      LINE COUNT FOR OUTPUT PAGE ORDERING
C     LCOUNT    MAXIMUM ALLOWABLE LINES PER PAGE OF OUTPUT DATA
C     ONMCON    DIGITAL REPRESENTATION OF FOTAC  FOR FOOTPADS  1 --4
C               RESPECTIVELY   ( SEE INPUT DEFINITIONS FOR FOTAC)
C     PHI       ANGULAR ORIENTATION OF VEHICLE IN (F) COORDINATE SYSTEM
C               SEE TEXT BENDIX REPORT  MM-64-9
C     PSI       ANGULAR ORIENTATION OF VEHICLE IN (F) COORDINATE SYSTEM
C               SEE TEXT BENDIX REPORT  MM-64-9
C     THETA     ANGULAR ORIENTATION OF VEHICLE IN (F) COORDINATE SYSTEM
C               SEE TEXT BENDIX REPORT  MM-64-9
C     PSIDOT    COMPONENT OF VEHICLE ANGULAR VELOCITY IN X-Y PLANE OF
C               (F) COORDINATE SYSTEM
C     PX1       HEIGHT OF FOOTPAD 1 ABOVE THE SURFACE AND NORMAL TO IT
C     PX2       HEIGHT OF FOOTPAD 2 ABOVE THE SURFACE AND NORMAL TO IT
C     PX3       HEIGHT OF FOOTPAD 3 ABOVE THE SURFACE AND NORMAL TO IT
C     PX4       HEIGHT OF FOOTPAD 4 ABOVE THE SURFACE AND NORMAL TO IT
C     PHIDOT    COMPONENT OF VEHICLE ANGULAR VELOCITY IN X-Z PLANE OF
C               (F) COORDINATE SYSTEM
C     PSIMAX    MAXIMUM  PSI ANGLE REACHED DURING THE ENTIRE COMPUTER RUN
C     PRNI      PRINT TIME ( 0.0,0.04,0.04SEC, ETC)
C     SO        STRUT LENGTH
C     SSTRUT(I,J)   STRUT LENGTH OF THE J TH STRUT OF THE I TH LEG SET
C     T         SPRING RATE OF THE UPPER STRUT
C     T2        SPRING RATE OF THE LOWER STRUTS
C     THEDT     COMPONENT OF VEHICLE ANGULAR VELOCITY IN Y-Z PLANE OF
C               (F) COORDINATE SYSTEM
C     SCOS      DIRECTION COSINES RELATING FIXED (F) AND MOVING (M)
C               COORDINATE SYSTEMS
C     SPRR(I,J)   PREVIOUS SHORTEST LENGTH OF STRUT I OF THE J TH LEG SET
C     SNTRVL    PRINT FREQUENCY ( EVERY 0.04 SEC.)
C     TIME      TIME AFTER TOUCHDOWN
C     TYPE(I)   TYPE OF STRUT - STRUT NO. 1 IS TYPE 1
C                                  STRUTS NOS.2 AND 3 ARE TYPE 2
C     VEL       VELOCITY OF VEHICLE C.G. IN X-Y PLANE OF (F)
C               COORDINATE SYSTEM
C     XFIF(I)   POSITION OF THE FOOTPAD I  IN THE J TH (X,Y,Z) DIRECTION
C               IN THE FIXED COORDINATE SYSTEM
C     XCG1 (OR XCG)   X POSITION OF VEHICLE C.G. IN (F) COORDINATE
C               SYSTEM
C     YCG1 (OR YCG)   Y POSITION OF VEHICLE C.G. IN (F) COORDINATE
C               SYSTEM
C     ZCG1 (OR ZCG)   Z POSITION OF VEHICLE C.G. IN (F) COORDINATE
C               SYSTEM
C     XSFCTP    PARTICULAR VALUE OF XFIF(I,J)
```

Figure 6-14. Main Program (Continued)

```
C     XFOT       X COORDINATE OF FOOTPAD IN FIXED COORDINATE SYSTEM
C     XDCG       VELOCITY OF VEHICLE C.G. IN X DIRECTION IN (F) COORDINATE
C                SYSTEM
C     YDCG       VELOCITY OF VEHICLE C.G. IN Y DIRECTION IN (F) COORDINATE
C                SYSTEM
C     ZDCG       VELOCITY OF VEHICLE C.G. IN Z DIRECTION IN (F) COORDINATE
C                SYSTEM
C     XBFT1      SAME AS VFOT(1,1)
C     XBFT2      SAME AS VFOT(2,1)
C     XBFT3      SAME AS VFOT(3,1)
C     XBFT4      SAME AS VFOT(4,1)
C     XXFX(I)    X POSITION OF FOOTPAD (I) IN THE (F) COORDINATE SYSTEM
C                AT THE INITIAL VALUE XCG1
C     YFOTJ      Y COORDINATE OF FOOTPAD IN THE (F) COORDINATE SYSTEM
C
C
C
C
      DIMENSION XXFX(4)
      DIMENSION CG(3)
      COMMON/LS1/BETAP,BETTDT,BTAMIN,CRUSH(12),DT,E,ETA,FORCEZ,FOTAC(4),
     1FXP(4),FORCEX,FORCEY,FC,FSUMZ,FSUMY,FSUMX,FXGRAV,FYGRAV,G1,G2,
     2G3,GND,GNDF,I,ITORE,J,PSIMAX,SCOS(3,3),SPRR(4,3),SSTRUT(4,3),
     3SO,SO1,SO2,TIME,TYPE(3),TORQZ,T,T2,U1,U2,U3,VASLUG,VFOT(4,3),W1E,
     4W2E,W3E,XCG,XDCG,X(3),XB(3,4),XFIF(4,3),XSFOTP(4),Y(3),YB(3,4),
     5YCG,YDCG,      Z(3),ZB(3,4),ZCG,ZDCG
      COMMON/LS2/BETADT(500),ICRSH1(500),ICRSH2(500),ICRSH3(500),
     1ICRSH4(500),IE,IFORCX,ITORQ,IX1(500),IX2(500),IX3(500),IX4(500),
     2ONMOON(500),PHI,PHIDOT(500),PSIDOT(500),PX1,PX2,PX3,PX4,THETA,
     3THEDT(500), TIME2(500),XBFT1(500),XBFT2(500),XBFT3(500),
     4XBFT4(500),IFORCY
      COMMON/LS3/ETA1,FOTAC1(4),HVEL,PITCH1,ROLL1,VFOT1(4,3),VVEL,
     1W1E1,W2E1,W3E1,XCG1,YAW1,YCG1,ZCG1,ZDCG1
      COMMON/LS5/GSUM,LCOUNT,LINE,PRNI,SNTRVL
      COMMON/LS6/BETA,IFLAG,PSI
      EQUIVALENCE (VASLUG,VASS),(XH(1),X(1)),(YH(1),Y(1)),
     1(ZH(1),Z(1)),(FSUMY,QFSUM),(FSUMZ,VFSUM),(FSUMX,WFSUM)
C
  999 CALL INPUT
C
      CALL INIT
C
  140 FORMAT(119H   TIME     XCG      YCG      ZCG      PHI     PSI    THETA    XDC
     1G    YDCG    ZDCG   FORCEX   FORCEY    TORQZ    BETA PX1 PX2 PX3 PX4 E)
C
C       THIS STATEMENT PUTS THE LOWEST FOOT DOWN ON THE SURFACE
C
      DO 105  I=1,4
  105 XXFX(I)=SCOS(1,1)*VFOT(I,1)+SCOS(1,2)*VFOT(I,2)+SCOS(1,3)*VFOT
     1 (I,3)+XCG
      XCG=XCG-AMIN1(XXFX(1),XXFX(2),XXFX(3),XXFX(4))-0.001
C
      CG(1)=XCG
      CG(2)=YCG
      CG(3)=ZCG
      DO 106 J=1,4
      DO 106 I=1,3
C
C     INITIALIZE FOOTPAD COORDINATES IN (F) COORDINATE SYSTEM
C
  106 XFIF(J,I)=SCOS(I,1)*VFOT(J,1)+SCOS(I,2)*VFOT(J,2)
```

Figure 6-14. Main Program (Continued)

```
     1+SCOS(I,3)*VFOT(J,3)+CG(I)
  950 FORMAT(1H1)
      PRINT 950
      PRINT 140
C
C     THE PRIMARY INTEGRATION DO LOOP STARTS HERE
C
C     THE PROGRAM RETURNS HERE AT THE START OF EACH INTEGRATION TIME STEP
C
   98 DO 223 I=1,4
C
C     UPDATE VFOT
C
      FOTAL=FOTAC(I)
      IF(FOTAL-2.5)221,223,223
  221 DO 222 J=1,3
  222 VFOT(I,J)=SCOS(1,J)*(XFIF(I,1)-XCG)+SCOS(2,J)*(XFIF(I,2)-YCG)+
     1   SCOS(3,J)*(XFIF(I,3)-ZCG)
  223 CONTINUE
C
      CALL STAB
C
      GO TO (1102,127),IFLAG
C
C     IS THIS A PRINT INTERVAL
C
  127 IF(PRNI-TIME)121,122,121
  122 PRNI=PRNI+SNTRVL
  132 CONTINUE
C
      CALL DATA
C
  141 FORMAT(F6.2,3F8.3,2F6.2,F7.2,3F7.2,3I8,F7.3,4F4.1,I2)
      PRINT 141,TIME,XCG,YCG,ZCG,PHI,PSI,THETA ,XDCG,YDCG,ZDCG,
     1IFORCX,IFORCY,ITORQ,BETA,PX1,PX2,PX3,PX4,IE
      ITORE=ITORE+1
      IF(LINE-LCOUNT)1003,1004,1004
 1003 LINE=LINE+1
      GO TO 121
 1004 PRINT 950
      PRINT 140
      LINE=1
  121 CONTINUE
      E=0.0
C
      CALL CONFIG
C
C     GND=0 IF ALL FEET OFF GROUND
C
      IF(GND-.5) 32,33,33
   33 DT=.0005
      GNDF=0.0
      GSUM=G1+G2+G3
      IF(ABS((GSUM-GSUMP+.2)/(GSUM+.1))-.1)  86,87,87
   86 DT=.01
   87 CONTINUE
      GSUMP=GSUM
      GO TO 34
   32 DT=.05
C
C     GNDF=0 UNLESS A FOOT WILL STRIKE IN NEXT INTERVAL
```

Figure 6-14. Main Program (Continued)

```
C
      IF(GNDF-.5)  88,89,89
   89 DT=.002
   88 CONTINUE
   34 CONTINUE
      GND=0.0
C
C     CAUSE CALCULATION TO OCCUR EXACTLY AT THE PRINT INTERVAL
C
      IF(TIME+DT-PRNI) 111,111,112
  112 DT=PRNI-TIME
  111 CONTINUE
      CALL INTEQM
      TIME=TIME+DT
C
C     CHECK TO BE SURE MOTIONS ARE MEANINGFUL
C
      IF(XCG) 97,97,96
   97 STOP
C
C     CHECK TO BE SURE VEHICLE C.G. IS MOVING
C
   96 VEL=SQRT(XDCG*XDCG+YDCG*YDCG)
      IF(VEL)  95,95,94
   95 PRINT 951,VEL
  951 FORMAT(10H   VEL     =,F10.5)
      GO TO 999
C
C     TEST TO SEE IF PROBLEM TIME EXCEEDS MAX. ALLOWABLE TIME
C
   94 IF(TIME-2.0)98,98,92
   92 PRINT 952,TIME
  952 FORMAT(10H   TIME    =,F10.5)
      PRINT 953,PSIMAX,BTAMIN,TIME
  953 FORMAT(10H   PSIMAX =,F10.5,10H   BTAMIN =,F10.5,10H   TIME     =,F10.5
     1)
 1102 PRINT 950
C
C     IF RUN IS OVER, PRINT THE FINAL SUMMARY PRINT
C
      PRINT 146
      LINE=1
      ITORE=ITORE-1
      DO 1000  N=1,ITORE
      PRINT 145,TIME2(N),IX1(N),IX2(N),IX3(N),IX4(N),XBFT1(N),XBFT2(N),
     1XBFT3(N),XBFT4(N),ONMOON(N),THEDT(N),PHIDOT(N),BETADT(N),
     2PSIDOT(N),ICRSH1(N),ICRSH2(N),ICRSH3(N),ICRSH4(N)
      IF(LINE-LCOUNT) 1001,1002,1002
 1001 LINE=LINE+1
      GO TO 1000
 1002 PRINT 950
      PRINT 146
      LINE=1
 1000 CONTINUE
      PRINT 950
      GO TO 999
  145 FORMAT(F6.2,4I7,5F7.2,2F8.3,F9.3,F8.3,I5,3I4)
  146 FORMAT(114H  TIME    FX1     FX2     FX3     FX4    XBFT1   XBFT2   XBFT3
     1  XBFT4 ONMOON   THEDT   PHIDOT  BETADT   PSIDOT         CRUSH)
      END
```

Figure 6-14. Main Program (Concluded)

```
C
C     TITLE       INPUT     SUBROUTINE INPUT
C
C     AUTHOR      J.C.GIBSON  BENDIX CORPORATION
C
C     DATE        NOVEMBER , 1964
C
C     PURPOSE     THE SUBROUTINE READS THE INPUT DATA CARDS AND PRINTS
C                 THE INPUT DATA AS PART OF THE OUTPUT RECORD
C
C     CALL        CALL  INPUT
C
C
C     NOTE        ALL UNITS ARE FEET, SECONDS,RADIANS AND SLUGS
C
C                 (M) DENOTES COORDINATE SYSTEM MOVING WITH THE VEHICLE
C                 (F)  DENOTES COORDINATE SYSTEM FIXED IN SPACE
C
C                 APPEARANCE OF  1  AFTER ANY VARIABLE INDICATES THE
C                 INITIAL VALUE OF THAT VARIABLE.
C                 ABSENCE OF THE  1  INDICATES THE INSTANTANEOUS VALUE .
C
C
C     INPUT       PUNCHED CARDS
C
C     INPUT DEFINITIONS
C
C     ETA1 (OR ETA)  ANGLE OF SLOPE IN PRINCIPLE DIRECTION
C     FOTAC1(I) OR (FOTAC(I))   MODE OF ACTION OF THE I TH FOOTPAD
C                 I = 1 CORRESPONDS TO SLIDING ON THE SURFACE
C                 I = 2 CORRESPONDS TO THE FOOTPAD STATIONARY ON THE SURFACE
C                 I = 3 CORRESPONDS TO THE FOOTPAD OFF THE SURFACE
C             NOTE FOTAC1(I) ARE PROGRAM INPUT CONSTANTS.  SET THEM EQUAL
C                 TO 3.0 FOR ALL RUNS
C     PITCH1  (OR PITCH ) INITIAL VEHICLE ORIENTATION  - SEE BENDIX
C                 REPORT  MM-64-9
C     YAW1 (OR YAW)         INITIAL VEHICLE ORIENTATION  - SEE BENDIX
C                 REPORT  MM-64-9
C     ROLL1 (OR ROLL)       INITIAL VEHICLE ORIENTATION  - SEE BENDIX
C                 REPORT  MM-64-9
C     H VEL       HORIZONTAL VELOCITY OF THE VEHICLE C.G. ( NORMAL TO
C                 THE GRAVITY VECTOR) AND IN THE DIRECTION OF THE PRINCIPLE
C                 SLOPE. (IN THE Y DIRECTION IN (F) COORDINATE SYSTEM)
C     U1          MASS MOMENT OF INERTIA OF VEHICLE ABOUT X AXIS IN (M)
C                 COORDINATE SYSTEM
C     U2          MASS MOMENT OF INERTIA OF VEHICLE ABOUT Y AXIS IN (M)
C                 COORDINATE SYSTEM
C     U3          MASS MOMENT OF INERTIA OF VEHICLE ABOUT Z AXIS IN (M)
C                 COORDINATE SYSTEM
C     VASLUG      VEHICLE MASS
C     VVEL        VERTICAL VELOCITY OF THE VEHICLE C.G. ( PARALLEL TO THE
C                 GRAVITY VECTOR)
C     VFOT1(I,J)  (OR VFOT(I,J))   I TH COMPONENT OF THE VECTOR POSITION
C                 OF THE J TH FOOTPAD IN (M) COORDINATE SYSTEM
C                 I = 1 IS X COMPONENT
C                 I = 2 IS THE Y COMPONENT
C                 I = 3 IS THE Z COMPONENT
C     W1E1 (OR W1E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE X AXIS IN THE
C                 (M) COORDINATE SYSTEM
C     W2E1 (OR W2E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Y AXIS IN THE
```

Figure 6-15. Subroutine - INPUT

```
C                  (M) COORDINATE SYSTEM
C        W3E1 (OR W3E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Z AXIS IN THE
C                  (M) COORDINATE SYSTEM
C        W1E1 (OR W1E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE X AXIS IN THE
C                  (M) COORDINATE SYSTEM
C        W2E1 (OR W2E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Y AXIS IN THE
C                  (M) COORDINATE SYSTEM
C        W3E1 (OR W3E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Z AXIS IN THE
C                  (M) COORDINATE SYSTEM
C        XB(2,4)     X COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C                    BODY ATTACH POINT (HARDPOINT)
C        YB(2,4)     Y COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C                    BODY ATTACH POINT (HARDPOINT)
C        ZB(2,4)     Z COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C                    BODY ATTACH POINT (HARDPOINT)
C        XCG         X POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C        YCG         Y POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C        ZCG         Z POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C        ZDCG1 (OR ZDCG) HORIZONTAL VELOCITY OF VEHICLE C.G. (NORMAL TO
C                    GRAVITY VECTOR) NORMAL TO THE PRINCIPLE DIRECTION OF
C                    THE SLOPE  ( IN Z DIRECTION IN (F) COORDINATE SYSTEM)
C
C        OUTPUT      1. PRINTED OUTPUT
C                    2. EQUIVALENCE TO COMMON STORAGE
C
         SUBROUTINE INPUT
C
         COMMON/LS1/BETAP,BETTDT,BTAMIN,CRUSH(12),DT,E,ETA,FORCEZ,FOTAC(4),
        1FXP(4),FORCEX,FORCEY,FC,FSUMZ,FSUMY,FSUMX,FXGRAV,FYGRAV,G1,G2,
        2G3,GND,GNDF,I,ITORE,J,PSIMAX,SCOS(3,3),SPRR(4,3),SSTRUT(4,3),
        3SO,SO1,SO2,TIME,TYPE(3),TORQZ,T,T2,U1,U2,U3,VASLUG,VFOT(4,3),W1E,
        4W2E,W3E,XCG,XDCG,X(3),XB(3,4),XFIF(4,3),XSFOTP(4),Y(3),YB(3,4),
        5YCG,YDCG,       Z(3),ZB(3,4),ZCG,ZDCG
         COMMON/LS3/ETA1,FOTAC1(4),HVEL,PITCH1,ROLL1,VFOT1(4,3),VVEL,
        1W1E1,W2E1,W3E1,XCG1,YAW1,YCG1,ZCG1,ZDCG1
C
C        READ INPUT CARDS BY FORMAT SHOWN IN BENDIX REPORT  MM-64-9
C
       1 READ 100,((XB(II,JJ),II=1,3),JJ=1,4),((YB(II,JJ),II=1,3),JJ=1,4),
        1((ZB(II,JJ),II=1,3),JJ=1,4),((VFOT1(JJ,II),JJ=1,4),II=1,3)
         READ 100,(FOTAC1(II),II=1,4),VVEL,HVEL
         READ 100,U1,U2,U3,XCG1,YCG1,ZCG1,W1E1,W2E1,W3E1,PITCH1,YAW1,
        1ROLL1,(TYPE(II),II=1,3),VASLUG,ZDCG1,ETA1
C
C        PRINT INPUT DATA AS PART OF OUTPUT RECORD
C
         PRINT 200,((XB(II,JJ),II=1,3),JJ=1,2)
         PRINT 201,((XB(II,JJ),II=1,3),JJ=3,4)
         PRINT 202,((YB(II,JJ),II=1,3),JJ=1,2)
         PRINT 203,((YB(II,JJ),II=1,3),JJ=3,4)
         PRINT 204,((ZB(II,JJ),II=1,3),JJ=1,2)
         PRINT 205,((ZB(II,JJ),II=1,3),JJ=3,4)
         PRINT 206,(VFOT1(II,1),II=1,4),(VFOT1(II,2),II=1,2)
         PRINT 207,(VFOT1(II,2),II=3,4),(VFOT1(II,3),II=1,4)
         PRINT 208,(FOTAC1(II),II=1,4),VVEL,HVEL
         PRINT 209,U1,U2,U3,XCG1,YCG1,ZCG1
         PRINT 210,W1E1,W2E1,W3E1,PITCH1,YAW1,ROLL1
         PRINT 211,(TYPE(II),II=1,3),VASLUG,ZDCG1,ETA1
     100 FORMAT(10X,6F10.5)
     200 FORMAT(10H   XB(1,1)=,F10.5,10H   XB(2,1)=,F10.5,10H   XB(3,1)=,F10.5
        1,10H   XB(1,2)=,F10.5,10H   XB(2,2)=,F10.5,10H   XB(3,2)=,F10.5)
```

Figure 6-15. Subroutine - INPUT (Continued)

```
201 FORMAT(10H  XB(1,3)=,F10.5,10H  XB(2,3)=,F10.5,10H  XB(3,3)=,F10.5
   1,10H  XB(1,4)=,F10.5,10H  XB(2,4)=,F10.5,10H  XB(3,4)=,F10.5)
202 FORMAT(10H  YB(1,1)=,F10.5,10H  YB(2,1)=,F10.5,10H  YB(3,1)=,F10.5
   1,10H  YB(1,2)=,F10.5,10H  YB(2,2)=,F10.5,10H  YB(3,2)=,F10.5)
203 FORMAT(10H  YB(1,3)=,F10.5,10H  YB(2,3)=,F10.5,10H  YB(3,3)=,F10.5
   1,10H  YB(1,4)=,F10.5,10H  YB(2,4)=,F10.5,10H  YB(3,4)=,F10.5)
204 FORMAT(10H  ZB(1,1)=,F10.5,10H  ZB(2,1)=,F10.5,10H  ZB(3,1)=,F10.5
   1,10H  ZB(1,2)=,F10.5,10H  ZB(2,2)=,F10.5,10H  ZB(3,2)=,F10.5)
205 FORMAT(10H  ZB(1,3)=,F10.5,10H  ZB(2,3)=,F10.5,10H  ZB(3,3)=,F10.5
   1,10H  ZB(1,4)=,F10.5,10H  ZB(2,4)=,F10.5,10H  ZB(3,4)=,F10.5)
206 FORMAT(10H VFOT 1,1=,F10.5,10H VFOT 2,1=,F10.5,10H VFOT 3,1=,F10.5
   1,10H VFOT 4,1=,F10.5,10H VFOT 1,2=,F10.5,10H VFOT 2,2=,F10.5)
207 FORMAT(10H VFOT 3,2=,F10.5,10H VFOT 4,2=,F10.5,10H VFOT 1,3=,F10.5
   1,10H VFOT 2,3=,F10.5,10H VFOT 3,3=,F10.5,10H VFOT 4,3=,F10.5)
208 FORMAT(10H FOTAC 1 =,F10.5,10H FOTAC 2 =,F10.5,10H FOTAC 3 =,F10.5
   1,10H FOTAC 4 =,F10.5,10H VVEL    =,F10.5,10H HVEL    =,F10.5)
209 FORMAT(10H  U1     =,F10.2,10H  U2     =,F10.2,10H  U3     =,F10.2
   1,10H  XCG1   =,F10.5,10H  YCG1   =,F10.5,10H  ZCG1   =,F10.5)
210 FORMAT(10H  W1E1   =,F10.5,10H  W2E1   =,F10.5,10H  W3E1   =,F10.5
   1,10H  PITCH1 =,F10.5,10H  YAW1   =,F10.5,10H  ROLL1  =,F10.5)
211 FORMAT(10H  TYPE 1 =,F10.5,10H  TYPE 2 =,F10.5,10H  TYPE 3 =,F10.5
   1,10H  VASLUG =,F10.5,10H  ZDCG1  =,F10.5,10H  ETA1   =,F10.5)
    RETURN
    END
```

Figure 6-15. Subroutine - INPUT (Concluded)

```
C
C     TITLE      INIT     SUBROUTINE INITIALIZE
C
C     AUTHOR     J.C.GIBSON   BENDIX PRODUCTS AEROSPACE DIVISION
C
C     DATE       NOVEMBER , 1964
C
C     PURPOSE    THIS SUBROUTINE INITIALIZES THE CONSTANTS FOR THE LAND3D
C                PROGRAM
C
C     METHOD     THE SUBROUTINE COMPUTES PROGRAM PARAMETERS FROM
C                GEOMETRIC RELATIONSHIPS
C
C     CALL       CALL INIT
C
C     NOTES      THIS PROGRAM WAS WRITTEN IN FORTRAN  IV
C                THIS PROGRAM EXECUTES ON UNIVAC  1107  COMPUTER
C
C     NOTE       ALL UNITS ARE FEET, SECONDS,RADIANS AND SLUGS
C
C                (M) DENOTES COORDINATE SYSTEM MOVING WITH THE VEHICLE
C                (F)  DENOTES COORDINATE SYSTEM FIXED IN SPACE
C
C                APPEARANCE OF  1  AFTER ANY VARIABLE INDICATES THE
C                INITIAL VALUE OF THAT VARIABLE.
C                ABSENCE OF THE  1  INDICATES THE INSTANTANEOUS VALUE  .
C
C
C     SUBROUTINES USED
C
C                LEGTYP   SETS SPRINGRATES AND STRUT FORCES FOR ALL STRUTS
C
C     INPUT      BY EQUIVALENCE TO COMMON STORAGE
C
C     INPUT DEFINITIONS
C
C     ETA1 (OR ETA)  ANGLE OF SLOPE IN PRINCIPLE DIRECTION
C     FC         STRUT PLASTIC STROKE FORCE
C     FOTAC1(I) OR (FOTAC(I))   MODE OF ACTION OF THE I TH FOOTPAD
C                I = 1 CORRESPONDS TO SLIDING ON THE SURFACE
C                I = 2 CORRESPONDS TO THE FOOTPAD STATIONARY ON THE SURFACE
C                I = 3 CORRESPONDS TO THE FOOTPAD OFF THE SURFACE
C             NOTE FOTAC1(I) ARE PROGRAM INPUT CONSTANTS.  SET THEM EQUAL
C                TO 3.0 FOR ALL RUNS
C     H VEL      HORIZONTAL VELOCITY OF THE VEHICLE C.G. ( NORMAL TO
C                THE GRAVITY VECTOR) AND IN THE DIRECTION OF THE PRINCIPLE
C                SLOPE. (IN THE Y DIRECTION IN (F) COORDINATE SYSTEM)
C     PITCH1  (OR PITCH ) INITIAL VEHICLE ORIENTATION   - SEE BENDIX
C                REPORT  MM-64-9
C     T          SPRING RATE OF THE UPPER STRUT
C     T2         SPRING RATE OF THE LOWER STRUTS
C     YAW1 (OR YAW)       INITIAL VEHICLE ORIENTATION   - SEE BENDIX
C                REPORT  MM-64-9
C     ROLL1 (OR ROLL)     INITIAL VEHICLE ORIENTATION   - SEE BENDIX
C                REPORT  MM-64-9
C     TYPE(I)    TYPE OF STRUT - STRUT NO. 1 IS TYPE 1
C                                STRUTS NOS.2 AND 3 ARE TYPE 2
C     VASLUG     VEHICLE MASS
C     VVEL       VERTICAL VELOCITY OF THE VEHICLE C.G. ( PARALLEL TO THE
C                GRAVITY VECTOR)
```

Figure 6-16. Subroutine - INIT

```
C     VFOT1(I,J)  (OR VFOT(I,J))    I TH COMPONENT OF THE VECTOR POSITION
C               OF THE J TH FOOTPAD IN (M) COORDINATE SYSTEM
C               I = 1 IS X COMPONENT
C               I = 2 IS THE Y COMPONENT
C               I = 3 IS THE Z COMPONENT
C     W1E1 (OR W1E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE X AXIS IN THE
C               (M) COORDINATE SYSTEM
C     W2E1 (OR W2E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Y AXIS IN THE
C               (M) COORDINATE SYSTEM
C     W3E1 (OR W3E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Z AXIS IN THE
C               (M) COORDINATE SYSTEM
C     XCG       X POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C     YCG       Y POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C     ZCG       Z POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C     XB(2,4)   X COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C               BODY ATTACH POINT (HARDPOINT)
C     YB(2,4)   Y COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C               BODY ATTACH POINT (HARDPOINT)
C     ZB(2,4)   Z COORDINATE (M) OF THE I TH STRUT OF THE J TH LEG SET
C               BODY ATTACH POINT (HARDPOINT)
C
C
C     OUTPUT    BY EQUIVALENCE TO COMMON STORAGE
C
C     OUTPUT DEFINITIONS
C
C     BETA      STABILITY ANGLE   SEE TEXT BENDIX REPORT  MM-64-9
C     BETAP     PREVIOUS VALUE OF BETA AT LAST ITERATION INTERVAL
C     BETAMIN   MINIMUM BETA ANGLE REACHED DURING THE COMPUTER RUN
C
C     CRUSH     OUTPUT INDICATOR  -  TWELVE DIGITS , ONE FOR EACH STRUT,
C               REPRESENTING THE FORCE CAUSING MECHANISM IN EACH STRUT
C          ORDER OF OUTPUT   1        2        3        4
C               STRUT      1 2 3    1 2 3    1 2 3    1 2 3
C                  THE DIGITAL CODE IS AS FOLLOWS
C                       0    NO FORCE BECAUSE FOOTPAD IS OFF SURFACE
C                       1    ELASTIC COMPRESSION IN STRUT
C                       2    PLASTIC COMPRESSION IN STRUT
C                       3    STRUT RE-EXTENDED FROM PREVIOUSLY CRUSHED
C                            POSITION BUT IS STILL SHORTER THAN ORIGINAL
C                            LENGTH
C                       8    STRUT STRETCHED BEYOND ORIGINAL LENGTH BUT
C                            LESS THAN 10000 LBS FORCE
C                       9    STRUT IN TENSION MORE THAN 10000 LBS
C
C     DT        ITERATION TIME INTERVAL
C     E         OUTPUT INDICATOR   E=0 IF LEG IS NOT COMPRESSING OR THE
C                  FORCE IN LEG IS LESS THAN 10000 LBS.   E=1 IF AT LEAST
C                  ONE LEG IS IN TENSION GREATER THAN 10000 LBS
C     IE       SAME AS E
C     ETA1 (OR ETA)  ANGLE OF SLOPE IN PRINCIPLE DIRECTION
C     FORCEX    NET FORCE ACTING ON THE VEHICLE C.G. IN THE X DIRECTION
C               IN THE (F) COORDINATE SYSTEM
C     FORCEY    NET FORCE ACTING ON THE VEHICLE C.G. IN THE Y DIRECTION
C               IN THE (F) COORDINATE SYSTEM
C     FORCEZ    NET FORCE ACTING ON THE VEHICLE C.G. IN THE Z DIRECTION
C               IN THE (F) COORDINATE SYSTEM
C     IFORCX    SAME AS FORCEX
C     IFORCY    SAME AS FORCEY
C     IFORCZ    SAME AS FORCEZ
C     TORQZ     COMPONENT OF TORQUE ACTING ON THE VEHICLE C.G. IN THE
```

Figure 6-16. Subroutine - INIT (Continued)

```
C                X-Y PLANE
C     ITORQ      SAME AS TORQZ
C     FXGRAV     GRAVITY FORCE IN X DIRECTION IN (F) COORDINATE SYSTEM
C     FYGRAV     GRAVITY FORCE IN Y DIRECTION IN (F) COORDINATE SYSTEM
C     GND        INDICATES IF ANY FOOTPAD IS ON THE GROUND
C                GND = 1  -- ONE OR MORE FEET ARE ON THE GROUND
C                GND  = 0   ALL FEET ARE OFF THE GROUND
C     GSUM       SUM OF THE TORQUES.  USED TO CONTROL DT  ( USED TO FIND IF
C                THE TORQUE IS CHANGING.  IF THE DIFFERENCE BETWEEN GSUM
C                AND GSUMP IS LARGE , TAKE SMALL DT TIME INCREMENTS
C                IF THE DIFFERENCE IS SMALL   TAKE LARGE DT TIME INCREMENTS
C     GSUMP      PREVIOUS VALUE OF GSUM
C     ITORE      STORAGE INDEX FOR FINAL OUTPUT PRINTING
C     LINE       LINE COUNT FOR OUTPUT PAGE ORDERING
C     LCOUNT     MAXIMUM ALLOWABLE LINES PER PAGE OF OUTPUT DATA
C     PRNI       PRINT TIME ( 0.0,0.04,0.04SEC, ETC)
C     PSIMAX     MAXIMUM  PSI ANGLE REACHED DURING THE ENTIRE COMPUTER RUN
C     SNTRVL     PRINT FREQUENCY ( EVERY 0.04 SEC.)
C     SO         STRUT LENGTH
C     SPRR(I,J)    PREVIOUS SHORTEST LENGTH OF STRUT I OF THE J TH LEG SET
C     SSTRUT(I,J)    STRUT LENGTH OF THE J TH STRUT OF THE I TH LEG SET
C     SCOS       DIRECTION COSINES RELATING FIXED (F) AND MOVING (M)
C                COORDINATE SYSTEMS
C     TYPE(I)    TYPE OF STRUT - STRUT NO. 1 IS TYPE 1
C                                STRUTS NOS.2 AND 3 ARE TYPE 2
C     TIME       TIME AFTER TOUCHDOWN
C     XDCG       VELOCITY OF VEHICLE C.G. IN X DIRECTION IN (F) COORDINATE
C                SYSTEM
C     YDCG       VELOCITY OF VEHICLE C.G. IN Y DIRECTION IN (F) COORDINATE
C                SYSTEM
C     ZDCG       VELOCITY OF VEHICLE C.G. IN Z DIRECTION IN (F) COORDINATE
C                SYSTEM
C     XSFOTP     PARTICULAR VALUE OF XFIF(I,J)
C
      SUBROUTINE INIT
C
C     INITIALIZING
C
      COMMON/LS1/BETAP,BETTDT,BTAMIN,CRUSH(12),DT,E,ETA,FORCEZ,FOTAC(4),
     1FXP(4),FORCEX,FORCEY,FC,FSUMZ,FSUMY,FSUMX,FXGRAV,FYGRAV,G1,G2,
     2G3,GND,GNDF,I,ITORE,J,PSIMAX,SCOS(3,3),SPRR(4,3),SSTRUT(4,3),
     3SO,SO1,SO2,TIME,TYPE(3),TORQZ,T,T2,U1,U2,U3,VASLUG,VFOT(4,3),W1E,
     4W2E,W3E,XCG,XDCG,X(3),XB(3,4),XFIF(4,3),XSFOTP(4),Y(3),YB(3,4),
     5YCG,YDCG,       Z(3),ZB(3,4),ZCG,ZDCG
      COMMON/LS3/ETA1,FOTAC1(4),HVEL,PITCH1,ROLL1,VFOT1(4,3),VVEL,
     1W1E1,W2E1,W3E1,XCG1,YAW1,YCG1,ZCG1,ZDCG1
      COMMON/LS5/GSUM,LCOUNT,LINE,PRNI,SNTRVL
C
C     PREPARE LINE COUNT, ETC.  FOR PRINTOUT
C
      ITORE=1
C     PRINT INTERVAL IS SNTRVL
      SNTRVL=.04
      LINE=1
      IF(SNTRVL-.05)1101,1100,1101
 1100 LCOUNT=40
      GO TO 1103
 1101 LCOUNT=50
 1103 DO 441 I=1,12
C
C     INITIALIZE CRUSH AND FOTAC(I) AND VFOT
```

Figure 6-16. Subroutine - INIT (Continued)

