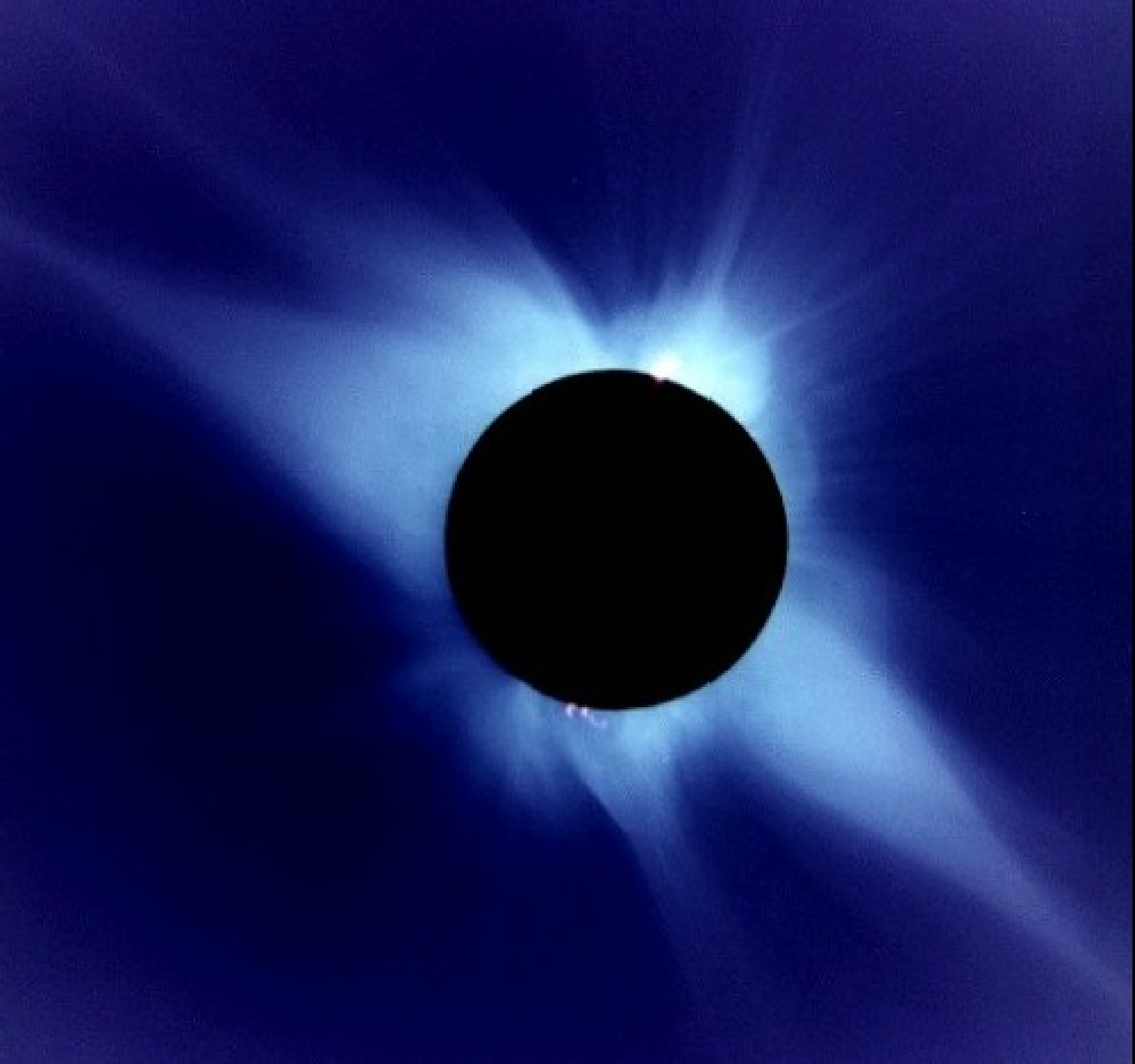


Solar Eclipse Computer Program Accurate to 1/2 Mile

The computer program shown below was used to solve for the center line of solar eclipses along the earth's surface. It was originally written in Fortran 4 and it worked on both DEC KL-75 and VAX mainframes. The program was one of the most accurate programs ever written for the purpose of solving for the solar eclipse center lines. The goal set for this computer program was to obtain a center line accurate to within 1/2 mile on the earth surface! This goal required the programmer to expend a total of 1,500 hours of personal time. Scientifically speaking, it required the programmer to include the effects of a total of 392 gravitational perturbations including those from the sun, relativistic phenomenon, five planets, and the non-spherical shape of the earth.

The improved accuracy in this program was partially met by solving for a center line using a unique calculation approach. Instead of solving for the Brown's fundamental plane published in many orbital physics textbooks, this program sought to solve for the intersection of the moon's shadow with an oblate spheroid, i.e. slightly flattened sphere. This was accomplished by first intersecting a spheroidal shaped earth using the assumed larger equatorial radius. The "true" radius of the earth calculated from the intersected latitude was then used to recalculate the moon shadow intersection using a new sphere using this improved earth radius. The convergence towards the ½ mile goal of the shadow on the earth's surface was surprisingly fast and only required 2 loops per longitude calculation.

In 1985, the major drawback of this approach was that it required more computer processor time, e.g. 2 mins of CPU time on a DEC KL-75 or ~ 2 secs on a VAX, than the conventional standard fundamental plane approach described by Brown. On the other hand, the benefit of this approach was that it allowed for the rapid corrections in the errors of solar eclipse calculations from errors in the known shape of the earth's true shape – new information now readily available from multinational GPS satellites.

Edwin C. Jones, MD, PhD (AE4TM)

