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TRIP (TRajectory Integration Program)

Program Description and Use

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ABSTRACT

This report describes a numerical integration computer program (called TRIP) based on Encke's method of integrating only the perturbations in the cartesian coordinates. The mathematical model can include Venus, Earth, Mars, Jupiter, the Moon, and the Sun as either central or disturbing bodies. In addition, full gravity field potentials are included for the Earth (7x7) and Moon (4x4) and J_2 only for Mars. Modification to expand the gravity models for the other planets is simple. Solar radiation pressure may also be included as an option in the input. The program uses the latest exported JPL double-precision planetary ephemerides (DE 19).

TRIP has the option of calculating shadow times of penumbra and umbra; printout may be obtained at specified times or, in the case of a planetary orbiter, at apoapsis or periapsis. Input data is very simple and there is a variety of coordinate systems for printout.

TRIP is available from the Goddard program library under number D00140. It is an IBM 360/95 and 91 program which has proven over the years to be accurate and very fast.

PROBLEM STATUS

This is a final report on one phase of the problem.

AUTHORIZATION

NRL Problem B01-10
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TRIP (TRAJECTORY INTEGRATION PROGRAM)

Program Description and Use

INTRODUCTION

The TRIP computer program was developed in 1968 primarily to provide an accurate and fast trajectory program to replace the n-body numerical integration programs then in use for mission analysis at the Goddard Space Flight Center in Greenbelt, Maryland. These were primarily large and very slow programs such as the old JPL Space Program. A second and equally important objective was to make the input format simple enough to be used without extensive study of a manual.

TRIP was developed along modular lines so that it could be easily modified. It uses a fourth-order predictor-corrector numerical integration subroutine (described later) which, because of the modularity, may be easily replaced by any integration package. Many options have been added to TRIP since it was first developed. However, because Encke's method is used, which requires rectification of the reference orbit, it was not considered advantageous to incorporate atmospheric drag.

Throughout the development of TRIP, its speed and simplicity have been maintained, making it a very useful and accurate tool. It was most recently used for the launch window analysis for Imp-I.

TRIP is currently running on the IBM 360/95 and 91 computer and is available in the Goodard program library (number D00140). The ephemeris system is available under the number D00149 (see ref. 5).

DESCRIPTION OF SUBROUTINES

The functions of the subroutines used in TRIP are described briefly below. Many of them came from the Quick Look Mission Analysis Program developed by Philco-Ford (Ref. 1). A complete listing of TRIP, exclusive of the ephemeris, appears in App. A.

MAIN - The driver for TRIP. Its primary function is to set up certain keys from the input data.

ADOT - (Ref. 1) Obtains the angle between two vectors.

ARES - (Ref. 2) Calculates the matrix necessary to transform coordinates from Earth mean equinox and equator of date to Mars mean equinox and equator of date.

ARKTNS - (Ref. 1) Obtains the arctangent of y/x.

CROSS - (Ref. 1) Finds the cross product of two 3-dimensional vectors.

DERIV - Calculates the disturbing accelerations due to the presence of other bodies and, when required, calls other subroutines to calculate accelerations due to gravity potential and solar radiation pressure. Performs rectification test.

DOT - (Ref. 1) Finds the dot product of two vectors.

FNOL II - (Ref. 3) Used for the numerical integration of a system of ordinary differential equations. A fourth-order Adams-Moulton predictor-corrector with a Runge-Kutta starter, FNOL II has the option of automatically varying the step size.

FNORM - (Ref. 1) Finds the magnitude of a 3-dimensional vector.

GETACC - (Ref. 4) Evaluates the disturbing acceleration due to zonal and tesseral harmonics of the Moon or Earth.

GETTAP - (Ref. 5) Used to position the ephemeris data set and read the correct data record.

GHA - (Ref. 1) Calculates the Greenwich hour angle.

GOTOR - (Ref. 1) Solves Kepler's equation for incremental eccentric anomaly on a conic section given the incremental mean anomaly (time).

HARMON - Computes acceleration due to oblateness of Mars and is the driver for GETACC.

INTR1 - (Ref. 5) Sets up the call to READE to find position and velocity of the other bodies with respect to the central body.

ITER - Calculates times of entrances and exits from penumbra and umbra.

KONSTK - Defines all constants needed by TRIP.

M1 - (Ref. 1) Multiplies a 3-dimensional vector by a 3 x 3 matrix.

MNA - (Ref. 1) Provides the matrix to transform from moon-centered coordinates in Earth's true equator and equinox to Moon-centered coordinates in the moon's true equator.

MULT - (Ref. 1) Forms the product of two 3x3 matrices.

NUTAIT - (Ref. 1) Calculates the matrix to relate coordinates in Earth's mean equator and equinox to the true equator and equinox.

ORB - (Ref. 1) Transforms cartesian state vector to keplerian elements.

ORB2X - (Ref. 1) Transforms keplerian elements to cartesian state vector.

OUT - Prints out various types of output as determined by keys set from input.

OUTX - (Ref. 1) Prints out cartesian and spherical coordinates. Called from subroutine OUT.

OVRLAY - (Ref. 1) Reads input data.

READE - (Ref. 5) Reads, interpolates, and translates ephemeris data from the JPL double-precision ephemeris system (DE-19).

ROTEQ - (Ref. 1) Provides the matrix to transform from mean equator and equinox of 1950.0 to mean equator and equinox of date.

RVOUT - (Ref. 1) Calculates spherical coordinates of position and velocity.

SHADOW - Driver for subroutine ITER. Sets up keys to be used in calculating shadow times.

SHIFTP - (Ref. 1) Provides the cartesian state vector of a probe relative to all the bodies in the ephemeris.

SOLAR - Calculates the perturbing acceleration due to solar radiation pressure.

SPER - (Ref. 1) Converts cartesian position to spherical coordinates.

STEPD - (Ref. 1) Obtains the state vector of a probe which is separated from an initial state by a time or angle increment, assuming only two-body motion.

TCONIC - (Ref. 1) Calculates time from periapsis corresponding to a given true anomaly on a conic section.

TERM - Contains termination logic for the numerical integrator. Determines when the proper conditions for termination have occurred.

TFRAC - (Ref. 1) Provides the integral and fractional parts of the sum of two numbers.

TIMEC - (Ref. 1) Computes whole and fractional days from January 1, 1950, at 0^{hr}.

TRAJ - The driver for FNOL II.

INPUT

All constants and variables needed for the program are contained in subroutine KONSTK, and built-in values are supplied there for everything except the state vector and the epoch times. The state vector, option keys, and epoch times are input through subroutine OVRLAY, which also provides for overlaying any of the built-in constants or variables. A complete description of the input necessary to run TRIP is given below.

The input format is 4 (I3, D12.8). The first three digits are fixed-point input (I3) and represent the C-array location of the variable in subroutine KONSTK. The C-array location is followed by the value desired.

C-array	Name (if any)	Variable
750		X (km) or a (km).
751		Y (km) or e.
752		Z (km) or θ (true anomaly-deg).
753		$\dot{X}$(km/sec) or Ω (deg).
754		$\dot{Y}$ (km/sec) or i (deg).
755		$\dot{Z}$ (km/sec) or ω (deg)
756		Epoch time (year, month, day in form of yymm.dd).
757		Epoch time (hour, minutes, seconds in form of hhmm.sec).

C-array	Name (if any)	Variable
758	Type	Reference coordinate system of input: 1. Earth mean equator and equinox of 1950, 0^h, Jan. 1, 2. True ecliptic and equinox of date, 3. Selenographic-true moon equator - rotating, 4. Mars mean equator of date, or 5. True Earth equator and equinox of date.
759		Stop time (year, month, day as above).
760		Stop time (hours, minutes, seconds as above).
761	TINC (days)	TINC = total days from start to stop time if only 1st and last point, or printout at periapsis or apoapsis is wanted, or printout at approximate steps of Δt is wanted (nearest time step to Δt). TINC = Δt if printout at exact intervals of Δt is wanted. Built-in value is 180 (days).
762	TOTAL ($\geqslant$1.)	1. If printout is wanted at the 1st and last points only, or if printout at periapsis or apoapsis is wanted, or if printout is wanted at approximate steps of Δt. $\frac{\text{total days}}{\Delta t}$ If printout is wanted at exact steps of Δt. Built-in value is 1. For printout at exact steps, an additional print occurs if TOTAL * $\Delta t \neq$ stop time
763	XM (Ref. 3)	100 000. If printout at 1st and last points is wanted, or if printout is wanted at periapsis, apoapsis, or exact intervals of Δt. 0. If printout is wanted at approximate steps of Δt. Built-in value is 0.
764	Y(8) (Ref. 3)	0. If printout is wanted at first and last points only; or if printout is wanted at periapsis, apoapsis, or exact steps of Δt. Δt (seconds) If printout is wanted at approximate steps of Δt. Built-in value is 86400. (sec.).

C-array	Name (if any)	Variable
765	SHADOW =	-1. Do not search for shadow times. ≥0. Time in days from epoch to begin search for shadow times. Built-in value is -1.
766	XNOR =	Central body for initial input state vector: 1. Earth, 2. Moon, 3. Sun, 4. Venus, 5. Mars, or 6. Jupiter. Built-in value is 1.
767	XNE	Error control for FNOL II. Controls the size of the automatic step calculated in FNOL II. Built-in value is 5. May be as high as 9. See Ref. 3 for details.
768	HARMONICS	Gravity potential key in form of abc., where a = Earth, b = Moon (see NOTE below), and c = Mars. 0. Do not include potential field. 1. Include potential field. Built-in value is 111. Only the central body potential field is used.
		NOTE: If the moon is the central body and lunar gravity harmonics are calculated, C-array number 901 must be input as zero.
769	SOLAR	Solar Pressure Key 0. Do not include solar pressure and ignore c(770) through c(774). 1. Include solar pressure. Built-in value is 0.
770	AREA	Cross-sectional area of spacecraft in cm^2. Built-in value is 22225. Used only if c(769) = 1.
771	XMASS	Total mass of spacecraft in gm. Built-in value is 113000. Used only if c(769) = 1.
772	Reflectivity of spacecraft	Values from 0. to 1., inclusive. Used only if c(769) = 1. 1. Perfect reflector. 0. Perfect absorber. Built-in value is 0.2.

C-array	Name (if any)	Variable
773	SPEC. REFLECTION of spacecraft	Fraction of particles specularly reflected. 1. 100%. 0. 0%. Built-in value is 1. May be 0. to 1., inclusive. Used only if c(769) = 1.
774	CONSTANT	Solar pressure at 1 A.U. Built-in value is 4.7×10^{-5} dynes/cm^2. Used only if c(769) = 1.
775	INPUT TYPE	0. Cartesian. 1. Orbital elements. Built-in value is 0. Actual values are input through c(750) - c(756).
776	APPER	Apoapsis and periapsis key. 0. Do not print at apoapsis or periapsis. 1. Print only at apoapsis. -1. Print only at periapsis. Built-in value is 0.
777	OUTPUT =	Output options in form of abcdefgh. a: Central body mean Earth equator of 1950. b: Selenographic. c: Mars mean equator of date. d: Central body true ecliptic and equinox of date. e: Earth-centered true ecliptic and equinox of date. f: Sun-centered true ecliptic and equinox of date. g: Central body true Earth equator and equinox of date. h: Earth-fixed latitude and longitude (only if Earth is central body). 0. Do not print this form. 1. Print this form. Built-in value is 10000011.

Cases may be stacked. When this is desired, cards for the 1st case are followed by a blank card and then the cards for the second case. There is no limit to the number of cases that may be stacked. Again, since an overlay method is used on input, only those variables different from those for the preceding case need be input. A blank card at the end of the last case is necessary to end the program. A sample of the input is shown in App. B.

OUTPUT

The output options are listed above in the description of array c(777). TRIP has the capability of automatically switching body centers when the probe leaves the sphere of influence of one body and enters that of another body. This switching does not interfere with the printout options.

Printout for the central body consists of both the cartesian state vector and instantaneous osculating elements; for other bodies, only the state vector. A sample of the output with an explanation is shown in App. B.

CONSTANTS

All constants needed by TRIP are listed in subroutine KONSTK and are either described there by a comment card or are described above in the input section. The constants in c(31) through c(38) are no longer used by the program but are not taken out.

Any or all of these constants may be changed for a particular run by including the proper array number and the new value in the input data.

KNOWN RESTRICTIONS AND ANOMALIES

There are two restrictions to be noted in using TRIP.

(a). Only one type of printout can be used in a run.

(b). The printout interval must be greater than 2 minutes, which is the initial time step in the integrator. If a request for a smaller interval is made, the program automatically sets the printout interval to be slightly greater than 2 minutes and prints out a message to this effect.

There are also two known anomalies in the program, which cause inconvenience but do not produce incorrect results:

(a). When periapsis printout is requested, occasionally the program will intersperse a printout at apoapsis and then continue with periapsis printouts. Similarly, a printout at periapsis may occur when printout is requested at apoapsis.

(b). When shadow times are requested, if the satellite is already in shadow at the time the shadow search is initiated, the printout of the shadow time is incorrect for that shadow interval only. All subsequent printout are correct. This bug occurs because the search procedure used requires a point before shadow occurs in order to iterate to the correct time. These incorrect shadow times will be obvious to the user. (See case 6, App. B.)

A final note of caution – when exact printout is asked for, the numerical integrator must restart after each printout time in order to continue. This procedure may result in a loss of accuracy due to numerical problems; that is, if two cases are stacked using the same trajectory, one asking for exact printout and the other asking for printout only at the last point, the final state vectors at the stop time may disagree somewhat. To a certain extent, the numerical errors may be minimized by increasing the size of the error control in array c(767), or by decreasing the rectification limit in array c(720). However, this is a problem inherent to a certain extent in any numerical integration routine and probably cannot be completely eliminated.

REFERENCES

1. Philco-Ford, WDL Division, "Programmer's Manual for Quick-Look Mission Analysis Program," Contract NAS 5-3342, WDL-TR 2217, Jan. 24, 1964.

2. Kaufman, B., "A Semi Analytic Method of Predicting the Variation in Periapsis of A Mars Orbiter," GSFC Document X-551-69-41, Feb. 1969.

3. Linnekin, J. S. and Belliveau, L. J., "FNOL2, A Fortran (IBM 7090) Subroutine For the Solution of Ordinary Differential Equations with Automatic Adjustment of the Interval of Integration," NOLTR 63-171, Naval Ordnance Laboratory, White Oak, Maryland, July 17, 1963.

4. Hartwell, J. G., and Lewis, T. R., "Mathematical and Programming Documentation of a General Purpose Integrator Using Power Series Methods," NAS1-9389, DBA Systems, Inc., Melbourne, Florida, Dec. 1969.

5. Linnekin, J. S., "DE-19* Direct Access Double Precision Ephemeris Package for the IBM 360/95" GSFC Document X-551-69-375, Sept. 1969.

