CT- 82-100-106LR

FAA WJH Technical Center
00092664

FAA TECHNICAL CENTER LETTER REPORT

PROGRAMS TO COMPUTE THE FIGURES

OF MERIT FOR THE GLOBAL POSITIONING SYSTEM (GPS)

by

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AVAILABLE IN ELECTRONIC FORMAT

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ABSTRACT

The programs were written to compute, on a Hewlett Packard minicomputer, the dilution of precision parameters for the Global Positioning System (GPS) and to plot these data versus Greenwich Mean Time (GMT). The programs evaluate the influence of satellite geometry upon these parameters and subsequently upon the accuracy of the GPS. The flowcharts of the programs, a printout of the transfer files, program listings and examples of the program output are included in this report.

This work was accomplished when the author, Erhard Buchberger, was on an exchange program at the FAA Technical Center from the West German Aerospace Establishment. For further information contact Robert Esposito, phone number (609) 641-8200, extension 3961.

Project No 049-311-110

Subprogram 049-330

Period From: February - September 1982

Key Words

GPS
Dilution of Precision
Almanac
Flow Charts

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INTRODUCTION

BACKGROUND

The FAA Technical Center has made use of a GPS almanac program originally written at the Texas A&M University for execution on a Texas Instrument 990/4 minicomputer (Reference 1). This program computes satellite azimuth and elevation, satellite rise and fall time and the geometric dilution of precision. M. Magrogan (Reference 2) modified these routines to analyze FAA test results on a Digital Equipment Corporation PDP-11/34 minicomputer.

SCOPE

This report documents further modifications and additions which permit the GPS almanac program to run on a Hewlett Packard (HP) 1000 minicomputer with the main task of computing the dilution of precision factors for the case of four space-vehicles, and of three satellites plus altitude input.

DISCUSSION

The major changes made by the Technical Center include:
- An almanac unpacking subroutine developed by N. Watts for the HP.
- Revision of the computation of the GPS epoch time.
- A matrix inversion subroutine which detects singularities.
- Computation of the dilution of precision factors for three satellites plus altitude data.
- Use of double precision in all computations.

In addition, all main programs allow several different types of input data to be used. In doing so, the programs ask for the data with an explaining comment. The main programs also include Block Data, that is, parts in which the Common Blocks are initially defined. This was not necessary with the PDP-11.

Table 1 displays the time parameters which are needed in some of the programs as input parameters. Special attention must be given to the fact that different units (day and second) and different origins are used.

The order of Keplerian parameters, which are included in the almanac and used to compute the satellite trajectories, is listed in table 2. Note that parameters 9 through 14 are computed in the program HDOO, with μ (used to calculate the mean motion) as the earth's universal gravitational constant. The algorithms and equations used in this program are given in references 5 through 9.

Three coordinate systems (reference 3) based on WGS-72 reference ellipsoid are utilized.

1. An earth-centered-earth-fixed (ECEF) system.
2. The east-north-up (ENU) system.
3. Geographic latitude, longitude and altitude.

Appendix A contains the transfer files for the main programs HDOO, PLGH, EBGD1, and EBGH. Appendix B gives the flowcharts for these programs plus the subroutines HDO1 and EB05. Appendix C provides listings of these programs and all subroutines. Each program is called on the HP computer with its name, and user prompting explicity asks for the required inputs. Appendix D and E respectively give examples of the data files and program output.

Program: HDOO (Pages C-1 through C-8)

This program computes and prints out the position of up to 4 satellites in ECEF coordinates and in azimuth and elevation angle related to the user position and HDOP and GDOP. It also generates a plot file with the figures of merit.

The following input data must be prepared: User position in geographical coordinates (latitude (LAT), longitude, (LON), and altitude (ALT) in feet). If the location is the FAA Technical Center, this information is already stored in the program. After the program has received user position, the geographical coordinates are converted into ECEF and printed out. The next data requested are the user times. The routine needs the start (TSTART) and stop time (TFIN) of the time interval to be evaluated, the time increment (TDEL) - (i.e., the difference between the points in time, for which the calculations are made), the time of collection (TC) of the almanac, and the date of use (DTU)-(see also table 1).

Then, the choice must be made whether the computations should be made with 4 satellites or 3 satellites plus altitude information. When 3 satellites are selected, the fourth satellite is simulated in the center of the earth.

The next decision concerns the input of the almanac for the satellites:

(1) If the almanac is on a magnetic tape, it must be stated so and then the entire almanac file is read from the tape. After this is successfully completed, the input is requested of the PRN No. of the first space vehicle. The program checks whether the satellite data is on tape. If not, the request is repeated, otherwise, the next satellite is requested.

(2) The second choice is to provide the program with the names of data files containing an almanac for each space vehicle, or the data can be typed in over the keyboard.

After the steps are successfully completed, the routine computes the rest of the almanac parameters, and prints all inputs out together with a title. The calculation and the output of the results take place after a prompting of a user selected name (less than 6 characters) of a plot file for the GDOP.

Program: PLHG (Pages C-9 through C-11)

This program is a continuation of HDOO. It was created because the plot software needs approximately 38,000 words of memory space since both routines together exceed the memory limits of the computer.

PLHG plots two data files generated by HDOO to compare HDOPs computed with three and with four satellites. After the input of the first file name, the user declares the logical unit of the plotting device and the ID of the device subroutine to initialize the plotter. Examples for this would be:

a)	LU = 20	ID = 5	Device: Printer
b)	LU = 1	ID = 1	Device: Monitor

Data is needed to enable the routine to draw a grid, select a time slot out of the complete files, and start and stop time. To ensure that data is available in the files for this period, because the records are formatted, the file can be looked up directly. Finally, the name of the second file must be entered, and the program then generates a plot as described under program HDOO.

Program: EBGD1 (Pages C-12 through C-14)

This program also delivers as final results HDOP and GDOP, but it does not utilize the satellite almanac as input data. The operator selects whether the H-matrix is inserted directly or whether the azimuth and elevation angles of the satellites are inputed. This routine then calculates the figures of merit, and also prints out the intermediate steps of the matrix conversions. The program can be used to evaluate the influence of special space vehicle geometries on the HDOP and GDOP.

Program: EBGH (Pages C-15 through C-19)

The routine also computes the figures of merit from user and satellite positions. It is possible to input the needed data over the keyboard; that is, to type the user position in geographical coordinates, the number of satellites to be used (three or four), and the satellite position in ECEF coordinates. Also, the operator may read the data from a file by providing the file name. Depending on the number of space vehicles stored in the file (NSAT), the program will print out an error message (NSAT <3), will ask whether the system is altimeter aided (NSAT = 3) or will just start computing (NSAT = 4). Due to restrictions in the subroutines, the system in this stage has to be altimeter aided, i.e., a fourth satellite is simulated in the earth center.

The H-matrix is computed in a different way from the other programs; the rotation of the marix into the ENU system is a separate step. This was made to check whether the programs deliver the same results. The program EBGH delivers a printout similar to EBGD1. It prints all matrices, the figures of merit, and the satellite positions.

Subroutine Description

EBO2: computes the rotation matrix, given on page C-20.
EBO3: converts user geographical coordinates into the ECEF system, given on page C-21.
EBO5: calls EB06 and EBO7 and computes satellite azimuth and elevation,given on page C-22.
EBO6: computes satellite position in ECEF, given on page C-23.
EBO7: computes user to satellite distance, given on page C-24.
EBO9: multiplies two matrices, given on page C-25.
EB12: converts seconds into hours, minutes and seconds, given on page C-26.
EB14: unpacks the almanac data (with assembly language subroutine DINTF), given on pages C-27 through C-29.
MINVD: inverts the matrices from the "Scientific Subroutine" package from DEC (Reference 4) given on pages C-32 through C-34.
DINTF. assembly language subroutine, unpacks the almanac data (with subroutine EB12), given on page C-35.
ENU: computes rotation matrix, given on page C-36.
HTRAN: converts H-matrix into its transpose, given on page C-37.
MLHHT: multiples the transpose of H-matrix by H-matrix, given on page C-38.
INVHP: inverts the matrices, but does not check for singularities, given on pages C-39 and C-40.

The previosuly tested subroutines ENU, HTRAN, MLHHT, and INVHP (from references 1 and 2) were used in one program to check the computations made by the other subroutines for a non-singluar matrix.

REFERENCES

1. A GPS Almanac, Wong, C.S., Texas A&M University.

2. Global Positioning System (GPS) Satellite Elevation and Azimuth Angles, Michael Magrogan, Letter Report, FAA, 1982.

3. Computer Program Development Specification for the Z-User-Set, Specification No. GP-US-305.

4. The Scientific Subroutine Package, Digital Equipment Corporation.

5. Handbook of Astronautical Engineering, Koelle, H.H., McGraw Hill, 1961.

6. Principle of Operation of NAVSTAR and System Characteristics, Milliken, R.J. and Zoller, C.J., Navigation, Vol. 25, pages 95-106, 1980.

7. Taschenbuch der Mathematik, Bronstein, I, and Semedjajew, K., Tuebner Verlagsgesellschaft Leipzig, 1960.

8. Using the Global Position Satellite System for Positioning and Navigation, Rhyne, T., Noe, P., and Painter, J., Altair Corporation.

9. Satellite Navigation, Klostermann, E., Lecture at the Carl-Cranz-Kurs, 1981.

Parameter	Start of Count	Unit
DTU - Date of use	Beginning of Year	Day
DTC - Date of collection of Almanac	Beginning of Year	Day
T - GPS - Time	Beginning of Day	Second
TC - Collection Time of Almanac	Beginning of week (0000 hours Sunday)	Second

The used time zone is Greenwich Mean Time (GMT)

TABLE 1. TIME PARAMETERS USED IN PROGRAMS

No. in Almanac	Keplerian Parameter	Name in Program and (GPS) - Name)
1	Eccentricity of ellipsoid	E (e)
2	Reference time for almanac	TOA (toa)
3	Orbit inclination	Di (i)
4	Drift rate of right ascension	OMD ($\dot{\Omega}$)
5	Square root of semi-major axis	RA ($\sqrt{A}$)
6	Right ascension of the orbit	OMO (Ω_0)
7	Argument of perigee	W (ω)
8	Mean anomaly	MO (Mo)
9	Semi-major axis	A
10	Cosine of orbit inclination angle	cos(i)
11	Sine of orbit inclination angle	sin(i)
12	Cosine of argument of perigee	cos(ω)
13	Sine of argument of perigee	sin(ω)
14	Mean motion	$\sqrt{\mu/A^3}$

TABLE 2. ORDER OF KEPLERIAN PARAMETERS

Transfer Files - These files are used to load programs which consist of several subroutines.

```
TEBGH   T=00004 IS ON CR00011 USING 00002 BLKS R=0000

0001    REL, %EBGH
0002    SEA, %ENU
0003    SEA, %EB12
0004    SEA, %EB03
0005    SEA, %HTRAN
0006    SEA, %NLHHT
0007    SEA, %INVHP
```

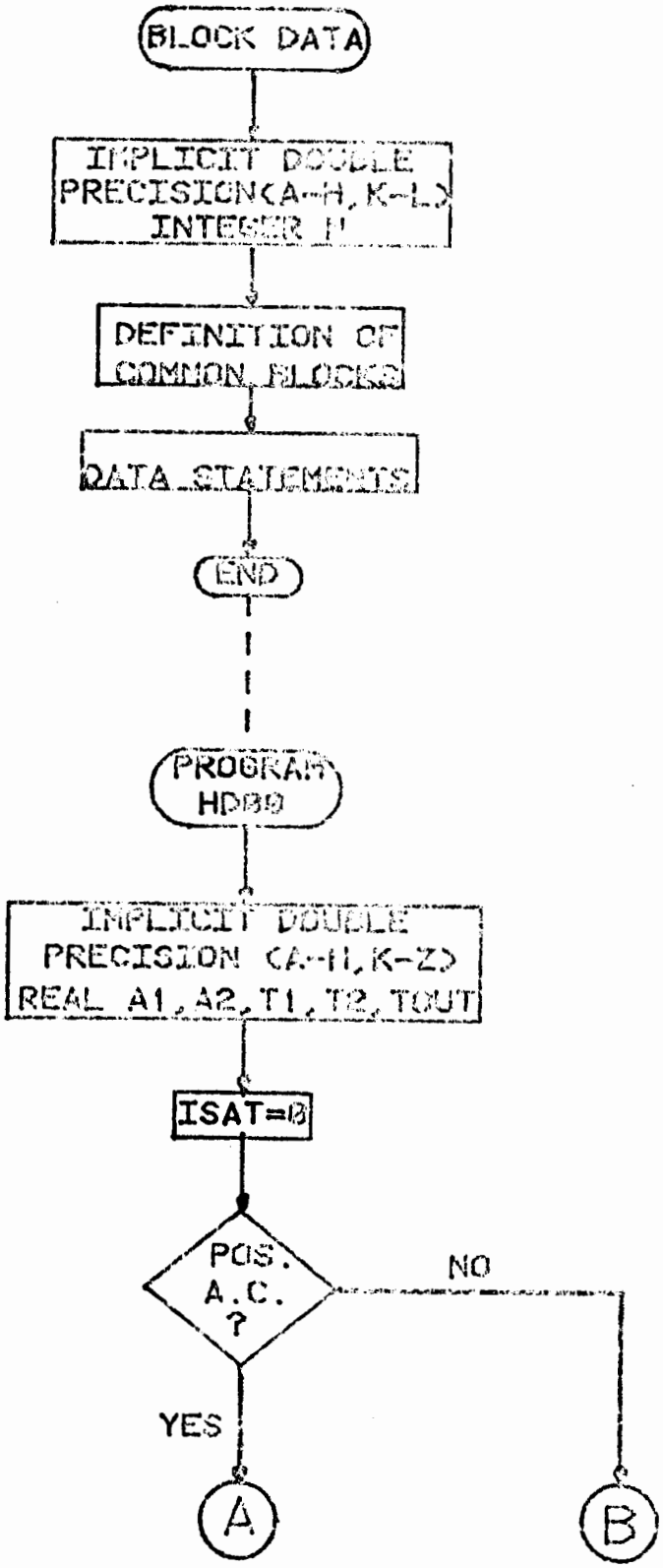
```
TEBGD1  T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001    REL, %EBGD1
0002    SEA, %EB09
0003    SEA, %MINVD
```

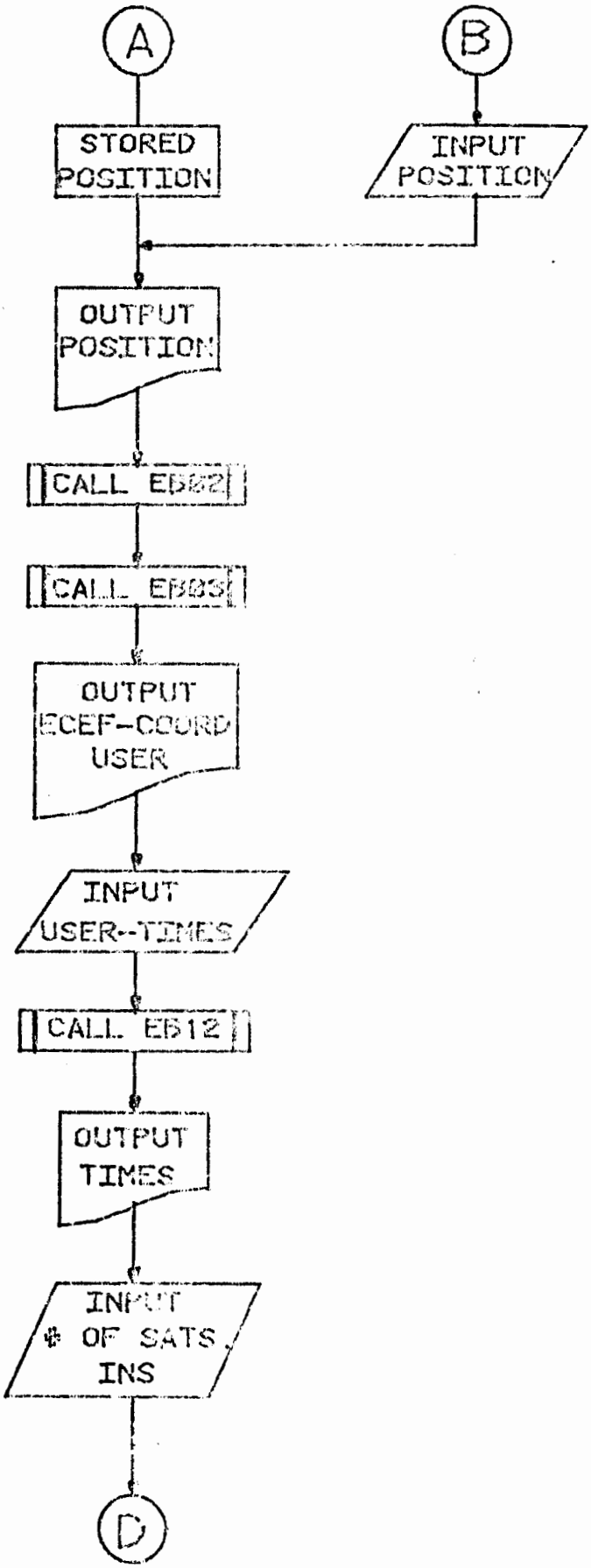
```
TPLHG   T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001   RE, %PLHG
0002   RE, %DLTBL
0003   SEA, %GPS
```