```
C
  441 CRUSH (I)=0
      DO 200 I=1,4
      FOTAC(I)=FOTAC1(I)
C
C     INITIALIZE INPUT PARAMETERS FOR THE RUN
C
      DO 200 J=1,3
  200 VFOT(I,J)=VFOT1(I,J)
      XCG=XCG1
      YCG=YCG1
      ZCG=ZCG1
      ZDCG=ZDCG1
      W1E=W1E1
      W2E=W2E1
      W3E=W3E1
      PITCH=PITCH1
      ROLL=ROLL1
      YAW=YAW1
      ETA=ETA1
C
C     CONVERT THE VELOCITY VECTOR OF THE C.G. TO THE (F) COORDINATE
C     SYSTEM
C
      YDCG=HVEL*COS(ETA)+VVEL*SIN(ETA)
      XDCG=VVEL*(-COS(ETA))+HVEL*( SIN(ETA))
      F=0.0
C
C     INITIALIZE XSFOTP
C
      DO 38  II=1,4
   38 XSFOTP(II)=0.0
C
C     INITIALIZE SPRR, THE SHORTEST PREVIOUS STRUT LENGTH AND SSTRUT,
C     THE PRESENT STRUT LENGTH
C
      DO 83 II=1,4
      DO 83 I=1,3
C
      CALL LEGTYP
C
      SPRR(II,I)=SQRT((VFOT(II,1)-XB(I,II))**2+(VFOT(II,2)-YB(I,II))**2
     1    +(VFOT(II,3)-ZB(I,II))**2)-FC/T
   83 SSTRUT(II,I)=SQRT((VFOT(II,1)-XB(I,II))**2+(VFOT(II,2)-YB(I,II))
     1**2+(VFOT(II,3)-ZB(I,II))**2)
      BETAP=0
      GND=0
      GNDF =0
      FORCEX=0
      FORCEY=0
      TORQZ=0
      DTMIN=1E2
      PSIMAX=-10
      TIME=0
      GSUM=+1E20
      PRNI=0
      DT=.0005
      BTAMIN=1E2
C
C     THE GRAVITY FORCES ARE CONSTANT
```

Figure 6-16. Subroutine - INIT (Continued)

```
      FXGRAV=-(32.2/6.0)*VASLUG*COS(ETA)
      FYGRAV= (32.2/6.0)*VASLUG*SIN(ETA)
C
C     COMPUTE SCOS FROM ROLL,PITCH AND YAW
C
      SCOS(1,1)=COS(PITCH)*COS(ROLL)+SIN(PITCH)*SIN(YAW)*SIN(ROLL)
      SCOS(2,1)=-SIN(PITCH)*COS(ROLL)+COS(PITCH)*SIN(YAW)*SIN(ROLL)
      SCOS(3,1)=-COS(YAW)*SIN(ROLL)
      SCOS(1,2)=SIN(PITCH)*COS(YAW)
      SCOS(2,2)=COS(PITCH)*COS(YAW)
      SCOS(3,2)=SIN(YAW)
      SCOS(1,3)=COS(PITCH)*SIN(ROLL)-SIN(PITCH)*SIN(YAW)*COS(ROLL)
      SCOS(2,3)=-SIN(PITCH)*SIN(ROLL)-COS(PITCH)*SIN(YAW)*COS(ROLL)
      SCOS(3,3)=COS(YAW)*COS(ROLL)
      SO1=SSTRUT(1,1)
      SO2=SSTRUT(1,2)
      SO3=SSTRUT(1,3)
      RETURN
      END
```

Figure 6-16. Subroutine - INIT (Concluded)

```
TITLE      STAB     THREE DIMENSIONAL STABILITY DETERMINATION

AUTHOR     J.C.GIBSON   BENDIX PRODUCTS AEROSPACE DIVISION

DATE       NOVEMBER , 1964

PURPOSE    THIS SUBROUTINE DETERMINES THE MINIMUM VEHICLE STABILITY
           ANGLE  BETA  FOR A THREE DIMENSIONAL VEHICLE LANDING

METHOD     SUBROUTINE DETERMINES THE MINIMUM ANGLE BETWEEN A GRAVITY
           VECTOR THROUGH THE VEHICLE C.G. AND A LINE THROUGH THE
           SURFACE CONTACT REGION IN THE DIRECTION OF MOTION.  SEE
           BENDIX REPORT  MM 64  - 9  FOR DETAILS

CALL       CALL STAB

NOTES      THIS PROGRAM WAS WRITTEN IN FORTRAN  IV

           THIS PROGRAM EXECUTES ON UNIVAC  1107  COMPUTER

NOTE       ALL UNITS ARE FEET, SECONDS.RADIANS AND SLUGS

           (M) DENOTES COORDINATE SYSTEM MOVING WITH THE VEHICLE
           (F)  DENOTES COORDINATE SYSTEM FIXED IN SPACE

           APPEARANCE OF  1  AFTER ANY VARIABLE INDICATES THE
           INITIAL VALUE OF THAT VARIABLE.
           ABSENCE OF THE  1  INDICATES THE INSTANTANEOUS VALUE .


INPUT      BY EQUIVALENCE TO COMMON STORAGE

INPUT DEFINITIONS

ETA1 (OR ETA)  ANGLE OF SLOPE IN PRINCIPLE DIRECTION
PSIMAX     MAXIMUM  PSI ANGLE REACHED DURING THE ENTIRE COMPUTER RUN
SCOS       DIRECTION COSINES RELATING FIXED (F) AND MOVING (M)
           COORDINATE SYSTEMS

VFOT1(I,J)  (OR VFOT(I,J))   I TH COMPONENT OF THE VECTOR POSITION
           OF THE J TH FOOTPAD IN (M) COORDINATE SYSTEM
           I = 1 IS X COMPONENT
           I = 2 IS THE Y COMPONENT
           I = 3 IS THE Z COMPONENT

XCG        X POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
YCG        Y POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
ZCG        Z POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
XDCG       VELOCITY OF VEHICLE C.G. IN X DIRECTION IN (F) COORDINATE
           SYSTEM
YDCG       VELOCITY OF VEHICLE C.G. IN Y DIRECTION IN (F) COORDINATE
           SYSTEM
ZDCG       VELOCITY OF VEHICLE C.G. IN Z DIRECTION IN (F) COORDINATE
           SYSTEM


OUTPUT     BY EQUIVALENCE TO COMMON STORAGE
```

Figure 6-17. Subroutine - STAB

```
C     OUTPUT DEFINITIONS
C
C     AA          DIRECTION OF THE VELOCITY VECTOR
C     AAA         RATIO OF Z AND Y VELOCITIES
C     BETA        STABILITY ANGLE   SEE TEXT BENDIX REPORT  MM-64-9
C     BETAMIN     MINIMUM BETA ANGLE REACHED DURING THE COMPUTER RUN
C     BETADT      RATE OF CHANGE OF THE STABILITY ANGLE BETA
C     BETAP       PREVIOUS VALUE OF BETA AT LAST ITERATION INTERVAL
C     IFLAG       INDICATOR FOR CONDITIONAL RETURN TO MAIN PROGRAM
C     PHI         ANGULAR ORIENTATION OF VEHICLE IN (F) COORDINATE SYSTEM
C                 SEE TEXT BENDIX REPORT  MM-64-9
C     PSI         ANGULAR ORIENTATION OF VEHICLE IN (F) COORDINATE SYSTEM
C                 SEE TEXT BENDIX REPORT  MM-64-9
C     THETA       ANGULAR ORIENTATION OF VEHICLE IN (F) COORDINATE SYSTEM
C                 SEE TEXT BENDIX REPORT  MM-64-9
C
C
      SUBROUTINE STAB
C
      COMMON/LS1/BETAP,BETTDT,BTAMIN,CRUSH(12),DT,E,ETA,FORCEZ,FOTAC(4),
     1FXP(4),FORCEX,FORCEY,FC,FSUMZ,FSUMY,FSUMX,FXGRAV,FYGRAV,G1,G2,
     2G3,GND,GNDF,I,ITORE,J,PSIMAX,SCOS(3,3),SPRR(4,3),SSTRUT(4,3),
     3SO,SO1,SO2,TIME,TYPE(3),TORQZ,T,T2,U1,U2,U3,VASLUG,VFOT(4,3),W1E,
     4W2E,W3E,XCG,XDCG,X(3),XB(3,4),XFIF(4,3),XSFOTP(4),Y(3),YB(3,4),
     5YCG,YDCG,       Z(3),ZB(3,4),ZCG,ZDCG
      COMMON/LS6/BETA,IFLAG,PSI
      DIMENSION YYFP(4),ZZFP(4)
C
C     FPTEST IS THE INSTABILITY TEST                                     RDIX
C                                                                    005 RDIX
      AA=ATAN(ZDCG/YDCG)                                             005 RDIX
      DO 125  I=1,4                                                  R DIX
      ZZFP(I)=SCOS(3,1)*VFOT(I,1)+SCOS(3,2)*VFOT(I,2)+SCOS(3,3)*VFOT R DIX
     1 (I,3)+ZCG                                                     R DIX
  125 YYFP(I)=SCOS(2,1)*VFOT(I,1)+SCOS(2,2)*VFOT(I,2)+SCOS(2,3)*VFOT R DIX
     1 (I,3)+YCG                                                     R DIX
      AAA=ZDCG/YDCG                                                    ERJ
      FPTEST=AMAX1((YYFP(1)+ZZFP(1)*AAA),(YYFP(2)+ZZFP(2)*AAA),(YYFP(3)  ERJ
     1 +ZZFP(3)*AAA),(YYFP(4)+ZZFP(4)*AAA))- YCG-ZCG*AAA
C
C     EVALUATE STABILITY PARAMETERS FOR PRINTING
C
      BETA=ATAN(FPTEST*COS(AA)/XCG)-ATAN(SIN(ETA)*COS(AA)/COS(ETA))
      BET=ABS(BETA)                                                  005 RDIX
      BTAMIN=AMIN1(BET,BTAMIN)
      PSI=ATAN(SCOS(2,1)/SCOS(1,1))
      PSIMAX=AMAX1(PSI,PSIMAX)
      BETTDT=(BETA-BETAP)/DT
      BETAP=BETA                                                     005 RDIX
      IF(BETA)130,130,140
C
C     IFLAG IS A FLAG FOR AN ERROR EXIT WITHIN THE MAIN PROGRAM
C
  130 IFLAG=1
  140 IFLAG=2
      RETURN
      END
```

Figure 6-17. Subroutine - STAB (Concluded)

```
 TITLE      INTEQM   SUBROUTINE INTEGRATION

AUTHOR      J.C.GIBSON   BENDIX PRODUCTS AEROSPACE DIVISION

DATE        NOVEMBER , 1964

PURPOSE     THIS SUBROUTINE DETERMINES VEHICLE MOTION AS THE RESULT
            OF THE FORCES IMPOSED ON THE VEHICLE AND SETS ITERATION
            INTERVAL ON THE BASIS OF ERROR TESTS

METHOD      SIMPLE RECTANGULAR INTEGRATION IS USED TO DETERMINE
            VEHICLE POSITION AT THE END OF THE TIME INTERVAL  DT .
            AN ERROR TEST ON THE THIRD TERM OF THE TAYLOR SERIES
            SERIES IS USED TO DETERMINE THE ITERATION INTERVAL SIZE

CALL        CALL INTEQM

NOTES       THIS PROGRAM WAS WRITTEN IN FORTRAN  IV

            THIS PROGRAM EXECUTES ON UNIVAC  1107  COMPUTER

NOTE        ALL UNITS ARE FEET, SECONDS,RADIANS AND SLUGS

            (M) DENOTES COORDINATE SYSTEM MOVING WITH THE VEHICLE
            (F)  DENOTES COORDINATE SYSTEM FIXED IN SPACE

            APPEARANCE OF  1  AFTER ANY VARIABLE INDICATES THE
            INITIAL VALUE OF THAT VARIABLE.
            ABSENCE OF THE  1  INDICATES THE INSTANTANEOUS VALUE .


INPUT       BY EQUIVALENCE TO COMMON STORAGE

INPUT DEFINITIONS

DT          ITERATION TIME INTERVAL
FORCEX      NET FORCE ACTING ON THE VEHICLE C.G. IN THE X DIRECTION
            IN THE (F) COORDINATE SYSTEM
FORCEY      NET FORCE ACTING ON THE VEHICLE C.G. IN THE Y DIRECTION
            IN THE (F) COORDINATE SYSTEM
FORCEZ      NET FORCE ACTING ON THE VEHICLE C.G. IN THE Z DIRECTION
            IN THE (F) COORDINATE SYSTEM
IFORCX      SAME AS FORCEX
IFORCY      SAME AS FORCEY
IFORCZ      SAME AS FORCEZ
TORQZ       COMPONENT OF TORQUE ACTING ON THE VEHICLE C.G. IN THE
            X-Y PLANE
ITORQ       SAME AS TORQZ
FXP         FORCE IN THE X DIRECTION ON THE FOOTPAD
FYP         FORCE IN THE Y DIRECTION ON THE FOOTPAD
FZP         FORCE IN THE Z DIRECTION ON THE FOOTPAD
G           TORQUES IN THE (M) COORDINATE SYSTEM
SCOS        DIRECTION COSINES RELATING FIXED (F) AND MOVING (M)
            COORDINATE SYSTEMS
U1          MASS MOMENT OF INERTIA OF VEHICLE ABOUT X AXIS IN (M)
            COORDINATE SYSTEM
U2          MASS MOMENT OF INERTIA OF VEHICLE ABOUT Y AXIS IN (M)
            COORDINATE SYSTEM
U3          MASS MOMENT OF INERTIA OF VEHICLE ABOUT Z AXIS IN (M)
```

Figure 6-22. Subroutine - INTEQM

```
C               COORDINATE SYSTEM
C     W1E1 (OR W1E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE X AXIS IN THE
C               (M) COORDINATE SYSTEM
C     W2E1 (OR W2E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Y AXIS IN THE
C               (M) COORDINATE SYSTEM
C     W3E1 (OR W3E)  ANGULAR VELOCITY OF VEHICLE ABOUT THE Z AXIS IN THE
C               (M) COORDINATE SYSTEM
C     XDCG      VELOCITY OF VEHICLE C.G. IN X DIRECTION IN (F) COORDINATE
C               SYSTEM
C     YDCG      VELOCITY OF VEHICLE C.G. IN Y DIRECTION IN (F) COORDINATE
C               SYSTEM
C     ZDCG      VELOCITY OF VEHICLE C.G. IN Z DIRECTION IN (F) COORDINATE
C               SYSTEM
C
C
C     OUTPUT    BY EQUIVALENCE TO COMMON STORAGE
C
C     OUTPUT DEFINITIONS
C
C     XCG       X POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C     YCG       Y POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C     ZCG       Z POSITION OF THE VEHICLE C.G. IN (F) COORDINATE SYSTEM
C
C
      SUBROUTINE INTEQM
C
      DIMENSION BRKT(3,3),VID(3,3),VIO(3,3),VIN(3,3),SN(3,3),BKP(3,3)
      COMMON/LS1/BETAP,BETTDT,BTAMIN,CRUSH(12),DT,E,ETA,FORCEZ,FOTAL(4),
     1FXP(4),FORCEX,FORCEY,FC,FSUMZ,FSUMY,FSUMX,FXGRAV,FYGRAV,G1,G2,
     2G3,GND,GNDF,I,ITORE,J,PSIMAX,SCOS(3,3),SPRR(4,3),SSTRUT(4,3),
     3SO,SO1,SO2,TIME,TYPE(3),TORQZ,T,T2,U1,U2,U3,VASLUG,VFOT(4,3),W1E,
     4W2E,W3E,XCG,XDCG,X(3),XB(3,4),XFIF(4,3),XSFOTP(4),Y(3),YB(3,4),
     5YCG,YDCG,      Z(3),ZB(3,4),ZCG,ZDCG
      EQUIVALENCE (VASLUG,VASS),(XH(1),X(1)),(YH(1),Y(1)),
     1(ZH(1),Z(1)),(FSUMY,QFSUM),(FSUMZ,VFSUM),(FSUMX,WFSUM)
C
C
C     EULER EQUATIONS
C
      WD1=G1/U1
      WD2=(1/U2)*(G2+(U3-U1)*W1E*W3E)
      WD3=(1/U3)*(G3+(U1-U2)*W2E*W1E)
C
C     FIND THE AVERAGE VALUES OF ANGULAR VELOCITY IN THE TIME INTERVAL
C     OF LENGTH DT
C
    6 W1=W1E+WD1*DT/2
      W2=W2E+WD2*DT/2
      W3=W3E+WD3*DT/2
C
C     CALCULATE NEW  V-VECTOR (I,J,K  AXES)
C
      BRKT(1,1)=-(W2*W2+W3*W3)
      BRKT(1,2)=W1*W2+WD3
      BRKT(1,3)=W1*W3-WD2
      BRKT(2,1)=W2*W1-WD3
      BRKT(2,2)=-(W1*W1+W3*W3)
      BRKT(2,3)=W2*W3+WD1
      BRKT(3,1)=W3*W1+WD2
      BRKT(3,2)=W3*W2-WD1
      BRKT(3,3)=-(W2*W2+W1*W1)
```

Figure 6-22. Subroutine - INTEQM (Continued)

```
C      ERROR CHECK ON 3RD TERM OF THE TAYLOR SERIES
C
       ERROR=0.0
       DO 3 I=1,3
       DO 3 J=1,3
     3 ERROR=ERROR+ABS(BRKT(I,J)-BKP(I,J))*DT*DT*DT/6.0
       IF(ERROR-.002*DT) 5,4,4
     4 DT=DT/2
       PRINT 100,DT
   100 FORMAT(10H  DT      =,F15.5)
       GO TO 6
C
C      STORE ANGULAR ACCELERATIONS FOR USE IN NEXT ERROR CHECK ON DT
C      INTERVAL SIZE
C
     5 DO 2  I=1,3
       DO 2  J=1,3
     2 BKP(I,J)=BRKT(I,J)
       VID(1,1)=0.0
       VID(1,2)=-W3E
       VID(1,3)=W2E
       VID(2,1)=W3E
       VID(2,2)=0.0
       VID(2,3)=-W1E
       VID(3,1)=-W2E
       VID(3,2)=W1E
       VID(3,3)=0.0
       VIO(1,1)=1.0
       VIO(1,2)=0.0
       VIO(1,3)=0.0
       VIO(2,1)=0.0
       VIO(2,2)=1.0
       VIO(2,3)=0.0
       VIO(3,1)=0.0
       VIO(3,2)=0.0
       VIO(3,3)=1.0
       DO 41 I=1,3
       DO 41 J=1,3
C
C      THIS GIVES THE POSITION OF THE NEW  V  VECTOR AT THE END OF THE
C      INTEGRATION INTERVAL EXPRESSED IN TERMS OF THE COORDINATE AXES MOVING
C      WITH THE BODY AS THEY WERE ORIENTED AT THE PREVIOUS INTERVAL
C
    41 VIN(I,J)=BRKT(I,J)*DT*DT/2+VID(I,J)*DT+VIO(I,J)
       DO 42  I=1,3
C
C      CALCULATE NEW DIRECTION COSINES FROM SYSTEM ROTATION
C
       DO 42  J=1,3
    42 SN(I,J)=SCOS(I,1)*VIN(J,1)+SCOS(I,2)*VIN(J,2)+SCOS(I,3)*VIN(J,3)
       DO 43  I=1,3
       DO 43  J=1,3
C      AVOID SCOS GREATER THAN UNITY
       IF(ABS(SN(I,J))-1) 43,43,44
    44 SN(I,J)=SN(I,J)/ABS(SN(I,J))
    43 SCOS(I,J)=SN(I,J)
C
C      INTEGRATE TO FIND ANGULAR VELOCITY AT THE END OF THE TIME INTERVAL DT
C
       W1E=W1E+WD1*DT
```

Figure 6-22. Subroutine - INTEQM (Continued)

```
      W2F=W2E+WD2*DT
      W3F=W3E+WD3*DT
C
C     INTEGRATE NEWTONS EQUATIONS
C
      XCG=XCG+XDCG*DT+FORCEX*DT*DT/(2.0*VASS)
      XDCG=XDCG+FORCEX*DT/VASS
      YCG=YCG+YDCG*DT+FORCEY*DT*DT/(2.0*VASS)
      YDCG=YDCG+FORCEY*DT/VASS
      ZCG=ZCG+ZDCG*DT+FORCEZ*DT*DT/(2.0*VASS)
      ZDCG=ZDCG+FORCEZ*DT/VASS
      RETURN
      END
```

Figure 6-22. Subroutine - INTEQM (Concluded)

```
XB(1,1)=  -1.50000 XB(2,1)=  -6.75000 XB(3,1)=  -6.75000 XB(1,2)=  -1.50000 XB(2,2)=  -6.75000 XB(3,2)=  -6.75000
XB(1,3)=  -1.50000 XB(2,3)=  -6.75000 XB(3,3)=  -6.75000 XB(1,4)=  -1.50000 XB(2,4)=  -6.75000 XB(3,4)=  -6.75000
YB(1,1)=   6.00000 YB(2,1)=   4.40000 YB(3,1)=   4.40000 YB(1,2)=    .00000 YB(2,2)=   4.07500 YB(3,2)=  -4.07500
YB(1,3)=  -6.00000 YB(2,3)=  -4.40000 YB(3,3)=  -4.40000 YB(1,4)=    .00000 YB(2,4)=  -4.07500 YB(3,4)=   4.07500
ZB(1,1)=    .00000 ZB(2,1)=   4.07500 ZB(3,1)=  -4.07500 ZB(1,2)=  -6.00000 ZB(2,2)=  -4.40000 ZB(3,2)=  -4.40000
ZB(1,3)=    .00000 ZB(2,3)=  -4.07500 ZB(3,3)=   4.07500 ZB(1,4)=   6.00000 ZB(2,4)=   4.40000 ZB(3,4)=   4.40000
VFOT 1,1= -12.63000 VFOT 2,1= -12.63000 VFOT 3,1= -12.63000 VFOT 4,1= -12.63000 VFOT 1,2=  12.08000 VFOT 2,2=    .00000
VFOT 3,2= -12.08000 VFOT 4,2=    .00000 VFOT 1,3=    .00000 VFOT 2,3= -12.08000 VFOT 3,3=    .00000 VFOT 4,3=  12.08000
FOTAC 1 =   3.00000 FOTAC 2 =   3.00000 FOTAC 3 =   3.00000 FOTAC 4 =   3.00000 VVEL    =   8.00000 HVEL    =    .00000
M1      = 9000.00   M2      = 11973.00  M3      = 11973.00  XCG1    =  30.00000 YCG1    =    .00000 ZCG1    =    .00000
1E1     =    .00000 T2E1    =    .00000 T3E1    =    .00000 PITCH1  =    .20950 YAW1    =    .39250 ROLL1   =    .00000
TYPE 1  =   1.00000 TYPE 2  =   2.00000 TYPE 3  =   2.00000 VASLUG  = 400.00000 ZDCG1   =    .00000 ETA1    =    .20950
```

Figure 6-23. Input Data Printout

```
TIME   XCG     YCG     ZCG    PHI  PSI  THETA  XDCG  YDCG  ZDCG  FORCEX  FORCEY  TORQZ   BETA PX1 PX2 PX3 PX4 E
 .00  14.670   .000   .000   .00 -.21  -.40  -7.83  1.66   .00       0       0       0  .531 4.6 3.3 -.0 1.4 0
 .04  14.559   .071   .003  -.00 -.21  -.40  -7.55  1.93   .13    5642    3665  -14493  .552 4.3 3.0  .0 1.0 0
 .08  14.267   .156   .011  -.00 -.21  -.40  -7.02  2.32   .34    5546    3996  -13605  .572 4.0 2.7  .0  .8 0
 .12  13.997   .256   .029  -.00 -.21  -.40  -6.47  2.72   .54    5479    4087  -13064  .566 3.7 2.4  .0  .5 0
 .16  13.749   .373   .055  -.00 -.20  -.40  -5.93  3.14   .76    5390    4206  -12431  .597 3.4 2.1  .0  .2 0
 .20  13.523   .507   .090  -.01 -.19  -.40  -5.39  3.57   .98    5303    4325  -11896  .606 3.0 1.9  .0 -.0 0
 .24  13.324   .660   .129  -.01 -.19  -.40  -4.46  4.06   .90   11628    5145  -16036  .605 2.7 1.7  .0  .0 0
 .28  13.170   .832   .159  -.01 -.18  -.40  -3.23  4.58   .68   12157    5213  -18011  .598 2.4 1.5  .0  .0 0
 .32  13.065  1.026   .179  -.01 -.16  -.40  -2.08  5.07   .35   10319    4145  -19244  .566 2.1 1.3  .0  .0 0
 .36  13.001  1.236   .186  -.01 -.15  -.40  -1.17  5.40  -.02    4850    1415   -6722  .573 1.9 1.2  .0  .0 0
 .40  12.963  1.455   .176  -.01 -.13  -.39   -.73  5.54  -.47    4118    1408   -5849  .551 1.6 1.0  .1  .0 0
 .44  12.941  1.679   .150  -.01 -.11  -.39   -.41  5.67  -.82    1767     983   -5575  .531 1.4  .8  .3  .0 0
 .48  12.927  1.907   .113  -.01 -.09  -.39   -.34  5.74  -.95    -691     207   -7871  .515 1.2  .6  .4  .0 0
 .52  12.909  2.138   .073  -.00 -.07  -.39   -.55  5.78  -.95   -2099     446      -0  .505  .9  .5  .6  .1 0
 .56  12.862  2.370   .038   .00 -.05  -.39   -.76  5.83  -.95   -2099     446      -0  .496  .7  .3  .7  .2 0
 .60  12.847  2.604  -.006   .01 -.03  -.39   -.97  5.87  -.99   -2099     446      -0  .486  .5  .1  .9  .3 0
 .64  12.805  2.839  -.045   .02 -.01  -.39  -1.08  5.88  -.91    2045    -952    1938  .480  .2  .0 1.0  .4 0
 .68  12.768  3.072  -.073   .02  .00  -.39   -.73  5.75  -.50    4850   -1596    5915  .487 -.0  .0 1.2  .5 0
 .72  12.753  3.295  -.085   .02  .02  -.39    .09  5.34  -.13   10430   -5631   14032  .492  .0  .0 1.4  .7 0
 .76  12.780  3.486  -.085   .03  .04  -.39   1.26  4.72   .15   11818   -6126   19915  .494  .0  .0 1.6  .8 0
 .80  12.853  3.673  -.074   .03  .05  -.39   2.40  4.14   .37   10539   -5506   19504  .495  .0  .0 1.8 1.0 0
 .84  12.969  3.828  -.057   .03  .07  -.39   3.36  3.62   .44    6650   -4397   14419  .469  .0  .0 2.1 1.1 0
 .88  13.114  3.965  -.047   .03  .08  -.39   3.84  3.25   .26    3722   -3127   12953  .470  .0  .1 2.3 1.3 0
 .92  13.274  4.090  -.035   .03  .08  -.39   4.09  3.03   .13    1618   -1623   10238  .451  .0  .2 2.6 1.5 0
 .96  13.438  4.209  -.031   .03  .09  -.39   4.04  3.01   .13   -2099     446      -0  .439  .0  .4 2.8 1.7 0
1.00  13.595  4.331  -.025   .03  .09  -.39   3.83  3.05   .13   -2099     446      -0  .430  .1  .5 3.1 1.9 0
1.04  13.744  4.454  -.020   .03  .10  -.39   3.62  3.10   .13   -2099     446      -0  .421  .2  .6 3.3 2.1 0
1.08  13.865  4.578  -.014   .03  .11  -.39   3.41  3.14   .13   -2099     446      -0  .413  .3  .7 3.5 2.3 0
1.12  14.017  4.705  -.009   .03  .11  -.39   3.20  3.18   .13   -2099     446      -0  .405  .4  .8 3.7 2.5 0
1.16  14.141  4.833  -.004   .03  .12  -.40   2.99  3.23   .13   -2099     446      -0  .397  .5  .9 3.9 2.6 0
1.20  14.256  4.963   .002   .03  .12  -.40   2.78  3.27   .13   -2099     446      -0  .389  .5 1.0 4.0 2.8 0
1.24  14.363  5.095   .007   .03  .13  -.40   2.57  3.32   .13   -2099     446      -0  .382  .6 1.1 4.2 2.9 0
1.28  14.462  5.229   .012   .03  .13  -.40   2.36  3.36   .13   -2099     446      -0  .375  .7 1.2 4.4 3.1 0
1.32  14.552  5.364   .018   .03  .14  -.40   2.15  3.41   .13   -2099     446      -0  .369  .7 1.2 4.5 3.2 0
1.36  14.634  5.501   .023   .03  .14  -.40   1.94  3.45   .13   -2099     446      -0  .362  .7 1.3 4.7 3.3 0
1.40  14.708  5.640   .028   .04  .15  -.40   1.73  3.50   .13   -2099     446      -0  .356  .8 1.3 4.8 3.5 0
1.44  14.773  5.781   .034   .04  .15  -.40   1.52  3.54   .13   -2099     446      -0  .350  .8 1.4 4.9 3.6 0
1.48  14.829  5.923   .039   .04  .16  -.40   1.31  3.59   .13   -2099     446      -0  .345  .8 1.4 5.1 3.7 0
1.52  14.878  6.068   .044   .04  .16  -.40   1.10  3.63   .13   -2099     446      -0  .340  .8 1.4 5.2 3.8 0
1.56  14.917  6.214   .050   .04  .17  -.40    .89  3.68   .13   -2099     446      -0  .334  .8 1.5 5.3 3.8 0
1.60  14.949  6.362   .055   .04  .17  -.41    .68  3.72   .13   -2099     446      -0  .330  .8 1.5 5.4 3.9 0
1.64  14.972  6.512   .060   .04  .18  -.41    .47  3.76   .13   -2099     446      -0  .325  .8 1.5 5.5 4.0 0
1.68  14.967  6.663   .066   .04  .19  -.41    .26  3.81   .13   -2099     446      -0  .321  .7 1.5 5.5 4.1 0
1.72  14.993  6.816   .071   .04  .19  -.41    .05  3.85   .13   -2099     446      -0  .316  .7 1.4 5.6 4.1 0
1.76  14.991  6.971   .076   .04  .20  -.41   -.16  3.90   .13   -2099     446      -0  .312  .7 1.4 5.7 4.2 0
1.80  14.969  7.128   .082   .04  .20  -.41   -.37  3.94   .13   -2099     446      -0  .309  .6 1.4 5.7 4.2 0
1.84  14.961  7.287   .087   .05  .21  -.41   -.58  3.99   .13   -2099     446      -0  .305  .6 1.3 5.8 4.2 0
1.88  14.934  7.447   .092   .05  .21  -.41   -.79  4.03   .13   -2099     446      -0  .302  .5 1.3 5.8 4.3 0
1.92  14.898  7.609   .098   .05  .22  -.41  -1.00  4.08   .13   -2099     446      -0  .299  .4 1.2 5.9 4.3 0
1.96  14.858  7.773   .103   .05  .22  -.41  -1.21  4.12   .13   -2099     446      -0  .296  .3 1.2 5.9 4.3 0

TIME   XCG     YCG     ZCG    PHI  PSI  THETA  XDCG  YDCG  ZDCG  FORCEX  FORCEY  TORQZ   BETA PX1 PX2 PX3 PX4 E
2.00  14.812  7.939   .108   .05  .23  -.42  -1.42  4.17   .13   -2099     446      -0  .293  .2 1.1 5.9 4.3 0
TIME   =   2.04000
PSIMAX =     .22845  BTAMIN =    .29316  TIME   =   2.04000
```

Figure 6-24. "On Line" Data Printout