Appendix A

LISTING OF TRIP

```
C----- ENCKE   PROGRAM   MAIN  . . . . . . .
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION X(3),V(3),R1(3,8),V1(3,8)
      DIMENSION DUM(3,3),DATEEC(3,3),DATECT(3,3),XX(3),XV(3)
      COMMON C(1000),IC(50),Z(3),VV(3),NCF,INF
      DIMENSION XNOT(3)
      DIMENSION ELI(6)
      COMMON/APPER/ FPROLD,OLD,XMAX
      COMMON/JTERM/MEARTH,MMOON,MMARS
      DATA BLK/6H      /,XNOT1/3HNOT/
      EQUIVALENCE (C(401),R1(1,1)),(C(425),V1(1,1)),
     1  (C(750),X(1)),(C(753),V(1))
      DIMENSION A(3,3),EN(3,3),EMN(3,3),DATE(3,3),SDATE(3,3),
     1DATET(3,3),SDATET(3,3),ADATE(3,3),ADATET(3,3),AR(3,3)
      COMMON/ROT/ DATE,SDATE,DATET,SDATET,ADATE,ADATET,DATEEC,DATECT,EN
      COMMON/XLIB/ SG,TA,XMLIB
      COMMON/TLP/TLU
      COMMON /SHAD/SHADK
      COMMON/PRINT/ IC50,ISEL,MARDAT,ICENEC,IEAREC,ISUNEC,ICDATE,IEARFX
      CALL KONSTK
    1 CALL OVRLAY
      C(462)=1.D0
      C(122)=1.D0
      FPROLD=0.D0
      OLD = 0.D0
      IF(C(775).EQ.0.D0) GO TO 2
      NTEMP=C(766)
      DO 5 I=1,6
5     ELI(I) = C(I+745)
      CALL ORB2X(X,V,ELI,C(NTEMP))
    2 CONTINUE
      IF(FNORM(X).EQ.0.D0) GO TO 20
      SHADK=0.0D0
      TS=C(756)
      DF=C(757)
      INP=C(758)
      ST=C(759)
      STF=C(760)
      TINC=C(761)
      TOTAL=C(762)
      C(1000)=C(765)
      XNOR=C(766)
      NE=C(767)
      MEARTH=C(768)/100.D0
      TEMP=C(768)-MEARTH*100
      MMOON=TEMP/10.D0
      TEMP=TEMP-MMOON*10
      MMARS=TEMP
      IC50=C(777)/10000000.D0
      TEMP=C(777)-IC50*10000000
      ISEL=TEMP/1000000.D0
      TEMP=TEMP-ISEL*1000000
      MARDAT=TEMP/100000.D0
      TEMP=TEMP-MARDAT*100000
      ICENEC=TEMP/10000.D0
      TEMP=TEMP-ICENEC*10000
      IEAREC=TEMP/1000.D0
      TEMP=TEMP-IEAREC*1000
      ISUNEC=TEMP/100.D0
      TEMP=TEMP-ISUNEC*100
```

```
      ICDATE=TEMP/10.D0
      TEMP=TEMP-ICDATE*10
      IEARFX=TEMP
      NTOTAL=TOTAL
      NOR=XNOR
      CALL TIMEC(TS,DF,TW,TF)
      CALL TIMEC(ST,STF,ST1,STF1)
      IF(C(100)) 60,50,50
   60 WRITE(6,30)
      GO TO 70
   50 WRITE(6,40)
   40 FORMAT(1H1,19HSHADOW IS REQUESTED)
   30 FORMAT(1H1,23HSHADOW IS NOT REQUESTED)
   70 CONTINUE
      XNOT(1)=BLK
      XNOT(2)=BLK
      XNOT(3)=BLK
      IF(MEARTH.LT.1) XNOT(1)=XNOT1
      IF(MMOON.LT.1) XNOT(2)=XNOT1
      IF(MMARS.LT.1) XNOT(3)=XNOT1
      WRITE(6,100) C(61),XNOT(1)
      WRITE(6,100) C(62),XNOT(2)
      WRITE(6,100) C(65),XNOT(3)
  100 FORMAT(1H0,13HHARMONICS OF ,A6,4H IS ,A4,8HINCLUDED)
      XNOT(1)=BLK
      IF(C(765).EQ.0.0D0) XNOT(1)=XNOT1
      WRITE(6,102) XNOT(1)
  102 FORMAT('0 SOLAR RADIATION PRESSURE IS ',A4,'INCLUDED')
      TIME=TW+TF
      TLC=TIME
      CALL ROTEQ(TIME,A)
      CALL NUTAIT(TIME,OM,CR,DT,EN,EPSIL)
      CALL MNA(TIME,OM,CR,DT,EPSIL,RC,G,GF,WW,EMN)
      XMLIB=180.D0*.0174532925D0 + CR-CM+TA-SG
      CALL MULT(EN,A,DATE)
      DUM(1,1)=1.0D0
      DUM(1,2)=0.D0
      DUM(1,3)=0.D0
      DUM(2,1)=0.D0
      DUM(2,2)=DCOS(EPSIL)
      DUM(2,3)=DSIN(EPSIL)
      DUM(3,1)=0.D0
      DUM(3,2)=-DSIN(EPSIL)
      DUM(3,3)=DCOS(EPSIL)
      CALL MULT(DUM,DATE,DATEEC)
      CALL MULT(EMN,DATE,SDATE)
      CALL ARES(TS,DF,AR)
      CALL MULT(AR,A,ADATE)
      DO 101 I=1,3
      DO 101 J=1,3
      DATECT(J,I)=DATEEC(I,J)
      DATET(J,I)=DATE(I,J)
      SDATET(J,I)=SDATE(I,J)
  101 ADATET(J,I)=ADATE(I,J)
      WRITE(6,6)
    6 FORMAT(1H0,31HINPUT IN MEAN EC AND EC OF 1950)
      CALL DATOUT(TW,TF,DAYM,FDATE,0)
      DO 600 I=1,3
      XX(I)=X(I)
  600 XV(I)=V(I)
```

```
      GO TO(200,300,400,500,700),INP
  300 CALL M1(X,DATECT,XX)
      CALL M1(V,DATECT,XV)
      GO TO 200
  400 CALL M1(X,SDATET,XX)
      CALL M1(V,SDATET,XV)
      GO TO 200
  500 CALL M1(X,ADATET,XX)
      CALL M1(V,ADATET,XV)
      GO TO 200
  700 CALL M1(X,DATET,XX)
      CALL M1(V,DATET,XV)
  200 CONTINUE
      DO 11 I=1,3
      C(I+499)=XX(I)
   11 C(I+502)=XV(I)
      CALL OLTX(XX,XV,NOLT)
      C(592)=TW
      C(593)=TF
      IF(C(764).GT.120.D0) GO TO 7
      IF(C(764).EQ.0.D0)GO TO 8
      C(764)=120.0000010
      WRITE(6,9)
    8 IF (TINC.GT.2.D0/1440.D0) GO TO 7
      TINC=0.00138888900
      WRITE(6,9)
    9 FORMAT('0*****************'/'0PRINT INTERVAL WAS LESS THAN INITIAL
     1 TIME STEP. RESET TO SLIGHTLY GREATER THAN TWO MINUTES.'/
     2'0*****************')
    7 CONTINUE
      TFF=TF
      KK=1
   13 TFF=TFF+TINC
      CALL TFRAC(TW,TFF,TWF,TFF)
   16 XMAX=0.D0
      CALL TRAJ(TWF,TFF,XX,XV,NE)
      IF(C(462).EQ.0.D0)GO TO 1
      TW=TWF
      DO 10 JJ=1,3
      C(JJ+499)=XX(JJ)
   10 C(JJ+502)=XV(JJ)
      STDT=(STI-C(592)+STF1-C(593))*86400.D0
      IF(STDT-120.D0.LE.0.D0) GO TO 1
      XMAX=0.D0
      IF(C(1000).GT.0.D0) C(1000)=0.D0
   14 IF(C(462).EQ.0.D0) GO TO 1
      IF(FPROLD.EQ.0.D0) GO TO 12
      FPROLD=0.D0
      OLD = 0.D0
      STDTPR=(TWF-C(592)+TFF-C(593))*86400.D0
      IF(STDTPR.LE.120.D0) GO TO 12
      IF (KK .LE. NTOTAL) GO TO 16
      GO TO 15
   12 KK=KK+1
   15 IF(KK.LE.NTOTAL) GO TO 13
      CALL TRAJ(STI,STF1,XX,XV,NE)
      IF(FPROLD.NE.0.D0)  GO TO 14
      GO TO 1
   20 CONTINUE
      STOP
      END
```

```
      REAL FUNCTION ADOT*8(X,Y)                                         17100
      IMPLICIT REAL*8(A-H,O-Z,$)                                        17200
      DIMENSION  X(3),  Y(3)                                            17300
C     FUNCTION RETURNS ANGLE IN DEGREES BETWEEN TWO INPUT VECTORS       17400
C     RANGE IS RESTRICTED TO (C,180)                                    17500
      A=FNORM(X)                                                        17600
      B=FNORM(Y)                                                        17700
      ANG=DOT(X,Y)/A/B                                                  17800
      ADOT=ARKTNS(180,ANG,DSQRT(1.0D0-ANG*ANG))*57.295779D0             17900
      RETURN                                                            18000
      END                                                               18100
```

```
      SUBROUTINE ARES(T1,T2,AR)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION AR(3,3),EE(3),O(3),EXO(3),EQ(3)
      DIMENSION TEM(3)
      DUM=0.D0
      DTR=0.01745329252D0
      IYR=T1/100.D0
      YR=IYR
      DT=YR-50.D0
      AOP= 317.793416667D0+0.65208330-2*DT
      DOP=54.6575D0+0.35D-2*DT
      BYR=YR*100.D0+1.01D0
      CALL TIMEC(BYR,DUM,TW,TF)
      CALL TIMEC(T1,T2,TW1,TF1)
      TAU= ((TW1-TW)+(TF1-TF))/365.25D0
      AO= AOP-0.001013D0*TAU
      DO= DOP-0.00063100*TAU
      TE= (TW1+TF1+18262.5D0)/36525.D0
      OM= 48.78644167D0+0.77059167D0*TE-0.13888889D-5*TE*TE
      XI= 1.85033333D0-0.675D-3*TE+0.12611111D-4*TE*TE
      E= 23.45229444D0-0.13012 5D-1*TE-0.16388889D-5*TE*TE
     1   +0.50277778D-6*TE*TE*TE
      AOR=AO*DTR
      DOR= DO*DTR
      OMR= OM*DTR
      XIR= XI*DTR
      ER=E*DTR
      SAO=DSIN(AOR)
      CAO=DCOS(AOR)
      SDO=DSIN(DOR)
      CDO=DCOS(DOR)
      SOM=DSIN(OMR)
      COM=DCOS(OMR)
      SI=DSIN(XIR)
      CI=DCOS(XIR)
      SE=DSIN(ER)
      CE=DCOS(ER)
C *******  THE FOLLOWING IS KAUFMAN'S METHOD  ******
      EE(1)=CAO*CDO
      EE(2)=SAO*CDO
      EE(3)=SDO
      O(1)=SI*SOM
      O(2)= -SI*COM*CE-CI*SE
      O(3)=-SI*COM*SE+CI*CE
      CALL CROSS(O,EE,EXO)
      EQ(1)=-SAO
      EQ(2)=CAO
      EQ(3)=0.D0
      CALL CROSS(EQ,EXO,TEM)
      SOMEG=DSQRT(TEM(1)**2+TEM(2)**2+TEM(3)**2)
      COMEG= DOT(EQ,EXO)
      OMG=ARKTNS(180,COMEG,SOMEG)
      SOMEG=DSIN(OMG)
      COMEG=DCOS(OMG)
      AOM = AOR+1.570796327D0
      XAI=1.570796327D0-DOR
      SAOM=DSIN(AOM)
      CAOM=DCOS(AOM)
      SAI=DSIN(XAI)
      CAI=DCOS(XAI)
```

```
      AR(1,1)=COMEG*CAOM-SOMEG*SAOM*CAI                                 24200
      AR(1,2)=COMEG*SAOM+SOMEG*CAOM*CAI                                 24300
      AR(1,3)=SOMEG*SAI                                                 24400
      AR(2,1)=-SOMEG*CAOM-COMEG*SAOM*CAI                                24500
      AR(2,2)=-SOMEG*SAOM+COMEG*CAOM*CAI                                24600
      AR(2,3)=COMEG*SAI                                                 24700
      AR(3,1)=SAOM*SAI                                                  24800
      AR(3,2)=-CAOM*SAI                                                 24900
      AR(3,3)=CAI                                                       25000
      RETURN                                                            25100
      END                                                               25200
```

```
      REAL FUNCTION ARKTNS*8(N,X,Y)
      IMPLICIT REAL*8(A-H,O-Z,$)
C     COMPUTES 4-QUADRANT ARCTANGENT OF Y/X IN RADIANS
C     N=360  ANGLE LIES IN RANGE (0,360) DEG
C     N=180  ANGLE LIES IN RANGE (-180,180) DEG
      TPI = 6.283185300000
      XA = DABS(X)
      YA = DABS(Y)
      IF(XA-YA)1,1,2
    1 Z=X/YA
      GO TO 3
    2 Z=Y/XA
      YA=XA
    3 D=DSQRT(1.0D0+Z*Z)
      YA=YA*D+X
      IF(YA)4,4,5
    4 ARKTNS=TPI/2.0D0
      GO TO 6
    5 ARKTNS=2.0D0*DATAN(Y/YA)
    6 IF(N-180)7,9,7
    7 IF(ARKTNS)8,9,9
    8 ARKTNS=ARKTNS+TPI
    9 RETURN
      END
```

```
      SUBROUTINE CROSS(A,B,C)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION A(3),B(3),C(3)
C     DIMENSION A(3),B(3),C(3)
      C(1)=A(2)*B(3)-A(3)*B(2)
      C(2)=A(3)*B(1)-A(1)*B(3)
      C(3)=A(1)*B(2)-A(2)*B(1)
      RETURN
      END
```

```
      SUBROUTINE DATOUT(T1,T2,DATE,FDATE,KDATE)
      IMPLICIT REAL*8(A-H,O-Z,$)
C     DATE RETURNED IN FORMAT(YEARS FROM 1900)(MONTH),(DAYS)
C     FDATE RETURNED IN FORMAT (HOURS)(MIN),(SECONDS)
C     K SET 0 FOR PRINTOUT, SET - OR + FOR NO OUTPUT
C     GIVES CALENDER DATE FROM T1(WHOLE DAYS FROM 1950)
C     ANDT2(FRACT OF DAY)
      DIMENSION C(12)
C     DIMENSION C(12)
      DATA Q0C0HL/6H  JAN./
      C(1 )=Q000HL
      DATA Q0C1HL/6H  FEB./
      C(2 )=Q001HL
      DATA Q0C2HL/6H MARCH/
      C(3 )=Q002HL
      DATA Q0C3HL/6H APRIL/
      C(4 )=Q003HL
      DATA Q0C4HL/6H   MAY/
      C(5 )=Q004HL
      DATA Q0C5HL/6H  JUNE/
      C(6 )=Q005HL
      DATA Q0C6HL/6H  JULY/
      C(7 )=Q006HL
      DATA Q0C7HL/6H  AUG./
      C(8)=Q007HL
      DATA Q0C8HL/6H SEPT./
      C( 9)=Q008HL
      DATA Q0C9HL/6H  OCT./
      C(10)=Q009HL
      DATA Q01CHL/6H  NOV./
      C(11)=Q010HL
      DATA Q011HL/6H  DEC./
      C(12)=Q011HL
      MD=0
      K=T1+365.0D0
      IF(T1)6,6,7
 6    WRITE (    6,100)
 6    RETURN
 100  FORMAT(23H DATE IS 1950 OR BEFORE)
 7    K1=K/1461
      K2=K-K1*1461
      KWN=K2/365
      KK=K1*4+1949+KWN
      N=1
      IF(KWN-3)112,111,111
 111  N=0
 112  KWN=K2-KWN*365
      IF(KWN)11,11,13
 11   MONTH=1
      MD=1
      GO TO 25
 13   CONTINUE
      KNW=0
      JJ=0
 135  JJ=JJ+1
      IF(12-JJ)23,23,137
C     J,F,M,A,M,J,J,A,S,O,N,MONTHS FOR GO TO
 137  GO TO (14,15,14,16,14,16,14,14,16,14,16,14),JJ
 14   CONTINUE
      KNW=KNW+31
```

```
      GO TO 17
 15   CONTINUE
      IF(N)18,18,19
 18   KNW=KNW+1
 19   KNW=KNW+28
      GO TO 17
 16   KNW=KNW+30
 17   CONTINUE
      IF(KWN-KNW)20,21,22
 22   CONTINUE
      MD=KNW
      GO TO 135
   20 CONTINUE
      MONTH=JJ
      MD=KWN-MD+1
      GO TO 25
   21 CONTINUE
       MONTH=JJ+1
      MD=1
      GO TO 25
 23   MONTH =12
      MD=KWN-MD+1
   25 CONTINUE
      TH=T2*24.0D0
       THP=IDINT(TH)
      FDATE=THP*100.0D0
      NHOUR=THP
       THP=(TH-THP)*60.0D0
      TH=IDINT(THP)
      FDATE=FDATE+TH
       NMIN=TH
      THP=(THP-TH)*60.0D0
      NSEC=THP
      FDATE=FDATE+THP/100.0D0
      TSEC=NSEC
      DATE=(KK-1900)*100+MONTH
      SP=MD
      DATE=DATE+SP/100.0D0
      IF(KDATE) 8,50,8
   50 CONTINUE
      THP=(THP-TSEC)*1000.0D0
      NFSEC=THP
      TT=IDINT(T2+.5D0)
      TP2=T2+.5D0-TT
      TP1=T1+TT+2433282.0D0
      WRITE (    6,101)C(MONTH),MD,KK,NHOUR,NMIN,NSEC      ,NFSEC,TP1,TP2
 101  FORMAT( 1H ,A6,I3,1H,,1X,I4,1H,,1X,I2,4HHRS,,I3,4HMIN,,I3,1H,,I3,
     13HSEC,50X,12HJULIAN DATE ,F8.0,T111,F9.8)
      GO TO 8
      END
```

```
      SUBROUTINE DERIV(X,Y,D)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION Y(20),R1(3,8),V1(3,8),D(20),CB(20),NP(5), RM(5),RM1(5),
     1DACC(3),Z1(3),VV1(3),RE(3),CACC(3) ,R2(3,8)
      DIMENSION DACC(3)
      DIMENSION SACC(3)
      COMMON C(1000),IC(50),Z(3),VV(3),NOR
      COMMON/JTERM/MEARTH,MMOON,MMARS
      COMMON/DISTRB/DACC,CACC,CACC
      COMMON /SHAD/SHADK
      EQUIVALENCE (C(401),R1(1,1)),(C(425),V1(1,1))
C   MUST CALCULATE POSITION OF PROBE FROM INCREMENTS
      DT=X
      U=C(NOR)
      IF(X.NE.0.D0) GO TO 321
      DO 322 I=1,3
      Z(I)=C(I+499)
  322 VV(I)=C(I+502)
      GO TO 323
  321 CONTINUE
      MN=1
      CALL STEPD(MN,DT,TA,C(500),C(503),U,Z,VV,1,CB)
  323 CONTINUE
      DO 10 I=1,3
      Z1(I)=Z(I)+Y(I)
   10 VV1(I)=VV(I)+Y(I+3)
      TW=C(592)
      TF=C(593)+(C(719)+C(506)+X)/86400.D0
      CALL TFRAC(TW,TF,TW,TF)
      CALL SHIFTP(NOR,Z1,VV1,TW,TF,R1,V1)
      NP(1)=2
      NP(2)=3
      NP(3)=4
      NP(4)=5
      NP(5)=6
      GO TO(1,2,3,90,80,100),NOR
    2 NP(1)=1
      GO TO 1
    3 NP(2)=1
      GO TO 1
   90 NP(3)=1
      GO TO 1
   80 NP(4)=1
      GO TO 1
  100 NP(5)=1
      GO TO 1
    1 CONTINUE
      DO 4 I=1,5
      NP1=NP(I)
      RM(I)=FNORM(R1(1,NP1))**3
      DO 5 J=1,3
    5 R2(J,I+3)=R1(J,NOR)-R1(J,NP1)
    4 RM1(I)=FNORM(R2(1,I+3))**3
      NP1=NP(1)
      NP2=NP(2)
      NP3=NP(3)
      NP4=NP(4)
      NP5=NP(5)
      DO 6 I=1,3
    6 DACC(I)=-C(NP1)*(R1(I,NP1)/RM(1)+R2(I,4)/RM1(1))-C(NP2)*(R1(I,NP2)
```

```
     1/RM(2)+R2(I,5)/RM1(2))
     2-C(NP3)*(R1(I,NP3)/RM(3)+R2(I,6)/RM1(3))-C(NP4)*(R1(I,NP4)
     3/RM(4) +R2(I,7) /RM1(4))-C(NP5)*(R1(I,NP5)/RM(5)+R2(I,8)/RM1(5))
      DO 7 I=1,3
    7 RE(I)=Z(I)+.5D0*Y(I)
      Q= DOT(RE,Y)/(FNORM(Z)**2)
      SUM =1.D0
      TERM=1.D0
      DO 8 K=2,50
      XK=K
      TERM=TERM*((.5D0-XK)*2.D0*Q/(XK-1.D0))
      SUM=SUM+TERM
      IF(DABS(TERM).LT.C.00001D0*SUM) GO TO 9
    8 CONTINUE
      WRITE(6,20)
   20 FORMAT(1H1,34HQ SERIES IN ENCKE DID NOT CONVERGE)
      STOP
    9 FQ=1.D0-SUM
      H=C(NOR)/(FNORM(Z)**3)
      DO 11 I=1,3
   11 CACC(I)=-H*Y(I)+H*FQ*R1(I,NOR)
      DO 30 I=1,3
   30 DACC(I)=0.D0
      GO TO (40,50,21,21,60,21),NOR
   40 IF(MEARTH.NE.1) GO TO 21
      GO TO 70
   50 IF(MMOON.NE.1) GO TO 21
      GO TO 70
   60 IF(MMARS.NE.1) GO TO 21
   70 CONTINUE
      TWTE=C(592)
      TFTE=C(593)+(C(506)+X)/86400.D0
      CALL TFRAC(TWTE,TFTE,TWTE,TFTE)
      TIMUP=TWTE+TFTE
      CALL HARMON(R1,V1,DACC,TIMUP)
   21 CONTINUE
      DO 13 I=1,3
   13 DACC(I)=          DACC(I)+CACC(I)
      RAT = FNORM(Y(1)) / FNORM(Z(1))
      IF(RAT.GE.C(720).OR.Q.GE.C(720)) C(122)=0.0D0
      DO 17 I=1,3
   17 DACC(I)=DACC(I)+CACC(I)
      IF(C(765).EQ.0.0D0.OR.SHADK.EQ.1.0D0) GO TO 551
C* * * * *   CALCULATE SOLAR PRESSURE * * * * * *
      CALL SOLAR(R1(1,3),SACC)
      DO 1000 I=1,3
 1000 DACC(I)=DACC(I) + SACC(I)
  551 C O N T I N U E
      DO 16 I=1,3
      D(I)=Y(I+3)
   16 D(I+3)=DACC(I)
      RETURN
      END
```

```
      REAL FUNCTION DOT*8(X,Y)                                          50900
      IMPLICIT REAL*8(A-H,O-Z,$)                                        51000
      DIMENSION X(3),Y(3)                                               51100
C     DIMENSION X(3),Y(3)                                               51200
      DOT = X(1)*Y(1) + X(2)*Y(2) + X(3)*Y(3)                           51300
      RETURN                                                            51400
      END                                                               51500
```

```
      SUBROUTINE FNOL2(J,N,G,L,M,NE,X,Y,D,CC,TT,CC)
      IMPLICIT REAL*8(A-H,O-Z,$)
      COMMON BERNIE(1000)
C
      DOUBLE PRECISION XD,YD,YA,YC,YP,Y1
C     DIMENSION Y(50),D(50),YB(30,6),GI2(30),GI3(30),GI4(30),EF(30),
      DIMENSION Y(8000)
      DIMENSION ZZ(5),D(50),YB(30,6),GI2(30),GI3(30),GI4(30),EF(30),
     1EF1(30),EF2(30),EF3(30),Y1(30),ERRCR(30),HA(30),YA(50),DA(50),
     2YC(30),YP(30),YD(50)
      EC=Y(N+3)
 5876 FORMAT(1H0,I7)
    1 H=G
    2 HZ=H
    3 LN=N+MAX0(L,3)
C     SUBROUTINE FNOL2(J,N,G,L,M,NE,X,Y,D,DERIV,TERM,CUT)
 6876 FORMAT(1H0,I7)
    4 NA=0
    5 NB=1
    6 NF=0
    7 NG=0
    8 F=0.D0
    9 FA=0.D0
   10 FB=0.D0
   11 FC=0.D0
   12 CONTINUE
   13 ENE=NE
C     DO 200 I=1,LN
C 200 YD(I)=DBLE(Y(I))
C     XD=DBLE(X)
      DO 200 I=1,LN
  200 YD(I)=Y(I)
      XD=X
   14 IF(J-3)15,21,15
   15 IF(NE)16,16,18
   16 JA=4
   17 GO TO 22
   18 RE1=10.D0**(-ENE)
   19 RE2=10.D0**(-ENE-3.0D0)
   20 REM=10.D0**(-ENE-1.5D0)
   21 JA=1
   22 DO 25 I=1,N
   23 DO 24 IC=1,5
   24 YB(I,IC)=0.D0
   25 ERROR(I)=0.D0
   26 CALL DERIV(X,Y,D)
      CALL TERM(X,Y,D,F)
      IF(DABS(F)-1.0D-9) 731,731,5209
 5209 CONTINUE
      DO 300 I=1,N
      GI2(I)=D(I)
      GI3(I)=D(I)
      GI4(I)=D(I)
  300 EF(I)=D(I)
C  27 CALL OUTPUT(X,Y,D,ERRCR,N,L,H)
 27   CALL OUT(X,Y,D,ERROR,N,L,H)
      IF(BERNIE(506).NE.0.D0) GO TO 29
   28 FD=Y(N+1)
   29 IF(J-2) 30,129,30
```

```
   30 GO TO(31,37,35,37),JA
   31 DO 33 I=1,LN
   32 YA(I)=YD(I)
   33 DA(I)=D(I)
   34 GO TO 37
   35 HB=H
   36 H=2.D0*H
   37 HD2 = .5D0*H
      DO 39 I=1,N
   38 YB(I,NB)=D(I)
      XL = D(I) * HD2
C  39 Y(I)=SNGL(YD(I)+XL)
 39   Y(I)=YD(I)+XL
C     X=SNGL(XD+HD2)
      X=XD+HD2
   40 CALL DERIV (X,Y,GI2)
   41 DO 42 I=1,N
      XL = GI2(I)*HD2
C  42 Y(I)=SNGL(YD(I)+XL)
 42   Y(I)=YD(I)+XL
   43 CALL DERIV (X,Y,GI3)
   44 DO 45 I=1,N
      XL=GI3(I)*H
C  45 Y(I)=SNGL(YD(I)+XL)
 45   Y(I)=YD(I)+XL
C     X=SNGL(XD+H)
      X=XD+H
   46 CALL DERIV(X,Y,GI4)
   47 HD6 =H/6.D0
      GO TO(48,55,60,66),JA
   48 DO 52 I=1,N
      XL=(D(I) + 2.D0*(GI2(I) + GI3(I)) +GI4(I))*HD6
   49 YC(I)=YD(I)+XL
   51 YD(I)=YA(I)
   52 ERROR(I)=0.D0
   53 JA=3
   54 GO TO 35
   55 DO 57 I=1,N
      XL=(D(I) + 2.D0*(GI2(I) + GI3(I)) +GI4(I))*HD6
   56 YD(I)=YD(I)+XL
C  57 ERROR(I)=SNGL(YD(I)-YP(I))/15.
 57   ERROR(I)=(YD(I)-YP(I))/15.D0
   58 JA=1
   59 GO TO 681
   60 DO 62 I=1,N
   61 YD(I)=YC(I)
      XL=(D(I) + 2.D0*(GI2(I) + GI3(I)) +GI4(I))*HD6
   62 YP(I)=YA(I)+XL
   63 H=HB
   64 JA=2
   65 GO TO 681
   66 DO 68 I=1,N
      XL=(D(I) + 2.D0*(GI2(I) + GI3(I)) +GI4(I))*HD6
   67 YD(I)=YD(I)+XL
   68 ERROR(I)=0.D0
  681 DO 69 I=1,N
C  69 Y(I)=SNGL(YD(I))
 69   Y(I)=YD(I)
      XD=XD+H
C     X=SNGL(XD)
```

```
      X=XD
   70 CALL DERIV(X,Y,D)
   71 FC=F
   72 CALL TERM(X,Y,D,F)
   73 IF(DABS(F)-1.0D-9 )731,731,733
  731 NF=5
  732 GO TO 124
  733 IF(F)74,124,76
   74 FA=1.D0
   75 GO TO 77
   76 FB=1.D0
   77 IF(FA-FB)83,78,83
   78 NF=NF+1
   79 JA=4
   80 NB=1
   81 H=H*F/(FC-F)
   82 IF(NF-4)37,37,124
   83 IF(NE)84,117,84
   84 IF(JA-1)117,85,117
   85 IF(J-3)86,117,86
   86 DO 95 I=1,N
      IF(Y(I))886,885,886
  885 HA(I)=1000.D0
      GO TO 95
  886 IF(EC)880,890,87
   87 IF(DABS(Y(I))-EC) 880,880,890
  880 IF(DABS(ERROR(I))-RE2) 882,94,881
  881 IF(DABS(ERROR(I))-RE1)94,94,882
  882 HA(I)=H*(REM/(DABS(ERROR(I))+.0000 0000100))**(.2D0)
  883 GO TO 95
  890 IF(DABS(ERROR(I)/Y(I))-RE2)892,94,891
  891 IF(DABS(ERROR(I)/Y(I))-RE1)94,94,892
  892 HA(I)=H*(REM/(DABS(ERROR(I)/Y(I))+.0000000001D0))**(.2D0)
  893 GO TO 95
   94 HA(I)=H
   95 CONTINUE
96    HB=DABS(HA(N))
97    DO 98 I=1,N
C 98  HB=AMIN1(ABS(HA(I)),HB)
98    HB=DMIN1(DABS(HA(I)),HB)
99    IF(DABS(H)-HB)100,117,101
100   IF(DABS(HZ)-DABS(H))101,101,116
101   DO 103 I=1,LN
102   YD(I)=YA(I)
C     Y(I)=SNGL(YD(I))
      Y(I)=YD(I)
103   D(I)=DA(I)
104   IF(NB-6) 107,105,105
105   XD=XD-H
106   GO TO 109
107   XD=XD-2.D0*H
108   HZ=H
109   H=DSIGN(HB,H)
      X=XD
C     X=SNGL(XD)
      CALL DERIV(X,Y,D)
      CALL TERM(X,Y,D,F)
  110 NB=1
  111 XABS=DABS(.000001D0*X)
  112 IF(DABS(H)-XABS)113,113,117
```

```
  113 NG=NG+1
 114   H=DSIGN(XABS,H)
  115  IF(NG - 10)124,150,150
  150  WRITE(6,1261) H
 1261  FORMAT (1H1,107HEXECUTION TERMINATED BECAUSE INTERVAL
       OF INTEGRATION LESS THAN 1.0E -6 TIMES INDEPENDENT
       VARIABLE (X).  X =,1PD15.7)
       STOP
  116 HZ=H
  117 IF(M)118,118,121
  118 IF(DABS(Y(N+1)-FD)-Y(N+2))29,119,119
  119 FD=FD+Y(N+2)
  120 GO TO 124
  121 NA=NA+1
  122 IF(M-NA)123,123,29
  123 NA=0
C124  CALL OUTPUT(X,Y,D,ERROR,N,L,H)
 124  CALL OUT(X,Y,D,ERROR,N,L,H)
  125 IF(NF-4)29,29,126
  126 CONTINUE
  128 RETURN
  129 NB=NB+1
  130 IF(NB-6)30,131,136
  131 DO 134 I=1,N
  132 EF3(I)=YB(I,3)
  133 EF2(I)=YB(I,4)
  134 EF1(I)=YB(I,5)
  135 GO TO 137
  136 NB=10
  137 HD24 =H/24.D0