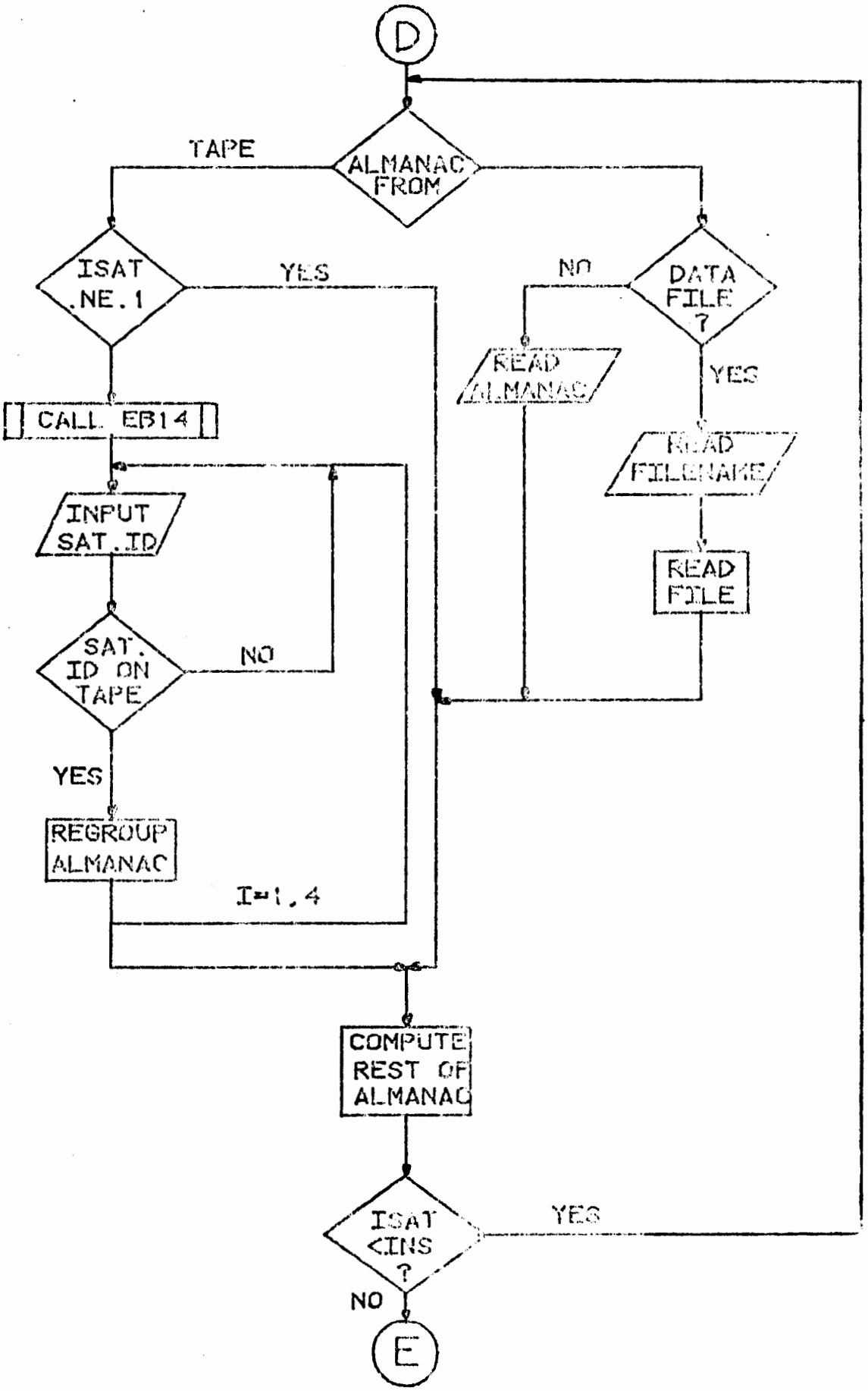
```
THD00   T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001    REA, %HD00
0002    SEA, %EB02
0003    SEA, %EB03
0004    SEA, %EB05
0005    SEA, %EB06
0006    SEA, %EB07
0007    SEA, %HD01
0008    SEA, %EB09
0009    SEA, %MINVD
0010    SEA, %EB12
0011    SEA, %EB14
0012    SEA, %DINTF
```

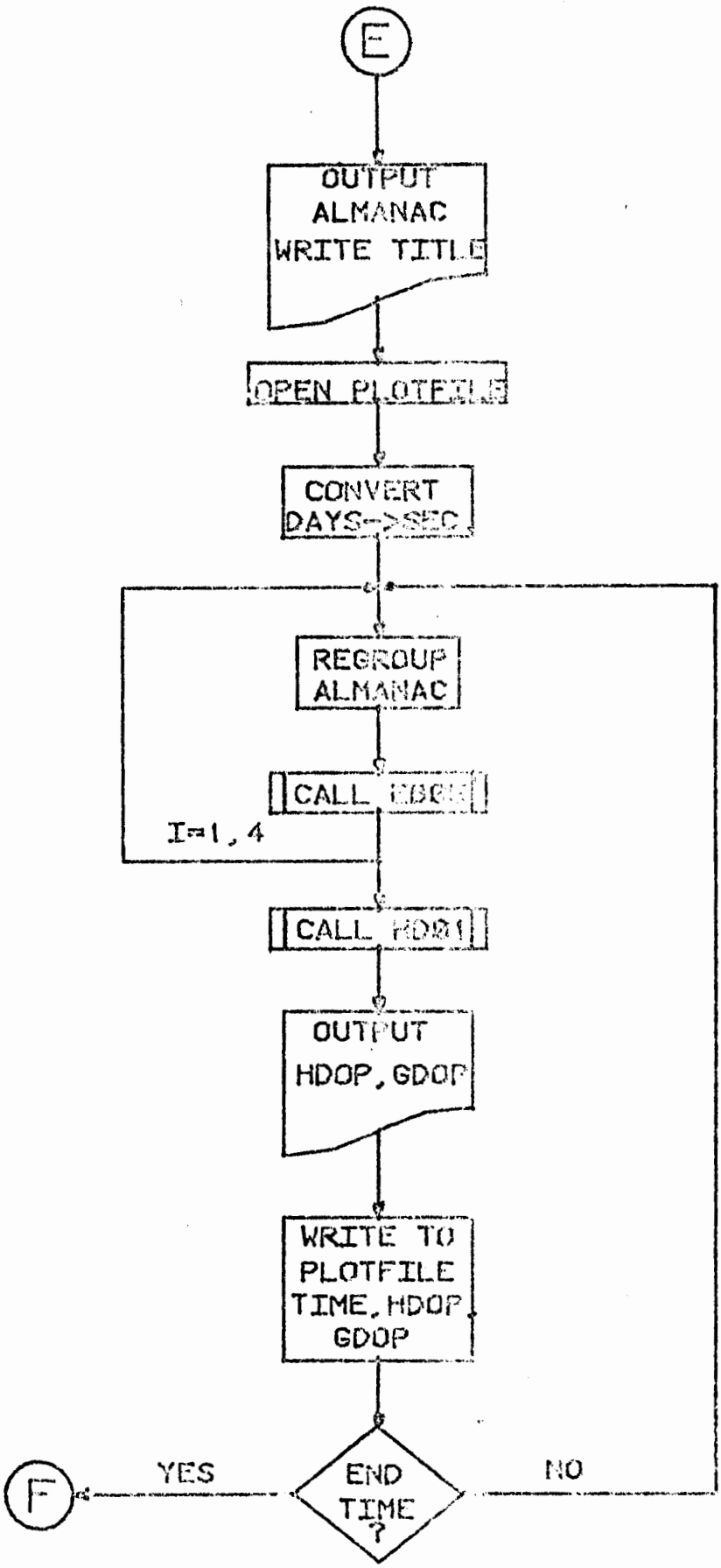
Flowcharts - These flowcharts were drawn on a Tektronix - minicomputer with a drafting software developed by a group of the Eglin AFB. Only new or significantly modified routines are included here.

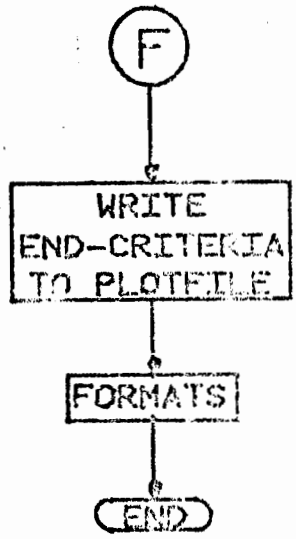
FLOWCHART HDOO




A
B
STORED POSITION
INPUT POSITION
OUTPUT POSITION
CALL EB02
CALL EB03
OUTPUT ECEF-COORD USER
INPUT USER--TIMES
CALL EB12
OUTPUT TIMES
INPUT # OF SATS INS
D


D
ALMANAC FROM
TAPE
DATA FILE ?
NO
YES
ISAT .NE. 1
YES
READ ALMANAC
CALL EB14
READ FILENAME
INPUT SAT.ID
READ FILE
SAT. ID ON TAPE
NO
YES
REGROUP ALMANAC
I=1,4
COMPUTE REST OF ALMANAC
ISAT <INS ?
YES
NO
E


E
OUTPUT
ALMANAC
WRITE TITLE
OPEN PLOTFILE
CONVERT
DAYS->SEC
REGROUP
ALMANAC
CALL
I=1,4
CALL
OUTPUT
HDOP, GDOP
WRITE TO
PLOTFILE
TIME, HDOP,
GDOP
END
TIME
?
YES
NO
F



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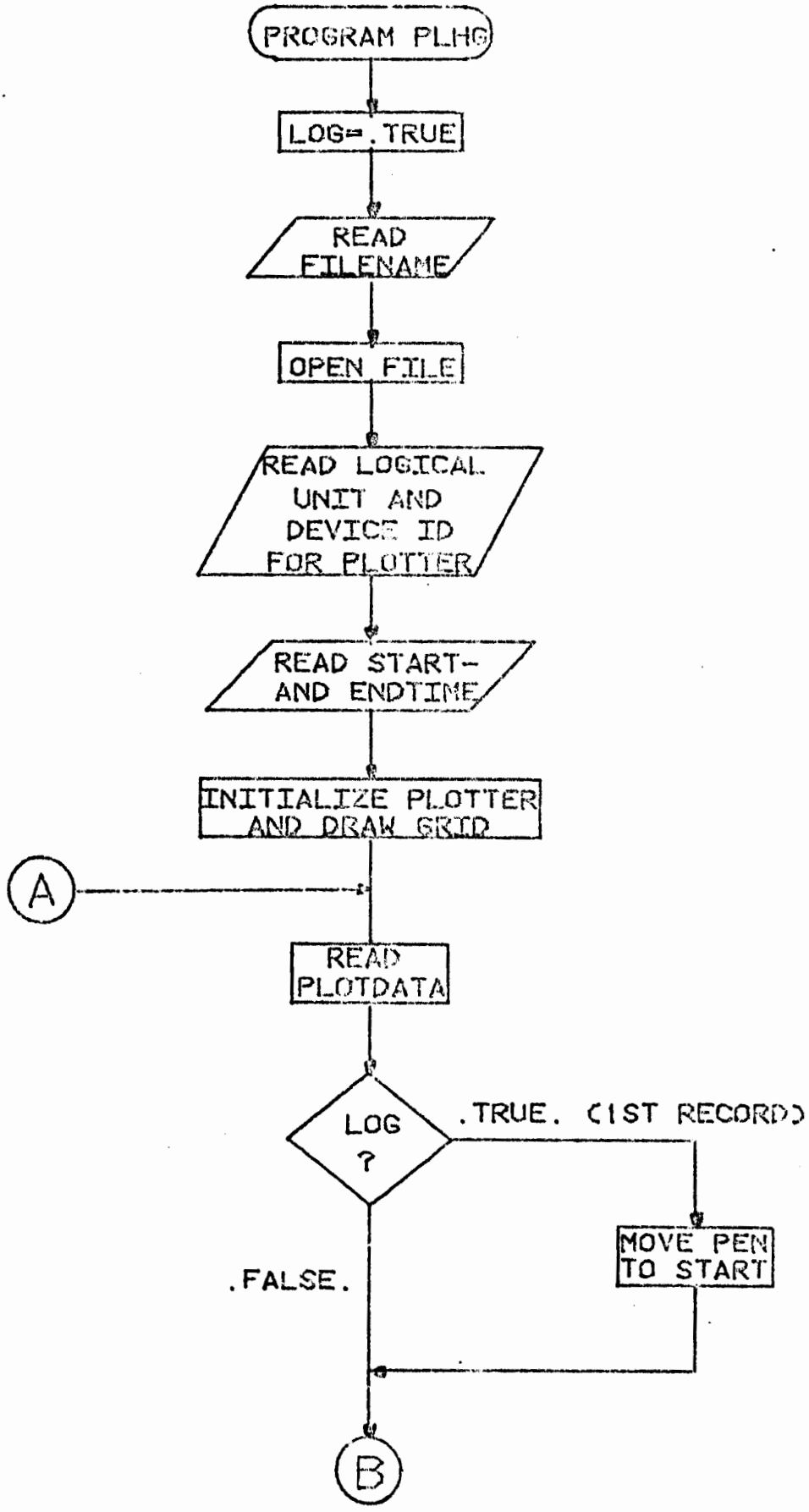
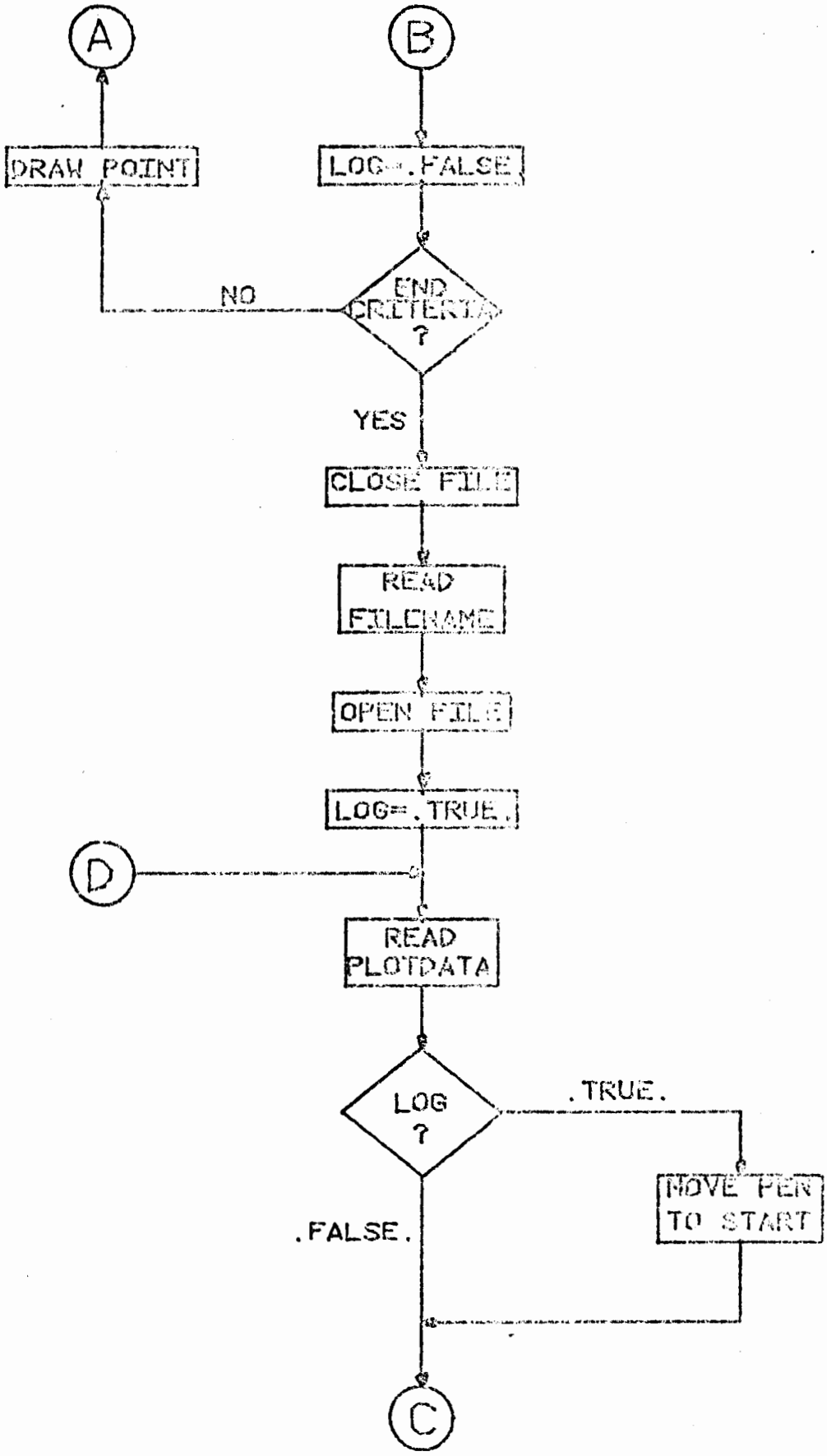
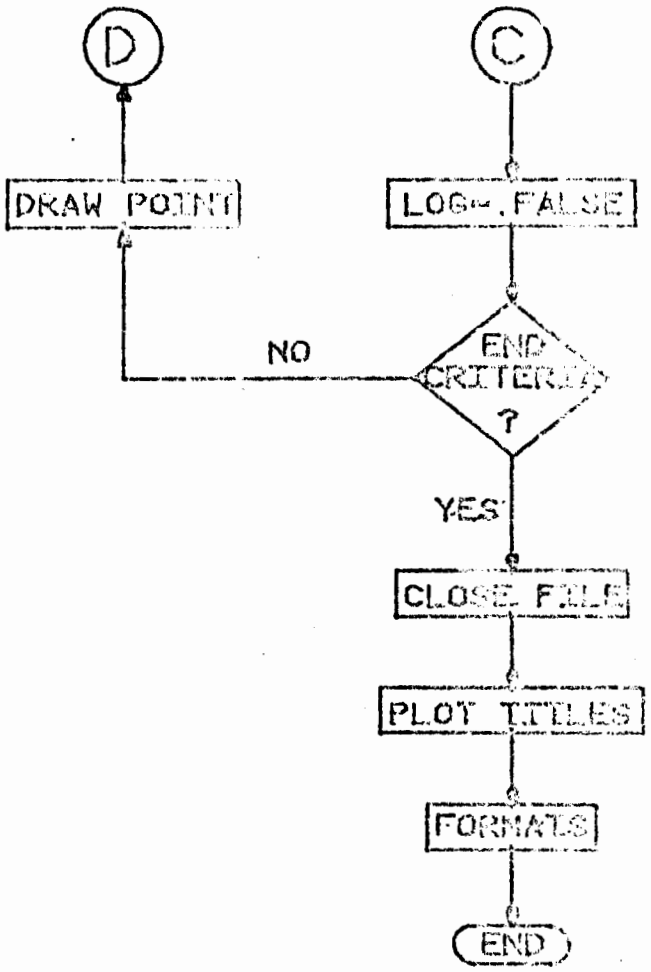
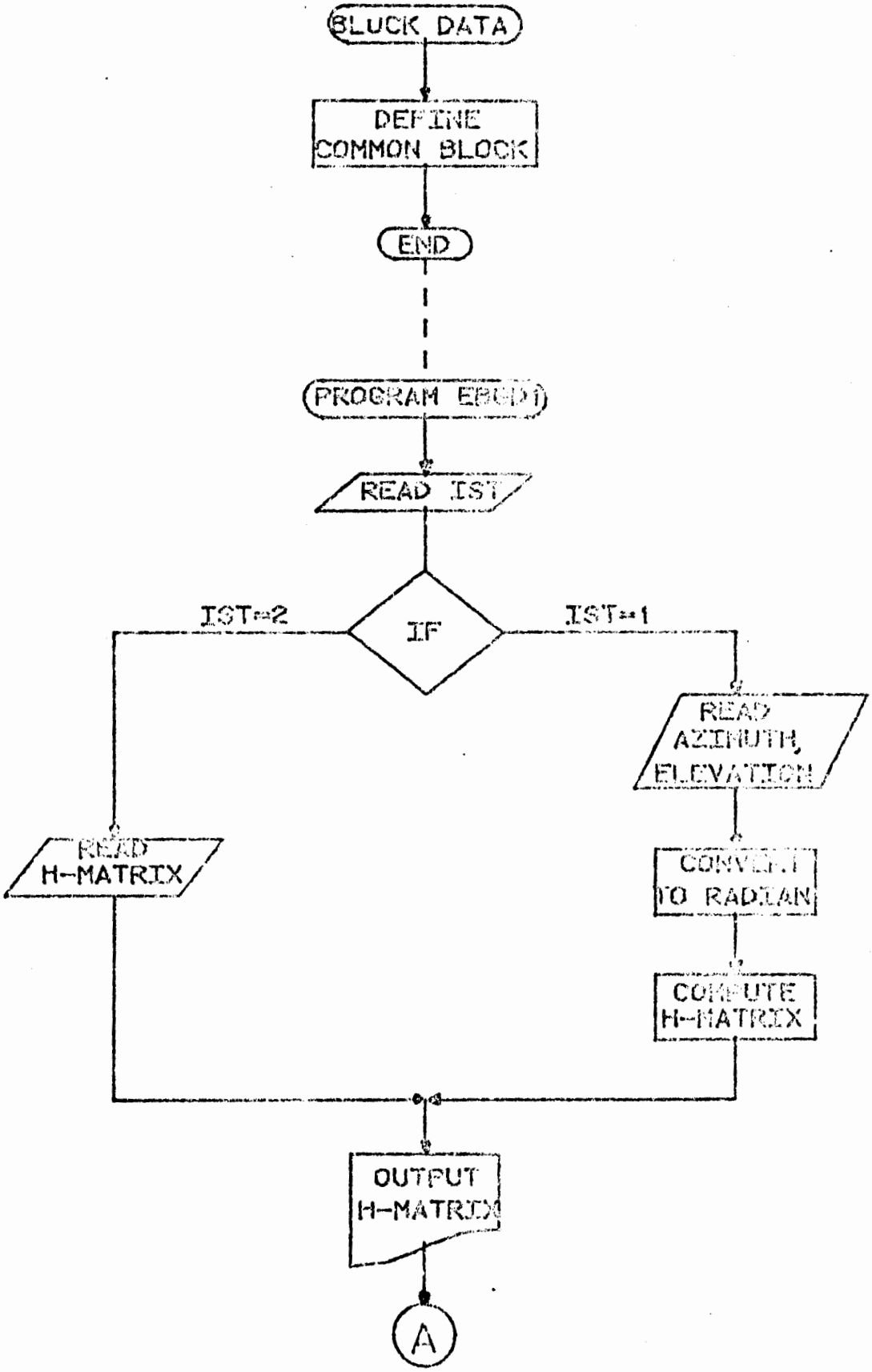
FLOWCHART PLHG