http://ecjones.org/

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C                  TOTAL SOLAR ECLIPSE PATH PROGRAM
C                          MAIN  PROGRAM
C                      SOLVES TOTALITY PATHS
C
C                         BY EDWIN C. JONES
C                             1984-1985
C
      DOUBLE PRECISION DATE,ET,ELEV,RLAT,RLONG,DELTAT,ALT,
     + DIFLO,DIFNOD,RMOLON,RMOLAT,SOLONG,DIAMON,DISP,RHRLO,RHRLA,RANGE,
     + ANGDIA,PHASE,RA,DECL,PAROFF,CDATE,CET,SOPARA,PARMON,DAJUL,DAFRC,
     + COMP1,COMP2,DIFN,DUR,CDA,CT,RRA,DIFND,UUU1,UUU2,UUU3,UUUF,
     + UTIME,RAD,RLST,TINC,DAJ,DAF,DAN,YR,DASTA,RED,RPR,ADDIT,
     + RADIUS,RGLST,EARX,EARY,EARZ,RMOX,RMOY,RMOZ,VARA,VARB,VARC,SQ,
     + VART,ECLLA,ECLLO,END,SIDE1,ACCUR,GRAZE,RMOXI,RMOYI,RMOXF,RMOYF,
     + EARXI,EARYI,EARXF,EARYF,SOLAT,RMOZI,RMOZF,DIS,TT,DIAMP
      REAL*8 NU0,NU1
      REAL CHEK
C                 CLEARING THE VARIABLES BELOW ...
      DATE=0.0D0
      ET=0.0D0
      ELEV=0.0D0
      DELTAT=0.0D0
      ALT=0.0D0
      DIFLO=0.0D0
      DIFNOD=0.0D0
      RMOLON=0.0D0
      RMOLAT=0.0D0
      SOLONG=0.0D0
      DIAMON=0.0D0
      DISP=0.0D0
      RHRLO=0.0D0
      RHRLA=0.0D0
      RANGE=0.0D0
      ANGDIA=0.0D0
      PHASE=0.0D0
      RA=0.0D0
      DECL=0.0D0
      CDATE=0.0D0
      CET=0.0D0
      SOPARA=0.0D0
      PARMON=0.0D0
      DAJUL=0.0D0
      DAFRC=0.0D0
      COMP1=0.0D0
      COMP2=0.0D0
      DIFN=0.0D0
      DUR=0.0D0
      CDA=0.0D0
      CT=0.0D0
      RRA=0.0D0
      DIFND=0.0D0
      UUU1=0.0D0
      UUU2=0.0D0
      UUU3=0.0D0
      UUUF=0.0D0
      UTIME=0.0D0
      RLST=0.0D0
      TINC=0.0D0
      DAJ=0.0D0
      DAF=0.0D0
      DASTA=0.0D0
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      RED=0.0D0
      RADIUS=0.0D0
      RGLST=0.0D0
      EARX=0.0D0
      EARY=0.0D0
      EARZ=0.0D0
      RMOX=0.0D0
      RMOY=0.0D0
      RMOZ=0.0D0
      VARA=0.0D0
      VARB=0.0D0
      VARC=0.0D0
      SQ=0.0D0
      VART=0.0D0
      ECLLA=0.0D0
      ECLLO=0.0D0
      END=0.0D0
      SIDE1=0.0D0
      GRAZE=0.0D0
      RMOXI=0.0D0
      RMOYI=0.0D0
      RMOXF=0.0D0
      RMOYF=0.0D0
      EARXI=0.0D0
      EARYI=0.0D0
      EARXF=0.0D0
      EARYF=0.0D0
      SOLAT=0.0D0
      RMOZI=0.0D0
      RMOZF=0.0D0
      TT=0.0D0
      DIAMP=0.0D0
      RPR=0.0D0
      ADDIT=0.0D0
      CHEK=0.0
C
C           ECLIPSE DATA IS PLACED IN A FILE CALLED PATH.DAT
C                 THIS FILE IS DEFINED AS UNIT=24
C
      OPEN(UNIT=24,FILE='PATH.DAT')
      DIS=1.00D0
      NU0=0.00D0
      NU1=0.00D0
450   WRITE(5,500)
500   FORMAT(' SOLUTION TYPE ? 0=CENTER LINE, 1=NORTH LIM, 2=SOUTH LIM')
      ACCEPT *,GRAZE
      IF (GRAZE.EQ.2.0D0) GRAZE=-1.0D0
      IF (GRAZE.EQ.-1.0D0) GOTO 455
      IF (GRAZE.EQ.0.0D0) GOTO 455
      IF (GRAZE.EQ.1.0D0) GOTO 455
      GOTO 450
455   WRITE(5,1000)
1000  FORMAT(' ENTER DATE(M.DY) AND ET(H.MS)')
      ACCEPT *,DATE,ET
      WRITE(5,2000)
2000  FORMAT(' ENTER ELEVATION DEFAULT (FEET ABOVE SEALEVEL)')
      ACCEPT *,ELEV
2560  WRITE(5,2550)
2550  FORMAT(' DO YOU WANT TO INPUT DELTA T ? (0=NO, 1=YES)')
      ACCEPT *,CHEK
      IF (CHEK.EQ.1.0) GOTO 2570
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```
      IF (CHEK.NE.0.0) GOTO 2560
      CALL JULDAY(DATE,ET,DAJUL,DAFRC,DAN,YR)
      TT=(DAJUL+DAFRC-2415020.0D0)/36525.0D0
      DELTAT=24.349D0+72.318D0*TT+29.950D0*TT**2
      GOTO 170
2570  WRITE(5,3000)
3000  FORMAT(' ENTER ET-UT IN SECONDS')
      ACCEPT *,DELTAT
170   WRITE(5,4000)
4000  FORMAT(' ENTER TIME INCREMENT IN MINUTES')
      ACCEPT *,TINC
      IF (TINC.GT.30.D0.OR.TINC.LT.0.02D0) GOTO 170
      TINC=TINC/1440.0D0
      RAD=57.2957795180D0
      PAROFF=0.0D0
      RLAT=0.0D0
      RLONG=0.0D0
      DAN=0.0D0
      YR=0.0D0
      LOP=0
C         1 SECOND ACCURACY WITH ACCUR=1.16D-5
      ACCUR=1.16D-5
C
C               ECLIPSE NOON IS CALCULATED BELOW
C
80    LOP=LOP+1
      CALL EVENT(DATE,ET,RLAT,RLONG,ELEV,DELTAT,ALT,DIFLO,DIFND,
     + RMOLON,RMOLAT,SOLONG,DIAMON,DISP,RHRLO,RHRLA,RANGE,ANGDIA,
     + PHASE,RRA,DECL,PAROFF,CDA,CT,SOPARA,PARMON,RLST,NU0,NU1,GRAZE,
     + SOLAT,DIS)
      CALL JULDAY(DATE,ET,DAJUL,DAFRC,DANUM,YEAR)
      COMP1=DAJUL+DAFRC
      CALL JULDAY(CDA,CT,DAJUL,DAFRC,DANUM,YEAR)
      COMP2=DAJUL+DAFRC
C         1 MINUTE ACCURACY WITH ACCUR=6.96D-4
      IF (LOP.GT.100) ACCUR=6.96D-4
C         2.5 MINUTE ACCURACY WITH ACCUR=1.74D-3
      IF (LOP.GT.300) ACCUR=1.74D-3
      IF (DABS(COMP1-COMP2).LE.ACCUR) GOTO 90
      DATE=CDA
      ET=CT
      GOTO 80
90    CALL SCALE(DIFND)
      IF (DIFND.LE.90.D0) DIFN=DIFND
      IF (DIFND.LE.180.D0.AND.DIFND.GT.90.D0) DIFN=180.D0-DIFND
      IF (DIFND.GT.180.D0.AND.DIFND.LE.270.D0) DIFN=DIFND-180.D0
      IF (DIFND.GT.270.D0) DIFN=360.D0-DIFND
      IF (DIFN.LE.18.52D0) GOTO 100
      UOT9=SNGL(DIFN)
      WRITE(5,5000) UOT9
5000  FORMAT(' A SOLAR ECLIPSE IS NOT POSSIBLE !',/,' DIFFERENCE IN NODES
     + =',F7.2)
      STOP
100   UOT10=SNGL(DATE)
      UUU1=IDINT(ET)
      UUU2=IDINT(100.D0*(ET-UUU1))
      UUU3=IDINT(1.D5*(ET-UUU1-1.D-2*UUU2))/10.0D0
      UUUF=(UUU1+UUU2/60.D0+UUU3/3600.D0)
      UTIME=UUUF-DELTAT/3600.0D0+1.D0/3600.0D0
      IF (UTIME.LT.0.D0) UTIME=UTIME+24.0D0
      IF (UTIME.GE.24.D0) UTIME=UTIME-24.0D0
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      UUU1=IDINT(UTIME)
      UUU2=UTIME-IDINT(UUU1+0.5D0)
      UUU3=3600.D0*UUU2
      UUU2=IDINT(UUU3/60.0D0)
      UUU3=IDINT(10.D0*(UUU3-UUU2*60.D0))/10.0D0
      UTIME=UUU1+1.D-2*UUU2+1.D-4*UUU3
      UOT11=SNGL(UTIME)
      WRITE(24,10000) UOT10,UOT11
10000 FORMAT(' SOLAR ECLIPSE DATE =',4X,F10.6,/,' NOON OF ECLIPSE =',
     + 8X,F8.4,X,' UT')
      UOT12=SNGL(RRA)
      UOT13=SNGL(DECL)
      UOT14=SNGL(ELEV)
      UOT15=SNGL(DELTAT)
      WRITE(24,10500) UOT12,UOT13,UOT14,UOT15
10500 FORMAT(' NOON RIGHT ASCENSION =',F10.4,' HOURS',/,
     + ' NOON DECLINATION =',5X,F10.4,' DEGREES',/,
     + ' ASSUMED ELEVATION THROUGHOUT ECLIPSE =',F10.2,
     + ' FEET',/,' ASSUMED ET-UT THROUGHOUT ECLIPSE =',5X,F6.1,
     + ' SECONDS')
      IF (DIFN.LT.15.52D0) GOTO 110
      ROCCUR=0.0
      UOT16=SNGL(DIFN)
      WRITE(5,6000) UOT16
6000  FORMAT(' A SOLAR ECLIPSE IS POSSIBLE !',/,' DIFFERENCE IN NODES =',
     + F7.2)
      UOT17=SNGL(DIFN)
      WRITE(24,7000) UOT17
7000  FORMAT(' A SOLAR ECLIPSE IS POSSIBLE !',/,' DIFFERENCE IN NODES =',
     + 2X,F7.2)
      GOTO 120
110   UOT18=SNGL(DIFN)
      WRITE(5,8000) UOT18
8000  FORMAT(' A SOLAR ECLIPSE MUST OCCUR !',/,' DIFFERENCE IN NODES =',
     + F7.2)
      UOT19=SNGL(DIFN)
      WRITE(24,9000) UOT19
9000  FORMAT(' A SOLAR ECLIPSE MUST OCCUR !',/,' DIFFERENCE IN NODES =',
     + 2X,F7.2)
      ROCCUR=1.0
      IF (GRAZE.EQ.-1.0D0) GOTO 205
      IF (GRAZE.EQ.1.0D0) GOTO 305
      WRITE(24,10001)
10001 FORMAT(' CENTER LINE SOLUTION !',/)
      GOTO 120
205   WRITE(24,10002)
10002 FORMAT(' SOUTH LIMIT SOLUTION !',/)
      GOTO 120
305   WRITE(24,10003)
10003 FORMAT(' NORTH LIMIT SOLUTION !',/)
120   PAROFF=0.0D0
      WRITE(24,12000)
12000 FORMAT(3X,'LONGITUDE',3X,'LATITUDE',2X,'CONJUNCTION',2X,'ALTITUDE',
     + 2X,'SOLAR DIAM',3X,'LUNAR DIAM',2X,'DURATION',2X,'PATH WIDTH',2X,
     + 'SIDE',2X,'TYPE')
      WRITE(24,12500)
12500 FORMAT(5X,'DEGS',8X,'DEGS',6X,'UT-H.MS',4X,'APP DEGS',5X,
     + 'DEGS',8X,'DEGS',8X,'MINS',6X,'NS-MI',/,/)
C
C           ECLIPSE PATH IS CALCULATED BELOW
C
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```
      CALL JULDAY(DATE,ET,DAJ,DAF,DAN,YR)
      DASTA=DAJ+DAF-.104167D0-DELTAT/86400.0D0
      END=DAJ+DAF+.208334D0-DELTAT/86400.0D0
      DASTA=IDINT(288.D0*(DASTA+DELTAT/86400.D0)+0.5D0)/288.0D0
      CALL CALEN(DASTA,DATE,ET)
      LOOP=2
      ISTART=0
130   LOOP=LOOP-1
      IF (ISTART.EQ.0) ALT=0.0D0
      IF (LOOP.EQ.0) LOOP=2
      IF (LOOP.EQ.2) GOTO 140
      CALL JULDAY(DATE,ET,DAJ,DAF,DAN,YR)
      IF (ALT.LT.10.0D0) DASTA=DAJ+DAF+TINC/5.0D0
      IF (ALT.LT.25.0D0.AND.ALT.GE.10.0D0) DASTA=DAJ+DAF+TINC/2.0D0
      IF (ALT.GE.25.0D0) DASTA=DAJ+DAF+TINC
      IF (DASTA.GT.END) GOTO 165
      CALL CALEN(DASTA,DATE,ET)
      CALL JULDAY(DATE,ET,DAJ,DAF,DAN,YR)
      CALL LST1(DAN,DAJ,YR,ET,DELTAT,0.00D0,RGLST,NU0)
      RADIUS=3963.204883D0+ELEV/5280.0D0
      GOTO 150
140   RADIUS=3963.204883D0*(0.998327073D0+0.001676438D0*
     +DCOS(2.D0*RLAT)-0.000003519D0*DCOS(4.D0*RLAT)+
     +0.000000008D0*DCOS(6.D0*RLAT))+ELEV/5280.0D0
150   CALL EVENT(DATE,ET,RLAT,RLONG,ELEV,DELTAT,ALT,DIFLO,DIFND,
     +RMOLON,RMOLAT,SOLONG,DIAMON,DISP,RHRLO,RHRLA,RANGE,ANGDIA,
     +PHASE,RRA,DECL,PAROFF,CDA,CT,SOPARA,PARMON,RLST,NU0,NU1,GRAZE,
     +SOLAT,DIS)
      EARX=DCOS((SOLONG+180.D0)/RAD)*DIS*92.95713036D6
      EARY=DSIN((SOLONG+180.D0)/RAD)*DIS*92.95713036D6
      EARZ=-DSIN(SOLAT/RAD)*DIS*92.95713036D6
      RMOX=EARX+DCOS(RMOLON/RAD)*DISP*238864.5D0*DCOS(RMOLAT/RAD)
      RMOY=EARY+DSIN(RMOLON/RAD)*DISP*238864.5D0*DCOS(RMOLAT/RAD)
      RMOZ=EARZ+DSIN(RMOLAT/RAD)*DISP*238864.5D0
      VARA=RMOX**2+RMOY**2+RMOZ**2
      VARB=-2.D0*(RMOX*EARX+RMOY*EARY+RMOZ*EARZ)
      VARC=EARX**2+EARY**2+EARZ**2-RADIUS**2
      SQ=VARB**2-4.D0*VARA*VARC
      IF (SQ.LT.0.D0.AND.ISTART.EQ.0) LOOP=2
      IF (SQ.LT.0.D0.AND.ISTART.EQ.0) GOTO 130
      IF (SQ.LT.0.D0.AND.ISTART.EQ.1) GOTO 160
      VART=(-VARB-DSQRT(SQ))/(2.D0*VARA)
C         MUST USE DOUBLE PRECISION FOR THE NEXT 24 LINES !
      RMOX=RMOX*VART
      RMOY=RMOY*VART
      RMOZ=RMOZ*VART
      RMOXI=IDINT(RMOX)
      RMOYI=IDINT(RMOY)
      RMOZI=IDINT(RMOZ)
      RMOXF=RMOX-RMOXI
      RMOYF=RMOY-RMOYI
      RMOZF=RMOZ-RMOZI
      EARXI=IDINT(EARX)
      EARYI=IDINT(EARY)
      EARZI=IDINT(EARZ)
      EARXF=EARX-EARXI
      EARYF=EARY-EARYI
      EARZF=EARZ-EARZI
      RMOXI=RMOXI-EARXI
      RMOYI=RMOYI-EARYI
      RMOZI=RMOZI-EARZI
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      RMOXF=RMOXF-EARXF
      RMOYF=RMOYF-EARYF
      RMOZF=RMOZF-EARZF
      RMOX=RMOXI+RMOXF
      RMOY=RMOYI+RMOYF
      RMOZ=RMOZI+RMOZF
      RADIUS=DSQRT(RMOX**2+RMOY**2+RMOZ**2)
      ECLLA=DASIN(RMOZ/RADIUS)*RAD
      ECLLO=DATAN(RMOY/RMOX)*RAD
      CALL ATANAM(RMOX,RMOY,ECLLO)
      CALL COCONV(DASTA,ECLLO,ECLLA,RLONG,RLAT,1.0D0,NU1)
C         REDUCTION FROM GEOCENTRIC TO GEODETIC LATITUDE IS BELOW .
      RED=-1.92428611D-1*DSIN(2.D0*RLAT)+3.2313888D-4*
     + DSIN(4.D0*RLAT)-7.2222222D-7*DSIN(6.D0*RLAT)
      RLAT=RLAT-RED
      RLONG=(RLONG-RGLST)*15.0D0
      RLONG=RLONG+180.0D0
      CALL SCALE(RLONG)
      RLONG=RLONG-180.0D0
      CALL LST1(DAN,DAJ,YR,ET,DELTAT,RLONG,RLST,NU0)
      SIDE1=(RLST-RRA)*15.0D0+180.0D0
      CALL SCALE(SIDE1)
      SIDE1=DABS(SIDE1-180.0D0)/15.0D0
      SIDE2=-1.0
      IF (SIDE1.GT.6.0D0) SIDE2=1.0
      CALL HORIZ(RLST,RLAT,RRA,DECL,ALT)
      IF (LOOP.EQ.1) GOTO 130
      ISTART=1
      RPR=RADIUS*DSIN(ALT/RAD)
      ADDIT=RPR*DSIN(DIAMON/RAD)/(3963.18D0/DTAN(PARMON/RAD)-RPR)
      ADDIT=RAD*DABS(DASIN(ADDIT))
      DIAMP=2.0D0*RAD*DASIN(0.272281D0*DSIN(PARMON/RAD))
      DIAMON=DIAMON+ADDIT
      DIAMP=DIAMP+ADDIT
      RHRLO=RHRLO-0.249567D0*(1.D0+0.09D0*DABS(DCOS(SOLONG/RAD)))*
     + DCOS((RLST-RRA)*15.D0/RAD)*DABS(DCOS((RLAT+RED)/RAD))
      DUR=DABS(ANGDIA-DIAMP)*60.D0/DSQRT(RHRLA**2+(RHRLO-0.041069/
     + DIS**2)**2)
      WIDTH=TAN(ABS(ANGDIA-DIAMON)/RAD)*4.277068E-5/TAN(PARMON/RAD)
      WIDTH=92.9E6*ATAN(WIDTH)/ABS(COS((RLAT+RED-DECL)/RAD))
C         CORRECTION FACTOR BELOW ...
      WIDTH=0.990984D0*WIDTH
      UOT1=SNGL(RLONG)
      UOT2=SNGL(RLAT)
      UUU1=IDINT(ET)
      UUU2=IDINT(100.D0*(ET-UUU1))
      UUU3=IDINT(1.D5*(ET-UUU1-1.D-2*UUU2))/10.0D0
      UUUF=(UUU1+UUU2/60.D0+UUU3/3600.D0)
      UTIME=UUUF-DELTAT/3600.0D0
      IF (UTIME.LT.0.D0) UTIME=UTIME+24.0D0
      IF (UTIME.GE.24.D0) UTIME=UTIME-24.0D0
      UUU1=IDINT(UTIME)
      UUU2=UTIME-UUU1
      UUU3=3600.D0*UUU2
      UUU2=IDINT(UUU3/60.0D0)
      UUU3=IDINT(10.D0*(UUU3-UUU2*60.D0))/10.0D0
      UTIME=UUU1+1.D-2*UUU2+1.D-4*IDINT(UUU3+0.5D0)
      UOT3=SNGL(UTIME)
      UOT4=SNGL(ALT)
      UOT5=SNGL(ANGDIA)
      UOT6=SNGL(DIAMON)
```