      DO 138 I=1,N
      XL =(55.D0*D(I) -59.D0*EF1(I) +37.D0*EF2(I)
                        -9.D0*EF3(I))*HD24
      YP(I)=YD(I)+XL
C 138 Y(I)=SNGL(YP(I))
C     X=SNGL(XD+H)
 138  Y(I)=YP(I)
      X=XD+H
  139 CALL DERIV(X,Y,EF)
  140 DO 142 I=1,LN
  141 YA(I)=YD(I)
  142 DA(I)=D(I)
  143 DO 148 I=1,N
      XL = (9.D0*EF(I) +19.D0*D(I) -5.D0*EF1(I) +EF2(I))*HD24
  144 YD(I)=YD(I)+XL
C 145 ERROR(I)=-SNGL(YD(I)-YP(I))/14.
 145  ERROR(I)=-(YD(I)-YP(I))/14.D0
  146 EF3(I)=EF2(I)
  147 EF2(I)=EF1(I)
  148 EF1(I)=D(I)
999   CONTINUE
  149 GO TO 681
       END
```

```
      REAL FUNCTION FNORM*8(X)                                          74700
      IMPLICIT REAL*8(A-H,O-Z,$)                                        74800
      DIMENSION X(3)                                                    74900
C     DIMENSION X(3)                                                    75000
    1 FNORM=DSQRT(X(1)**2+X(2)**2+X(3)**2)                              75100
    3 RETURN                                                            75200
      END                                                               75300
```

```
      SUBROUTINE GETACC (LCT,ICT,CNN,SNN,ECN,PVA,CTT,CTB,UMT,VMT,NTE)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION LCT(1),ICT(1),CNN(1),SNN(1),ECN(1)
      DIMENSION PVA(1),CTT(1),CTB(1),UMT(1),VMT(1)
      EQUIVALENCE (XP,PX),(YP,PY),(ZP,PZ)
      ERD=ECN(1)
      XMU=ECN(2)
      ALF=ECN(3)
      PX= PVA(1)
      PY= PVA(2)
      PZ= PVA(3)
      CGB=DCOS(ALF)
      SGB=DSIN(ALF)
      RMT=1.0D0/(PX*PX+PY*PY+PZ*PZ)
      TMA=RMT*ERD
      CLT=TMA*(XP*CGB+YP*SGB)
      SLT=TMA*(YP*CGB-XP*SGB)
      RZR=TMA*ZP
      RMR=TMA*ERD
      TWR=0.5D0/ERD
      RMO=DSQRT(RMT)
      LMX=0
      LNC=1
      LA=LCT(2)
      IF (NTE-1)15,15,20
   15 LA=0
   20 LB=LCT(1)
      LC=LA
      NB=NTE+1
      DO 75 I=1,NB
      KA=LA-1
      KB=LB
      KC=LC+1
      IF (KB-KA)30,35,35
   30 KB=KA
   35 IF (LC) 50,50,40
   40 IF (KB-KC)45,50,50
   45 KB=KC
   50 LNC=LNC+KB+1
      ICT(I)=LNC
      LA=LB
      LB=LC
      LC=LCT(I+2)
      IF (LMX-LA)60,65,65
   60 LMX=LA
   65 IF (I-NTE+1)75,70,70
   70 LC=0
   75 CONTINUE
      TMA=2.0D0
      TMB=2.0D0
      DO 90 I=1,LMX
      CTT(I)=-TMA
      CTB(I)= TMB
      TMA=TMA+2.0D0
      TMB=TMB+TMA
   90 CONTINUE
      UMT(1)=XMU*RMO
      VMT(1)=0.0D0
      LA=1
      LB=1
```

```
      NA=2                                                              81400
      KB=2                                                              81500
      DO 160 I=1,NB                                                     81600
      KC=ICT(I)-1                                                       81700
      KA=I-1                                                            81800
      TMB=KA+KA                                                         81900
      TMA=TMB+1.0D0                                                     82000
      TMC=1.0D0                                                         82100
      IF (KC-KB)140,100,100                                             82200
  100 DO 130 LC=KB,KC                                                   82300
      TMD=RZR*UMT(LB)*TMA                                               82400
      TME=RZR*VMT(LB)*TMA                                               82500
      IF (KB-LC)110,120,120                                             82600
  110 TMD=TMD-RMR*UMT(LB-1)*TMB                                         82700
      TME=TME-RMR*VMT(LB-1)*TMB                                         82800
  120 UMT(NA)=TMD/TMC                                                   82900
      VMT(NA)=TME/TMC                                                   83000
      TMA=TMA+2.0D0                                                     83100
      TMB=TMB+1.0D0                                                     83200
      TMC=TMC+1.0D0                                                     83300
      NA=NA+1                                                           83400
  130 LB=LB+1                                                           83500
  140 IF (I-NB)150,160,160                                              83600
  150 TMC=KA+KA+1                                                       83700
      UMT(NA)=TMC*(CLT*UMT(LA)-SLT*VMT(LA))                             83800
      VMT(NA)=TMC*(CLT*VMT(LA)+SLT*UMT(LA))                             83900
      NA=NA+1                                                           84000
      KB=KC+2                                                           84100
      LB=LB+1                                                           84200
      LA=LB                                                             84300
  160 CONTINUE                                                          84400
      TMA=0.0D0                                                         84500
      TMB=0.0D0                                                         84600
      TMC=0.0D0                                                         84700
      TMD=0.5D0                                                         84800
      KB=1                                                              84900
      LA=ICT(1)                                                         85000
      LB=2                                                              85100
      LC=LA                                                             85200
      DO 260 I=1,NTE                                                    85300
      KC=LCT(I)                                                         85400
      IF (KC)260,260,210                                                85500
  210 IF (I-2)230,215,220                                               85600
  215 LA=3                                                              85700
      GO TO 225                                                         85800
  220 LA=ICT(I-2)+2                                                     85900
  225 LB=ICT(I-1)+1                                                     86000
      LC=ICT(I)                                                         86100
  230 DO 250 NA=1,KC                                                    86200
      TME=CTB(NA)                                                       86300
      TMF=TME                                                           86400
      IF (I-1)235,235,240                                               86500
  235 TMF=TMD*TME                                                       86600
      TME=NA                                                            86700
      TMD=TMD*TME                                                       86800
      TME=NA+2                                                          86900
      TMD=TMD/TME                                                       87000
      TME=-TMF                                                          87100
  240 RMR=TME*UMT(LA)                                                   87200
      RZR=TMF*VMT(LA)                                                   87300
```

```
      CLT=UMT(LC)
      SLT=VMT(LC)
      TME=RMR-CLT
      TMF=RZR+SLT
      RMR=RMR+CLT
      RZR=RZR-SLT
      CLT=CNM(KB)
      SLT=SNM(KB)
      TMA=TMA+CLT*TME+SLT*RZR
      TMB=TMB-CLT*TMF+SLT*RMR
      TMC=TMC+CTT(NA)*(CLT*UMT(LB)+SLT*VMT(LE))
      LA=LA+1
      LB=LB+1
      LC=LC+1
  250 KB=KB+1
  260 CONTINUE
      TMA=TMA*TWR
      TMB=TMB*TWR
      PVA(7)=(CGB*TMA-SGB*TMB)
      PVA(8)=(SGB*TMA+CGB*TMB)
      PVA(9)=TMC*TWR
      RETURN
      END
```

```
      SUBROUTINE GETTAP
      DEFINE FILE 10(956,6636,L,IV)
      DOUBLE PRECISION TAB3,JDI,JDF,JD1,TDAY,JDIF,JDP
      REAL NUTAT
      REAL*8 TAB31
      COMMON/CETBL2/ICW,ICENT,IREG(13)
      COMMON/CETBL3/TAB3(829),NUTAT(204),CKSU
      COMMON/CETBL9/JD1,TDAY,JDIF,IERR1
      DATA IV/0/
      DATA IWPRV/0/
      JDP=JD1+TDAY
      IF(JDP.LT.2438760.5D0.OR.JDF.GT.2446424.5D0)GO TO 100
      IERR1=0
      IF(ICW.NE.1) GO TO 205
      DO 333 I=1,204
333   NUTAT(I)=0.
      ICW=2
      IW=1
      READ(10'IW)TAB3
      TAB31=TAB3(1)
205   IW=IDINT((JDP-TAB31)/8.D0)+1.D0
      IF(IW.EQ.IWPRV)GO TO 220
      IWPRV=IW
200   READ(10'IW)TAB3
      IF(JDP-TAB3(1))210,220,230
210   IW=IW-2
      GO TO 200
230   IW=IW+1
      IF(JDP-(TAB3(1)+8.D0))220,200,200
220   JDIF=JDP-TAB3(1)
      RETURN
101   FORMAT(' EPHEMERIS ERROR--JULIAN DATE ',D25.7,' IS
       BEFORE JAN 1965
     1OR AFTER DEC 1985')
100   WRITE(6,101)JDP
      STOP
      END
```

```
      SUBROUTINE GHA(TSEC,D,GHAN,DA,OMEGA)
      IMPLICIT REAL*8(A-H,O-Z)
      OMEGA=.00417807420D0/(1.D0+5.21D-13*D)
      DD=0.D0
      DD=D
      DD=DD*(.98564735D0/360.D0)
      DX=IDINT(DD)
      DD=DD-DX
      DF=DD
      TEM1=100.07554D0+360.D0*DF+2.9015D-13*D*D
     1+OMEGA*TSEC
    1 IF(TEM1)2,3,3
    2 TEM1=TEM1+360.D0
      GO TO 1
    3 IF(TEM1-360.D0)5,4,4
    4 TEM1=TEM1-360.D0
      GO TO 3
    5 GHAN=TEM1+DA*57.29577950D0
      RETURN
      END
```

```
      SUBROUTINE GOTOR(K,VM,C,F,E1)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION C(2),F(4)
      DIMENSION C(2),F(4)
C
C
C
C
      NMAX=20
      N=0
      GO TO (1,2),K
    1 CONTINUE
C     FIRST GUESS IS OBTAINED FOR ELLIPTICAL CASE
    8 CONTINUE
      IF(E1-1.0D0)30,31,31
   30 CONTINUE
      D2=E1*E1
      F(1)=E1*D2*(.16666667D+00-D2*(.833333333D-02-D2*(.198412698D-03-D2
     1*(.275573192D-05-D2*.25052108 3D-07))))
      F(2)=D2*(.5D0-D2*(.41666667D-01-D2*(.13888889D-02-D2*(.24801587D-0
     14-D2*.27557319D-06))))
      F(3)=E1-F(1)
      F(4)=1.0D0-F(2)
      GO TO 3
   31 CONTINUE
      F(3)=DSIN(E1)
      F(4)=DCOS(E1)
      F(1)=E1-F(3)
      F(2)=1.0D0-F(4)
      GO TO 3
    2 CONTINUE
C     FIRST GUESS IS OBTAINED FORHYPERBOLIC CASE
    5 CONTINUE
      IF(E1-1.0D0)32,33,33
   32 CONTINUE
      D2=E1*E1
      F(1) =E1*D2*(.16666667D+00+D2*(.833333333D-02+D2*(.198412698D-03+D2
     1*(.275573192D-05+D2*.25052108 3D-07))))
      F(2)=D2*(0.5D0+D2*(.41666667D-01+D2*(.13888889D-02+D2*(.24801587D-
     104+D2*.27557319D-06))))
      F(3)=E1+F(1)
      F(4)=1.0D0+F(2)
      GO TO 3
   33 CONTINUE
      EX=.5D0*DEXP(E1)
      OX=.25D0/EX
      F(3)=EX-OX
      F(4)=EX+OX
      F(1)=F(3)-E1
      F(2)=F(4)-1.0D0
    3 CONTINUE
      CM=F(1)+C(1)*F(3)+C(2)*F(2)
      DM=F(2)+C(1)*F(4)+C(2)*F(3)
      DE=(VM-CM)/DM
      ERROR=DE
      AB=DABS(DE)
      IF(AB-1.0D0)10,10,11
   11 DE=DE/AB
   10 E2=E1+DE
      IF ((E2+E1).EQ. 0.D0)   GO TO 4
```

```
      IF(DABS((E2-E1)/(E2+E1))-3.D-8)4,4,5
    5 CONTINUE
      IF(N-NMAX)6,7,7
    7 CONTINUE
      GO TO 4
    6 CONTINUE
      N=N+1
      E1=E2
      GO TO (8,9),K
    4 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE HARMON(R1,V1,ACC,TIME)
      IMPLICIT REAL*8 (A-H,O-Z,$)
      DIMENSION DATEEC(3,3),DATECT(3,3)
      DIMENSION R1(3,8),V1(3,8),RR(3),ACC(3),TEMP(3),DATE(3,3),
     1  SDATE(3,3),DATET(3,3),SDATET(3,3),ADATE(3,3),ADATET(3,3)
      DIMENSION A(3,3),EN(3,3),EMN(3,3),AE(3,3),LCT(8),ICT(9),
     1  CNM(36),SNM(36),ECN(3),PVA(9),CTT(8),CTE(8),UMT(45),VMT(45),
     2  LCTM(5),ICTM(6),CNMM(15),SNMM(15),CTTM(5),CTEM(5),UMTM(21),
     3  VMTM(21)
      COMMON/ROT/ DATE,SDATE,DATET,SDATET,ADATE,ADATET,DATEEC,DATECT,EN
      COMMON/XLIB/ SG,TA,XMLIB
      COMMON C(1000),IC(50),Z(3),VV(3),NDF
      COMMON/TUP/ TLU
      DATA LCT/8,7,6,5,4,3,2,1/, LCTM/5,4,3,2,1/
      EQUIVALENCE  (C(200),CNM(1)), (C(236),SNM(1)),(C(272),CNMM(1))
      EQUIVALENCE (C(287),SNMM(1))
      KEY=1
      IF( DABS(TLU-TIME) .LT. C(501) )  GO TO 100
      TLU=TIME
      KEY=2
      CALL ROTEQ(TIME,A)
      CALL NUTAIT(TIME,OM,CR,DT,EN,EPSIL)
      CALL MULT(EN,A,DATE)
      DO 101 I=1,3
      DO 101  J=1,3
101   DATET(J,I) = DATE(I,J)
100   CONTINUE
      GO TO (20,4,80,80,5),  NDF
 20   CONTINUE
      NTE=8
      ECN(1) = C(21)
      ECN(2) = C(1)
      ITIME = TIME
      T2 = (TIME-ITIME)*86400.0D0
      T1 = ITIME
      DA = EN(2,1)
      CALL GHA(T2,T1,GHAN,DA,OMEGA)
      ECN(3) = GHAN*.0174532925 2D0
      CALL M1(R1(1,1),DATE,RR)
      DO 1 I=1,3
  1   PVA(I) = RR(I)
      CALL GETACC(LCT,ICT,CNM,SNM,ECN,PVA,CTT,CTE,UMT,VMT,NTE)
      CALL M1 (PVA(7),DATET,ACC)
      RETURN
  4   CONTINUE
      GO TO (200,202),  KEY
202   CALL MNA(TIME,OM,CR,DT,EPSIL,RO,G,GF,WW,EMN)
      CALL MULT(EMN,DATE,SDATE)
      DO 201 I=1,3
      DO 201 J=1,3
201   SDATET(J,I) = SDATE(I,J)
200   CONTINUE
      DP=TIME
      TP=DP/36525.D0
      T2P=TP*TP
      T3P=T2P*TP
      OM=12.11279D0-.052953922D0*DP +.0020795D0*TP
     1   +.002081D0*T2P+.2D-5*T3P
      CR=64.375452D0 +13.176397D0*DP -.001131575D0*TP
     1   -.00113015D0*T2P+ .15D-5*T3P
```

```
      EPSIL=23.4457587D0-.01309404D0*TP -.88D-6*T2P +.5D-6*T3P
      OM=OM*C(75)
      CR=CR*C(75)
      EPSIL=EPSIL*C(75)
      XMLIB = 180.D0*.017453292520 + CR-CM+TA-SG
      NTE=5
      ECN(1) = C(22)
      ECN(2) = C(2)
      ECN(3) = 0.D0
      CALL M1(R1(1,2),SDATE,RR)
      DO 2 I=1,3
    2 PVA(I) = RR(I)
      CALL GETACC(LCTM,ICTM,CNMM,SNMM,ECN,PVA,CTTM,CTEM,UMTM,VMTM,NTE)
      CALL M1(PVA(7),SDATET,ACC)
      RETURN
    5 CONTINUE
      XJ2 = C(725)
      XJ3 = C(726)
      RE = C(25)
      U = C(5)
      R = FNORM(R1(1,5))
      GO TO (300,302), KEY
  302 ITIME = TIME
      T2 = TIME-ITIME
      T1 = ITIME
      CALL DATOUT (T1,T2,DATE,FDATE,0)
      CALL ARES(DATE,FDATE,AR)
      CALL MULT(AR,A,ADATE)
      DO 301 I=1,3
      DO 301 J=1,3
  301 ADATET(J,I) = ADATE(I,J)
  300 CONTINUE
      CALL M1(R1(1,5),ADATE,RR)
      R2 = R**2
      R5 = R**5
      R7 = R5*R2
      RE2 = RE*RE
      RE3 = RE2*RE
      Z2 = RR(3)*RR(3)
      Z3 = Z2*RR(3)
      COEF = -1.5D0*U*XJ2*RE2/R5
      DO 10 I=1,3
   10 PVA(I+6) = COEF*(-5.D0*Z2*RR(I)/R2 + RR(I))
      PVA(9) = PVA(9) + COEF*2.D0*RR(3)
      IF(XJ3.EQ.0.D0)  GO TO 13
      COEF = -.5D0*U*XJ3*RE3/R7
      DO 14 I=1,3
   14 TEMP(I) = COEF*(-35.D0*Z3*RR(I)/R2 + 15.D0*RR(I)*RR(3))
      TEMP(3) = TEMP(3) + COEF*(15.D0*Z2-3.D0*R2)
      DO 15 I=1,3
   15 PVA(I+6) = PVA(I+6) + TEMP(I)
   13 CALL M1(PVA(7),ADATET,ACC)
C     CONTINUE
   60 RETURN
      END
```

```
      SUBROUTINE INTR1(TW,TF,NB,POS,IDUM,VEL,DUM2)                      114000
      IMPLICIT REAL*8 (A-H,O-Z)                                         114100
C*********************************************************************** 114200
C        THIS VERSION OF THE 360 JPL DOUBLE PRECISION EPHEMERIS         114300
C     WAS MODIFIED BY JERRY S. LINNEKIN OF CODE 551 GSFC,GREENBELT MD.  114400
C     IT HAS BEEN MODIFIED TO HANDLE  SEVEN BODIES INSTEAD OF THE       114500
C     NORMAL ELEVEN. THE BODIES AND ORDER ARE EARTH,MOON,SUN,VENUS,MARS, 114600
C     SATURN AND JUPITER. SATURN AND JUPITER HAVE BEEN INTERCHANGED     114700
C     TO CORRESPOND TO THE QUICK LOOK MISSION ANALYSIS PROGRAM.         114800
C     THE READ ROUTINE-GETTAP HAS BEEN MODIFIED TO USE THE DIRECT ACCESS 114900
C     READ FEATURE OF 360 FORTRANH.IN ADDITION,THE NUTATION VARIABLES   115000
C     HAVE BEEN ELIMINATED FROM THIS VERSION SO THAT AN EPHEMERIS       115100
C     RECORD WILL FIT ON ONE TRACK OF A 2316 DISK PACK.                 115200
C     THE DECK AS IT APPEARS HERE IS SET UP AS A DIRECT REPLACEMENT     115300
C     FOR THE SINGLE PRECISION  INTR1 IN THE QUICK LOOK MISSION         115400
C     ANALYSIS PROGRAM.                                                 115500
C*********************************************************************** 115600
C     IN ADDITION TO THE ABOVE CHANGES,THE FOLLOWING COMMENT CARDS      115700
C     DESCRIBE THE CHANGES NECESSARY TO USE THIS PACKAGE WITH THE       115800
C     MARK2 PROGRAM ,THE MARK2 COVERAGE PROGRAM AND THE QUICK LOOK      115900
C     COVERAGE PROGRAM                                                  116000
C       ******          MARK2 PROGRAM     *********                     116100
C     SUBROUTINE ANTR (TW,TF,NB,POS,VEL) MK2 PROGRAM                    116200
C     DATA NCENT/3,11,10,2,4,5,6/        MARK2                          116300
C     NCENTR=NCENT(NB)                   FOR MARK II                    116400
C       ******   MARK2 COVERAGE PROGRAM*********                        116500
C     SUBROUTINE ANTR1(TW,TF,NB,POS,KK,VEL,DIS)   MK2 COVERAGE PROGRAM  116600
C     DATA NCENT/3,11,10,2,4,5,6/        MARK2                          116700
C     NCENTR=NCENT(NB)                                                  116800
C       ******  COVER -QUICK LOOK COVERAGE PROG  ****                   116900
C      NO CHANGE NECESSARY DUE TO CAREFUL PLANNING BY PROGRAMMER        117000
C*********************************************************************** 117100
C        TO EXTEND THE EPHEMERIS FOR ALL BODIES,CHANGE THE  FOLLOWING   117200
C     POS(21) TO POS(33),VEL(21) TO VEL(33) AND NCENT(7) TO NCENT(11)   117300
C     REPLACE  THE NCENT DATA CARD WITH                                 117400
C     DATA NCENT/3,11,10,2,4,5,6,1,7,8,9/                               117500
C     THIS WILL RESULT IN THE FOLLOWING BODIES IN THE ORDER             117600
C     THAT THEY ARE LISTED EARTH,MOON,SUN,VENUS,MARS,JUPITER,SATURN,    117700
C     MERCURY,URANUS,NEPTUNE AND PLUTO.                                 117800
C*********************************************************************** 117900
C     ARGUMENT DESCRIPTION                                              118000
C     TW    INPUT, WHOLE DAYS FROM 1950, REAL*8                         118100
C     TF    INPUT, FRACTIONAL DAYS FROM 1950, REAL*8                    118200
C     NB      INPUT, CENTRAL BODY NUMBER (1-EARTH, 2-MOON, 3-SUN,       118300
C     4-VENUS, 5-MARS, 6-SATURN, 7-JUPITER), INTEGER*4                  118400
C     POS   OUTPUT, POSITION ARRAY, POS(1)-POS(3), EARTH X,Y,Z          118500
C     VEL   OUTPUT, VELOCITY ARRAY, REAL*8                              118600
C     NCENTR   CENTRAL BODY NUMBER (3-EARTH,11-MOON, 10-SUN, 2-VENUS,   118700
C     AU   ASTRONOMICAL UNIT                                            118800
C     REM   EQUATORIAL RADIUS OF EARTH                                  118900
C     4-MARS, 6-SATURN, 5-JUPITER)                                      119000
C     EMRAT   EARTH MOON MASS RATIO                                     119100
      REAL*8 JED,NUT                                                    119200
      REAL*8 JEDPRV                                                     119300
      REAL*8 JDN                                                        119400
      REAL*8 JEZ                                                        119500
      REAL*8 JD1                                                        119600
      DIMENSION POS(21),VEL(21),NCENT(7),IREG(13),TAECUT(6,12),NUT(4)   119700
      COMMON /CETBL1/ AU,REM,TPD,EMRAT                                  119800
      COMMON /CETBL2/ ICN,NCENTR,IREG                                   119900
```

```
      COMMON /CETBL4/ TABOUT,NLT
      DATA NCENT/3,11,10,2,4,6,5/
      DATA JEDPRV/0.D0/,IERR/0/
      DATA IFIRST/0/
      DATA NCENTP/0/
      IF(IFIRST.NE.0)GO TO 20
      ICW=1
      IFIRST=1
      AU=149597900.D0
      REM=6378.1492D0
      TPD=86400.D0
      EMRAT=81.301D0
 20   DO 10 I=1,13
   10 IREQ(I)=2
      IF(TF-.5D0)38,39,39
   38 SEC1=TF*86400.D0
      GO TO 40
   39 DT=TW+.5D0
      SEC1=(TF-.5D0)*86400.D0
      GO TO 41
   40 DT=TW
 41   JD1=DT+2433282.5D0
C*********************************************************************
C*********************************************************************
      TSEC=SEC1
      JED=JD1
      JEZ=JED+TSEC
      NCENTR=NCENT(NB+1)
      IF(JEZ.EQ.JEDPRV.AND.NCENTR.EQ.NCENTP) GO TO 1
      JEDPRV=JEZ
      NCENTP=NCENTR
      CALL READE(JED,TSEC,IERR)
      IF(IERR.EQ.0) GO TO 1
      WRITE(6,100) IERR,NCENTR,ICW,JD3
  100 FORMAT(23H0EPHEMERIS ERROR, IERR=,I3,2I5,D14.2)
    1 CONTINUE
      DO 2 J=1,7
      DO 2 I=1,3
      II=(J-1)*3+I
      JJ=NCENT(J)
      POS(II)=TABOUT(I,JJ)
    2 VEL(II)=TABOUT(I+3,JJ)
      RETURN
      END
```

```
      SUBROUTINE ITER(IB,R1,V1,F,K,KK,DT,F,V)
      IMPLICIT REAL*8(A-H,O-Z,$)
      COMMON C(1000),IC(50),Z(3),VV(3),NCR
      COMMON/STEPS/ STEP,XOLD
      DIMENSION X1(3),R1(3,8),R(3,8),V1(3,8),V(3,8),RR(3),VVV(3),CB(20)
      COUNT=0.D0