```
TIME   FX1    FX2    FX3    FX4   XBFT1  XBFT2  XBFT3  XBFT4 ONMOON   THEDT  PHIDOT  BETADT  PSIDOT        CRUSH
 .00     0      0      0      0   12.83  12.83  12.83  12.83  33.33    .000  -.000 1061.603  -.000    0    0    0    0
 .04     0      0   7742      0   12.83  12.83  12.51  12.83  33.23    .002  -.008    .606    .019    0    0  222    0
 .08     0      0   7645      0   12.83  12.83  12.29  12.83  33.23    .006  -.027    .000    .067    0    0  222    0
 .12     0      0   7579      0   12.83  12.83  11.98  12.83  33.23    .010  -.045    .326    .112    0    0  222    0
 .16     0      0   7490      0   12.83  12.83  11.78  12.83  33.23    .013  -.063    .248    .155    0    0  222    0
 .20     0      0   7403      0   12.83  12.83  11.62  12.83  33.23    .017  -.079    .168    .195    0    0  222    0
 .24     0      0   7314   6413   12.83  12.83  11.59  12.58  33.22    .018  -.076   -.110    .241    0    0  222  122
 .28     0      0   7111   7146   12.83  12.83  11.45  12.41  33.22    .014  -.045   -.200    .299    0    0  212  222
 .32     0      0   5317   7101   12.83  12.83  11.46  12.32  33.22    .012  -.014  -2.000    .362    0    0  111  222
 .36     0      0      0   6940   12.83  12.83  11.54  12.29  33.32    .016   .019    .000    .430    0    0    0  221
 .40     0      0      0   6218   12.83  12.83  11.54  12.31  33.32    .010   .064   -.545    .449    0    0    0  111
 .44     0      0      0   3886   12.83  12.83  11.54  12.38  33.32    .003   .105    .000    .468    0    0    0  111
 .48     0      0      0   1408   12.83  12.83  11.54  12.48  33.32   -.006   .136   -.296    .488    0    0    0  113
 .52     0      0      0      0   12.83  12.83  11.54  12.48  33.33   -.006   .136   -.240    .488    0    0    0    0
 .56     0      0      0      0   12.83  12.83  11.54  12.48  33.33   -.006   .136   -.242    .488    0    0    0    0
 .60     0      0      0      0   12.83  12.83  11.54  12.48  33.33   -.008   .136   -.244    .488    0    0    0    0
 .64     0   4145      0      0   12.83  12.70  11.54  12.48  32.33   -.008   .133    .000    .487    0  111    0    0
 .68     0   6949      0      0   12.83  12.52  11.54  12.48  32.33   -.008   .102    .249    .474    0  222    0    0
 .72  5586   6943      0      0   12.61  12.38  11.54  12.48  22.33   -.007   .058    .059    .442  122  222    0    0
 .76  6968   6949      0      0   12.46  12.31  11.54  12.48  22.33   -.007   .032    .059    .376  222  222    0    0
 .80  7018   5620      0      0   12.39  12.31  11.54  12.48  22.33   -.007   .004    .000    .309  222  111    0    0
 .84  6707   2043      0      0   12.38  12.36  11.54  12.48  22.33   -.004  -.025    .000    .245  112  131    0    0
 .88  5822      0      0      0   12.43  12.41  11.54  12.48  23.33    .003  -.022   -.511    .198  111    0    0    0
 .92  3716      0      0      0   12.51  12.41  11.54  12.48  23.33    .002  -.003   -.443    .160  111    0    0    0
 .96     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.235    .133    0    0    0    0
1.00     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.230    .133    0    0    0    0
1.04     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.221    .133    0    0    0    0
1.08     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.212    .133    0    0    0    0
1.12     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.203    .133    0    0    0    0
1.16     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.195    .133    0    0    0    0
1.20     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.187    .133    0    0    0    0
1.24     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.180    .133    0    0    0    0
1.28     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.172    .133    0    0    0    0
1.32     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.165    .133    0    0    0    0
1.36     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.158    .133    0    0    0    0
1.40     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.152    .133    0    0    0    0
1.44     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.145    .133    0    0    0    0
1.48     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.139    .133    0    0    0    0
1.52     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.133    .133    0    0    0    0
1.56     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.127    .133    0    0    0    0
1.60     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.121    .133    0    0    0    0
1.64     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.115    .133    0    0    0    0
1.68     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.110    .133    0    0    0    0
1.72     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.104    .133    0    0    0    0
1.76     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .024   -.099    .133    0    0    0    0
1.80     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .023   -.093    .133    0    0    0    0
1.84     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .023   -.088    .133    0    0    0    0
1.88     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .023   -.083    .133    0    0    0    0
1.92     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .023   -.078    .133    0    0    0    0
1.96     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .023   -.073    .133    0    0    0    0

TIME   FX1    FX2    FX3    FX4   XBFT1  XBFT2  XBFT3  XBFT4 ONMOON   THEDT  PHIDOT  BETADT  PSIDOT        CRUSH
2.00     0      0      0      0   12.61  12.41  11.54  12.48  33.33   -.013   .023   -.068    .133    0    0    0    0
```

Figure 6-25. Final Printout of Stored Data

SECTION VII

GENERAL NON-PLANAR LUNAR LANDING COMPUTER PROGRAM

INTRODUCTION

This computer program is basically an extension of the Planar Lunar Landing Computer Program. An attempt was made to use as much of the original planar program as possible and to keep the flow of the non-planar program about the same.

METHOD

The motion of the vehicle and that of the footpads is computed in the ground coordinate system while the geometry is computed in the vehicle coordinate system. These two coordinate systems are related by a set of direction cosines.

The following procedure is used to set up the initial orientation of the vehicle.

First, consider the vehicle oriented in the ground coordinate system with leg No. 1 in the "+Y" direction, leg No. 3 in the "-Y" direction and leg No. 4 in the "+Z" direction. A right-handed coordinated system is used. From this basic orientation, the vehicle is rotated through a pitch angle, yaw angle, and roll angle in that order. This sets the initial direction cosine matrix relating the vehicle coordinate system to the ground coordinate system. This matrix of original direction cosines is:

$$[XL] = \begin{bmatrix} (\cos\alpha \cos\gamma - \sin\alpha \sin\beta \sin\gamma) & (-\sin\alpha \cos\beta) & (\cos\alpha \sin\gamma + \sin\alpha \sin\beta \cos\gamma) \\ (\sin\alpha \cos\gamma + \cos\alpha \sin\beta \sin\gamma) & (\cos\alpha \cos\beta) & (\sin\alpha \sin\gamma - \cos\alpha \sin\beta \cos\gamma) \\ (-\cos\beta \sin\gamma) & (\sin\beta) & (\cos\beta \cos\gamma) \end{bmatrix}$$

where for this matrix

α = pitch angle

β = yaw angle

γ = roll angle

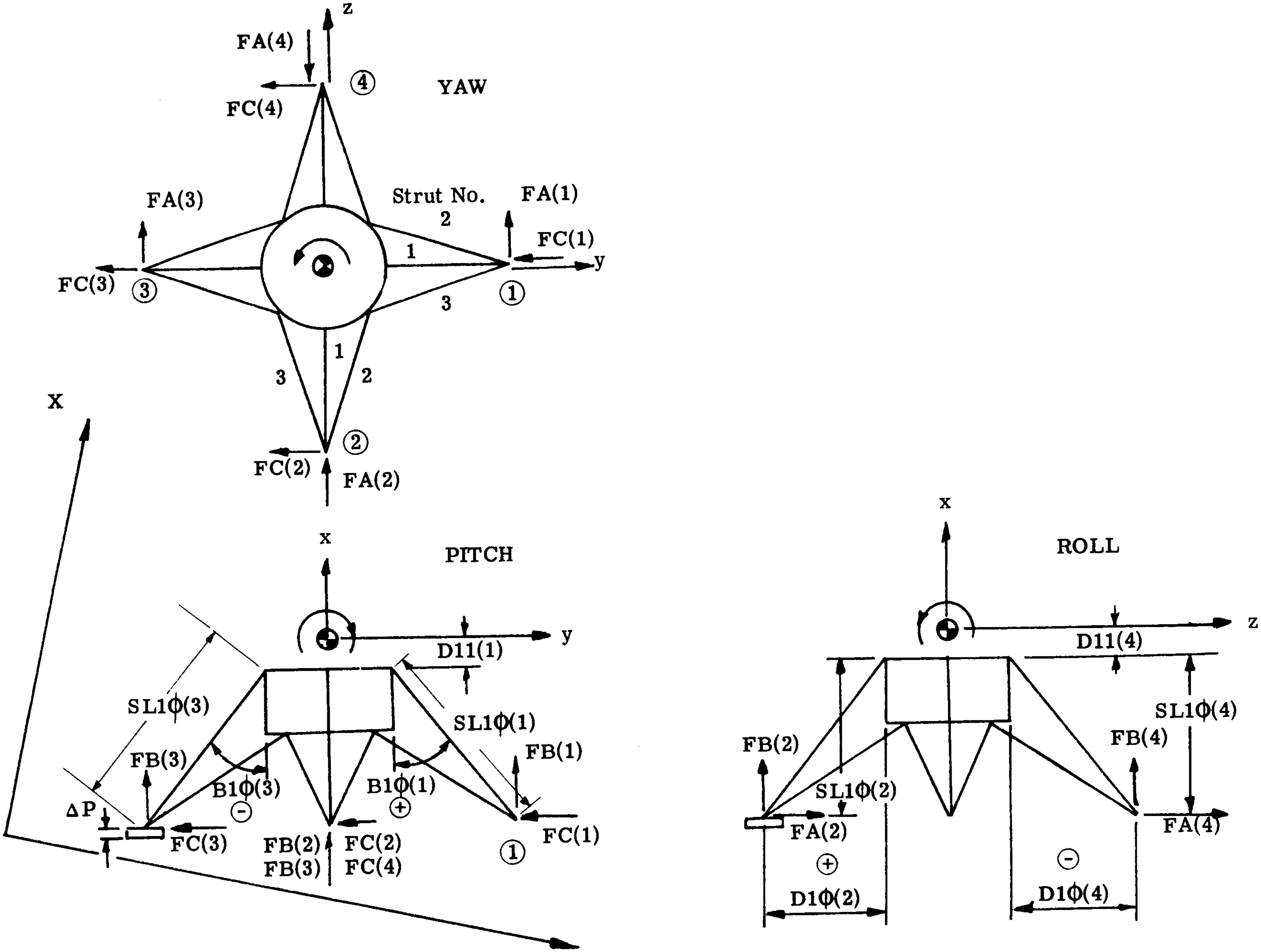


Figure 7-1. Initial Vehicle Orientation

NOTE: $[XL]\,[XL]^T = [I]$ or $[XL]^T = [XL]^{-1}$

That is, the transpose of this matrix is equal to the inverse of the matrix.

The vehicle coordinate system and the ground coordinate system are related by the following matrix equations:

$$\begin{Bmatrix} xp \\ yp \\ zp \end{Bmatrix} = [XL] \begin{Bmatrix} xpv \\ ypv \\ zpv \end{Bmatrix} + \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}$$

where

x_p, y_p, and z_p are pad coordinates in the ground coordinate system.

x_{pv}, y_{pv}, and z_{pv} are pad coordinates in the vehicle coordinate system.

X, Y, and Z are vehicle coordinates in ground system.

The vehicle is initially set so that the lowest leg is into the ground .001 feet.

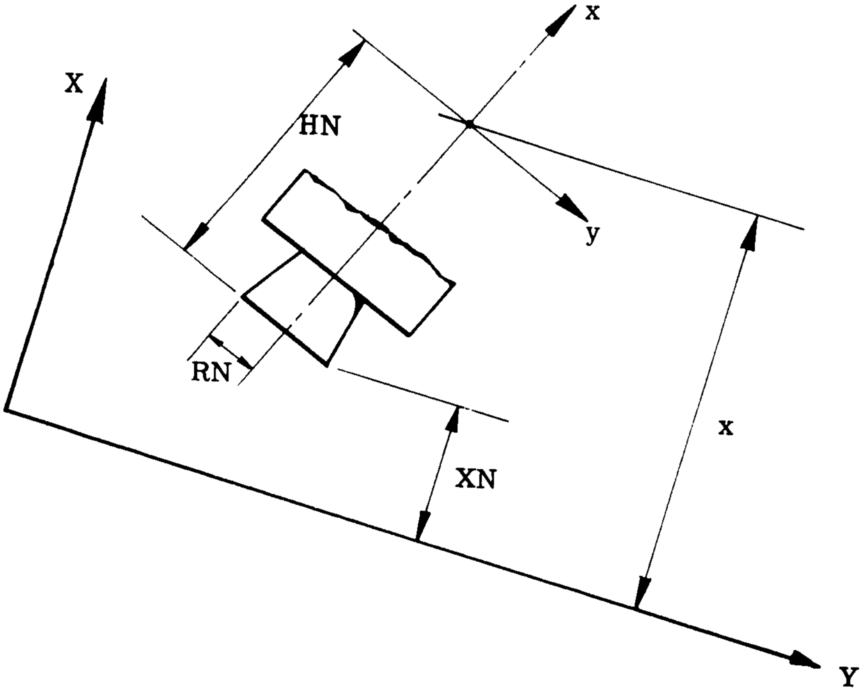
The initial velocities are given in the ground coordinate system. The right hand rule is used to determine the signs of the angular velocities (See Figure 7-1).

The strut geometry is computed in the vehicle coordinate system. This part of the program is therefore basically the same as the planar program.

The footpad motion is computed in the ground coordinate system as was the case in the planar program. This portion of the non-planar program is again very similar to the planar program.

Since some computations are done in the ground coordinate system and others are done in the vehicle coordinate system, a set of directions cosines relating the two sets of axes must be kept updated. This is done for every time increment after the equations of motion are integrated. The updating of direction cosines and the integration of the equations of motion are handled in subroutine INTEQM. A description of this subroutine can be found on page 5-36 (Reference 1).

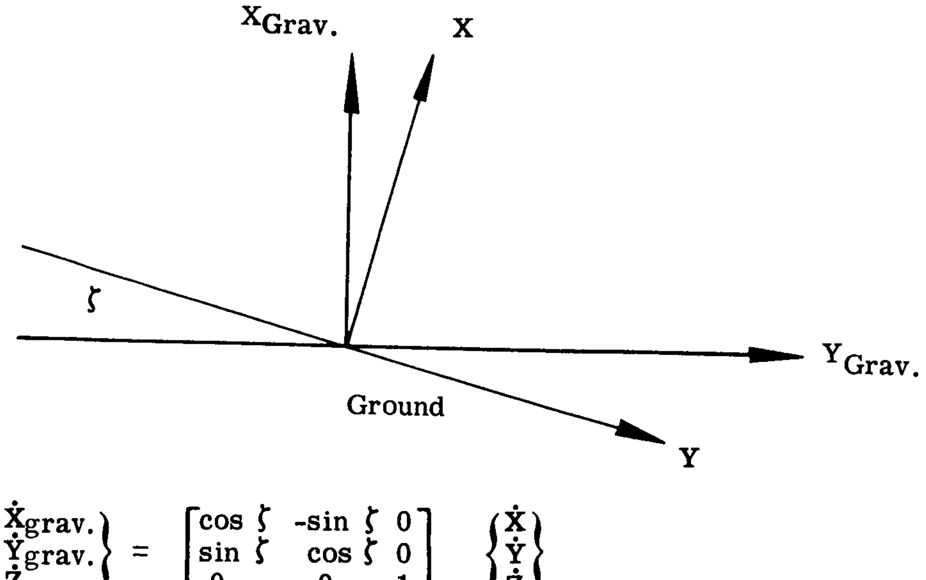
NOZZLE CLEARANCE



$$XN = X\text{-}HN \left\{XL(1, 1)\right\} - RN \left\{SIN11\right\}$$

$$SIN11 = \sqrt{1.0 - XL(1, 1)^2}$$

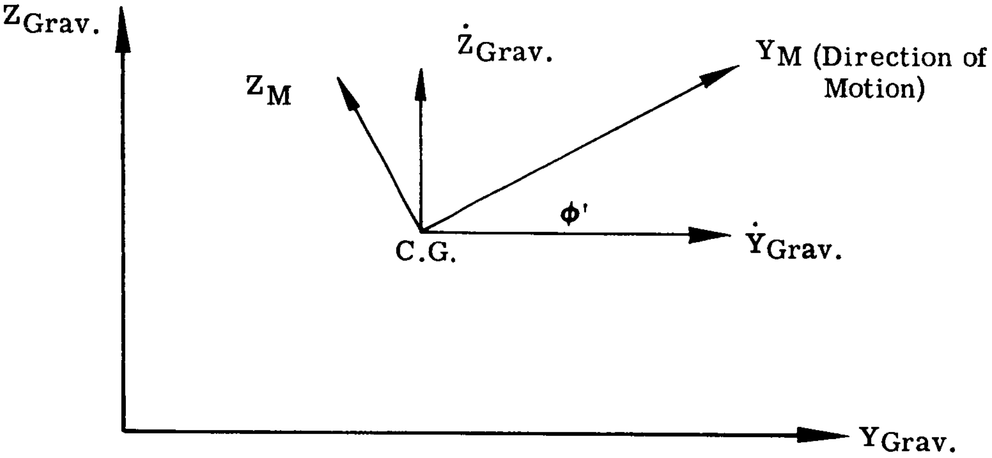
STABILITY CHECK



$$\begin{Bmatrix} \dot{X}_{grav.} \\ \dot{Y}_{grav.} \\ \dot{Z}_{grav.} \end{Bmatrix} = \begin{bmatrix} \cos\zeta & -\sin\zeta & 0 \\ \sin\zeta & \cos\zeta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{Bmatrix}$$

$$\begin{Bmatrix} X_{Grav.} \\ Y_{Grav.} \\ Z_{Grav.} \end{Bmatrix} = \begin{bmatrix} \cos\zeta & -\sin\zeta & 0 \\ \sin\zeta & \cos\zeta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}$$

$$\begin{Bmatrix} XP_{Grav.} \\ YP_{Grav.} \\ ZP_{Grav.} \end{Bmatrix} = \begin{bmatrix} \cos\zeta & -\sin\zeta & 0 \\ \sin\zeta & \cos\zeta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} XP \\ YP \\ ZP \end{Bmatrix}$$



$$\phi' = \tan^{-1}\left[\frac{\dot{Z}_{Grav.}}{\dot{Y}_{Grav.}}\right]$$

$$\begin{Bmatrix} X_M \\ Y_M \\ Z_M \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi' & \sin\phi' \\ 0 & -\sin\phi' & \cos\phi' \end{bmatrix} \begin{Bmatrix} X_{Grav.} \\ Y_{Grav.} \\ Z_{Grav.} \end{Bmatrix}$$

$$\begin{Bmatrix} XP_M \\ YP_M \\ ZP_M \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi' & \sin\phi' \\ 0 & -\sin\phi' & \cos\phi' \end{bmatrix} \begin{Bmatrix} XP_{Grav.} \\ YP_{Grav.} \\ ZP_{Grav.} \end{Bmatrix}$$

where

X, Y, and Z are coordinates of vehicle in ground coordinate system.

$\dot{X}$, $\dot{Y}$, and $\dot{Z}$ are vehicle velocities in ground coordinate system.

$X_{Grav.}$, $Y_{Grav.}$, and $Z_{Grav.}$, are vehicle coordinates in the gravitational coordinate system.

XP, YP, and ZP are pad coordinates in the ground coordinate system.

X_M, Y_M, and Z_M are vehicle coordinates in the coordinate system of motion.

XP_M, YP_M, and ZP_M are pad coordinates in the coordinate system of motion.

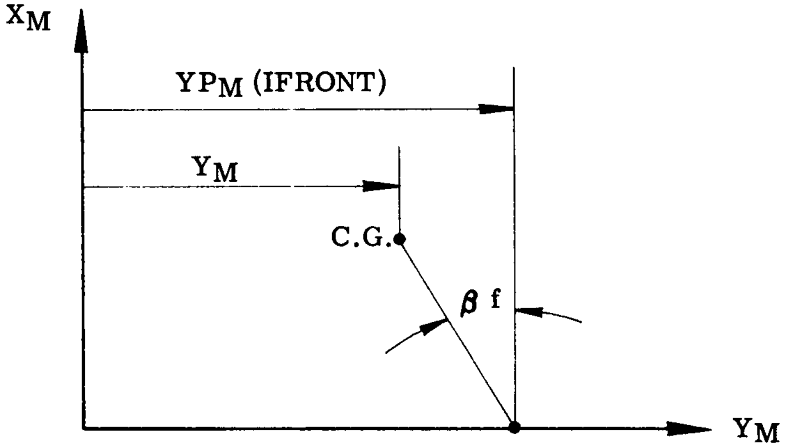
Using these basic relationships between coordinate systems, the following is obtained.

$$Y_M = X \sin\zeta \cos\phi' + Y \cos\zeta \cos\phi' + Z \sin\phi'$$

$$YP_M(i) = XP(i) \sin\zeta \cos\phi' + YP(i) \cos\zeta \cos\phi' + ZP(i) \sin\phi'$$

If $YP_M(i) > Y_M$ for all legs, the vehicle is considered unstable.

The stability angle tabulated in the output (BETAF) is computed for the leg with the largest value of YP_M.



$$\beta_F = \tan^{-1}\left[\frac{YP_M(\text{IFRONT}) - Y_M}{X_M - XP_M\ (\text{IFRONT})}\right]$$

where

IFRONT = index of front leg in direction of motion.

CONCLUSIONS

This non-planar program has not been completely checked out.

The planar run included in this report is the same run that is included in the Planar Lunar Landing Program. Some of the differences in these two runs would be due to the different integration routines used.

Perfect symmetry is not maintained in this planar run. Some of this can be attributed to roundoff error. For instance, the initial x_p values are slightly different and therefore the forces developed in the two legs on the ground will not be completely symmetrical.

In non-planar runs made, the motion looked reasonable although no detailed studies were made. No comparisons have been made with non-planar test data.

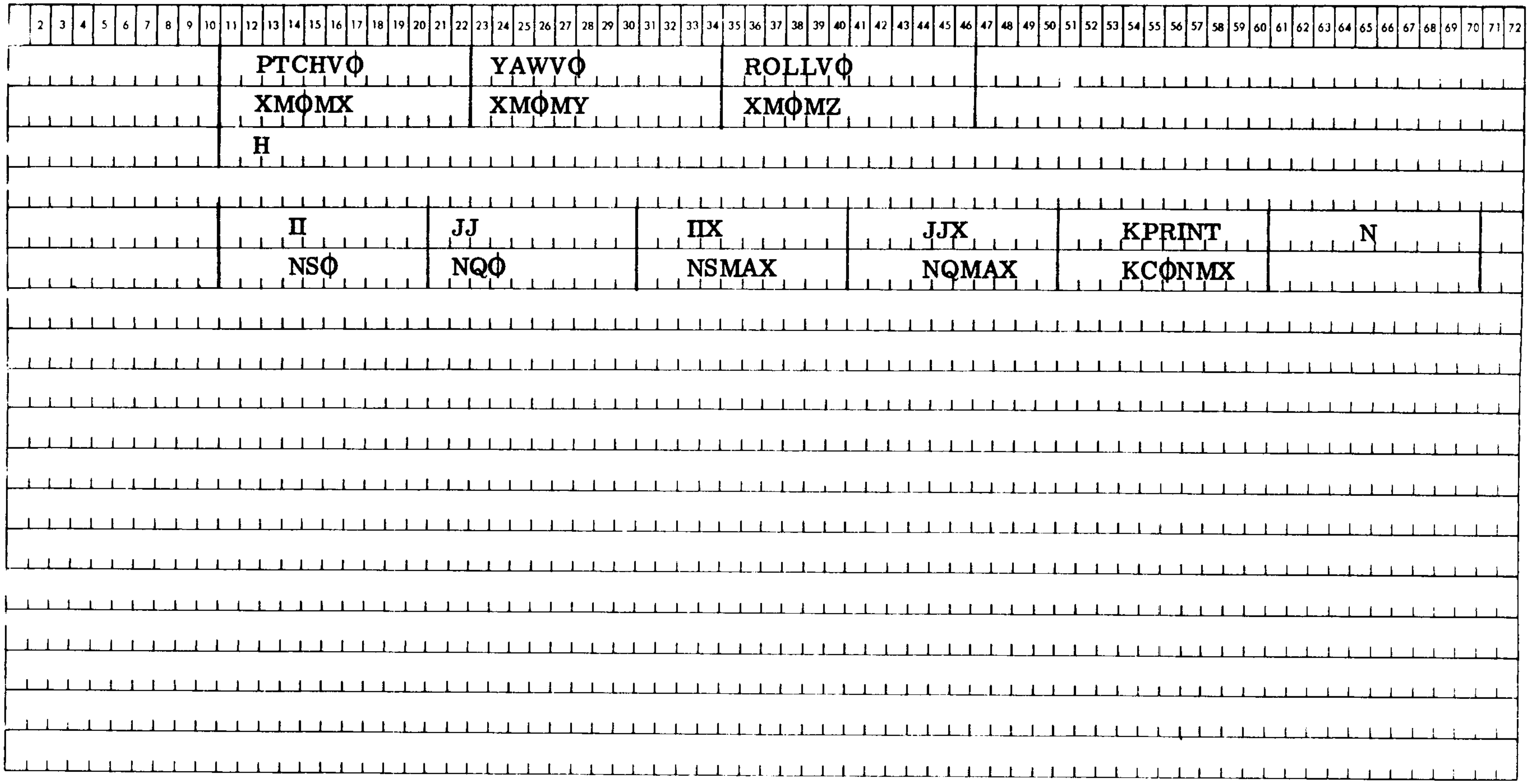
Figure 7-2 illustrates the input data format. Figures 7-3 through 7-6 are flow diagrams for the program and its subroutines. Figures 7-7 through 7-10 are complete program listings. Figures 7-11 through 7-18 are sample output data from the program. Figure 7-11 is a printout of the input data used. Figure 7-12 prints out some auxiliary inputs required by the main program. These are computed by the subroutine INCON. Figure 7-13 output data indicates the instantaneous vehicle orientation. Figure 7-14 is a summary printout of pertinent information for the run. Figure 7-15 presents the footpad positions and forces for footpads 2 and 3. Figure 7-16 presents the forces acting on the footpads from the struts.

Figures 7-17 and 7-18 are similar to Figures 7-15 and 7-16 but present this information for footpads 1 and 4.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72

COLUMNS	ALPHA(1)	ALPHA(2)	ALPHA(3)	ALPHA(4)	ALPHA(5)
1-10	D(1)	D(2)	D(3)	ETC.	
USED	D11(1)	D11(2)			
FOR	F11(1)	F11(2)			
I. D.	F22(1)	F22(2)			0.0 IN THIS
	F33(1)	F33(2)			COLUMN FOR
	GRDMU(1)	GRDMU(2)			FOUR LEG
	P1(1)	P1(2)			VEHICLE
	P2(1)	P2(2)			
	P3(1)	P3(2)			
	R1(1)	R1(2)			
	R2(1)	R2(2)			
	THETA(1)	THETA(2)			
	RP(1)	RP(2)			
	SKS(1)	SKS(2)			
	DELTAP	DELTAT	EPS2		
	EPS3	EPS4	EPS5		
	FINT	GRAV	HN		
	PMASS	RUNNØØ	RN		
	SK1	SK2	SK3		
	SKE1	SKE2	SKE3		
	SERNØ	VMASS	ZETA		
	PITCHØ	YAWØ	RØLLØ		

Figure 7-2. Input Data Form



	PTCHVØ	YAWVØ	ROLLVØ			
	XMØMX	XMØMY	XMØMZ			
	H					
	II	JJ	IIX	JJX	KPRINT	N
	NSØ	NQØ	NSMAX	NQMAX	KCØNMX	

Figure 7-2. Input Data Form (Continued)

MAIN

MAIN GENERAL NON-PLANAR COMPUTER PROGRAM

11-10-64
Page 1

This program determines detailed non-planar motions of Lunar Landing Vehicle from touchdown to rest or instability.

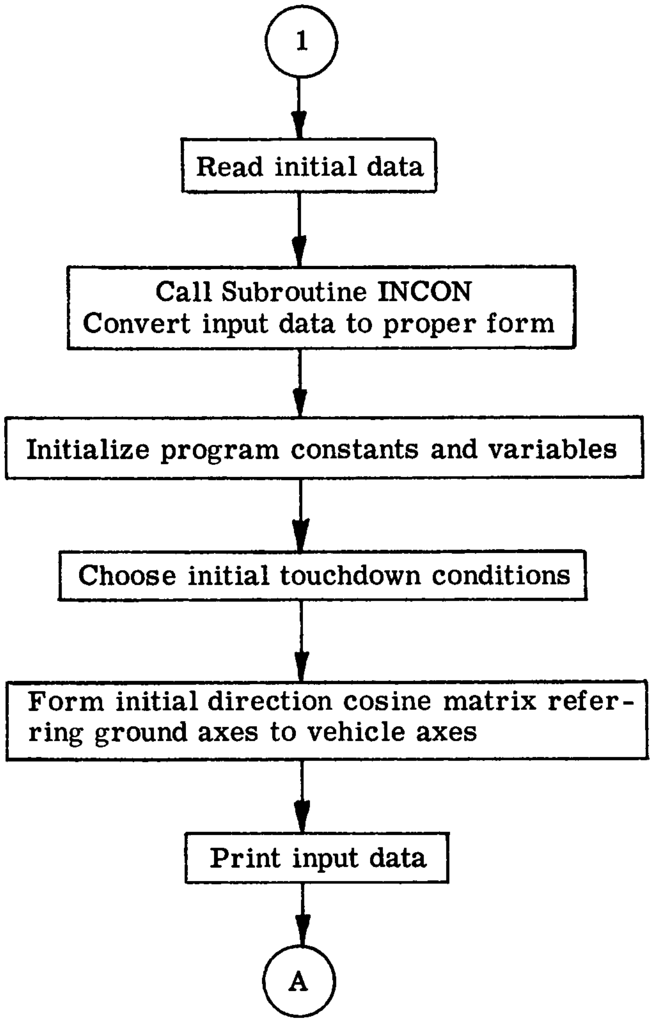


Figure 7-3. Main Computer Program

MAIN MAIN GENERAL NON-PLANAR COMPUTER PROGRAM (Continued) Page 2

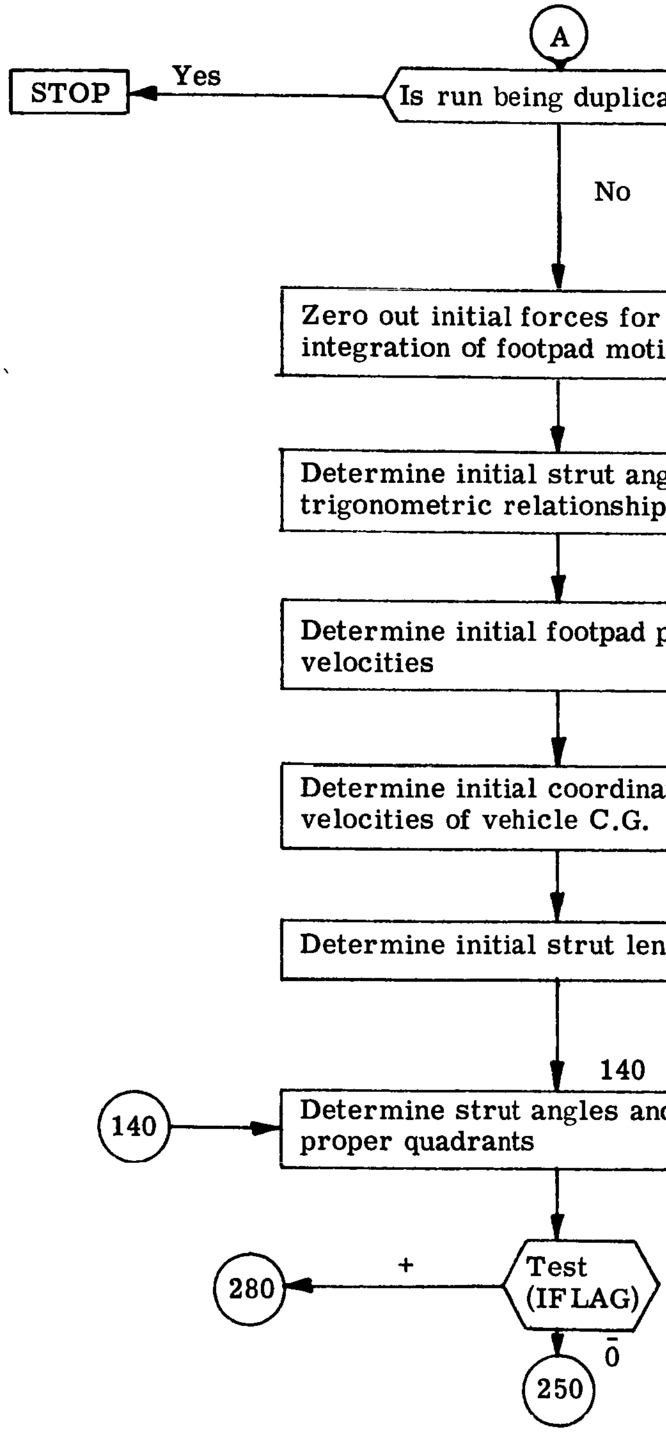


Figure 7-3. Main Computer Program (Continued)

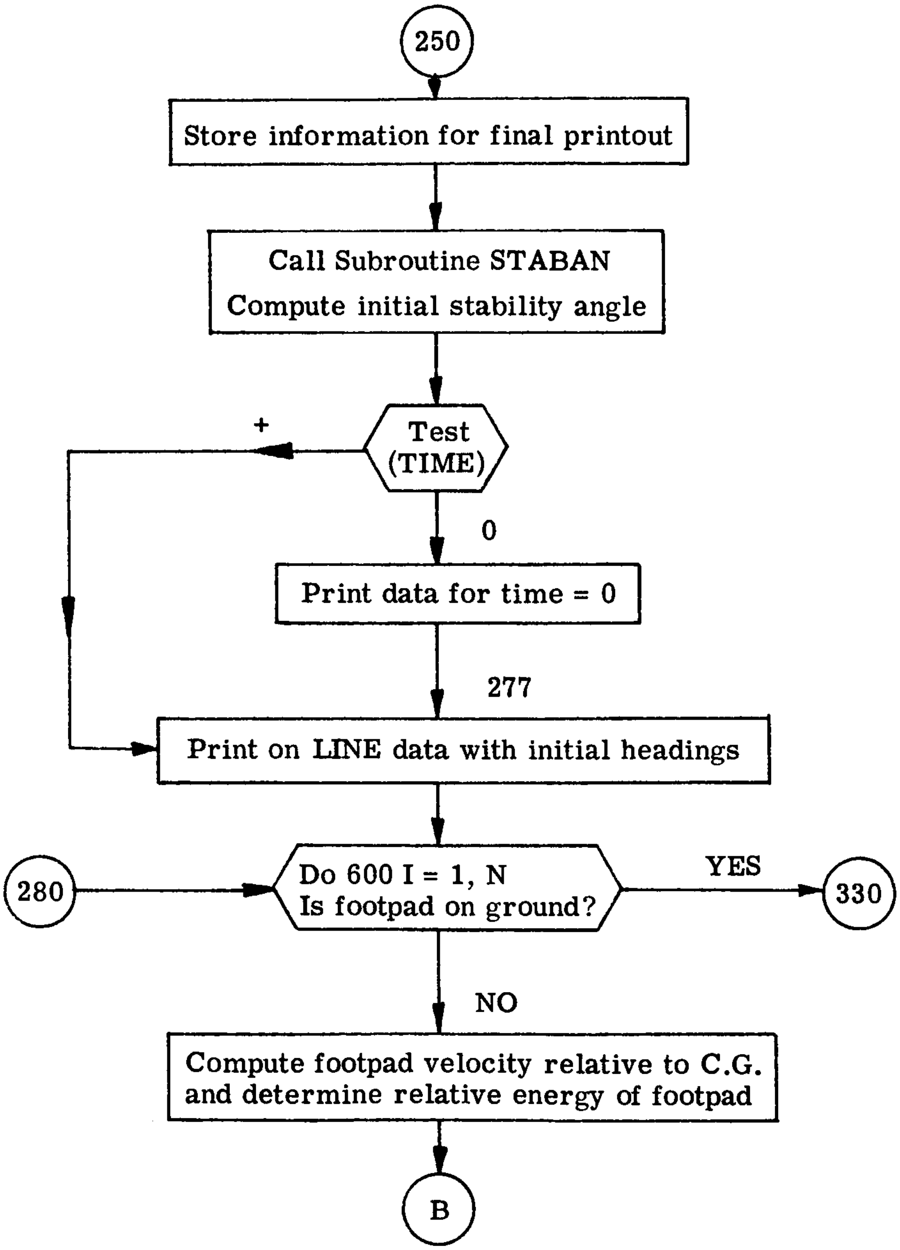


Figure 7-3. Main Computer Program (Continued)

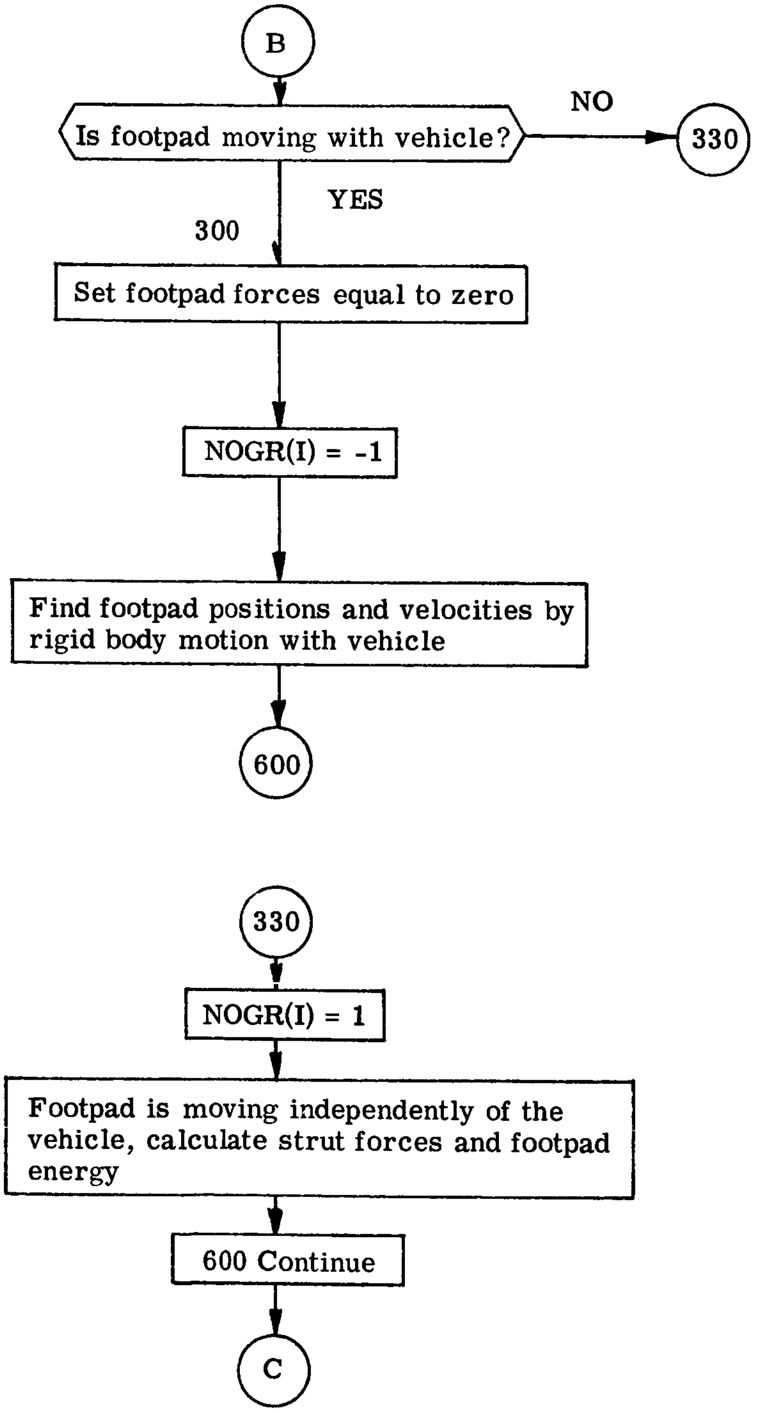


Figure 7-3. Main Computer Program (Continued)

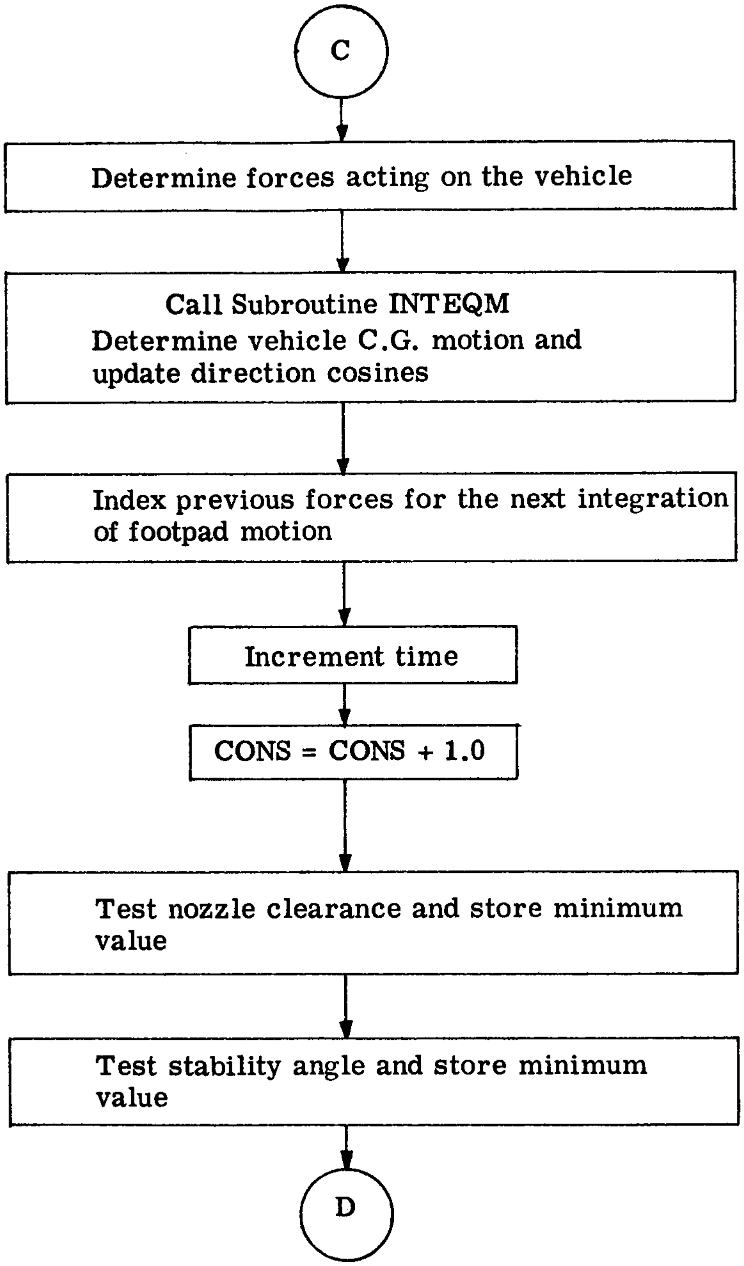


Figure 7-3. Main Computer Program (Continued)

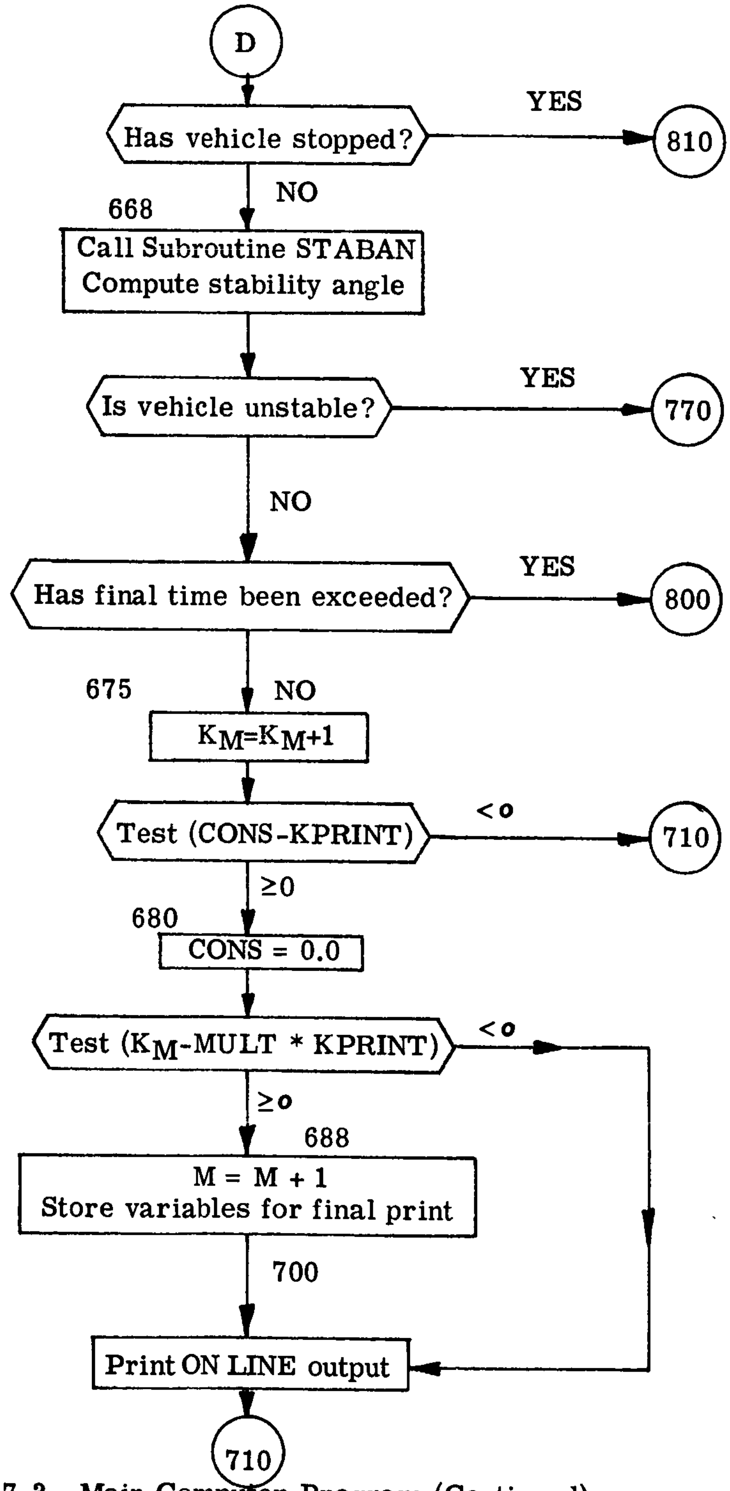


Figure 7-3. Main Computer Program (Continued)

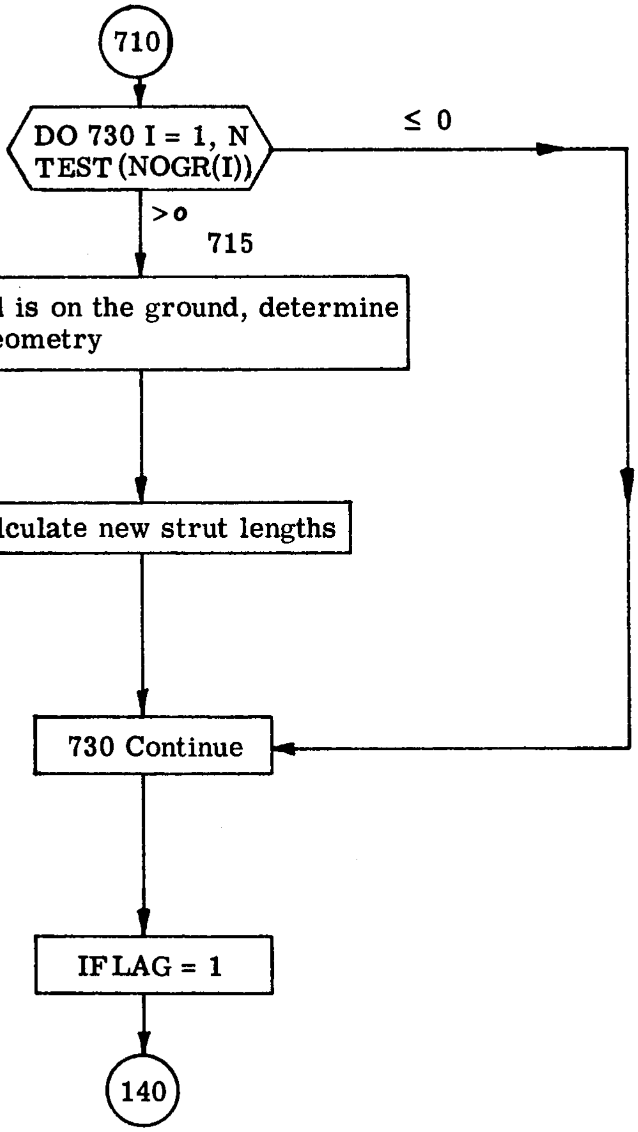


Figure 7-3. Main Computer Program (Continued)

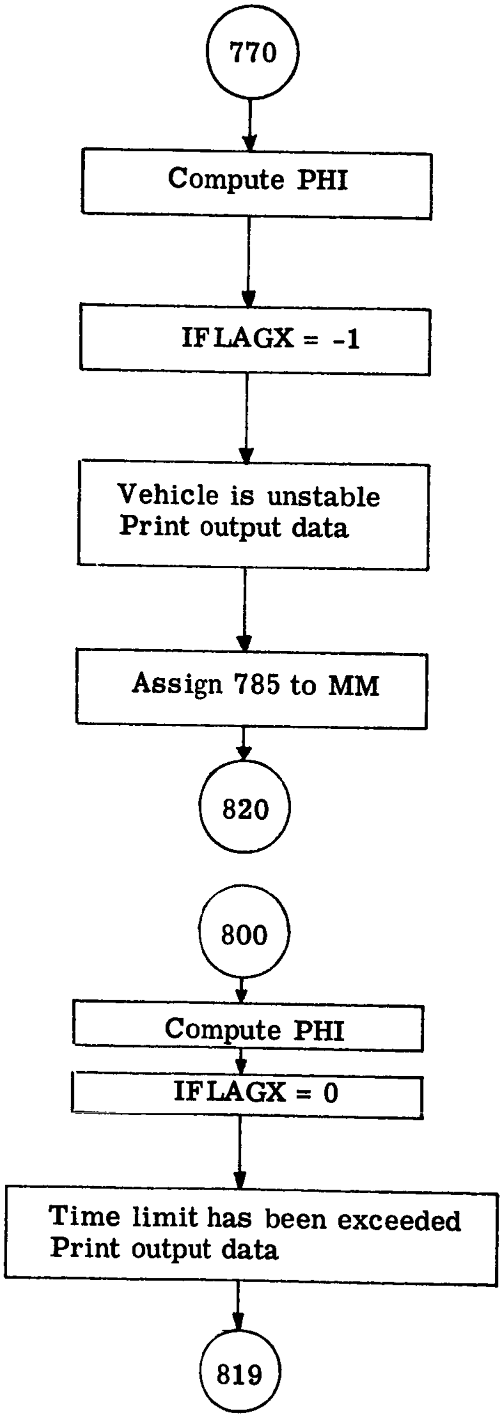


Figure 7-3. Main Computer Program (Continued)

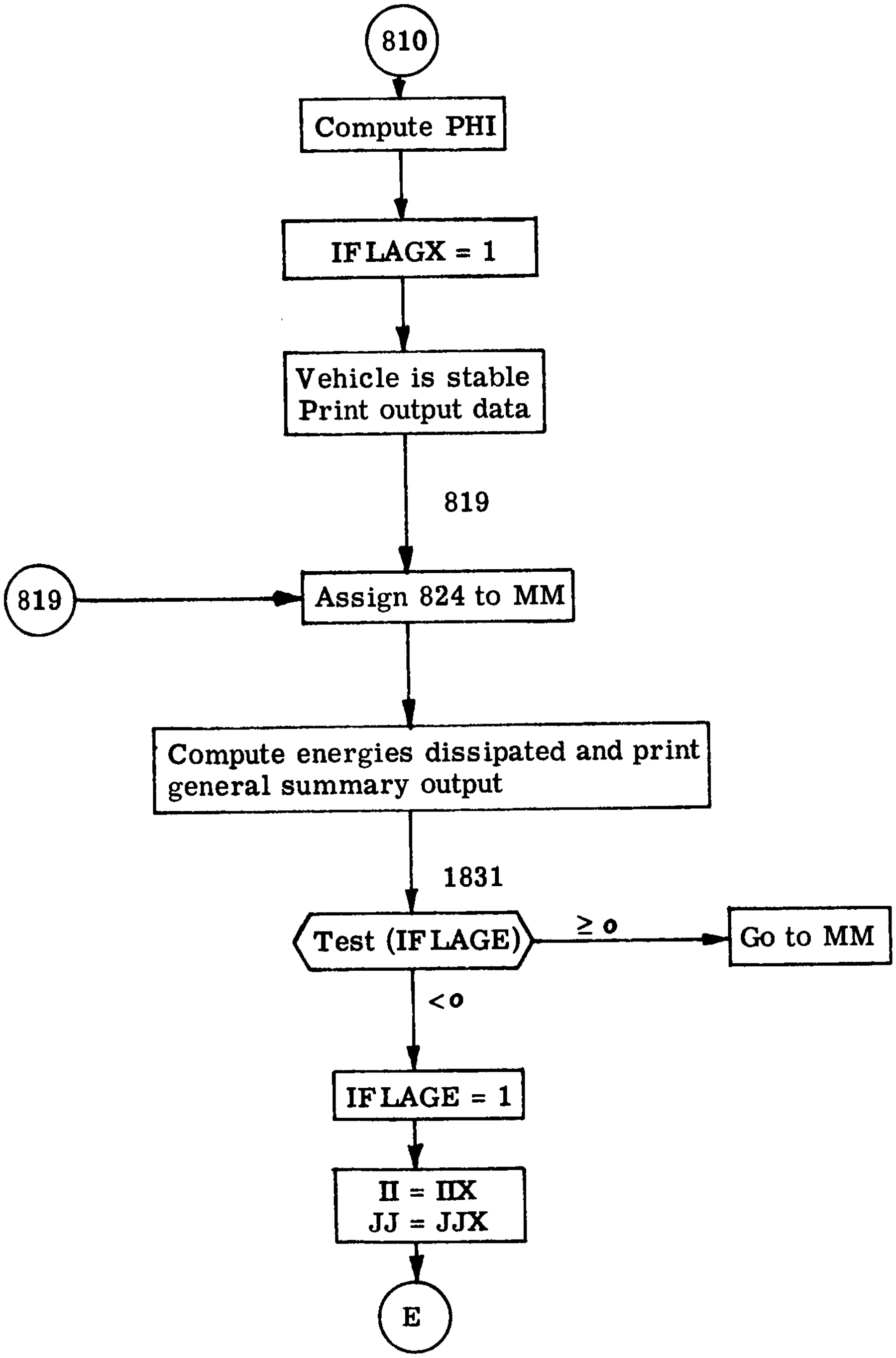


Figure 7-3. Main Computer Program (Continued)

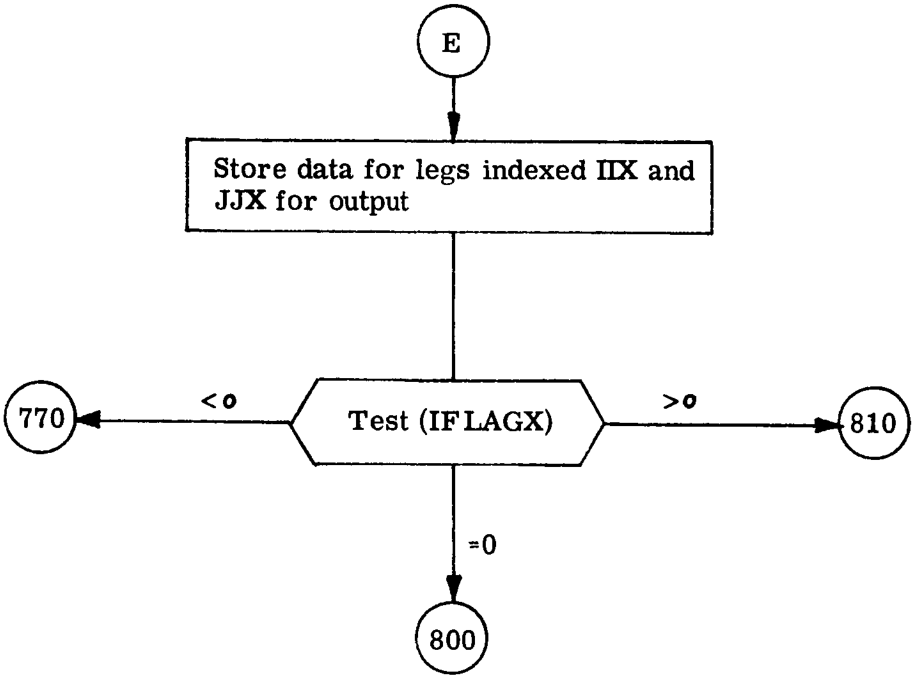


Figure 7-3. Main Computer Program (Continued)

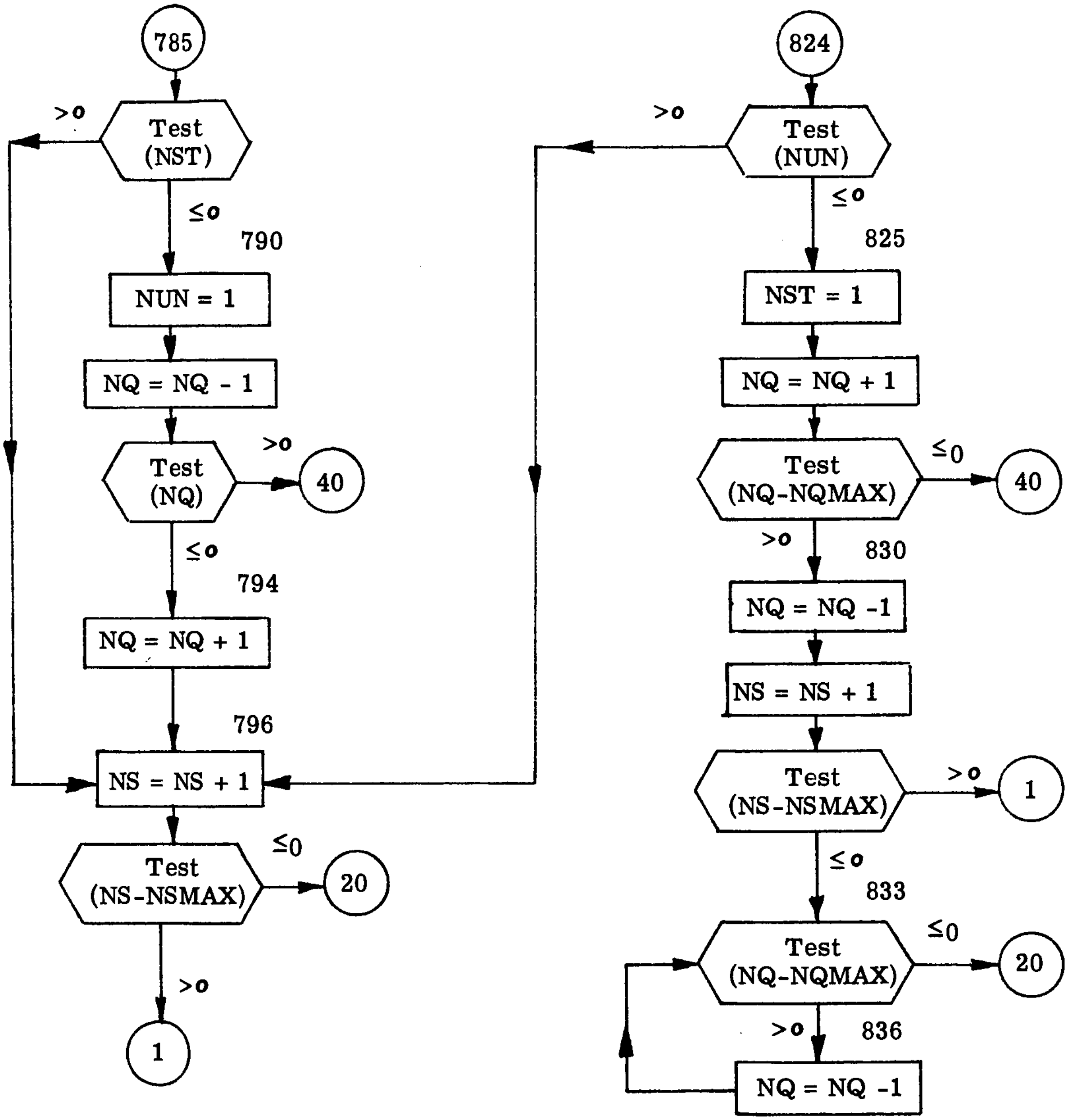


Figure 7-3. Main Computer Program (Concluded)

INCON CONVERT INPUT DATA

This subroutine converts the input data to a form that is used in the program.

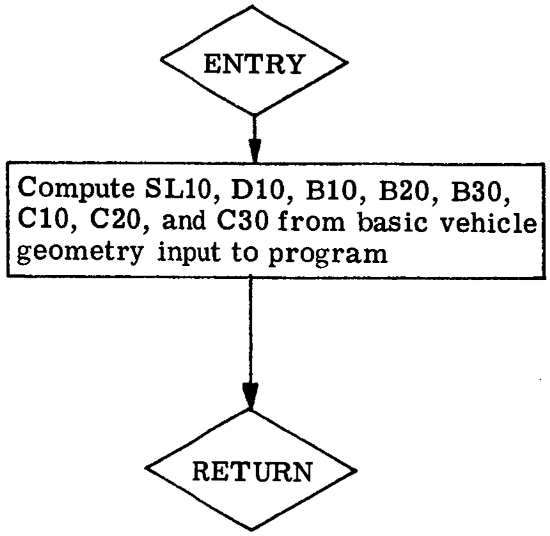


Figure 7-4. Subroutine - INCON

STABAN COMPUTE STABILITY ANGLE

This subroutine determines the critical leg for stability and calculates the stability angle for this leg.

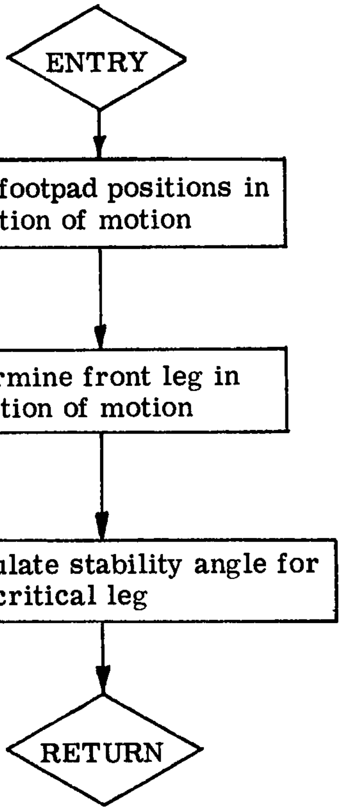


Figure 7-5. Subroutine - STABAN

This subroutine integrates the equations of motion for the vehicle and updates the direction cosines relating the ground coordinate system to the vehicle coordinate system

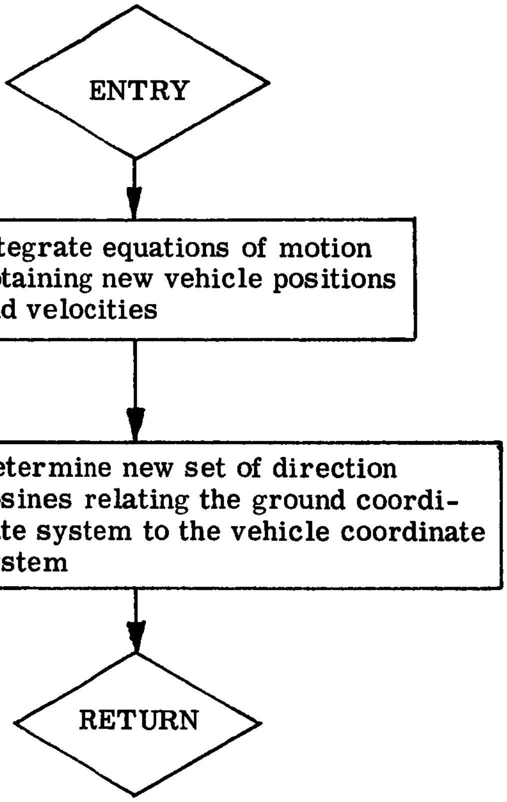


Figure 7-6. Subroutine - INTEQM