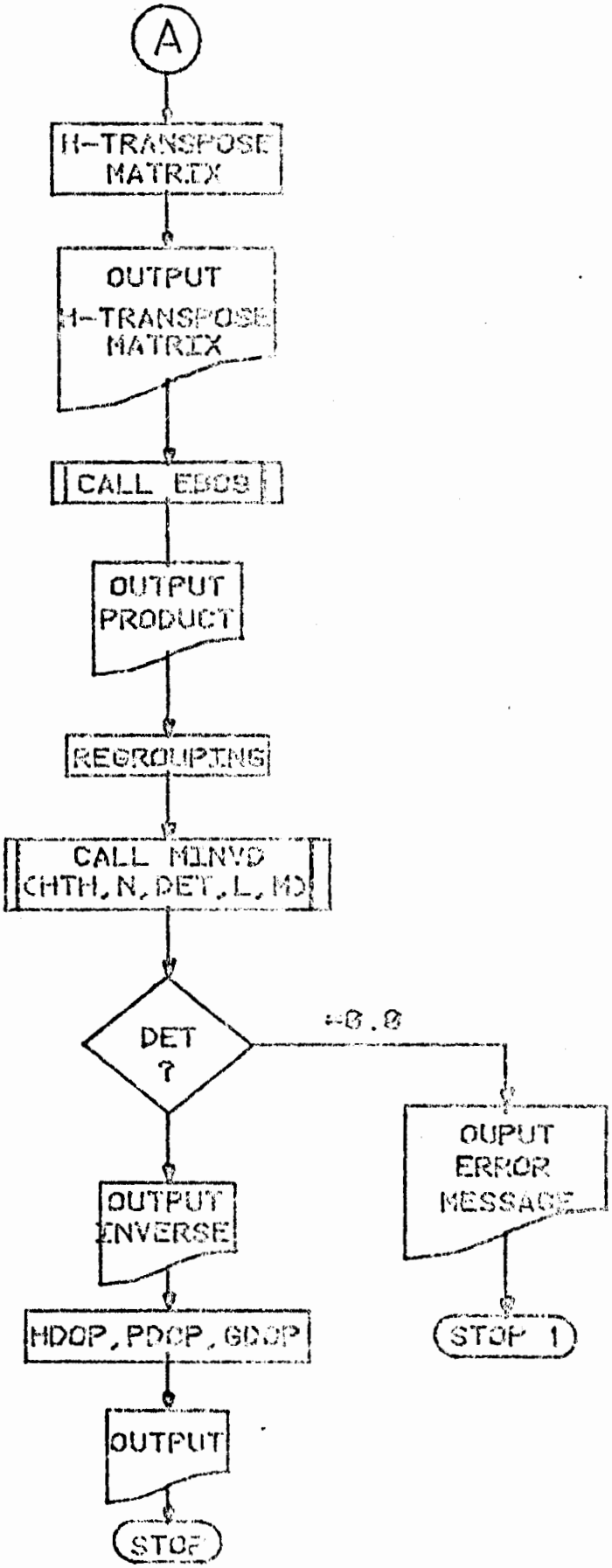



A
B
DRAW POINT
LOG=.FALSE.
NO
END CRITERIA ?
YES
CLOSE FILE
READ FILENAME
OPEN FILE
LOG=.TRUE.
D
READ PLOTDATA
LOG ?
.TRUE.
MOVE PEN TO START
.FALSE.
C