      ZRS=6.965D5
      XK=1
      F=0.D0
      DT=0.D0
      T=0.D0
      LK=1
      TOLD=0.D0
      FOLD=0.D0
      NN=1
      IF(KK.EQ.2) XK=-1
C  K=1 MEANS EARTH SHADOW, K=2 MEANS MOON SHADOW
C   K=3 MEANS OTHER PLANET SHADOW
C  KK=1 MEANS PENUMBRA, KK=2 MEANS UMBRA
      DO 2000 I=1,8
      DO 2000 J=1,3
      R(J,I)=R1(J,I)
 2000 V(J,I)=V1(J,I)
      GO TO (1,2,10),K
    1 DO 3 I=1,3
    3 X1(I)=R(I,1)-R(I,3)
      SEVA= ADOT(X1,R(1,1))
      RFS=FNORM(R(1,3))
      RFE= FNORM(R(1,1))
      DELS= DARSIN(6500.D0/RFE)*57.2957795D0
      ZRE=6500.D0
      GO TO 4
    2 DO 5 I=1,3
    5 X1(I)=R(I,2)-R(I,3)
      SEVA= ADOT(X1,R(1,2))
      RFS= FNORM(R(1,3))
      RFE= FNORM(R(1,2))
      DELS=DARSIN(1738.D0/RFE)*57.2957795D0
      ZRE=1738.D0
      GO TO 4
   10 DO 20 I = 1, 3
   20 X1(I) = R(I, NOR) - R(I,3)
      SEVA= ADOT(X1,R(1,NOR))
      RFS=FNORM(R(1,3))
      RFE= FNORM(R(1,NOR))
      DELS=DARSIN(C(NOR+20)/RFE)*57.2957795D0
      ZRE=C(NOR+20)
    4 CONTINUE
      ZRE=DSIGN(ZRE,XK)
      SIG=DARSIN((ZRS+ZRE)/RFS)*57.2957795D0
      F=SEVA+DELS+XK*SIG-180.D0
      IF(DABS(F).LE.0.000001D0) RETURN
      IF(COUNT.GT.100.D0) GO TO 11
      GO TO (6,7),LK
    6 LK=2
      DT=-STEP
      GO TO 8
    7 DT=(TOLD*F-T*FOLD)/(F-FOLD)
    8 FOLD=F
      TOLD=T
```

```
      T=DT                                                              130400
      CALL STEPD(NN,DT,TA,R1(1,IB),V1(1,IB),C(IB),RR,VVV,1,CB)          130500
      TIM= C(593)+(XOLD+C(506)+T)/E6400.D0                              130600
      CALL TFRAC(C(592),TIM,TT,TTF)                                     130700
      CALL SHIFTP(IB,RR,VVV,TT,TTF,R,V)                                 130800
      COUNT=COUNT+1.D0                                                  130900
      GO TO (1,2,10),K                                                  131000
   11 WRITE(6,12)                                                       131100
   12 FORMAT(1H0,22HMAX ITERATIONS IN ITER)                             131200
      STOP                                                              131300
      END                                                               131400
```

```
      SUBROUTINE KONSTK
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION C(1000),IC(50)
      DIMENSION S(40,1),SSS(40,6)
      DIMENSION DNAME(2,6)
      DIMENSION D(7,3)
C THE FOLLOWING STATEMENT(S) HAVE BEEN MANUFACTURED BY THE TRANSLATOR TO
C   COMPENSATE FOR THE FACT THAT EQUIVALENCE DOES NOT RECORDER COMMON---
      COMMON  C
      COMMON  IC      , SSS
C     DIMENSION C(1000),IC(50)
C     DIMENSION S(40,1),SSS(40,6)
C     DIMENSION DNAME(2,6)
C     DIMENSION D(7,3)
C     COMMON C,IC,SSS
      EQUIVALENCE (C(201),S(1,1)),(C(341),D(1,1)),(C(448),DNAME(1,1))
C     DEFINES CONSTANTS NEEDED BY PROGRAM
C
      DO 1 I=1,1000
    1 C(I)=0.0D0
C     PLANETARY GRAVITATIONAL CONSTANTS (KM3/SEC2)
      C(1) = 398603.2D0
      C(2) = 4902.778D0
      C(3) = .13271545D12
      C(4) = 324769.5D0
      C(5)=42915.515D0
      C(6)=.12671059D9
      C(7)=10000.0D0
      C(8)=10000.0D0
C     RADIUS OF SPHERE OF INFLUENCE (KM)
      C(11)=925000.0D0
      C(12)=66000.0D0
      C(13)=1.D10
      C(14)=616000.0D0
      C(15)=565000.0D0
      C(16)=.48D8
      C(17)=100000.0D0
      C(18)=100000.0D0
C     IMPACT RADIUS  (KM)
      C(21)=6378.165D0
      C(22)=1738.0D0
      C(23)=694000.0D0
      C(24)=6050.0D0
      C(25) = 3417.0D0
      C(26)=71000.0D0
      C(27)=10000.0D0
      C(28)=10000.0D0
C     MINIMUM TIME STEP FOR OUTPUT (SEC)
      C(31)=43200.0D0
      C(32)=21600.0D0
      C(33)=1728000.0D0
      C(34)=43200.0D0
      C(35)=43200.0D0
      C(36)=86400.0D0
      C(37)=43200.0D0
      C(38)=43200.0D0
C     SIDEREAL ROTATION RATES  (RAD/SEC)
      C(41)=.72921152D-4
C     INTERPOLATION INTERVALS FOR EPHEMERIS  (DAYS)
      C(51)=40.0D0
```

```
      C(54)=40.0D0
      C(55)=40.0D0
      C(56)=100.0D0
C     NAMES OF EPHEMERIS BODIES
      DATA Q000HL/6H EARTH/
      C(61)=Q000HL
      DATA Q001HL/6H  MOON/
      C(62)=Q001HL
      DATA Q002HL/6H   SUN/
      C(63)=Q002HL
      DATA Q003HL/6H VENUS/
      C(64)=Q003HL
      DATA Q004HL/6H  MARS/
      C(65)=Q004HL
      DATA Q005HL/6HJUPTER/
      C(66)=Q005HL
      DATA Q006HL/6HBODY 7/
      C(67)=Q006HL
      DATA Q007HL/6HBODY 8/
      C(68)=Q007HL
C     ASTRONOMICAL UNIT IN KM
      C(70)=.1495D9
C     SECONDS PER MEAN SOLAR DAY AND RECIPROCAL
      C(71)=86400.0D0
      C(72)=1.1574074D-5
C     SEMI-MAJOR AND SEMI-MINOR AXES OF THE EARTH (KM)
      C(73)=6378.2064D0
      C(74)=6356.5838D0
C     DEGREE-RADIAN CONVERSIONS
      C(75)=.01745329 3D0
      C(76) = 57.2957795D0
      C(77) = 1.57079632D0
      C(78) = 3.14159265D0
      C(79) = 6.28318530D0
      DATA Q008HL/6H     K/
      C(85)=Q008HL
      DATA Q009HL/6HM-KM/S/
      C(86 )=Q009HL
      DATA Q010HL/6HEC-DEG/
      C(87)=Q010HL
      DATA Q011HL/6H     L/
      C(88 )=Q011HL
      DATA Q012HL/6HNITS A/
      C(89 )=Q012HL
      DATA Q013HL/6HU--DEG/
      C(90 )=Q013HL
      DATA Q014HL/6H   EQL/
      C(91)=Q014HL
      DATA Q015HL/6HATOR O/
      C(92)=Q015HL
      DATA Q016HL/6HF DATE/
      C(93)=Q016HL
      DATA Q017HL/6H  ECLI/
      C(94)=Q017HL
      DATA Q018HL/6HPTIC O/
      C(95)=Q018HL
      C(96)=Q016HL
      DATA Q019HL/6H     S/
      C(97)=Q019HL
      DATA Q020HL/6HELENOG/
```

```
      C(98)=Q020HL                                                      143500
      DATA Q021HL/6HRAPHIC/                                             143600
      C(99)=Q021HL                                                      143700
      C(122)=1.0D0                                                      143800
C ****  THE FOLLOWING ARE EARTH POTENTIAL COEFFICIENTS  ****            143900
C       C(200) THRU C(207) IS C(0,0) THRU C(7,0)                        144000
C       C(208) THRU C(214) IS C(1,1) THRU C(7,1)                        144100
C       C(215) THRU C(220) IS C(2,2) THRU C(7,2)                        144200
C       C(221) THRU C(225) IS C(3,3) THRU C(7,3)                        144300
C       C(226) THRU C(229) IS C(4,4) THRU C(7,4)                        144400
C       C(230) THRU C(232) IS C(5,5) THRU C(7,5)                        144500
C       C(233) THRU C(234) IS C(6,6) THRU C(7,6)                        144600
C       C(235) IS C(7,7)                                                144700
C       C(236) THRU C(243) IS S(0,0) THRU S(7,0)                        144800
C       C(244) THRU C(250) IS S(1,1) THRU S(7,1)                        144900
C       C(251) THRU C(256) IS S(2,2) THRU S(7,2)                        145000
C       C(257) THRU C(261) IS S(3,3) THRU S(7,3)                        145100
C       C(262) THRU C(265) IS S(4,4) THRU S(7,4)                        145200
C       C(266) THRU C(268) IS S(5,5) THRU S(7,5)                        145300
C       C(269) THRU C(270) IS S(6,6) THRU S(7,6)                        145400
C       C(271)          IS S(7,7)                                       145500
      C(200)=0.0D0                                                      145600
      C(201)=0.0D0                                                      145700
      C(202)=-.108264500002D-2                                          145800
      C(203)=0.254599999 9D-5                                           145900
      C(204) = .164 D-5                                                 146000
      C(205) = .210 D-6                                                 146100
      C(206) = -.645999999993D-6                                        146200
      C(207) = .332999999998D-6                                         146300
      C(208) = 0.D0                                                     146400
      C(209) = 0.D0                                                     146500
      C(210) = .209111899862 D-5                                        146600
      C(211) = -.542646846485 D-6                                       146700
      C(212) = -.676515582477D-7                                        146800
      C(213) = -.369794022 46 D-7                                       146900
      C(214) = .144189235 78 D-6                                        147000
      C(215) = .153563789676D-5                                         147100
      C(216) = .250708728736D-6                                         147200
      C(217) = .737902432577D-7                                         147300
      C(218) = .102117707526D-6                                         147400
      C(219) = .858383031385D-8                                         147500
      C(220) = .362552678174 D-7                                        147600
      C(221) = .782277124813D-7                                         147700
      C(222) = .508569773273D-7                                         147800
      C(223) = -.171778742888D-7                                        147900
      C(224) = -.119630040940D-8                                        148000
      C(225) = -.352147606138 D-8                                       148100
      C(226) = -.111982938 75 D-8                                       148200
      C(227) = -.206336328204D-8                                        148300
      C(228) = -.166560812946D-9                                        148400
      C(229) = -.322776554575D-9                                        148500
      C(230) = .384108946188D-9                                         148600
      C(231) = -.252611520257 D-9                                       148700
      C(232) = .268980462153D-10                                        148800
      C(233) = -.931915036559D-11                                       148900
      C(234) = -.145066738 26D-10                                       149000
      C(235) = .102027945339D-11                                        149100
      C(236) = 0.D0                                                     149200
      C(237) = 0.D0                                                     149300
      C(238) = 0.D0                                                     149400
```

```
      C(239) = 0.D0
      C(240) = 0.D0
      C(241) = 0.D0
      C(242) = 0.D0
      C(243) = 0.D0
      C(244) = 0.D0
      C(245) = 0.D0
      C(246) = .2873128376320-6
      C(247) = -.4449324667790-6
      C(248) = -.8820393C748 D-7
      C(249) = -.2124348E397 D-7
      C(250) = .1141803C8536 D-6
      C(251) = -.8720667501 18 D-6
      C(252) = -.1837615837 37 D-6
      C(253) = .1478040933150-6
      C(254) = -.3754565474840-7
      C(255) = -.4553162166 48 D-7
      C(256) = .1623518E6106 D-7
      C(257) = .2258982C7164 D-6
      C(258) = -.1135467178870-7
      C(259) = .2312408154 25 D-9
      C(260) = .6427505790650-9
      C(261) = .2535462764220-9
      C(262) = .4859636964750-8
      C(263) = .4983216986304 D-9
      C(264) = -.1960875025120-8
      C(265) = -.2166C0C56362D-9
      C(266) = -.1457644206050-8
      C(267) = -.3696360264510-9
      C(268) = .1911176567930-10
      C(269) = -.3611188268660D-10
      C(270) = .4372814139240-11
      C(271) = .1780851409540-11
C ****  THE FOLLOWING ARE MOON POTENTIAL COEFFICIENTS  ****
C       C(272) THRU C(276) IS C(0,0) THRU C(4,0)
C       C(277) THRU C(280) IS C(1,1) THRU C(4,1)
C       C(281) THRU C(283) IS C(2,2) THRU C(4,2)
C       C(284) THRU C(285) IS C(3,3) THRU C(4,3)
C       C(286)        IS C(4,4)
C       C(287) THRU C(291) IS S(0,0) THRU S(4,0)
C       C(292) THRU C(295) IS S(1,1) THRU S(4,1)
C       C(296) THRU C(298) IS S(2,2) THRU S(4,2)
C       C(299) THRU C(300) IS S(3,3) THRU S(4,3)
C       C(301)             IS S(4,4)
      C(272)=C.0D0
      C(273)=C.0D0
      C(274)=-.207108D-3
      C(275)=C.21D-4
      C(279)=C.34D-4
      C(281)=C.20716D-4
      C(284)=C.02583D-4
C     C(462)= FLAG FOR IMPACT
      C(462)=1.D0
      C(506)=0.D0
C     C(719)= REDUCTION FROM UNIVERSIAL TO EPHM TIME 1966
      C(719)=40.0D0
C       C(720)= RETIFICATION LIMIT IN ROUTINE DERIV
      C(720)=C.025D0
C       C(725)= J2 OF MARS
      C(725)=C.1946667D-2
```

```
C       C(726)= J3 /F MARS
        C(726)=0.D0
C         C(758) STANDS FOR TYPE OF INPUT
C                =1   EARTH MEAN EQUATOR AND EQUINOX OF 1950
C                =2   TRUE EQUINOX AND ECLIPTIC OF DATE
C                =3   SELENOGRAPHIC TRUE MOON EQUATOR OF DATE
C                =4   MARS MEAN EQUATOR OF DATE
C                =5   TRUE EARTH EQUATOR AND EQUINOX OF DATE
        C(758)=1.D0
C         C(761) IS DAYS FOR INTEGRATION
        C(761)=180.0D0
        C(762)=1.0D0
        C(763)=0.0D0
        C(764)=66400.D0
        C(765)=-1.0D0
        C(766)=1.0D0
        C(767)=5.0D0
        C(768)=111.D0
C---- C(769) SOLAR PRESS KEY       0.0=D0 NOT INCLUDE  1.0= INCLUDE
        C(769)=0.0D0
C---- C(770) AREA FOR SOLAR PRESSURES (CM.**2)
        C(770)=22225.D0
C---- C(771) MASS FOR SOLAR PRESS (GM.)
        C(771)=113000.D0
C---- C(772) REFLECTIVITY
        C(772)=0.2D0
C---- C(773) FRACTION OF PARTICLES REFLECTED
        C(773)=1.0D0
C---- C(774) SOLAR PRESS AT ONE A.U.
        C(774)=4.7D-5
C --- C(775) IS KEY FOR INPUT.=0. INPUT IS CARTESIAN.=1. INPUT IS
C        ORBITAL ELEMENTS
        C(775)=0.D0
C ---- C(776) IS KEY FOR STOPPING AT APOGEE OR PERIGEE.
C ---- =0. DO NOT STOP.  =1. STOP AT APOGEE. =-1. STOP AT PERIGEE
        C(776)=0.D0
C----C(777) IS THE KEY FOR EXTRA OUTOUT AND IS IN THE FORM ABCDEFGH.
C----C MEANS DO NOT PRINT AND 1 MEANS PRINT.
C---- A= CENTRAL BODY MEAN EARTH EQUATOR OF 1950
C---- B= MOON FIXED
C---- C= MARS MEAN EQUATOR OF DATE
C---- D= CENTRAL BODY TRUE ECLIPTIC AND EQUINOX OF DATE
C---- E= EARTH CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
C---- F=   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
C---- G= CENTRAL BODY TRUE EARTH EQUATOR OF DATE
C---- H=EARTH FIXED LATITUDE AND LONGITUDE
        C(777)=10000011.
C         C(901) IS DELTA T FOR UPDATING TRANSFORMATIONS IN HARMON
        C(901)=15.D0
C      THESE CONSTANTS WERE DEFINED IN MAIN
        IC(1)=0
        IC(2)=0
        RETURN
        END
```

```
      SUBROUTINE M1 (X,A,Y)                                             160900
      IMPLICIT REAL*8(A-H,O-Z,$)                                        161000
C     SUBROUTINE GIVES Y=AX                                             161100
      DIMENSION  X(3),Y(3),A(3,3)                                       161200
C     DIMENSION  X(3),Y(3),A(3,3)                                       161300
      DO 1 I=1,3                                                        161400
      Y(I)=0.D0                                                         161500
      DO 1 J=1,3                                                        161600
    1 Y(I)=Y(I)+A(I,J)*X(J)                                             161700
      RETURN                                                            161800
      END                                                               161900
```

```
      SUBROUTINE MNA(TIME,OM,CR,DT,EPSIL,RC,G,GP,WW,EM)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION EM(3,3),DF(3)
      COMMON/XLIB/ SG,TA
C
C
C
      D = TIME
      T = D/36525.D0
      T2 = T*T
      T3 = T2*T
      A=13.064992D0
      DO 6 I=1,3
      DD=0.D0
      DD=D
      DD=DD*(A/360.D0)
      DD=DD-IDINT(DD)
      DF(I)=DD
      GO TO (4,5,6),I
    4 A=.9856005D0
      GO TO 6
    5 A=.1643586D0
    6 CONTINUE
      G=215.54013D0+360.D0*DF(1)
      GP=358.009067D0+360.D0*DF(2)
      WW=196.745632D0+360.D0*DF(3)
      G = G*.017453296D0
      GP = GP*.017453296D0
      WW = WW*.017453296D0
      YN = 1.535D0*.017453296D0
      RO = -.0297222D0*DCOS(G)+.0102777D0*DCOS(G+2.D0*WW)
     1     -.00305555D0*DCOS (2.D0*G+2.D0*WW)
      TA = -.00333D0*DSIN(G)+.0163888D0*DSIN(GP)
     1   +.0050D0*DSIN(2.D0*WW)
      SG = -.0302777D0*DSIN(G) + .0102777D0*DSIN(G+2.D0*WW)
     1     -.00305555D0*DSIN (2.D0*G+2.D0*WW)
      SG = (SG*.017453296D0)/DSIN (YN)
      RO = RO*.017453296D0
      TA = TA*.017453296D0
      YN = YN + RO
      RO = OM + SG + DT
      CI = DCOS (RO)*DSIN (EPSIL)*DSIN (YN)
     1    +DCOS (EPSIL)*DCOS (YN)
      SI = 1.D0 - CI**2
      SI = DSQRT (SI)
      SO = -DSIN (RO)*DSIN (YN)/SI
      CO = 1.D0 - SO**2
      CO = DSQRT (CO)
      SD = -DSIN (RO)*DSIN (EPSIL)/SI
      CD = -DSIN (RO)*SC*DCOS (EPSIL) - DCOS (RO)*CO
      DL=ARKTNS(0,CD,SD)
    8 CONTINUE
      CA = DL + (CR + TA) - (CM + SG)
      SA = DSIN (CA)
      CA = DCOS (CA)
      RO = DCOS (RO)*DSIN (EPSIL)/(SI*CD)
      EM(1,1) = CA*CO - SA*SO*CI
      EM(1,2) = CA*SO + SA*CO*CI
      EM(1,3) = SA*SI
      EM(2,1) = -SA*CO - CA*SC*CI
      EM(2,2) = -SA*SO + CA*CC*CI
      EM(2,3) = CA*SI
      EM(3,1) = SO*SI
      EM(3,2) = -CO*SI
      EM(3,3) = CI
      RETURN
      END
```

```
      SUBROUTINE MULT(A,B,C)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION A(3,3),B(3,3),C(3,3)
C     DIMENSION A(3,3),B(3,3),C(3,3)
      DO 1 I=1,3
      DO 1 J=1,3
      C(I,J) = 0.D0
      DO 1 K=1,3
    1 C(I,J) = C(I,J) + A(I,K)*B(K,J)
      RETURN
      END
```

```
      SUBROUTINE NUTAIT (TIME,CM,CR,DT,EN,EPSIL)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION EN(3,3)
C     DIMENSION EN(3,3)
      DD7=0.D0
      D = TIME
      T = D/36525.0D0
      T2 = T*T
      T3 = T2*T
      OM= 12.11279D0-.052953922D0*D+.00207950D0*T+.00208100D0*T2+.000002
     200D0*T3
      CR = 64.375452D0+13.176397D0*D-.001131575D0*T-.00113015D0*T2+.0000
     2019D0*T3
      GP = 208.84399D0+.111404C8D0*D-.01033400D0*T-.01034300D0*T2-.00001
     2200D0*T3
      VL = 280.08121D0+.9856473 4D0*D+.00030300D0*(T+T2)
      G = 282.08053D0+.470684D-04*D+.00045525D0*T+.00045750D0*T2+.000003
     2000D0*T3
      OM = OM*.017453296D0
      CR = CR*.017453296D0
      GP = GP*.017453296D0
      VL = VL*.017453296D0
      G = G*.017453296D0
      DE1 = 25.8844D0D0 * DCOS(CM)
      DE2 = -.2511D0 * DCOS(2.D0*CM)
      DE3 = 1.5336D0*DCOS(2.D0*VL)
      DE4 = .0666D0* DCOS( 3.D0* VL -G )
      DE5 = -.0258D0 * DCOS( VL+G )
      DE6 = - .0163D0 * DCOS( 2.D0*VL-CM)
      DE7 = -.0067D0 * DCOS( 2.D0*GP - CM )
      DE = DE1 + DE2 + DE3 + DE4 + DE5 + DE6 + DE7
      DD1 = .2456D0 * DCOS(2.D0*CR)
      DD2 = .0508D0 * DCOS( 2.D0* CR - CM)
      DD3 = .0365D0 * DCOS(3.D0* CR - GP )
      DD4 = -.0139D0 * DCOS( CR+GP)
      DD5 = -.0086D0 * DCOS( CR-GP+CM )
      DD6 = .0083D0 * DCOS( CR-GP-CM )
      DD8 = .0061D0 * DCOS( 3.D0 * CR+GP - 2.D0*VL )
      DD9 = .0064D0 * DCOS( 3.D0*CR -GP -CM)
      DD = DD1 + DD2 + DD3 + DD4 + DD5 + DD6 + DD7 + DD8 + DD9
      DT1 = -( 47.8927D0D0 + .0482D0*T) * DSIN(CM)
      DT2 = .58D0 * DSIN( 2.D0*CM )
      DT3 = -3.5361D0D0 * DSIN( 2.D0 * VL )
      DT4 = -.1378D0 * DSIN( 3.D0*VL -G )
      DT5 = .0594D0 * DSIN( VL+G )
      DT6 = .0344D0 * DSIN( 2.D0*VL - CM)
      DT7 = .0125D0 * DSIN( 2.D0*GP - CM )
      DT8 = .35D0 * DSIN( VL-G )
      DT9 = .0125D0 * DSIN( 2.D0*VL - 2.D0*GP )
      DT = DT1 + DT2 + DT3 + DT4 + DT5 + DT6 + DT7 + DT8 + DT9
      DS1 = -.5658D0 * DSIN( 2.D0*CR )
      DS2 = -.095D0 * DSIN( 2.D0*CR - CM )
      DS3 = -.0725D0 * DSIN( 3.D0*CR - GP )
      DS4 = .0317D0 * DSIN( CR+GP )
      DS5 = .0161D0 * DSIN( CR -GP +CM )
      DS6 = .0158D0 * DSIN( CR -GP -CM )
      DS7 = -.0144D0 * DSIN( 3.D0*CR + GP - 2.D0*VL )
      DS8 = -.0122D0 * DSIN( 3.D0*CR - GP - CM )
      DS9 = .1875D0 * DSIN( CR - GP )
      DS10 = .0078D0 * DSIN( 2.D0*CR - 2.D0*GP )
```

```
DS11 = .0414D0 * DSIN( CR + GP - 2.D0*VL )
DS12 = .0167D0 * DSIN( 2.D0*CR - 2.D0*VL )
DS13 = -.0089D0 * DSIN( 4.D0*CR - 2.D0*VL )
DS = DS1+DS2+DS3+DS4+DS5+DS6+DS7+DS8+DS9+DS10+DS11+DS12+DS13
DE = .17453296D-5*(DE+DD)
DT = .17453296D-5*(DT+DS)
EB = 23.4457587D0-.0130940400*T-.0000008800*T2+.0000000500*T3
EB = EB*.01745329600
EPSIL = EB+DE
EN(1,1) = 1.0D0
EN(1,2)=-DT*DCOS(EB)
EN(1,3)=-DT*DSIN(EB)
EN(2,1) = -EN(1,2)
EN(2,2) = 1.0D0
EN(2,3) = -DE
EN(3,1) = -EN(1,3)
EN(3,2) = DE
EN(3,3) = 1.0D0
RETURN
END
```

```
      SUBROUTINE ORB(X,DX,U,NCUT)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION C(1000)
      DIMENSION X(3),DX(3),B(3)
C THE FOLLOWING STATEMENT(S) HAVE BEEN MANUFACTURED BY THE TRANSLATOR TO
C   COMPENSATE FOR THE FACT THAT EQUIVALENCE DOES NOT REORDER COMMON---
      COMMON  C