```
      TYPE=-1.0
      IF (DIAMON.GT.ANGDIA) TYPE=1.0
      UOT7=SNGL(DUR)
      IF (SIDE2.EQ.-1.0.AND.TYPE.EQ.-1.0) GOTO 161
      IF (SIDE2.EQ.-1.0.AND.TYPE.EQ.1.0) GOTO 162
      IF (SIDE2.EQ.1.0.AND.TYPE.EQ.-1.0) GOTO 163
      IF (SIDE2.EQ.1.0.AND.TYPE.EQ.1.0) GOTO 164
      STOP
160   WRITE(5,15000)
      WRITE(24,15000)
15000 FORMAT(/,' COMPLETE')
      STOP
165   IF (ROCCUR.EQ.1.0) GOTO 175
      WRITE(24,15500)
15500 FORMAT(' A PARTIAL SOLAR ECLIPSE MAY OCCUR !')
      GOTO 160
175   WRITE(24,15550)
15550 FORMAT(' A PARTIAL SOLAR ECLIPSE MUST OCCUR !')
      GOTO 160
      STOP
161   WRITE(24,14001) UOT1,UOT2,UOT3,UOT4,UOT5,UOT6,UOT7,WIDTH
14001 FORMAT(X,F10.3,2X,F9.3,F12.4,F10.2,3F12.4,4X,F7.2,5X,'FR',4X,'AN')
      GOTO 130
162   WRITE(24,14002) UOT1,UOT2,UOT3,UOT4,UOT5,UOT6,UOT7,WIDTH
14002 FORMAT(X,F10.3,2X,F9.3,F12.4,F10.2,3F12.4,4X,F7.2,5X,'FR',4X,'TO')
      GOTO 130
163   WRITE(24,14003) UOT1,UOT2,UOT3,UOT4,UOT5,UOT6,UOT7,WIDTH
14003 FORMAT(X,F10.3,2X,F9.3,F12.4,F10.2,3F12.4,4X,F7.2,5X,'BA',4X,'AN')
      GOTO 130
164   WRITE(24,14004) UOT1,UOT2,UOT3,UOT4,UOT5,UOT6,UOT7,WIDTH
14004 FORMAT(X,F10.3,2X,F9.3,F12.4,F10.2,3F12.4,4X,F7.2,5X,'BA',4X,'TO')
      GOTO 130
      END
C
C                        SUBROUTINES FOLLOW
C                 EPOCH 1900.0 ORBITAL ELEMENTS USED
C                    UNLESS OTHERWISE INDICATED
C
C                         MAIN SUBROUTINE
C     SOLVES SOLAR ECLIPSE CIRCUMSTANCES FOR A SINGLE LOCATION
C                          AND TIME ...
C
      SUBROUTINE EVENT(DATE,ET,RLAT,RLONG,ELEV,DELTAT,ALT,DIFLO,
     + DIFNOD,RMOLON,RMOLAT,SOLONG,DIAMON,DISP,RHRLO,RHRLA,RANGE,
     + ANGDIA,PHASE,RA,DECL,PAROFF,CDATE,CET,SOPARA,PARMON,RLST,
     + NU0,NU1,GRAZE,SOLAT,DIS)
      DOUBLE PRECISION DATE,ET,RMOLON,RMOLAT,SOLONG,DAJUL,DAFRC,
     + FJULDA,RLST,ELONG,ELAT,RA,DECL,SOLAT,TRA,TDECL,CDATE,DIS,
     + CET,RLAT,RLONG,ELEV,DELTAT,ALT,DIFLO,ANGDIA,PHASE,PAROFF,DANUM,
     + EYEAR,RANGE,SOPARA,RHRLA,RHRLO,DISP,DIAMON,PARMON,DIFNOD,CEN,
     + TOFF,CONJ,CCJUL,CCFRC,ZRA,ZDECL,RHRSUN,GRAZE,RPR,ADDIT,RAD
      REAL*8 NU0,NU1
      DAJUL=0.0D0
      DAFRC=0.0D0
      FJULDA=0.0D0
      ELONG=0.0D0
      ELAT=0.0D0
      TRA=0.0D0
      TDECL=0.0D0
      DANUM=0.0D0
      EYEAR=0.0D0
```

```
      CEN=0.0D0
      TOFF=0.0D0
      CONJ=0.0D0
      CCJUL=0.0D0
      CCFRC=0.0D0
      ZRA=0.0D0
      ZDECL=0.0D0
      RHRSUN=0.0D0
      RPR=0.0D0
      ADDIT=0.0D0
      RAD=57.2957795100D0
      CALL JULDAY(DATE,ET,DAJUL,DAFRC,DANUM,EYEAR)
      FJULDA=DAJUL+DAFRC
      CALL LST1(DANUM,DAJUL,EYEAR,ET,DELTAT,RLONG,RLST,NU0)
      CCJUL=DAJUL
      CCFRC=DAFRC
      CALL ORBIT(DAJUL,DAFRC,RHRLA,RHRLO,PHASE,DISP,DIAMON,PARMON,
     + DIFNOD,TRA,TDECL,RA,DECL,ANGDIA,SOPARA,NU0,NU1,DIS)
      RHRSUN=RLST-RA
      IF (PAROFF.EQ.0.0D0) GOTO 700
      CALL PARALL(RLAT,ELEV,RLST,RA,DECL,SOPARA,RHRSUN)
700   ZRA=RA
      ZDECL=DECL
      CALL COCONV(FJULDA,SOLONG,SOLAT,ZRA,ZDECL,-1.0D0,NU1)
      IF (PAROFF.EQ.0.0D0) GOTO 800
      CALL PARALL(RLAT,ELEV,RLST,TRA,TDECL,PARMON,RHRSUN)
800   CALL COCONV(FJULDA,RMOLON,RMOLAT,TRA,TDECL,-1.0D0,NU1)
      CALL HORIZ(RLST,RLAT,RA,DECL,ALT)
      RPR=3956.6D0*DSIN(ALT/RAD)
      ADDIT=RPR*DSIN(DIAMON/RAD)/(3963.18D0/DTAN(PARMON/RAD)-RPR)
      ADDIT=RAD*DABS(DASIN(ADDIT))
C         THE 0.9958D0 IS A CORRECTION FACTOR BELOW .
      RMOLAT=RMOLAT+GRAZE*0.9958D0*DABS(DIAMON+ADDIT-ANGDIA)/2.0D0
      CEN=RMOLON-SOLONG+180.0D0
      CALL SCALE(CEN)
      CEN=CEN-180.0D0
      TOFF=CEN/((RHRLO-0.041D0)*24.0D0)
      CONJ=FJULDA-TOFF
      CALL CALEN(CONJ,CDATE,CET)
      DIFLO=RMOLON-SOLONG
      RETURN
      END
C
C         COMPUTES THE JULIAN DATE FOR A GIVEN CALENDAR DATE
C
      SUBROUTINE JULDAY(DATE,ET,DAJUL,DAFRC,DANUM,YEAR)
      DOUBLE PRECISION DATE,DATEN,DAJUL,DAFRC,ET,C,RMONTH,DANUM,YEAR,
     + DAY,RMONP,YEARP,B,D,HOURS,RMINS,SECS,RMULT,FRYR,CHK,ACHK
      DATEN=0.0D0
      C=0.0D0
      RMONTH=0.0D0
      DAY=0.0D0
      RMONP=0.0D0
      YEARP=0.0D0
      B=0.0D0
      D=0.0D0
      HOURS=0.0D0
      RMINS=0.0D0
      SECS=0.0D0
      RMULT=0.0D0
      FRYR=0.0D0
```

```
      ACHK=0.0D0
      CHK=1.0D0
      IF (DABS(DATE).EQ.DATE) GOTO 180
      DATE=DABS(DATE)
      ACHK=1.0D0
      CHK=-1.0D0
180   RMONTH=IDINT(DATE)
      DAY=IDINT(100.D0*(DATE-RMONTH))
      YEAR=IDINT(((CHK*(1.D6*(DATE-RMONTH-1.D-2*DAY)))+ACHK)+0.5D0)
      RMONP=RMONTH
      YEARP=YEAR
      IF (RMONTH.EQ.1.0D0.OR.RMONTH.EQ.2.0D0) YEARP=YEARP-1.0D0
      IF (RMONTH.EQ.1.0D0.OR.RMONTH.EQ.2.0D0) RMONP=RMONP+12.0D0
      DATEN=YEAR+1.D-2*RMONTH+1.D-4*DAY
      B=0.D0
      IF (DATEN.GT.1582.1015D0) B=2.D0-IDINT(YEARP/100.D0)+
     + IDINT(IDINT(YEARP/100.D0)/4.D0)
      C=IDINT(365.25D0*YEARP)
      D=IDINT(30.6001D0*(RMONP+1.D0))
      DAJUL=B+C+D+DAY+1720994.5D0
      DAFRC=ET
      HOURS=IDINT(ET)
      RMINS=IDINT(100.D0*(ET-HOURS))
      SECS=IDINT(1.D5*(ET-HOURS-1.D-2*RMINS))/10.0D0
      DAFRC=(HOURS+RMINS/60.D0+SECS/3600.D0)/24.0D0
      RMULT=63.0D0
      FRYR=YEAR/4.0D0
      IF (FRYR.EQ.IDINT(FRYR)) RMULT=RMULT-1.0D0
      IF (RMONTH.GT.2.0D0) GOTO 10
      DANUM=IDINT((RMONTH-1.0D0)*RMULT/2.0D0)
      GOTO 30
10    DANUM=IDINT(30.6D0*(RMONTH+1.0D0))-RMULT
30    DANUM=DANUM+DAY
      RETURN
      END
C
C                         METHOD #1
C     COMPUTES THE LOCAL SIDEREAL TIME FOR A GIVEN TIME AND LOCATION
C                  NOTE:  ACCOUNTS FOR NUTATION .
C
      SUBROUTINE LST1(DANUM,DAJUL,YEAR,ET,DELTAT,RLONG,RLST,NU0)
      DOUBLE PRECISION DAJUL,ET,RLST,T,R,RLONG,DANUM,YEAR,DELTAT,
     + A,C,B,TO,HOURS,RMINS,SECS,DHRS,GST,CORR
      REAL*8 NU0
      T=0.0D0
      R=0.0D0
      B=0.0D0
      TO=0.0D0
      HOURS=0.0D0
      RMINS=0.0D0
      SECS=0.0D0
      DHRS=0.0D0
      GST=0.0D0
      CORR=0.0D0
      A=0.0657098D0
      C=1.002738D0
      T=(DAJUL-DANUM-2415020.D0)/36525.0D0
      R=6.6460656D0+2400.051262D0*T+0.00002581D0*T**2
      B=24.D0-(R-24.D0*(YEAR-1900.D0))
      TO=A*DANUM-B
      HOURS=IDINT(ET)
```

```
      RMINS=IDINT(100.D0*(ET-HOURS))
      SECS=IDINT(1.D5*(ET-HOURS-1.D-2*RMINS))/10.0D0
      SECS=SECS-DELTAT
      DHRS=HOURS+RMINS/60.D0+SECS/3600.0D0
      TO=TO+C*DHRS
      GST=TO
      IF (TO.GT.24.D0) GST=TO-24.0D0
      IF (TO.LT.0.D0) GST=TO+24.0D0
      RLST=GST+RLONG/15.0D0+0.91746406D0*NU0/15.0D0
C      CORR IS A FUDGE FACTOR TO MAKE RLST AGREE WITH THE EPHEMERIS !
      CORR=((DAJUL-2415020.0D0)*4.8605825D-7)-0.000021D0
      RLST=RLST+CORR
      IF (RLST.GT.24.D0) RLST=RLST-24.0D0
      IF (RLST.LT.0.D0) RLST=RLST+24.0D0
      RETURN
      END
C
C                            METHOD #2
C     COMPUTES THE LOCAL SIDEREAL TIME FOR A GIVEN TIME AND LOCATION
C                 NOTE: ACCOUNTS FOR NUTATION .
C                 NOTE: NOT AS ACCURATE AS METHOD #1 !
C
      SUBROUTINE LST2(DAJUL,ET,DELTAT,NU0,RLONG,RLST)
      DOUBLE PRECISION DD,DAJUL,T,ET,DELTAT,RLONG,RLST,HOURS,
     + RMINS,SECS,GST,DHRS
      REAL*8 KD,NU0
      DD=0.0D0
      T=0.0D0
      HOURS=0.0D0
      RMINS=0.0D0
      SECS=0.0D0
      GST=0.0D0
      DHRS=0.0D0
      KD=0.0D0
      DD=DAJUL-2415020.0D0
      T=DD/36525.0D0
      KD=IDINT(DD/1000.0D0+0.5D0)
      DD=DD-1000.0D0*KD
      HOURS=IDINT(ET)
      RMINS=IDINT(100.D0*(ET-HOURS))
      SECS=IDINT(1.D5*(ET-HOURS-1.D-2*RMINS))/10.0D0
      SECS=SECS-DELTAT
      DHRS=HOURS+RMINS/60.D0+SECS/3600.0D0
      DD=DD+DHRS/24.0D0+DELTAT/86400.0D0
      GST=279.690983D0+0.9856473354D0*DD+265.6473354D0*KD+
     + T**2/2583.0D0
      CALL SCALE(GST)
      GST=GST+15.0D0*DHRS+0.91746406D0*NU0
      CALL SCALE(GST)
C         THE -11.98602289D0 WAS ADDED TO MAKE RLST AGREE WITH JAN 01
C         1980'S EPHEMERIS APPARENT VALUE !
      RLST=(GST+RLONG)/15.0D0-11.98602289D0
      IF (RLST.GT.24.D0) RLST=RLST-24.0D0
      IF (RLST.LT.0.D0) RLST=RLST+24.0D0
      RETURN
      END
C
C           SCALES ANGLES WITHIN 0 AND 360 DEGREES
C
      SUBROUTINE SCALE(ANGLE)
      DOUBLE PRECISION ANGLE
```