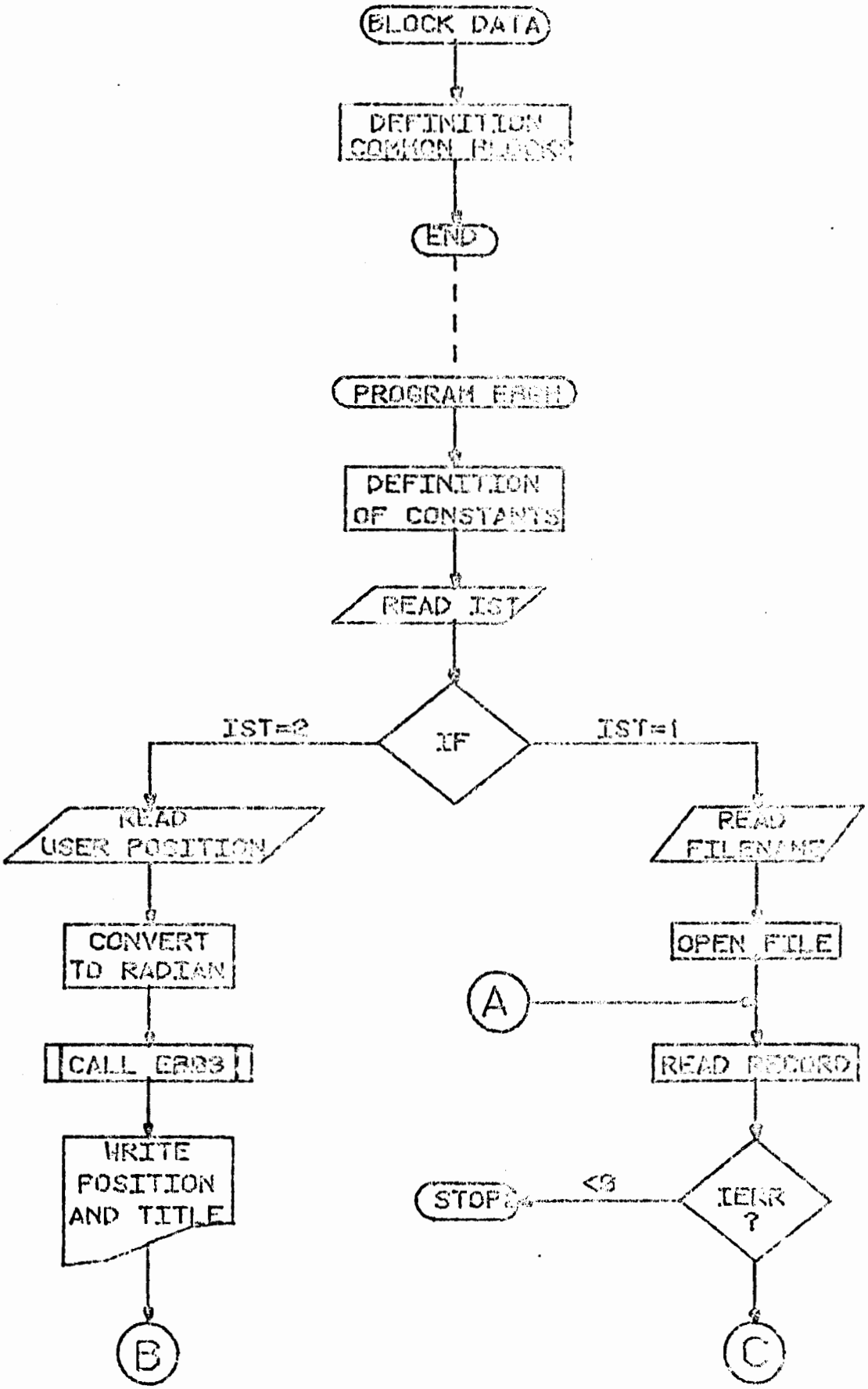

D
C
DRAW POINT
LOGI=.FALSE
NO
END CRITERIA ?
YES
CLOSE FILE
PLOT TITLES
FORMATS
END

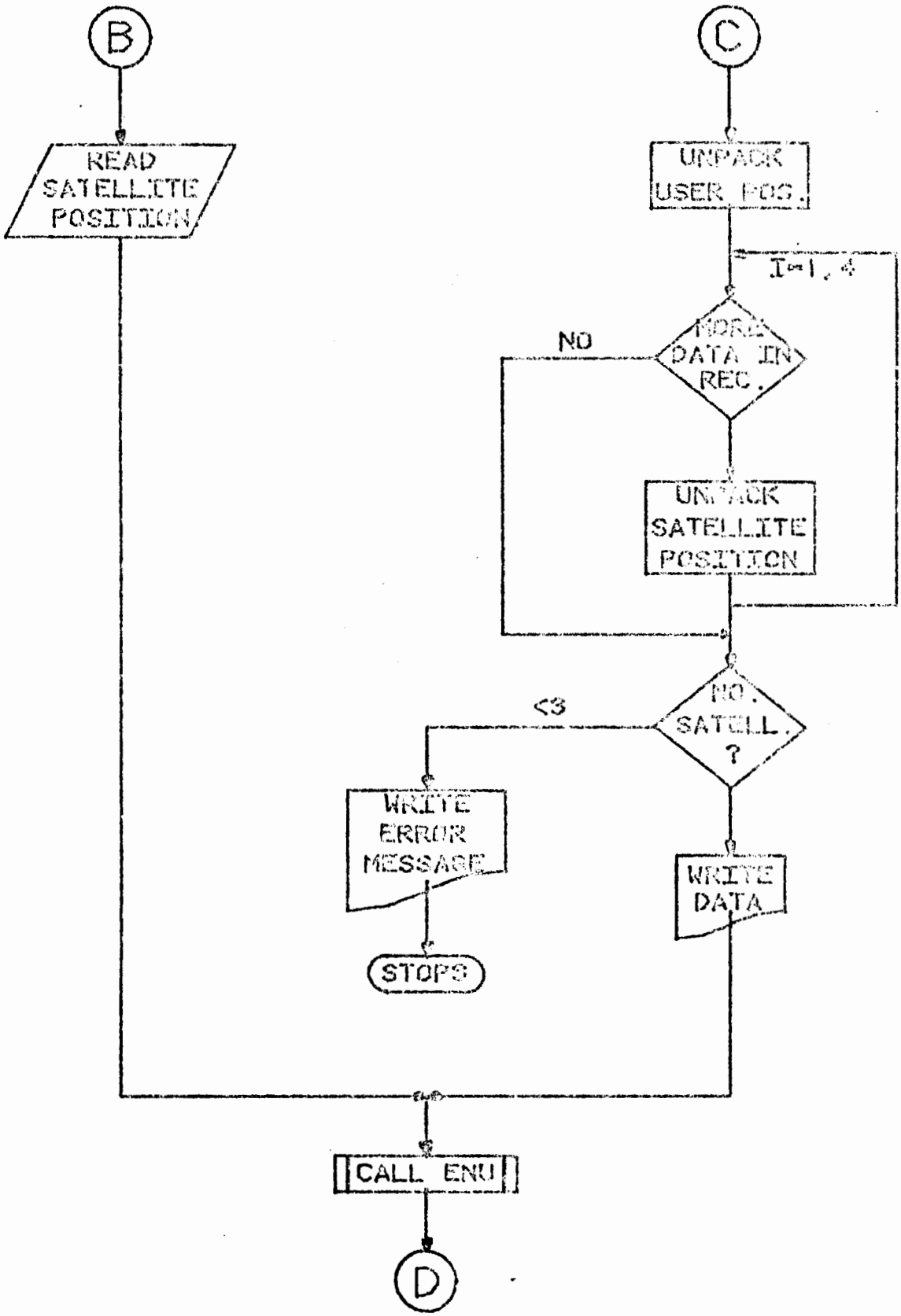
FLOWCHART EBGD1

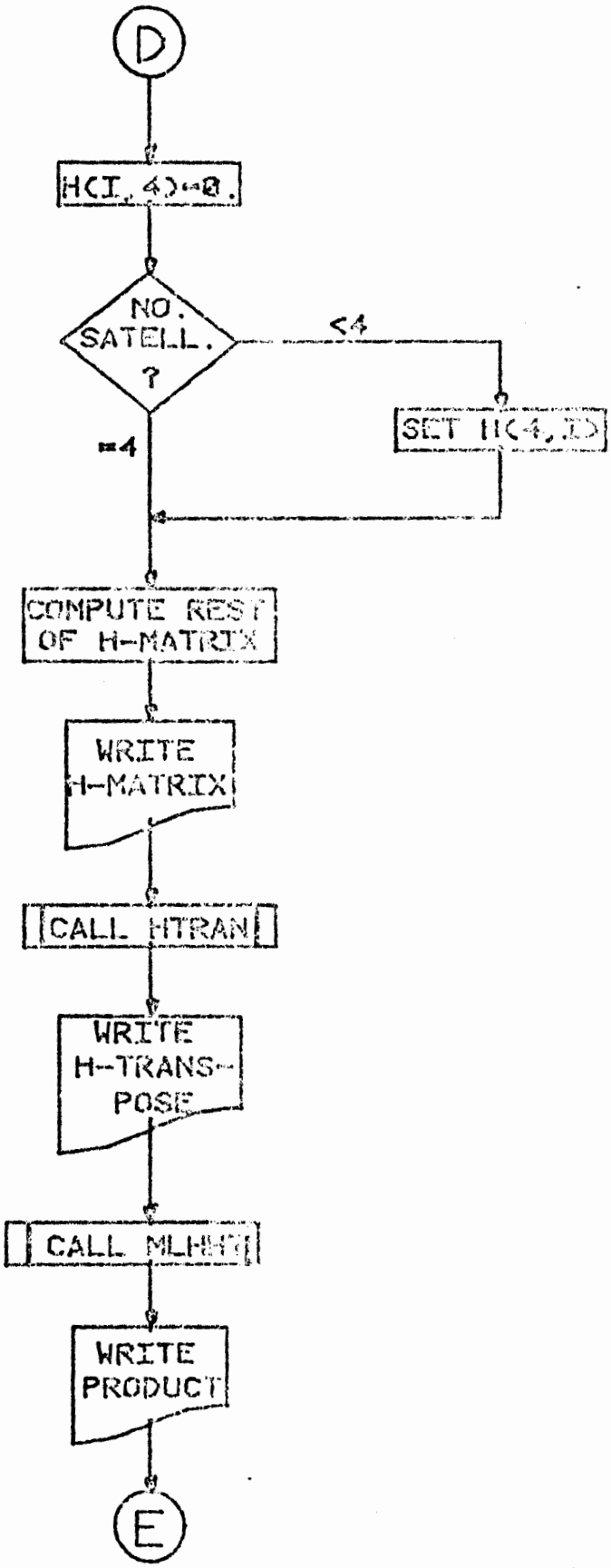


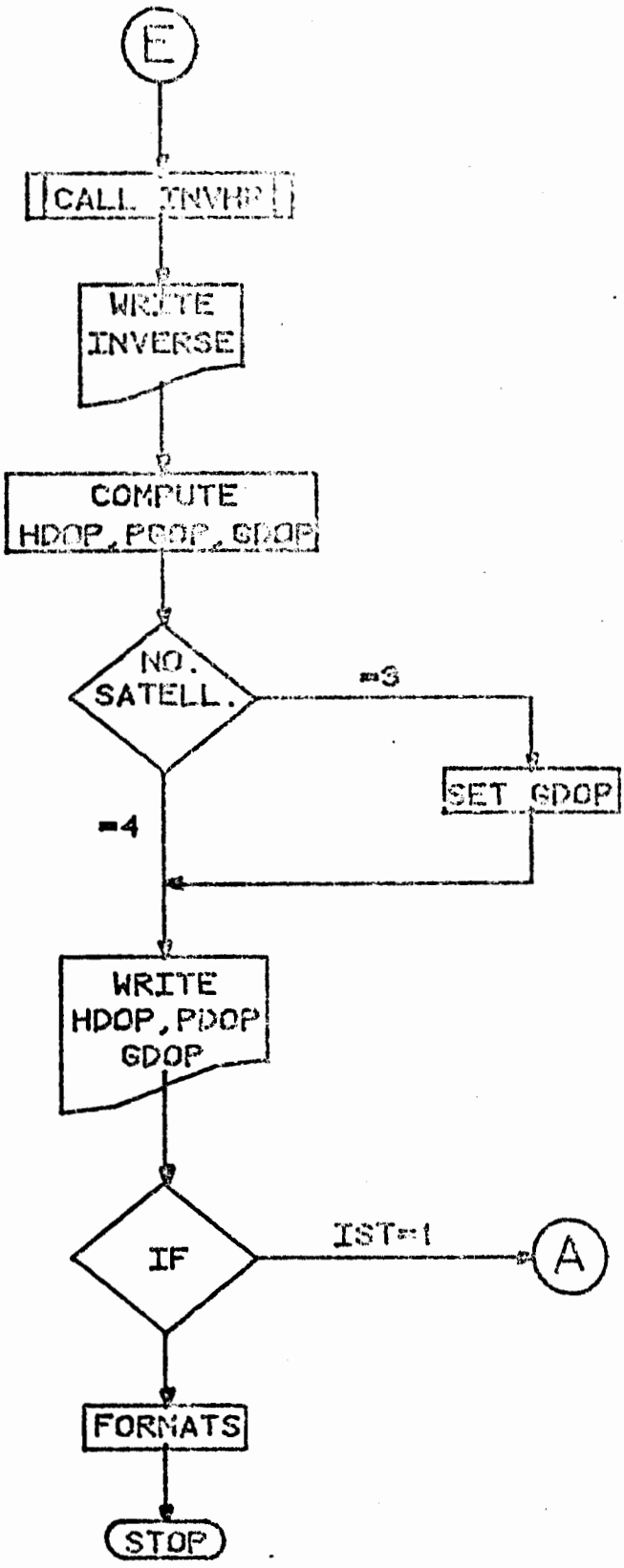

A
H-TRANSPOSE MATRIX
OUTPUT H-TRANSPOSE MATRIX
CALL EB09
OUTPUT PRODUCT
REGROUPING
CALL MINV(CHTH,N,DET,L,M)
DET ?
+0.0
OUPUT ERROR MESSAGE
STOP 1
OUTPUT INVERSE
HDOP,PDOP,GDOP
OUTPUT
STOP

FLOWCHART EBGH

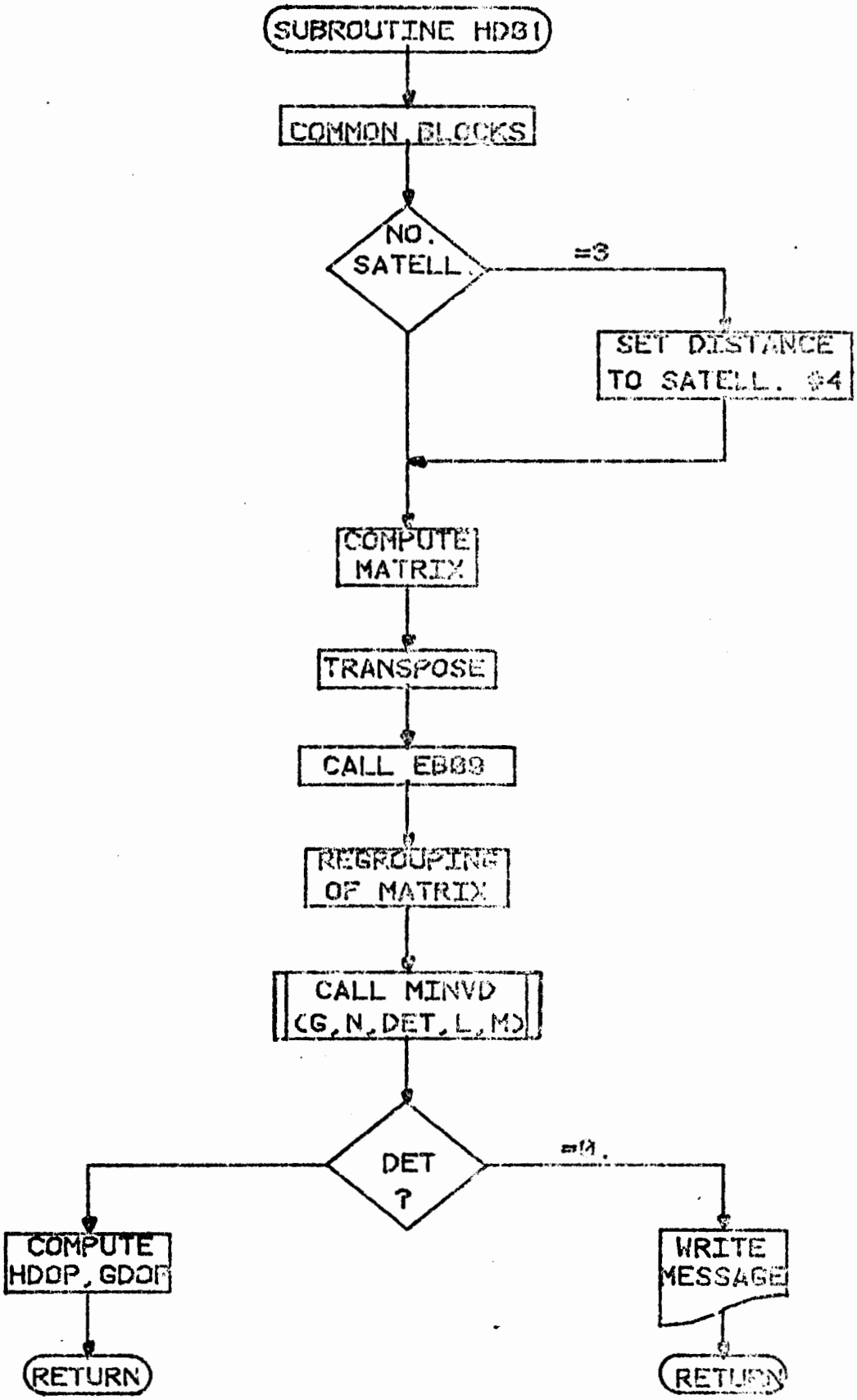



B
READ SATELLITE POSITION
C
UNPACK USER POS.
I=1,4
MORE DATA IN REC.
NO
UNPACK SATELLITE POSITION
NO. SATELL. ?
<3
WRITE ERROR MESSAGE
STOP3
WRITE DATA
CALL ENU
D

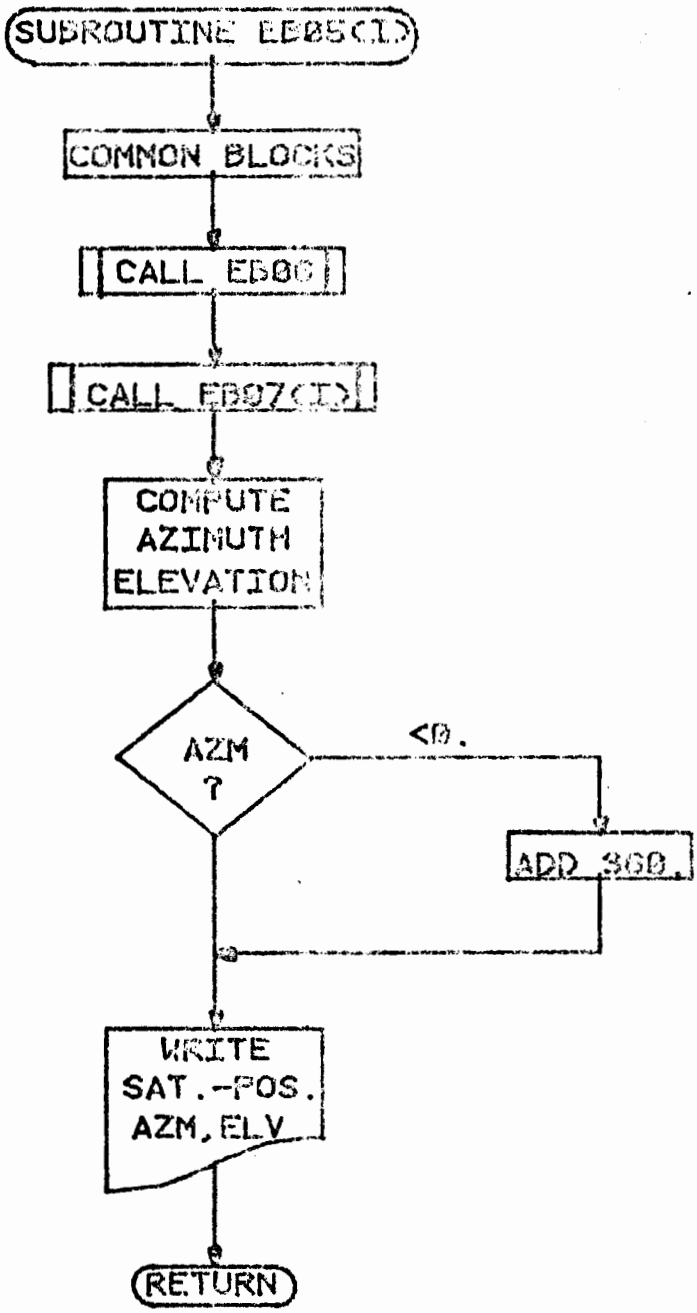

D
H(I, 4)=0.
NO. SATELL. ?
<4
SET H(4,J)
=4
COMPUTE REST OF H-MATRIX
WRITE H-MATRIX
CALL HTRAN
WRITE H-TRANS-POSE
CALL MLHHT
WRITE PRODUCT
E


E
CALL INVHP
WRITE INVERSE
COMPUTE HDOP, PDOP, GDOP
NO. SATELL.
=3
SET GDOP
=4
WRITE HDOP, PDOP GDOP
IF
IST=1
A
FORMATS
STOP