C     COMMON C
C     DIMENSION C(1000)
C     DIMENSION X(3),DX(3),B(3)
      EQUIVALENCE (C(700),SMA),(C(701),ECC),(C(702),OINC),(C(703),OMG)
     1,(C(704),BEP),(C(705),RCA),(C(706),C3),(C(707),THET),(C(708),PERV)
     2,(C(709),P),(C(710),BB  ),(C(711),TPER)
      CALL CROSS(X,DX,B)
      R2 = DOT(X,X)
      R=DSQRT(R2)
      V2 = DOT(DX,DX)
      B2 = DOT(B,B)
      BB=DSQRT(B2)
      A=DOT(X,DX)/U
      P  = B2/U
      C3 = V2-2.0D0*U/R
      SMA=-U/C3
      ECC=DSQRT(DABS(1.0D0+C3*P/U))
      OINC=ARKTNS(180,B(3),DSQRT(B(1)**2+B(2)**2))
      OMG= ARKTNS(360,-B(2),B(1))
      RCA=P/(1.0D0+ECC)
      THT=ARKTNS(360,(P-R),BB*A)
      BET= ARKTNS(360,X(2)*B(1)-X(1)*B(2),X(3)*BB)
      BEP= BET-THT
      IF(BEP) 2,3,3
    2 BEP=BEP+6.2831853D0
    3 CONTINUE
      RTD=57.29577951D0
      OINC=OINC*RTD
      OMG=OMG*RTD
      BEP=BEP*RTD
      PERV=DSQRT(DABS(C3+2.0D0*U/RCA))
      VIMP=PERV-DSQRT(U/RCA)
      CTAS=(P/R-1.0D0)/ECC
      IF(DABS(CTAS).LT.1.D0) GO TO 200
      STAS=0.D0
      CTAS=DSIGN(1.0D0,CTAS)
      GO TO 201
  200 STAS=DSQRT(1.0D0-CTAS*CTAS)
      STAS = DSIGN( STAS,A )
  201 CONTINUE
      THE=ARKTNS(180,CTAS,STAS)
      THET=THE*RTD
      CALL TCONIC(U,ECC,SMA,P,THE,TPER,FAC)
      TPER=TPER/86400.0D0
      IF(SMA)10,10,11
   10 WRITE (    6,7)SMA,ECC,OINC,OMG,BEP,RCA,C3,THET,PERV,    F,VIMP,TPER
    7 FORMAT(5H  SMAD15.8,5H  ECCD15.8,5H  INCD15.8,5H  LAND15.8,
     15H  APFD15.8,5H  RCAD15.8/5H   C3D15.8,5H THETD15.8,5H PERVD15.8,
     25H  SLRD15.8,5H IMPVD15.8,5H TPERD15.8)
      GO TO 12
   11 F1=A*U/DSQRT(U*SMA)
      F2=1.0D0-R/SMA
      SINE=F1/ECC
```

```
      COSE=F2/ECC                                                       183800
      E=ARKTNS(360.,COSE,SINE)                                          183900
      XMAN=(E-ECC*SINE)*RTD                                             184000
      PERH = FAC * C(79) / 3600.D0                                      184100
      APBK=SMA*(1.D0+ECC)                                               184200
      WRITE (    6,5)SMA,ECC,CINC,CNG,EEP,RCA,C3,THET,APEK,    XMAN,PERH,T  184300
     1PER                                                               184400
    5 FORMAT(5H  SMAD15.8,5H  ECCD15.8,5H  INCD15.8,5H  LANC15.8,       184500
     15H  APFD15.8,5H  RCAD15.8/5H   C3D15.8,5H THETD15.8,5H APOGD15.8, 184600
     25H  MAND15.8,5H PERHD15.8,5H TPERD15.8)                           184700
   12 CONTINUE                                                          184800
      RETURN                                                            184900
      END                                                               185000
```

```
      SUBROUTINE ORB2X(X,VX,EL,U)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION X(3),VX(3),EL(6),A(3,2)
C     EL CONSISTS OF INPUT ORBITAL ELEMENTS
C     (1) SEMI-MAJOR AXIS (+ IF ELLIPTIC, -FOR HYPERBOLIC)
C     (2) ECCENTRICITY     (LESS THAN 1. ELLIPTIC, GREATER HYPERBOLIC)
C     (3) TRUE ANOMALY     (DEGREES)
C     ***IF C379 CHANGED TO 1., MEAN ANOMALY IS USED FOR INPUT
      C379 = 0.D0
C     (4) LONGITUDE OF THE ASCENDING NODE (DEGREES)
C     (5) INCLINATION    (DEGREES)
C     (6) ARGUMENT OF PERIAPSIS (DEGREES)
      DATA DR/.017453293D0/
      COM=DCOS(DR*EL(4))
      SOM=DSIN(DR*EL(4))
      CIN=DCOS(DR*EL(5))
      SNI=DSIN(DR*EL(5))
      IF(C379  )10,10,20
 20   XM=EL(3)*DR
      ECC=EL(2)
      E=XM+ECC*DSIN (XM)+(ECC**2/2.D0)*DSIN (2.D0*XM)+(ECC**3/24.D0)*(9.
     1D0*DSIN (3.D0*XM)-3.D0*DSIN (XM))+(ECC**4/192.D0)*(64.D0*DSIN (4.D
     *0*XM)-32.D0*DSIN (2.D0*XM))
      CTA=(DCOS (E)-ECC)/(1.D0-ECC*DCOS (E))
      STA=DSQRT (1.D0-ECC**2)*DSIN (E)/(1.D0-ECC*DCOS (E))
      TAA=ARKTNS(180,CTA,STA)
      GO TO 21
 10   CTA=DCOS (DR*EL(3))
      STA=DSIN(DR*EL(3))
      TAA=EL(3)*DR
   21 TBB=TAA+EL(6)*DR
      CBA=DCOS(TBB)
      SBA=DSIN(TBB)
      A(1,1)=COM*CBA-(SOM*CIN)*SBA
      A(2,1)=SOM*CBA+(COM*CIN)*SBA
      A(3,1)=SNI*SBA
      A(1,2)=-COM*SBA-(SOM*CIN)*CBA
      A(2,2)=-SOM*SBA+(COM*CIN)*CBA
      A(3,2)=SNI*CBA
      P=EL(1)*(1.0D0-EL(2)**2)
      R=P/(1.0D0+EL(2)*CTA)
C     R IS THE RADIUS VECTOR MAGNITUDE
      VR=EL(2)*STA*DSQRT(U/P)
C     VR IS THE RADIAL COMPONENT OF VELOCITY
      VT=DSQRT(U*(2.0D0/R-1.0D0/EL(1))-VR*VR)
C     VT IS THE TANGENTIAL COMPONENT OF VELOCITY
      DO 1 I=1,3
      X(I)=R*A(I,1)
      VX(I)=VR*A(I,1)+VT*A(I,2)
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OLT(X,Y,D,ERRCR,N,L,H)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION A(3,3),EN(3,3),EMN(3,3),AR(3,3)
      DIMENSION DATE(3,3),SDATE(3,3),DATET(3,3),SDATET(3,3),ADATE(3,3),
     1ADATET(3,3),DATEEC(3,3),DATECT(3,3),XX(3),XV(3)
      DIMENSION Y(20),D(20),ERRCR(30)
      DIMENSION RATE(3),PERT(3), PERTT(3)
      DIMENSION DACC(3),CACC(3),DACC(3)
      DIMENSION R1(3,8),V1(3,8)
      DIMENSION  XTEMP(3), VTEMP(3)
      DIMENSION DUM(3,3)
      COMMON/DISTRB/DACC,CACC,CACC
      COMMON /ROT/ DATE,SDATE,DATET,SDATET,ADATE,ADATET,DATEEC,DATECT
      COMMON/TIME/TW,TF
      COMMON C(1000),IC(50),Z(3),VV(3),NCR,INF
      COMMON/TUP/TLU
      COMMON/PRINT/ ICSC,ISEL,MARDAT,ICENEC,IEARFC,ISUNEC,ICDATE, IEARFX
      DATA ST/-1./,ST1/-1./
      EQUIVALENCE (C(401),R1(1,1)),(C(425),V1(1,1))
    3 TIM   =C(593)+(X+C(506))/86400.D0
      CALL TFRAC(C(592),TIM    ,TW,TF)
      IF (C(122)  .NE. 0.D0 ) GO TO 3000
      ST1 = TW
      ST = TF
      IF(C(594)-(C(506)+X).GT.0.D0) GO TO 50
 3000 IF(TW.EQ.ST1.AND.DABS(TF-ST).LE..00002D0) GO TO 50
      DO 1002 JJ=1,3
 1002 PERT(JJ)=DACC(JJ)-CACC(JJ)
      ST1=TW
      ST=TF
      WRITE(6,9)
    9 FORMAT(1H0)
      CALL DATOUT(TW,TF,DAYM,FDATE,0)
      TP=TW+TF
      TLU=TP
      CALL ROTEQ(TP,A)
      CALL NUTATT(TP,DM,DR,DT,EN,EPSIL)
      CALL MULT(EN,A,DATE)
      DUM(1,1)=1.D0
      DUM(1,2)=0.D0
      DUM(1,3)=0.D0
      DUM(2,1)=0.D0
      DUM(2,2)=DCOS(EPSIL)
      DUM(2,3)=DSIN(EPSIL)
      DUM(3,1)=0.D0
      DUM(3,2)=-DUM(2,3)
      DUM(3,3)= DUM(2,2)
      CALL MULT(DUM,DATE,DATEEC)
      DO 800 I=1,3
      DO 800 J=1,3
  800 DATET(J,I)=DATE(I,J)
C
  100 IF(ICDATE.EQ.0) GO TO 30
      CALL M1(R1(1,NOR),DATE,XX)
      CALL M1(V1(1,NOR),DATE,XV)
      WRITE(6,48) C(NOR+60)
   48 FORMAT(1H0,A6,1X,'CENTERED',3X,'TRUE EARTH EQUATOR AND EQUINOX OF
     1DATE')
      CALL OLTX(XX,XV,NOUT)
      CALL ORB(XX,XV,C(NOR),NOUT)
```

```
   30 IF(ICSO.EQ.0.AND.C(777).NE.0.D0) GO TO 31
      WRITE(6,10) C(NOR+60)
   10 FORMAT(1H0,A6,1X,8HCENTERED,3X,51HCENTRAL ECDY MEAN EARTH EQUATOR
     1AND EQUINOX OF 1950)
      CALL OUTX(R1(1,NOR),V1(1,NCR),NOUT)
      CALL ORB(R1(1,NOR),V1(1,NCR),C(NCR),NOUT)
   31 IF(IEARFX.EQ.0.OR.NOR.NE.1) GO TO 200
      ITIME=TP
      T2=(TP-ITIME)*86400.D0
      T1=ITIME
      DA=EN(2,1)
      CALL GHA(T2,T1,GHAN,DA,OMEGA)
      GHAN=GHAN*C(75)
      CALL M1(R1(1,NOR),DATE,XTEMP)
      SINT=DSIN(GHAN)
      COST=DCOS(GHAN)
      XX(1)= XTEMP(1)*COST+XTEMP(2)*SINT
      XX(2)=-XTEMP(1)*SINT+XTEMP(2)*COST
      XX(3)=XTEMP(3)
      XLATI=DARSIN(XX(3)/FNORM(XX))*C(76)
      XLONGI=ARKTNS(180,XX(1),XX(2))*C(76)
C
  200 CONTINUE
      IF(ISEL.EQ.0.OR.NOR.NE.2) GO TO 300
      CALL MNA(TP,UM,CR,DT,EPSIL,RO,G,GF,WW,EMN)
      CALL MULT(EMN,DATE,SDATE)
      DO 801 I=1,3
      DO 801 J=1,3
  801 SDATET(J,I)=SDATE(I,J)
      CALL M1(R1(1,NOR),SDATE,XX)
      CALL M1(V1(1,NOR),SDATE,XV)
      CALL M1(PERT,SDATE,PERTT)
      WRITE(6,500) C(NOR+60)
  500 FORMAT(1H0,A6,1X,'FIXED TRUE MOON EQUATOR OF DATE')
      CALL OUTX(XX,XV,NOUT)
      CALL ORB(XX,XV,C(NOR),NOUT)
  300 CONTINUE
      IF(MARDAT.EQ.0.OR.NOR.NE.5) GO TO 1001
      CALL ARES(DAYM,FDATE,AR)
      CALL MULT(AR,A,ADATE)
      DO 802 I=1,3
      DO 802 J=1,3
  802 ADATET(J,I)=ADATE(I,J)
      CALL M1(R1(1,NOR),ADATE,XX)
      CALL M1(V1(1,NOR),ADATE,XV)
      CALL M1(PERT,ADATE,PERTT)
      WRITE(6,700) C(NOR+60)
  700 FORMAT(1H0,A6,1X,35HCENTERED MARS MEAN EQUATOR OF DATE )
  600 CALL OUTX(XX,XV,NOUT)
      CALL ORB(XX,XV,C(NOR),NOUT)
C
C
 1001 IOR=NOR
  400 CONTINUE
      IF(IOR.EQ.NOR.AND.ICENEC.NE.0) GO TO 34
      IF(IOR.EQ.1.AND.IEAREC.NE.0) GO TO 34
      IF(IOR.EQ.3.AND.ISUNEC.NE.0) GO TO 34
      GO TO 32
   34 CALL M1(R1(1,IOR),DATEEC,XX)
      CALL M1(V1(1,IOR),DATEEC,XV)
```

```
C
      WRITE(6,900) C(IOR+60)
  900 FORMAT(1H0,A6,1X,'CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE')
      CALL OUTX(XX,XV,NOUT)
C
      IF(IOR.EQ.NOR) CALL ORB(XX,XV,C(NCF),NOUT)
   32 CONTINUE
      IF(IOR.EQ.3.AND.NOR.NE.3) GO TO 14
      IF(IOR.EQ.1) GO TO 1000
      IOR=1
      GO TO 400
 1000 IF(IOR.EQ.3) GO TO 14
      IF(NOR.EQ.3) GO TO 14
      IOR=3
      GO TO 400
   14 CONTINUE
      IF(NOR.NE.1.OR.IEARFX.EQ.0) GO TO 33
      WRITE(6,3001) XLATI,XLONGI
 3001 FORMAT('0EARTH FIXED LATITUDE(DEG)'D15.8,3X,'LONGITUDE(DEG)'D15.8)
   33 CONTINUE
      WRITE(6,21)C(461)
   21 FORMAT(20H0NUMBER OF STEPS IS D20.8)
C
C
C
   50 RETURN
      END
```

```
      SUBROUTINE OUTX(X,VX,NOUT)                                        204900
      IMPLICIT REAL*8(A-H,O-Z,$)                                        205000
      DIMENSION X(3),VX(3),C(6)                                         205100
C     DIMENSION X(3),VX(3),C(6)                                         205200
      CALL RVOUT(X,VX,C)                                                205300
      WRITE (    6,5)X,VX,C                                             205400
    5 FORMAT(5H     XD15.8,5H     YD15.8,5H     ZD15.8,5H    DXD15.8,   205500
     1 5H    DYD15.8,5H    DZD15.8/5H     RD15.8,5H  DECD15.8,5H    RAD15.8,  205600
     2 5H     VD15.8,5H   PTHD15.8,5H    AZD15.8)                       205700
      RETURN                                                            205800
      END                                                               205900
```

```
      SUBROUTINE OVRLAY
      IMPLICIT REAL*8(A-H,O-Z,$)
      COMMON S(1000),IC(5)
      DIMENSION BUFP(4),IND(4)
   16 FORMAT(4(I3,D12.8))
  994 FORMAT(1H0)
  995 FORMAT(4(5X,I3,D17.8))
  996 FORMAT('1',40X,13HOVERLAY INPUT)
      K=-1
   15 CONTINUE
      READ(5,16,END=20) (IND(I),BUFP(I),I=1,4)
      DO 10 N=1,4
      N=N
      GO TO (11,12,12,12),N
   11 CONTINUE
      IF(IND(N))13,13,17
   17 IF(K)18,19,19
   18 WRITE(6,996)
      K=0
   19 CONTINUE
      WRITE(6,995) (IND(J),BUFP(J),J=1,4)
      GO TO 14
   12 IF(IND(N)) 15,15,14
   14 CONTINUE
      J=IND(N)
      S(J)=BUFP(N)
   10 CONTINUE
      GO TO 15
   13 CONTINUE
      WRITE(6,994)
       RETURN
   20 STOP
      END
```

```
      SUBROUTINE READE(JED,TSEC,IERR)
       IMPLICIT REAL*8(A-H,O-Z)
C      READE.                    READ,INTERPOLATE,TRANSLATE JPL EPHEMERIS
C     J.E. EKELUND, MESA SCIENTIFIC CORP., 1965 SEPT 15
C     C.L. LAWSON, JPL, 1966 MAR 17
C     READ JPL EPHEMERIS AT THE JULIAN EPHEMERIS DATE
C     GIVEN BY (JED+TSEC/86400.D0)
C
C**   ITEMS COMMUNICATED THROUGH THE CALLING SEQUENCE **
C
C     JED       REFERENCE JULIAN EPHEMERIS DATE.
C     TSEC      SECONDS OF EPHEMERIS TIME PAST JED.
C               ANY COMBINATION OF VALUES OF JED AND TSEC
C               IS ACCEPTABLE AS LONG AS (JED+TSEC/86400.D0)
C               IS WITHIN THE RANGE OF THE EPHEMERIS TAPE
C               BEING USED. HOWEVER TO OBTAIN THE
C               FINEST POSSIBLE RESOLUTION IN INTERPOLATION
C               THE NUMBER JED MUST BE AN EXACT MACHINE
C               NUMBER. FOR EXAMPLE JED COULD BE A DATE ENDING
C               WITH .0 OR .5 .
C     IERR      ERROR FLAG
C               0=NO ERROR
C               1=(JED+TSEC/86400.D0) LESS THAN FIRST DATE
C                  ON TAPE
C               2=(JED+TSEC/86400.D0) GREATER THAN LAST DATE
C                  ON TAPE
C               3=SOME IREQ(I) IS NOT 0,1, OR 2
C               4=ICENT   IS NOT IN THE RANGE 1 THRU 11
C               5=ICW IS NOT 1,2, OR 3
C
C * THE FOLLOWING ITEMS ARE INPUT THROUGH COMMON **
C *  COMMON BLOCK CETBL1 *
C     AU            A.U. EXPRESSED IN DESIRED OUTPUT UNITS
C     RE            EQUATORIAL RADIUS OF EARTH IN DESIRED OUTPUT UNITS
C                   RE IS USED TO SCALE THE LUNAR EPHEMERIS
C     TPD              DESIRED NUMBER OF TIME UNITS PER DAY
      COMMON/CETBL2/ICW,ICENT  ,IREQ(13)
C
C *  COMMON BLOCK CETBL2 *
C     ICW       FLAG INDICATING STATUS OF COMMON BLOCKS REC2 AND CETBL3
C               1 MEANS NEITHER BLOCKS CONTAIN VALID DATA
C               2 MEANS BOTH BLOCKS CONTAIN VALID DATA
C               3 MEANS REC2 IS VALID, CETBL3 IS NOT
C               USER MUST SET ICW=1 BEFORE INITIAL CALL
C     ICENTR    SPECIFIES CENTRAL BODY FOR COORDINATE
C               TRANSLATION AS FOLLOWS..
C                1 MERC      5 JUP       9 PLUTO
C                2 VENUS     6 SAT      10 SUN
C                3 EARTH     7 URANUS   11 MOON
C                4 MARS      8 NEP
C     IREQ()    IREQ(J) SPECIFIES OUTPUT DESIRED FOR
C               BODY NO. J.
C               IREQ(J)=0 NO OUTPUT
C                       1 POSITION
C                       2 POSITION AND VELOCITY
C               J RUNS FROM 1 TO 11 AS FOLLOWS..
C                1 MERC      5 JUP       9 PLUTO
C                2 VENUS     6 SAT      10 SUN
C                3 EARTH     7 URANUS   11 MOON
C                4 MARS      8 NEP      12 EARTH-MOON-BARYCENTER
```

```
C                                        13 NUTATION
C *   COMMON BLOCK CETBL3 *
C    TAB3 829 DOUBLE PREC. WORD BUFFER TO ACCOMODATE  J.D. AND EPHEMERIS.
C    NUTAT 204 SINGLE PREC. WORD BUFFER TO ACCOMODATE NUTATION DATA.
C    CKSUM 1 S.P. WORD FOR CHECKSUM.
C** THE FOLLOWING ITEMS ARE OUTPUT THROUGH COMMON **
C *   COMMON BLOCK CETBL4 *
C      TABOUT( , )  PLANETARY AND LUNAR OUTPUT, SCALED AND
C        TRANSLATED WITH RESPECT TO CENTER.
C                   TABOUT (I,J) CONTAINS OUTPUT FOR
C                   BODY NO. J. (1 .LE. J .LE. 12)
C                   THE INDEX I IDENTIFIES COMPONENTS AS FOLLOWS..
C                   1=X        2=Y        3=Z
C                   4=XDOT     5=YDOT     6=ZDOT
C      NUT( )       NUTATION OUTPUT
C                   NUT(1)=DELTA LONGITUDE
C                   NUT(2)=DELTA OBLIQUITY
C                   NUT(3)=TIME DERIVATIVE OF NUT(1)
C                   NUT(4)=TIME DERIVATIVE OF NUT(2)
C
      COMMON /CETBL5/ BIVECT( 6,13)
C
C *   COMMON BLOCK CETBL5 *
C      BIVECT( , )  WORKING ARRAY. CONTENTS ARE INTERPOLATED
C                   AND SCALED BUT NOT TRANSLATED. 1ST INDEX RUNS
C                   OVER X,Y,Z,XDOT,YDOT,ZDOT AS IN TABOUT
C                   BUT 2ND INDEX IS DIFFERENT AS FOLLOWS..
C              BODIES 1 THRU 9 ARE HELIOCENTRIC.
C                   1 MERC      5 JUP       9 PLUTO
C                   2 VENUS     6 SAT      10 MOON REL TO EARTH
C                   3 ERTHMN    7 URANUS   11 ERTHMN REL TO EARTH
C                   4 MARS      8 NEP      12 ERTHMN REL TO MOON
C                                          13 SEE 4092+
C
C      THE COMMON BLOCK 'CETBL9' IS FOR COMMUNICATION
C      BETWEEN RDEP2 AND GETR2.
      COMMON /CETBL1/          AU,RE,TFD,ENRAT
      COMMON /CETBL3/ TAB3(829),NUTAT(204),CKSUM
      COMMON/CETBL4/TABOUT(6,12),NUT(4)
      COMMON/CETBL9/JD1,TDAY,JDIF,IERRI
      LOGICAL WFLAG
      INTEGER KREQ(12),MCENT(11),M1(20),JREC(11), IPOS(11),IVEL(11)
      REAL NUTAT ,STP(11)
      DOUBLE PRECISION       AU,RE,ENRAT,  TFD,TAB3,BIVECT,TABOUT,NUT
      DOUBLE PRECISION JD1,TDAY,JDIF ,JED
      DOUBLE PRECISION TSEC,RAT, FAC,U(2,3),C,TEMP
C                                        FAC=1/86400
      DATA FAC/1.15740740740740D-5/
C
      DATA STP/ 2.,8*4.,2*.5/
      DATA KREQ/5,5,2,6*5,4,3,1/
      DATA MCENT/15,15,0,6*15,10,5/
      DATA M1/11,0,10,11,0,12,10,0,12,0,3,3,3,0,0,3,13,13,0,0/
      DATA
     * IPOS  /02,092,146,200,254,308,362,416,470,524,1/
     *,IVEL  /47,119,173,227,281,335,389,443,497,677,103/
      DATA U/6*0.D0/
C
  499 CONTINUE
      JD1=JED
```

```
      TDAY=TSEC*FAC
C
C     IERR1=IERR
      CALL GETTAP
C
      IF(IERR1 .NE. 0) GO TO 5000
      IF(ICENT .GE. 1 .AND. ICENT .LE. 11) GO TO 10
      IERR1=4
      GO TO 5000
   10 CONTINUE
C
C                                 SET JREQ()TO CONTROL INTERPOLATION
      DO 20 I=1,10
      IF(IREQ(I) .GE. 0 .AND. IREQ(I) .LE. 2) GO TO 20
      IERR1=3
      GO TO 5000
   20 JREQ(I)=IREQ(I)
C                                 EARYCENTER FLAG
      JREQ(3)=IREQ(12)
      MAXPL=JREQ(1)
      DO 24 I=2,10
   24 MAXPL=MAX0(MAXPL,JREQ(I))
      MAXEM=MAX0(IREQ(3),IREQ(11))
      MAXALL=MAX0(MAXPL,MAXEM)
      IF(ICENT.EQ.3.OR.ICENT.EQ.11) GO TO 28
C                                 CENTER IS NOT EARTH OR MOON
C                                 10=MOON,3=EARTHMN
      JREQ(10)=MAXEM
      JREQ(3)=MAX0(JREQ(3),MAXEM)
      JREQ(ICENT)=MAXALL
      GO TO 32
C
C                                 CENTER IS EARTH OR MOON
C                                 10=MOON,3=EARTHMN
   28 JREQ(10)=MAXALL
      JREQ(3)=MAXPL
   32 JREQ(11)=IREQ(13)
      LUNAR=JREQ(10)
      IBARY=JREQ(3)*3
C
C                                 JREQ( )IS NOW SET
C
      SAVE=0.
 6001 CONTINUE
      DO 240 IBODY=1,11
      IF(JREQ(IBODY)) 240,240,40
   40 IF(STP(IBODY).EQ.SAVE) GO TO 165
      SAVE=STP(IBODY)
  160 TEMP=JDIF/SAVE
      KK=TEMP
      U(1,1)=TEMP-FLOAT(KK)
      IF(U(1,1))161,165,161
  161 CONTINUE
      U(2,1)=1.D0-U(1,1)
      DO 163 IU=1,2
      U(IU,3)=U(IU,1)*U(IU,1)
      U(IU,2)=(U(IU,3)-1.D0)/6.D0
  163 U(IU,3)=(U(IU,3)-4.D0)/20.D0
  165 IF(IBODY-10) 169,167,220
  167 C=RE
```

```
      GO TO 172
  169 C=AU
C                                   INTERPOLATE IBODY=1,2,...,10
  172 IGET1=IPOS(IBODY)+KK*9
      IC1=1
  200 CONTINUE
      IF(U(1,1))203,201,203
  203 IGET2=IGET1+6
      DO 204 IGET=IGET1,IGET2,3
      BIVECT(IC1,IBODY)=
     *            C*(U(2,1)*(TAB3(IGET    )+
     *               U(2,2)*(TAB3(IGET+ 1)+
     *               U(2,3)* TAB3(IGET+ 2)))+
     *               U(1,1)*(TAB3(IGET+ 9)+
     *               U(1,2)*(TAB3(IGET+10)+
     *               U(1,3)* TAB3(IGET+11))) )
  204 IC1=IC1+1
      GO TO 205
  201 IC2=IC1+2
      DO 202 I=IC1,IC2
      BIVECT(I,IBODY)=C*TAB3(IGET1)
  202 IGET1=IGET1+3
  205 CONTINUE
      JREQ(IBODY)=JREQ(IBODY)-1
      IF(JREQ(IBODY)) 240,240,207
  207 IGET1=IVEL(IBODY)+KK*9
      IC1=4
      C=C/TPD
      GO TO 200
C
C                                   INTERPOLATE   IBODY=11   NUTATION
C
  220 C=1.D0
      IGET1=IPOS(IBODY)+KK*6
      IC1=1
  222 IGET2=IGET1+3
  225 IF(U(1,1))228,226,228
  228 DO 230 IGET=IGET1,IGET2,3
      NUT(IC1)=
     *   C*(U(2,1)*(NUTAT(IGET  )+
     *      U(2,2)*(NUTAT(IGET+1)+
     *      U(2,3)* NUTAT(IGET+2)))+
     *      U(1,1)*(NUTAT(IGET+6)+
     *      U(1,2)*(NUTAT(IGET+7)+
     *      U(1,3)* NUTAT(IGET+8))) )
  230 IC1=IC1+1
      GO TO  232
  226 DO 227 IGET=IGET1,IGET2,3
      NUT(IC1)=C*NUTAT(IGET)
  227 IC1=IC1+1
  232 CONTINUE
      JREQ(IBODY)=JREQ(IBODY)-1
      IF(JREQ(IBODY)) 240,240,236
  236 C=C/TPD
      IGET1=IVEL(IBODY)+KK*6
      IC1=3
      GO TO 222
  240 CONTINUE
C
C                                   INTERPOLATION IS FINISHED
```

```
C                                RESULTS ARE IN BIVECT( , )AND NUT( )
C                                TEST MOON REQUEST
      IF(LUNAR    ) 4020,4020,4010
C                                NOTE..EMRAT=EARTH MASS/MOON MASS
C                                SET BIVECT( ,11)=ERTHMN CENTERED AT EARTH
C                                SET BIVECT( ,12)=ERTHMN CENTERED AT MOON
 4010 RAT=1.D0/(EMRAT+1.D0)
      IMAX=LUNAR * 3
      DO 4016 I=1,IMAX
      BIVECT(I,11)=RAT*BIVECT(I,10)
 4016 BIVECT(I,12)=-EMRAT*BIVECT(I,11)
C
 4020 WFLAG=.FALSE.
      KCENT=MCENT(ICENT)
C
C                                BEGIN TRANSLATION LOOP
C
      DO 4108  IBODY=1,12
      IF(IREQ(IBODY)) 4108,4108,4024
 4024 IMAX=IREQ(IBODY)*3
      KASE=KCENT+KREQ(IBODY)
      K1=M1(KASE)
      GO TO (4032,4040,4032,4048,4052,
     *       4032,4068,4040,4048,4056,
     *       4032,4076,4076,4040,4028,
     *       4084,4088,4088,4064,4080),KASE
C
C                                KASE=15
 4028 K1=IBODY
C                                KASE=1,3,6,11
 4032 DO 4036 I=1,IMAX
 4036 TABOUT(I,IBODY)=BIVECT(I,K1)
      GO TO 4108
C                                KASE=2,8,14
 4040 DO 4044 I=1,IMAX
 4044 TABOUT(I,IBODY)=0.D0
      GO TO 4108