```
C
C     TITLE     MAIN PROGRAM   GENERAL THREE DIMENSIONAL LUNAR LANDING
C               DYNAMICS COMPUTER PROGRAM
C
C     AUTHOR    J. CADORET    BENDIX PRODUCTS AEROSPACE DIVISION
C
C     DATE      NOV. 1964
C
C     PURPOSE   THIS PROGRAM COMPUTES THE DETAILED VEHICLE MOTIONS FOR
C               A THREE DIMENSIONAL LUNAR LANDING
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM WAS COMPILED ON THE UNIVAC 1107 DIGITAL
C               COMPUTER
C
C               THIS PROGRAM HAS BEEN CHECKED OUT TO A LIMITED EXTENT
C               ONLY.  FURTHER CHECK OUT AND CORRELATION WITH A PHYSICAL
C               DROP TEST MODEL ARE CURRENTLY IN PROGRESS.  AS THE
C               RESULT OF THIS LIMITED CHECKOUT, THE RESULTS OF THIS
C               PROGRAM SHOULD BE USED WITH CAUTION
C
C                  6 DEGREES OF FREEDOM
C
C     LUNAR LANDING DYNAMICS COMPUTER PROGRAM
C     FOR ASSYMMETRIC VEHICLE LANDING GEAR CONFIGURATION
C     USING PARABOLIC INTEGRATION ON FOOTPAD MOTIONS
C
C
C
C
C     INPUT     BY EQUIVALENCE TO COMMON STORAGE
C
C     NOTE  AN INPUT PARAMETER FOLLOWED BY A 0 IMPLIES THE INITIAL VALUE
C               AS  B10(I).   THE INSTANTANEOUS VALUE OF THE PARAMETER
C               IS DEFINED WITHOUT THE  0   AS B1(I).
C     ALPHA     ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C               SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     BETAF     STABILITY ANGLE FOR FRONT LEG IN THE DIRECTION OF MOTION
C     BETMIN    MINIMUM STABILITY ANGLE
C     B10       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     B20       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B2PREV    VALUE OF B2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     B30       ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C               BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     B3PREV    VALUE OF B3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     CONS      COUNTER FOR DETERMINING ON LINE PRINT FREQUENCY
C     COSC      COS(THETA)
C     COSD      COS(B1)
C     COSE      COS(THETA-ALPHA/2.0)
C     COSG      COS(THETA+ALPHA/2.0)
C     C10,C20,C30      ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C               THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C               TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     C1PREV    VALUE OF C1 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C2PREV    VALUE OF C2 AT THE END OF THE PREVIOUS TIME INCREMENT
C     C3PREV    VALUE OF C3 AT THE END OF THE PREVIOUS TIME INCREMENT
C     D         VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
```

Figure 7-7. Main Program

```
C     DELTAP    DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C               LEG STRUTS
C     DELTAT    TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     DELTTT    TIME INCREMENT USED IN THE INTEGRATION OF FOOTPAD
C               MOTION.   DELTTT= DELTAT/KCONMX
C     D10       INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C               OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C               TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     D11       VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     EGBAL1    ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND C.G.
C               DROP
C     EGBAL2    ENERGY DISSIPATED BASED ON PLASTIC STROKE OF ALL STRUTS
C     EGBAL3    ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC
C               STROKE OF ALL STRUTS
C     ENPRO(I)  PERCENT OF TOTAL ENERGY ABSORBED BY  STROKING OF THE
C               STRUTS OF LEG SET I
C     EPSEN     PROGRAM CONSTANT EQUAL TO 10 PERCENT OF THE POSSIBLE
C               POTENTIAL ENERGY WHICH COULD BE STORED IN A FOOTPAD
C               AS THE RESULT OF ELASTIC STROKING OF  THE UPPER STRUT
C     EPS2      MINIMUM ALLOWABLE FOOTPAD SLIDING VELOCITY
C     EPS3      LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN X DIRECTION
C     EPS4      LIMITING MINIMUM VELOCITY OF VEHICLE C.G. IN Y AND Z
C               DIRECTIONS
C     EPS5      LIMITING MINIMUM ANGULAR VELOCITIES
C     NOTE      IF XVEL IS LESS THAN EPS3, YVEL AND ZVEL ARE LESS THAN
C               EPS4 AND THE ANGULAR VELOCITIES ARE LESS THAN EPS5
C               SIMULTANEOUSLY AND THE FOOTPADS ARE ALL LESS THAN 1 FT.
C               FROM THE GROUND, THE PROGRAM TERMINATES
C     E1(I)     POTIENTAL ENERGY STORED IN STRUT NO.1 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     E2(I)     POTIENTAL ENERGY STORED IN STRUT NO.2 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     E3(I)     POTIENTAL ENERGY STORED IN STRUT NO.3 OF LEG I DUE TO
C               COMPRESSION OR EXTENSION OF THE LEG
C     FA(I)     FORCE IN THE Z DIRECTION ACTING ON THE VEHICLE C.G. AS
C               THE RESULTANT OF THE STRUT FORCES IN THE THREE STRUTS
C               OF THE I TH LEG SET
C     FAG(I)    FORCE IN THE Z DIRECTION ACTING ON THE VEHICLE C.G. AS
C               THE RESULTANT OF THE STRUT FORCES IN THE THREE STRUTS
C               OF THE I TH LEG SET (GROUND COORDINATE SYSTEM)
C     FB(I)     FORCE, PARALLEL TO THE VEHICLE CENTERLINE  ACTING ON THE
C               VEHICLE C.G. AS THE RESULTANT OF THE STRUT FORCES IN
C               THE THREE STRUTS OF THE I TH LEG SET
C     FBG(I)    FORCE IN THE X DIRECTION ACTING ON THE VEHICLE C.G. AS
C               THE RESULTANT OF THE STRUT FORCES IN THE THREE STRUTS
C               OF THE I TH LEG SET (GROUND COORDINATE SYSTEM)
C     FC(I)     FORCE, NORMAL TO VEHICLE CENTERLINE IN THE X-Y PLANE
C               ACTING ON THE VEHICLE C.G. AS THE RESULTANT OF THE STRUT
C               FORCES IN THE THREE STRUTS OF THE I TH LEG SET
C     FCG(I)    FORCE IN THE Y DIRECTION ACTING ON THE VEHICLE C.G. AS
C               THE RESULTANT OF THE STRUT FORCES IN THE THREE STRUTS
C               OF THE I TH LEG SET (GROUND COORDINATE SYSTEM)
C     FINT      MAXIMUM ALLOWABLE TIME FOR COMPUTER RUN
C     FX        SAME AS FXP
C     FXP(I)    FORCE IN THE X DIRECTION ON THE FOOTPAD (I)
C     FXPLG1    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPLG2    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
```

Figure 7-7. Main Program (Continued)