```
      ANGLE=ANGLE-(360.D0*IDINT(ANGLE/360.D0))
      IF (ANGLE.LT.0.D0) ANGLE=ANGLE+360.0D0
      RETURN
      END
C
C             CORRECTS FOR ARCTANGENT AMBIGUITIES
C
      SUBROUTINE ATANAM(X,Y,ANGLE)
      DOUBLE PRECISION ANGLE,X,Y,QUAD
      QUAD=0.0D0
      ANGLE=ANGLE-(360.D0*IDINT(ANGLE/360.D0))-360.0D0
      IF (Y.LT.0.D0) GOTO 20
      IF (X.LT.0.D0) QUAD=90.0D0
      IF (X.GT.0.D0) QUAD=0.0D0
      IF (X.EQ.0.D0.OR.Y.EQ.0.D0) GOTO 50
      GOTO 40
20    IF (X.GT.0.D0) QUAD=270.0D0
      IF (X.LT.0.D0) QUAD=180.0D0
      IF (X.EQ.0.D0) GOTO 50
40    IF (QUAD.LE.ANGLE) GOTO 50
      ANGLE=ANGLE+180.0D0
      GOTO 40
50    IF (Y.EQ.0.D0.AND.X.GT.0.D0) ANGLE=0.0D0
      IF (X.EQ.0.D0.AND.Y.GT.0.D0) ANGLE=90.0D0
      IF (Y.EQ.0.D0.AND.X.LT.0.D0) ANGLE=180.0D0
      IF (X.EQ.0.D0.AND.Y.LT.0.D0) ANGLE=270.0D0
      RETURN
      END
C
C             CORRECTS FOR GEOCENTRIC PARALLAX
C
      SUBROUTINE PARALL(RLAT,ELEV,RLST,RA,DECL,PARA,RHRSUN)
      DOUBLE PRECISION RLAT,RLST,RA,DECL,ELEV,PARA,U,RHP,PSIL,PCOL,
     + ANGHR,R,DIFF,ANGHRP,RAD,RHRSUN,SGN,RA1,DECL1,RA2,DECL2,U2,
     + PSIL2,PCOL2,DIFF2,ANGHP2,FCOS,ALTBAK,ALTPOL,ALTFRO,AL1,AL2,
     + DDCL,TH2
      U=0.0D0
      RHP=0.0D0
      PSIL=0.0D0
      PCOL=0.0D0
      ANGHR=0.0D0
      R=0.0D0
      DIFF=0.0D0
      ANGHRP=0.0D0
      SGN=0.0D0
      RA1=0.0D0
      DECL1=0.0D0
      RA2=0.0D0
      DECL2=0.0D0
      U2=0.0D0
      PSIL2=0.0D0
      PCOL2=0.0D0
      DIFF2=0.0D0
      ANGHP2=0.0D0
      FCOS=0.0D0
      ALTBAK=0.0D0
      ALTPOL=0.0D0
      ALTFRO=0.0D0
      AL1=0.0D0
      AL2=0.0D0
      DDCL=0.0D0
```

```
      TH2=0.0D0
      RAD=57.2957795100D0
      IF (DABS(RLAT).GT.90.D0) GOTO 320
      U=DATAN(0.996647D0*DTAN(RLAT/RAD))*RAD
C               SOURCE OF UNDERFLOW BELOW -----RHP-----NO HARM !!!
      RHP=ELEV*4.7788D-8
      PSIL=0.996647D0*DSIN(U/RAD)+RHP*DSIN(RLAT/RAD)
      PCOL=DCOS(U/RAD)+RHP*DCOS(RLAT/RAD)
      ANGHR=15.D0*(RLST-RA)
      R=1.D0/DSIN(PARA/RAD)
      DIFF=DATAN(PCOL*DSIN(ANGHR/RAD)/(R*DCOS(DECL/RAD)-
     + PCOL*DCOS(ANGHR/RAD)))*RAD
      ANGHRP=ANGHR+DIFF
      DIFF=DIFF/15.0D0
      RA=RA-DIFF
      DECL=RAD*DATAN(DCOS(ANGHRP/RAD)*(R*DSIN(DECL/RAD)-PSIL)/
     + (R*DCOS(DECL/RAD)*DCOS(ANGHR/RAD)-PCOL))
      RETURN
C               SOLVES PARALLAX FOR ARTIC REGIONS
320   SGN=1.0D0
      IF (RLAT.LT.0.D0) SGN=-1.0D0
      U=DATAN(0.996647D0*DTAN((SGN*180.D0-RLAT)/RAD))*RAD
C               SECOND SOURCE OF MINOR UNDERFLOW BELOW !
      RHP=ELEV*4.7788D-8
      PSIL=0.996647D0*DSIN(U/RAD)+RHP*DSIN((SGN*180.D0-RLAT)/RAD)
      PCOL=DCOS(U/RAD)+RHP*DCOS((SGN*180.D0-RLAT)/RAD)
      ANGHR=15.D0*(RLST-RA)
      R=1.D0/DSIN(PARA/RAD)
      DIFF=DATAN(PCOL*DSIN(ANGHR/RAD)/(R*DCOS(DECL/RAD)-
     + PCOL*DCOS(ANGHR/RAD)))*RAD
      ANGHRP=ANGHR+DIFF
      DIFF=DIFF/15.0D0
      RA1=RA-DIFF
      DECL1=RAD*DATAN(DCOS(ANGHRP/RAD)*(R*DSIN(DECL/RAD)-PSIL)/
     + (R*DCOS(DECL/RAD)*DCOS(ANGHR/RAD)-PCOL))
C     U2=DATAN(0.996647D0*DTAN(SGN*90.D0/RAD))*RAD
      U2=SGN*90.D0
      PSIL2=0.996647D0*DSIN(U2/RAD)+RHP*DSIN(SGN*90.D0/RAD)
      PCOL2=DCOS(U2/RAD)+RHP*DCOS(SGN*90.D0/RAD)
      DIFF2=DATAN(PCOL2*DSIN(ANGHR/RAD)/(R*DCOS(DECL/RAD)-PCOL2*
     + DCOS(ANGHR/RAD)))*RAD
      ANGHP2=ANGHR+DIFF2
      DIFF2=DIFF2/15.0D0
      RA2=RA-DIFF2
      DECL2=RAD*DATAN(DCOS(ANGHP2/RAD)*(R*DSIN(DECL/RAD)-PSIL2)/
     + (R*DCOS(DECL/RAD)*DCOS(ANGHR/RAD)-PCOL2))
      FCOS=DCOS(360.D0*RHRSUN/(RAD*24.0D0))
      ALTBAK=DASIN(DSIN(DECL/RAD)*DSIN(RLAT/RAD)+DCOS(DECL/RAD)*
     + DCOS(RLAT/RAD)*DCOS(15.D0*RHRSUN/RAD))*RAD
      ALTPOL=DASIN(DSIN(DECL/RAD)*DSIN(SGN*90.D0/RAD)+DCOS(DECL/RAD)*
     + DCOS(SGN*90.D0/RAD)*DCOS(15.D0*RHRSUN/RAD))*RAD
      ALTFRO=DASIN(DSIN(DECL/RAD)*DSIN((SGN*180.D0-RLAT)/RAD)+
     + DCOS(DECL/RAD)*DCOS((SGN*180.D0-RLAT)/RAD)*
     + DCOS(15.D0*RHRSUN/RAD))*RAD
      RA=2.D0*RA2-RA1
      RA=RA*15.0D0
      CALL SCALE(RA)
      RA=RA/15.0D0
      AL1=(ALTPOL+ALTFRO)/2.0D0
      AL2=(ALTPOL+ALTBAK)/2.0D0
      IF (DABS(AL1).LT.1.D-6.AND.AL1.GE.0.D0) AL1=1.0D-6
```

```
      IF (DABS(AL1).LT.1.D-6.AND.AL1.LT.0.D0) AL1=-1.0D-6
      DDCL=DECL2-DECL1
      TH2=DDCL*DSIN(AL2/RAD)/DSIN(AL1/RAD)
      DECL=DECL1+DABS(FCOS)*(DDCL+TH2)
      RETURN
      END
C
C        PERFORMS COORDINATE CONVERSIONS BASED ON THE FLAG
C        IF FLAG = -1.0 , EQUATORIAL TO ECLIPTIC CONVERSION
C        IF FLAG = +1.0 , ECLIPTIC TO EQUATORIAL CONVERSION
C        NOTE: MAKES NUTATION AND PRECESSION CORRECTIONS
C        NOTE: EPOCH 2000.0 EQUATION FOR PRECESSION USED
C
      SUBROUTINE COCONV(FJULDA,ELONG,ELAT,RA,DECL,FLAG,NU1)
      DOUBLE PRECISION FJULDA,ELONG,ELAT,RA,DECL,EPS,A,B,C,D,
     + FLAG,Y,X,RAD
      REAL*8 NU1
      EPS=0.0D0
      A=0.0D0
      B=0.0D0
      C=0.0D0
      D=0.0D0
      Y=0.0D0
      X=0.0D0
      RAD=57.2957795100D0
      T=(FJULDA-2451545.0D0)/36525.0D0
      EPS=23.439291D0-(46.815D0*T+0.0006D0*T**2-0.00181D0*T**3)/
     + 3600.0D0
      EPS=EPS+NU1
      IF (FLAG.EQ.1.0D0) A=ELONG
      IF (FLAG.EQ.1.0D0) B=ELAT
      IF (FLAG.EQ.-1.0D0) A=RA*15.0D0
      IF (FLAG.EQ.-1.0D0) B=DECL
      Y=DSIN(A/RAD)*DCOS(EPS/RAD)-FLAG*DTAN(B/RAD)*DSIN(EPS/RAD)
      X=DCOS(A/RAD)
      C=DATAN(Y/X)*RAD
      CALL ATANAM(X,Y,C)
      D=RAD*DASIN(DSIN(B/RAD)*DCOS(EPS/RAD)+
     + FLAG*DCOS(B/RAD)*DSIN(EPS/RAD)*DSIN(A/RAD))
      IF (FLAG.EQ.1.0D0) RA=C/15.0D0
      IF (FLAG.EQ.1.0D0) DECL=D
      IF (FLAG.EQ.-1.0D0) ELONG=C
      IF (FLAG.EQ.-1.0D0) ELAT=D
      RETURN
      END
C
C          CALCULATES THE APPARENT ALTITUDE OF THE SUN/MOON
C
      SUBROUTINE HORIZ(RLST,RLAT,RA,DECL,ALT)
      DOUBLE PRECISION RLST,RLAT,RA,DECL,ALT,ANGHR,TALT,TZEANG,
     + AZEANG,RAD
      ANGHR=0.0D0
      TALT=0.0D0
      TZEANG=0.0D0
      AZEANG=0.0D0
      RAD=57.2957795100D0
      ANGHR=(RLST-RA)*15.0D0
      TALT=RAD*DASIN(DSIN(DECL/RAD)*DSIN(RLAT/RAD)+
     + DCOS(DECL/RAD)*DCOS(RLAT/RAD)*DCOS(ANGHR/RAD))
      TZEANG=90.D0-TALT
      AZEANG=TZEANG
```

```
      IF (TZEANG.LT.75.D0) AZEANG=TZEANG-0.01616D0*DTAN(TZEANG/RAD)+
     + 1.861D-5*DTAN(TZEANG/RAD)**3
      IF (TZEANG.GE.75.0D0.AND.TZEANG.LE.90.57D0) AZEANG=0.9672D0*
     + (TZEANG-75.D0)+74.9407D0
      ALT=90.D0-AZEANG
      RETURN
      END
C
C          COMPUTES THE CALENDAR DATE FROM THE JULIAN DATE
C
      SUBROUTINE CALEN(CJULDA,VDATE,VET)
      DOUBLE PRECISION CJULDA,VDATE,VET,A,B,F,C,D,E,G,TDAY,RMON,
     + DAY,FRC,TIME,RHOURS,RMINS,SECS,YEAR,CKK,ACKK
      A=0.0D0
      B=0.0D0
      F=0.0D0
      C=0.0D0
      D=0.0D0
      E=0.0D0
      G=0.0D0
      TDAY=0.0D0
      RMON=0.0D0
      DAY=0.0D0
      FRC=0.0D0
      TIME=0.0D0
      RHOURS=0.0D0
      RMINS=0.0D0
      SECS=0.0D0
      YEAR=0.0D0
      CKK=0.0D0
      ACKK=0.0D0
      I=IDINT(CJULDA+0.5D0)
      F=CJULDA+0.5D0-DFLOAT(I)
      B=DFLOAT(I)
      IF (I.GT.2299160) A=IDINT((DFLOAT(I)-1867216.25D0)/36524.25D0)
      IF (I.GT.2299160) B=DFLOAT(I)+1.D0+A-IDINT(A/4.D0)
      C=B+1524.0D0
      D=IDINT((C-122.1D0)/365.25D0)
      E=IDINT(365.25D0*D)
      G=IDINT((C-E)/30.6001D0)
      TDAY=C-E+F-IDINT(30.6001D0*G)
      IF (G.LT.13.5D0) RMON=G-1.0D0
      IF (G.GT.13.5D0) RMON=G-13.0D0
      IF (RMON.GT.2.5D0) YEAR=D-4716.0D0
      IF (RMON.LT.2.5D0) YEAR=D-4715.0D0
      DAY=IDINT(TDAY)
      FRC=TDAY-DAY
      TIME=24.0D0*FRC
      RHOURS=IDINT(TIME)
      RMINS=IDINT(60.D0*(TIME-RHOURS))
      SECS=IDINT(10.D0*(3600.D0*(TIME-RHOURS-RMINS/60.D0)))/10.0D0
      CKK=1.0D0
      ACKK=0.0D0
      IF (IDINT(YEAR+0.5D0).LE.0.D0) CKK=-1.0D0
      IF (IDINT(YEAR+0.5D0).LE.0.D0) ACKK=-1.0D0
      VDATE=CKK*(RMON+1.D-2*DAY+1.D-6*IDINT(DABS(YEAR+ACKK)+0.5D0))
      VDATE=IDINT(VDATE*1.D6+0.5D0)/1.0D6
      VET=RHOURS+1.D-2*RMINS+1.D-4*SECS
      RETURN
      END
C
```