C                                KASE=4,9
 4048 K2=3
      GO TO 4100
C                                KASE=5
 4052 L2=11
      GO TO 4060
C                                KASE=10
 4056 L2=12
 4060 K1=IBODY
      K2=13
      GO TO 4092
C                                KASE=19
 4064 K1=ICENT
C                                KASE=7
 4068 DO 4072 I=1,IMAX
 4072 TABOUT(I,IBODY)=-BIVECT(I,K1)
      GO TO 4108
C                                KASE=12,13
 4076 K2=KASE-1
      GO TO 4100
C                                KASE=20
 4080 K1=IBODY
C                                KASE=16
```

```
 4084 K2=ICENT
      GO TO 4100
C                                KASE=17,18
 4088 L2=ICENT
      K2=KASE-6
 4092 IF(WFLAG) GO TO 4100
      WFLAG=.TRUE.
C
C                                BIVECT( ,13)IS AN AUXILIARY VECTOR
C                                NEEDED WHEN KASE=5,10,17,18.
C                FOR KASE=05     BIVECT( ,13)=EARTH  CENTERED AT SUN
C                FOR KASE=10     BIVECT( ,13)=MOON  CENTERED AT SUN
C                FOR KASE=17,18     BIVECT( ,13)=EARTHMN  CENTERED AT ICENT
C
      DO 4096 I=1,IBARY
 4096 BIVECT(I,13)=BIVECT(I,3)-BIVECT(I,L2)
 4100 DO 4104 I=1,IMAX
 4104 TABOUT(I,IBODY)=BIVECT(I,K1)-BIVECT(I,K2)
 4108 CONTINUE
 5000 IERR=IERR1
      RETURN
      END
```

```
SUBROUTINE ROTEQ(TIME,A)
IMPLICIT REAL*8(A-H,O-Z,$)
DIMENSION A(3,3)
T = TIME/36525.D0
T2 = T*T
T3 = T2*T
A(1,1) = 1.D0 - .00029657D0*T2 - .00000013D0*T3
A(1,2) = -.02234988D0*T - .00000676D0*T2 + .00000221D0*T3
A(2,1) = -A(1,2)
A(1,3) = -.00971711D0*T + .00000207D0*T2 + .00000096D0*T3
A(3,1) = -A(1,3)
A(2,2) = 1.D0 - .00024976D0*T2 - .00000015D0*T3
A(2,3) = -.00010859D0*T2 - .00000003D0*T3
A(3,2) = A(2,3)
A(3,3) = 1.D0 - .00004721D0*T2 + .00000002D0*T3
RETURN
END
```

```
      SUBROUTINE RVOUT(A,B,C)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION A(3),B(3),C(6)
C     C IS RADIUS, LAT, LON, VELOCITY, GAMMA, AZIMUTH
      CALL SPER(A,C)
      C(4)=FNORM(B)
      C(5)=90.D0-ADOT(A,B)
      VE=B(2)*A(1)-B(1)*A(2)
      VN=C(1)*B(3)-A(3)*DOT(A,B)/C(1)
      C(6)=57.29577951D0*ARKTNS(1E0,VN,VE)
      RETURN
      END
```

```
      SUBROUTINE SHADOW(R1,V1,X,  STEP)
      IMPLICIT REAL*8(A-H,O-Z,$)
      COMMON C(1000),IC(50),Z(3),VV(3),NCF
      COMMON /SHAD/SHADK
      DIMENSION R1(3,8),V1(3,8)
      DIMENSION X1(3)
      DIMENSION R(3,8),V(3,8)
      DATA IPFLAG/1/,IUFLAG/1/,IMFLAG/1/,IMUFLG/1/, FLAG/0./,FLAG1/0./,
     1FLAG2/0./,FLAG3/0./
      DATA IVFLAG/1/,IVUFLG/1/,PFLAG/0./,FUFLAG/0./
    6 FORMAT(1H0,15HBODY CENTER IS ,A6)
      IF(STEP.EQ.0.D0)RETURN
      GO TO (41,41,505 ,400,400,400),NCF
   41 CONTINUE
      DO 4 I=1,3
    4 X1(I)=R1(I,1)-R1(I,3)
      SEVA=ADOT(X1,R1(1,1))
      RFS=FNORM(R1(1,3))
      RFE=FNORM(R1(1,1))
      DELS=DARSIN(6500.D0/RFE)*57.2957795D0
      IF(SEVA-90.D0) 300,300,301
  301 ZRS=6.965D5
      ZRE=6500.D0
      ZPSIG=DARSIN((ZRS+ZRE)/RFS)*57.2957795D0
      FS=SEVA+DELS+ZPSIG-180.D0
      IF(FS) 300,302,302
  302 FLAG=1.D0
      IF(IPFLAG.NE.1) GO TO 1000
      K=1
      N=1
      IPFLAG=2
      KK=1
      WRITE(6,5)
    5 FORMAT(1H0,60HPROBE ENTERED EARTH FENUMERA. TIME AND CREIT ARE GIV
     1EN BELOW)
      SHADK=1.0D0
      GO TO 20
 1000 CONTINUE
      ZSIGMA=DARSIN((ZRS-ZRE)/RFS)*57.2957795D0
      FS=DELS-ZSIGMA+SEVA-180.D0
      IF(FS)303,304,304
  304 FLAG1=1.D0
      IF(IUFLAG.NE.1) GO TO 310
      K=1
      IUFLAG=2
      N=2
      KK=2
      WRITE(6,7)
    7 FORMAT(1H0,57HPROBE ENTERED EARTH UMERA. TIME AND CRBIT ARE GIVEN
     1BELOW)
      SHADK=1.0D0
      GO TO 20
  300 FLAG=0.D0
  303 FLAG1=0.D0
  310 DO 30 I=1,3
   30 X1(I)=R1(I,2)-R1(I,3)
      SEVA=ADOT(X1,R1(1,2))
      IF(SEVA-90.D0) 2000,2000,901
  901 ZRS=6.965D5
      ZRE=1738.D0
```

```
      ZPSIG=DARSIN((ZRS+ZRE)/RFS)*57.2957795D0
      DELM=DARSIN(C(22)/FNORM(R1(1,2)))*57.2957795D0
      FS=SEVA+DELM+ZPSIG-180.D0
      IF(FS) 2000,902,902
  902 FLAG2=1.D0
      IF(IMFLAG.NE.1) GO TO 3000
      K=2
      IMFLAG=2
      N=3
      KK=1
      WRITE(6,8)
    8 FORMAT(1H0,59HPROBE ENTERED MOON PENUMBRA. TIME AND ORBIT ARE GIVE
     1N BELOW)
      SHADK=1.0D0
      GO TO 20
 3000 CONTINUE
      ZSIGMA=DARSIN((ZRS-ZRE)/RFS)*57.2957795D0
      FS=DELM-ZSIGMA+SEVA-180.D0
      IF(FS)2001,904,904
  904 FLAG3=1.D0
      IF(IMUFLG.NE.1) GO TO 2010
      K=2
      IMUFLG=2
      N=4
      KK=2
      WRITE(6,9)
    9 FORMAT(1H0,56HPROBE ENTERED MOON UMBRA. TIME AND ORBIT ARE GIVEN B
     1ELOW)
      SHADK=1.0D0
      GO TO 20
 2000 FLAG2=0.D0
 2001 FLAG3=0.D0
 2010 CONTINUE
      IF(IPFLAG.NE.2.OR.FLAG.NE.0.D0) GO TO 11
      WRITE(6,12)
   12 FORMAT(1H0,61HPROBE HAS LEFT EARTH PENUMBRA. TIME AND ORBIT ARE GI
     1VEN BELOW)
      SHADK=0.0D0
      K=1
      N=5
      KK=1
      IPFLAG=1
      GO TO 20
   11 IF(IUFLAG.NE.2.OR.FLAG1.NE.0.D0) GO TO 14
      WRITE(6,13)
   13 FORMAT(1H0,58HPROBE HAS LEFT EARTH UMBRA. TIME AND ORBIT ARE GIVEN
     1 BELOW)
      SHADK=0.0D0
      KK=2
      N=6
      K=1
      IUFLAG=1
      GO TO 20
   14 IF(IMFLAG.NE.2.OR.FLAG2.NE.0.D0) GO TO 15
      WRITE(6,16)
   16 FORMAT(1H0,60HPROBE HAS LEFT MOON PENUMBRA. TIME AND ORBIT ARE GIV
     1EN BELOW)
      SHADK=0.0D0
      KK=1
      K=2
```

```
      N=7
      IMFLAG=1
      GO TO 20
   15 IF(IMUFLG.NE.2.OR.FLAG3.NE.0.D0) GO TO 505
      WRITE(6,18)
   18 FORMAT(1H0,57HPROBE HAS LEFT MOON UMBRA. TIME AND OREIT ARE GIVEN
     1BELOW)
      SHADK=0.0D0
      K=2
      N=8
      KK=2
      IMUFLG=1
   20 CALL ITER(NOR,R1,V1,FS,K,KK,DT,R,V)
      TIM=C(593)+(X+C(506)+DT)/86400.D0
      CALL TFRAC(C(592),TIM,TT,TTF)
      CALL DATOUT(TT,TTF,DATE,FDATE,0)
C
C
C
      GO TO (1000,310,3000,2010,11,14,15,505 ,405,502,503,505),N
  400 DO 401 I=1,3
  401 X1(I)=R1(1,NOR)-R1(I,3)
      SEVA=ADOT(X1,R1(1,NOR))
      RFS=FNORM(R1(1,3))
      RFE=FNORM(R1(1,NOR))
      DELS=DARSIN(C(NOR+20)/RFE)*57.2957795D0
      IF(SEVA-90.D0)500,500,402
  402 ZRS=6.965D5
      ZRE=C(NOR+20)
      ZPSIG=DARSIN((ZRS+ZRE)/RFS)*57.2957795D0
      FS=SEVA+DELS+ZPSIG-180.D0
      IF(FS)500,403,403
  403 PFLAG=1.D0
      IF(IVFLAG.NE.1) GO TO 405
      K=3
      N=9
      IVFLAG=2
      KK=1
      WRITE(6,404)C(NOR+60)
  404 FORMAT(1H0,26HPROBE ENTERED PENUMBRA OF ,A6,30HTIME AND ORBIT ARE
     1GIVEN BELOW)
      SHADK=1.0D0
      GO TO 20
  405 CONTINUE
      ZSIGMA=DARSIN((ZRS-ZRE)/RFS)*57.2957795D0
      FS=DELS-ZSIGMA+SEVA-180.D0
      IF(FS)501,406,406
  406 PUFLAG=1.D0
      IF(IVUFLG.NE.1) GO TO 502
      K=3
      IVUFLG=2
      N=10
      KK=2
      WRITE(6,407) C(NOR+60)
  407 FORMAT(1H0,23HPROBE ENTERED UMBRA OF ,A6,30HTIME AND ORBIT ARE GIV
     1EN BELOW)
      SHADK=1.0D0
      GO TO 20
  500 PFLAG=0.D0
  501 PUFLAG=0.D0
```

```
502 IF(IVFLAG.NE.2.OR.PFLAG.NE.0.D0) GO TO 503
    WRITE(6,504) C(NOR+60)
504 FORMAT(1H0,27HPROBE HAS LEFT PENUMBRA OF ,A6,30HTIME AND OREIT ARE
   1 GIVEN BELOW)
    SHADK=0.0D0
    K=3
    N=11
    KK=1
    IVFLAG=1
    GO TO 20
503 IF(IVUFLG.NE.2.OR.PUFLAG.NE.0.D0) GO TO 505
    WRITE(6,506) C(NOR+60)
506 FORMAT(1H0,24HPROBE HAS LEFT UMBRA OF ,A6,30HTIME AND ORBIT ARE GI
   1VEN BELOW)
    SHADK=0.0D0
    KK=2
    N=12
    K=3
    IVUFLG=1
    GO TO 20
505 CONTINUE
    RETURN
    END
```

```
      SUBROUTINE SHIFTP(NOR,R,V,TW,TF,RR,VV)
      IMPLICIT REAL*8(A-H,O-Z,$)
      DIMENSION C(1000),IC(50),R(3),V(3),RR(3,8),VV(3,8),PO(22),VE(22),
     1R1(3,2),V1(3,2),N(2),SPAR(20,2),T1(2,2)
      DIMENSION X(3),W(3)
      COMMON  C        , IC
      EQUIVALENCE (C(663),R1(1,1)),(C(681),V1(1,1)),(C(695),T1(1,1)),
     1(IC(1),IB1), (IC(2),IB2),(IC(12),N(1)),(C(71),SFMSD),(C(3),US)
     2,(C(801),PO(1)),(C(823),VE(1)),(C(561),SFAF(1,1))
     3,(C(699),SWNET)
      IC(2)=0.D0
      IF(SWNET)100,100,18
  100 DIS=1.D10
      DO 1 I=1,3
      X(I)=R(I)
    1 W(I)=V(I)
      NM1=NOR-1
      IF(NOR-6)4,3,2
    2 KKK=-1
      NM1=2
      GO TO 7
3     NM1 = 6
    4 CONTINUE
      KKK=0
      IF(IB1-6)5,5,6
    5 IF(IB2-6)9,9,6
    6 KKK=1
    7 CONTINUE
      DO 8 I=1,2
      K=I+6
      TT=(IDINT(TW-T1(1,I))+TF-T1(2,I))*SFMSD
      CALL STEPD(N(I),TT,TA,R1(1,I),V1(1,I),US,RR(1,K),VV(1,K),1,
     1SPAR(1,I))
    8 CONTINUE
    9 CONTINUE
      CALL INTR1(TW,TF,NM1,PO,1,VE,DIS)
      IF(KKK)10,12,12
   10 NOR=NOR
      DO 11 I=1,3
      X(I)=X(I)+RR(I,NOR)
   11 W(I)=W(I)+VV(I,NOR)
   12 CONTINUE
      DO 13 J=1,5
      DO 13 I=1,3
      L=3*J-3+I
      RR(I,J)=X(I)-PO(L)
   13 VV(I,J)=W(I)-VE(L)
      DO 14 I=1,3
      RR(I,6)=X(I)-PO(I+18)
   14 VV(I,6)=W(I)-VE(I+18)
      IF(KKK)15,17,15
   15 DO 16 I=1,2
      K=I+6
      DO 16 J=1,3
      RR(J,K)=RR(J,3)-RR(J,K)
   16 VV(J,K)=VV(J,3)-VV(J,K)
   17 CONTINUE
      GO TO 35
   18 TT=((TW-T1(1,1))+TF-T1(2,1))*SFMSD
      M=2
```

```
      CALL STEPD(M,TT,TA,R1(1,1),V1(1,1),C(3),RR(1,1),VV(1,1),1,
     1SPAR(1,1))
      TT=((TW-T1(1,2))+TF-T1(2,2))*SFMSD
      IF(IC(1)+IC(2)-3)19,19,25
   19 M=2
      CALL STEPD(M,TT,TA,R1(1,2),V1(1,2),C(1),RR(1,2),VV(1,2),1,
     1SPAR(1,2))
      DO 24 I=1,3
      IF(NOR-2)20,21,22
   20 RR(I,3)=-RR(I,1)
      VV(I,3)=-VV(I,1)
      RR(I,1)=0.D0
      VV(I,1)=0.D0
      GO TO 23
   21 RR(I,3)=-RR(I,1)-RR(I,2)
      VV(I,3)=-VV(I,1)-VV(I,2)
      RR(I,2)=0.D0
      VV(I,2)=0.D0
      GO TO 23
   22 RR(I,2)=RR(I,2)+RR(I,1)
      VV(I,2)=VV(I,2)+VV(I,1)
      RR(I,3)=0.D0
      VV(I,3)=0.D0
   23 DO 24 J=1,3
      RR(I,J)=R(I)-RR(I,J)
      VV(I,J)=V(I)-VV(I,J)
   24 CONTINUE
      GO TO 35
   25 M=2
      IF(IC(1)-3)27,27,26
   26 K=IC(1)
      GO TO 28
   27 K=IC(2)
   28 CONTINUE
      CALL STEPD(M,TT,TA,R1(1,2),V1(1,2),C(3),RR(1,K),VV(1,K),1,
     1SPAR(1,2))
      DO 34 I=1,3
      IF(NOR-3)29,31,32
   29 RR(I,3)=-RR(I,1)
      VV(I,3)=-VV(I,1)
      IF(K.EQ.3) GO TO 30
      RR(I,K)=RR(I,K)-RR(I,1)
      VV(I,K)=VV(I,K)-VV(I,1)
   30 RR(I,1)=0.D0
      VV(I,1)=0.D0
      GO TO 33
   31 RR(I,3)=0.D0
      VV(I,3)=0.D0
      GO TO 33
   32 RR(I,1)=-RR(I,K)+RR(I,1)
      VV(I,1)=-VV(I,K)+VV(I,1)
      RR(I,3)=-RR(I,K)
      VV(I,3)=-VV(I,K)
      RR(I,K)=0.D0
      VV(I,K)=0.D0
   33 RR(I,1)=R(I)-RR(I,1)
      VV(I,1)=V(I)-VV(I,1)
      RR(I,3)=R(I)-RR(I,3)
      VV(I,3)=V(I)-VV(I,3)
      IF(K.EQ.1.OR.K.EQ.3) GO TO 34
```

```
      RR(I,K)=R(I)-RR(I,K)                                              276700
      VV(I,K)=V(I)-VV(I,K)                                              276800
   34 CONTINUE                                                          276900
   35 CONTINUE                                                          277000
      RETURN                                                            277100
      END                                                               277200
```

```
      SUBROUTINE SOLAR (R,SACC)
      IMPLICIT REAL * 8 (A-H,O-Z)
      COMMON C(1000)
      DIMENSION R(3),SACC(3),RX(3)
      P=C(774)
      A=C(770)
      EM=C(771)
      GAMMA=C(772)
      SIGMA=C(773)
      C1=P*A*(1.0 + 2.0/3.0*GAMMA + 1.0/3.0*GAMMA*SIGMA)/EM
      DO 11 J=1,3
      RX(J)=R(J) / 1.495D8
11    C O N T I N U E
      RAU=(RX(1)**2 + RX(2)** 2 +RX(3)**2)**0.5
      C2=C1/RAU**3
      DO 12 K=1,3
      SACC(K)=C2*RX(K)*1.0D-5
12    C O N T I N U E
100   RETURN
      END
```

```
      SUBROUTINE SPER(X,Y)
      IMPLICIT REAL*8(A-H,O-Z,$)
C     CONVERTS CARTESIAN TO SPHERICAL. RETURNS IN DEG
      DIMENSION X(3),Y(3)
C     DIMENSION X(3),Y(3)
      RTD=.57295779 5D+02
      A=X(1)*X(1)+X(2)*X(2)
      Y(1)=DSQRT(A+X(3)*X(3))
      Y(2)=DATAN(X(3)/DSQRT(A))*RTD
      Y(3)=ARKTNS(180. X(1),X(2))*RTD
      RETURN
      END
```

```
      SUBROUTINE STEPD(N,T,TA,R,V,U,RR,VV,M,SE)
      IMPLICIT REAL*8(A-H,O-Z,$)
C     CB IS A STORAGE VECTOR WHOSE ELEMENTS ARE
C     (1) INITIAL TRUE ANOMALY          (11) ANGULAR MOMENTUM SQUARED H2
C     (2) SEMI-LATUS RECTUM             (12) ANGULAR MOMENTUM MAGNITUDE H
C     (3) ECCENTRICITY                  (13) MU TIMES RADIUS MAGNITUDE UR
C     (4) RADIUS-SQUARED                (14) R DOT V
C     (5) RADIUS MAGNITUDE              (15) H2-UR
C     (6) SEMI-MAJOR AXIS (A)           (16) H*RDOTV
C     (7) ABSOLUTE VALUE OF (A)         (17) U/(R*H2)
C     (8) MEAN MOTION                   (18) RV/H
C     (9) TIME COEFFICIENT  R/ABA       (19) TIME FROM PERIAPSIS (+ OR -)
C     (10)TIME COEFFICIENT RV/SQRT(UA)  (20) SWITCH 1 ELLIP, 2 HYPER
      DIMENSION R(3),V(3),HVEC(3),RR(3),VV(3),F(4),CE(20)
      DIMENSION SB(20)
C     DIMENSION R(3),V(3),HVEC(3),RR(3),VV(3),F(4),CE(20)
C     DIMENSION SB(20)
C
C
C
C
      N=N
      GO TO (1,7),N
    1 CONTINUE
      PI=.3141592650D+01
      TPI=.6283185307D+01
      CB(4)=DOT(R,R)
      CB(5)=DSQRT(CB(4))
      V2=DOT(V,V)
      CB(14)=DOT(R,V)
      VM=DSQRT(V2)
      CB(6)=CB(5)/(2.0D0-CB(5)*V2/U)
      CB(7)=DABS(CB(6))
      CB(8)=DSQRT(U/CB(7))/CB(7)
      CB(9)=CB(5)/CB(7)
      CB(10)=CB(14)/DSQRT(U*CB(7))
      CALL CROSS(R,V,HVEC)
      CB(11)=DOT(HVEC,HVEC)
      CB(12)=DSQRT(CB(11))
      CB(13)=U*CB(5)
      CB(2)=CB(11)/U
      EC2=1.0D0-CB(2)/CB(6)
      IF(EC2.GE.(-1.D-6).AND.EC2.LE.0.D0) GO TO 200
      CB(3)=DSQRT(EC2)
      GO TO 201
  200 CB(3)=0.D0
  201 CONTINUE
      CB(15)=CB(11)-CB(13)
      CB(16)=CB(12)*CB(14)
      CB(17)=U/(CB(5)*CB(11))
      CB(18)=CB(14)/CB(12)
      CB(1)=ARKTNS(180,CB(15),CB(16))
      TA2=CB(1)
      IF(CB(6))3,3,2
    2 CONTINUE
      CB(20)=1.0D0
      E1=CB(8)*T
      GO TO 4
    3 CONTINUE
      CB(20)=2.0D0
```

```
      E1=0.0D0
    4 CONTINUE
      CALL TCONIC(U,CB(3),CB(6),CB(2),TA2,TFP,FAC)
      N=N
      GO TO (6,5),N
    5 CONTINUE
      T=TFP-CB(19)+TAP*PD
      GO TO 12
    6 CONTINUE
      CB(19)=TFP
      N=2
      DO 60 I=1,20
   60 SB(I)=CB(I)
      GO TO 700
    7 CONTINUE
      DO 70 I=1,20
   70 CB(I)=SB(I)
  700 CONTINUE
      PD=TPI/CB(8)
      IF(M)8,8,11
    8 CONTINUE
C     TA IS THE INCREMENTAL TRUE ANOMALY
      CT=DCOS(TA)
      ST=DSIN(TA)
      EF=CT-ST*CB(18)
      GE=ST*CB(4)/CB(12)
      R2OR1=CB(11)/(CB(13)+CB(15)*CT-CB(16)*ST)
      EF=R2OR1*EF
      GE=R2OR1*GE
      EFD=CB(17)*(CB(14)-CB(14)*CT-CB(12)*ST)
      GED=(CB(15)+CB(13)*CT)/CB(11)
      TA2=CB(1)+TA
      TAP=IDINT(TA2/TPI)
      TA2=TA2-TPI*TAP
      IF(IDINT(TA2/PI)) 9,4,10
    9 TAP=TAP-1.0D0
      GO TO 4
   10 TAP=TAP+1.0D0
      GO TO 4
   11 CONTINUE
      K=CB(20)
      EMDT=CB(8)*T
      CALL GOTOR(K,EMDT,CB(9),F,E1)
      EF=-F(2)/CB(9)+1.0D0
      GE=-F(1)/CB(8)+T
      ROA=F(2)+CB(9)*F(4)+CB(10)*F(3)
      EFD=-CB(7)*CB(8)*F(3)/(CB(5)*ROA)
      GED=-F(2)/ROA+1.0D0
      TA=ARKTNS(180,CB(4)*EF+CB(14)*GE,CB(12)*GE)
      IF(K-1)110,110,12
  110 CONTINUE
      TAP=IDINT(T/PD)
      IF(TA*T)111,112,112
  111 TAP=TAP+DSIGN(1.0D0,T)
  112 TA=TA+TAP*TPI
   12 CONTINUE
      DO 13 I=1,3
      RR(I)=EF*R(I)+GE*V(I)
      VV(I)=EFD*R(I)+GED*V(I)
   13 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TCONIC(U,EC,A,SLR,TA2,T,FAC)
      IMPLICIT REAL*8(A-H,O-Z,$)
      TANG(QCCOFL)=DSIN(QOOOFL)/DCCS(QOOOFL)
      AB = DABS(A)
      FAC=AB*DSQRT(AB/U)
      ECA=(1.0D0-EC)/(1.0D0+EC)
      ABE = DSQRT( DABS(ECA) )
      THE=TANG(.5D0*TA2)
      IF(ABE-.00005D0)11,11,12
   12 CONTINUE
      ECA=2.0D0*DATAN(ABE*THE)
      IF(A)14,11,13
   13 T=FAC*(ECA-EC*DSIN(ECA))
      GO TO 16
   14 ANG=.78539816D0 + ECA/2.D0
      T=FAC*(EC*TANG(ECA)-DLOG(TANG(ANG)))
      GO TO 16
   11 FAC=DSQRT(SLR**3/U)*2.0D0/((1.0D0+EC)**2)
      EC1=ECA*THE**2
      T=FAC*(THE+THE**3*((1.0D0-2.0D0*ECA)/3.0D0-(2.0D0-3.0D0*ECA)*EC1/5
     1.0D0+(3.0D0-4.0D0*ECA)*EC1**2/7.0D0-(4.0D0-5.0D0*ECA)*EC1**3/9.0D0
     2))
   16 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TERM(X,Y,D,F)
      IMPLICIT REAL*8(A-H,O-Z,$)
      COMMON  C(1000),IC(50),Z(3),VV(3),NCR
      COMMON/APPER/ FPROLD ,OLD,XMAX
      DIMENSION R1(3,8),V1(3,8)
      DIMENSION Y(20),D(20)
      COMMON/STEPS/ STEP,XOLDD
      EQUIVALENCE (C(401),R1(1,1)), (C(425),V1(1,1))
      DATA XOLD/0./
      STEP = X-XOLD
      XOLD=X
      XOLDD=XOLD
      Y(7)=X+C(506)
      C(461) = C(461)+1.D0
      F=C(554)-(C(506)+X)
      IF(C(776).EQ.0.D0) GO TO 5
      FPR=C(776)*(90.D0-ADOT(R1(1,NOR),V1(1,NCR)))
      IF (FPR.GT. 0.D0 .AND. X .NE. 0.D0) OLD=FPR
      IF(FPROLD.EQ.0.D0.AND.FPR.GT.0.D0) GO TO 5
      IF (X .EQ. 0.D0 .OR. OLD .EQ. 0.D0) GO TO 5
      FPROLD=1.D0
      F=FPR
    5 CONTINUE
      IF(C(1000))4000,10,10
   10 IF(DABS(X+C(506)).LE.XMAX) GO TO 4000
      XMAX=DABS(X+C(506))
      IF(XMAX-C(1000)*86400.D0)4000,11,11
   11 CONTINUE
      CALL SHADOW(R1,V1,XOLD,STEP)
 4000 CONTINUE
      IF(FNORM(R1(1,NOR)).GT.C(NCR+20)) GO TO 2
      WRITE(6,3) C(NOR+60)
    3 FORMAT(1H0,19HPROBE HAS IMPACTED ,A6)
      F=0.D0
      C(122)=10.D0
      C(462)=0.D0
      RETURN
    2 CONTINUE
      IOR=3
      IF(FNORM(R1(1,1)).LT.C(11)) IOR=1
      IF(FNORM(R1(1,2)).LT.C(12)) IOR=2
      IF(FNORM(R1(1,4)).LT.C(14)) IOR=4
      IF(FNORM(R1(1,5)).LT.C(15)) IOR=5
      IF(FNORM(R1(1,6)).LT.C(16)) IOR=6
      IF(IOR.EQ.NOR) GO TO 1
      NOR=IOR
      F=0.D0
      C(122)=2.D0
      RETURN
    1 IF(C(122).EQ.0.D0.AND.F.GT.0.D0) F=0.D0
      RETURN
      END
```

```
      SUBROUTINE  TFRAC(T1,T2,TW,TF)
      IMPLICIT REAL*8(A-H,O-Z,$)
      TW=T1
      TF=T2
    3 CONTINUE
      IF(TF)1,2,2
    1 CONTINUE
      TW=TW-1.0D0
      TF=TF+1.0D0
      GO TO 3
    2 CONTINUE
      TDUM=IDINT(TF)
      TW=TW+TDUM
      TF=TF-TDUM
      RETURN
      END
```

```
      SUBROUTINE TIMEC(T1,T2,T3,T4)
      IMPLICIT REAL*8(A-H,O-Z,$)
C     T1 IS AN INPUT IN FORM (YEARS FROM 1900)(MONTH OF YEAR)
C     (DAY OF MONTH
C     WRITTEN AS 6501.12 FOR JAN. 12, 1965
C     T2 IS AN INPUT IN FORM (HOUR OF DAY)(MINUTE OF HOUR)
C     (SECOND OF MINUTE)
C     WRITTEN AS 1301.3032 FOR 1PM, 1 MINUTE, 30.32 SECOND
C     T3  IS WHOLE DAYS FROM 1950 OUTPUT
      T4=0.0D0
      TA=IDINT(T1)
      TA1=TA/100.0D0+.01D0
      TY1= IDINT(TA1)
      TY= TY1-60.0D0
      IY=TY
      IF (IY) 15,15,16
 15   CONTINUE
      WRITE (    6,17)
 17   FORMAT (37H EXIT FROM TIMEC. DATE 1960 OR BEFORE)
      CALL EXIT
 16   CONTINUE
      ND=3652
      K=1
      DO 1 I=1, IY
      KK=K-I
      IF (KK) 2,2,3
    2 CONTINUE
      ND=ND + 366
      K=K+4
      GO TO 1
    3 CONTINUE
      ND=ND +365
    1 CONTINUE
      TY2=TA-TY1*100.0D0+.1D0
      IY2=IDINT(TY2)
      IF (IY2) 10,10,11
   11 CONTINUE
      IF (12-IY2) 10,12,12
   10 CONTINUE
      WRITE (    6,13)
 13   FORMAT(37H INPUT TIME IS WRONG. EXIT FROM TIMEC)
      CALL EXIT
   12 CONTINUE
      DO 4 I=1,IY2
      I=I
C            JAN FEB MAR APRIL MAY JUNE JULY AUG SEPT OCT NOV
      GO TO (4,6,7,6,8,6,8,6,6,8,6,8),I
    6 CONTINUE
      ND=ND + 31
      GO TO 4
    7 CONTINUE
      IF(KK-1)9,14,9
   14 CONTINUE
      ND=ND +29
      GO TO 4
    9 CONTINUE
      ND=ND +28
      GO TO 4
    8 CONTINUE
      ND=ND +30
```

```
4 CONTINUE
  TB1=(T1-TA)*100.0D0+.1D0
  ND=ND+IDINT(TB1)
  ND=ND-1
  T3=ND
  TA=IDINT(T2)
  T4=(T2-TA)/864.0D0
  TB=TA/100.0D0+.1D0
  TB1=IDINT(TB)
  TB2=TA-TB1*100.0D0+.1D0
  TB3=IDINT(TB2)
  T4=T4+TB1/24.0D0+TB3/24.0D0/60.0D0
  RETURN
  END
```

```
      SUBROUTINE TRAJ(T1D,T1F,R,V,NE)
      IMPLICIT REAL*8(A-H,O-Z,$)
      COMMON C(1000),IC(50),Z(3),VV(3),NOF
      COMMON/TIME/TW,TF
      DIMENSION R1(3,8),V1(3,8),R(3),V(3),Y(20),D(20)
      EQUIVALENCE (C(401),R1(1,1)),(C(425),V1(1,1))
      J=2
      N=6
      L=0
      C(461)=0.D0
      C(506)=0.D0
      C(590)=T1D
      C(591)=T1F
      C(594)=(C(590)-C(592)+C(591)-C(593))*86400.D0
      IF(C(594).EQ.0.D0) RETURN
      Y(9)=-1.D0
      M=C(763)
      G=DSIGN(120.D0,C(594))
      Y(8)=C(764)
    2 DO 1 I=1,6
    1 Y(I)=0.D0
      X=0.D0
      CALL FNOL2(J,N,G,L,M,NE,X,Y,D,DERIV,TERM,CUT)
      IF(C(122).EQ.1.D0) GO TO 3
      IF(C(122).EQ.2.D0) GO TO 6
      IF(C(122).EQ.10.D0) RETURN
      IF(C(594)-(C(506)+X).LE.0.D0) GO TO 3
      CONTINUE
      C(506)=C(506)+X
      C(122)=1.D0
      DO 5 I=1,3
      C(I+499)=R1(I,NOR)
    5 C(I+502)=V1(I,NOR)
      GO TO 2
    6 CONTINUE
      C(122)=1.D0
      WRITE(6,7) C(NOR+60)
    7 FORMAT(20H0BODY CENTER IS NOW A6)
      DO 8 I=1,3
      C(I+499)=R1(I,NOR)
    8 C(I+502)=V1(I,NOR)
      C(506)=C(506)+X
      GO TO 2
    3 CONTINUE
      DO 13 I=1,3
      R(I)=R1(I,NOR)
   13 V(I)=V1(I,NOR)
      C(122)=1.D0
      C(592)=TW
      C(593)=TF
      RETURN
      END
```