FLOWCHART HD01



FLOWCHART EB05



```
0001  FTN4X,L,Y
0002  C ***************************
0003  C *    FILENAME : &HD00     *
0004  C ***************************
0005        BLOCK DATA
0006        IMPLICIT DOUBLE PRECISION (A-H,K-Z)
0007        INTEGER N
0008        COMMON /CNST/PI,RTD,OMF,AE,E2,OMF2,SGC,ERATE,PI2
0009        COMMON/TIME/TDEL,TFIN
0010        COMMON/AZM/ELV(4),AZM(4)
0011        COMMON/POS/LAT,LON,ALT,R
0012        COMMON/NAC/TUY,TCY,TKC,DTC(4),DTU,TC,T
0013        COMMON/DB2/AD1(14)
0014        COMMON/DTX/U(4),D(4,4),RBAR(4)
0015        COMMON/SAT/S(4)
0016        COMMON/HDOP/HDOP,INS,GDOP
0017        COMMON/ELEV/E(3,3)
0018        COMMON/MAT/A(4,4),AT(4,4),AAT(4,4)
0019        COMMON/BLG/G(4,4),N
0020        COMMON/ALM/AD2(14,24),ID1(24)
0021        COMMON/EPH/C(7),K,S1(7)
0022        DATA PI/3.1415926500/,RTD/57.2957795D0/,PI2/6.283185300/
0023        DATA OMF/.99664722000/,AE/6.378135D6/
0024        DATA E2/6.694317778D-3/,OMF2/.99330568300/
0025        DATA SGC/1.99649907/,ERATE/7.292115147D-5/
0026        END
0027  $FILES (1,1)
0028        PROGRAM HD00
0029  C ***************************************************************
0030  C *  ROUTINE COMPUTES FOR A PROMPTED TIME (DAY AND TIME INTERVALL  *
0031  C * DURING THIS DAY) AND A PROMPTED USER POSITION THE POSITION OF  *
0032  C * 4 GPS SATELLITES,THE AZIMUTH AND ELEVATION ANGLES, THE DISTANCE*
0033  C * TO THE USER AND THE HDOP AND GDOP.                            *
0034  C *  THE SATELLITE POSITIONS ARE COMPUTED FROM THE ALMANAC DATA BY *
0035  C * A MODIFIED PROGRAM OF THE TEXAS A&M-UNIVERSITY.               *
0036  C *  A PLOTFILE WITH A TIME TAGGED HDOP IS CREATED.               *
0037  C *                                                              *
0038  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -*
0039  C *                                                              *
0040  C *   USED SUBROUTINES:     EB02                                 *
0041  C *                         EB03                                 *
0042  C *                         EB05                                 *
0043  C *                         EB06                                 *
0044  C *                         EB07                                 *
0045  C *                         HD01                                 *
0046  C *                         EB09                                 *
0047  C *                         MINVD                                *
0048  C *                         EB12                                 *
0049  C *                         EB14                                 *
0050  C *                         DINTF                                *
0051  C *                                                              *
0052  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -*
0053  C *                                                              *
0054  C *  USED EARTH-REFERENCE-ELLIPSOID : WGS-72                     *
0055  C *                                                              *
0056  C *   IMPORTANT VARIABLES AND CONSTANTS :                        *
0057  C *   INTEGER : IST,IST1,IST2       --> CONTROL-PARAMETERS       *
0058  C *             I,II,J,I1,I2,I3     --> INDEX FOR DO-LOOPS       *
```

```
0059  C *              N                    --> SIZE OF MATRIX (USED IN      *
0060  C *                                       INVERSION SUBROUTINE)        *
0061  C *              INS                  --> NUMBER OF SATELLITES FOR     *
0062  C *                                       HDOP COMPUTATION             *
0063  C *              ISAT                 --> INDEX OF SATELLITES          *
0064  C *              ID (4)               --> PRN NO. OF USED SATELLITES   *
0065  C *              ID1 (24)             --> PRN NO. OF ALL SATELLITES    *
0066  C *              INAM (3)             --> NAME OF PLOTFILE             *
0067  C *                                                                    *
0068  C *   REAL     : A1,A2,T1,T2,TOUT     --> ONLY FOR OUTPUT,ALL REAL-    *
0069  C *                                       VARIABLES ARE NOT INVOLVED   *
0070  C *                                       IN ANY SIGNIFICANT COMPUTAT.*
0071  C *                                                                    *
0072  C *   DOUBLE PRECISION :                                               *
0073  C *              AD (14,4)            --> ALMANAC FOR 4 SATELLITES     *
0074  C *              AD1 (14)             --> ALMANAC JUST USED            *
0075  C *              AD2 (14,24)          --> ALMANAC FOR 24 SATELLITES    *
0076  C *              ALT                  --> ALTITUDE                     *
0077  C *              AE                   --> RADIUS OF EARTH              *
0078  C *              AZM (4)              --> AZIMUTH ANGLE OF SATELLITE   *
0079  C *              A(4,4),AT(4,4),      --> MATRIX,INVERTED MATRIX AND   *
0080  C *              AAT(4,4)                 MULTIPLICATION MATRIX.       *
0081  C *                                       A CONTAINS THE DIRECTION-    *
0082  C *                                       COSINES IN ENU COORDINATES   *
0083  C *              D(4,4)               --> DISTANCES FROM USER TO 4     *
0084  C *                                       SATELLITES IN ECEF COORD.    *
0085  C *              DTC(4)               --> DATE OF COLLECTION IN DAYS   *
0086  C *                                       FROM BEGINNING OF THE YEAR   *
0087  C *              DTU                  --> DATE OF USE IN DAYS (CONVER-*
0088  C *                                       TED INTO SECONDS) FROM       *
0089  C *                                       BEGINNING OF THE YEAR        *
0090  C *              E (3,3)              --> MATRIX CONTAINING SINES AND  *
0091  C *                                       COSINES OF USER POSITION     *
0092  C *              E2                   --> SQUARE-ROOT OF THE EXCENTRI-*
0093  C *                                       CITY OF THE EARTH ELLIPSOID  *
0094  C *              ELV (4)              --> ELEVATIONANGLE OF SATELLITES*
0095  C *              ERATE                --> EARTH ROTATION RATE          *
0096  C *              G (4,4)              --> MATRIX FOR INVERSION-SUBROU.*
0097  C *              GDOP                 --> GEOMETRIC DILUTION OF PRECI-*
0098  C *                                       SION                         *
0099  C *              HDOP                 --> HORIZONTAL DILUTION OF       *
0100  C *                                       PRECISION                    *
0101  C *              LAT                  --> LATITUDE                     *
0102  C *              LON                  --> LONGITUDE                    *
0103  C *              PI,PI2               --> PI(3.1415...) AND 2*PI       *
0104  C *              RTD                  --> RADIAN TO DEGREE CONVERSION  *
0105  C *                                       FACTOR (180/PI)              *
0106  C *              RBAR                 --> LENGTH OF VECTOR USER-SATEL.*
0107  C *              S (4)                --> SATELLITE-POSITION IN ECEF   *
0108  C *              SGC                  --> SQUARE ROOT OF GRAVITATIONAL*
0109  C *                                       CONSTANT OF THE EARTH        *
0110  C *                        ALL TIMES IN GMT AND IN SECONDS              *
0111  C *              T                    --> GPS TIME                     *
0112  C *              TC                   --> COLLECTION TIME,START OF     *
0113  C *                                       COUNT AT BEGINNING OF EPOCH  *
0114  C *              TCY                  --> TIME OF COLLECTION STARTING  *
0115  C *                                       AT BEGINNING OF YEAR         *
0116  C *              TDEL                 --> TIME INCREMENT               *
0117  C *              TFIN                 --> END TIME                     *
0118  C *              TKC                  --> DIFFERENCE BETWEEN COLLEC-   *
```

```
C *                                          TIONTIME AND REFERENCETIME, *
C *                                          WRAPAROUNDS CONSIDERED      *
C *            TUY                    --> TIME OF USE                    *
C *            U (4)                  --> USER POSITION IN ECEF-COORD,*
C *                                                                      *
C ************************************************************************
C
C
      IMPLICIT DOUBLE PRECISION(A-H,K-Z)
      REAL A1,A2,T2,T1,TOUT
      DIMENSION AD(14,4),ID(4),INAM(3)
      COMMON/TIME/TDEL,TFIN
      COMMON/AZM/ELV(4),AZM(4)
      COMMON/POS/LAT,LON,ALT,R
      COMMON/NAC/TUY,TCY,TKC,DTC(4),DTU,TC,T
      COMMON/CNST/PI,RTD,OMF,AE,E2,OMF2,SGC,ERATE,PI2
      COMMON/DB2/AD1(14)
      COMMON/DTX/U(4),D(4,4)
      COMMON/SAT/S(4)
      COMMON/ALM/AD2(14,24),ID1(24)
      COMMON/HDOP/HDOP,INS,GDOP
      ISAT=0
C .....................................................................
C                        INPUT
C
C **********  INPUT THE LATITUDE,LONGITUDE AND THE ALTITUDE **********
C          LON WEST AND LAT SOUTH ARE DENOTED BY A NEGATIVE VALUE
C
      WRITE (16,1)
1     FORMAT (//"   INPUT USER POSITION"
     1/          " ATLANTIC CITY (=1) OTHER POSITION (=2)"
     2/          " ANSWER :_")
      READ (16,98) IST
      IF(IST.EQ.2) GOTO 1001
C ----------------------
      LAT=0.395D2
      LON=-0.745D2
      ALT=0.1D3
      GOTO 1002
C ----------------------
1001  CONTINUE
      WRITE (16,2)
2     FORMAT (/"   USER POSITION IN DEGREES (FORMAT :G15.8)"
     1/          " LATITUDE          :_")
      READ (16,97) LAT
      WRITE (16,3)
3     FORMAT (" LONGITUDE         :_")
      READ (16,97) LON
      WRITE (16,4)
4     FORMAT (" ALTITUDE IN FEET :_")
      READ (16,97) ALT
1002  CONTINUE
C --------------------
      WRITE (6,50) LAT,LON,ALT
50    FORMAT (" PROGRAM   * H D 0 0 *"
     1/          " ---------------------"
     2//         " USER-POSITION :  "
     3/          "   LATITUDE :",G15.8," DEGREE"
     4/          "   LONGITUDE:",G15.8," DEGREE"
     5/          "   ALTITUDE :",G15.8," FEET")
```

```
0179        LAT=LAT/RTD
0180        LON=LON/RTD
0181        ALT=ALT/0.32809D1
0182  C
0183  C ********** EB02 COMPUTES E-MATRIX **********
0184  C
0185        CALL EB02
0186  C
0187  C ********** EB03 TAKES LAT, LON, AND ALT; **********
0188  C             IT RETURNS X,Y,Z IN U-VECTOR
0189  C
0190        CALL EB03
0191        WRITE (6,51) (U(I),I=1,3)
0192  51    FORMAT (/" ECEF-COORDINATES :",7X,"X",14X,"Y",14X,"Z"
0193       1/         "--------------------",3G15.8)
0194        U(4)=0.
0195  C
0196  C ********** READ USER TIME **********
0197  C
0198        WRITE (16,7)
0199  7     FORMAT (/" USER TIME (FORMAT : G15.8)"
0200       1/         "  STARTTIME (T),ENDTIME (TFIN) TIME INCREMENT (TDEL)"
0201       2/         " AND ALMANAC COLLECTION TIME (TC) IN SECONDS."
0202       3/         " START OF COUNT : T,TFIN,TDEL --> EVERY DAY AT 00:00"
0203       4/         "                  TC          --> BEGINNING OF EPOCH"
0204       5/         " TSTART=_")
0205        READ (16,97) T
0206        WRITE (16,8)
0207  8     FORMAT (" TFIN  =_")
0208        READ (16,97) TFIN
0209        WRITE (16,9)
0210  9     FORMAT (" TDEL  =_")
0211        READ (16,97) TDEL
0212        WRITE (16,32)
0213  32    FORMAT (" TC    =_")
0214        READ (16,97) TC
0215        WRITE (16,10)
0216  10    FORMAT (" DATE OF USE IN DAYS FROM JANUARY,FIRST :_")
0217        READ (16,97) DTU
0218        WRITE (16,31)
0219  31    FORMAT ( " 3 OR 4 SATELLITES FOR HDOP-COMPUTATION :_")
0220        READ (16,98) INS
0221  C --------------
0222        CALL EB12(T,T1)
0223        CALL EB12(TFIN,T2)
0224        WRITE (6,52) T,T1,TFIN,T2,TDEL,DTU
0225  52    FORMAT (//" USERTIMES :"
0226       1/          "   START (TSTART): ",G15.8," SEC. = ",F5.2," HOURS"
0227       2/          "   END (TFIN)    : ",G15.8," SEC. = ",F5.2," HOURS"
0228       3/          "   INCR. (TDEL)  : ",G15.8," SEC"
0229       4/          "   DATE (DTU)    : ",G15.8," DAYS")
0230  C
0231  C ********** READ ALMANACS **********
0232  C
0233        WRITE (16,12)
0234  12    FORMAT ( " ALMANAC-DATA FROM TAPE (=1) ? _")
0235        READ (16,98) IST1
0236  1000  CONTINUE
0237        ISAT=ISAT+1
0238        IF(IST1.EQ.1) GOTO 1009
```

```
0239        WRITE (16,13) ISAT
0240  13    FORMAT (/" OWN ALMANAC =1 OR DATA FROM FILE =2 FOR SV NO.",I2,"?"
0241       1/         " ANSWER :_")
0242        READ (16,98) IST
0243        IF(IST.EQ.1) GOTO 1005
0244  C -----------------
0245        WRITE (16,14)
0246  14    FORMAT (/" FILENAME :_")
0247        READ(16,92) INAM
0248        OPEN (2,FILE=INAM,FORM='FORMATTED')
0249        READ (2,96) DTC(ISAT),ID(ISAT)
0250        READ (2,91) (AD(I,ISAT),I=1,4)
0251        READ (2,91) (AD(I,ISAT),I=5,8)
0252        CLOSE(2)
0253        WRITE (16,15) ID(ISAT)
0254  15    FORMAT ( " SATELLITE ID = ",I2)
0255        GOTO 1010
0256  C -----------------
0257  1005  CONTINUE
0258        WRITE (16,16) ISAT
0259  16    FORMAT ( " ####### ALMANAC-DATA FOR SATELLITE ",I2,"#######"
0260       1/         " FORMAT :D12.4"
0261       2//        " DATE OF COLLECTION                    :_")
0262        READ (16,99) DTC(ISAT)
0263        WRITE (16,17)
0264  17    FORMAT (" EXCENTRICITY                          :_")
0265        READ (16,99) AD(1,ISAT)
0266        WRITE (16,18)
0267  18    FORMAT (" REFERENCE TIME                        :_")
0268        READ (16,99) AD(2,ISAT)
0269        WRITE (16,19)
0270  19    FORMAT (" ORBIT INCLINATION (IO)                :_")
0271        READ (16,99) AD(3,ISAT)
0272        WRITE (16,20)
0273  20    FORMAT (" DRIFT RATE OF (IO)                    :_")
0274        READ (16,99) AD(4,ISAT)
0275        WRITE (16,21)
0276  21    FORMAT (" SQARE ROOT OF GREAT HALF-AXIS         :_")
0277        READ (16,99) AD(5,ISAT)
0278        WRITE (16,22)
0279  22    FORMAT (" RIGHT ASCENSION OF ORBIT              :_")
0280        READ (16,99) AD(6,ISAT)
0281        WRITE (16,23)
0282  23    FORMAT (" ARGUMENT OF PERIGEE                   :_")
0283        READ (16,99) AD(7,ISAT)
0284        WRITE (16,24)
0285  24    FORMAT (" MEAN ANOMALY                          :_")
0286        READ (16,99) AD(8,ISAT)
0287        WRITE (16,25)
0288  25    FORMAT (" SATELLITE ID                          :_")
0289        READ (16,98) ID(ISAT)
0290        GOTO 1010
0291  C ------------
0292  1009  CONTINUE
0293        IF(ISAT.NE.1) GOTO 1010
0294        CALL EB14
0295        DO 107 I1=1,4
0296  1011  CONTINUE
0297        WRITE (16,26) I1
0298  26    FORMAT ( " ID OF SATELLITE (",I2,") : _")
```

```
0299          READ (16,98) ID(I1)
0300          DO 108 I2=1,24
0301          IF(ID(I1).NE.ID1(I2).AND.I2.LT.24) GOTO 108
0302          IF(ID(I1).EQ.ID1(I2)) GOTO 1012
0303          WRITE (16,27) ID(I1)
0304    27    FORMAT ( " =====> SATELLITE ALMANAC OF SAT.(",I2,") NOT ON"
0305         1" TAPE !! <=====")
0306          GOTO 1011
0307    108   CONTINUE
0308    1012  CONTINUE
0309          DO 107 I3=1,8
0310          AD(I3,I1)=AD2(I3,I2)
0311          ID(I1)=ID1(I2)
0312    107   CONTINUE
0313    C ---------------------
0314    1010  CONTINUE
0315          AD(9,ISAT)=AD(5,ISAT)**2
0316          AD(10,ISAT)=COS(AD(3,ISAT))
0317          AD(11,ISAT)=SIN(AD(3,ISAT))