```
C           CALCULATES THE EQUATORIAL POSITIONS OF THE MOON AND SUN.
C           NOTE: USES BROWN'S LUNAR THEORY AND NEWCOMB'S THEORY.
C           NOTE: EPOCH 1900.0 ASSUMED UNLESS OTHERWISE INDICATED.
C
C       1. BASED PARTIALLY ON 1980.0 IAU SYSTEM OF ASTRONOMICAL
C          CONSTANTS AND PARTIALLY ON "J.MEEUS'S TABLES OF MOON AND
C          SUN."
C       2. ACCURACY TO 3/4 MILE IF DELTA T IS ACCURATE TO 5 SECONDS.
C       3. ACCURACY TO 1/2 MILE POSSIBLE WITH ADDITIONAL LUNAR LATITUDE
C          TERMS AND TWO ADDITIONAL ADDITIVE TERMS.
C
        SUBROUTINE ORBIT(DAJUL,DAFRC,RHRLA,RHRLO,PHASE,DISP,DIAMON,
     +  PARMON,DIFNOD,MRA,MDECL,SRA,SDECL,DIASUN,PARSUN,NU0,NU1,R)
        DOUBLE PRECISION DAJUL,DAFRC,RHRLA,RHRLO,PHASE,DISP,DIAMON,
     +  PARMON,DIFNOD,SRA,SDECL,DIASUN,PARSUN,DD,T,V,Q,S,X,PI,
     +  PT,BT,R,RAD,Y,A,B,C,D,E,F,RADD,RADMP,RADM,RADF,RADJ,RADV,
     +  RADS,RADQ,RADOM,LTP
        REAL*8 MRA,MDECL,KD,LP,M,MP,L,OM,J,OB,NU0,NU1,LT,LPP
        RHRLA=0.0D0
        RHRLO=0.0D0
        PHASE=0.0D0
        DISP=0.0D0
        DIAMON=0.0D0
        PARMON=0.0D0
        DIFNOD=0.0D0
        MRA=0.0D0
        MDECL=0.0D0
        SRA=0.0D0
        SDECL=0.0D0
        DIASUN=0.0D0
        PARSUN=0.0D0
        NU0=0.0D0
        NU1=0.0D0
        R=0.0D0
        DD=0.0D0
        T=0.0D0
        V=0.0D0
        Q=0.0D0
        S=0.0D0
        X=0.0D0
        PI=0.0D0
        PT=0.0D0
        BT=0.0D0
        Y=0.0D0
        A=0.0D0
        B=0.0D0
        C=0.0D0
        D=0.0D0
        E=0.0D0
        F=0.0D0
        RADD=0.0D0
        RADMP=0.0D0
        RADM=0.0D0
        RADF=0.0D0
        RADJ=0.0D0
        RADV=0.0D0
        RADS=0.0D0
        RADQ=0.0D0
        RADOM=0.0D0
        KD=0.0D0
        LP=0.0D0
```

```
      M=0.0D0
      MP=0.0D0
      L=0.0D0
      OM=0.0D0
      J=0.0D0
      OB=0.0D0
      LT=0.0D0
      LPP=0.0D0
      LTP=0.0D0
      RAD=57.2957795100D0
      DD=DAJUL-2415020.D0
      T=DD/36525.0D0
      KD=IDINT(DD/1000.D0+.5D0)
      DD=DD-1000.D0*KD+DAFRC
C         FUNDAMENTAL ARGUMENTS OF BROWN'S LUNAR THEORY ARE BELOW .
      LP=270.434358D0+13.1763965268D0*DD+216.3965268D0*KD-T**2/882.6D0
     + +T**3/526.0D3
      CALL SCALE(LP)
      M=358.47583D0+.9856002670D0*DD+265.6002669D0*KD-T**2/6666.7D0-
     + T**3/33.0D4
      CALL SCALE(M)
      D=350.737681D0+12.1907491914D0*DD+310.7491914D0*KD-T**2/696.4D0+
     + T**3/526.0D3
      CALL SCALE(D)
      F=11.2508889D0+13.22935045D0*DD+269.350449D0*KD-T**2/311.4D0-
     + T**3/3.0D6
      CALL SCALE(F)
      MP=296.1046083D0+13.064992447D0*DD+104.9924465D0*KD+T**2/
     + 108.8D0+T**3/69500.0D0
      CALL SCALE(MP)
      L=279.696680D0+.9856473354D0*DD+265.6473354D0*KD+T**2/3300.3D0
      CALL SCALE(L)
      OM=259.183275D0-.0529539222D0*DD-52.9539221994D0*KD+T**2/
     + 481.2D0+T**3/5.0D5
      CALL SCALE(OM)
      V=63.07037D0+.6165213685D0*DD+256.5213685D0*KD
      CALL SCALE(V)
      J=221.64742D0+.9025179176D0*DD+182.5179176D0*KD
      CALL SCALE(J)
      Q=165.94905D0+.4615761716D0*DD+101.5761716D0*KD
      CALL SCALE(Q)
      S=193.1323D0+.9521494604D0*DD+232.1494604D0*KD
      CALL SCALE(S)
C         LUNAR ABERRATION CORRECTION BELOW .
      LP=LP+0.018D0*DCOS(MP-2.D0*D)/3600.0D0
      LP=LP+0.007D0*DCOS(2.D0*D)/3600.0D0
C         ADDITIVE TERMS OF BROWN'S LUNAR THEORY ARE BELOW .
      F=F-DSIN((OM+289.65D0-.90D0*T)/RAD)/1935.5D0
      X=DSIN((84.110D0+16.209D0*T)/RAD)/11612.9D0
      LP=LP+X
      MP=MP+X
      D=D+X
      F=F+X
      X=DSIN((235.669D0+150.679D0*T)/RAD)/15189.9D0
      LP=LP+X
      MP=MP+X
      D=D+X
      F=F+X
      X=DSIN((315.6D0+893.3D0*T)/RAD)/17822.0D0
      L=L+X
      M=M+X
```

```
      X=.266D0*DSIN((31.8D0+119.D0*T)/RAD)/3600.0D0
      L=L+X
      M=M+X
      X=(1.882D0-.016D0*T)*DSIN((57.24D0+150.27D0*T)/RAD)/3600.0D0
      L=L+X
      M=M+X
      X=DSIN((OM+275.05D0-2.30D0*T)/RAD)
      F=F-X/231.07D0
      MP=MP+X/3208.56D0
      X=X/12765.9D0
      LP=LP+X
      D=D+X
      F=F+X
      X=DSIN(OM/RAD)
      LP=LP+X/495.8D0
      MP=MP+X/385.56D0
      D=D+X/495.8D0
      F=F-X/40.5867D0
      X=DSIN((346.56D0+132.87D0*T-.0091731D0*T**2)/RAD)/252.28D0
      LP=LP+X
      MP=MP+X
      D=D+X
      F=F+X
      X=DSIN((51.2D0+20.2D0*T)/RAD)
      LP=LP+X/4286.0D0
      MP=MP+X/1224.0D0
      D=D+X/497.2D0
      M=M-X/562.5D0
      F=F+X/17142.9D0
      L=L-X/562.5D0
C         OBLIQUITY OF THE ECLIPTIC IS CALCULATED BELOW USING THE
C         EPOCH 2000.0 EQUATION FOR THE OBLIQUITY .
      T=T-1.0D0
      OB=23.439291D0-T/76.89823D0-T**2/6.25D6+
     + T**3/1984127.0D0
      T=T+1.0D0
      E=1.D0-.0024954D0*T-.000007522D0*T**2
C         TERMS FOR BOTH NUTATIONS ARE BELOW .
      NU0=(-(17.2327D0+.01737D0*T)*DSIN(OM/RAD)+(.2088D0+.00002D0*T)*
     + DSIN((2.D0*OM)/RAD)-1.273D0*DSIN((2.D0*L)/RAD)-.2037D0*
     + DSIN((2.D0*LP)/RAD)+.126D0*DSIN(M/RAD)+.0675D0*DSIN(MP/RAD)-
     + .0497D0*DSIN((2.D0*L+M)/RAD)+.0214D0*DSIN((2.D0*L-M)/RAD))/
     + 3600.0D0
      NU1=((9.21D0+.00091D0*T)*DCOS(OM/RAD)-(.0904D0-.00004D0*T)*
     + DCOS((2.D0*OM)/RAD)+.552D0*DCOS((2.D0*L)/RAD)+
     + .0884D0*DCOS((2.D0*LP)/RAD)+.0216D0*DCOS((2.D0*L+M)/RAD)-
     + .0093D0*DCOS((2.D0*L-M)/RAD))/3600.0D0
      OB=OB+NU1
C         BEGIN CALCULATING LUNAR ELEMENTS ...
      PI=3422.54D0
      CALL SCALE(D)
      CALL SCALE(MP)
      CALL SCALE(M)
      CALL SCALE(F)
      CALL SCALE(J)
      CALL SCALE(V)
      CALL SCALE(S)
      CALL SCALE(Q)
      RADD=D/RAD
      RADMP=MP/RAD
      RADM=M/RAD
```

```
      RADF=F/RAD
      RADJ=J/RAD
      RADV=V/RAD
      RADS=S/RAD
      RADQ=Q/RAD
      RADOM=OM/RAD
      CALL ATERMS(RADD,RADMP,RADM,RADF,RADJ,RADV,RADS,RADQ,E,LT)
      CALL EXTRAA(RADD,RADMP,RADM,RADF,E,LTP)
      CALL CTERMS(RADD,RADMP,RADM,RADF,RADJ,RADV,RADS,RADQ,E,PT)
      LP=LP+LT/3600.0D0+LTP/3600.0D0
      PI=PI+PT
      PI=PI+PI**3/255272.D6
      CALL BTERMS(RADD,RADMP,RADM,RADF,RADJ,RADV,RADS,RADQ,E,BT,RADOM)
      B=BT/3600.0D0
      B=B*(1.D0-.0004664D0*DCOS(OM/RAD))*(1.D0-.0000754D0*
     + DCOS((OM+275.05D0-2.3D0*T)/RAD))*(1.D0-.00008966D0*
     + DCOS((OM+289.65D0-.9D0*T)/RAD))
C         LUNAR CORRECTION FACTORS BELOW ...
      B=B+0.000019D0
      LP=LP-0.000176D0
      PI=PI-0.097D0
      LP=LP+NUO
      LPP=LP
      MDECL=DCOS(B/RAD)*DSIN(LP/RAD)*DSIN(OB/RAD)+DSIN(B/RAD)*
     + DCOS(OB/RAD)
      MDECL=RAD*DASIN(MDECL)
      Y=DSIN(LP/RAD)*DCOS(OB/RAD)-DTAN(B/RAD)*DSIN(OB/RAD)
      X=DCOS(LP/RAD)
      MRA=RAD*DATAN(Y/X)
      CALL ATANAM(X,Y,MRA)
      MRA=MRA/15.0D0
      PARMON=PI/3600.0D0
      DIAMON=(0.0799D0/3600.0D0+0.272453D0*PARMON)*2.0D0
      DISP=0.0165944D0/DTAN(PARMON/RAD)
      RHRLA=4.932D-2*DCOS(F/RAD)
      RHRLO=6.714705D3*DSIN(DIAMON/RAD)**2
      DIFNOD=F
C         BEGIN CALCULATING SOLAR ELEMENTS ...
      R=.01675104D0*E
      R=1.00000003D0*(1.D0+R**2/2.D0-(R-3.D0*R**3/8.0D0)*
     + DCOS(M/RAD)-(R**2/2.D0-R**4/3.0D0)*DCOS((2.D0*M)/RAD)-3.D0*
     + R**3*DCOS((3.D0*M)/RAD)/8.0D0-R**4*DCOS((4.D0*M)/RAD)/3.0D0)
      CALL DTERMS(RADD,RADMP,RADM,RADF,RADJ,RADV,RADS,RADQ,LT,T)
      L=L+LT/3600.0D0
      CALL ETERMS(RADD,RADMP,RADM,RADF,RADJ,RADV,RADS,RADQ,LT)
      R=R*(1.D0+LT/1.D7)
      CALL FTERMS(RADD,RADMP,RADM,RADF,RADJ,RADV,RADS,RADQ,LT)
      LT=LT/3600.0D0
      L=L+2502.D0*(8.8D0/R)*DCOS(B/RAD)*DSIN((LP-L)/RAD)/(PI*3600.0D0)
      LT=LT+2502.D0*(8.8D0/R)*DSIN(B/RAD)/(PI*3600.0D0)
      R=R+.0121200D0*(8.8D0/R)*DCOS(B/RAD)*DCOS((LP-L)/RAD)/PI
C         SOLAR ABERRATION IS CALCULATED BELOW .
      L=L-20.47D0*(1.D0+.01675104D0*E*DCOS(M/RAD))/3600.0D0
      L=L+NUO
C         SOLAR CORRECTION FACTORS BELOW ...
      LT=LT-0.000007D0
      L=L+0.000017D0
C         R IS OK TO SIX PLACES .
      PHASE=0.5D0*(1.D0-DCOS((LPP-L)/RAD))
C             SOLAR DIAMETER ALLOWS FOR IRRADIATION...
      DIASUN=0.533989D0/R
```