```
C     FXPLG3    AVERAGE FORCE IN THE X DIRECTION ACTING ON FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FXPL31    FXPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FXPL33    FXPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FXPL35    FXPLG3 VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     FXPL37    FXPLG3 VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     FX1       FX     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FX3       FX     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FX5       FX     VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     FX7       FX     VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     FYPLG1    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG2    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO 2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPLG3    AVERAGE FORCE IN THE Y DIRECTION ACTING ON  FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FYPL31    FYPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FYPL33    FYPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FYPL35    FYPLG3 VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     FYPL37    FYPLG3 VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     FZPLG1    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.1
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG2    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.2
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPLG3    AVERAGE FORCE IN THE Z DIRECTION ACTING ON FOOTPAD NO.3
C               DURING THE TIME INTERVAL DT.   THIS FORCE IS DEFINED BY
C               THE PARABOLIC INTEGRATION PROCEDURE
C     FZPL31    FZPLG3 VALUE FOR LEG II    STORED FOR FINAL PRINT
C     FZPL33    FZPLG3 VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     FZPL35    FZPLG3 VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     FZPL37    FZPLG3 VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     F1(I)     PLASTIC STROKE FORCE IN STRUT NO.1 OF LEG I
C     F2(I)     PLASTIC STROKE FORCE IN STRUT NO.2 OF LEG I
C     F3(I)     PLASTIC STROKE FORCE IN STRUT NO.3 OF LEG I
C     F11       PLASTIC STROKE FORCE FOR UPPER STRUT (NO. 1)
C     F22       PLASTIC STROKE FORCE FOR LOWER STRUT NO. 2
C     F33       PLASTIC STROKE FORCE FOR LOWER STRUT NO. 3
C     GRAV      LOCAL GRAVITY
C     GRDMU     COEFFICIENT OF FRICTION BETWEEN VEHICLE FOOTPADS AND GROUND
C     GRFX      FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               (GROUND COORDINATE SYSTEM )    THIS FORCE IS USED
C               IN THE INTEGRATION OF EQUATIONS OF MOTION
C     GRFY      FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C               (GROUND COORDINATE SYSTEM )    THIS FORCE IS USED
C               IN THE INTEGRATION OF EQUATIONS OF MOTION
C     GRFZ      FORCE ACTING IN THE Z DIRECTION ON THE VEHICLE C.G.
C               (GROUND COORDINATE SYSTEM )    THIS FORCE IS USED
C               IN THE INTEGRATION OF EQUATIONS OF MOTION
C     H         DISTANCE FROM THE BOTTOM OF THE FOOTPAD TO THE VEHICLE
C               CENTER OF GRAVITY
C     HN        VERTICAL DISTANCE BETWEEN VEHICLE C.G. AND THE LOWEST
C               POINT ON THE NOZZLE CONE
C     IBEMIN    INDEX OF CRITICAL LEG FOR MINIMUM STABILITY ANGLE
C     IFLAG     FLAG FOR INITIALIZING THE PROGRAM
C     IFLAGE    FLAG USED TO PRINT ADDITIONAL OUTPUT
```

Figure 7-7. Main Program (Continued)

```
C     IFLAGX       FLAG USED IN FINAL PRINT   IFLAGX=+1  VEHICLE WAS STABLE,
C                  IFLAGX=0  MAXIMUM ALLOWABLE TIME WAS EXCEEDED,
C                  IFLAGX=-1  VEHICLE WAS UNSTABLE
C     IFRONT       INDEX OF FRONT LEG  (THE FRONT LEG IN THE DIRECTION OF
C                  MOTION IS THE CRITICAL LEG FOR STABILITY)
C     II           PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                  PRINTED AS OUTPUT  (INITIAL SUMMARY OUTPUT)
C     IIX          PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                  PRINTED AS OUTPUT  (ADDITIONAL SUMMARY OUTPUT)
C     IP           PRINT INDICATOR
C     IQ           PRINT INDICATOR
C     IR           PRINT INDICATOR
C     JJ           PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                  PRINTED AS OUTPUT  (INITIAL SUMMARY OUTPUT)
C     JJX          PARAMETER SPECIFYING WHICH LEG SET DATA WILL BE
C                  PRINTED AS OUTPUT  (ADDITIONAL SUMMARY OUTPUT)
CC    KCONMX       NUMBER OF ITERATIONS OF FOOTPAD CALCULATIONS PER  (DELTAT)
C                  TIME INTERVAL
C     KM           COUNTER FOR DETERMINING THE FREQUENCY OF THE STORED
C                  PRINTING
C     KPRINT       COMPUTATION INCREMENTS BETWEEN PRINTOUT INTERVALS
C     LINE         PRINTOUT LINE COUNTER
C     M            INDEX USED TO STORE VARIABLES FOR PRINT AT END OF RUN
C     MULT         INDICATOR FLAG USED TO PRINT STORED OUTPUT DATA AT LESS
C                  FREQUENT INTERVALS IF FINT IS SUCH THAT THE DIMENSIONED
C                  STORAGE CAPACITY FOR THE STORED VARIABLES WILL BE EXCEEDED.
C     N            NUMBER OF LEGS ON THE VEHICLE
C     NOGR(I)      INDICATES IF FOOTPAD (I) IS MOVING WITH THE VEHICLE.  IF
C                  NOGR(I)=-1, FOOTPAD IS MOVING WITH THE VEHICLE.  IF
C                  NOGR(I) =+1, FOOTPAD IS MOVING INDEPENDENTLY
C     NQO          STARTING COLUMN IN VELOCITY INPUT ARRAY
C     NQMAX        ENDING COLUMN IN VELOCITY ARRAY
C     NSO          STARTING ROW IN VELOCITY INPUT ARRAY
C     NSMAX        ENDING ROW IN VELOCITY ARRAY
C     NOTE         SEE WRITEUP FOR DISCUSSION OF VELOCITY ARRAY
C     NST          FLAG FOR DETERMINING STABILITY PROFILE INPUT SEQUENCE
C     NUN          FLAG FOR DETERMINING STABILITY PROFILE INPUT SEQUENCE
C     PHI          ANGLE BETWEEN VEHICLE CENTERLINE AND GRAVITY VECTOR
C     PITCH        INSTANTANEOUS PITCH ANGLE OF THE VEHICLE
C     PITCHO       INITIAL PITCH ANGLE OF THE VEHICLE
C     PITCHV       INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE
C     PMASS        MASS OF EACH FOOTPAD
C     PRXVEL       IN MULTIPLE RUNS, THIS IS THE INITIAL X VELOCITY OF THE
C                  PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C     PRYVEL       IN MULTIPLE RUNS, THIS IS THE INITIAL Y VELOCITY OF THE
C                  PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C     PRZVEL       IN MULTIPLE RUNS, THIS IS THE INITIAL Z VELOCITY OF THE
C                  PREVIOUS RUN.  IT IS USED TO PREVENT DUPLICATE RUNS.
C     PTCHVO       INITIAL PITCH VELOCITY OF THE VEHICLE
C     P1           FRICTION FORCE IN STRUT NO. 1
C     P2           FRICTION FORCE IN STRUT NO. 2
C     P3           FRICTION FORCE IN STRUT NO. 3
C     RMOMGX       MOMENT OF INERTIA OF FOOTPADS ABOUT X AXIS (YAW)
C                  THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C                  GROUND AT THE INSTANT UNDER INVESTIGATION
C     RMOMGY       MOMENT OF INERTIA OF FOOTPADS ABOUT Y AXIS (ROLL)
C                  THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C                  GROUND AT THE INSTANT UNDER INVESTIGATION
C     RMOMGZ       MOMENT OF INERTIA OF FOOTPADS ABOUT Z AXIS (PITCH)
C                  THIS TERM INCLUDES ONLY THOSE FOOTPADS WHICH ARE OFF THE
C                  GROUND AT THE INSTANT UNDER INVESTIGATION
```

Figure 7-7. Main Program (Continued)

```
C     RMOMX     TOTAL MOMENT OF INERTIA (VEHICLE AND FOOTPADS) ABOUT X AXIS
C     RMOMY     TOTAL MOMENT OF INERTIA (VEHICLE AND FOOTPADS) ABOUT Y AXIS
C     RMOMZ     TOTAL MOMENT OF INERTIA (VEHICLE AND FOOTPADS) ABOUT Z AXIS
C     RN        EXHAUST NOZZLE RADIUS
C     ROLL      INSTANTANEOUS ROLL ANGLE OF THE VEHICLE
C     ROLLO     INITIAL ROLL ANGLE OF THE VEHICLE
C     ROLLV     INSTANTANEOUS ROLL VELOCITY OF THE VEHICLE
C     ROLLVO    INITIAL ROLL VELOCITY OF THE VEHICLE
C     RP(I)     RADIUS OF FOOTPAD (I)
C     RUNNOO    RUN NUMBER  ( FOR IDENTIFICATION ONLY)
C     R1        RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2        RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     SERNO     SERIES NUMBER ( FOR IDENTIFICATION ONLY)
C     SINC      SIN(THETA)
C     SIND      SIN(B1)
C     SING      SIN(C1)
C     SINI      SIN(C3)
C     SINJ      SIN(THETA-ALPHA/2.0)
C     SINK      SIN(THETA+ALPHA/2.0)
C     SINL      SIN(C2)
C     SKE1      TENSIL ELASTIC SPRINGRATE OF STRUT NO. 1 (UPPER)
C     SKE2      TENSIL ELASTIC SPRINGRATE OF STRUT NO. 2 (LOWER)
C     SKE3      TENSIL ELASTIC SPRINGRATE OF STRUT NO. 3 (LOWER)
C     SKS       SPRINGRATE UNDER VEHICLE FOOTPADS
C     SK1       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 1(UPPER)
C     SK2       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO. 2(LOWER)
C     SK3       COMPRESSIVE ELASTIC SPRINGRATE OF STRUT NO.3 (LOWER)
C     SL1       PROJECTED LENGTH OF STRUT NO.1 IN PLANE PARALLEL TO
C               DIRECTION OF MOTION
C     SL1M      MINIMUM LENGTH TO WHICH STRUT NO.1 HAS BEEN COMPRESSED
C               DURING THIS RUN
C     SL1O      INITIAL VALUE OF SL1
C     SL1PRE    LENGTH OF STRUT NO.1 AT THE END OF THE PREVIOUS TIME
C               INCREMENT
C     SL1T      TRUE INSTANTANEOUS LENGTH OF STRUT NO.1
C     SL1TO     TRUE INITIAL LENGTH OF STRUT NO.1
C     SL2       INSTANTANEOUS LENGTH OF STRUT NO.2 ,PROJECTED IN A PLANE
C               PARALLEL TO THE DIRECTION OF MOTION
C     SL2M      MINIMUM LENGTH TO WHICH STRUT NO.2 HAS BEEN COMPRESSED
C               DURING THIS RUN
C     SL2PRE    LENGTH OF STRUT NO.2 AT THE END OF THE PREVIOUS TIME
C               INCREMENT
C     SL2T      TRUE INSTANTANEOUS LENGTH OF STRUT NO.2
C     SL2TO     TRUE INITIAL LENGTH OF STRUT NO.2
C     SL3       INSTANTANEOUS LENGTH OF STRUT NO.3 ,PROJECTED IN A PLANE
C               PARALLEL TO THE DIRECTION OF MOTION
C     SL3M      MINIMUM LENGTH TO WHICH STRUT NO.3 HAS BEEN COMPRESSED
C               DURING THIS RUN
C     SL3PRE    LENGTH OF STRUT NO.3 AT THE END OF THE PREVIOUS TIME
C               INCREMENT
C     SL3T      TRUE INSTANTANEOUS LENGTH OF STRUT NO.3
C     SL3TO     TRUE INITIAL LENGTH OF STRUT NO.3
C     THETA     ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C               DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C               CENTERLINE AND UPPER HARDPOINT
C     TIM       TIME   STORED FOR FINAL PRINT
C     TIME      TIME AFTER TOUCHDOWN
C     TIMBMI    TIME WHEN MIMIMUM STABILITY ANGLE OCCURS
C     TMINXN    TIME WHEN MINIMUM NOZZLE CLEARANCE OCCURS
C     VEMX      TORQUE ABOUT THE X AXIS OF THE VEHICLE
C               (GROUND COORDINATE SYSTEM )    THIS TORQUE IS USED
```

Figure 7-7. Main Program (Continued)

```
C                IN THE INTEGRATION OF EQUATIONS OF MOTION
C     VEMY       TORQUE ABOUT THE Y AXIS OF THE VEHICLE
C                (GROUND COORDINATE SYSTEM )    THIS TORQUE IS USED
C                IN THE INTEGRATION OF EQUATIONS OF MOTION
C     VEMZ       TORQUE ABOUT THE Z AXIS OF THE VEHICLE
C                (GROUND COORDINATE SYSTEM )    THIS TORQUE IS USED
C                IN THE INTEGRATION OF EQUATIONS OF MOTION
C     VMASS      VEHICLE MASS
C     X          INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XL(I,J)    SET OF DIRECTION COSINES RELATING VEHICLE COORDINATE
C                SYSTEM TO FIXED COORDINATE SYSTEM
C     XMIN       MINIMUM VALUE OF XP (USED ONLY FOR INITIAL POSITIONING
C                OF VEHICLE)
C     XMOMX      MOMENT OF INERTIA OF VEHICLE ABOUT X AXIS (YAW)
C     XMOMY      MOMENT OF INERTIA OF VEHICLE ABOUT Y AXIS (ROLL)
C     XMOMZ      MOMENT OF INERTIA OF VEHICLE ABOUT Z AXIS (PITCH)
C     XN         INSTANTANEOUS NOZZLE CLEARANCE NORMAL TO THE SURFACE
C     XNMIN      MINIMUM VALUE OF NOZZLE CLEARANCE
C     XP(I)      X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     XPV(I)     X POSITION OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C     XPVEL(I)   VELOCITY OF THE I TH FOOTPAD IN THE X DIRECTION IN THE
C                FIXED COORDINATE SYSTEM
C     XPVVEL(I)  X VELOCITY OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C     XPVVLR(I)  X VELOCITY OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C                WITH RIGID BODY MOTION
C     XP1        XP     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     XP3        XP     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     XP5        XP     VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     XP7        XP     VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     XVEL       INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C     XVELO      INITIAL VERTICAL VELOCITY OF VEHICLE C.G.
C     XVELOO     SAME AS XVELO
C     Y          INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YAW        INSTANTANEOUS YAW ANGLE OF THE VEHICLE
C     YAWO       INITIAL YAW ANGLE OF THE VEHICLE
C     YAWV       INSTANTANEOUS YAW VELOCITY OF THE VEHICLE
C     YAWVO      INITIAL YAW VELOCITY OF THE VEHICLE
C     YP(I)      Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     YPV(I)     Y POSITION OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C     YPVEL(I)   VELOCITY OF THE I TH FOOTPAD IN THE Y DIRECTION IN THE
C                FIXED COORDINATE SYSTEM
C     YPVVEL(I)  Y VELOCITY OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C     YPVVLR(I)  Y VELOCITY OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C                WITH RIGID BODY MOTION
C     YP1        YP     VALUE FOR LEG II    STORED FOR FINAL PRINT
C     YP3        YP     VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     YP5        YP     VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     YP7        YP     VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     YVEL       INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C     YVELO      INITIAL HORIZONTAL VELOCITY OF VEHICLE C.G.
C     YVELOO     SAME AS YVELO
C     Z          INSTANTANEOUS Z POSITION OF THE VEHICLE C.G.
C     ZETA       GROUND SLOPE
C     ZP(I)      Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZPV(I)     Z POSITION OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C     ZPVEL(I)   VELOCITY OF THE I TH FOOTPAD IN THE Z DIRECTION IN THE
C                FIXED COORDINATE SYSTEM
C     ZPVVEL(I)  Z VELOCITY OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C     ZPVVLR(I)  Z VELOCITY OF FOOTPAD I IN THE VEHICLE COORDINATE SYSTEM
C                WITH RIGID BODY MOTION
C     ZP1        ZP     VALUE FOR LEG II    STORED FOR FINAL PRINT
```

Figure 7-7. Main Program (Continued)

```
C     ZP3       ZP    VALUE FOR LEG JJ    STORED FOR FINAL PRINT
C     ZP5       ZP    VALUE FOR LEG IIX   STORED FOR FINAL PRINT
C     ZP7       ZP    VALUE FOR LEG JJX   STORED FOR FINAL PRINT
C     ZVEL      INSTANTANEOUS Z VELOCITY OF THE VEHICLE C.G.
C     ZVELO     INITIAL TRANSVERSE VELOCITY OF VEHICLE C.G.
C     ZVELOO    SAME AS ZVELO
C
C
C
      DIMENSION B1(5),B2(5),B3(5),C1(5),C2(5),C3(5),SL1TO(5),SL2TO(5),
     1SL3TO(5),SL1T(5),SL2T(5),SL3T(5),SL1(5),SL2(5),SL3(5),B1O(5),
     1SL1O(5),D1O(5),D1(5),THETA(5),XP(5),YP(5),ZP(5),B2O(5),B3O(5),
     1C1O(5),C2O(5),C3O(5),XPVEL(5),YPVEL(5),ZPVEL(5),F1(5),F2(5),F3(5),
     1FA(5),FB(5),FC(5),SL1M(5),SL2M(5),SL3M(5),
     1B2MI(5),B2PL(5),B2PREV(5),B3MI(5),B3PL(5),B3PREV(5),C1MI(5),
     1C1PL(5),C1PREV(5),C2MI(5),C2PL(5),C2PREV(5),C3MI(5),C3PL(5),
     1C3PREV(5),SL1PRE(5),SL2PRE(5),SL3PRE(5),GRDMU(5),FX(5),
     1XVELO(14,8),YVELO(14,8),ZVELO(14,8),         PADENG(5),E1(5),
     1E2(5),E3(5),TIM(200) ,XP3(200) ,YP3(200) ,ZP3(200) ,NOGR(5)
      DIMENSION  FXPLG3(5),FYPLG3(5),FZPLG3(5),
     1COSC(5),SINC(5),SIND(5),COSD(5),SING(5),SINJ(5),
     1SINI(5),COSE(5),COSG(5),SINK(5),SINL(5),
     1FXPLG1(5),FXPLG2(5),FYPLG1(5),FYPLG2(5),FZPLG1(5),FZPLG2(5),
     1 R1(5),R2(5),D11(5),D(5),F11(5),F22(5),F33(5),P1(5),P2(5),P3(5),
     1XP1(200) ,YP1(200) ,ZP1(200) ,FX1(200) ,FX3(200) ,FXPL33(200) ,
     1FYPL33(200) ,FZPL33(200) ,FXPL31(200) ,FYPL31(200) ,FZPL31(200) ,
     1XP5(200) ,YP5(200) ,ZP5(200) ,XP7(200) ,YP7(200) ,ZP7(200) ,
     1FX5(200) ,FX7(200) ,FXPL37(200) ,FYPL37(200) ,FZPL37(200)
      DIMENSION  FXPL35(200),FYPL35(200),FZPL35(200),
     1ENGY(5),ENPRO(5),      EPSEN(5),                ALPHA(5),
     1XL(3,3),XPV(5),YPV(5),ZPV(5),XPVVEL(5),YPVVEL(5),ZPVVEL(5),
     1FAG(5),FBG(5),FCG(5),XPVVLR(5),YPVVLR(5),ZPVVLR(5),RP(5),SKS(5)
C
C     READ INITIAL DATA
C
    1 READ 1000,(ALPHA(I),I=1,5),(D(I),I=1,5),(D11(I),I=1,5),
     1 (F11(I),I=1,5),(F22(I),I=1,5),(F33(I),I=1,5),(GRDMU(I),I=1,5),
     2 (P1(I),I=1,5),(P2(I),I=1,5),(P3(I),I=1,5),(R1(I),I=1,5),
     3 (R2(I),I=1,5),(THETA(I),I=1,5),(RP(I),I=1,5),(SKS(I),I=1,5)
      READ 1005,DELTAP,DELTAT,EPS2,EPS3,EPS4,EPS5,FINT,GRAV,HN,PMASS,
     1 RUNNOO,RN,SK1,SK2,SK3,SKE1,SKE2,SKE3,SERNO,VMASS,ZETA,PITCHO,
     2 YAWO,ROLLO,PTCHVO,YAWVO,ROLLVO,XMOMX,XMOMY,XMOMZ,H
      READ 1010,II,JJ,IIX,JJX,KPRINT,N,NSO,NQO,NSMAX,NQMAX,KCONMX
      READ 1015,((XVELO(ML,NL),YVELO(ML,NL),ZVELO(ML,NL),ML=1,NQMAX),NL=
     1 1,NSMAX)
C
C     CONVERT INPUT DATA TO PROPER FORM TO BE USED BY THE PROGRAM
      CALL INCON(R1,R2,RP,H,D11,D,DELTAP,THETA,ALPHA,SL1O,D1O,
     1 B1O,B2O,B3O,C1O,C2O,C3O,N,1)
C
C     INITIALIZE PROGRAM CONSTANTS
C
      DO 5 I=1,N
    5 EPSEN(I)=F11(I)*F11(I)/(SK1*20.0)
C
C     DETERMINE PRINTOUT FREQUENCY OF STORED OUTPUT
C
      FACTOR=FINT/200.0
      XPRINT=KPRINT
      IF(FACTOR-(DELTAT*XPRINT))7,8,8
    7 MULT=1
```

Figure 7-7. Main Program (Continued)

```
      GO TO 15
    8 IF(FACTOR-2.0*(DELTAT*XPRINT))9,12,12
    9 MULT=2
      GO TO 15
   12 MULT=5
C
C     SET STARTING POINT IN VELOCITY ARRAY
C
   15 NS=NSO
      NQ=NQO
C
C     INITIALIZE PROGRAM VARIABLES
C
      IFLAGE=-1
      RUNNO=RUNNOO-1.0
      PRXVEL=100.0
      PRYVEL=100.0
      PRZVEL=100.0
      XMIN=100.0
   20 NST=0
      NUN=0
   40 RUNNO=RUNNO+1.0
      LINE=0
C
C     ZERO OUT LINE COUNT
C
      KM=0
C
C     CHOOSE INITIAL TOUCHDOWN CONDITIONS
C
      PITCH=PITCHO
      YAW=YAWO
      ROLL=ROLLO
      PITCHV=PTCHVO
      YAWV=YAWVO
      ROLLV=ROLLVO
      XVELOO=XVELO(NQ,NS)
      YVELOO=YVELO(NQ,NS)
      ZVELOO=ZVELO(NQ,NS)
      XVEL=XVELO(NQ,NS)
      YVEL=YVELO(NQ,NS)
      ZVEL=ZVELO(NQ,NS)
C
C     FORM INIT. DIRECTION COSINE MATRIX    GROUND AXES TO VEHICLE AXES
C
      XL(1,1)=COS (PITCH)*COS (ROLL)-SIN (PITCH)*SIN (YAW)*SIN (ROLL)
      XL(2,1)=COS (PITCH)*SIN (YAW)*SIN (ROLL)+SIN (PITCH)*COS (ROLL)
      XL(3,1)=-COS (YAW)*SIN (ROLL)
      XL(1,2)=-SIN (PITCH)*COS (YAW)
      XL(2,2)=COS (PITCH)*COS (YAW)
      XL(3,2)=SIN (YAW)
      XL(1,3)=COS (PITCH)*SIN (ROLL)+SIN (PITCH)*SIN (YAW)*COS (ROLL)
      XL(2,3)= SIN (PITCH)*SIN (ROLL)-COS (PITCH)*SIN (YAW)*COS (ROLL)
      XL(3,3)=COS (YAW)*COS (ROLL)
C
C     PRINT INPUT DATA
C
      PRINT 1066
      PRINT 1025,(ALPHA(I),I=1,5)
      PRINT 1026,(D(I),I=1,5)
      PRINT 1027,(D11(I),I=1,5)
```

Figure 7-7. Main Program (Continued)

```
      PRINT 1028,(F11(I),I=1,5)
      PRINT 1029,(F22(I),I=1,5)
      PRINT 1030,(F33(I),I=1,5)
      PRINT 1031,(GRDMU(I),I=1,5)
      PRINT 1032,(P1(I),I=1,5)
      PRINT 1033,(P2(I),I=1,5)
      PRINT 1034,(P3(I),I=1,5)
      PRINT 1035,(R1(I),I=1,5)
      PRINT 1036,(R2(I),I=1,5)
      PRINT 1037,(RP(I),I=1,5)
      PRINT 1038,(THETA(I),I=1,5)
      PRINT 1039,(SKS(I),I=1,5)
      PRINT 1045,DELTAP,DELTAT,EPS2
      PRINT 1046,EPS3,EPS4,EPS5
      PRINT 1047,FINT,GRAV,HN
      PRINT 1048,PMASS,RUNNOO,RN
      PRINT 1049,SK1,SK2,SK3
      PRINT 1050,SKE1,SKE2,SKE3
      PRINT 1051,SERNO,VMASS,ZETA
      PRINT 1052,PITCHO,YAWO,ROLLO
      PRINT 1053,PTCHVO,YAWVO,ROLLO
      PRINT 1054,XMOMX,XMOMY,XMOMZ
      PRINT 1055,H
      PRINT 1056
      PRINT 1060,II,JJ,IIX,JJX,KPRINT,N
      PRINT 1061,NSO,NQO,NSMAX,NQMAX,KCONMX
      PRINT 1065,((XVELO(ML,NL),YVELO(ML,NL),ZVELO(ML,NL),ML=1,NQMAX),NL
     1=1,NSMAX)
      PRINT 1020
      PRINT 1021,((XL(I,J),J=1,3),I=1,3)
C
C     TEST IF TOUCHDOWN VELOCITIES DUPLICATE THOSE OF PREVIOUS RUN.
C     IF SO,CHOOSE NEXT POINT IN VELOCITY ARRAY.  OTHERWISE CONTINUE
C
      IF(PRXVEL-XVELOO)44,43,44
   43 IF(PRYVEL-YVELOO) 44,50,44
   50 IF(PRZVEL-ZVELOO) 44,845,44
   44 PRXVEL=XVELOO
      PRYVEL=YVELOO
      PRZVEL=ZVELOO
C
C     INITIALIZE PROGRAM VARIABLES
C
      TCONMX=KCONMX
      DELTTT=DELTAT/TCONMX
C
C     ZERO OUT INITIAL FORCES FOR PARABOLIC INTEGRATION OF FOOTPAD
C     FORCES
C
      DO 70 I=1,N
      E1(I)=0.0
      E2(I)=0.0
      E3(I)=0.0
      FXPLG3(I)=0.0
      FYPLG3(I)=0.0
      FZPLG3(I)=0.0
      FXPLG1(I)=0.0
      FXPLG2(I)=0.0
      FYPLG1(I)=0.0
      FYPLG2(I)=0.0
      FZPLG1(I)=0.0
```

Figure 7-7. Main Program (Continued)

```
      FZPLG2(I)=0.0
C
C     DETERMINE INITIAL STRUT ANGLES AND TRIGONOMETRIC RELATIONSHIPS
C
      B1(I)=B10(I)
      COSC(I)=COS (THETA(I))
      SINC(I)=SIN (THETA(I))
      SL1(I)=SL10(I)
      B2PREV(I)=B20(I)
      B3PREV(I)=B30(I)
      C1PREV(I)=C10(I)
      C2PREV(I)=C20(I)
      C3PREV(I)=C30(I)
   70 D1(I)=D10(I)
C
C     DETERMINE FOOTPAD POSITIONS AND VELOCITIES
C
      DO 75 I=1,N
      XPV(I)=-D11(I)-SL10(I)*COS (B10(I))
      YPV(I)=R1(I)*COSC(I)+SL10(I)*SIN (B10(I))
      ZPV(I)=-R1(I)*SINC(I)-D10(I)
      XP(I)=XL(1,1)*XPV(I)+XL(1,2)*YPV(I)+XL(1,3)*ZPV(I)
      YP(I)=XL(2,1)*XPV(I)+XL(2,2)*YPV(I)+XL(2,3)*ZPV(I)
   75 ZP(I)=XL(3,1)*XPV(I)+XL(3,2)*YPV(I)+XL(3,3)*ZPV(I)
      DO 78 I=1,N
      IF(XP(I)-XMIN) 77,78,78
   77 XMIN=XP(I)
   78 CONTINUE
      DO 79 I=1,N
   79 XP(I)=XP(I)-XMIN+DELTAP    -.001
C
C     FIX COORDINATES OF VEHICLE C.G.
C
      X=-XMIN+DELTAP
      Y=0.0
      Z=0.0
      XO=X
      DO 82 I=1,N
      XPVVEL(I)=     -PITCHV*YPV(I)+ROLLV*ZPV(I)
      YPVVEL(I)=      PITCHV*XPV(I)-YAWV*ZPV(I)
      ZPVVEL(I)=      YAWV*YPV(I)-ROLLV*XPV(I)
      XPVEL(I)=XL(1,1)*XPVVEL(I)+XL(1,2)*YPVVEL(I)+XL(1,3)*ZPVVEL(I)
     1  +XVEL
      YPVEL(I)=XL(2,1)*XPVVEL(I)+XL(2,2)*YPVVEL(I)+XL(2,3)*ZPVVEL(I)
     1  +YVEL
   82 ZPVEL(I)=XL(3,1)*XPVVEL(I)+XL(3,2)*YPVVEL(I)+XL(3,3)*ZPVVEL(I)
     1  +ZVEL
C
C     INITIALIZE PROGRAM FOR STRUT LENGTH CALCULATIONS
C
      DO 100 I=1,N
      NOGR(I)=1
      SL1PRE(I)=0.0
      SL2PRE(I)=0.0
      SL3PRE(I)=0.0
      SL1M(I)=F11(I)/SK1
      SL2M(I)=F22(I)/SK2
  100 SL3M(I)=F33(I)/SK3
      TIME=0.0
      CONS=0.0
      XNMIN=100.0
```

Figure 7-7. Main Program (Continued)

```
      BETMIN=10.0
      IBEMIN=0
      IFLAG=-1
C
C     DETERMINE TRIGONOMETRIC RELATIONSHIPS FOR STRUT LENGTH
C     CALCULATIONS.
C
      DO 130 I=1,N
      SIND(I)=SIN (B1(I))
      COSD(I)=COS (B1(I))
      COSE(I)=COS (THETA(I)-ALPHA(I)/2.0)
      COSG(I)=COS (THETA(I)+ALPHA(I)/2.0)
      SINJ(I)=SIN (THETA(I)-ALPHA(I)/2.0)
      SINK(I)=SIN (THETA(I)+ALPHA(I)/2.0)
C
C     DETERMINE STRUT LENGTHS
C
      SL1TO(I)=SQRT (SL1(I)*SL1(I)+D1(I)*D1(I))
      HALF3=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))*(SL1(I)*
     1SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))
      HALF4=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL2(I)=SQRT(HALF3+HALF4)
      SL2TO(I)=SQRT (SL2(I)*SL2(I)+(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I))*
     1(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I)))
      HALF1=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))*
     1(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))
      HALF2=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL3(I)=SQRT(HALF1+HALF2)
      SL3TO(I)=SQRT (SL3(I)*SL3(I)+(D1(I)-R2(I)*SINK(I)+R1(I)*SINC(I))*
     1(D1(I)-R2(I)*SINK(I)+R1(I)*SINC(I)))
      SL1T(I)=SL1TO(I)
      SL2T(I)=SL2TO(I)
  130 SL3T(I)=SL3TO(I)
C
C     DETERMINE STRUT ANGLES AND ASSIGN TO PROPER QUADRANTS
C
  140 DO 240 I=1,N
      IF(NOGR(I))240,240,145
  145 B2(I)=ATAN ((SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))/(SL1(I)*
     1COSD(I)-D(I)))
      B2MI(I)=B2(I)-3.14159265359
      B2PL(I)=B2(I)+3.14159265359
      DIFF1=ABS (B2MI(I)-B2PREV(I))
      DIFF2=ABS (B2(I)-B2PREV(I))
      DIFF3=ABS (B2PL(I)-B2PREV(I))
      IF(DIFF1-DIFF2)150,152,152
  150 IF(DIFF1-DIFF3)154,158,158
  152 IF(DIFF2-DIFF3)160,158,158
  154 B2(I)=B2MI(I)
      GO TO 160
  158 B2(I)=B2PL(I)
  160 B2PREV(I)=B2(I)
      B3(I)=ATAN ((SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))/(SL1(I)*
     1COSD(I)-D(I)))
      B3MI(I)=B3(I)-3.14159265359
      B3PL(I)=B3(I)+3.14159265359
      DIFF1=ABS (B3MI(I)-B3PREV(I))
      DIFF2=ABS (B3(I)-B3PREV(I))
      DIFF3=ABS (B3PL(I)-B3PREV(I))
      IF(DIFF1-DIFF2)170,172,172
  170 IF(DIFF1-DIFF3)174,178,178
```

Figure 7-7. Main Program (Continued)

```
  172 IF(DIFF2-DIFF3)180,178,178
  174 B3(I)=B3MI(I)
      GO TO 180
  178 B3(I)=B3PL(I)
  180 B3PREV(I)=B3(I)
      IF(D1(I))182,181,182
  181 C1(I)=1.5708
      GO TO 183
  182 C1(I)=ATAN (SL1(I)/D1(I))
  183 C1MI(I)=C1(I)-3.14159265359
      C1PL(I)=C1(I)+3.14159265359
      DIFF1=ABS (C1MI(I)-C1PREV(I))
      DIFF2=ABS (C1(I)-C1PREV(I))
      DIFF3=ABS (C1PL(I)-C1PREV(I))
      IF(DIFF1-DIFF2)190,192,192
  190 IF(DIFF1-DIFF3)194,198,198
  192 IF(DIFF2-DIFF3)200,198,198
  194 C1(I)=C1MI(I)
      GO TO 200
  198 C1(I)=C1PL(I)
  200 C1PREV(I)=C1(I)
      C2(I)=ATAN (SL2(I)/(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I)))
      C2MI(I)=C2(I)-3.14159265359
      C2PL(I)=C2(I)+3.14159265359
      DIFF1=ABS (C2MI(I)-C2PREV(I))
      DIFF2=ABS (C2(I)-C2PREV(I))
      DIFF3=ABS (C2PL(I)-C2PREV(I))
      IF(DIFF1-DIFF2)210,212,212
  210 IF(DIFF1-DIFF3)214,218,218
  212 IF(DIFF2-DIFF3)220,218,218
  214 C2(I)=C2MI(I)
      GO TO 220
  218 C2(I)=C2PL(I)
  220 C2PREV(I)=C2(I)
      C3(I)=ATAN (SL3(I)/(D1(I)+R1(I)*SINC(I)-R2(I)*SINK(I)))
      C3MI(I)=C3(I)-3.14159265359
      C3PL(I)=C3(I)+3.14159265359
      DIFF1=ABS (C3MI(I)-C3PREV(I))
      DIFF2=ABS (C3(I)-C3PREV(I))
      DIFF3=ABS (C3PL(I)-C3PREV(I))
      IF(DIFF1-DIFF2)230,232,232
  230 IF(DIFF1-DIFF3)234,236,236
  232 IF(DIFF2-DIFF3)238,236,236
  234 C3(I)=C3MI(I)
      GO TO 238
  236 C3(I)=C3PL(I)
  238 C3PREV(I)=C3(I)
  240 CONTINUE
      IF(IFLAG)250,250,280
C
C     STORE INFORMATION FOR FINAL PRINTOUT
C
  250 M=1
      TIM(M)=TIME
      XP1(M)=XP(II)
      YP1(M)=YP(II)
      ZP1(M)=ZP(II)
      XP3(M)=XP(JJ)
      YP3(M)=YP(JJ)
      ZP3(M)=ZP(JJ)
      FX1(M)=0.0
```

Figure 7-7. Main Program (Continued)