0318          AD(12,ISAT)=COS(AD(7,ISAT))
0319          AD(13,ISAT)=SIN(AD(7,ISAT))
0320          AD(14,ISAT)=SGC/(AD(5,ISAT)*AD(9,ISAT))
0321          IF(ISAT.LT.INS) GOTO 1000
0322    C .....................................................................
0323    C
0324    C ********** OUTPUT ALMANAC **********
0325    C
0326          A1=SNGL(DTC(1))
0327          A2=SNGL(TC)
0328          WRITE (6,53) A1,A2,(ID(I),I=1,4)
0329    53    FORMAT (/"     USED ALMANACS          DTC= ",F5.0,"    TC= ",F7.0,
0330         1/          "     ------------- "
0331         2/          " SAT. ID : ",I3,19X,I3,19X,I3,19X,I3)
0332          WRITE (6,54) ((AD(I,J),J=1,4),I=1,14)
0333    54    FORMAT (4(10X,D12.4,))
0334    C .....................................................................
0335    C                 CALCULATIONS AND OUTPUT
0336    C
0337    C ********** WRITE TITLE **********
0338    C
0339          WRITE (6,61)
0340    61    FORMAT (//" OUTPUT OF COMPUTATIONS "
0341         1/           " ---------------------- "
0342         2//         " ================================================= "
0343         2/          " ! THE PRINTOUT IS ARRANGED AS FOLLOWING EXAMPLE :  !"
0344         3/          " ! -----------------                                !"
0345         4/          " ! TIME                                             !"
0346         5/          " !POSITION OF SATELLITES IN ECEF-COORDINATES (X,Y,Z)!"
0347         6/          " !AND ELEVATION AND AZIMUTH (3-4 LINES)             !"
0348         7/          " !- - - - - - - - - -                               !"
0349         8/          " !  HDOP AND GDOP                                   !"
0350         9/          " !------------------                                !"
0351         A/          " !    ALL VALUES ARE IN METER                       !"
0352         B/          " ================================================")
0353          WRITE (16,29)
0354    29    FORMAT (" NAME OF PLOTFILE :_")
0355          READ (16,92) INAM
0356          OPEN(2,FILE=INAM,FORM='FORMATTED')
0357          WRITE (2,92) INAM
0358          WRITE (2,98) INS
```

```
0359  C
0360  C ----------  BEGINNING OF COMPUTATION-LOOP ----------------------->
0361  C
0362        DTU=(DTU-1.)*0.864D5
0363        TCY=(DTC(1)-1.)*0.864D5+DMOD(TC,0.864D5)
0364  1004  CONTINUE
0365        CALL EB12 (T,TOUT)
0366        WRITE (6,70)
0367        WRITE (6,62) TOUT
0368  62    FORMAT ( " TIME : ",F7.4," HOURS ")
0369        DO 102 I=1,INS
0370        DO 101 J=1,14
0371        AD1(J)=AD(J,I)
0372  101   CONTINUE
0373  C
0374  C ********** COMPUTATION OF POSITION,DISTANCE TO USER **********
0375  C             AND AZIMUTH AND ELEVATION OF SATELLITE(I)
0376  C
0377        II=I
0378        CALL EB05(II)
0379  102   CONTINUE
0380  C
0381  C ********** COMPUTATION OF INVERTED G-MATRIX,HDOP AND GDOP **********
0382  C
0383        CALL HD01
0384        WRITE (6,71)
0385        WRITE (6,63) HDOP,GDOP
0386  63    FORMAT (G15.8,5X,G15.8)
0387        A1=SNGL(HDOP)
0388        A2=SNGL(GDOP)
0389        TOUT=SNGL(T)/3600.
0390        WRITE (2,90) TOUT,A1,A2
0391        WRITE (6,70)
0392        T=T+TDEL
0393        IF (T.LE.TFIN) GOTO 1004
0394  C <-------------------  END OF COMPUTATION-LOOP----------------<--
0395  C
0396  C ********** WRITE END-CRITERIA TO PLOTFILE **********
0397  C
0398        TOUT=0.
0399        A1=0.
0400        A2=0.
0401        WRITE (2,90) TOUT,A1,A2
0402        CLOSE (2)
0403        STOP
0404  C
0405  C ********** FORMATS **********
0406  C
0407  70    FORMAT ( " ------------------------ ")
0408  71    FORMAT ( " - - - - - - - - - - - - - ")
0409  90    FORMAT (1X,3F12.6)
0410  91    FORMAT (4D18.8)
0411  92    FORMAT (3A2)
0412  93    FORMAT (I4)
0413  94    FORMAT (4E12.4)
0414  95    FORMAT (A4)
0415  96    FORMAT (G15.8,I3)
0416  97    FORMAT(G15.8)
0417  98    FORMAT(I2)
0418  99    FORMAT(D12.4)
```

```
0419          END
0420
```

```
&PLHG  T=00004 IS ON CR00011 USING 00018 BLKS R=0000

0001  FTN4X,L,Y
0002  $FILES (1,1)
0003        PROGRAM PLHG
0004  C ***************************************************************
0005  C *                FILENAME :   &PLHG                           *
0006  C *                ^^^^^^^^^^^^^^^^^^                           *
0007  C * PROGRAM PLOTS DATA FILES GENERATED BY THE PROGRAM "HD00"     *
0008  C * TO COMPARE THE HDOP'S COMPUTED FOR A SITUATION WITH FOUR     *
0009  C * SATELLITES (PLOTFILE 1) AND WITH THREE SATELLITES (PLOT-     *
0010  C * FILE 2).                                                    *
0011  C *                                                             *
0012  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -*
0013  C *   USED SUBROUTINES : DLTBL,GPS  (PLOTLIBRARY)               *
0014  C *                                                             *
0015  C ***************************************************************
0016  C
0017        DIMENSION IGCB(192),INAM1(3),INAM2(3)
0018        LOGICAL LOG
0019  C
0020  C ********** READ NAME OF FILE,LOGICAL UNIT AND ID OF **********
0021  C                         DEVICE SUB
0022  C
0023        LOG=.TRUE.
0024        WRITE (16,1)
0025  1     FORMAT (" NAME OF PLOTFILE 1 :_")
0026        READ (16,92) INAM1
0027        OPEN (2,FILE=INAM1,FORM='FORMATTED')
0028        READ (2,92) INAM1
0029        READ (2,93) INS
0030        WRITE (16,3)
0031  3     FORMAT ( " LOGICAL UNIT (LU) AND ID OF DEVICE-SUBROUTINE"
0032       1/         "   LU =_")
0033        READ (16,93) LU
0034        WRITE (16,4)
0035  4     FORMAT ( "   ID =_")
0036        READ (16,93) ID
0037  C
0038  C ********** INITIALIZE PLOTTER AND DRAW GRID **********
0039  C
0040        WRITE (16,5)
0041  5     FORMAT ( " START-AND ENDTIME IN HOURS."
0042       1/         " TSTART :_")
0043        READ (16,94) TSTART
0044        WRITE (16,6)
0045  6     FORMAT ( " TEND   :_")
0046        READ (16,94) TEND
0047        CALL PLOTR (IGCB,ID,1,LU)
0048        CALL SETAR (IGCB)
0049        CALL FRAME (IGCB)
0050        CALL VIEWP (IGCB,30.,90.,20.,60.)
0051        CALL WINDW (IGCB,TSTART,TEND,0.,20.)
0052        CALL FXD (IGCB,2)
0053        CALL LGRID (IGCB,-0.25,5.,0.,0.,1.,1.,1.)
0054  C
0055  C ********** DATA INPUT FROM FILES AND PLOT **********
0056  C
0057        CALL LINE (IGCB,0)
0058  1000  CONTINUE
```

```
0059          READ (2,95) TOUT,HDOP,GDOP
0060          IF(LOG) CALL MOVE (IGCB,TOUT,HDOP)
0061          LOG=.FALSE.
0062          IF(TOUT.LT.0.01.AND.HDOP.LT.0.01) GOTO 1001
0063          CALL DRAW(IGCB,TOUT,HDOP)
0064          GOTO 1000
0065    1001  CONTINUE
0066          CLOSE(2)
0067    C ---------------------
0068          WRITE (16,2)
0069    2     FORMAT ( " NAME OF PLOTFILE 2 :_")
0070          READ (16,92) INAM2
0071          OPEN (3,FILE=INAM2,FORM='FORMATTED')
0072          READ (3,92) INAM2
0073          READ (3,93) INS2
0074          CALL LINE(IGCB,1)
0075          LOG=.TRUE.
0076    1002  CONTINUE
0077          READ (3,95) TOUT,HDOP,GDOP
0078          IF(LOG) CALL MOVE (IGCB,TOUT,HDOP)
0079          LOG=.FALSE.
0080          IF(TOUT.LT.0.01.AND.HDOP.LT.0.01) GOTO 1003
0081          CALL DRAW (IGCB,TOUT,HDOP)
0082          GOTO 1002
0083    1003  CONTINUE
0084          CLOSE (3)
0085    C
0086    C ********** PLACE TITLES AND OTHER INFORMATION ***********
0087    C
0088          CALL VIEWP (IGCB,10.,100.,10.,90.)
0089          CALL WINDW (IGCB,10.,100.,10.,90.)
0090          CALL MOVE (IGCB,55.,80.)
0091          CALL CPLOT (IGCB,-11.,0.,0)
0092          CALL LABEL (IGCB)
0093          WRITE (LU,7)
0094    7     FORMAT ("GRAPH OF HDOP VS. TIME")
0095          CALL MOVE  (IGCB,55.,10.)
0096          CALL CPLOT (IGCB,-8.,0.,0)
0097          CALL LABEL (IGCB)
0098          WRITE (LU,8)
0099    8     FORMAT ("GMT-TIME IN HOURS")
0100          CALL MOVE (IGCB,1.,50.)
0101          CALL LABEL (IGCB)
0102          WRITE (LU,9)
0103    9     FORMAT ("HDOP")
0104          CALL LINE (IGCB,0)
0105          CALL MOVE (IGCB,30.,70.)
0106          CALL DRAWI (IGCB,15.,0.)
0107          CALL MOVEI (IGCB,2.,0.)
0108          CALL CPLOT (IGCB,0.,-0.25,0)
0109          CALL LABEL (IGCB,)
0110          WRITE (LU,10)
0111    10    FORMAT ("4 SAT.")
0112          CALL LINE (IGCB,1)
0113          CALL MOVE (IGCB,65.,70.)
0114          CALL DRAWI (IGCB,15.,0.)
0115          CALL MOVEI (IGCB,2.,0.)
0116          CALL CPLOT (IGCB,0.,-0.25,0)
0117          CALL LABEL (IGCB)
0118          WRITE (LU,11)
```

```
0119   11     FORMAT ("3 SAT.")
0120          CALL PLOTR (IGCB,ID,0)
0121   C
0122   C ********** FORMATS **********
0123   C
0124   92     FORMAT (3A2)
0125   93     FORMAT (I2)
0126   94     FORMAT (F8.6)
0127   95     FORMAT (1X,3F12.6)
0128          CALL PLOTR (IGCB,ID,0)
0129          STOP
0130          END
```

```
&EBGD1 T=00004 IS ON CR00011 USING 00018 BLKS R=0000

0001  FTN4X,L,Y
0002  C ************************
0003  C *   FILENAME : &EBGD1   *
0004  C ************************
0005        BLOCK DATA
0006        IMPLICIT DOUBLE PRECISION (A-H,O-Z)
0007        COMMON/MAT/HT(4,4),H(4,4),HTH(4,4)
0008        END
0009        PROGRAM EBGD1
0010  C ***************************************************************
0011  C *  ROUTINE TO CALCULATE GDOP WITH INSERTED H-MATRIX OR WITH     *
0012  C * AZIMUTH- AND ELEVATIONANGLE.                                 *
0013  C *                                                             *
0014  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - *
0015  C *   USED SUBROUTINES : EB09                                   *
0016  C *                      MINVD                                  *
0017  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - *
0018  C *     MICHAEL J. MAGROGAN  CO-OP  ACT-100D  FEBRUARY 1981     *
0019  C *     ERHARD BUCHBERGER           ACT-100B  APRIL 1982        *
0020  C***************************************************************
0021  C
0022        IMPLICIT DOUBLE PRECISION (A-H,O-Z)
0023        DIMENSION AZ(4),EL(4),HPROD(4,4),L(4),M(4)
0024        COMMON/MAT/HT(4,4),H(4,4),HTH(4,4)
0025        N=4
0026        RTD=57.2957795
0027  C .............................................................
0028  C                          INPUT
0029  C
0030  C ********** INPUT H-MATRIX OR ANGLES **********
0031  C
0032        WRITE (6,17)
0033  17    FORMAT ( " PROGRAM *EBGD1*"
0034       1/        " ^^^^^^^^^^^^^^^^")
0035        WRITE (16,9)
0036  9     FORMAT ( " SELECT INPUT :"
0037       1/        " H-MATRIX=1    ANGLES=2"
0038       2/        " ANSWER   :_")
0039        READ (16,91) IST
0040        IF(IST.EQ.2) GOTO 1002
0041  C -----------------
0042        DO 100 I=1,4
0043        DO 100 J=1,4
0044        WRITE (16,10) I,J
0045  10    FORMAT ( " ELEMENT (",I2,",",I2,") :_")
0046        READ (16,90) H(I,J)
0047  100   CONTINUE
0048        GOTO 1003
0049  C -----------------
0050  1002  CONTINUE
0051        WRITE (6,15)
0052  15    FORMAT (//" AZIMUTH        ELEVATION")
0053        DO 103 I=1,4
0054        WRITE (16,13) I
0055  13    FORMAT ( " AZIMUTH(",I2,")   :_")
0056        READ (16,90) AZ(I)
0057        WRITE (16,14) I
0058  14    FORMAT ( " ELEVATION(",I2,") :_")
```

```
0059          READ (16,90) EL(I)
0060          WRITE (6,16) AZ(I),EL(I)
0061    16    FORMAT (2D12.4)
0062          AZ(I)=AZ(I)/RTD
0063          EL(I)=EL(I)/RTD
0064          H(I,1)=COS(EL(I))*COS(AZ(I))
0065          H(I,2)=COS(EL(I))*SIN(AZ(I))
0066          H(I,3)=SIN(EL(I))
0067          H(I,4)=1.
0068    103   CONTINUE
0069    C -----------------
0070    1003  CONTINUE
0071          WRITE (6,4)
0072    4     FORMAT (//" H-MATRIX")
0073          WRITE (6,5) ((H(I,J),J=1,4),I=1,4)
0074    5     FORMAT (4D16.8)
0075    C .....................................................................
0076    C                            COMPUTATONS
0077    C
0078    C ********** COMPUTE THE TRANSPOSE OF THE H MATRIX **********
0079    C
0080          DO 101 I=1,4
0081          DO 101 J=1,4
0082          HT(I,J)=H(J,I)
0083    101   CONTINUE
0084          WRITE (6,6)
0085    6     FORMAT (/" H-TRANSPOSE-MATRIX ")
0086          WRITE (6,5) ((HT(I,J),J=1,4),I=1,4)
0087    C
0088    C ********** CALL EB09 TO MULTIPLY THE H AND H TRANSPOSE **********
0089    C                              MATRIX
0090    C
0091          CALL EB09
0092          WRITE (6,7)
0093    7     FORMAT (/" HT*H-MATRIX ")
0094          WRITE (6,5) ((HTH(I,J),J=1,4),I=1,4)
0095    C
0096    C ********** CALL MINVD TO COMPUTE THE INVERSE OF THE H AND **********
0097    C                            H TRANSPOSE PRODUCT MATRIX
0098    C
0099          DO 102 I=1,4
0100          DO 102 J=1,4
0101          HPROD(I,J)=HTH(I,J)
0102    102   CONTINUE
0103          CALL MINVD (HPROD,N,DET,L,M)
0104          IF(DET.LT.1.0D-5) GOTO 1000
0105          WRITE (6,8)
0106    8     FORMAT (/" INVERTED HT*H-MATRIX ")
0107          WRITE (6,5) ((HPROD(I,J),J=1,4),I=1,4)
0108    C
0109    C ********** THE TRACE OF THE MATRIX IS THE SUM OF ITS **********
0110    C                                ELEMENTS
0111    C
0112          TRACEZ=HPROD(1,1)+HPROD(2,2)
0113          HDOPV=DSQRT(TRACEZ)
0114          TRACEZ=TRACEZ+HPROD(3,3)+HPROD(4,4)
0115          GDOPV=DSQRT(TRACEZ)
0116          GOTO 1001
0117    C ----------------------
0118    1000  CONTINUE
```

```
0119          WRITE (16,1) DET
0120    1     FORMAT ( " DETERMINANT OF MATRIX : ",D16.8)
0121          WRITE (6,12)
0122          WRITE (16,12)
0123    12    FORMAT ( " ********************************************* "
0124         1/         " *HT*H-MATRIX IS SINGULAR (DETERMINANT=0.)* "
0125         2/         " ********************************************* ")
0126          STOP1
0127    C -----------------------
0128    1001  CONTINUE
0129          HDOP=SNGL(HDOPV)
0130          GDOP=SNGL(GDOPV)
0131          WRITE (16,11) HDOP,GDOP
0132          WRITE (6,11) HDOP,GDOP
0133    11    FORMAT ( " HDOP = ",F15.8," GDOP = ",F15.8)
0134    C
0135    C ********** FORMATS **********
0136    C
0137    90    FORMAT (D16.8)
0138    91    FORMAT (I2)
0139          STOP
0140          END
```

```
%EBGH  T=00004 IS ON CR00011 USING 00024 BLKS R=0000

0001  FTN4X,L,Y
0002  C ************************
0003  C *    FILENAME : %EBGH    *
0004  C ************************
0005        BLOCK DATA
0006        DOUBLE PRECISION ENUP,XP,YP,ZP,H,HT,HPROD,HDOPV,GDOPV
0007        DOUBLE PRECISION PI,RTD,OMF,AE,E2,OMF2,U,LAT,LON,ALT
0008        DOUBLE PRECISION XS,YS,ZS,TRACEZ,X,Y,Z,NORM
0009        DOUBLE PRECISION SGC,ERATE,XY
0010        COMMON/COORD/ENUP(3,3),XP,YP,ZP,H(4,4),HT(4,4),HPROD(4,4),
0011       1LSAT(4),XS(4),YS(4),ZS(4),HDOPV,GDOPV
0012        COMMON/CNST/PI,RTD,OMF,AE,E2,OMF2,SGC,ERATE
0013        COMMON/DTX/U(4)
0014        COMMON/POS/LAT,LON,ALT,XY
0015        END
0016        PROGRAM EBGH
0017  C ***************************************************************
0018  C *    ROUTINE TO CALCULATE HDOP,PDOP AND GDOP WITH PROMPTED      *
0019  C * USER- AND SATELLITE-POSITIONS.                                *
0020  C *    INPUT IS POSSIBLE OVER THE KEYBOARD OR FROM A DATAFILE.    *
0021  C *                                                               *
0022  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -*
0023  C *    THE ORIGINAL PROGRAM WAS MADE BY MICHAEL J. MAGROGAN,CO-OP,*