```
      PARSUN=(8.794D0/R)/3600.0D0
      SDECL=DCOS(LT/RAD)*DSIN(L/RAD)*DSIN(OB/RAD)+DSIN(LT/RAD)*
     + DCOS(OB/RAD)
      SDECL=RAD*DASIN(SDECL)
      Y=DSIN(L/RAD)*DCOS(OB/RAD)-DTAN(LT/RAD)*DSIN(OB/RAD)
      X=DCOS(L/RAD)
      SRA=RAD*DATAN(Y/X)
      CALL ATANAM(X,Y,SRA)
      SRA=SRA/15.0D0
C         CONVERTS R.A. TO IAU EARTH/MOON MASS-RATIO (81.30) SYSTEM
      SRA=SRA+2.78D-7*DSIN(D/RAD)-5.56D-7
      RETURN
      END
C
C         THE FOLLOWING SIX SUBROUTINES ARE PERIODIC TERMS
C         DEVELOPED IN BROWN'S LUNAR THEORY AND NEWCOMB'S
C         SOLAR THEORY ...
C
C     -----------------------------------------------------
C
C     CODEO: SOLAR AND PLANETARY TERMS IN LUNAR LONGITUDE
C
      SUBROUTINE ATERMS(D,MP,M,F,J,V,S,Q,E,COR1)
      DIMENSION AC(72)
      DOUBLE PRECISION AC,D,F,V,S,Q,E,COR1,HAVE1
      REAL*8 MP,M,J
      DATA (AC(I),I=1,29)/4586.46488,2369.9112,668.147485,411.6065,
     + 211.657319,205.962346,191.95263,165.144714,147.686127,
     + 125.153814,109.672472,55.172668,45.0985013,39.5271821,
     + 38.4269101,30.7737402,28.4735382,24.4213217,18.6117905,
     + 18.0234253,14.5772717,14.3885577,13.9001518,13.1937268,
     + 9.70119084,9.36564865,8.6287178,8.46555023,8.09651362/
      DATA (AC(I),I=30,54)/
     + 7.64800418,7.48574532,7.41349909,6.380851,5.73925206,
     + 4.39072671,3.99584563,3.21441261,2.92025975,2.73841624,
     + 2.57940525,2.5304558,2.49393617,2.1505719,1.97900173,
     + 1.87733107,1.74997188,1.43978153,1.29694013,1.26834622,
     + 1.22429453,1.18984224,1.17865502,1.16680709,1.13619002/
      DATA (AC(I),I=55,72)/
     + 1.08750754,1.05998885,.992520473,.950931494,.821078099,
     + .758689967,.680376443,.661591745,.642343176,.637929399,
     + .587809332,.584435151,.570455938,.559361546,.556846665,
     + .55094513,.5395769,0.179/
      DATA HAVE1/0.0D0/
      RAD=57.2957795100D0
      IF (HAVE1.EQ.1.0D0) GOTO 10
      HAVE1=1.0D0
      AC(3)=AC(3)*E
      AC(6)=AC(6)*E
      AC(8)=AC(8)*E
      AC(9)=AC(9)*E
      AC(11)=AC(11)*E
      AC(17)=AC(17)*E
      AC(18)=AC(18)*E
      AC(20)=AC(20)*E
      AC(21)=AC(21)*E
      AC(25)=AC(25)*E
      AC(27)=AC(27)*E
      AC(29)=AC(29)*E**2
      AC(30)=AC(30)*E
      AC(31)=AC(31)*E**2
```