```
      FX3(M)=0.0
      FXPL31(M)=FXPLG3(II)
      FYPL31(M)=FYPLG3(II)
      FZPL31(M)=FZPLG3(II)
      FXPL33(M)=FXPLG3(JJ)
      FYPL33(M)=FYPLG3 (JJ)
      FZPL33(M)=FZPLG3(JJ)
      XP5(M)=XP(IIX)
      YP5(M)=YP(IIX)
      ZP5(M)=ZP(IIX)
      XP7(M)=XP(JJX)
      YP7(M)=YP(JJX)
      ZP7(M)=ZP(JJX)
      FX5(M)=0.0
      FX7(M)=0.0
      FXPL35(M)=FXPLG3(IIX)
      FYPL35(M)=FYPLG3(IIX)
      FZPL35(M)=FZPLG3(IIX)
      FXPL37(M)=FXPLG3(JJX)
      FYPL37(M)=FYPLG3(JJX)
      FZPL37(M)=FZPLG3(JJX)
C
C     COMPUTE INITIAL STABILITY ANGLE
C
      CALL STABAN(XVEL,YVEL,ZVEL,X,Y,Z,XP,YP,ZP,ZETA,N,BETAF,IFRONT)
      IF(TIME)275,275,277
C
C     PRINT INPUTED ANGLES AS CALCULATED BY THE COMPUTER AT TIME  =  0
C     AS CHECK ON DATA PROGRAMMING
C
  275 PRINT 940
      PRINT 1084,(B10(I),I=1,N)
      PRINT 1085,(B20(I),I=1,N)
      PRINT 1086,(B30(I),I=1,N)
      PRINT 1087,(C10(I),I=1,N)
      PRINT 1088,(C20(I),I=1,N)
      PRINT 1089,(C30(I),I=1,N)
      PRINT 1090,(SL10(I),I=1,N)
      PRINT 1091,(D10(I),I=1,N)
      PRINT 1056
      PRINT 1070,(XP(I),I=1,N)
      PRINT 1071,(YP(I),I=1,N)
      PRINT 1072,(ZP(I),I=1,N)
      PRINT 1073,(XPV(I),I=1,N)
      PRINT 1074,(YPV(I),I=1,N)
      PRINT 1075,(ZPV(I),I=1,N)
      PRINT 1056
      PRINT 1076,(XPVEL(I),I=1,N)
      PRINT 1077,(YPVEL(I),I=1,N)
      PRINT 1078,(ZPVEL(I),I=1,N)
      PRINT 1079,(XPVVEL(I),I=1,N)
      PRINT 1080,(YPVVEL(I),I=1,N)
      PRINT 1081,(ZPVVEL(I),I=1,N)
C
C     PRINT  ON  LINE  DATA
C
  277 PRINT 1066
      PRINT 1095,SERNO,RUNNO
      PRINT 1096
      PRINT 1097,TIME,X,Y,Z,XVEL,YVEL,ZVEL,PITCHV,ROLLV,YAWV,BETAF,
     1 IFRONT
```

Figure 7-7. Main Program (Continued)

```
      RMOMGX=0.0
      RMOMGY=0.0
      RMOMGZ=0.0
  280 DO 600 I=1,N
C
C     TEST IF FOOTPAD IS ON THE GROUND
C
      IF(XP(I)-DELTAP       )330,330,290
C
C     COMPUTE FOOTPAD VELOCITY RELATIVE TO C.G. AND DETERMINE RELATIVE
C     ENERGY OF FOOTPAD
C
  290 XPVVLR(I)=      -PITCHV*YPV(I)+ROLLV*ZPV(I)
      YPVVLR(I)=       PITCHV*XPV(I)-YAWV*ZPV(I)
      ZPVVLR(I)=       YAWV*YPV(I)-ROLLV*XPV(I)
      PADENG(I)=PMASS/2.0*((XPVVLR(I)-XPVVEL(I))**2+(YPVVLR(I)-
     1 YPVVEL(I))**2+(ZPVVLR(I)-ZPVVEL(I))**2)+E1(I)+E2(I)+E3(I)
C
C     TEST IF FOOTPAD IS MOVING WITH THE VEHICLE
C
      IF(PADENG(I)-EPSEN(I))300,300,330
C
C     FOOTPAD IS MOVING WITH THE VEHICLE.  SET FORCES EQUAL TO ZERO
C
  300 FA(I)=0.0
      FB(I)=0.0
      FC(I)=0.0
      FAG(I)=0.0
      FBG(I)=0.0
      FCG(I)=0.0
      FXPLG1(I)=0.0
      FXPLG2(I)=0.0
      FXPLG3(I)=0.0
      FYPLG1(I)=0.0
      FYPLG2(I)=0.0
      FYPLG3(I)=0.0
      FZPLG1(I)=0.0
      FZPLG2(I)=0.0
      FZPLG3(I)=0.0
      RMOMGX=RMOMGX+PMASS*(YPV(I)**2+ZPV(I)**2)
      RMOMGY=RMOMGY+PMASS*(XPV(I)**2+ZPV(I)**2)
      RMOMGZ=RMOMGZ+PMASS*(XPV(I)**2+YPV(I)**2)
      NOGR(I)=-1
C
C     FIND FOOTPAD POSITIONS AND VELOCITY BY RIGID BODY MOTION WITH
C     THE VEHICLE
C
      XPV(I)=-D11(I)-SL1(I)*COS (B1(I))
      YPV(I)=R1(I)*COSC(I)+SL1(I)*SIN (B1(I))
      ZPV(I)=-R1(I)*SINC(I)-D1(I)
      XPVVEL(I)=      -PITCHV*YPV(I)+ROLLV*ZPV(I)
      YPVVEL(I)=       PITCHV*XPV(I)-YAWV*ZPV(I)
      ZPVVEL(I)=       YAWV*YPV(I)-ROLLV*XPV(I)
      XP(I)=XL(1,1)*XPV(I)+XL(1,2)*YPV(I)+XL(1,3)*ZPV(I)+X
      YP(I)=XL(2,1)*XPV(I)+XL(2,2)*YPV(I)+XL(2,3)*ZPV(I)+Y
      ZP(I)=XL(3,1)*XPV(I)+XL(3,2)*YPV(I)+XL(3,3)*ZPV(I)+Z
      XPVEL(I)=XL(1,1)*XPVVEL(I)+XL(1,2)*YPVVEL(I)+XL(1,3)*ZPVVEL(I)
     1  +XVEL
      YPVEL(I)=XL(2,1)*XPVVEL(I)+XL(2,2)*YPVVEL(I)+XL(2,3)*ZPVVEL(I)
     1  +YVEL
      ZPVEL(I)=XL(3,1)*XPVVEL(I)+XL(3,2)*YPVVEL(I)+XL(3,3)*ZPVVEL(I)
```

Figure 7-7. Main Program (Continued)

```
     1  +ZVEL
      FX(I)=0.0
      GO TO 600
C
C     FOOTPAD IS MOVING INDEPENDENTLY OF THE VEHICLE , CALCULATE STRUT
C     FORCES AND FOOTPAD ENERGY
C
  330 SL=SL1TO(I)-SL1T(I)
      NOGR(I)=1
      IF(SL-SL1M(I)+F11(I)/SK1)334,334,375
  334 IF(SL)340,367,367
  340 IF(SL-SL1PRE(I))343,360,360
  343 F1(I)=SKE1*SL-P1(I)
      E1(I)=SKE1*SL*SL/2.0
      GO TO 393
  350 F1(I)=-P1(I)
      E1(I)=0.0
      GO TO 393
  360 F1(I)=SKE1*SL+P1(I)
      E1(I)=SKE1*SL*SL/2.0
      GO TO 393
  367 IF(SL-SL1PRE(I))350,370,370
  370 F1(I)=P1(I)
      E1(I)=0.0
      GO TO 393
  375 IF(SL-SL1M(I))378,390,390
  378 IF(SL-SL1PRE(I))385,380,380
  380 F1(I)=SK1*(SL-SL1M(I)+F11(I)/SK1)+P1(I)
      E1(I)=(SK1/2.0)*(SL-SL1M(I)+F11(I)/SK1)*(SL-SL1M(I)+F11(I)/SK1)
      GO TO 393
  385 F1(I)=SK1*(SL-SL1M(I)+F11(I)/SK1)-P1(I)
      E1(I)=(SK1/2.0)*(SL-SL1M(I)+F11(I)/SK1)*(SL-SL1M(I)+F11(I)/SK1)
      GO TO 393
  390 F1(I)=F11(I)+P1(I)
      E1(I)=(SK1/2.0)*(SL-SL1M(I)+F11(I)/SK1)*(SL-SL1M(I)+F11(I)/SK1)
  393 IF(SL-SL1M(I))400,400,396
  396 SL1M(I)=SL
  400 SL1PRE(I)=SL
      SL=SL2TO(I)-SL2T(I)
      IF(SL-SL2M(I)+F22(I)/SK2)403,403,433
  403 IF(SL)406,425,425
  406 IF(SL-SL2PRE(I))410,420,420
  410 F2(I)=SKE2*SL-P2(I)
      E2(I)=SKE2*SL*SL/2.0
      GO TO 450
  412 F2(I)=-P2(I)
      E2(I)=0.0
      GO TO 450
  420 F2(I)=SKE2*SL+P2(I)
      E2(I)=SKE2*SL*SL/2.0
      GO TO 450
  425 IF(SL-SL2PRE(I))412,430,430
  430 F2(I)=P2(I)
      E2(I)=0.0
      GO TO 450
  433 IF(SL-SL2M(I))436,446,446
  436 IF(SL-SL2PRE(I))443,440,440
  440 F2(I)=SK2*(SL-SL2M(I)+F22(I)/SK2)+P2(I)
      E2(I)=(SK2/2.0)*(SL-SL2M(I)+F22(I)/SK2)*(SL-SL2M(I)+F22(I)/SK2)
      GO TO 450
  443 F2(I)=SK2*(SL-SL2M(I)+F22(I)/SK2)-P2(I)
```

Figure 7-7. Main Program (Continued)

```
      E2(I)=(SK2/2.0)*(SL-SL2M(I)+F22(I)/SK2)*(SL-SL2M(I)+F22(I)/SK2)
      GO TO 450
  446 F2(I)=F22(I)+P2(I)
      E2(I)=(SK2/2.0)*(SL-SL2M(I)+F22(I)/SK2)*(SL-SL2M(I)+F22(I)/SK2)
  450 IF(SL-SL2M(I))454,454,452
  452 SL2M(I)=SL
  454 SL2PRE(I)=SL
      SL=SL3TO(I)-SL3T(I)
      IF(SL-SL3M(I)+F33(I)/SK3)458,458,486
  458 IF(SL)460,480,480
  460 IF(SL-SL3PRE(I))465,475,475
  465 F3(I)=SKE3*SL-P3(I)
      E3(I)=SKE3*SL*SL/2.0
      GO TO 505
  470 F3(I)=-P3(I)
      E3(I)=0.0
      GO TO 505
  475 F3(I)=SKE3*SL+P3(I)
      E3(I)=SKE3*SL*SL/2.0
      GO TO 505
  480 IF(SL-SL3PRE(I))470,483,483
  483 F3(I)=P3(I)
      E3(I)=0.0
      GO TO 505
  486 IF(SL-SL3M(I))490,500,500
  490 IF(SL-SL3PRE(I))496,493,493
  493 F3(I)=SK3*(SL-SL3M(I)+F33(I)/SK3)+P3(I)
      E3(I)=SK3/2.0 *(SL-SL3M(I)+F33(I)/SK3)*(SL-SL3M(I)+F33(I)/SK3)
      GO TO 505
  496 F3(I)=SK3*(SL-SL3M(I)+F33(I)/SK3)-P3(I)
      E3(I)=SK3/2.0 *(SL-SL3M(I)+F33(I)/SK3)*(SL-SL3M(I)+F33(I)/SK3)
      GO TO 505
  500 F3(I)=F33(I)+P3(I)
      E3(I)=SK3/2.0 *(SL-SL3M(I)+F33(I)/SK3)*(SL-SL3M(I)+F33(I)/SK3)
  505 IF(SL-SL3M(I))510,510,507
  507 SL3M(I)=SL
  510 SL3PRE(I)=SL
C
C     CALCULATE COMPONENTS OF STRUT FORCE
C
      SING(I)=SIN (C1(I))
      SINL(I)=SIN (C2(I))
      SINI(I)=SIN (C3(I))
      FA(I)=F1(I)*COS (C1(I))+F2(I)*COS (C2(I))+F3(I)*COS (C3(I))
      FB(I)=F1(I)*SING(I)*COSD(I)+F2(I)*SINL(I)*COS (B2(I))+F3(I)*
     1SINI(I)*COS (B3(I))
      FC(I)=F1(I)*SING(I)*SIND(I)+F2(I)*SINL(I)*SIN (B2(I))+F3(I)*
     1SINI(I)*SIN (B3(I))
      FBG(I)=-XL(1,1)*FB(I)+XL(1,2)*FC(I)-XL(1,3)*FA(I)
      FCG(I)=-XL(2,1)*FB(I)+XL(2,2)*FC(I)-XL(2,3)*FA(I)
      FAG(I)= XL(3,1)*FB(I)-XL(3,2)*FC(I)+XL(3,3)*FA(I)
C
C     DETERMINE FORCES ACTING ON FOOTPAD AND FOOTPAD MOTIONS
C
      KCON=0
  515 KCON=KCON+1
      SLVEL=SQRT ((YPVEL(I))*(YPVEL(I))+(ZPVEL(I))*(ZPVEL(I)))
      IF(SLVEL-EPS2)530,535,535
  530 SLVEL=EPS2
  535 FXP=SKS(I)*(DELTAP-XP(I))
      IF(FXP)540,540,545
```

Figure 7-7. Main Program (Continued)

```
  540 FX(I)=0.0
      GO TO 550
  545 FX(I)=FXP
  550 TEMP2=GRDMU(I)*FX(I)/(PMASS*SLVEL)
      FYPLG3(I)=(FCG(I)/PMASS+GRAV*SIN (ZETA))*PMASS
      YP(I)=YP(I)+YPVEL(I)*DELTTT+(19.0*FYPLG3(I)-10.0*FYPLG2(I)+3.0*
     1FYPLG1(I))*DELTTT*DELTTT/(24.0*PMASS)-TEMP2*YPVEL(I)*DELTTT*
     2DELTTT/2.0
      YPVEL(I)=YPVEL(I)+(23.0*FYPLG3(I)-16.0*FYPLG2(I)+5.0*FYPLG1(I))*
     1DELTTT/(12.0*PMASS)-TEMP2*YPVEL(I)*DELTTT
      FZPLG3(I)=FAG(I)
      ZP(I)=ZP(I)+ZPVEL(I)*DELTTT+(19.0*FZPLG3(I)-10.0*FZPLG2(I)+3.0*
     1FZPLG1(I))*DELTTT*DELTTT/(24.0*PMASS)-TEMP2*ZPVEL(I)*DELTTT*
     2DELTTT/2.0
      ZPVEL(I)=ZPVEL(I)+(23.0*FZPLG3(I)-16.0*FZPLG2(I)+5.0*FZPLG1(I))*
     1DELTTT/(12.0*PMASS)-TEMP2*ZPVEL(I)*DELTTT
      FXPLG3(I)=FBG(I)-GRAV*COS (ZETA)*PMASS
      XP(I)=XP(I)+XPVEL(I)*DELTAT+(19.0*FXPLG3(I)-10.0*FX PLG2(I)+3.0*
     1FXPLG1(I))*DELTTT*DELTTT/(24.0*PMASS)+FX(I)*DELTTT*DELTTT/
     2(2.0*PMASS)
      XPVEL(I)=XPVEL(I)+(23.0*FXPLG3(I)-16.0*FXPLG2(I)+5.0*FXPLG1(I))*
     1DELTTT/(12.0*PMASS)+FX(I)*DELTTT/PMASS
      XPV(I)=XL(1,1)*(XP(I)-X)+XL(2,1)*(YP(I)-Y)+XL(3,1)*(ZP(I)-Z)
      YPV(I)=XL(1,2)*(XP(I)-X)+XL(2,2)*(YP(I)-Y)+XL(3,2)*(ZP(I)-Z)
      ZPV(I)=XL(1,3)*(XP(I)-X)+XL(2,3)*(YP(I)-Y)+XL(3,3)*(ZP(I)-Z)
      XPVVEL(I)=XL(1,1)*(XPVEL(I)-XVEL)+XL(2,1)*(YPVEL(I)-YVEL)
     1 +XL(3,1)*(ZPVEL(I)-ZVEL)
      YPVVEL(I)=XL(1,2)*(XPVEL(I)-XVEL)+XL(2,2)*(YPVEL(I)-YVEL)
     1 +XL(3,2)*(ZPVEL(I)-ZVEL)
      ZPVVEL(I)=XL(1,3)*(XPVEL(I)-XVEL)+XL(2,3)*(YPVEL(I)-YVEL)
     1 +XL(3,3)*(ZPVEL(I)-ZVEL)
      IF(KCON-KCONMX)  515,600,600
  600 CONTINUE
C
C     DETERMINE FORCES ACTING ON THE VEHICLE
C
      GRFX=-FBG(1)-FBG(2)-FBG(3)-FBG(4)-VMASS*GRAV*COS (ZETA)
      GRFY=-FCG(1)-FCG(2)-FCG(3)-FCG(4)+VMASS*GRAV*SIN (ZETA)
      GRFZ= FAG(1)+FAG(2)+FAG(3)+FAG(4)
      VEMX=0.0
      VEMY=0.0
      VEMZ=0.0
      DO 610 I=1,N
      VEMX=VEMX-FA(I)*(SL1(I)*SIN (B1(I))+R1(I)*COSC(I))+FC(I)*
     1 (R1(I)*SINC(I)+D1(I))
      VEMY=VEMY-FA(I)*(SL1(I)*COS (B1(I))+D11(I))+FB(I)*
     1 (R1(I)*SINC(I)+D1(I))
  610 VEMZ=VEMZ+FB(I)*(R1(I)*COSC(I)+SL1(I)*SIN (B1(I)))-FC(I)*
     1 (SL1(I)*COS (B1(I))+D11(I))
      RMOMX=XMOMX+RMOMGX
      RMOMY=XMOMY+RMOMGY
      RMOMZ=XMOMZ+RMOMGZ
      RMOMGX=0.0
      RMOMGY=0.0
      RMOMGZ=0.0
C
C     DETERMINE VEHICLE C.G. MOTIONS
C
      PITCHV=-PITCHV
      YAWV=-YAWV
      ROLLV=-ROLLV
```

Figure 7-7. Main Program (Continued)

```
      CALL INTEQM(VEMX,VEMY,VEMZ,YAWV,ROLLV,PITCHV,DELTAT,X,XVEL,GRFX,
     1 Y,YVEL,GRFY,Z,ZVEL,GRFZ,XL,VMASS,RMOMX,RMOMY,RMOMZ)
      PITCHV=-PITCHV
      YAWV=-YAWV
      ROLLV=-ROLLV
C
C     INDEX PREVIOUS FORCES FOR THE NEXT INTEGRATION OF FOOTPAD
C     MOTION
C
      DO 639 I=1,N
      IF(NOGR(I))639,639,638
  638 FXPLG1(I)=FXPLG2(I)
      FXPLG2(I)=FXPLG3(I)
      FYPLG1(I)=FYPLG2(I)
      FYPLG2(I)=FYPLG3(I)
      FZPLG1(I)=FZPLG2(I)
      FZPLG2(I)=FZPLG3(I)
  639 CONTINUE
C
C     INCREMENT TIME FOR NEXT CALCULATION
C
      TIME=TIME+DELTAT
      CONS=CONS+1.0
C
C     TEST NOZZLE  =  GROUND CLEARANCE AND STORE MINIMUM VALUE
C
      XN=X-HN*XL(1,1)-RN*SQRT (1.0-XL(1,1)*XL(1,1))
      IF(XN-XNMIN)650,651,651
  650 XNMIN=XN
      TMINXN=TIME-DELTAT
      IF(TIME-2.0*DELTAT)653,653,651
C
C     TEST STABILITY ANGLE AND STORE MINIMUM VALUE
C
  651 IF(BETAF-BETMIN) 652,653,653
  652 BETMIN=BETAF
      TIMBMI=TIME-DELTAT
      IBEMIN=IFRONT
C
C     TEST IF VEHICLE IS STOPPED
C
  653 IF(ABS (XVEL)-EPS3) 654,654,668
  654 IF(ABS (YVEL)-EPS4) 655,655,668
  655 IF(ABS (ZVEL)-EPS4) 656,656,668
  656 IF(ABS (YAWV)-EPS5) 657,657,668
  657 IF(ABS (ROLLV)-EPS5) 658,658,668
  658 IF(ABS (PITCHV)-EPS5) 663,663,668
  663 DO 665 I=1,N
      IF(XP(I)-1.0)665,665,668
  665 CONTINUE
      GO TO 810
C
C     COMPUTE STABILITY ANGLE
C
  668 CONTINUE
      CALL STABAN(XVEL,YVEL,ZVEL,X,Y,Z,XP,YP,ZP,ZETA,N,BETAF,IFRONT)
C
C     TEST IF VEHICLE IS UNSTABLE
C
      IF(BETAF) 770,674,674
  674 IF(TIME-FINT)675,800,800
```

Figure 7-7. Main Program (Continued)

```
C
C     SET LINE COUNT AND STORAGE FOR PLOT ROUTINE
C
  675 KM=KM+1
      IF(CONS-KPRINT)710,680,680
  680 CONS=0.0
  687 IF(KM-MULT*KPRINT)700,688,688
C
C     STORE VARIABLES FOR THE PRINT TO BE MADE AT THE END OF THE RUN
C
  688 M=M+1
      TIM(M)=TIME
      XP3(M)=XP(JJ)
      YP3(M)=YP(JJ)
      ZP3(M)=ZP(JJ)
      XP1(M)=XP(II)
      YP1(M)=YP(II)
      ZP1(M)=ZP(II)
      FX1(M)=FX(II)
      FX3(M)=FX(JJ)
      FXPL33(M)=FXPLG3(JJ)
      FYPL33(M)=FYPLG3(JJ)
      FZPL33(M)=FZPLG3(JJ)
      FXPL31(M)=FXPLG3(II)
      FYPL31(M)=FYPLG3(II)
      FZPL31(M)=FZPLG3(II)
      XP5(M)=XP(IIX)
      YP5(M)=YP(IIX)
      ZP5(M)=ZP(IIX)
      XP7(M)=XP(JJX)
      YP7(M)=YP(JJX)
      ZP7(M)=ZP(JJX)
      FX5(M)=0.0
      FX7(M)=0.0
      FXPL35(M)=FXPLG3(IIX)
      FYPL35(M)=FYPLG3(IIX)
      FZPL35(M)=FZPLG3(IIX)
      FXPL37(M)=FXPLG3(JJX)
      FYPL37(M)=FYPLG3(JJX)
      FZPL37(M)=FZPLG3(JJX)
      KM=0
C
C     RECORD LINE COUNT FOR PRINT HEADINGS
C
  700 LINE=LINE+1
      IF(LINE-49)705,705,707
  705 PRINT 1097,TIME,X,Y,Z,XVEL,YVEL,ZVEL,PITCHV,ROLLV,YAWV,BETAF,
     1 IFRONT
      GO TO 710
  707 PRINT 1066
      PRINT 1096
      PRINT 1097,TIME,X,Y,Z,XVEL,YVEL,ZVEL,PITCHV,ROLLV,YAWV,BETAF,
     1 IFRONT
      LINE=0
  710 DO 730 I=1,N
      IF(NOGR(I))730,730,715
C
C     IF FOOTPAD IS ON THE GROUND, DETERMINE STRUT GEOMETRY
C
  715 SL1(I)=SQRT ((YPV(I)-R1(I)*COSC(I))**2+(XPV(I)+D11(I))**2)
      B1(I)=ATAN ((YPV(I)-R1(I)*COSC(I))/(-D11(I)-XPV(I)))
```

Figure 7-7. Main Program (Continued)

```
C
C     RESET PROGRAM CONSTANTS
C
      COSD(I)=COS (B1(I))
      SIND(I)=SIN (B1(I))
C
C     CALCULATE NEW STRUT LENGTHS
C
  720 D1(I)=-ZPV(I)-R1(I)*SINC(I)
      SL1T(I)=SQRT (SL1(I)*SL1(I)+D1(I)*D1(I))
      HALF3=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))*(SL1(I)*
     1SIND(I)+R1(I)*COSC(I)-R2(I)*COSE(I))
      HALF4=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL2(I)=SQRT(HALF3+HALF4)
      SL2T(I)=SQRT (SL2(I)*SL2(I)+(D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I))*(
     1D1(I)+R1(I)*SINC(I)-R2(I)*SINJ(I)))
      HALF1=(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))*
     1(SL1(I)*SIND(I)+R1(I)*COSC(I)-R2(I)*COSG(I))
      HALF2=(SL1(I)*COSD(I)-D(I))*(SL1(I)*COSD(I)-D(I))
      SL3(I)=SQRT(HALF1+HALF2)
      SL3T(I)=SQRT ((SL3(I)*SL3(I))+(D1(I)-R2(I)*SINK(I)+R1(I)*
     1SINC(I))*(D1(I)-R2(I)*SINK(I)+R1(I)*SINC(I)))
  730 CONTINUE
      IFLAG=1
      GO TO 140
C
C     VEHICLE IS UNSTABLE    PRINT OUTPUT DATA
C
  770 IFLAGX=-1
      PRINT 1066
      PRINT 1095,SERNO,RUNNO
      PRINT 905,TIME
      ASSIGN 785 TO MM
      GO TO 820
C
C     CHOOSE NEW VELOCITY CONDITIONS FROM INPUTED ARRAY FOR THE NEXT
C     RUN .
C
  785 IF(NST) 790,790,796
  790 NUN=1
      NQ=NQ-1
      IF(NQ)794,794,40
  794 NQ=NQ+1
  796 NS=NS+1
      IF(NS-NSMAX)20,20,840
  800 IFLAGX=0
      PRINT 1066
      PRINT 1095,SERNO,RUNNO
      PRINT 906,TIME
      GO TO 819
C
C     VEHICLE IS STABLE AND HAS STOPPED .  PRINT OUTPUT DATA
C
  810 IFLAGX=1
      PRINT 1066
      PRINT 1095,SERNO,RUNNO
      PRINT 904,TIME
  819 ASSIGN 824 TO MM
C
C     PRINT SUMMARY OUTPUT
```

Figure 7-7. Main Program (Continued)

```
 820 PRINT 907,(SL1M(I),I=1,N)
     PRINT 908,(SL2M(I),I=1,N)
     PRINT 909,(SL3M(I),I=1,N)
     PRINT 910,XNMIN,TMINXN
     PRINT 936,IBEMIN,BETMIN,TIMBMI
     EGBAL1=VMASS/2.0*(XVELOO**2-XVEL**2+YVELOO**2-YVEL**2+ZVELOO**2
    1 -ZVEL**2)+XMOMX/2.0*(YAWVO**2-YAWV**2)+XMOMY/2.0*(ROLLVO**2
    2 -ROLLV**2)+XMOMZ/2.0*(PTCHVO**2-PITCHV**2)
    3 +((XO-X)*COS (ZETA)+Y*SIN (ZETA))*VMASS*GRAV
     EGBAL2=0.0
     EGBAL3=0.0
     DO 821 I=1,N
 821 ENGY(I)=0.0
     DO 822 I=1,N
     ENGY(I)=     ((F11(I)+P1(I))*(SL1M(I)-F11(I)/SK1)+(F22(I)+P2(I))*(
    1SL2M(I)-F22(I)/SK2)+(F33(I)+P3(I))*(SL3M(I)-F33(I)/SK3))
     EGBAL2=EGBAL2+ENGY(I)
 822 EGBAL3=EGBAL3+     ((F11(I)+P1(I))*(SL1M(I)-F11(I)/(2.0*SK1))+(
    1F22(I)+P2(I))*(SL2M(I)-F22(I)/(2.0*SK2))+(F33(I)+P3(I))*(SL3M(I)-
    2F33(I)/(2.0*SK3)))
     DO 2822 I=1,N
2822 ENPRO(I)=(ENGY(I)/EGBAL2)*100.0
     PRINT 917,EGBAL1
     PRINT 918,EGBAL2
     PRINT 934,EGBAL3
     PRINT 938,IFRONT,BETAF
     PRINT 939,(ENPRO(I),I=1,N)
     IP=1
     IQ=50
     IR=-1
1822 IF(M-IQ)1823,1824,1824
1823 IQ=M
     IR=1
C
C    PRINT STORED OUTPUT INFORMATION
C
1824 PRINT 1066
     PRINT 930,II,II,II,JJ,JJ,JJ,II,JJ
     PRINT 931,(TIM(I),XP1(I),YP1(I),ZP1(I),XP3(I),YP3(I),ZP3(I),
    1FX1(I),FX3(I),I=IP,IQ)
     IF(IR)1825,1825,1826
1825 IP=IP+50
     IQ=IQ+50
     GO TO 1822
1826 IP=1
     IQ=50
     IR=-1
1827 IF(M-IQ)1828,1829,1829
1828 IQ=M
     IR=1
1829 PRINT 1066
     PRINT 932,II,II,II,JJ,JJ,JJ
     PRINT 933,(TIM(I),FXPL31(I),FYPL31(I),FZPL31(I),FXPL33(I),
    1FYPL33(I),FZPL33(I),I=IP,IQ)
     IF(IR)1830,1830,1831
1830 IP=IP+50
     IQ=IQ+50
     GO TO 1827
C
C    PLOTS MAY BE INSERTED HERE
```

Figure 7-7. Main Program (Continued)

```
 1831 IF(IFLAGE) 1905,1935,1935
 1905 IFLAGE=1
      II=IIX
      JJ=JJX
      DO 1910 I=1,M
      XP1(I)=XP5(I)
      YP1(I)=YP5(I)
      ZP1(I)=ZP5(I)
      XP3(I)=XP7(I)
      YP3(I)=YP7(I)
      ZP3(I)=ZP7(I)
      FX1(I)=FX5(I)
      FX3(I)=FX7(I)
      FXPL31(I)=FXPL35(I)
      FYPL31(I)=FYPL35(I)
      FZPL31(I)=FZPL35(I)
      FXPL33(I)=FXPL37(I)
      FYPL33(I)=FYPL37(I)
 1910 FZPL33(I)=FZPL37(I)
      IF(IFLAGX) 770,800,810
 1935 GO TO MM
C
C     CHOOSE NEW VELOCITY CONDITIONS FROM INPUTED ARRAY FOR THE NEXT
C     RUN .
C
  824 IF(NUN) 825,825,796
  825 NST=1
      NQ=NQ+1
      IF(NQ-NQMAX     )40,40,830
  830 NQ=NQ-1
      NS=NS+1
      IF(NS-NSMAX)833,833,840
  833 IF(NQ-NQMAX     )20,20,836
  836 NQ=NQ-1
      GO TO 833
  840 PRINT 1066
      GO TO 1
C
C     REMEMBER INITIAL STARTING VELOCITIES TO PREVENT DUPLICATE
C     RUNS BECAUSE OF INPUT ERRORS
C
  845 PRINT 1066
      PRINT 935
      STOP
C
C
C
C     FORMAT STATEMENTS FOR OUTPUT INFORMATION
C
C
C
C
  904 FORMAT(11H     STABLE,F7.3,5HSECS.///)
  905 FORMAT(13H     UNSTABLE,F7.3,5HSECS.///)
  906 FORMAT(9H     TIME,F7.3,5HSECS.///)
  907 FORMAT(32H     MAXIMUM STROKE  NO. 1 STRUT,5F12.3//)
  908 FORMAT(32H                     NO. 2 STRUT,5F12.3//)
  909 FORMAT(32H                     NO. 3 STRUT,5F12.3///)
  910 FORMAT(///32H    MINIMUM CLEARANCE OF NOZZLE=,F7.3,55H
     1TIME WHEN THE MINIMUM CLEARANCE OCCURS    =,F7.3///)
  911 FORMAT(54H     MINIMUM CLEARANCE BETWEEN SHOCK STRUT AND FRAME =)
```

Figure 7-7. Main Program (Continued)