0024  C * ACT 100B, ALSO THE SUBROUTINES "ENU","HTRAN","MLHHT","INVHP",*
0025  C *                                                               *
0026  C *    FURTHER USED SUBROUTINES : EB03,EB12                       *
0027  C *                                                               *
0028  C * - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -*
0029  C *    THE COMMON-BLOCKS ARE DEFINED TO FIT THE PROGRAM "HD00".   *
0030  C *                                                               *
0031  C ***************************************************************
0032  C
0033        DIMENSION IBUF(69),IDCB(144),NAME(3),ISATV(4)
0034        COMMON /COORD/ ENUP(3,3),XP,YP,ZP,H(4,4),HT(4,4),HPROD(4,4),
0035       +LSAT(4),XS(4),YS(4),ZS(4),HDOPV,GDOPV
0036        COMMON/CNST/PI,RTD,OMF,AE,E2,OMF2
0037        COMMON/DTX/U(4)
0038        COMMON/POS/LAT,LON,ALT
0039        DOUBLE PRECISION ENUP,XP,YP,ZP,H,HT,HPROD,HDOPV,GDOPV,PDOPV
0040        DOUBLE PRECISION PI,RTD,OMF,AE,E2,OMF2,U,LAT,LON,ALT
0041        DOUBLE PRECISION XS,YS,ZS,TRACEZ,X,Y,Z,NORM,TIME,BUF(15)
0042        EQUIVALENCE (IBUF,TIME),(IBUF(5),BUF),(IBUF(65),ISATV)
0043        REAL LAT1,LON1
0044  C
0045  C ********** DEFINITION OF CONSTANTS **********
0046  C
0047        RTD=57.2957795D0
0048        AE=6.378135D6
0049        E2=6.694317778D-3
0050        OMF2=0.993305683D0
0051  C
0052  C ********** THIS PROGRAM NEEDS AIRPLANE POSITION(XP,YP,ZP) **********
0053  C   AND FOUR SATELLITE POSITIONS (XS(1-4),YS(1-4),ZS(1-4)) AS INPUTS
0054  C
0055        WRITE (16,10)
0056  10    FORMAT ( " COORDINATES INPUT FROM FILE (=1) ?  :_")
0057        READ (16,92) IST
0058        IF(IST.EQ.1) GOTO 1000
```

```
0059  C ..................................................................
0060  C                    INPUT OVER KEYBOARD
0061  C
0062  C ********** USER POSITION **********
0063  C
0064        WRITE (16,1)
0065  1     FORMAT ( " INPUT USER POSITION IN GEOGR. COORDINATES (ALTITUDE
0066       1 IN FEET)"
0067       2/         " LATITUDE :_")
0068        READ (16,91) LAT1
0069        WRITE (16,2)
0070  2     FORMAT ( " LONGITUDE:_")
0071        READ (16,91) LON1
0072        WRITE (16,3)
0073  3     FORMAT ( " ALTITUDE :_")
0074        READ (16,91) ALT1
0075        LAT=DBLE(LAT1)/RTD
0076        LON=DBLE(LON1)/RTD
0077        ALT=DBLE(ALT1)/0.32809D1
0078  C
0079  C ********** COMPUTE ECEF-COORDINATES WITH SUBR. EB03 **********
0080  C
0081        CALL EB03
0082        XP=U(1)
0083        YP=U(2)
0084        ZP=U(3)
0085        WRITE (6,4) LAT1,LON1,ALT1,XP,YP,ZP
0086  4     FORMAT ( " PROGRAM *EBGH*        VERSION A"
0087       1/         " ----------------"
0088       2//        " USER-COORDINATES :"
0089       3/         " LAT =",G15.8,"  LON =",G15.8,"  ALT =",G15.8,
0090       4/         " XP  =",G15.8,"  YP  =",G15.8,"  ZP  =",G15.8)
0091  C
0092  C ********** SATELLITE-POSITION **********
0093  C
0094        WRITE (16,15)
0095  15    FORMAT ( " HOW MANY SATELLITES ?  :_")
0096        READ (16,92) NSAT
0097        IST2=1
0098        WRITE (16,5)
0099  5     FORMAT ( " INPUT SATELLITE-POSITION IN ECEF.")
0100        DO 101 I=1,NSAT
0101        WRITE (16,6)I
0102  6     FORMAT ( " XS(",I2,") =_")
0103        READ (16,90) XS(I)
0104        WRITE (16,7) I
0105  7     FORMAT ( " YS(",I2,") =_")
0106        READ (16,90) YS(I)
0107        WRITE (16,8) I
0108  8     FORMAT ( " ZS(",I2,") =_")
0109        READ (16,90) ZS(I)
0110        WRITE (6,9) I,XS(I),YS(I),ZS(I)
0111  9     FORMAT ( " SAT.NO :",I2," XS =",D16.8," YS =",D16.8," ZS ="
0112       1,D16.8)
0113  101   CONTINUE
0114        GOTO 1001
0115  C ..................................................................
0116  C
0117  C                    INPUT FROM FILE
0118  C
```

```
0119  C   BECAUSE OF RESTRICTION IN THE SUBROUTINES THE SYSTEM HAS TO BE
0120  C  ALTIMETER AIDED.
0121  C
0122  1000  CONTINUE
0123        WRITE (16,11)
0124  11    FORMAT ( " FILENAME :_")
0125        READ (16,93) NAME
0126        CALL OPEN (IDCB,IERR,NAME,0,0)
0127        IF(IERR.LT.0) STOP1
0128        WRITE (6,12) NAME
0129  12    FORMAT ( " PROGRAM *EBGH*      VERSION B"
0130       1/         "^^^^^^^^^^^^^^^^"
0131       2//        " FILENAME : ",3A2,/)
0132        NUM=1
0133        NSAT=4
0134        WRITE (16,16)
0135  16    FORMAT ( " SYSTEM ALTIMETER AIDED (=1) ?  :_")
0136        READ (16,92) IST2
0137  1002  CONTINUE
0138        CALL READF (IDCB,IERR,IBUF,068,LEN,NUM)
0139        IF(IERR.LT.0) STOP2
0140        XP=BUF(1)
0141        YP=BUF(2)
0142        ZP=BUF(3)
0143        I=0
0144        DO 102 K=1,4
0145        IF(ISATV(K).EQ.0) GOTO 102
0146        I=I+1
0147        ISATV(I)=ISATV(K)
0148        XS(I)=BUF(K+3)
0149        YS(I)=BUF(K+7)
0150        ZS(I)=BUF(K+11)
0151  102   CONTINUE
0152        IF(I-3) 1004,1005,1006
0153  C ----------------------
0154  1004  WRITE (16,22)
0155  22    FORMAT ( " ******************************"
0156       1/         " +ONLY TWO SATELLITES IN FILE*"
0157       2/         " ******************************")
0158        STOP3
0159  C ----------------------
0160  1005  NSAT=3
0161  1006  CONTINUE
0162        CALL EB12(TIME,TOUT)
0163        WRITE (6,13) NUM,TIME,TOUT,XP,YP,ZP
0164  13    FORMAT ( " RECORD-NO. : ",I3,
0165       1/         " TIME        : ",D14.6," SEC. ==> ",F8.4," HOURS GMT"
0166       2/         " USERPOSITION  --->  ",3D16.8,
0167       3/         " SATELLITE-POSITIONS :"
0168       4/,10X,"XS",14X,"YS",14X,"ZS")
0169        WRITE (6,14) ((ISATV(I),XS(I),YS(I),ZS(I)),I=1,NSAT)
0170  14    FORMAT (I3,3D16.8)
0171  C .....................................................................
0172  C                              COMPUTATIONS
0173  C
0174  C ********** CALL ENU TO FILL ENUP MATRIX **********
0175  C
0176  1001  CONTINUE
0177        CALL ENU
0178  C
```

```
0179  C ********** FILL COLUMN 4 OF H MATRIX WITH 1'S. **********
0180  C
0181        DO 40 I=1,4
0182         H(I,4)=1.D0
0183     40 CONTINUE
0184        IF(NSAT.EQ.4) GOTO 1003
0185        IF(IST2.NE.1) GOTO 1003
0186        H(4,1)=0.
0187        H(4,2)=0.
0188        H(4,3)=-1.
0189        H(4,4)=0.
0190  1003  CONTINUE
0191        DO 50 I=1,NSAT
0192  C
0193  C ********** SATELLITE POSITION VECTOR MINUS AIRPLANE **********
0194  C                          POSITION VECTOR
0195  C
0196          X=XS(I)-XP
0197          Y=YS(I)-YP
0198          Z=ZS(I)-ZP
0199  C
0200  C ********** MAGNITUDE OF THE VECTOR BETWEEN THE SATELLITE **********
0201  C                           AND THE AIRPLANE
0202  C
0203          NORM=DSQRT(X**2+Y**2+Z**2)
0204  C
0205  C ********** UNIT VECTOR FROM THE VECTOR BETWEEN THE **********
0206  C                   SATELLITE AND THE AIRPLANE
0207  C
0208        X=X/NORM
0209        Y=Y/NORM
0210        Z=Z/NORM
0211  C
0212  C ********** CONVERT FROM ECEF COORDINATES TO ENU COOR- **********
0213  C            DINATES USING ENUP-MATRIX AND FILL UP H-MATRIX
0214  C
0215        H(I,1)=ENUP(1,1)*X+ENUP(1,2)*Y+ENUP(1,3)*Z
0216        H(I,2)=ENUP(2,1)*X+ENUP(2,2)*Y+ENUP(2,3)*Z
0217        H(I,3)=ENUP(3,1)*X+ENUP(3,2)*Y+ENUP(3,3)*Z
0218     50 CONTINUE
0219        WRITE (6,17)
0220  17    FORMAT (/" H-MATRIX")
0221        WRITE (6,94) ((H(I,J),J=1,4),I=1,4)
0222  C
0223  C ********** CALL HTRAN TO COMPUTE THE TRANSPOSE OF **********
0224  C                        THE H-MATRIX
0225  C
0226        CALL HTRAN
0227        WRITE (6,18)
0228  18    FORMAT (/" H-TRANSPOSE-MATRIX")
0229        WRITE (6,94) ((HT(I,J),J=1,4),I=1,4)
0230  C
0231  C ********** CALL MLHHT TO MULTIPLY THE H AND H **********
0232  C                     TRANSPOSE MATRIX
0233        CALL MLHHT
0234        WRITE (6,19)
0235  19    FORMAT (/" HT*H-MATRIX")
0236        WRITE (6,94) ((HPROD(I,J),J=1,4),I=1,4)
0237  C
0238  C ********** CALL INVHP TO COMPUTE THE INVERSE OF THE H AND **********
```

```
0239  C                        HTRANSPOSE PRODUCT MATRIX
0240  C
0241        CALL INVHP
0242        WRITE (6,20)
0243  20    FORMAT (/" INVERTED H*HT-MATRIX")
0244        WRITE (6,94) ((HPROD(I,J),J=1,4),I=1,4)
0245  C
0246  C ********** THE TRACE OF THE MATRIX IS THE SUM OF ITS ***********
0247  C                           DIAGONAL ELEMENTS
0248  C
0249        TRACEZ=HPROD(1,1)+HPROD(2,2)
0250        HDOPV=DSQRT(TRACEZ)
0251        PDOPV=DSQRT(TRACEZ+HPROD(3,3))
0252        TRACEZ=TRACEZ+HPROD(3,3)+HPROD(4,4)
0253        GDOPV=DSQRT(TRACEZ)
0254        HDOP=SNGL(HDOPV)
0255        PDOP=SNGL(PDOPV)
0256        GDOP=SNGL(GDOPV)
0257        IF(NSAT.EQ.3.AND.IST2.NE.1) GDOP=1.E20
0258        WRITE (6,21) HDOP,PDOP,GDOP
0259        WRITE (16,21) HDOP,PDOP,GDOP
0260  21    FORMAT ( " HDOP = ",F10.5," PDOP = ",F10.5," GDOP = ",F10.5,//)
0261        NUM=NUM+1
0262        IF(IST.EQ.1) GOTO 1002
0263  C
0264  C ********** FORMATS **********
0265  C
0266  90    FORMAT (D16.8)
0267  91    FORMAT (F15.8)
0268  92    FORMAT (I2)
0269  93    FORMAT (3A2)
0270  94    FORMAT (4D16.8)
0271        STOP
0272        END
```

```
&EB02  T=00004 IS ON CR00011 USING 00012 BLKS R=0000

0001   FTN4X,L,Y
0002   C ***************************************************
0003   C *          FILENAME : &EB02                       *
0004   C *                                                 *
0005   C *        PROGRAM COMPUTES THE E-MATRIX            *
0006   C ***************************************************
0007   C
0008         SUBROUTINE EB02
0009         IMPLICIT DOUBLE PRECISION (A-H,K-Z)
0010         COMMON/ELEV/E(3,3)
0011         COMMON/POS/LAT,LON,ALT,R
0012   C ------------------
0013         SN=DSIN(LON)
0014         CN=DCOS(LON)
0015         ST=DSIN(LAT)
0016         CT=DCOS(LAT)
0017         E(1,1)=-SN
0018         E(1,2)=CN
0019         E(1,3)=0.0
0020         E(2,1)=-CN*ST
0021         E(2,2)=-SN*ST
0022         E(2,3)=CT
0023         E(3,1)=CN*CT
0024         E(3,2)=SN*CT
0025         E(3,3)=ST
0026         RETURN
0027         END
```

```
&EB03  T=00004 IS ON CR00011 USING 00012 BLKS R=0000

0001  FTN4X,L,Y
0002  C ***************************************************
0003  C *                FILENAME :  &EB03                *
0004  C *                                                 *
0005  C * COMPUTES THE USER-POSITION IN ECEF-COORDINATES *
0006  C * (TU-VECTOR=U-VECTOR (IN MAINPROGRAM) )          *
0007  C *                                                 *
0008  C ***************************************************
0009  C
0010        SUBROUTINE EB03
0011        IMPLICIT DOUBLE PRECISION(A-Z)
0012        COMMON/CNST/PI,RTD,OMF,AE,E2,OMF2,SGC,ERATE
0013        COMMON/DTX/TU(4)
0014        COMMON/POS/LAT,LON,ALT,XY
0015  C -----------------
0016        SLAT=DSIN(LAT)
0017        XY=AE/DSQRT(1.E0-E2*SLAT*SLAT)
0018        TU(3)=(XY*OMF2+ALT)*SLAT
0019        XY=(XY+ALT)*DCOS(LAT)
0020        TU(1)=XY*DCOS(LON)
0021        TU(2)=XY*DSIN(LON)
0022        RETURN
0023        END
```

```
&EB05  T=00004 IS ON CR00011 USING 00012 BLKS R=0000

0001  FTN4X,L,Y
0002  C ***************************************************************
0003  C *                FILENAME :  &EB05                            *
0004  C *                                                             *
0005  C *      COMPUTES ELEVATION AND AZIMUTH OF SATELLITES AND IN    *
0006  C *   SUB. "EB06" THE POSITION AND IN SUB. "EB07" THE DISTANCE  *
0007  C *   USER-SATELLITE.                                           *
0008  C *                                                             *
0009  C ***************************************************************
0010  C
0011        SUBROUTINE EB05 (I)
0012        IMPLICIT DOUBLE PRECISION (A-H,K-Z)
0013        DIMENSION Y(4,3)
0014        COMMON/ELEV/E(3,3)
0015        COMMON/SAT/S(4)
0016        COMMON/AZM/ELV(4),AZM(4)
0017        COMMON/CNST/PI,RTD,OMF,AE,E2,OMF2,SGC,ERATE
0018        COMMON/DTX/U(4),D(4,4),RBAR(4)
0019  C ---------------------
0020        CALL EB06
0021        CALL EB07(I)
0022        DO 100 II=1,3
0023        Y(I,II)=0.D0
0024        DO 100 III=1,3
0025        Y(I,II)=Y(I,II)+S(III)*E(II,III)
0026  100   CONTINUE
0027  C
0028  C ********** COMPUTATION OF ELEVATION AND AZIMUTH OF **********
0029  C                      SATELLITES AND OUTPUT
0030  C
0031        Y(I,3)=Y(I,3)-AE
0032        SY=DSQRT(Y(I,1)*Y(I,1)+Y(I,2)*Y(I,2))
0033        ELV(I)=DATAN2(Y(I,3),SY)*RTD
0034        AZM(I)=DATAN2(Y(I,1),Y(I,2))*RTD
0035        IF(AZM(I).LT.0.) AZM(I)=AZM(I)+360.0
0036        WRITE (6,1) (S(J),J=1,3),ELV(I),AZM(I)
0037  1     FORMAT (5(2X,D12.4))
0038        RETURN
0039        END
```

```
&EB06  T=00004 IS ON CR00011 USING 00018 BLKS P=0000

0001   FTN4X,L,Y
0002   C ***************************************************
0003   C *                  FILENAME :  &EB06                *
0004   C *                                                   *
0005   C * COMPUTES THE ACTUAL POSITION OF THE SATELLITE     *
0006   C * IN ECEF-COORDINATES ( S-VECTOR = X,Y,Z )          *
0007   C *                                                   *
0008   C ***************************************************
0009   C
0010          SUBROUTINE EB06
0011          IMPLICIT DOUBLE PRECISION (A-Z)
0012          INTEGER I
0013          COMMON/NAC/TUY,TCY,TKC,DTC(4),DTU,TC,T
0014          COMMON/CNST/PI,RTD,OMF,AE,E2,OMF2,SGC,ERATE,PI2
0015          COMMON/SAT/X,Y,Z,MK
0016          COMMON/DB2/ECC,TOE,INOT,NRATE,SRAD,OMED,OME,MNOT,R,CINO,
0017         *SINO,COME,SOME,C
0018   C ---------------------------
0019          A=TC-TOE
0020          TUY=DTU+T
0021          IF(A.GT.-0.3024D6.AND.A.LT.3024D6) TKC=A
0022          IF(A.LT.-0.3024D6) TKC=A+0.6048D6
0023          IF(A.GT.0.3024D6) TKC=A-0.6048D6
0024          TK=TUY-TCY+TKC
0025          OGA=OMEO+(NRATE-ERATE)*TK-ERATE*TOE
0026          MK=MNOT+C*TK
0027        6 IF(MK.GE.-PI2)GO TO 7
0028          MK=MK+PI2
0029          GO TO 6
0030        7 IF(MK.LE.PI2)GO TO 8
0031          MK=MK-PI2
0032          GO TO 7
0033        8 EK=MK+ECC*DSIN(MK)
0034          DO 100 I=1,4
0035          COSE=DCOS(EK)
0036          SINE=DSIN(EK)
0037          TK=1.-ECC*COSE
0038   100    EK=EK-(EK-MK-ECC*SINE)/TK
0039          COSE=(COSE-ECC)/TK
0040          SINE=DSQRT(1.-ECC*ECC)*SINE/TK
0041          EK=COSE*COME-SINE*SOME
0042          MK=SINE*COME+COSE*SOME
0043          SINE=2.*MK*EK
0044          COSE=2.*EK*EK-1.
0045          RK=TK*R
0046          X=RK*EK
0047          Y=RK*MK
0048          Z=Y*SINO
0049          EK=CINO*Y
0050          SINE=DSIN(OGA)
0051          COSE=DCOS(OGA)
0052          Y=X*SINE+EK*COSE
0053          X=X*COSE-EK*SINE
0054          RETURN
0055          END
```

```
&EB07  T=00004 IS ON CR00011 USING 00012 BLKS R=0000

0001   FTN4X,L,Y
0002   C ***************************************************
0003   C *              FILENAME : &EB07                   *
0004   C *                                                 *
0005   C *     COMPUTES DISTANCES TO SATTELLITE            *
0006   C *                                                 *
0007   C ***************************************************
0008   C
0009         SUBROUTINE EB07(I)
0010         IMPLICIT DOUBLE PRECISION (A-H,K-Z)
0011         COMMON/SAT/S(4)
0012         COMMON/DTX/U(4),D(4,4),R(4)
0013   C -----------------------
0014         R(I)=0.
0015         DO 100 J=1,3
0016         D(I,J)=S(J)-U(J)
0017         R(I)=D(I,J)*D(I,J)+R(I)