Appendix B

EXAMPLES

CASE 1: Apoapsis Printout*

Case 1 is an example of the input and output formats for printout at apoapsis. A detailed explanation will be helpful.

INPUT

C array	Variable
750	Semimajor axis of 53500 km.
751	Eccentricity is .86915888.
752	True anomaly is 180 deg.
753	Right ascension of node is 45 deg.
754	Inclination to reference plane is 30 deg.
755	Argument of periapsis is 45 deg.
756	Epoch date is March 13, 1971.
757	Epoch time is $0^h\ 0^m\ 0^s$.
(758)†	Input reference coordinate system is Earth mean equator and equinox of 1950, January 1, 0^h.
759	Stop date is March 17, 1971.
760	Stop time is 0^h.
761	Apoapsis printout is wanted; therefore c(761) is total integration time of 4 days.
(762)†	=1. for apoapsis printout.
763	Apoapsis printout is wanted.
764	Apoapsis printout is wanted.
(765)†	No shadow is wanted.
(767)†	Built-in error control used.
(768)†	Include harmonics for Earth, Moon and Mars whichever is the central body.
(769)†	No solar pressure — ignore c(770) through c(774).
775	Input in keplerian elements.
776	Printout at apogee only.
777	Three types of output requested: (1) Central body; mean earth equator and equinox of 1950 (2) Central body; true ecliptic and equinox of date (3) Sun-centered; true ecliptic and equinox of date.

OUTPUT

The first block of output shows that shadow times have not been requested and that central body oblateness of the Earth, Moon, or Mars, whichever is the central body, is requested. However, in this case, no oblateness is calculated since Venus is the central body.

---

*Apoapsis printout is a form of exact print and requires restarting the integrator.

†Built-in value is used; therefore not included in input.

The next block of output is the epoch time and the input transformed into the mean Earth equator and equinox of 1950, January 1 at 0^h, which is the working coordinate system of TRIP.

Next comes the epoch input transformed to those output options specified. In this case, the initial position of the satellite was at apoapsis. This is followed by similar output at the requested times. The output definitions are as follows:

X → DZ	State vector in km and km/sec.
R	Radius magnitude (km).
DEC	Declination of satellite in degrees referenced to the stated coordinate plane.
RA	Right ascension or longitude of the satellite in degrees referenced to the stated coordinate plane.
V	Velocity magnitude in km/sec.
PTH	Flight path angle in degrees.
AZ	Azimuth in degrees.
SMA	Semimajor axis in km.
ECC	Eccentricity.
INC	Inclination in degrees to the reference plane.
LAN	Longitude of the ascending node in degrees.
APF	Argument of perifocus in degrees.
RCA	Radius of closest approach (periapsis) in km.
C3	Twice the total energy per unit mass in km^2/sec^2 $(-\mu/a)$.
THET	True anomaly in degrees.
APOG	Apoapsis in km.
MAN	Mean anomaly in degrees.
PERH	Period in hours.
TPER	Time to periapsis in days.

In the final block is the number of integration steps taken. Since printout at apoapsis, periapsis, or exact time steps requires restarting the numerical integrator, this is the number of steps taken from the previous output time.

```
                                    OVERLAY INPUT
   750   0.53500000D 05     751   0.86915888D 00     752   0.18000000D 03     753   0.45000000D 02
   754   0.30000000D 02     755   0.45000000D 02     756   0.71031300D 04     757   0.0
   759   0.71031700D 04     760   0.0                761   0.40000000D 01     763   0.10000000D 06
   764   0.0                766   0.40000000D 01     775   0.10000000D 01     776   0.10000000D 01
   777   0.10010100D 08       0   0.0                  0   0.0                  0   0.0

SHADOW IS NOT REQUESTED

HARMONICS OF  EARTH IS     INCLUDED

HARMONICS OF   MOON IS     INCLUDED

HARMONICS OF   MARS IS     INCLUDED

 SOLAR RADIATION PRESSURE IS NOT INCLUDED

INPUT IN MEAN EQ AND EQ OF 1950
 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                          JULIAN DATE 2441023.50000000
   X-0.66987181D 04    Y-0.93301269D 05    Z-0.35355344D 05   DX 0.60820127D 00   DY 0.43667315D-01   DZ-0.23047003D 00
   R 0.10000000D 06  DEC-0.20704814D 02   RA-0.94106598D 02    V 0.65186812D 00  PTH-0.32082440D-04   AZ 0.11220765D 03

 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                          JULIAN DATE 2441023.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.66987181D 04    Y-0.93301269D 05    Z-0.35355344D 05   DX 0.60820127D 00   DY 0.43667315D-01   DZ-0.23047003D 00
   R 0.10000000D 06  DEC-0.20704814D 02   RA-0.94106598D 02    V 0.65186812D 00  PTH-0.32082440D-04   AZ 0.11220765D 03
 SMA 0.53500000D 05  ECC 0.86915888D 00  INC 0.30000001D 02  LAN 0.45000001D 02  APE 0.45000001D 02  RCA 0.69999999D 04
  C3-0.60704579D 01 THET-0.18000000D 03 APOG 0.10000000D 06  MAN 0.18000003D 03 PERH 0.37898360D 02 TPER-0.78956402D 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.61786177D 04    Y-0.99699083D 05    Z 0.46816203D 04   DX 0.60846345D 00   DY-0.48452343D-01   DZ-0.22881576D 00
   R 0.10000000D 06  DEC 0.26833517D 01   RA-0.93546237D 02    V 0.65186813D 00  PTH-0.32091145D-04   AZ 0.11057361D 03
 SMA 0.53500000D 05  ECC 0.86915888D 00  INC 0.23739744D 02  LAN 0.93563595D 02  APE 0.35240308D 03  RCA 0.70000000D 04
  C3-0.60704579D 01 THET-0.18000000D 03 APOG 0.10000000D 06  MAN 0.18000003D 03 PERH 0.37898361D 02 TPER-0.78956403D 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.45020224D 08    Y-0.98820657D 08    Z 0.12252727D 07   DX 0.32232205D 02   DY-0.14730173D 02   DZ-0.22565886D 01
   R 0.10859947D 09  DEC 0.64645294D 00   RA-0.11449283D 03    V 0.35510354D 02  PTH 0.26436764D-01   AZ 0.93643981D 02

NUMBER OF STEPS IS        0.10000000D 01

 MARCH 14, 1971, 13HRS, 54MIN, 18. 22SEC                                          JULIAN DATE 2441025.0793752

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.66476603D 04    Y-0.93311852D 05    Z-0.35381564D 05   DX 0.60740092D 00   DY 0.44079755D-01   DZ-0.23037301D 00
   R 0.10001574D 06  DEC-0.20717464D 02   RA-0.94074943D 02    V 0.65111491D 00  PTH 0.14210455D-13   AZ 0.11227509D 03
 SMA 0.53500359D 05  ECC 0.86944052D 00  INC 0.30021418D 02  LAN 0.45042161D 02  APE 0.44995693D 02  RCA 0.69869788D 04
  C3-0.60704172D 01 THET 0.18000000D 03 APOG 0.10001574D 06  MAN 0.18000000D 03 PERH 0.37898742D 02 TPER 0.78955120D 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.61274450D 04    Y-0.99718957D 05    Z 0.46617735D 04   DX 0.60766095D 00   DY-0.48039464D-01   DZ-0.22889083D 00
   R 0.10001574D 06  DEC 0.26715471D 01   RA-0.93516241D 02    V 0.65111491D 00  PTH-0.86762704D-08   AZ 0.11060475D 03
 SMA 0.53500359D 05  ECC 0.86944052D 00  INC 0.20769750D 02  LAN 0.93550873D 02  APE 0.35244718D 03  RCA 0.69869788D 04
  C3-0.60704172D 01 THET 0.18000000D 03 APOG 0.10001574D 06  MAN 0.18000000D 03 PERH 0.37898742D 02 TPER 0.78955120D 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.40662721D 08    Y-0.10072803D 09    Z 0.94745511D 06   DX 0.32838482D 02   DY-0.13317135D 02   DZ-0.22718938D 01
   R 0.10863007D 09  DEC 0.49973152D 00   RA-0.11198335D 03    V 0.35508786D 02  PTH 0.58735146D-01   AZ 0.93669174D 02

NUMBER OF STEPS IS        0.38300000D 03

 MARCH 16, 1971,  3HRS, 48MIN, 38.373SEC                                          JULIAN DATE 2441026.65877747

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.65937871D 04    Y-0.93320554D 05    Z-0.35407949D 05   DX 0.60669211D 00   DY 0.44506980D-01   DZ-0.23028183D 00
   R 0.10002963D 06  DEC-0.20730613D 02   RA-0.94041653D 02    V 0.65045053D 00  PTH-0.12258994D-09   AZ 0.11224347D 03
 SMA 0.53500686D 05  ECC 0.86968873D 00  INC 0.30042213D 02  LAN 0.45018105D 02  APE 0.44995168D 02  RCA 0.69717021D 04
  C3-0.60703802D 01 THET 0.18000000D 03 APOG 0.10002963D 06  MAN 0.18000000D 03 PERH 0.37899089D 02 TPER 0.78956435D 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.60734350D 04    Y-0.99737159D 05    Z 0.46410284D 04   DX 0.60694994D 00   DY-0.47614743D-01   DZ-0.22897006D 00
   R 0.10002963D 06  DEC 0.26597804D 01   RA-0.93484689D 02    V 0.65045053D 00  PTH-0.87927425D-08   AZ 0.11083467D 03
 SMA 0.53500686D 05  ECC 0.86968873D 00  INC 0.20797904D 02  LAN 0.93539300D 02  APE 0.35249182D 03  RCA 0.69717021D 04
  C3-0.60703802D 01 THET 0.18000000D 03 APOG 0.10002963D 06  MAN 0.18000000D 03 PERH 0.37899089D 02 TPER 0.78956435D 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.36226536D 08    Y-0.10244098D 09    Z 0.66780978D 06   DX 0.33382116D 02   DY-0.11879542D 02   DZ-0.22843815D 01
   R 0.10865984D 09  DEC 0.35213490D 00   RA-0.10947529D 03    V 0.35506384D 02  PTH 0.90716859D-01   AZ 0.93687927D 02

NUMBER OF STEPS IS        0.39100000D 03

 MARCH 16, 1971, 23HRS, 59MIN, 59.999SEC                                          JULIAN DATE 2441027.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.19604373D 05    Y-0.12628315D 05    Z 0.28774590D 04   DX-0.19447190D 01   DY-0.41235115D 01   DZ-0.88677635D 00
   R 0.23496501D 05  DEC 0.70342879D 01   RA-0.14771206D 03    V 0.46645513D 01  PTH 0.53431129D 02   AZ 0.11928907D 03
 SMA 0.53486510D 05  ECC 0.86984222D 00  INC 0.30049831D 02  LAN 0.45103320D 02  APE 0.44997016D 02  RCA 0.69614249D 04
  C3-0.60722161D 01 THET 0.12084725D 03 APOG 0.10000759D 06  MAN 0.11762487D 02 PERH 0.37891020D 02 TPER 0.51572300D-01

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.19549654D 05    Y-0.10543338D 05    Z 0.76638528D 04   DX-0.19231652D 01   DY-0.41602679D 01   DZ 0.62689485D 00
   R 0.23496501D 05  DEC 0.19036471D 02   RA-0.15168154D 03    V 0.46645513D 01  PTH 0.53431129D 02   AZ 0.98569746D 02
 SMA 0.53486510D 05  ECC 0.86984222D 00  INC 0.20811088D 02  LAN 0.93560772D 02  APE 0.35251044D 03  RCA 0.69614249D 04
  C3-0.60722161D 01 THET 0.12084725D 03 APOG 0.10000759D 06  MAN 0.11762486D 02 PERH 0.37891003D 02 TPER 0.51572300D-01

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.33648114D 08    Y-0.10318365D 09    Z 0.52134149D 06   DX 0.31115991D 02   DY-0.15203437D 02   DZ-0.12301146D 01
   R 0.10859481D 09  DEC 0.27506639D 00   RA-0.10816143D 03    V 0.34653532D 02  PTH 0.78439682D 01   AZ 0.92084921D 02

NUMBER OF STEPS IS        0.24700000D 03
```

CASE 2: **Periapsis Printout***

The only difference here from case 1 is the input array c(776), which now requests ouput at periapsis. Notice that the initial position was at periapsis.

*Periapsis printout is a form of exact print and requires restarting the integrator.

```
                                   OVERLAY INPUT
    750   0.535000000 05      751   0.869158880 00      752   0.0                 753   0.450000000 02
    754   0.300000000 02      755   0.450000000 02      756   0.710313000 04      757   0.0
    759   0.710317000 04      760   0.0                 761   0.400000000 01      763   0.100000000 05
    764   0.0                 766   0.400000000 01      775   0.100000000 01      776   -0.100000000 01
    777   0.100101000 08        0   0.0                   0   0.0                   0   0.0

SHADOW IS NOT REQUESTED

HARMONICS OF  EARTH IS      INCLUDED

HARMONICS OF   MOON IS      INCLUDED

HARMONICS OF   MARS IS      INCLUDED

 SOLAR RADIATION PRESSURE IS NOT INCLUDED

INPUT IN MEAN EQ AND EQ OF 1950
 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                          JULIAN DATE 2441023.50000000
   X 0.468910820 03    Y 0.653108860 04    Z 0.247487380 04   DX-0.868858920 01   DY-0.623813050 00   DZ 0.329243130 01
   R 0.699999990 04  DEC 0.207046120 02   RA 0.858933970 02    V 0.931240190 01  PTH 0.805947830-06   AZ 0.677923450 02

 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                          JULIAN DATE 2441023.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.468910820 03    Y 0.653108860 04    Z 0.247487380 04   DX-0.868858920 01   DY-0.623813050 00   DZ 0.329243130 01
   R 0.699999990 04  DEC 0.207046120 02   RA 0.858933970 02    V 0.931240190 01  PTH 0.805947830-06   AZ 0.677923450 02
 SMA 0.535000000 05  ECC 0.869158880 00  INC 0.360000010 02  LAN 0.450000010 02  APE 0.450000010 02  RCA 0.699999990 04
  C3-0.607045790 01 THET 0.0             APOG 0.100000000 06  MAN 0.595118400-16 PERH 0.378983600 02 TPER 0.0

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.432503800 03    Y 0.697893570 04    Z-0.327713630 03   DX-0.869233480 01   DY 0.692182460 00   DZ 0.326879630 01
   R 0.699999990 04  DEC-0.268335340 01   RA 0.864537590 02    V 0.931240190 01  PTH 0.797243720-06   AZ 0.694269890 02
 SMA 0.535000040 05  ECC 0.869158890 00  INC 0.207397440 02  LAN 0.935635950 02  APE 0.352403080 03  RCA 0.699999990 04
  C3-0.607045740 01 THET 0.0             APOG 0.100000010 06  MAN 0.360000000 03 PERH 0.378983650 02 TPER 0.0

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.450136130 08    Y-0.987139790 08    Z 0.122026340 07   DX 0.229314070 02   DY-0.139895380 02   DZ 0.124107360 01
   R 0.108499800 09  DEC 0.644402490 00   RA-0.114513000 03    V 0.268904580 02  PTH 0.689486030 01   AZ 0.874133550 02

NUMBER OF STEPS IS        0.100000000 01

 MARCH 14, 1971, 13HRS, 55MIN, 15.398SEC                                          JULIAN DATE 2441025.08003933

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.466299100 03    Y 0.651653760 04    Z 0.247091360 04   DX-0.869734010 01   DY-0.631128590 00   DZ 0.329875530 01
   R 0.698471540 04  DEC 0.207174730 02   RA 0.859246000 02    V 0.932329530 01  PTH-0.295453550-07   AZ 0.677728420 02
 SMA 0.534995850 05  ECC 0.869443560 00  INC 0.360220800 02  LAN 0.450422060 02  APE 0.449952630 02  RCA 0.698471540 04
  C3-0.607050500 01 THET-0.112943640-05 APOG 0.100014450 06  MAN 0.360000000 03 PERH 0.378979200 02 TPER-0.170924660-09

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.427969270 03    Y 0.696398620 04    Z-0.325557910 03   DX-0.870106380 01   DY 0.687940160 00   DZ 0.327750870 01
   R 0.698471540 04  DEC-0.267152690 01   RA 0.864933310 02    V 0.932329530 01  PTH-0.382215650-07   AZ 0.693950690 02
 SMA 0.534995850 05  ECC 0.869443570 00  INC 0.207690260 02  LAN 0.935503250 02  APE 0.352447310 03  RCA 0.698471540 04
  C3-0.607050450 01 THET-0.162553660-05 APOG 0.100014460 06  MAN 0.360000000 03 PERH 0.378979240 02 TPER-0.246002570-09

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.406543160 08    Y-0.106622110 09    Z 0.942350560 06   DX 0.235299990 02   DY-0.125805560 02   DZ 0.123440010 01
   R 0.108528660 09  DEC 0.497503490 00   RA-0.112000170 03    V 0.267105780 02  PTH 0.614779400 01   AZ 0.873894080 02

NUMBER OF STEPS IS        0.214000000 03

 MARCH 16, 1971,  3HRS, 50MIN, 33. 34SEC                                          JULIAN DATE 2441026.66010457

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.459660290 03    Y 0.650367230 04    Z 0.246764760 04   DX-0.870502920 01   DY-0.630501770 00   DZ 0.330427530 01
   R 0.697124860 04  DEC 0.207306360 02   RA 0.859574020 02    V 0.933292220 01  PTH 0.355271370-14   AZ 0.677558160 02
 SMA 0.534992140 05  ECC 0.869694370 00  INC 0.300427350 02  LAN 0.450818660 02  APE 0.449943270 02  RCA 0.697124860 04
  C3-0.607054710 01 THET-0.676967130-06 APOG 0.100027190 06  MAN 0.360000000 03 PERH 0.378975250 02 TPER-0.101864900-09

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.423376020 03    Y 0.695085960 04    Z-0.323436020 03   DX-0.870972820 01   DY 0.683327980 00   DZ 0.328550630 01
   R 0.697124860 04  DEC-0.265923290 01   RA 0.865142270 02    V 0.933292220 01  PTH-0.867001050-08   AZ 0.693649910 02
 SMA 0.534992140 05  ECC 0.869694380 00  INC 0.207592370 02  LAN 0.935381660 02  APE 0.352492070 03  RCA 0.697124860 04
  C3-0.607054660 01 THET-0.138327140-05 APOG 0.100027190 06  MAN 0.360000000 03 PERH 0.378975300 02 TPER-0.208719940-09

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.362162810 08    Y-0.102335650 09    Z 0.862609740 06   DX 0.240668680 02   DY-0.111473920 02   DZ 0.123102410 01
   R 0.108557090 09  DEC 0.349723600 00   RA-0.100488720 03    V 0.265517170 02  PTH 0.537448570 01   AZ 0.873637730 02

NUMBER OF STEPS IS        0.212000000 03

 MARCH 16, 1971, 23HRS, 59MIN, 59.999SEC                                          JULIAN DATE 2441027.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.399498690 04    Y-0.928745600 05    Z-0.363154730 05   DX 0.613694780 00   DY 0.174879650 00   DZ-0.180109110 00
   R 0.998002960 05  DEC-0.213387590 02   RA-0.924352690 02    V 0.663056150 00  PTH-0.105581500 02   AZ 0.111682620 03
 SMA 0.535151090 05  ECC 0.869775870 00  INC 0.300555130 02  LAN 0.450999980 02  APE 0.449941230 02  RCA 0.696895860 04
  C3-0.606874410 01 THET-0.178396690 03 APOG 0.100061260 06  MAN 0.191339670 03 PERH 0.379144160 02 TPER-0.740122430 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.342975880 04    Y-0.996752310 05    Z 0.363099400 04   DX 0.613224170 00   DY 0.919919900-01   DZ-0.234812820 00
   R 0.998002960 05  DEC 0.208502950 01   RA-0.919707320 02    V 0.663056160 00  PTH-0.105581500 02   AZ 0.110713120 03
 SMA 0.535151090 05  ECC 0.869775870 00  INC 0.208132050 02  LAN 0.935251850 02  APE 0.352519690 03  RCA 0.696895870 04
  C3-0.606874410 01 THET-0.178396690 03 APOG 0.100061260 06  MAN 0.191339670 03 PERH 0.379144160 02 TPER-0.740122430 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.338319940 08    Y-0.103272780 09    Z 0.517308640 06   DX 0.336523800 02   DY-0.109654180 02   DZ-0.229372230 01
   R 0.108674460 09  DEC 0.272738530 00   RA-0.104138710 03    V 0.354680740 02  PTH-0.108281260 00   AZ 0.937074410 02

NUMBER OF STEPS IS        0.700000000 02
```

CASE 3: Printout at Exact Intervals†

This case represents printout requested at intervals of exactly 1-1/2 days. While this feature may be extremely useful in some cases, it is inefficient in that it requires the integrator to restart after every printout.

The differences in input are:

(1) c(761) is 1.5 since printout is wanted at exactly 1.5-day intervals.

(2) c(762) is 2., which is the total days (4) divided by Δt (1.5) and truncated. Note that c(762)* $\Delta t \neq 4$ and therefore TRIP gives a final printout after 4 days, which is at the requested stop time.

(3) c(776) uses the built-in value of 0. since printout is not wanted at perigee or apogee.

†Do not request exact printout and printout at apoapsis or periapsis in the same run. TRIP can not handle this multiple type output.

```
                                   INVERTY INPUT
    750   0.535000000 05    751   0.269150000 00    752   0.0                  753   0.650000000 02
    754   0.300000000 02    755   0.450000000 02    756   0.710313000 04       757   0.0
    759   0.710317000 04    760   0.0               761   0.150000000 01       762   0.260000000 01
    763   0.100000000 06    764   0.0               766   0.400000000 01       775   0.100000000 01
    777   0.100101000 00    0     0.0               0     0.0                  0     0.0

SHADOW IS NOT REQUESTED

HARMONICS OF  EARTH IS      INCLUDED

HARMONICS OF   MOON IS      INCLUDED

HARMONICS OF   MARS IS      INCLUDED

 SOLAR RADIATION PRESSURE IS NOT INCLUDED

INPUT IN MEAN ED AND ED OF 1950
 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                                    JULIAN DATE 2441023.50000000
   X 0.468910820 03    Y 0.653108880 04    Z 0.267483380 04    DX-0.868856920 01    DY-0.623813050 00    DZ 0.329263130 01
   R 0.699999990 04  DEC 0.207048120 02   RA 0.858933970 02    V 0.931240190 01   PTH 0.805947830-06    AZ 0.677923450 02

 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                                    JULIAN DATE 2441023.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.468910820 03    Y 0.653108880 04    Z 0.267483380 04    DX-0.868856920 01    DY-0.623813050 00    DZ 0.329263130 01
   R 0.699999990 04  DEC 0.207048120 02   RA 0.858933970 02    V 0.931240190 01   PTH 0.805947830-06    AZ 0.677923450 02
 SMA 0.535000000 05  ECC 0.869158880 00  INC 0.300000010 02  LAN 0.450000010 02   APE 0.450000010 02   RCA 0.699999990 04
  C3-0.607045740 01 THET 0.0            APOG 0.100000000 06  MAN 0.595118600-16  PERH 0.378983600 02  TPER 0.0

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.432503800 03    Y 0.697893570 04    Z-0.327713630 03    DX-0.869234680 01    DY 0.692192660 00    DZ 0.326879630 01
   R 0.699999990 04  DEC-0.268335340 01   RA 0.866537500 02    V 0.931240190 01   PTH 0.797243720-06    AZ 0.696268900 02
 SMA 0.535000040 05  ECC 0.869158890 00  INC 0.207397460 02  LAN 0.935634590 02   APE 0.352603080 03   RCA 0.699999990 04
  C3-0.607045740 01 THET 0.0            APOG 0.100000010 06  MAN 0.360000000 03  PERH 0.378983650 02  TPER 0.0

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.450136130 08    Y-0.987139790 08    Z 0.122028360 07    DX 0.229316070 02    DY-0.139985490 02    DZ 0.124102360 01
   R 0.108499600 09  DEC 0.644402490 00   RA-0.116514000 03    V 0.268904580 02   PTH 0.690880130 01    AZ 0.674133550 02

NUMBER OF STEPS IS        0.100000000 01

 MARCH 14, 1971, 11HRS, 59MIN, 59.999SEC                                                   JULIAN DATE 2441024*********

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.206043740 05    Y-0.186791550 05    Z-0.159705030 05    DX-0.638309320 00    DY 0.336768890 01    DZ 0.162789430 01
   R 0.319622370 05  DEC-0.299987260 02   RA-0.424724930 02    V 0.377860180 01   PTH-0.573302660 02    AZ 0.887567830 02
 SMA 0.534990260 05  ECC 0.869441570 00  INC 0.300228000 02  LAN 0.450421680 02   APE 0.449952080 02   RCA 0.699874000 04
  C3-0.607056850 01 THET-0.132862960 03 APOG 0.100013300 06  MAN 0.341752260 03  PERH 0.378973250 02  TPER-0.800394120-01

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.205267080 05    Y-0.233841700 05    Z-0.722089820 04    DX-0.657706410 00    DY 0.371557620 01    DZ 0.161702570 00
   R 0.319622370 05  DEC-0.130852880 02   RA-0.487232230 02    V 0.377860180 01   PTH-0.573302660 02    AZ 0.106288860 03
 SMA 0.534990270 05  ECC 0.869441570 00  INC 0.207699030 02  LAN 0.935502750 02   APE 0.352447240 03   RCA 0.699874000 04
  C3-0.607056840 01 THET-0.132862960 03 APOG 0.100013300 06  MAN 0.341752260 03  PERH 0.378973260 02  TPER-0.800394120-01

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.408570080 08    Y-0.100550450 09    Z 0.949581830 06    DX 0.315440930 02    DY-0.962512230 01    DZ-0.188072430 01
   R 0.108567890 09  DEC 0.501233370 00   RA-0.112111580 03    V 0.330334670 02   PTH-0.516301150 01    AZ 0.942319100 02

NUMBER OF STEPS IS        0.163000000 03

 MARCH 15, 1971, 23HRS, 59MIN, 59.999SEC                                                   JULIAN DATE 2441026.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.217416410 05    Y-0.383157830 05    Z-0.245506890 05    DX 0.927110400D-01   DY 0.242723580 01    DZ 0.953264740 00
   R 0.504331920 05  DEC-0.291301490 02   RA-0.604286800 02    V 0.280935700 01   PTH-0.603688460 02    AZ 0.976935740 02
 SMA 0.535000470 05  ECC 0.869688160 00  INC 0.300426960 02  LAN 0.450812370 02   APE 0.449932320 02   RCA 0.697168960 04
  C3-0.607045260 01 THET-0.148501420 03 APOG 0.100028400 06  MAN 0.323500410 03  PERH 0.378984100 02  TPER-0.160101420 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.219751740 05    Y-0.445061450 05    Z-0.728065310 04    DX 0.791102680-01    DY 0.280656670 01    DZ-0.910816910-01
   R 0.504331920 05  DEC-0.830035490 01   RA-0.638743500 02    V 0.280935700 01   PTH-0.603688460 02    AZ 0.109137520 03
 SMA 0.535000470 05  ECC 0.869688160 00  INC 0.207979720 02  LAN 0.935377300 02   APE 0.352490860 03   RCA 0.697168970 04
  C3-0.607045260 01 THET-0.148501420 03 APOG 0.100028400 06  MAN 0.323500410 03  PERH 0.378984110 02  TPER-0.160101420 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.366477610 08    Y-0.102222730 09    Z 0.686065680 06    DX 0.328024180 02    DY-0.937088830 01    DZ-0.214459260 01
   R 0.108595660 09  DEC 0.360919980 00   RA-0.109723210 03    V 0.341820280 02   PTH-0.379409430 01    AZ 0.935811190 02

NUMBER OF STEPS IS        0.193000000 03

 MARCH 16, 1971, 23HRS, 59MIN, 59.999SEC                                                   JULIAN DATE 2441027.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.396945620 04    Y-0.928742910 05    Z-0.363155320 05    DX 0.613695750 00    DY 0.174896750 00    DZ-0.180102530 00
   R 0.998000500 05  DEC-0.213388510 02   RA-0.924350220 02    V 0.663059780 00   PTH-0.105594560 02    AZ 0.111682530 03
 SMA 0.535150100 05  ECC 0.869775960 00  INC 0.300555130 02  LAN 0.450999380 02   APE 0.449941680 02   RCA 0.696896000 04
  C3-0.606875530 01 THET-0.178396490 03 APOG 0.100061000 06  MAN 0.191361110 03  PERH 0.379163110 02  TPER-0.740116080 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.342944650 04    Y-0.996750050 05    Z 0.363083240 05    DX 0.613225050 00    DY 0.920103010-01    DZ-0.234613580 00
   R 0.998000500 05  DEC 0.208494170 01   RA-0.919705000 02    V 0.663059780 00   PTH-0.105594560 02    AZ 0.110713130 03
 SMA 0.535150100 05  ECC 0.869775960 00  INC 0.208132050 02  LAN 0.935251880 02   APE 0.352519740 03   RCA 0.696896000 04
  C3-0.606875530 01 THET-0.178396490 03 APOG 0.100061000 06  MAN 0.191361110 03  PERH 0.379163110 02  TPER-0.740116080 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.338319940 08    Y-0.103272780 09    Z 0.517308470 06    DX 0.336523810 02    DY-0.109654000 02    DZ-0.224372300 01
   R 0.108674460 09  DEC 0.272738450 00   RA-0.108138710 03    V 0.356880690 02   PTH-0.108309650 00    AZ 0.937074430 02

NUMBER OF STEPS IS        0.183000000 03
```