```
 912 FORMAT(32H                                ,5F12.3///)
 914 FORMAT(32H      MAXIMUM STROKE  NO. 1 STRUT,4F12.3//)
 915 FORMAT(32H                      NO. 2 STRUT,4F12.3//)
 916 FORMAT(32H                      NO. 3 STRUT,4F12.3//)
 917 FORMAT(66H      ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND
    1C.G. DROP=,F11.3///)
 918 FORMAT(48H      ENERGY DISSIPATED BASED ON PLASTIC STROKE =,F11.3//
    1/)
 930 FORMAT(21H         TIME       XP(,I1,11H)        YP(,I1,11H)        ZP
    1(,I1,12H)          XP(,I1,11H)        YP(,I1,11H)        ZP(,I1,13H)
    1          FX(,I1,14H)          FX(,I1,1H)/)
 931 FORMAT(7F12.3,2F14.1)
 932 FORMAT(24H         TIME       FXPLG3(,I1,13H)      FYPLG3(,I1,13H)
    1 FZPLG3(,I1,13H)      FXPLG3(,I1,13H)      FYPLG3(,I1,13H)      FZPLG
    13(,I1,1H)/)
 933 FORMAT(F12.3,6F14.1)
 934 FORMAT(65H      ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC
    1 STROKE =,F11.3///)
 935 FORMAT(98H  X AND Y VELOCITIES ARE IDENTICAL TO THOSE OF THE PREVI
    1OUS RUN.  CHECK THE INPUT DATA FOR ERRORS )
 936 FORMAT(29H     MINIMUM STABILITY ANGLE B,I1,1H=,F7.3,55H
    1 TIME WHEN THIS STABILITY ANGLE OCCURS       =,F7.3///)
 938 FORMAT(27H     FINAL STABILITY ANGLE B,I1,1H=,F7.3///)
 939 FORMAT(48H     ENERGY DISTRIBUTION BETWEEN LEGS - PERCENT =,5F8.3//
    1/)
 940 FORMAT(//26H1  CALCULATED INPUT VALUES//)
1000 FORMAT(10X,5F12.5)
1005 FORMAT(10X,3F12.5)
1010 FORMAT(10X,6I10)
1015 FORMAT(10X,6F10.3)
1020 FORMAT(63H0     INIT. DIRECTION COSINE MATRIX   GROUND AXES TO VEHIC
    1LE AXES/)
1021 FORMAT(3F20.8)
1025 FORMAT(10X,10HALPHA     =,5F15.5)
1026 FORMAT(10X,10HD         =,5F15.5)
1027 FORMAT(10X,10HD11       =,5F15.5)
1028 FORMAT(10X,10HF11       =,5F15.5)
1029 FORMAT(10X,10HF22       =,5F15.5)
1030 FORMAT(10X,10HF33       =,5F15.5)
1031 FORMAT(10X,10HGRDMU     =,5F15.5)
1032 FORMAT(10X,10HP1        =,5F15.5)
1033 FORMAT(10X,10HP2        =,5F15.5)
1034 FORMAT(10X,10HP3        =,5F15.5)
1035 FORMAT(10X,10HR1        =,5F15.5)
1036 FORMAT(10X,10HR2        =,5F15.5)
1037 FORMAT(10X,10HRP        =,5F15.5)
1038 FORMAT(10X,10HTHETA     =,5F15.5)
1039 FORMAT(10X,10HSKS       =,5F15.5)
1045 FORMAT(10X,10HDELTAP    =,F15.5,10H   DELTAT =,F15.5,10H   EPS2    =,F
    115.5)
1046 FORMAT(10X,10HEPS3      =,F15.5,10H   EPS4   =,F15.5,10H   EPS5    =,F
    115.5)
1047 FORMAT(10X,10HFINT      =,F15.5,10H   GRAV   =,F15.5,10H   HN      =,F
    115.5)
1048 FORMAT(10X,10HPMASS     =,F15.5,10H   RUNNOO =,F15.5,10H   RN      =,F
    115.5)
1049 FORMAT(10X,10HSK1       =,F15.5,10H   SK2    =,F15.5,10H   SK3     =,F
    115.5)
1050 FORMAT(10X,10HSKE1      =,F15.5,10H   SKE2   =,F15.5,10H   SKE3    =,F
    115.5)
1051 FORMAT(10X,10HSERNO     =,F15.5,10H   VMASS  =,F15.5,10H   ZETA    =,F
```

Figure 7-7. Main Program (Continued)

```
     115.5)
1052 FORMAT(10X,10HPITCHO        =,F15.5,10H     YAWO    =,F15.5,10H     ROLLO   =,F
     115.5)
1053 FORMAT(10X,10HPTCHVO        =,F15.5,10H     YAWVO   =,F15.5,10H     ROLLVO  =,F
     115.5)
1054 FORMAT(10X,10HXMOMX         =,F15.5,10H     XMOMY   =,F15.5,10H     XMOMZ   =,F
     115.5)
1055 FORMAT(10X,10HH             =,F15.5)
1056 FORMAT(1H0)
1060 FORMAT(10X,10H         II =,I5,10H        JJ =,I5,10H        IIX =,I5,10H
     1     JJX =,I5,10H  KPRINT =,I5,10H        N =,I5)
1061 FORMAT(10X,10H        NSO =,I5,10H       NQO =,I5,10H      NSMAX =,I5,10H
     1  NQMAX =,I5,10H  KCONMX =,I5)
1065 FORMAT(15H0         XVELO,15H                 YVELO,15H                 ZVELO,15
     1H             XVELO,15H            YVELO,15H            ZVELO/(F17.4,5F15
     2.4))
1066 FORMAT(1H1)
1070 FORMAT(10X,10H        XP  =,5F15.8)
1071 FORMAT(10X,10H        YP  =,5F15.8)
1072 FORMAT(10X,10H        ZP  =,5F15.8)
1073 FORMAT(10X,10H       XPV  =,5F15.8)
1074 FORMAT(10X,10H       YPV  =,5F15.8)
1075 FORMAT(10X,10H       ZPV  =,5F15.8)
1076 FORMAT(10X,10H     XPVEL  =,5F15.8)
1077 FORMAT(10X,10H     YPVEL  =,5F15.8)
1078 FORMAT(10X,10H     ZPVEL  =,5F15.8)
1079 FORMAT(10X,10H    XPVVEL  =,5F15.8)
1080 FORMAT(10X,10H    YPVVEL  =,5F15.8)
1081 FORMAT(10X,10H    ZPVVEL  =,5F15.8)
1084 FORMAT(10X,10H       B10  =,5F15.8)
1085 FORMAT(10X,10H       B20  =,5F15.8)
1086 FORMAT(10X,10H       B30  =,5F15.8)
1087 FORMAT(10X,10H       C10  =,5F15.8)
1088 FORMAT(10X,10H       C20  =,5F15.8)
1089 FORMAT(10X,10H       C30  =,5F15.8)
1090 FORMAT(10X,10H      SL10  =,5F15.8)
1091 FORMAT(10X,10H       D10  =,5F15.8)
1095 FORMAT(13H   SERIES NO.,F7.2,10H    RUN NO.,F7.2///)
1096 FORMAT(114H TIME        X          Y          Z          XVEL        YVEL
     1    ZVEL      PITCHV      ROLLV        YAWV       BETAF      LEG NO./)
1097 FORMAT(F6.3,3F9.3,7F10.3,I8)
      END
```

Figure 7-7. Main Program (Concluded)

```
C
C     TITLE      INCON       SUBROUTINE INCON
C
C     AUTHOR     J. GIBSON     BENDIX PRODUCTS AEROSPACE DIVISION
C
C     DATE       NOV. 1964
C
C     PURPOSE    THIS SUBROUTINE CONVERTS THE INPUT DATA TO THE PROPER
C                FORM FOR USE IN THE MAIN PROGRAM
C
C     CALL       CALL INCON
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM WAS COMPILED ON THE UNIVAC 1107 DIGITAL
C                COMPUTER
C
C     INPUT      BY EQUIVALENCE TO COMMON
C
C     SYMBOL     DEFINITION
C
C     ALPHA      ANGLE(IN PLANE PERPENDICULAR TO THE VEHICLE CENTERLINE)
C                SUBTENDED BY THE LOWER HARDPOINTS AND VEHICLE C.G.
C     D          VERTICAL DISTANCE BETWEEN UPPER AND LOWER HARDPOINTS
C     DELTAP     DISTANCE FROM BOTTOM OF FOOTPAD TO INTERSECTION OF THE
C                LEG STRUTS
C     D11        VERTICAL DISTANCE FROM VEHICLE C.G. TO UPPER HARDPOINT
C     H          DISTANCE FROM THE BOTTOM OF THE FOOTPAD TO THE VEHICLE
C                CENTER OF GRAVITY
C     RP(I)      RADIUS OF FOOTPAD (I)
C     R1         RADIUS OF UPPER HARDPOINT MOUNTING CIRCLE
C     R2         RADIUS OF LOWER HARDPOINT MOUNTING CIRCLE
C     THETA      ANGLE BETWEEN PLANE PARALLEL TO VEHICLE CENTERLINE IN
C                DIRECTION OF VEHICLE MOTION AND PLANE THROUGH VEHICLE
C                CENTERLINE AND UPPER HARDPOINT
C
C OUTPUT      THROUGH LABELED COMMON
C
C     SYMBOL     DEFINITION
C
C     B10        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 1 AND VEHICLE CENTERLINE
C     B20        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 2 AND VEHICLE CENTERLINE
C     B30        ANGLE ( PROJECTED IN PLANE PARALLEL TO VEHICLE MOTION)
C                BETWEEN STRUT NO. 3 AND VEHICLE CENTERLINE
C     C10,C20,C30     ANGLE , IN PLANE FORMED BY STRUT AND A NORMAL TO
C                THE DIRECTION OF MOTION, BETWEEN STRUT AND A PLANE NORMAL
C                TO THE VEHICLE CENTERLINE  -  FOR STRUTS 1,2,3 RESPECTIVELY
C     D10        INITIAL LENGTH (PROJECTED IN PLANE NORMAL TO DIRECTION
C                OF VEHICLE MOTION) OF THE COMPONENT (IN PLANE PERPENDICULAR
C                TO THE VEHICLE CENTERLINE) OF STRUT NO 1 LENGTH
C     SL10       INITIAL VALUE OF SL1
C
C
      SUBROUTINE INCON(R1,R2,RP,H,D11,D,DELTAP,THETA,ALPHA,SL10,D10,
     1B10,B20,B30,C10,C20,C30,N,K)
      DIMENSION R1(5),R2(5),RP(5),THETA(5),ALPHA(5),SL10(5),D10(5),B10(5
     1),B20(5),B30(5),C10(5),C20(5),C30(5),D11(5),D(5),C1ANG(5),
     1C2ANG(5),C3ANG(5)
```

Figure 7-8. Subroutine INCON

```
    1 DO 100 I=1,N,K
      SL10(I)=SQRT((H-DELTAP-D11(I))*(H-DELTAP-D11(I))+((RP(I)-R1(I))*
     1COS(THETA(I)))*((RP(I)-R1(I))*COS(THETA(I))))
      D10(I)=(RP(I)-R1(I))*SIN(THETA(I))
      B10(I)=ATAN((RP(I)-R1(I))*COS(THETA(I))/(H-DELTAP-D11(I)))
      B20(I)=ATAN((RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)-ALPHA(I)/2.0
     1))/(H-DELTAP-D11(I)-D(I)))
      B30(I)=ATAN((RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)+ALPHA(I)/2.0
     1))/(H-DELTAP-D11(I)-D(I)))
      IF (D10(I)) 10,11,10
   10 C1ANG(I)=ATAN(ABS(SL10(I)/D10(I)))
   11 S2X=RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)-ALPHA(I)/2.0)
      SL200=SQRT(S2X*S2X+(H-DELTAP-D11(I)-D(I))*(H-DELTAP-D11(I)-D(I)))
      C2ANG(I)=ATAN(ABS(SL200/(RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)-
     1ALPHA(I)/2.0))))
      S3X=RP(I)*COS(THETA(I))-R2(I)*COS(THETA(I)+ALPHA(I)/2.0)
      SL300=SQRT(S3X*S3X+(H-DELTAP-D11(I)-D(I))*(H-DELTAP-D11(I)-D(I)))
      C3ANG(I)=ATAN(ABS(SL300/(RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)+
     1ALPHA(I)/2.0))))
   64 IF (THETA(I)) 68,70,72
   68 C10(I)=3.14159265359-C1ANG(I)
      GO TO 76
   70 C10(I)=1.5707963
      GO TO 76
   72 C10(I)=C1ANG(I)
   76 IF (RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)-ALPHA(I)/2.0)) 80,82,84
   80 C20(I)=3.14159265359-C2ANG(I)
      GO TO 88
   82 C20(I)=1.5707963
      GO TO 88
   84 C20(I)=C2ANG(I)
   88 IF (RP(I)*SIN(THETA(I))-R2(I)*SIN(THETA(I)+ALPHA(I)/2.0)) 92,94,96
   92 C30(I)=3.14159265359-C3ANG(I)
      GO TO 100
   94 C30(I)=1.5707963
      GO TO 100
   96 C30(I)=C3ANG(I)
  100 CONTINUE
      RETURN
      END
```

Figure 7-8. Subroutine INCON (Concluded)

```
C
C     TITLE      STABAN        SUBROUTINE STABILITY ANGLE
C
C     AUTHOR     J. CADORET    BENDIX PRODUCTS AEROSPACE DIVISION
C
C     DATE       NOV. 1964
C
C
C     PURPOSE    THIS SUBROUTINE COMPUTES THE VEHICLE STABILITY ANGLE
C
C     CALL       CALL STABAN
C
C     NOTE       THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE       THIS PROGRAM WAS COMPILED ON THE UNIVAC 1107 DIGITAL
C                COMPUTER
C
C     INPUT      BY EQUIVALENCE TO COMMON
C
C     SYMBOL     DEFINITION
C
C     N          NUMBER OF LEGS ON THE VEHICLE
C     X          INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XP(I)      X POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     XVEL       INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C     Y          INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YP(I)      Y POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     YVEL       INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C     ZETA       GROUND SLOPE
C     Z          INSTANTANEOUS Z POSITION OF THE VEHICLE C.G.
C     ZP(I)      Z POSITION OF FOOTPAD I IN THE FIXED COORDINATE SYSTEM
C     ZVEL       INSTANTANEOUS Z VELOCITY OF THE VEHICLE C.G.
C
C     OUTPUT     BY EQUIVALENCE TO COMMON
C
C     SYMBOL     DEFINITION
C
C     BETAF      STABILITY ANGLE FOR FRONT LEG IN THE DIRECTION OF MOTION
C     IFRONT     INDEX OF FRONT LEG  (THE FRONT LEG IN THE DIRECTION OF
C                MOTION IS THE CRITICAL LEG FOR STABILITY)
C
C
      SUBROUTINE STABAN(XVEL,YVEL,ZVEL,X,Y,Z,XP,YP,ZP,ZETA,N,BETAF,
     1 IFRONT)
      DIMENSION XP(5),YP(5),ZP(5),XPM(5),YPM(5)
      YVELGV=XVEL*SIN(ZETA)+YVEL*COS(ZETA)
      ZVELGV=ZVEL
      PHIPR=ATAN(ZVELGV/YVELGV)
      YM=X*SIN(ZETA)*COS(PHIPR)+Y*COS(ZETA)*COS(PHIPR)+Z*SIN(PHIPR)
      DO 10 IX=1,N
   10 YPM(IX)=XP(IX)*SIN(ZETA)*COS(PHIPR)+YP(IX)*COS(ZETA)*COS(PHIPR)
     1 +ZP(IX)*SIN(PHIPR)
C
C     FIND LARGEST VALUE OF YPM(I)
C
      IFRONT=1
      DO 20 IX=2,N
      IF(YPM(IX)-YPM(IFRONT)) 20,20,18
   18 IFRONT=IX
   20 CONTINUE
```

Figure 7-9. Subroutine STABAN

```
XM=X*COS(ZETA)-Y*SIN(ZETA)
XPM(IFRONT)=XP(IFRONT)*COS(ZETA)-YP(IFRONT)*SIN(ZETA)
BETAF=ATAN((YPM(IFRONT)-YM)/(XM-XPM(IFRONT)))
RETURN
END
```

Figure 7-9. Subroutine STABAN (Concluded)

```
C
C     TITLE     INTEQM       SUBROUTINE INTEQM
C
C     AUTHOR    R. DIX          BENDIX PRODUCTS AEROSPACE DIVISION
C
C     DATE      NOV. 1964
C
C     PURPOSE   THIS SUBROUTINE INTEGRATES THE EQUATIONS OF MOTION
C
C     CALL      CALL INTEQM
C
C     NOTE      THIS PROGRAM WAS WRITTEN IN FORTRAN IV
C
C     NOTE      THIS PROGRAM WAS COMPILED ON THE UNIVAC 1107 DIGITAL
C               COMPUTER
C
C     INPUT     BY EQUIVALENCE TO COMMON
C
C     SYMBOL    DEFINITION
C
C     G1        TORQUE ABOUT THE X AXIS OF THE VEHICLE
C               (GROUND COORDINATE SYSTEM )
C     G2        TORQUE ABOUT THE Y AXIS OF THE VEHICLE
C               (GROUND COORDINATE SYSTEM )
C     G3        TORQUE ABOUT THE Z AXIS OF THE VEHICLE
C               (GROUND COORDINATE SYSTEM )
C     Q1        TOTAL MOMENT OF INERTIA (VEHICLE AND FOOTPADS) ABOUT X AXIS
C     Q2        TOTAL MOMENT OF INERTIA (VEHICLE AND FOOTPADS) ABOUT Y AXIS
C     Q3        TOTAL MOMENT OF INERTIA (VEHICLE AND FOOTPADS) ABOUT Z AXIS
C     XMASS     VEHICLE MASS
C
C     OUTPUT    BY EQUIVALENCE TO COMMON
C
C     SYMBOL    DEFINITION
C
C     DT        TIME INTERVAL BETWEEN PROGRAM CALCULATIONS
C     FORCEX    FORCE ACTING IN THE X DIRECTION ON THE VEHICLE C.G.
C               (GROUND COORDINATE SYSTEM )
C     FORCEY    FORCE ACTING IN THE Y DIRECTION ON THE VEHICLE C.G.
C               (GROUND COORDINATE SYSTEM )
C     FORCEZ    FORCE ACTING IN THE Z DIRECTION ON THE VEHICLE C.G.
C               (GROUND COORDINATE SYSTEM )
C     W1E       INSTANTANEOUS YAW VELOCITY OF THE VEHICLE
C     W2E       INSTANTANEOUS ROLL VELOCITY OF THE VEHICLE
C     W3E       INSTANTANEOUS PITCH VELOCITY OF THE VEHICLE
C     XCOS(I,J) SET OF DIRECTION COSINES RELATING VEHICLE COORDINATE
C               SYSTEM TO FIXED COORDINATE SYSTEM
C     XCG       INSTANTANEOUS X POSITION OF THE VEHICLE C.G.
C     XDCG      INSTANTANEOUS X VELOCITY OF THE VEHICLE C.G.
C     YCG       INSTANTANEOUS Y POSITION OF THE VEHICLE C.G.
C     YDCG      INSTANTANEOUS Y VELOCITY OF THE VEHICLE C.G.
C     ZCG       INSTANTANEOUS Z POSITION OF THE VEHICLE C.G.
C     ZDCG      INSTANTANEOUS Z VELOCITY OF THE VEHICLE C.G.
C
C
      SUBROUTINE INTEQM(G1,G2,G3,W1E,W2E,W3E,DT,XCG,XDCG,FORCEX,
     1     YCG,YDCG,FORCEY,ZCG,ZDCG,FORCEZ,XCOS,XMASS,Q1,Q2,Q3)
C     INTEGRATE EQUATIONS OF MOTION
      DIMENSION  BRKT(3,3),VID(3,3),VIO(3,3),VIN(3,3),XN(3,3),XCOS(3,3)
C     INTEGRATE EQUATIONS
```

Figure 7-10. Subroutine INTEQM

```
      WD1=G1/Q1
      WD2=(1.0/Q2)*(G2+(Q3-Q1)*W1E*W3E)
      WD3=(1.0/Q3)*(G3+(Q1-Q2)*W2E*W1E)
      W1=W1E+WD1*DT/2.0
      W2=W2E+WD2*DT/2.0
      W3=W3E+WD3*DT/2.0
      XCG=XCG+XDCG*DT+FORCEX*DT*DT/(2.0*XMASS)
      XDCG=XDCG+FORCEX*DT/XMASS
      YCG=YCG+YDCG*DT+FORCEY*DT*DT/(2.0*XMASS)
      YDCG=YDCG+FORCEY*DT/XMASS
      ZCG=ZCG+ZDCG*DT+FORCEZ*DT*DT/(2.0*XMASS)
      ZDCG=ZDCG+FORCEZ*DT/XMASS
C     CALCULATE NEW  V-VECTOR (I,J,K  AXES)
      BRKT(1,1)=-(W2*W2+W3*W3)
      BRKT(1,2)=W1*W2+WD3
      BRKT(1,3)=W1*W3-WD2
      BRKT(2,1)=W2*W1-WD3
      BRKT(2,2)=-(W1*W1+W3*W3)
      BRKT(2,3)=W2*W3+WD1
      BRKT(3,1)=W3*W1+WD2
      BRKT(3,2)=W3*W2-WD1
      BRKT(3,3)=-(W2*W2+W1*W1)
      VID(1,1)=0.0
      VID(1,2)=-W3E
      VID(1,3)=W2E
      VID(2,1)=W3E
      VID(2,2)=0.0
      VID(2,3)=-W1E
      VID(3,1)=-W2E
      VID(3,2)=W1E
      VID(3,3)=0.0
      VIO(1,1)=1.0
      VIO(1,2)=0.0
      VIO(1,3)=0.0
      VIO(2,1)=0.0
      VIO(2,2)=1.0
      VIO(2,3)=0.0
      VIO(3,1)=0.0
      VIO(3,2)=0.0
      VIO(3,3)=1.0
      DO 41 I=1,3
      DO 41 J=1,3
   41 VIN(I,J)=BRKT(I,J)*DT*DT/2.0+VID(I,J)*DT+VIO(I,J)
      DO 42  I=1,3
      DO 42  J=1,3
   42 XN(I,J)=XCOS(I,1)*VIN(J,1)+XCOS(I,2)*VIN(J,2)+XCOS(I,3)*VIN(J,3)
      DO 43  I=1,3
      DO 43  J=1,3
C     AVOID LCOS GREATER THAN UNITY
      IF(ABS (XN(I,J))-1.0) 43,43,44
   44 XN(I,J)=XN(I,J)/ABS (XN(I,J))
   43 XCOS(I,J)=XN(I,J)
      W1E=W1E+WD1*DT
      W2E=W2E+WD2*DT
      W3E=W3E+WD3*DT
      RETURN
      END
```

Figure 7-10. Subroutine INTEQM (Concluded)

```
ALPHA    =       1.49200       1.49200       1.49200       1.49200       .00000
D        =       5.25000       5.25000       5.25000       5.25000       .00000
D11      =       1.50000       1.50000       1.50000       1.50000       .00000
F11      =    5411.00000    5411.00000    5411.00000    5411.00000       .00000
F22      =    1737.00000    1737.00000    1737.00000    1737.00000       .00000
F33      =    1737.00000    1737.00000    1737.00000    1737.00000       .00000
GRDMU    =       2.00000       2.00000       2.00000       2.00000       .00000
P1       =     100.00000     100.00000     100.00000     100.00000       .00000
P2       =     100.00000     100.00000     100.00000     100.00000       .00000
P3       =     100.00000     100.00000     100.00000     100.00000       .00000
R1       =       6.00000       6.00000       6.00000       6.00000       .00000
R2       =       6.00000       6.00000       6.00000       6.00000       .00000
RP       =      12.08000      12.08000      12.08000      12.08000       .00000
THETA    =        .00000       1.57080       3.14159      -1.57080       .00000
SKS      =  125000.00000  125000.00000  125000.00000  125000.00000       .00000
DELTAP   =        .25000  DELTAT =             .00200  FPS2     =           .05000
FPS3     =        .40000  FPS4   =             .40000  FPS5     =           .01000
FINT     =       2.00000  GRAV   =            5.32000  HN       =          6.58300
PMASS    =       4.00000  FUNNOO =            1.00000  PN       =          1.87500
SK1      =  125000.00000  SK2    =       125000.00000  SK3      =     125000.00000
SKE1     =  125000.00000  SKE2   =       125000.00000  SKE3     =     125000.00000
SERNO    =    1608.00000  VMASS  =          400.00000  ZETA     =           .22685
PITCHO   =       -.22685  YAWO   =            -.78540  ROLLO    =           .00000
PTCHVO   =        .00000  YAWVO  =             .00000  ROLLVO   =           .00000
XMOMX    =     999.90000  XMOMY  =        11873.00000  XMOMZ    =      11873.00000
H        =      12.83000

      II =     2      JJ =     3     IIX =     1     JJX =     4  KPRINT =   10       N =     4
     NSO =     1     NOO =     1   NSMAX =     1   NQMAX =     1  KCOMMY =    3

XVELO           YVELO           ZVELO           XVELO           YVELO           ZVELO
-9.7437          2.2495          .0000

INIT. DIRECTION COSINE MATRIX   GROUND AXES TO VEHICLE AXES

 .97437969           .15903492           .15903492
-.22490934           .68899047           .68899047
-.00000000          -.70710678           .70710678
```

Figure 7-11. Input Data Printout

```
CALCULATED INPUT VALUES

       B10 =      .50187261      .00000002     -.50187261      .00000002
       B20 =      .92108223     -.60971668     -.92108224      .60971674
       B30 =      .92108223      .60971672     -.92108220     -.60971666
       C10 =     1.57079630     1.06892371     1.57079628     2.07266890
       C20 =     1.17099242      .74739524     1.97060019     2.39419740
       C30 =     1.97060025      .74739527     1.17099237     2.39419740
      SL10 =    12.63854410    11.08000010    12.63854410    11.08000010
       D10 =      .00000000     6.08000000      .00000037    -6.08000000


       XP  =     4.09128380      .24900000      .24900036     4.09128380
       YP  =    11.15236430    -5.49364510    -5.49364580    11.15236460
       ZP  =    -8.54184980    -8.54185010     8.54184930     8.54184960
      XPV  =   -12.57999990   -12.58000000   -12.57999990   -12.58000000
      YPV  =    12.07999990      .00000037   -12.07999990      .00000037
      ZPV  =     -.00000000   -12.08000000     -.00000074    12.08000000


     XPVEL =    -9.74370000    -9.74370000    -9.74370000    -9.74370000
     YPVEL =     2.24950000     2.24950000     2.24950000     2.24950000
     ZPVEL =      .00000000      .00000000      .00000000      .00000000
    XPVVEL =     -.00000000     -.00000000      .00000000      .00000000
    YPVVEL =      .00000000      .00000000      .00000000     -.00000000
    ZPVVEL =      .00000000      .00000000      .00000000      .00000000
```

Figure 7-12. Calculated Input Values

```
SERIES NO.1608.00    RUN NO.    1.00

TIME      X       Y       Z      XVEL     YVEL     ZVEL   PITCHV   ROLLV    YAWV   DLTAF   LEG NO.

.000   14.429    .000    .000   -9.744   2.250    .000    .000    .000    .000   .594     +
.020   14.232    .045   -.000   -9.669   2.299   -.000    .013   -.013   -.000   .597     1
.040   14.041    .092   -.000   -9.332   2.439    .000    .021   -.031   -.000   .597     +
.060   13.858    .142   -.000   -8.967   2.588   -.000    .051   -.051   -.000   .596     1
.080   13.685    .196    .000   -8.422   2.802    .000    .075   -.075   -.000   .594     +
.100   13.522    .255   -.000   -7.832   3.050   -.000    .096   -.096    .001   .592     1
.120   13.372    .318   -.000   -7.249   3.305   -.000    .116   -.116   -.000   .589     1
.140   13.233    .387   -.000   -6.664   3.567    .000    .136   -.136    .000   .585     +
.160   13.105    .461    .000   -6.087   3.834    .001    .156   -.156   -.001   .581     4
.180   12.989    .541    .000   -5.507   4.112    .002    .175   -.175   -.002   .577     +
.200   12.885    .626    .000   -4.928   4.398    .003    .193   -.193   -.002   .571     4
.220   12.792    .716    .000   -4.347   4.692    .003    .212   -.212   -.004   .565     +
.240   12.711    .813    .000   -3.774   4.989    .004    .231   -.230   -.007   .560     +
.260   12.641    .916    .000   -3.205   5.289    .004    .251   -.249   -.004   .551     4
.280   12.582   1.024    .000   -2.669   5.556    .006    .276   -.274   -.000   .546     +
.300   12.534   1.138    .001   -2.206   5.748    .009    .311   -.310    .005   .531     4
.320   12.493   1.254    .001   -1.826   5.919    .003    .342   -.342    .005   .529     +
.340   12.459   1.374    .001   -1.604   6.045    .006    .363   -.364    .009   .519     4
.360   12.428   1.496    .001   -1.604   6.096   -.001    .370   -.372    .016   .507     1
.380   12.395   1.618    .001   -1.708   6.123   -.001    .370   -.372    .016   .497     1
.400   12.360   1.741    .001   -1.811   6.147   -.001    .370   -.372    .016   .487     1
.420   12.322   1.864    .001   -1.915   6.171   -.001    .370   -.372    .016   .477     1
.440   12.283   1.987    .001   -2.019   6.195   -.001    .369   -.372    .016   .464     1
.460   12.242   2.112    .001   -2.122   6.219   -.001    .359   -.373    .016   .454     1
.480   12.198   2.236    .001   -2.226   6.243   -.001    .339   -.373    .016   .447     1
.500   12.152   2.362    .001   -2.275   6.236   -.007    .316   -.372    .015   .441     1
.520   12.110   2.484    .001   -1.933   6.000   -.003    .344   -.347    .017   .439     1
.540   12.074   2.602    .000   -1.555   5.743   -.008    .311   -.324    .021   .434     1
.560   12.047   2.714    .000   -1.115   5.435   -.010    .299   -.302    .021   .431     1
.580   12.030   2.819    .000    -.612   5.077   -.012    .278   -.281    .019   .426     1
.600   12.023   2.917   -.000    -.090   4.710   -.014    .257   -.261    .017   .422     1
.620   12.027   3.007   -.001     .438   4.342   -.016    .236   -.241    .012   .417     1
.640   12.041   3.090   -.001     .970   3.974   -.018    .215   -.221    .007   .414     1
.660   12.066   3.166   -.001    1.510   3.603   -.018    .155   -.201    .000   .410     1
.680   12.102   3.234   -.002    2.054   3.235   -.015    .174   -.150    .009   .405     1
.700   12.148   3.296   -.002    2.585   2.891   -.017    .151   -.156   -.007   .401     1
.720   12.204   3.350   -.002    3.042   2.617   -.008    .126   -.131   -.007   .396     1
.740   12.269   3.401   -.002    3.342   2.457   -.003    .101   -.103   -.000   .393     1
.760   12.337   3.440   -.002    3.437   2.398    .005    .086   -.087    .012   .385     1
.780   12.405   3.498   -.002    3.346   2.416    .006    .088   -.085    .014   .381     1
.800   12.471   3.546   -.002    3.242   2.440    .006    .086   -.085    .014   .379     1
.820   12.534   3.595   -.002    3.139   2.464    .006    .086   -.085    .014   .377     1
.840   12.596   3.645   -.002    3.035   2.488    .006    .086   -.085    .014   .374     1
.860   12.656   3.695   -.001    2.931   2.512    .006    .087   -.085    .014   .372     1
.880   12.713   3.745   -.001    2.828   2.536    .006    .087   -.085    .014   .371     1
.900   12.769   3.796   -.001    2.724   2.560    .006    .087   -.085    .014   .367     1
.920   12.822   3.848   -.001    2.620   2.584    .006    .087   -.085    .014   .365     1
.940   12.874   3.899   -.001    2.517   2.608    .006    .087   -.085    .014   .367     1
.960   12.923   3.952   -.001    2.413   2.632    .006    .087   -.085    .014   .363     1
.980   12.970   4.095   -.001    2.309   2.656    .006    .087   -.080    .014   .359     1
```

Figure 7-13. Output Data (Part 1)

```
 TIME      X        Y        Z       XVEL     YVEL     ZVEL   PITCHV    ROLLV     YAWV    BETAF   LEG NO.

 1.000   13.015   4.058   -.001    2.206    2.680    .006     .087    -.086     .014     .356      1
 1.020   13.058   4.112   -.000    2.102    2.704    .006     .087    -.086     .014     .353      1
 1.040   13.099   4.166   -.000    1.998    2.728    .006     .087    -.086     .014     .351      1
 1.060   13.138   4.221   -.000    1.895    2.751    .006     .087    -.086     .014     .349      1
 1.080   13.175   4.276   -.000    1.791    2.775    .006     .087    -.086     .014     .347      1
 1.100   13.210   4.332    .000    1.687    2.799    .006     .087    -.086     .014     .344      1
 1.120   13.243   4.388    .000    1.584    2.823    .006     .087    -.086     .014     .342      1
 1.140   13.273   4.445    .000    1.480    2.847    .006     .087    -.086     .014     .34       1
 1.160   13.302   4.502    .000    1.376    2.871    .006     .087    -.086     .014     .337      1
 1.180   13.328   4.560    .001    1.273    2.895    .006     .087    -.086     .014     .335      1
 1.200   13.353   4.618    .001    1.169    2.919    .006     .087    -.086     .014     .333      1
 1.220   13.375   4.677    .001    1.065    2.943    .006     .087    -.086     .014     .330      1
 1.240   13.395   4.736    .001     .962    2.967    .006     .087    -.086     .014     .328      1
 1.260   13.414   4.795    .001     .858    2.991    .006     .087    -.086     .014     .326      1
 1.280   13.430   4.855    .001     .754    3.015    .006     .087    -.086     .014     .323      1
 1.300   13.444   4.916    .001     .651    3.039    .006     .087    -.086     .014     .321      1
 1.320   13.456   4.977    .001     .547    3.063    .006     .087    -.086     .014     .319      1
 1.340   13.466   5.038    .002     .443    3.086    .006     .087    -.086     .014     .316      1
 1.360   13.474   5.100    .002     .340    3.110    .006     .087    -.086     .014     .314      1
 1.380   13.479   5.163    .002     .236    3.134    .006     .087    -.086     .014     .312      1
 1.400   13.483   5.226    .002     .132    3.158    .006     .087    -.086     .014     .309      1
 1.420   13.485   5.289    .002     .029    3.182    .006     .087    -.086     .014     .307      1
 1.440   13.484   5.353    .002    -.075    3.206    .006     .087    -.086     .014     .305      1
 1.460   13.482   5.417    .002    -.179    3.230    .006     .087    -.086     .014     .302      1
 1.480   13.477   5.482    .002    -.282    3.254    .006     .087    -.086     .014     .300      1
 1.500   13.470   5.547    .003    -.386    3.278    .006     .087    -.086     .014     .298      1
 1.520   13.461   5.613    .003    -.490    3.302    .006     .087    -.086     .014     .295      1
 1.540   13.451   5.680    .003    -.593    3.326    .006     .087    -.086     .014     .293      1
 1.560   13.438   5.746    .003    -.697    3.350    .006     .087    -.086     .014     .291      1
 1.580   13.423   5.814    .003    -.801    3.374    .006     .087    -.086     .014     .289      1
 1.600   13.406   5.881    .003    -.905    3.398    .006     .087    -.086     .014     .286      1
 1.620   13.387   5.949    .003   -1.008    3.421    .006     .087    -.086     .014     .284      1
 1.640   13.365   6.018    .003   -1.112    3.445    .006     .087    -.086     .014     .282      1
 1.660   13.342   6.087    .004   -1.216    3.469    .006     .087    -.086     .014     .279      1
 1.680   13.317   6.157    .004   -1.319    3.493    .006     .087    -.086     .014     .277      1
 1.700   13.289   6.227    .004   -1.423    3.517    .006     .087    -.086     .014     .275      1
 1.720   13.260   6.298    .004   -1.527    3.541    .006     .087    -.086     .014     .272      1
 1.740   13.229   6.368    .004   -1.535    3.514    .057     .086    -.086     .014     .267      4
 1.760   13.202   6.437    .006   -1.129    3.313    .079     .076    -.079    -.000     .267      4
 1.780   13.184   6.501    .008    -.616    3.074    .110     .050    -.063    -.000     .271      4
 1.800   13.178   6.559    .010    -.029    2.805    .107     .031    -.044    -.001     .269      4
 1.820   13.183   6.613    .012     .570    2.534    .101     .011    -.025     .001     .265      4
 1.840   13.200   6.661    .014    1.161    2.268    .097    -.007    -.006     .003     .263      4
 1.860   13.229   6.704    .016    1.709    2.015    .091    -.023     .010     .006     .261      4
 1.880   13.268   6.742    .018    2.129    1.797    .078    -.029     .010     .004     .256      4
 1.900   13.313   6.776    .019    2.344    1.633    .052    -.022     .010    -.012     .249      4
 1.920   13.360   6.807    .020    2.351    1.536    .035    -.005    -.006    -.009     .241      4
 1.940   13.407   6.838    .020    2.282    1.508    .028     .006    -.017     .016     .236      4
 1.960   13.451   6.868    .021    2.160    1.527    .029     .007    -.018     .023     .235      4
 1.980   13.494   6.899    .021    2.076    1.551    .029     .007    -.018     .023     .234      4

 TIME      X        Y        Z       XVEL     YVEL     ZVEL   PITCHV    ROLLV     YAWV    BETAF   LEG NO.