```
      AC(32)=AC(32)*E**2
      AC(35)=AC(35)*E
      AC(38)=AC(38)*E
      AC(39)=AC(39)*E
      AC(40)=AC(40)*E**2
      AC(41)=AC(41)*E**2
      AC(42)=AC(42)*E
      AC(43)=AC(43)*E
      AC(45)=AC(45)*E
      AC(47)=AC(47)*E
      AC(49)=AC(49)*E
      AC(52)=AC(52)*E
      AC(53)=AC(53)*E**2
      AC(55)=AC(55)*E
      AC(60)=AC(60)*E**2
      AC(61)=AC(61)*E
      AC(64)=AC(64)*E
      AC(68)=AC(68)*E
      AC(70)=AC(70)*E
10    COR1=.292D0*DSIN(2.D0*MP+M+180.0D0/RAD)
      COR1=COR1+.311D0*DSIN(2.D0*M+MP+180.0D0/RAD)
      COR1=COR1+.482D0*DSIN(3.D0*MP+M+180.0D0/RAD)
      COR1=COR1-.492D0*DSIN(MP)-.249D0*DSIN(2.D0*MP)-
     + .624D0*DSIN(3.D0*MP)+.51D0*DSIN(M)-.343D0*DSIN(3.D0*M)
      COR1=COR1-.67D0*DSIN(MP-M)+.254D0*DSIN(2.D0*(MP-M))
      COR1=COR1-.921D0*DSIN(MP+M+180.0D0/RAD)-
     + .296D0*DSIN(2.D0*(MP+M))
      COR1=COR1+AC(66)*DSIN(2.*F-D)+AC(67)*DSIN(6.*D-2.*MP)+
     + AC(68)*DSIN(M-D)+AC(69)*DSIN(2.*MP-2.*D+2.*F)+
     + AC(70)*DSIN(3.*MP+M+180./RAD)+AC(71)*DSIN(2.*MP-2.*D-2.*F)+
     + AC(72)*DSIN(2.*F-2.*D+MP+180./RAD)
      COR1=COR1+AC(58)*DSIN(2.*D-4.*MP)+
     + AC(59)*DSIN(V)+AC(60)*DSIN(MP-2.*M+2.*D)+AC(61)*DSIN(3.*MP-M)+
     + AC(62)*DSIN(3.*V+2.*D-MP)+AC(63)*DSIN(J+1.2/RAD)+
     + AC(64)*DSIN(MP-M-4.*D)+AC(65)*DSIN(2.*MP+D+180./RAD)
      COR1=COR1+AC(52)*DSIN(2.*D+2.*MP-M)+
     + AC(53)*DSIN(2.*M+MP+180./RAD)+
     + AC(54)*DSIN(2.*D-MP+2.*J+180.3/RAD)+AC(55)*DSIN(M+D-MP)+
     + AC(56)*DSIN(2.*D+3.*MP)+AC(57)*DSIN(MP+2.*D+2.*F+180./RAD)
      COR1=COR1+AC(43)*DSIN(2.*D-M-2.*F)+AC(44)*DSIN(MP+4.*D)+
     + AC(45)*DSIN(4.*D-M)+AC(46)*DSIN(2.*MP-D)+
     + AC(47)*DSIN(2.*F-M-2.*D)+AC(48)*DSIN(2.*F-2.*MP)+
     + AC(49)*DSIN(M+D+MP)+AC(50)*DSIN(2.*MP-3.*D)+
     + AC(51)*DSIN(4.*D-3.*MP)
      COR1=COR1+AC(36)*DSIN(2.*MP+2.*F+180./RAD)+
     + AC(37)*DSIN(3.*D-MP+180./RAD)+
     + AC(38)*DSIN(M+2.*D+MP+180./RAD)+
     + AC(39)*DSIN(4.*D-2.*MP-M)+AC(40)*DSIN(MP-2.*M)+
     + AC(41)*DSIN(MP-2.*M-2.*D)+AC(42)*DSIN(M+2.*D-2.*MP)
      COR1=COR1+AC(30)*DSIN(2.*MP+M+180./RAD)+
     + AC(31)*DSIN(2.*M+180./RAD)+AC(32)*DSIN(2.*D-MP-2.*M)+
     + AC(33)*DSIN(MP+2.*D-2.*F+180./RAD)+
     + AC(34)*DSIN(2.*F+2.*D+180./RAD)+AC(35)*DSIN(4.*D-M-MP)
      COR1=COR1+AC(20)*DSIN(M+D)+AC(21)*DSIN(MP-M+2.*D)+
     + AC(22)*DSIN(2.*D+2.*MP)+AC(23)*DSIN(4.*D)+
     + AC(24)*DSIN(3.*MP-2.*D+180./RAD)+AC(25)*DSIN(2.*MP-M)+
     + AC(26)*DSIN(MP-2.*F-2.*D)+AC(27)*DSIN(2.*D-M-2.*MP)+
     + AC(28)*DSIN(MP+D+180./RAD)+AC(29)*DSIN(2.*D-2.*M)
      COR1=COR1+AC(11)*DSIN(MP+M+180./RAD)+
     + AC(12)*DSIN(2.*F-2.*D+180./RAD)+AC(13)*DSIN(2.*F+MP+180./RAD)+
     + AC(14)*DSIN(2.*F-MP+180./RAD)+AC(15)*DSIN(4.*D-MP)+
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     + AC(16)*DSIN(4.*D-2.*MP)+AC(17)*DSIN(M+2.*D-MP+180./RAD)+
     + AC(18)*DSIN(2.*D+M+180./RAD)+AC(19)*DSIN(MP-D)
       COR1=COR1+AC(1)*DSIN(2.*D-MP)+AC(2)*DSIN(2.*D)+
     + AC(3)*DSIN(M+180./RAD)+AC(4)*DSIN(2.*F+180./RAD)+
     + AC(5)*DSIN(2.*MP-2.*D+180./RAD)+
     + AC(6)*DSIN(2.*D-M-MP)+AC(7)*DSIN(2.*D+MP)+AC(8)*DSIN(2.*D-M)+
     + AC(9)*DSIN(MP-M)+AC(10)*DSIN(D+180./RAD)
       COR1=COR1+22639.550D0*DSIN(MP)+769.016D0*DSIN(2.D0*MP)+
     + 36.124D0*DSIN(3.D0*MP)+1.938D0*DSIN(4.D0*MP)+
     + .113D0*DSIN(5.D0*MP)
       RETURN
       END
C
C      CODES 1-4,6: SOLAR AND PLANETARY TERMS IN LUNAR LATITUDE
C
       SUBROUTINE BTERMS(D,MP,M,F,J,V,S,Q,E,COR2,OM)
       DIMENSION BC(86)
       DOUBLE PRECISION BC,E,D,F,V,S,Q,COR2,OM,HAVE2
       REAL*8 MP,M,J
       DATA (BC(I),I=1,29)/18461.48,6.299,1010.179,999.694461,
     + 623.657799,199.485222,166.578783,117.261605,61.9121347,
     + 33.3581678,31.7626928,29.6887429,15.5643,15.1219735,
     + 12.1405507,8.90103066,8.00114798,7.46270134,6.75657343,
     + 6.57897955,6.48990836,5.65362957,5.35725523,5.33076588,
     + 5.09630773,4.86072925,4.79456044,3.98147168,3.67486076/
       DATA (BC(I),I=30,54)/
     + 2.99851677,2.81395146,2.4133191,2.18154504,2.1461975,
     + 1.77373266,1.62393555,1.582652,1.52289975,1.51572666,
     + 1.32351672,1.26834622,1.18984224,1.1398057,1.098212,
     + 1.02120686,.826591787,.810664018,.806132078,.804227109,
     + .79390622,.668697931,.657115341,.642343176,.633913704/
       DATA (BC(I),I=55,69)/
     + .598130221,.59228949,.474279554,.427995999,.41767511,
     + .387624784,.348127556,.34281833,.327044827,.318683717,
     + .31181878,.306383178,.301420758,.291022736,.273182666/
       DATA (BC(I),I=70,86)/
     + .266304247,.254777211,.243250174,.239032626,.216774323,
     + .210891028,.207838561,.171272696,.152213808,.146118429,
     + .140373296,.140373296,.140373296,.136033883,.134011111,
     + .129859444,.129859444/
       DATA HAVE2/0.0D0/
       RAD=57.29577951D0D0
       IF (HAVE2.EQ.1.0D0) GOTO 20
       HAVE2=1.0D0
       BC(12)=BC(12)*E
       BC(15)=BC(15)*E
       BC(16)=BC(16)*E
       BC(17)=BC(17)*E
       BC(18)=BC(18)*E
       BC(19)=BC(19)*E
       BC(21)=BC(21)*E
       BC(22)=BC(22)*E
       BC(24)=BC(24)*E
       BC(25)=BC(25)*E
       BC(26)=BC(26)*E
       BC(35)=BC(35)*E
       BC(40)=BC(40)*E
       BC(41)=BC(41)*E
       BC(43)=BC(43)*E
       BC(44)=BC(44)*E**2
       BC(46)=BC(46)*E
```

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      BC(47)=BC(47)*E
      BC(48)=BC(48)*E
      BC(49)=BC(49)*E
      BC(50)=BC(50)*E
      BC(52)=BC(52)*E
      BC(53)=BC(53)*E
      BC(55)=BC(55)*E
      BC(59)=BC(59)*E
      BC(60)=BC(60)*E**2
      BC(62)=BC(62)*E
      BC(64)=BC(64)*E**2
      BC(65)=BC(65)*E
      BC(67)=BC(67)*E
      BC(69)=BC(69)*E**2
      BC(73)=BC(73)*E
      BC(74)=BC(74)*E
      BC(77)=BC(77)*E
      BC(78)=BC(78)*E
      BC(83)=BC(83)*E**2
      BC(86)=BC(86)*E
20    COR2=.083D0*DSIN(F+2.D0*OM)
      COR2=COR2-.137D0*DSIN(MP+F)+.031D0*DSIN(2.D0*MP+F)+
     + .091D0*DSIN(4.D0*MP+F)-.262D0*DSIN(M+F)-.056D0*DSIN(2.D0*M+F)
      COR2=COR2+.165D0*DSIN(MP-M+F)
      COR2=COR2-.101D0*DSIN(MP+M+180.0D0/RAD+F)
      COR2=COR2+.558D0*DSIN(MP-2.D0*M+F)
      COR2=COR2+.117D0*DSIN(2.D0*M+MP+180.0D0/RAD+F)
      COR2=COR2+.076D0*DSIN(3.D0*MP-M+F)
      COR2=COR2+.119D0*DSIN(3.D0*MP+M+180.0D0/RAD+F)
      COR2=COR2-.026D0*DSIN(2.D0*MP-M+F)
      COR2=COR2+.053D0*DSIN(2.D0*MP+M+180.0D0/RAD+F)
      COR2=COR2+BC(83)*DSIN(F-2.*D-2.*M)+BC(84)*DSIN(2.*D-F-4.*MP)+
     + BC(85)*DSIN(3.*F-2.*MP)+BC(86)*DSIN(2.*MP-F-M+2.*D)
      COR2=COR2+BC(78)*DSIN(F+4.*D-M)+BC(79)*DSIN(2.*D-F+3.*MP)+
     + BC(80)*DSIN(2.*D+3.*F+180./RAD)+
     + BC(81)*DSIN(F-MP+D)+BC(82)*DSIN(F+2.*D+3.*MP)
      COR2=COR2+BC(72)*DSIN(2.*D-MP+3.*F+180./RAD)+
     + BC(73)*DSIN(M+F+MP+2.*D+180./RAD)+
     + BC(74)*DSIN(F+4.*D-M-2.*MP)+BC(75)*DSIN(MP+F+4.*D)+
     + BC(76)*DSIN(F-MP+3.*D+180./RAD)+
     + BC(77)*DSIN(4.*D-F+M-MP+180./RAD)
      COR2=COR2+BC(65)*DSIN(F-M-2.*MP)+BC(66)*DSIN(MP+F-3.*D)+
     + BC(67)*DSIN(2.*MP-M-F)+BC(68)*DSIN(3.*F-MP-2.*D)+
     + BC(69)*DSIN(MP+F-2.*D+2.*M+180./RAD)+
     + BC(70)*DSIN(F+4.*MP)+BC(71)*DSIN(F+2.*D-3.*MP)
      COR2=COR2+BC(57)*DSIN(MP+4.*D-F)+BC(58)*DSIN(MP+F-D)+
     + BC(59)*DSIN(4.*D-F-M)+BC(60)*DSIN(2.*D-2.*M+F)+
     + BC(61)*DSIN(F-3.*D)+BC(62)*DSIN(F+4.*D-M-MP)+
     + BC(63)*DSIN(2.*D-MP-3.*F)+BC(64)*DSIN(2.*D-MP+F-2.*M)
      COR2=COR2+BC(50)*DSIN(MP+F-2.*D-M)+
     + BC(51)*DSIN(MP+F+D+180./RAD)+
     + BC(52)*DSIN(F+2.*MP+M-2.*D+180./RAD)+
     + BC(53)*DSIN(M+F+2.*MP+180./RAD)+BC(54)*DSIN(4.*D-F-2.*MP)+
     + BC(55)*DSIN(4.*D-F-M-MP)+BC(56)*DSIN(F-MP-D)
      COR2=COR2+BC(40)*DSIN(M+F+2.*D-MP+180./RAD)+
     + BC(41)*DSIN(M+F+2.*D+180./RAD)+BC(42)*DSIN(F+4.*D)+
     + BC(43)*DSIN(2.*D-M+F+MP)+BC(44)*DSIN(2.*D-2.*M-F)+
     + BC(45)*DSIN(MP+3.*F+180./RAD)+
     + BC(46)*DSIN(F-2.*D-M-MP)+BC(47)*DSIN(F-M+2.*MP)+
     + BC(48)*DSIN(D+M-F)+BC(49)*DSIN(M+F+D)
      COR2=COR2+BC(34)*DSIN(2.*D-F+2.*MP)+BC(35)*DSIN(MP-M-F+2.*D)+
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     +  BC(36)*DSIN(2.*MP-F-2.*D)+BC(37)*DSIN(3.*MP-F)+
     +  BC(38)*DSIN(2.*MP+2.*D+F)+BC(39)*DSIN(2.*D-F-3.*MP)
        COR2=COR2+BC(25)*DSIN(F-M-MP)+BC(26)*DSIN(F-M)+
     +  BC(27)*DSIN(F-D)+BC(28)*DSIN(3.*MP+F)+
     +  BC(29)*DSIN(4.*D-F)+BC(30)*DSIN(F-MP+4.*D)+
     +  BC(31)*DSIN(MP-3.*F)+BC(32)*DSIN(F+4.*D-2.*MP)+
     +  BC(33)*DSIN(2.*D-3.*F)
        COR2=COR2+BC(18)*DSIN(MP+F-2.*D+M+180./RAD)+
     +  BC(19)*DSIN(MP-M+F)+BC(20)*DSIN(4.*D-F-MP)+
     +  BC(21)*DSIN(M+F+180./RAD)+BC(22)*DSIN(MP-M-F)+
     +  BC(23)*DSIN(F+D+180./RAD)+BC(24)*DSIN(M+F+MP+180./RAD)
        COR2=COR2+BC(10)*DSIN(2.*D-F+MP)+BC(11)*DSIN(2.*MP-F)+
     +  BC(12)*DSIN(2.*D-M-F)+BC(13)*DSIN(2.*D-F-2.*MP)+
     +  BC(14)*DSIN(MP+F+2.*D)+BC(15)*DSIN(F-2.*D-M)+
     +  BC(16)*DSIN(2.*D-MP+F-M)+BC(17)*DSIN(2.*D-M+F)
        COR2=COR2+BC(1)*DSIN(F)+BC(2)*DSIN(3.*F+180./RAD)+
     +  BC(3)*DSIN(MP+F)+BC(4)*DSIN(MP-F)+BC(5)*DSIN(2.*D-F)+
     +  BC(6)*DSIN(2.*D-MP+F)+BC(7)*DSIN(2.*D-MP-F)+
     +  BC(8)*DSIN(2.*D+F)+BC(9)*DSIN(2.*MP+F)
        RETURN
        END
C
C       CODE5: SOLAR AND PLANETARY TERMS IN LUNAR PARALLAX
C
        SUBROUTINE CTERMS(D,MP,M,F,J,V,S,Q,E,CORP)
        DIMENSION CC(72)
        DOUBLE PRECISION CC,D,F,V,S,Q,E,CORP,HAVE3
        REAL*8 MP,M,J
        DATA (CC(I),I=1,32)/34.311626,28.2332988,.399851245,0.0,
     +  .303971512,1.44375509,3.08616319,1.9179068,1.1529927,
     +  .977931771,.949208085,.105298327,0.0,.71385674,.600874992,
     +  .372272389,.225621978,.299851677,0.0,.149114567,.230178443,
     +  .283137647,.260877822,.118984224,.126834622,0.0,0.0,
     +  .10932918,.0916493464,.103930554,0.0,.0483264264/
        DATA (CC(I),I=33,72)/
     +  .0480764182,0.0,.0673642377,0.0,.0385959915,.0483264264,
     +  .0322216802,0.0,0.0,0.0,0.0,.0432284506,.0337691957,0.,0.,
     +  0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +  0.,0.,0.,0.,0.,.0831966815/
        DATA HAVE3/0.0D0/