CASE 4: Printout At Approximate Intervals

This case requests printout at approximately 1.5-day intervals. This means that printout is obtained at the first step of the integrator beyond the time actually requested. This type of printout does not require the numerical integrator to restart and is therefore much more efficient than any of the types discussed in cases 1-3. Where possible it should be used instead of the exact printouts.

The differences in input are:
(1) c(761) is set equal to the total time of 4 days.
(2) c(762) use the built-in value of 1. and therefore does not appear in the input.
(3) c(763) uses the built-in value of 0. and therefore does not appear in the input.
(4) c(764) is set to 1.5 days in seconds.

Note that the printout of the number of integration steps taken is cumulative and represents the number of total steps taken from epoch, whereas in the exact printouts of cases 1 through 3 it represents the steps taken from the last printout.

```
                                   OVERLAY INPUT
    750   0.53500000D 05    751   0.86915888D 00    752   0.0                 753   0.45000000D 02
    754   0.30000000D 02    755   0.45000000D 02    756   0.71031300D 04      757   0.0
    759   0.71031700D 04    760   0.0               761   0.40000000D 01      0     0.0
    764   0.12960000D 06    766   0.40000000D 01    775   0.10000000D 01      777   0.10010100D 08

SHADOW IS NOT REQUESTED

HARMONICS OF  EARTH IS      INCLUDED

HARMONICS OF   MOON IS      INCLUDED

HARMONICS OF   MARS IS      INCLUDED

 SOLAR RADIATION PRESSURE IS NOT INCLUDED

INPUT IN MEAN EQ AND EQ OF 1950
 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                    JULIAN DATE 2441023.50000000
   X 0.46891082D 03    Y 0.65310888D 04    Z 0.24748738D 04    DX-0.86885892D 01    DY-0.62381305D 00    DZ 0.32926313D 01
   R 0.69999999D 04  DEC 0.20704812D 02   RA 0.85893397D 02     V 0.93124019D 01   PTH 0.80594783D-06    AZ 0.67792345D 02

 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                    JULIAN DATE 2441023.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.46891082D 03    Y 0.65310888D 04    Z 0.24748738D 04    DX-0.86885892D 01    DY-0.62381305D 00    DZ 0.32926313D 01
   R 0.69999999D 04  DEC 0.20704812D 02   RA 0.85893397D 02     V 0.93124019D 01   PTH 0.80594783D-06    AZ 0.67792345D 02
 SMA 0.53500000D 05  ECC 0.86915888D 00  INC 0.30000001D 02   LAN 0.45000001D 02   APE 0.45000001D 02   RCA 0.69999999D 04
  C3-0.60704579D 01 THET 0.0             APOG 0.10000000D 06  MAN 0.59511840D-16 PERH 0.37898365D 02 TPER 0.0

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.43250380D 03    Y 0.69789357D 04    Z-0.32771363D 03    DX-0.86923348D 01    DY 0.69218246D 00    DZ 0.32687963D 01
   R 0.69999999D 04  DEC-0.26833534D 01   RA 0.86453759D 02     V 0.93124019D 01   PTH 0.79724372D-06    AZ 0.69426989D 02
 SMA 0.53500004D 05  ECC 0.86915888D 00  INC 0.20739744D 02   LAN 0.93563595D 02   APE 0.35240308D 03   RCA 0.69999999D 04
  C3-0.60704574D 01 THET 0.0             APOG 0.10000001D 06  MAN 0.36000000D 03 PERH 0.37898365D 02 TPER 0.0

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.45013613D 08    Y-0.98713979D 08    Z 0.12202634D 07    DX 0.22931407D 02    DY-0.13989538D 02    DZ 0.12410236D 01
   R 0.10849960D 09  DEC 0.64440249D 00   RA-0.11451300D 03     V 0.26890458D 02   PTH 0.68948603D 01    AZ 0.87413355D 02

NUMBER OF STEPS IS        0.10000000D 03

 MARCH 14, 1971, 12HRS,  2MIN, 39.468SEC                                    JULIAN DATE 2441025.00184570

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.20299962D 05    Y-0.18142930D 05    Z-0.15708859D 05    DX-0.67144090D 00    DY 0.33776167D 01    DZ 0.16536783D 01
   R 0.31432827D 05  DEC-0.29984101D 02   RA-0.41788500D 02     V 0.38201806D 01   PTH-0.57158648D 02    AZ 0.88146875D 02
 SMA 0.53498994D 05  ECC 0.86944164D 00  INC 0.30022080D 02   LAN 0.45042153D 02   APE 0.44995230D 02   RCA 0.69847400D 04
  C3-0.60705721D 01 THET-0.13225041D 03 APOG 0.10001325D 06  MAN 0.34217304D 03 PERH 0.37897291D 02 TPER-0.76193691D-01

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.20419182D 05    Y-0.22788668D 05    Z-0.71941796D 04    DX-0.69103459D 00    DY 0.37531548D 01    DZ 0.17343581D 00
   R 0.31432827D 05  DEC-0.13230831D 02   RA-0.48138914D 02     V 0.38201806D 01   PTH-0.57158648D 02    AZ 0.10615595D 03
 SMA 0.53498995D 05  ECC 0.86944164D 00  INC 0.20769905D 02   LAN 0.93550280D 02   APE 0.35244727D 03   RCA 0.69847400D 04
  C3-0.60705720D 01 THET-0.13225041D 03 APOG 0.10001325D 06  MAN 0.34217304D 03 PERH 0.37897292D 02 TPER-0.76193691D-01

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.40851980D 08    Y-0.10056196D 09    Z 0.94928284D 06    DX 0.31511442D 02    DY-0.95859794D 01    DZ-0.18690069D 01
   R 0.10854722D 09  DEC 0.50107774D 00   RA-0.11710880D 03     V 0.37990199D 02   PTH-0.52088229D 01    AZ 0.93215593D 02

NUMBER OF STEPS IS        0.16200000D 03

 MARCH 16, 1971,  0HRS,  2MIN, 25.910SEC                                    JULIAN DATE 2441026.50168878

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.21753957D 05    Y-0.37961548D 05    Z-0.24413030D 05    DX 0.86417448D-01    DY 0.26414265D 01    DZ 0.96235341D 00
   R 0.50102150D 05  DEC-0.29158722D 02   RA-0.60185030D 02     V 0.26256139D 01   PTH-0.60356620D 02    AZ 0.97574927D 02
 SMA 0.53500112D 05  ECC 0.86968824D 00  INC 0.30042698D 02   LAN 0.45081255D 02   APE 0.44993188D 02   RCA 0.69718938D 04
  C3-0.60704453D 01 THET-0.14828662D 03 APOG 0.10002853D 06  MAN 0.32388444D 03 PERH 0.37898479D 02 TPER-0.15841724D 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.21986114D 05    Y-0.44425645D 05    Z-0.72937186D 04    DX 0.70930557D-01    DY 0.26231676D 01    DZ-0.86370637D-01
   R 0.50102150D 05  DEC-0.83706909D 01   RA-0.63669335D 02     V 0.26256139D 01   PTH-0.60356620D 02    AZ 0.10910718D 03
 SMA 0.53500112D 05  ECC 0.86968824D 00  INC 0.20797981D 02   LAN 0.93537740D 02   APE 0.35249085D 03   RCA 0.69718938D 04
  C3-0.60704452D 01 THET-0.14828662D 03 APOG 0.10002853D 06  MAN 0.32388444D 03 PERH 0.37898479D 02 TPER-0.15841724D 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.36642975D 08    Y-0.10222410D 09    Z 0.68375299D 06    DX 0.32704793D 02    DY-0.93527209D 01    DZ-0.21418913D 01
   R 0.10859531D 09  DEC 0.36075609D 00   RA-0.10972059D 03     V 0.34149570D 02   PTH-0.38141091D 01    AZ 0.93577868D 02

NUMBER OF STEPS IS        0.36500000D 03

 MARCH 16, 1971, 23HRS, 59MIN, 59.999SEC                                    JULIAN DATE 2441027.50000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.39499488D 04    Y-0.92874642D 05    Z-0.36315474D 05    DX 0.61369424D 00    DY 0.17447986D 00    DZ-0.18011044D 00
   R 0.99800375D 05  DEC-0.21338742D 02   RA-0.92435316D 02     V 0.66305502D 00   PTH-0.10557860D 02    AZ 0.11168266D 03
 SMA 0.53515142D 05  ECC 0.86977594D 00  INC 0.30055514D 02   LAN 0.45099938D 02   APE 0.44994123D 02   RCA 0.69869589D 04
  C3-0.60687404D 01 THET-0.17839673D 03 APOG 0.10006132D 06  MAN 0.19133935D 03 PERH 0.37914451D 02 TPER-0.74012453D 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.34298376D 04    Y-0.99675307D 05    Z 0.36310257D 04    DX 0.61322366D 00    DY 0.91947973D-01    DZ-0.23481253D 00
   R 0.99800376D 05  DEC 0.20850466D 01   RA-0.91970776D 02     V 0.66305502D 00   PTH-0.10557860D 02    AZ 0.11071312D 03
 SMA 0.53515142D 05  ECC 0.86977594D 00  INC 0.20813205D 02   LAN 0.93525185D 02   APE 0.35251968D 03   RCA 0.69869589D 04
  C3-0.60687404D 01 THET-0.17839673D 03 APOG 0.10006132D 06  MAN 0.19133935D 03 PERH 0.37914451D 02 TPER-0.74012453D 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.33831994D 08    Y-0.10327278D 09    Z 0.51730867D 06    DX 0.33652380D 02    DY-0.10965422D 02    DZ-0.22437220D 01
   R 0.10867446D 09  DEC 0.27273855D 00   RA-0.10813871D 03     V 0.35468075D 02   PTH-0.10927489D 00    AZ 0.93707440D 02

NUMBER OF STEPS IS        0.53500000D 03
```

CASE 5: First and Last Point Printout

This case represents the most efficient type of run but also the one that gives the least information, being useful only when the final point is all that is desired. Note that the total steps taken will be the same as for case 4. The differences in input from case 4 are:

(1) c(763) is again set to 100 000.
(2) c(764) is set to 0.

```
                                        OVERLAY INPUT
    750   0.535000000 05     751   0.869158860 00     752   0.0                      753   0.450000000 02
    754   0.300000000 02     755   0.450000000 02     756   0.710317130 04           757   0.0
    759   0.710317000 04     760   0.0                761   0.400000000 01           763   0.100000000 06
    764   0.0                766   0.400000000 01     775   0.100000000 01           777   0.100101000 00

SHADOW IS NOT REQUESTED

HARMONICS OF   EARTH IS      INCLUDED

HARMONICS OF   MOON IS       INCLUDED

HARMONICS OF   MARS IS       INCLUDED

 SOLAR RADIATION PRESSURE IS NOT INCLUDED

INPUT IN MEAN EO AND EQ OF 1950
 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                          JULIAN DATE 2441023.500000000
   X 0.468910820 03     Y 0.653108860 04     Z 0.247487380 04    DX-0.868858020 01    DY-0.623813050 00    DZ 0.329243130 01
   R 0.699999990 04   DEC 0.207048120 02    RA 0.858933070 02     V 0.931240190 01   PTH 0.305947830-06    AZ 0.677923650 02

 MARCH 13, 1971,  0HRS,  0MIN,  0.  0SEC                                          JULIAN DATE 2441023.500000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.468910820 03     Y 0.653108860 04     Z 0.247487380 04    DX-0.868858020 01    DY-0.623813050 00    DZ 0.329243130 01
   R 0.699999990 04   DEC 0.207048120 02    RA 0.858933070 02     V 0.931240190 01   PTH 0.305947830-06    AZ 0.677923650 02
 SMA 0.535000000 05   ECC 0.869158860 00   INC 0.300000010 02   LAM 0.450000010 02   APE 0.450000010 02   RCA 0.699999990 04
  C3-0.607045790 01 THET 0.0              APOG 0.100000000 06   MAN 0.595110400-16 PERH 0.378983600 02 TPER 0.0

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X 0.432503800 03     Y 0.697893570 04     Z-0.327713630 03    DX-0.869233490 01    DY 0.692182660 00    DZ 0.326879630 01
   R 0.699999990 04   DEC-0.268335340 01    RA 0.864537590 02     V 0.931240190 01   PTH 0.797243720-06    AZ 0.694268990 02
 SMA 0.535000040 05   ECC 0.869158890 00   INC 0.207397440 02   LAM 0.935535960 02   APE 0.352463080 03   RCA 0.699999000 04
  C3-0.607045740 01 THET 0.0              APOG 0.100000010 06   MAN 0.360000000 03 PERH 0.378983650 02 TPER 0.0

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.450136130 08     Y-0.987139790 08     Z 0.122026340 07    DX 0.229314070 02    DY-0.139895380 02    DZ 0.124102350 01
   R 0.108499960 09   DEC 0.644402490 00    RA-0.114813000 03     V 0.268004580 02   PTH 0.689468030 01    AZ 0.676133550 02

NUMBER OF STEPS IS        0.100000000 01

 MARCH 16, 1971, 23HRS, 59MIN, 59.999SEC                                          JULIAN DATE 2441027.500000000

 VENUS CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.394994880 04     Y-0.928746420 05     Z-0.263156760 05    DX 0.613694260 00    DY 0.174975860 00    DZ-0.180110660 00
   R 0.998003750 05   DEC-0.213387420 02    RA-0.924353160 02     V 0.663055020 00   PTH-0.105579600 02    AZ 0.111662643 03
 SMA 0.535151420 05   ECC 0.869775940 00   INC 0.300555140 02   LAM 0.450909380 02   APE 0.460061230 02   RCA 0.698895000 04
  C3-0.606874040 01 THET-0.178396730 03  APOG 0.100061320 06   MAN 0.191333350 03 PERH 0.379144510 02 TPER-0.740126530 00

 VENUS CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.342983760 04     Y-0.996753070 05     Z 0.363102570 04    DX 0.613223660 00    DY 0.919879730-01    DZ-0.234812530 00
   R 0.998003760 05   DEC 0.208504600 01    RA-0.919707760 02     V 0.663055020 00   PTH-0.105578600 02    AZ 0.110713120 03
 SMA 0.535151420 05   ECC 0.869775940 00   INC 0.208132050 02   LAM 0.935251850 02   APE 0.352519460 03   RCA 0.698895000 04
  C3-0.606874040 01 THET-0.178396730 03  APOG 0.100061420 06   MAN 0.191333350 03 PERH 0.379144510 02 TPER-0.740126530 00

   SUN CENTERED TRUE ECLIPTIC AND EQUINOX OF DATE
   X-0.338319940 08     Y-0.103272760 09     Z 0.517309670 06    DX 0.336523800 02    DY-0.109654220 02    DZ-0.229372290 01
   R 0.108674460 09   DEC 0.272738550 00    RA-0.108138710 03     V 0.354580750 02   PTH-0.108274860 00    AZ 0.937074400 02

NUMBER OF STEPS IS        0.535000000 03
```

CASE 6: Shadow Printout

This case is for an Earth satellite and includes printout of latitude and longitude of the satellite as well as shadow times. Note that, as explained earlier in the section on known bugs, the satellite was in shadow at the start, and therefore the first shadow times are incorrect. This is obvious since the times show the spacecraft entering umbra first! The second sequence of shadow times is correct. Note also, that the oblateness effects of the Earth were included here. The input data differences from the previous cases are:

(1) c(750) through c(755) are now state vector components.
(2) c(758) shows that the state vector is referenced to the true Earth equator and equinox of date.
(3) c(761), c(762) (built-in value), c(763), c(764) indicate that only the first and last points are requested.
(4) c(765) indicates that shadow times are requested from the outset.
(5) c(766) is the built-in value indicating the Earth is the central body.
(6) c(775) is the built-in value indicating input is cartesian state vector.
(7) c(777) is the built-in values for output options.

```
                                        OVERLAY 1 PUT
    750  -0.60233886D 04      751   0.44334920D 03      752  -0.26847468D 04      0   0.0
    753  -0.19974716D 01      754  -0.10246019D 02      755   0.27891272D 01      0   0.0
    756   0.71031000D 04      757   0.17060000D 04      758   0.50000000D 01      0   0.0
    759   0.71031400D 04      760   0.17060000D 04      761   0.40000000D 01    763   0.10000000D 06
    764   0.0                 765   0.0                   0   0.0                 0   0.0

SHADOW IS REQUESTED

PARAMETICS OF  EARTH IS      INCLUDED

PARAMETICS OF   MOON IS      INCLUDED

PARAMETICS OF   MARS IS      INCLUDED

 SOLAR RADIATION PRESSURE IS NOT INCLUDED

INPUT IN MEAN EQ AND EQ OF 1950
 MARCH 10, 1971, 17HRS,  5MIN, 59.999SEC                                                    JULIAN DATE 2441021.21250000
   X-0.60267703D 04    Y 0.47207734D 03    Z-0.26872306D 04   DX-0.20406788D 01   DY-0.10238251D 02   DZ 0.27937168D 01
   R 0.66095109D 04  DEC-0.23847320D 02   RA 0.17552116D 03    V 0.10806989D 02  PTH 0.71412335D-06   AZ 0.73582150D 02


 MARCH 10, 1971, 17HRS,  5MIN, 59.999SEC                                                    JULIAN DATE 2441021.21250000

 EARTH CENTERED   TRUE EARTH EQUATOR AND EQUINOX OF DATE
   X-0.60233886D 04    Y 0.44334886D 03    Z-0.26847468D 04   DX-0.19974716D 01   DY-0.10246019D 02   DZ 0.27891272D 01
   R 0.66095109D 04  DEC-0.23966001D 02   RA 0.17579036D 03    V 0.10806989D 02  PTH 0.78403980D-06   AZ 0.73594402D 02
 SMA 0.10423670D 06  ECC 0.93659133D 00  INC 0.28767108D 02  LAN 0.22985461D 03  APE 0.30243082D 03  RCA 0.66095109D 04
  C3-0.38240197D 01 TPET 0.0             APOG 0.20186369D 06  PAN 0.36000000D 03 PERH 0.93033203D 02 TPER 0.0

 EARTH CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X-0.60267703D 04    Y 0.47207734D 03    Z-0.26872306D 04   DX-0.20406788D 01   DY-0.10238251D 02   DZ 0.27937168D 01
   R 0.66095109D 04  DEC-0.23847320D 02   RA 0.17552116D 03    V 0.10806989D 02  PTH 0.71412335D-06   AZ 0.73582150D 02
 SMA 0.10423669D 06  ECC 0.93659132D 00  INC 0.28767691D 02  LAN 0.22943659D 03  APE 0.30259487D 03  RCA 0.66095109D 04
  C3-0.38240202D 01 TPET-0.18607565D-05 APOG 0.20186387D 06  PAN 0.36000000D 03 PERH 0.93033184D 02 TPER-0.22988879D-09

EARTH FIXED LATITUDE(DEG)-0.23966001D 02   LONGITUDE(DEG) 0.11157053D 03

NUMBER OF STEPS IS        0.10000000D 01

PROBE ENTERED EARTH PENUMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 10, 1971, 17HRS, 16MIN, 23.134SEC                                                    JULIAN DATE 2441021.21971221

PROBE ENTERED EARTH UMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 10, 1971, 17HRS, 16MIN, 17.222SEC                                                    JULIAN DATE 2441021.21964378

PROBE HAS LEFT EARTH PENUMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 10, 1971, 17HRS, 16MIN, 23.214SEC                                                    JULIAN DATE 2441021.21971313

PROBE HAS LEFT EARTH UMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 10, 1971, 17HRS, 16MIN, 17.301SEC                                                    JULIAN DATE 2441021.21964369

PROBE ENTERED EARTH PENUMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 14, 1971, 13HRS,  8MIN, 58.499SEC                                                    JULIAN DATE 2441025.04789930

PROBE ENTERED EARTH UMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 14, 1971, 13HRS,  9MIN,  3.905SEC                                                    JULIAN DATE 2441025.04796187

PROBE HAS LEFT EARTH UMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 14, 1971, 13HRS, 29MIN, 14.175SEC                                                    JULIAN DATE 2441025.06196962

PROBE HAS LEFT EARTH PENUMBRA, TIME AND ORBIT ARE GIVEN BELOW
 MARCH 14, 1971, 13HRS, 29MIN, 20.287SEC                                                    JULIAN DATE 2441025.06204037


 MARCH 14, 1971, 17HRS,  5MIN, 59.999SEC                                                    JULIAN DATE 2441025.21250000

 EARTH CENTERED   TRUE EARTH EQUATOR AND EQUINOX OF DATE
   X 0.38553026D 05    Y-0.33418891D 05    Z 0.24436614D 05   DX 0.26991756D 01   DY-0.73091724D 00   DZ 0.13952991D 01
   R 0.58525363D 05  DEC 0.29070716D 02   RA-0.41098979D 02    V 0.31251404D 01  PTH 0.65985060D 02   AZ 0.90108811D 02
 SMA 0.10339762D 06  ECC 0.93576683D 00  INC 0.29070902D 02  LAN 0.22487708D 03  APE 0.30369537D 03  RCA 0.66155710D 04
  C3-0.38550519D 01 TPET 0.14650036D 03 APOG 0.20153690D 06  PAN 0.14868521D 02 PERH 0.91912125D 02 TPER 0.15817090D 00

 EARTH CENTERED   CENTRAL BODY MEAN EARTH EQUATOR AND EQUINOX OF 1950
   X 0.38450788D 05    Y-0.33502054D 05    Z 0.24357999D 05   DX 0.26985445D 01   DY-0.74367911D 00   DZ 0.13897126D 01
   R 0.58525363D 05  DEC 0.28982473D 02   RA-0.41318675D 02    V 0.31251404D 01  PTH 0.66985060D 02   AZ 0.90200483D 02
 SMA 0.10339762D 06  ECC 0.93576683D 00  INC 0.28983104D 02  LAN 0.22826757D 03  APE 0.30386158D 03  RCA 0.66155710D 04
  C3-0.38550519D 01 TPET 0.14650036D 03 APOG 0.20153690D 06  PAN 0.14868521D 02 PERH 0.91912124D 02 TPER 0.15817090D 00

EARTH FIXED LATITUDE(DEG) 0.29070716D 02   LONGITUDE(DEG)-0.10925127D 03

NUMBER OF STEPS IS        0.71100000D 03
```

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13. ABSTRACT

This report describes a numerical integration computer program (called TR based on Encke's method of integrating only the perturbations in the cartesian coordinates. The mathematical model can include Venus, Earth, Mars, Jupiter, Moon, and the Sun as either central or disturbing bodies. In addition, full gravit field potentials are included for the Earth (7×7) and Moon (4×4) and J_2 only for Mars. Modification to expand the gravity models for the other planets is simple. Solar radiation pressure may also be included as an option in the input. The pro gram uses the latest exported JPL double-precision planetary ephemerides (DE

TRIP has the option of calculating shadow times of penumbra and umbra; pri out may be obtained at specified times or, in the case of a planetary orbiter, at apoapsis or periapsis. Input data is very simple and there is a variety of coordi nate systems for printout.

TRIP is available from the Goddard program library under number D00140. is an IBM 360/95 and 91 program which has proven over the years to be accurat and very fast.

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