 2.000   13.534   6.930    .022    1.973    1.575    .029     .007    -.018     .023     .234      1
```

Figure 7-13. Output Data (Part 1 - Concluded)

```
SERIES NO.1608.00    RUN NO.    1.00


  TIME  2.002SECS.


  MAXIMUM STROKE  NO. 1 STRUT        .719        1.374        1.375        .709
                  NO. 2 STRUT        .616         .691        1.001        .462
                  NO. 3 STRUT        .514         .996         .688        .626


 MINIMUM CLEARANCE OF NOZZLE=  3.400            TIME WHEN THE MINIMUM CLEARANCE OCCURS    =   .570


 MINIMUM STABILITY ANGLE B1=    .234            TIME WHEN THIS STABILITY ANGLE OCCURS     =  1.000


  ENERGY DISSIPATED BASED ON VEHICLE VELOCITIES AND  C.G. DROP=  23894.445


  ENERGY DISSIPATED BASED ON PLASTIC STROKE =  32150.126


  ENERGY DISSIPATED BASED ON PLASTIC AND FULL ELASTIC STROKE =  32729.353


 FINAL STABILITY ANGLE B1=   .234


 ENERGY DISTRIBUTION BETWEEN LEGS - PERCENT =  17.902  32.302  32.328  17.469
```

Figure 7-14. Summary Output Data

```
 TIME     XP(2)     YP(2)     ZP(2)     XP(3)     YP(3)     ZP(3)      FX(2)      FX(3)

 .000      .249    -5.494    -8.542      .249    -5.494     8.542         .0         .0
 .020      .194    -5.545    -8.442      .184    -5.545     8.442     6270.5     6271.1
 .040      .161    -5.581    -8.383      .161    -5.581     8.383    10195.9    10196.3
 .060      .172    -5.595    -8.359      .172    -5.595     8.359    10530.2    10530.6
 .080      .190    -5.600    -8.344      .190    -5.600     8.344     8065.3     8061.7
 .100      .194    -5.607    -8.337      .194    -5.607     8.335     7664.3     7652.9
 .120      .200    -5.613    -8.328      .199    -5.611     8.323     6803.3     6694.7
 .140      .204    -5.616    -8.318      .205    -5.615     8.312     6315.2     6169.1
 .160      .206    -5.624    -8.306      .207    -5.628     8.299     5846.0     5661.8
 .180      .208    -5.631    -8.293      .209    -5.636     8.289     5483.0     5321.6
 .200      .206    -5.639    -8.280      .206    -5.644     8.277     5591.6     5556.7
 .220      .204    -5.647    -8.267      .204    -5.651     8.261     5676.7     5716.1
 .240      .199    -5.656    -8.255      .197    -5.658     8.254     6273.8     6473.1
 .260      .195    -5.663    -8.244      .195    -5.665     8.244     6811.2     6638.9
 .280      .200    -5.671    -8.232      .200    -5.673     8.231     6329.7     6298.9
 .300      .208    -5.681    -8.215      .208    -5.680     8.216     5313.9     5272.6
 .320      .217    -5.692    -8.203      .217    -5.686     8.203     4162.6     4132.4
 .340      .233    -5.694    -8.197      .233    -5.690     8.195     2106.8     2254.7
 .360      .252    -5.695    -8.195      .256    -5.691     8.192         .0         .0
 .380      .295    -5.698    -8.199      .295    -5.699     8.189         .0         .0
 .400      .338    -5.699    -8.202      .340    -5.706     8.185         .0         .0
 .420      .381    -5.699    -8.205      .381    -5.711     8.182         .0         .0
 .440      .422    -5.698    -8.208      .421    -5.715     8.179         .0         .0
 .460      .463    -5.695    -8.212      .461    -5.717     8.175         .0         .0
 .480      .503    -5.691    -8.215      .499    -5.718     8.172         .0         .0
 .500      .541    -5.686    -8.219      .537    -5.718     8.168         .0         .0
 .520      .582    -5.679    -8.222      .576    -5.716     8.165         .0         .0
 .540      .625    -5.667    -8.227      .618    -5.710     8.161         .0         .0
 .560      .671    -5.653    -8.231      .664    -5.703     8.156         .0         .0
 .580      .724    -5.638    -8.236      .715    -5.695     8.151         .0         .0
 .600      .783    -5.624    -8.240      .773    -5.686     8.147         .0         .0
 .620      .847    -5.610    -8.245      .836    -5.678     8.143         .0         .0
 .640      .918    -5.598    -8.248      .906    -5.670     8.139         .0         .0
 .660      .995    -5.587    -8.251      .981    -5.661     8.136         .0         .0
 .680     1.078    -5.576    -8.254     1.063    -5.652     8.133         .0         .0
 .700     1.157    -5.567    -8.256     1.150    -5.645     8.131         .0         .0
 .720     1.260    -5.558    -8.256     1.242    -5.634     8.131         .0         .0
 .740     1.355    -5.545    -8.256     1.336    -5.619     8.131         .0         .0
 .760     1.447    -5.526    -8.257     1.428    -5.601     8.130         .0         .0
 .780     1.537    -5.502    -8.259     1.515    -5.582     8.128         .0         .0
 .800     1.625    -5.478    -8.261     1.607    -5.562     8.126         .0         .0
 .820     1.711    -5.454    -8.263     1.693    -5.542     8.124         .0         .0
 .840     1.795    -5.428    -8.265     1.776    -5.521     8.122         .0         .0
 .860     1.877    -5.403    -8.267     1.860    -5.499     8.120         .0         .0
 .880     1.957    -5.376    -8.269     1.941    -5.478     8.118         .0         .0
 .900     2.035    -5.349    -8.271     2.019    -5.455     8.116         .0         .0
 .920     2.110    -5.322    -8.273     2.096    -5.432     8.114         .0         .0
 .940     2.184    -5.294    -8.275     2.170    -5.409     8.111         .0         .0
 .960     2.256    -5.266    -8.277     2.243    -5.385     8.109         .0         .0
 .980     2.326    -5.237    -8.280     2.313    -5.360     8.107         .0         .0
```

Figure 7-15. Output Data (Part 2)

```
 TIME      XP(2)      YP(2)      ZP(2)      XP(3)      YP(3)      ZP(3)        FX(2)        FY(2)

 1.000     2.394     -5.207     -8.282      2.382     -5.335      8.105         .0           .0
 1.020     2.460     -5.177     -8.284      2.448     -5.309      8.103         .            .0
 1.040     2.523     -5.146     -8.286      2.513     -5.282      8.101         .0           .0
 1.060     2.585     -5.115     -8.288      2.575     -5.256      8.098         .            .0
 1.080     2.645     -5.084     -8.290      2.635     -5.229      8.096         .0           .0
 1.100     2.703     -5.051     -8.293      2.694     -5.201      8.094         .0           .0
 1.120     2.758     -5.019     -8.295      2.750     -5.173      8.092         .0           .0
 1.140     2.812     -4.985     -8.297      2.805     -5.144      8.089         .0           .0
 1.160     2.864     -4.952     -8.299      2.857     -5.115      8.087         .            .0
 1.180     2.914     -4.917     -8.302      2.907     -5.085      8.085         .0           .
 1.200     2.961     -4.882     -8.304      2.956     -5.054      8.083         .0           .0
 1.220     3.007     -4.847     -8.306      3.002     -5.023      8.080         .0           .
 1.240     3.051     -4.811     -8.308      3.046     -4.992      8.078         .0           .0
 1.260     3.092     -4.774     -8.311      3.089     -4.960      8.076         .0           .0
 1.280     3.132     -4.737     -8.313      3.129     -4.927      8.073         .0           .0
 1.300     3.170     -4.700     -8.315      3.167     -4.896      8.071         .0           .0
 1.320     3.205     -4.662     -8.318      3.203     -4.860      8.068         .0           .
 1.340     3.239     -4.623     -8.320      3.236     -4.826      8.066         .0           .
 1.360     3.270     -4.584     -8.322      3.270     -4.791      8.064         .0           .
 1.380     3.300     -4.544     -8.325      3.300     -4.756      8.061         .0           .
 1.400     3.327     -4.504     -8.327      3.328     -4.720      8.059         .0           .0
 1.420     3.353     -4.463     -8.329      3.355     -4.685      8.056         .0           .
 1.440     3.377     -4.422     -8.332      3.379     -4.647      8.054         .0           .0
 1.460     3.398     -4.380     -8.334      3.401     -4.609      8.051         .0           .
 1.480     3.418     -4.338     -8.337      3.421     -4.571      8.049         .0           .0
 1.500     3.435     -4.295     -8.339      3.440     -4.533      8.046         .0           .0
 1.520     3.451     -4.251     -8.342      3.456     -4.493      8.044         .0           .0
 1.540     3.464     -4.207     -8.344      3.470     -4.454      8.041         .0           .
 1.560     3.475     -4.163     -8.347      3.482     -4.414      8.039         .0           .
 1.580     3.485     -4.118     -8.349      3.492     -4.373      8.036         .0           .
 1.600     3.492     -4.072     -8.352      3.500     -4.332      8.034         .0           .0
 1.620     3.498     -4.026     -8.354      3.506     -4.290      8.031         .0           .
 1.640     3.501     -3.979     -8.357      3.510     -4.248      8.028         .0           .
 1.660     3.502     -3.932     -8.359      3.512     -4.205      8.026         .0           .
 1.680     3.502     -3.884     -8.362      3.513     -4.161      8.023         .0           .0
 1.700     3.499     -3.836     -8.364      3.511     -4.117      8.021         .0           .0
 1.720     3.494     -3.787     -8.367      3.507     -4.073      8.018         .            .
 1.740     3.488     -3.738     -8.365      3.501     -4.028      8.016         .0           .0
 1.760     3.485     -3.691     -8.370      3.497     -3.983      8.015         .0           .0
 1.780     3.488     -3.646     -8.369      3.497     -3.937      8.015         .0           .
 1.800     3.496     -3.600     -8.369      3.502     -3.891      8.015         .0           .
 1.820     3.511     -3.555     -8.369      3.514     -3.846      8.015         .            .
 1.840     3.533     -3.509     -8.370      3.532     -3.801      8.015         .0           .0
 1.860     3.560     -3.464     -8.371      3.557     -3.757      8.014         .0           .
 1.880     3.594     -3.418     -8.372      3.588     -3.715      8.013         .0           .
 1.900     3.633     -3.378     -8.372      3.625     -3.676      8.012         .0           .
 1.920     3.679     -3.345     -8.371      3.667     -3.637      8.014         .0           .
 1.940     3.729     -3.317     -8.371      3.714     -3.608      8.013         .0           .
 1.960     3.778     -3.286     -8.376      3.761     -3.584      8.009         .0           .
 1.980     3.825     -3.255     -8.381      3.807     -3.561      8.003         .0           .

 TIME      XP(2)      YP(2)      ZP(2)      XP(3)      YP(3)      ZP(3)        FX(2)        FX(2)

 2.000     3.870     -3.223     -8.386      3.851     -3.537      7.998         .0           .0
```

Figure 7-15. Output Data (Part 2 - Concluded)

```
TIME      FXPLG3(2)    FYPLG3(2)    FZPLG3(2)    FXPLG3(3)    FYPLG3(3)    FZPLG3(3)

 .000           .0           .0           .0           .0           .0           .0
 .020      -1715.8       -238.0       1369.0      -1715.8       -238.0      -1368.9
 .040      -1880.7       -272.7       1184.0      -1880.5       -272.6      -1183.8
 .060      -2636.4       -522.7       1332.8      -2636.6       -522.8      -1333.0
 .080      -7408.3      -2445.1       3797.2      -7408.5      -2445.2      -3797.2
 .100      -7353.5      -2517.6       3829.8      -7353.8      -2514.4      -3828.3
 .120      -7299.1      -2567.9       3859.1      -7301.0      -2582.8      -3855.7
 .140      -7248.0      -2652.5       3884.4      -7249.9      -2651.6      -3880.3
 .160      -7199.7      -2727.3       3903.0      -7200.6      -2726.6      -3898.9
 .180      -7153.9      -2795.8       3916.9      -7153.4      -2800.0      -3914.3
 .200      -7111.7      -2867.3       3926.9      -7111.1      -2872.2      -3924.1
 .220      -7072.3      -2941.5       3931.1      -7073.0      -2945.5      -3926.6
 .240      -7036.6      -3013.7       3932.5      -6868.3      -2794.6      -3862.2
 .260      -6740.3      -2738.3       3625.5      -6336.7      -2540.2      -3531.3
 .280      -5910.2      -1978.2       3505.0      -5763.4      -1795.4      -3444.1
 .300      -5384.1      -1586.0       3295.5      -5376.5      -1564.6      -3290.3
 .320      -4164.0      -1262.1       2581.4      -4414.6      -1360.0      -2910.0
 .340      -2472.1       -763.3       1685.6      -2367.0       -735.7      -1697.6
 .360        120.7        111.4        -51.5           .0           .0           .0
 .380           .0           .0           .0           .0           .0           .0
 .400           .0           .0           .0           .0           .0           .0
 .420           .0           .0           .0           .0           .0           .0
 .440           .0           .0           .0           .0           .0           .0
 .460           .0           .0           .0           .0           .0           .0
 .480           .0           .0           .0           .0           .0           .0
 .500           .0           .0           .0           .0           .0           .0
 .520           .0           .0           .0           .0           .0           .0
 .540           .0           .0           .0           .0           .0           .0
 .560           .0           .0           .0           .0           .0           .0
 .580           .0           .0           .0           .0           .0           .0
 .600           .0           .0           .0           .0           .0           .0
 .620           .0           .0           .0           .0           .0           .0
 .640           .0           .0           .0           .0           .0           .0
 .660           .0           .0           .0           .0           .0           .0
 .680           .0           .0           .0           .0           .0           .0
 .700           .0           .0           .0           .0           .0           .0
 .720           .0           .0           .0           .0           .0           .0
 .740           .0           .0           .0           .0           .0           .0
 .760           .0           .0           .0           .0           .0           .0
 .780           .0           .0           .0           .0           .0           .0
 .800           .0           .0           .0           .0           .0           .0
 .820           .0           .0           .0           .0           .0           .0
 .840           .0           .0           .0           .0           .0           .0
 .860           .0           .0           .0           .0           .0           .0
 .880           .0           .0           .0           .0           .0           .0
 .900           .0           .0           .0           .0           .0           .0
 .920           .0           .0           .0           .0           .0           .0
 .940           .0           .0           .0           .0           .0           .0
 .960           .0           .0           .0           .0           .0           .0
 .980           .0           .0           .0           .0           .0           .0
```

Figure 7-16. Output Data (Part 3)

```
TIME      FXPLG3(2)    FYPLG3(2)    FZPLG3(2)    FXPLG3(3)    FYPLG3(3)    FZPLG3(3)

1.000        .0           .0           .0           .0           .0           .0
1.020        .0           .0           .0           .0           .0           .0
1.040        .0           .0           .0           .0           .0           .0
1.060        .0           .0           .0           .0           .0           .0
1.080        .0           .0           .0           .0           .0           .0
1.100        .0           .0           .0           .0           .0           .0
1.120        .0           .0           .0           .0           .0           .0
1.140        .0           .0           .0           .0           .0           .0
1.160        .0           .0           .0           .0           .0           .0
1.180        .0           .0           .0           .0           .0           .0
1.200        .0           .0           .0           .0           .0           .0
1.220        .0           .0           .0           .0           .0           .0
1.240        .0           .0           .0           .0           .0           .0
1.260        .0           .0           .0           .0           .0           .0
1.280        .0           .0           .0           .0           .0           .0
1.300        .0           .0           .0           .0           .0           .0
1.320        .0           .0           .0           .0           .0           .0
1.340        .0           .0           .0           .0           .0           .0
1.360        .0           .0           .0           .0           .0           .0
1.380        .0           .0           .0           .0           .0           .0
1.400        .0           .0           .0           .0           .0           .0
1.420        .0           .0           .0           .0           .0           .0
1.440        .0           .0           .0           .0           .0           .0
1.460        .0           .0           .0           .0           .0           .0
1.480        .0           .0           .0           .0           .0           .0
1.500        .0           .0           .0           .0           .0           .0
1.520        .0           .0           .0           .0           .0           .0
1.540        .0           .0           .0           .0           .0           .0
1.560        .0           .0           .0           .0           .0           .0
1.580        .0           .0           .0           .0           .0           .0
1.600        .0           .0           .0           .0           .0           .0
1.620        .0           .0           .0           .0           .0           .0
1.640        .0           .0           .0           .0           .0           .0
1.660        .0           .0           .0           .0           .0           .0
1.680        .0           .0           .0           .0           .0           .0
1.700        .0           .0           .0           .0           .0           .0
1.720        .0           .0           .0           .0           .0           .0
1.740        .0           .0           .0           .0           .0           .0
1.760        .0           .0           .0           .0           .0           .0
1.780        .0           .0           .0           .0           .0           .0
1.800        .0           .0           .0           .0           .0           .0
1.820        .0           .0           .0           .0           .0           .0
1.840        .0           .0           .0           .0           .0           .0
1.860        .0           .0           .0           .0           .0           .0
1.880        .0           .0           .0           .0           .0           .0
1.900        .0           .0           .0           .0           .0           .0
1.920        .0           .0           .0           .0           .0           .0
1.940        .0           .0           .0           .0           .0           .0
1.960        .0           .0           .0           .0           .0           .0
1.980        .0           .0           .0           .0           .0           .0

TIME      FXPLG3(2)    FYPLG3(2)    FZPLG3(2)    FXPLG3(3)    FYPLG3(3)    FZPLG3(3)

2.000        .0           .0           .0           .0           .0           .0
```

Figure 7-16. Output Data (Part 3 - Concluded)

```
 TIME      XP(1)     YP(1)     ZP(1)     XP(4)     YP(4)     ZP(4)      FX(1)      FY(1)

  .000     4.091    11.152    -8.542     4.091    11.152     8.542        .0         .0
  .020     3.915    11.192    -8.542     3.915    11.192     8.542        .0         .0
  .040     3.718    11.234    -8.542     3.715    11.234     8.542        .0         .0
  .060     3.522    11.273    -8.542     3.522    11.273     8.542        .0         .0
  .080     3.329    11.310    -8.542     3.329    11.310     8.542        .0         .0
  .100     3.140    11.344    -8.542     3.140    11.344     8.542        .0         .0
  .120     2.957    11.377    -8.542     2.957    11.377     8.542        .0         .0
  .140     2.779    11.410    -8.542     2.775    11.409     8.542        .0         .0
  .160     2.606    11.441    -8.542     2.605    11.441     8.542        .0         .0
  .180     2.439    11.472    -8.542     2.435    11.472     8.542        .0         .0
  .200     2.277    11.502    -8.542     2.277    11.502     8.542        .0         .0
  .220     2.122    11.532    -8.542     2.123    11.532     8.541        .0         .0
  .240     1.973    11.561    -8.543     1.974    11.560     8.541        .0         .0
  .260     1.830    11.590    -8.544     1.831    11.595     8.540        .0         .0
  .280     1.692    11.618    -8.544     1.695    11.625     8.540        .0         .0
  .300     1.557    11.643    -8.543     1.560    11.649     8.541        .0         .0
  .320     1.421    11.660    -8.542     1.424    11.660     8.542        .0         .0
  .340     1.285    11.671    -8.541     1.287    11.671     8.543        .0         .0
  .360     1.147    11.678    -8.539     1.146    11.675     8.545        .0         .0
  .380     1.008    11.684    -8.536     1.005    11.676     8.547        .0         .0
  .400      .869    11.689    -8.534      .868    11.676     8.549        .0         .0
  .420      .729    11.694    -8.532      .726    11.675     8.551        .0         .0
  .440      .588    11.698    -8.530      .584    11.674     8.553        .0         .0
  .460      .446    11.701    -8.528      .441    11.672     8.555        .0         .0
  .480      .303    11.704    -8.527      .297    11.670     8.557        .0         .0
  .500      .274    11.719    -8.513      .274    11.679     8.547        .0         .0
  .520      .233    11.795    -8.445      .235    11.749     8.465        .0         .0
  .540      .186    11.834    -8.409      .186    11.782     8.455        .0         .0
  .560      .177    11.846    -8.396      .176    11.791     8.444        .0         .0
  .580      .183    11.858    -8.386      .182    11.805     8.434        .0         .0
  .600      .188    11.870    -8.377      .187    11.819     8.420        .0         .0
  .620      .192    11.881    -8.366      .192    11.834     8.406        .0         .0
  .640      .197    11.890    -8.357      .196    11.848     8.390        .0         .0
  .660      .196    11.900    -8.347      .199    11.863     8.380        .0         .0
  .680      .198    11.912    -8.335      .199    11.871     8.372        .0         .0
  .700      .201    11.922    -8.321      .202    11.886     8.361        .0         .0
  .720      .211    11.932    -8.312      .211    11.894     8.351        .0         .0
  .740      .226    11.939    -8.304      .226    11.900     8.343        .0         .0
  .760      .245    11.942    -8.300      .244    11.904     8.336        .0         .0
  .780      .283    11.956    -8.298      .284    11.919     8.339        .0         .0
  .800      .328    11.977    -8.295      .329    11.932     8.342        .0         .0
  .820      .371    11.999    -8.293      .373    11.949     8.345        .0         .0
  .840      .413    12.021    -8.290      .415    11.967     8.347        .0         .0
  .860      .452    12.043    -8.287      .455    11.985     8.350        .0         .0
  .880      .489    12.066    -8.285      .492    12.003     8.352        .0         .0
  .900      .524    12.089    -8.282      .528    12.022     8.355        .0         .0
  .920      .558    12.113    -8.279      .562    12.041     8.358        .0         .0
  .940      .589    12.137    -8.277      .594    12.061     8.360        .0         .0
  .960      .618    12.161    -8.274      .623    12.081     8.363        .0         .0
  .980      .645    12.186    -8.272      .651    12.101     8.365        .0         .0
```

Figure 7-16. Output Data (Part 4)

```
TIME       XP(1)      YP(1)      ZP(1)      XP(4)      YP(4)      ZP(4)      FX(1)      FX(4)

1.000      .670      12.212     -8.269      .677     12.122      8.368      .0         .
1.020      .694      12.237     -8.267      .701     12.143      8.370      .0         .
1.040      .715      12.264     -8.264      .722     12.165      8.372      .0         .
1.060      .734      12.290     -8.262      .742     12.187      8.375      .0         .
1.080      .751      12.317     -8.259      .760     12.210      8.378      .0         .
1.100      .766      12.345     -8.257      .776     12.233      8.380      .0         .
1.120      .780      12.373     -8.254      .789     12.257      8.383      .0         .
1.140      .791      12.401     -8.252      .801     12.281      8.385      .0         .
1.160      .800      12.430     -8.249      .811     12.305      8.388      .0         .
1.180      .807      12.459     -8.247      .819     12.330      8.390      .0         .
1.200      .812      12.489     -8.244      .824     12.355      8.392      .0         .
1.220      .816      12.519     -8.242      .825     12.381      8.395      .          .
1.240      .817      12.550     -8.240      .830     12.407      8.397      .0         .
1.260      .816      12.580     -8.237      .830     12.433      8.399      .0         .
1.280      .813      12.612     -8.235      .825     12.460      8.402      .0         .
1.300      .809      12.644     -8.232      .823     12.486      8.404      .0         .
1.320      .802      12.676     -8.230      .817     12.516      8.406      .0         .
1.340      .793      12.709     -8.228      .809     12.544      8.409      .0         .
1.360      .782      12.742     -8.225      .799     12.572      8.411      .0         .
1.380      .769      12.775     -8.223      .787     12.602      8.413      .          .
1.400      .755      12.809     -8.221      .772     12.631      8.415      .0         .
1.420      .738      12.844     -8.219      .756     12.661      8.418      .0         .
1.440      .719      12.879     -8.216      .735     12.692      8.420      .0         .
1.460      .698      12.914     -8.214      .716     12.722      8.422      .0         .
1.480      .675      12.949     -8.212      .696     12.754      8.424      .0         .
1.500      .651      12.986     -8.210      .671     12.786      8.426      .0         .
1.520      .624      13.022     -8.207      .645     12.818      8.428      .0         .
1.540      .595      13.059     -8.205      .617     12.850      8.431      .0         .
1.560      .564      13.097     -8.203      .587     12.883      8.433      .0         .
1.580      .532      13.135     -8.201      .555     12.917      8.435      .0         .
1.600      .497      13.173     -8.199      .521     12.951      8.437      .0         .
1.620      .460      13.212     -8.197      .484     12.985      8.439      .0         .
1.640      .421      13.251     -8.195      .446     13.020      8.441      .0         .
1.660      .381      13.290     -8.192      .406     13.055      8.443      .0         .
1.680      .338      13.330     -8.190      .364     13.091      8.445      .0         .
1.700      .293      13.371     -8.188      .320     13.127      8.447      .0         .
1.720      .246      13.412     -8.168      .274     13.163      8.449      .0         .
1.740      .212      13.423     -8.177      .244     13.197      8.450      .          .
1.760      .207      13.427     -8.171      .189     13.221      8.432      .0         .
1.780      .192      13.433     -8.165      .199     13.210      8.420      .0         .
1.800      .190      13.439     -8.157      .199     13.211      8.410      .0         .
1.820      .190      13.448     -8.148      .195     13.270      8.394      .0         .
1.840      .196      13.461     -8.132      .194     13.240      8.374      .0         .
1.860      .203      13.475     -8.114      .200     13.261      8.354      .0         .
1.880      .219      13.480     -8.109      .214     13.269      8.343      .0         .
1.900      .238      13.465     -8.105      .233     13.274      8.337      .0         .
1.920      .245      13.487     -8.104      .244     13.278      8.335      .          .
1.940      .256      13.495     -8.104      .247     13.281      8.335      .0         .
1.960      .299      13.524     -8.102      .276     13.294      8.337      .0         .
1.980      .341      13.554     -8.099      .316     13.316      8.339      .          .

TIME       XP(1)      YP(1)      ZP(1)      XP(4)      YP(4)      ZP(4)      FX(1)      FX(4)

2.000      .380      13.565     -8.097      .354     13.329      8.342      .0         .
```

Figure 7-17. Output Data (Part 4 - Concluded)

```
TIME     FXPLG3(1)   FYPLG3(1)   FZPLG3(1)   FXPLG3(4)   FYPLG3(4)   FZPLG3(4)

 .000        .0          .0          .0          .0          .0          .0
 .020        .0          .0          .0          .0          .0          .0
 .040        .0          .0          .0          .0          .0          .0
 .060        .0          .0          .0          .0          .0          .0
 .080        .0          .0          .0          .0          .0          .0
 .100        .0          .0          .0          .0          .0          .0
 .120        .0          .0          .0          .0          .0          .0
 .140        .0          .0          .0          .0          .0          .0
 .160        .0          .0          .0          .0          .0          .0
 .180        .0          .0          .0          .0          .0          .0
 .200        .0          .0          .0          .0          .0          .0
 .220        .0          .0          .0          .0          .0          .0
 .240        .0          .0          .0          .0          .0          .0
 .260        .0          .0          .0          .0          .0          .0
 .280        .0          .0          .0          .0          .0          .0
 .300        .0          .0          .0          .0          .0          .0
 .320        .0          .0          .0          .0          .0          .0
 .340        .0          .0          .0          .0          .0          .0
 .360        .0          .0          .0          .0          .0          .0
 .380        .0          .0          .0          .0          .0          .0
 .400        .0          .0          .0          .0          .0          .0
 .420        .0          .0          .0          .0          .0          .0
 .440        .0          .0          .0          .0          .0          .0
 .460        .0          .0          .0          .0          .0          .0
 .480        .0          .0          .0          .0          .0          .0
 .500   -6601.2      4257.6      3793.1     -6607.0      4242.6     -3808.4
 .520   -6596.2      4271.1      3769.1     -6596.5      4255.6     -3767.6
 .540   -4618.6      2568.6      2420.3     -4745.6      2676.1     -2698.4
 .560   -4175.9      2445.7      2177.9     -4279.4      2441.7     -2307.9
 .580   -5299.8      3245.3      2094.8     -5660.4      2692.5     -2929.5
 .600   -5774.5      3535.6      3283.7     -5946.6      3570.6     -3492.
 .620   -6618.3      4145.1      3801.6     -6457.1      3865.9     -3739.1
 .640   -6626.9      4117.2      3807.7     -6560.3      4000.6     -3765.1
 .660   -6640.4      4069.6      3807.7     -6626.7      4070.1     -3812.6
 .680   -6657.4      4063.8      3802.4     -6487.5      3790.1     -3756.9
 .700   -6106.0      3467.7      3553.6     -5927.2      3157.6     -3479.6
 .720   -5116.6      2567.3      3130.6     -5205.1      2566.6     -3171.6
 .740   -3168.8      1314.4      2298.8     -3360.8      1254.7     -1854.5
 .760    -930.3       348.0       711.9      -977.3       352.5      -610.5
 .780        .0          .0          .0          .0          .0          .0
 .800        .0          .0          .0          .0          .0          .0
 .820        .0          .0          .0          .0          .0          .0
 .840        .0          .0          .0          .0          .0          .0
 .860        .0          .0          .0          .0          .0          .0
 .880        .0          .0          .0          .0          .0          .0
 .900        .0          .0          .0          .0          .0          .0
 .920        .0          .0          .0          .0          .0          .0
 .940        .0          .0          .0          .0          .0          .0
 .960        .0          .0          .0          .0          .0          .0
 .980        .0          .0          .0          .0          .0          .0
```

Figure 7-18. Output Data (Part 5)

```
TIME      FXPLG3(1)    FYPLG3(1)    FZPLG3(1)    FXPLG3(4)    FYPLG3(4)    FZPLG3(4)

1.000            .0           .0           .0           .0           .0           .0
1.020            .0           .0           .0           .0           .0           .0
1.040            .0           .0           .0           .0           .0           .0
1.060            .0           .0           .0           .0           .0           .0
1.080            .0           .0           .0           .0           .0           .0
1.100            .0           .0           .0           .0           .0           .0
1.120            .0           .0           .0           .0           .0           .0
1.140            .0           .0           .0           .0           .0           .0
1.160            .0           .0           .0           .0           .0           .0
1.180            .0           .0           .0           .0           .0           .0
1.200            .0           .0           .0           .0           .0           .0
1.220            .0           .0           .0           .0           .0           .0
1.240            .0           .0           .0           .0           .0           .0
1.260            .0           .0           .0           .0           .0           .0
1.280            .0           .0           .0           .0           .0           .0
1.300            .0           .0           .0           .0           .0           .0
1.320            .0           .0           .0           .0           .0           .0
1.340            .0           .0           .0           .0           .0           .0
1.360            .0           .0           .0           .0           .0           .0
1.380            .0           .0           .0           .0           .0           .0
1.400            .0           .0           .0           .0           .0           .0
1.420            .0           .0           .0           .0           .0           .0
1.440            .0           .0           .0           .0           .0           .0
1.460            .0           .0           .0           .0           .0           .0
1.480            .0           .0           .0           .0           .0           .0
1.500            .0           .0           .0           .0           .0           .0
1.520            .0           .0           .0           .0           .0           .0
1.540            .0           .0           .0           .0           .0           .0
1.560            .0           .0           .0           .0           .0           .0
1.580            .0           .0           .0           .0           .0           .0
1.600            .0           .0           .0           .0           .0           .0
1.620            .0           .0           .0           .0           .0           .0
1.640            .0           .0           .0           .0           .0           .0
1.660            .0           .0           .0           .0           .0           .0
1.680            .0           .0           .0           .0           .0           .0
1.700            .0           .0           .0           .0           .0           .0
1.720            .0           .0           .0           .0           .0           .0
1.740       -1675.1        938.7       1037.9      -1374.0        709.1       -868.7
1.760       -7188.4       3117.3       3725.5      -4727.0       1851.5      -2566.6
1.780       -7195.9       3061.3       3730.7      -6159.0       2601.0      -3424.5
1.800       -6702.7       2909.0       3422.2      -7192.0       2970.1      -3625.5
1.820       -6687.9       2886.2       3538.0      -7203.2       2945.0      -3619.5
1.840       -6953.6       2926.6       3622.7      -6672.7       2835.7      -3676.1
1.860       -6040.8       2672.1       3273.2      -6163.2       2637.1      -3391.9
1.880       -4108.5       2140.5       2189.7      -4793.0       2271.0      -2762.9
1.900       -1836.1       1538.5        910.9      -2397.0       1665.0      -1366.0
1.920        -473.6        652.9         84.5       -832.5       1069.1       -237.1
1.940            .0           .0           .0       -259.1        407.8        -26.6
1.960            .0           .0           .0           .0           .0           .0
1.980            .0           .0           .0           .0           .0           .0

TIME      FXPLG3(1)    FYPLG3(1)    FZPLG3(1)    FXPLG3(4)    FYPLG3(4)    FZPLG3(4)

2.000            .0           .0           .0           .0           .0           .0
```

Figure 7-18. Output Data (Part 5 - Concluded)