        RAD=57.2957795100D0
        IF (HAVE3.EQ.1.0D0) GOTO 30
        HAVE3=1.0D0
        CC(3)=CC(3)*E
        CC(6)=CC(6)*E
        CC(8)=CC(8)*E
        CC(9)=CC(9)*E
        CC(11)=CC(11)*E
        CC(17)=CC(17)*E
        CC(18)=CC(18)*E
        CC(20)=CC(20)*E
        CC(21)=CC(21)*E
        CC(25)=CC(25)*E
        CC(29)=CC(29)*E**2
        CC(30)=CC(30)*E
        CC(32)=CC(32)*E**2
        CC(35)=CC(35)*E
        CC(38)=CC(38)*E
        CC(39)=CC(39)*E
        CC(45)=CC(45)*E
30      CORP=CC(66)*DCOS(2.*F-D)+CC(67)*DCOS(6.*D-2.*MP)+
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     + CC(68)*DCOS(M-D)+CC(69)*DCOS(2.*MP-2.*D+2.*F)+
     + CC(70)*DCOS(3.*MP+M+180./RAD)+CC(71)*DCOS(2.*MP-2.*D-2.*F)+
     + CC(72)*DCOS(2.*F-2.*D+MP+180./RAD)
       CORP=CORP+CC(58)*DCOS(2.*D-4.*MP)+
     + CC(59)*DCOS(V)+CC(60)*DCOS(MP-2.*M+2.*D)+
     + CC(61)*DCOS(3.*MP-M)+CC(62)*DCOS(3.*V+2.*D-MP)+
     + CC(63)*DCOS(J+1.2/RAD)+CC(64)*DCOS(MP-M-4.*D)+
     + CC(65)*DCOS(2.*MP+D+180./RAD)
       CORP=CORP+CC(52)*DCOS(2.*D+2.*MP-M)+
     + CC(53)*DCOS(2.*M+MP+180./RAD)+
     + CC(54)*DCOS(2.*D-MP+2.*J+180.3/RAD)+CC(55)*DCOS(M+D-MP)+
     + CC(56)*DCOS(2.*D+3.*MP)+CC(57)*DCOS(MP+2.*D+2.*F+180./RAD)
       CORP=CORP+CC(43)*DCOS(2.*D-M-2.*F)+
     + CC(44)*DCOS(MP+4.*D)+CC(45)*DCOS(4.*D-M)+CC(46)*DCOS(2.*MP-D)+
     + CC(47)*DCOS(2.*F-M-2.*D)+CC(48)*DCOS(2.*F-2.*MP)+
     + CC(49)*DCOS(M+D+MP)+CC(50)*DCOS(2.*MP-3.*D)+
     + CC(51)*DCOS(4.*D-3.*MP)
       CORP=CORP+CC(36)*DCOS(2.*MP+2.*F+180./RAD)+
     + CC(37)*DCOS(3.*D-MP+180./RAD)+CC(38)*DCOS(M+2.*D+MP+180./RAD)+
     + CC(39)*DCOS(4.*D-2.*MP-M)+CC(40)*DCOS(MP-2.*M)+
     + CC(41)*DCOS(MP-2.*M-2.*D)+CC(42)*DCOS(M+2.*D-2.*MP)
       CORP=CORP+CC(30)*DCOS(2.*MP+M+180./RAD)+
     + CC(31)*DCOS(2.*M+180./RAD)+CC(32)*DCOS(2.*D-MP-2.*M)+
     + CC(33)*DCOS(MP+2.*D-2.*F+180./RAD)+
     + CC(34)*DCOS(2.*F+2.*D+180./RAD)+CC(35)*DCOS(4.*D-M-MP)
       CORP=CORP+CC(20)*DCOS(M+D)+CC(21)*DCOS(MP-M+2.*D)+
     + CC(22)*DCOS(2.*D+2.*MP)+CC(23)*DCOS(4.*D)+
     + CC(24)*DCOS(3.*MP-2.*D+180./RAD)+CC(25)*DCOS(2.*MP-M)+
     + CC(26)*DCOS(MP-2.*F-2.*D)+CC(27)*DCOS(2.*D-M-2.*MP)+
     + CC(28)*DCOS(MP+D+180./RAD)+CC(29)*DCOS(2.*D-2.*M)
       CORP=CORP+CC(11)*DCOS(MP+M+180./RAD)+
     + CC(12)*DCOS(2.*F-2.*D+180./RAD)+CC(13)*DCOS(2.*F+MP+180./RAD)+
     + CC(14)*DCOS(2.*F-MP+180./RAD)+CC(15)*DCOS(4.*D-MP)+
     + CC(16)*DCOS(4.*D-2.*MP)+CC(17)*DCOS(M+2.*D-MP+180./RAD)+
     + CC(18)*DCOS(2.*D+M+180./RAD)+CC(19)*DCOS(MP-D)
       CORP=CORP+CC(1)*DCOS(2.*D-MP)+CC(2)*DCOS(2.*D)+
     + CC(3)*DCOS(M+180./RAD)+CC(4)*DCOS(2.*F+180./RAD)+
     + CC(5)*DCOS(2.*MP-2.*D+180./RAD)+CC(6)*DCOS(2.*D-M-MP)+
     + CC(7)*DCOS(2.*D+MP)+CC(8)*DCOS(2.*D-M)+
     + CC(9)*DCOS(MP-M)+CC(10)*DCOS(D+180./RAD)
       CORP=CORP+186.5398D0*DCOS(MP)+10.1657D0*DCOS(2.D0*MP)+
     + .6215D0*DCOS(3.D0*MP)+.0401D0*DCOS(4.D0*MP)+
     + .0026D0*DCOS(5.D0*MP)
       RETURN
       END
C
C      NEWCOMB'S TERMS IN SOLAR LONGITUDE
C
       SUBROUTINE DTERMS(D,MP,M,F,J,V,S,Q,COR3,T)
       DIMENSION DC(43)
       DOUBLE PRECISION DC,D,F,V,S,Q,COR3,T
       REAL*8 MP,M,J
       DATA (DC(I),I=1,43)/4.838,5.526,.666,.21,.084,2.497,
     + 1.559,1.024,.154,.152,.144,.123,.116,.075,.074,.419,.108,
     + .32,.112,.273,2.043,.129,1.77,.585,.5,.425,.204,.154,.106,
     + .101,.085,7.208,2.731,.164,2.6,1.61,.556,.21,.163,.08,
     + .073,.073,.069/
       RAD=57.29577951D0D0
       COR3=DC(39)*DCOS(J+M+110.2/RAD)+
     + DC(40)*DCOS(4.*J-2.*M+83.9/RAD)+
     + DC(41)*DCOS(J-2.*M+187.9/RAD)+DC(42)*DCOS(2.*J-2.*M+75.7/RAD)+
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     +   DC(43)*DCOS(2.*J+M+263.9/RAD)
         COR3=COR3+DC(32)*DCOS(J+91.09/RAD)+
     +   DC(33)*DCOS(2.*J+270.25/RAD)+DC(34)*DCOS(3.*J+265.2/RAD)+
     +   DC(35)*DCOS(J-M+174.77/RAD)+DC(36)*DCOS(2.*J-M+292.6/RAD)+
     +   DC(37)*DCOS(3.*J-M+177.31/RAD)+DC(38)*DCOS(3.*J-2.*M+193.2/RAD)
         COR3=COR3+DC(27)*DCOS(5.*Q-2.*M+185.5/RAD)+
     +   DC(28)*DCOS(6.*Q-2.*M+185./RAD)+
     +   DC(29)*DCOS(7.*Q-3.*M+53.3/RAD)+
     +   DC(30)*DCOS(6.*Q-3.*M+53.9/RAD)+DC(31)*DCOS(5.*Q-M+139.3/RAD)
         COR3=COR3+DC(20)*DCOS(Q+90.6/RAD)+
     +   DC(21)*DCOS(2.*Q+89.76/RAD)+DC(22)*DCOS(3.*Q+273./RAD)+
     +   DC(23)*DCOS(2.*Q-M+306.27/RAD)+
     +   DC(24)*DCOS(4.*Q-2.*M+185.82/RAD)+
     +   DC(25)*DCOS(4.*Q-M+316.94/RAD)+DC(26)*DCOS(3.*Q-M+317.7/RAD)
         COR3=COR3+DC(14)*DCOS(V+M+87.5/RAD)+
     +   DC(15)*DCOS(V-M+358.8/RAD)+
     +   DC(16)*DCOS(S+90.34/RAD)+DC(17)*DCOS(2.*S+270.1/RAD)+
     +   DC(18)*DCOS(S-M+259.22/RAD)+DC(19)*DCOS(2.*S-M+273.1/RAD)
         COR3=COR3+DC(8)*DCOS(3.*V-2.*M+50.85/RAD)+
     +   DC(9)*DCOS(5.*V-3.*M+34.1/RAD)+
     +   DC(10)*DCOS(4.*V-2.*M+227.4/RAD)+
     +   DC(11)*DCOS(4.*V-M+79./RAD)+DC(12)*DCOS(5.*V-2.*M+229.8/RAD)+
     +   DC(13)*DCOS(2.*V+M+90.7/RAD)
         COR3=COR3+DC(1)*DCOS(V+90./RAD)+DC(2)*DCOS(2.*V+90.12/RAD)+
     +   DC(3)*DCOS(3.*V+270.41/RAD)+DC(4)*DCOS(4.*V+89.8/RAD)+
     +   DC(5)*DCOS(5.*V+270.1/RAD)+DC(6)*DCOS(2.*V-M+257.75/RAD)+
     +   DC(7)*DCOS(3.*V-M+77.96/RAD)
         COR3=COR3+(6910.057D0-17.24D0*T-.052D0*T**2)*DSIN(M)+
     +   (72.338D0-.361D0*T)*DSIN(2.D0*M)+(1.054D0-.001D0*T)*
     +   DSIN(3.D0*M)+.018D0*DSIN(4.D0*M)+0.015D0*DSIN(D)
         RETURN
         END
C
C        NEWCOMB'S TERMS IN SOLAR RANGE
C
         SUBROUTINE ETERMS(D,MP,M,F,J,V,S,Q,COR4)
         DIMENSION W(44)
         DOUBLE PRECISION W,D,F,V,S,Q,COR4
         REAL*8 MP,M,J
         DATA (W(I),I=1,44)/54.32,157.54,24.06,8.66,3.75,1.84,34.47,
     +   20.01,4.51,4.47,3.68,3.25,2.16,2.16,1.59,1.36,1.2,9.88,3.73,
     +   2.58,3.45,47.36,3.87,11.01,4.95,3.48,3.2,2.46,2.42,2.05,1.38,
     +   1.2,162.73,92.7,6.47,33.6,18.49,5.62,4.79,4.01,2.6,2.37,1.84,
     +   1.7/
         RAD=57.2957795100D0
         COR4=W(39)*DCOS(J+M+23.6/RAD)+
     +   W(40)*DCOS(3.*J-2.*M+103.3/RAD)+
     +   W(41)*DCOS(4.*J-2.*M+353.9/RAD)+W(42)*DCOS(2.*J+M+173.6/RAD)+
     +   W(43)*DCOS(J-2.*M+278.1/RAD)+W(44)*DCOS(4.*J-M+86.1/RAD)
         COR4=COR4+W(34)*DCOS(2.*J+180.22/RAD)+
     +   W(35)*DCOS(3.*J+175.9/RAD)+W(36)*DCOS(2.*J-M+202.58/RAD)+
     +   W(37)*DCOS(3.*J-M+87.23/RAD)+W(38)*DCOS(J-M+250.2/RAD)
         COR4=COR4+W(25)*DCOS(3.*Q-M+227.8/RAD)+
     +   W(26)*DCOS(2.*Q-M+40.9/RAD)+W(27)*DCOS(6.*Q-2.*M+94.9/RAD)+
     +   W(28)*DCOS(5.*Q-M+49.3/RAD)+W(29)*DCOS(4.*Q-2.*M+277.6/RAD)+
     +   W(30)*DCOS(5.*Q-2.*M+95.7/RAD)+W(31)*DCOS(7.*Q-2.*M+276.8/RAD)+
     +   W(32)*DCOS(2.*Q+M+1.3/RAD)+W(33)*DCOS(J+1.1/RAD)
         COR4=COR4+W(14)*DCOS(4.*V-2.*M+138.4/RAD)+
     +   W(15)*DCOS(V-M+139.4/RAD)+W(16)*DCOS(5.*V-M+166.7/RAD)+
     +   W(17)*DCOS(2.*V-2.*M+340.6/RAD)+W(18)*DCOS(S+.36/RAD)+
     +   W(19)*DCOS(2.*S+180.1/RAD)+W(20)*DCOS(2.*S-M+182.6/RAD)+
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     +  W(21)*DCOS(Q+.6/RAD)+W(22)*DCOS(2.*Q-.3/RAD)+
     +  W(23)*DCOS(3.*Q+182.3/RAD)+W(24)*DCOS(4.*Q-M+226.92/RAD)
        COR4=COR4+W(1)*DCOS(V)+W(2)*DCOS(2.*V+.12/RAD)+
     +  W(3)*DCOS(3.*V+180.27/RAD)+W(4)*DCOS(4.*V-.11/RAD)+
     +  W(5)*DCOS(5.*V+180./RAD)+W(6)*DCOS(6.*V-.3/RAD)+
     +  W(7)*DCOS(3.*V-M+347.95/RAD)+W(8)*DCOS(2.*V-M+168.5/RAD)+
     +  W(9)*DCOS(4.*V-M+348.8/RAD)+W(10)*DCOS(3.*V-2.*M+142.2/RAD)+
     +  W(11)*DCOS(2.*V+M+.2/RAD)+W(12)*DCOS(5.*V-2.*M+139.9/RAD)+
     +  W(13)*DCOS(V+M+355.9/RAD)+7.0D-8*DCOS(D)
        RETURN
        END
C
C       NEWCOMB'S TERMS IN SOLAR LATITUDE
C
        SUBROUTINE FTERMS(D,MP,M,F,J,V,S,Q,COR5)
        DIMENSION FC(16)
        DOUBLE PRECISION FC,D,F,V,S,Q,COR5
        REAL*8 MP,M,J
        DATA (FC(I),I=1,16)/.21,.092,.067,.031,.029,.023,.019,.014,
     +  .014,.012,.012,.166,.023,.018,.017,.016/
        RAD=57.2957795100D0
        COR5=FC(9)*DCOS(2.*V-2.*M+233./RAD)+
     +  FC(10)*DCOS(2.*V+271./RAD)+FC(11)*DCOS(4.*V-2.*M+244./RAD)+
     +  FC(12)*DCOS(2.*J-M+268.6/RAD)+FC(13)*DCOS(J-2.*M)+
     +  FC(14)*DCOS(3.*J-2.*M+182./RAD)+FC(15)*DCOS(J+5./RAD)+
     +  FC(16)*DCOS(J-M+272./RAD)
        COR5=COR5+FC(1)*DCOS(3.*V-M+64.5/RAD)+FC(2)*DCOS(V-M+64.6/RAD)+
     +  FC(3)*DCOS(2.*V-M+244.8/RAD)+FC(4)*DCOS(4.*V-M+65.4/RAD)+
     +  FC(5)*DCOS(V+M+116./RAD)+FC(6)*DCOS(2.*V+M+295./RAD)+
     +  FC(7)*DCOS(5.*V-2.*M+233./RAD)+FC(8)*DCOS(3.*V+M+114./RAD)
        RETURN
        END
C
C       CODEO: ADDITIONAL SOLAR AND PLANETARY TERMS IN LUNAR LONGITUDE
C           EXTRA TERMS WITH COEFFICIENT RANGE .5 TO .15 ARC SECONDS
C
        SUBROUTINE EXTRAA(D,MP,M,F,E,COR6)
        DOUBLE PRECISION D,MP,M,F,E,COR6
        COR6=-.393*DSIN(MP-6.D0*D)-.289*E*DSIN(M+4.D0*D)+
     +  .403*DSIN(3.D0*D)+.213*DSIN(2.D0*MP+4.D0*D)+.283*E*
     +  DSIN(MP-M+4.D0*D)-.189*E*E*DSIN(2.D0*M+2.D0*D)-.151*E*E*
     +  DSIN(2.D0*M-4.D0*D)+.150*E*DSIN(M+3.D0*D)-.293*
     +  DSIN(3.D0*MP-6.D0*D)-.290*E*DSIN(2.D0*MP+M+2.D0*D)
        COR6=COR6+.360*E*DSIN(2.D0*MP-M-4.D0*D)-.311*E*E*
     +  DSIN(MP+2.D0*M-4.D0*D)-.344*E**3*DSIN(3.D0*M-2.D0*D)-
     +  .301*DSIN(MP+2.D0*F-4.D0*D)+.202*DSIN(MP-2.D0*F-4.D0*D)+
     +  .415*E*DSIN(M+2.D0*F)+.384*E*DSIN(M-2.D0*F-2.D0*D)+
     +  .233*E*DSIN(MP+M-3.D0*D)-.276*E*DSIN(MP-M-3.D0*D)
        COR6=COR6+.255*DSIN(2.D0*F+D)+.254*DSIN(2.D0*F-3.D0*D)-
     +  .482*E*DSIN(3.D0*MP+M-2.D0*D)-.183*E*DSIN(3.D0*MP-M-2.D0*D)-
     +  .297*E*E*DSIN(2.D0*MP+2.D0*M-2.D0*D)-.161*E*E*
     +  DSIN(2.D0*MP+2.D0*M-4.D0*D)+.254*E*E*DSIN(2.D0*MP-2.D0*M-2.D0*D)
        COR6=COR6-.250*E**3*DSIN(MP+3.D0*M-2.D0*D)-.459*
     +  DSIN(2.D0*MP-2.D0*F+2.D0*D)+.173*DSIN(2.D0*MP-2.D0*F-4.D0*D)+
     +  .263*E*DSIN(MP+M+2.D0*F)+.426*E*DSIN(MP+M-2.D0*F-2.D0*D)-.304*
     +  E*DSIN(MP-M+2.D0*F)-.372*E*DSIN(MP-M-2.D0*F+2.D0*D)+.418*
     +  DSIN(4.D0*F)-.352*E*DSIN(2.D0*MP-M-D)-.330*DSIN(3.D0*MP+2.D0*F)
        RETURN
        END
C                       ! END OF PROGRAM !
```