0018   100   CONTINUE
0019         R(I)=DSQRT(R(I))
0020         D(I,4)=1.0
0021         RETURN
0022         END
```

```
&EB09  T=00004 IS ON CR00011 USING 00012 BLKS R=0000

0001   FTN4X,L,Y
0002   C ***************************************************
0003   C *               FILENAME : &EB09                  *
0004   C *                                                 *
0005   C * MULTIPLICATES TWO MATRICES --> H*G=A            *
0006   C *                                                 *
0007   C ***************************************************
0008   C
0009         SUBROUTINE EB09
0010         IMPLICIT DOUBLE PRECISION (A-H,L-Z)
0011         COMMON/MAT/G(4,4),H(4,4),A(4,4)
0012   C ------------------
0013         DO 100 I=1,4
0014         DO 100 J=1,4
0015         TEMP=0.0D0
0016         DO 101 K=1,4
0017         TEMP=TEMP+H(I,K)*G(K,J)
0018   101   CONTINUE
0019         A(I,J)=TEMP
0020   100   CONTINUE
0021         RETURN
0022         END
```

```
&EB12  T=00004 IS ON CR00011 USING 00012 BLKS R=0000

0001   FTN4X,L,Y
0002   C ***************************************************
0003   C *               FILENAME : &EB12                  *
0004   C *                                                 *
0005   C * ROUTINE TO CONVERT SECONDS TO HOURS MIN SEC.    *
0006   C *                                                 *
0007   C ***************************************************
0008   C
0009         SUBROUTINE EB12 (TMIN,THR)
0010         IMPLICIT DOUBLE PRECISION (A-Z)
0011         REAL THR
0012         INTEGER*4 HR,MIN,SEC
0013   C ----------------------
0014         THR=(SNGL(TMIN)/3600.0)+.00005
0015         HR=INT(THR)
0016         THR=(THR-HR)*60
0017         MIN=INT(THR)
0018         THR=(THR-MIN)*60
0019         SEC=INT(THR)
0020         THR=HR+(MIN*.01)+(SEC*.0001)+.00005
0021         RETURN
0022         END
```

```
&EB14  T=00004 IS ON CR00011 USING 00024 BLKS R=0000

0001   FTN4,L,Y
0002   C ***************************************************
0003   C *              FILENAME : &EB14                   *
0004   C * READS ALMANAC-DATA FROM DATA-TAPE,CONVERTS IT   *
0005   C * INTO DOUBLE PRECISION AND CREATES ARRAY WITH    *
0006   C * DATA FOR MAINPROGRAM.                          *
0007   C *                                                 *
0008   C ***************************************************
0009   C
0010         SUBROUTINE EB14
0011         DOUBLE PRECISION AD,A,B,C,DTC
0012         COMMON/ALM/AD(14,24),ID1(24)
0013         COMMON/NAC/A,B,C,DTC
0014         DIMENSION IALMAC(12,24),ISVPRN(24),ID(24)
0015         INTEGER ALMAC(24,24),IAR(2),IBUF(310),IDARY(24)
0016         EQUIVALENCE(IBUF(16),IALMAC)
0017         REAL OMD,OMO,MO
0018         INTEGER H
0019         DATA PI/3.14159265/,ISVPRN/4,7,6,8,5,9,18*0/
0020   C
0021   C  ISTAD IS THE STARTING ADDRESS OF ALMANAC DATA AND IWCNT IS THE NUMBER
0022   C  OF WORDS IN THE ALMANAC DATA.
0023   C
0024         DATA ISTAD/172700B/,IWCNT/310/,LU8/8/
0025   C
0026   C  CALL EXEC TO READ IN ALMANAC DATA.
0027   C
0028   100   CALL EXEC(1,LU8,IBUF,IWCNT)
0029         CALL ABREG(IERR,NWRD)
0030         IF(NWRD .NE. 288) GO TO 100
0031         DO 40 J=1,24
0032            DO 50 I=1,12
0033            I2=2*I
0034            I1=I2-1
0035            ITMP=IALMAC(I,J)
0036            ALMAC(I1,J)=IAND(ITMP,377B)
0037            ALMAC(I2,J)=ISHFT(ITMP,-8)
0038   50       CONTINUE
0039   40    CONTINUE
0040         WRITE(16,120)
0041         READ(16,*)DTC
0042   C
0043   C  GET SATELLITE ID(PRN NUMBER) FROM ALMANAC DATA.
0044   C
0045         DO 10 J=1,24
0046            DO 20 I=1,24
0047            ID(I)=ALMAC(1,I)
0048   C
0049   C  TEST TO SEE IF SATELLITE IS IN PRN NUMBER ORDER.
0050   C
0051            IF(ID(I).EQ. 0)GO TO 20
0052            IF(ID(I).EQ. ISVPRN(J))GO TO 30
0053   20       CONTINUE
0054         GO TO 10
0055   C
0056   C  GET ECENTRICITY OF SATELLITE ORBIT FROM ALMANAC DATA.
0057   C
0058   30    IAR(2)=IOR(ISHFT(ALMAC(2,I),8),ALMAC(3,I))
```

```
0059          IDARY(J)=ID
0060          IAR(1)=0
0061          ID1(J)=ID(I)
0062    C
0063    C  ECENTRICITY IS SCALED BY A FACTOR OF 2**-21.
0064    C
0065          E=DINTF(IAR)*4.7683716E-7
0066    C
0067    C  GET TIME OF APPLICABILITY OF THE ALMANAC PARAMETERS.
0068    C
0069          IAR(2)=ALMAC(4,I)
0070          IAR(1)=0
0071    C
0072    C  TOA(SECONDS) IS SCALED BY A FACTOR OF 2**12.
0073    C
0074          TOA=DINTF(IAR)*4096.0
0075    C
0076    C  GET SATELLITE ORBIT INCLINATION FROM ALMANAC DATA.
0077    C
0078          IAR(2)=IOR(ISHFT(ALMAC(5,I),8),ALMAC(6,I))
0079          IAR(1)=0
0080          IF(IAR(2) .LT. 0) IAR(1)=-1
0081    C
0082    C  DI(SEMICIRCLES) IS SCALED BY A FACTOR OF 2**-19 INCREMENTED
0083    C  BY 1/3 AND MULTIPLIED BY PI TO YIELD RADIANS.
0084    C
0085          DI=((DINTF(IAR)*1.9073486E-6)+(1.0/3.0))*PI
0086    C
0087    C  GET DRIFT RATE OF LONGITUDE OF ASCENDING NODE OF THE ORBIT
0088    C  FROM ALMANAC DATA.
0089    C
0090          IAR(1)=0
0091          IAR(2)=IOR(ISHFT(ALMAC(7,I),8),ALMAC(8,I))
0092          IF(IAR(2) .LT. 0) IAR(1)=-1
0093    C
0094    C  OMD (SEMICIRCLES/SEC) IS SCALED BY A FACTOR OF 2**-38 AND
0095    C  MULTIPLIED BY PI TO YIELD RADIANS/SEC.
0096    C
0097          OMD=DINTF(IAR)*PI*3.6379788E-12
0098    C
0099    C  GET HEALTH WORD FROM ALMANAC DATA.
0100    C
0101          H=ALMAC(9,I)
0102    C
0103    C  GET THE SQUARE ROOT OF THE SEMI-MAJOR AXIS OF THE ORBIT
0104    C  FROM ALMANAC DATA.
0105    C
0106          IAR(1)=ALMAC(10,I)
0107          IAR(2)=IOR(ISHFT(ALMAC(11,I),8),ALMAC(12,I))
0108    C
0109    C  RA(METERS) IS SCALED BY A FACTOR OF 2**-11.
0110    C
0111          RA=DINTF(IAR)*4.8828125E-4
0112    C
0113    C  GET THE RIGHT ASCENSION OF THE ORBIT FROM ALMANAC DATA.
0114    C
0115          IAR(2)=IOR(ISHFT(ALMAC(14,I),8),ALMAC(15,I))
0116          IAR(1)=ALMAC(13,I)
0117          IF(IAND(ALMAC(13,I),200B).NE.0)IAR(1)=IOR(IAR(1),177400B)
0118    C
```

```
0119   C  OMO(SEMICIRCLES)IS SCALED BY A FACTOR OF 2**-23 AND
0120   C  MULTIPLIED BY PI TO YIELD RADIANS.
0121   C
0122          OMO=DINTF(IAR)*PI*1.1920929E-7
0123   C
0124   C  GET THE ARGUMENT OF PERIGEE FROM ALMANAC DATA.
0125   C
0126          IAR(1)=ALMAC(16,I)
0127          IAR(2)=IOR(ISHFT(ALMAC(17,I),8),ALMAC(18,I))
0128          IF(IAND(IAR(1),200B).NE.0)IAR(1)=IOR(IAR(1),177400B)
0129   C
0130   C  W(SEMICIRCLES) IS SCALED BY A FACTOR OF 2**-23 AND
0131   C  MULTIPLIED BY PI TO YIELD RADIANS.
0132   C
0133          W=DINTF(IAR)*PI*1.1920929E-7
0134   C
0135   C  GET MEAN ANOMALY AT TOA FROM ALMANAC DATA.
0136   C
0137          IAR(1)=ALMAC(19,I)
0138          IF(IAND(IAR(1),200B).NE.0)IAR(1)=IOR(IAR(1),177400B)
0139          IAR(2)=IOR(ISHFT(ALMAC(20,I),8),ALMAC(21,I))
0140   C
0141   C  MO(SEMICIRCLES) IS SCALED BY A FACTOR OF 2**-23 AND
0142   C  MULTIPLIED BY PI TO YIELD RADIANS.
0143   C
0144          MO=DINTF(IAR)*PI*1.1920929E-7
0145          AD(1,J)=DBLE(E)
0146          AD(2,J)=DBLE(TOA)
0147          AD(3,J)=DBLE(DI)
0148          AD(4,J)=DBLE(OMD)
0149          AD(5,J)=DBLE(RA)
0150          AD(6,J)=DBLE(OMO)
0151          AD(7,J)=DBLE(W)
0152          AD(8,J)=DBLE(MO)
0153   10     CONTINUE
0154          RETURN
0155   120    FORMAT(" ENTER COLLECTION DATE FOR ALMANAC DATA(NTH DAY)_")
0156          END
```

```
&HD01  T=00004 IS ON CR00011 USING 00018 BLKS R=0000

0001  FTN4X,L,Y
0002  C ***************************************************
0003  C *                FILENAME : &HD01                 *
0004  C *                                                 *
0005  C * COMPUTES THE G-MATRIX,INVERTES AND TRANSPONES   *
0006  C * IT AND COMPUTES THE HDOP AND GDOP.              *
0007  C *  FORMULAS FROM : MILLIKEN/ZOLLER                *
0008  C *                  "NAVSTAR OPERATION"            *
0009  C *                                                 *
0010  C ***************************************************
0011  C
0012        SUBROUTINE HD01
0013        IMPLICIT DOUBLE PRECISION (A-H,K-M,O-Z)
0014        DIMENSION IL(4),IM(4)
0015        COMMON/POS/LAT,LON,ALT
0016        COMMON/DTX/U(4),D(4,4)
0017        COMMON/CNST/PI,RTD
0018        COMMON/BLG/G(4,4),N              !  FOR MATRIXINVERSION
0019        COMMON/MAT/A(4,4),AT(4,4),AAT(4,4)
0020        COMMON/HDOP/HDOP,INS,GDOP
0021        N=4
0022  C
0023  C ********** COMPUTATION OF A (=G) **********
0024  C
0025        A1=DSIN(LON)
0026        A2=DCOS(LON)
0027        A3=DSIN(LAT)
0028        A4=DCOS(LAT)
0029        IF(INS.EQ.4) GOTO 1000
0030        DO 102 I=1,4
0031        D(4,I)=U(I)
0032  102   CONTINUE
0033  1000  CONTINUE
0034        DO 100 I=1,4
0035        A5=1./DSQRT(D(I,1)*D(I,1)+D(I,2)*D(I,2)+D(I,3)*D(I,3))
0036        A(I,1)=(-D(I,1)*A1+D(I,2)*A2)*A5
0037        A(I,2)=(-D(I,1)*A3*A2-D(I,2)*A3*A1+D(I,3)*A4)*A5
0038        A(I,3)=(D(I,1)*A4*A2+D(I,2)*A4*A1+D(I,3)*A3)*A5
0039        A(I,4)=1.
0040  100   CONTINUE
0041  C
0042  C ********** MATRIX-TRANSPONATION **********
0043  C
0044        DO 101 I=1,4
0045        DO 101 J=1,4
0046        AT(I,J)=A(J,I)
0047  101   CONTINUE
0048  C
0049  C ********** MULTIPLICATION OF MATRIZES (AT*A)=AAT **********
0050  C
0051        CALL EB09
0052  C
0053  C ********** INVERSION OF AAT AND COMPUTATION OF HDOP **********
0054  C
0055        DO 103 I=1,4
0056        DO 103 J=1,4
0057        G(I,J)=AAT(I,J)
0058  103   CONTINUE
```

```
0059          CALL MINVD(G,N,DET,IL,IM)
0060          IF(DET.EQ.0.0D0) GOTO 1001
0061          HDOP=DSQRT(G(1,1)+G(2,2))
0062          GDOP=DSQRT(G(1,1)+G(2,2)+G(3,3)+G(4,4))
0063          RETURN
0064    1001  CONTINUE
0065          WRITE (6,1)
0066          WRITE (16,1)
0067    1     FORMAT ( " ********************* "
0068         1/          " *MATRIX SINGULAR* "
0069         2/          " ********************* ")
0070          RETURN
0071          END
```

```
&MINVD T=00003 IS ON CR00011 USING 00024 BLKS R=0000

0001  FTN4X,L,Y
0002  C
0003  C     ..................................................................
0004  C
0005  C        SUBROUTINE MINVD           HP-VERSION
0006  C
0007  C        PURPOSE
0008  C           INVERT A MATRIX
0009  C
0010  C        USAGE
0011  C           CALL MINVD(A,N,D,L,M)
0012  C
0013  C        DESCRIPTION OF PARAMETERS
0014  C           A - INPUT MATRIX, DESTROYED IN COMPUTATION AND REPLACED BY
0015  C               RESULTANT INVERSE.
0016  C           N - ORDER OF MATRIX A
0017  C           D - RESULTANT DETERMINANT
0018  C           L - WORK VECTOR OF LENGTH N
0019  C           M - WORK VECTOR OF LENGTH N
0020  C
0021  C        REMARKS
0022  C           MATRIX A MUST BE A GENERAL MATRIX
0023  C
0024  C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
0025  C           NONE
0026  C
0027  C        METHOD
0028  C           THE STANDARD GAUSS-JORDAN METHOD IS USED. THE DETERMINANT
0029  C           IS ALSO CALCULATED. A DETERMINANT OF ZERO INDICATES THAT
0030  C           THE MATRIX IS SINGULAR.
0031  C
0032  C     ..................................................................
0033  C
0034        SUBROUTINE MINVD(A,N,D,L,M)
0035        IMPLICIT DOUBLE PRECISION (A-H,O-T,V-Z)
0036        IMPLICIT REAL*4 (U)
0037        DIMENSION A(1),L(1),M(1)
0038  C
0039  C        SEARCH FOR LARGEST ELEMENT
0040  C
0041        D=1.0D0
0042        NK=-N
0043        DO 80 K=1,N
0044        NK=NK+N
0045        L(K)=K
0046        M(K)=K
0047        KK=NK+K
0048        BIGA=A(KK)
0049        DO 20 J=K,N
0050        IZ=N*(J-1)
0051        DO 20 I=K,N
0052        IJ=IZ+I
0053     10 IF(DABS(BIGA)-DABS(A(IJ))) 15,20,20
0054     15 BIGA=A(IJ)
0055        L(K)=I
0056        M(K)=J
0057     20 CONTINUE
0058  C
```

```
0059  C         INTERCHANGE ROWS
0060  C
0061          J=L(K)
0062          IF(J-K) 35,35,25
0063       25 KI=K-N
0064          DO 30 I=1,N
0065          KI=KI+N
0066          HOLD=-A(KI)
0067          JI=KI-K+J
0068          A(KI)=A(JI)
0069       30 A(JI) =HOLD
0070  C
0071  C         INTERCHANGE COLUMNS
0072  C
0073       35 I=M(K)
0074          IF(I-K) 45,45,38
0075       38 JP=N*(I-1)
0076          DO 40 J=1,N
0077          JK=NK+J
0078          JI=JP+J
0079          HOLD=-A(JK)
0080          A(JK)=A(JI)
0081       40 A(JI) =HOLD
0082  C
0083  C         DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
0084  C         CONTAINED IN BIGA)
0085  C
0086       45 IF(BIGA) 48,46,48
0087       46 D=0.0D0
0088          RETURN
0089       48 DO 55 I=1,N
0090          IF(I-K) 50,55,50
0091       50 IK=NK+I
0092          A(IK)=A(IK)/(-BIGA)
0093       55 CONTINUE
0094  C
0095  C         REDUCE MATRIX
0096  C
0097          DO 65 I=1,N
0098          IK=NK+I
0099          HOLD=A(IK)
0100          IJ=I-N
0101          DO 65 J=1,N
0102          IJ=IJ+N
0103          IF(I-K) 60,65,60
0104       60 IF(J-K) 62,65,62
0105       62 KJ=IJ-I+K
0106          A(IJ)=HOLD*A(KJ)+A(IJ)
0107       65 CONTINUE
0108  C
0109  C         DIVIDE ROW BY PIVOT
0110  C
0111          KJ=K-N
0112          DO 75 J=1,N
0113          KJ=KJ+N
0114          IF(J-K) 70,75,70
0115       70 A(KJ)=A(KJ)/BIGA
0116       75 CONTINUE
0117  C
0118  C         PRODUCT OF PIVOTS
```

```
0119   C
0120         D=D*BIGA
0121   C
0122   C           REPLACE PIVOT BY RECIPROCAL
0123   C
0124         A(KK)=1.0D0/BIGA
0125      80 CONTINUE
0126   C
0127   C           FINAL ROW AND COLUMN INTERCHANGE
0128   C
0129         K=N
0130     100 K=(K-1)
0131         IF(K) 150,150,105
0132     105 I=L(K)
0133         IF(I-K) 120,120,108
0134     108 JQ=N*(K-1)
0135         JR=N*(I-1)
0136         DO 110 J=1,N
0137         JK=JQ+J
0138         HOLD=A(JK)
0139         JI=JR+J
0140         A(JK)=-A(JI)
0141     110 A(JI) =HOLD
0142     120 J=M(K)
0143         IF(J-K) 100,100,125
0144     125 KI=K-N
0145         DO 130 I=1,N
0146         KI=KI+N
0147         HOLD=A(KI)
0148         JI=KI-K+J
0149         A(KI)=-A(JI)
0150     130 A(JI) =HOLD
0151         GO TO 100
0152     150 RETURN
0153         END
```

```
&DINTF T=00004 IS ON CR00013 USING 00003 BLKS R=0000

0001  ASMB,L
0002         NAM   DINTF
0003         ENT   DINTF
0004         EXT   .FLTD
0005  DINTF  NOP
0006         ISZ   DINTF
0007         LDA   DINTF,I
0008         STA   IBF
0009         ISZ   DINTF
0010         DLD   IBF,I
0011         AND   B377
0012         JSB   .FLTD
0013         JMP   DINTF,I
0014  IBF    BSS   1
0015  B377   OCT   377
0016         END
```

```
&ENU   T=00003 IS ON CR00002 USING 00023 BLKS R=0000

0001  FTN4,M,Y
0002  C*************************************************************************
0003  C                                                                        *
0004  C       THIS SUBROUTINE FILLS THE ENUP MATRIX.                           *
0005  C                                                                        *
0006  C       MICHAEL J. MAGROGAN  CO-OP  ACT-100D  FEBRUARY 1981              *
0007  C                                                                        *
0008  C*************************************************************************
0009        SUBROUTINE ENU
0010  C  THIS SUBROUTINE IS PASSED AIRCRAFT POSITION(XP,YP,ZP) FROM THE MAIN
0011  C  PROGRAM(GDOP) AND RETURNS THE FILLED ENUP MATRIX.
0012        COMMON /COORD/ ENUP(3,3),XP,YP,ZP,H(4,4),HT(4,4),HPROD(4,4),
0013       +LSAT(4),XS(4),YS(4),ZS(4),HDOPV,GDOPV
0014        DOUBLE PRECISION ENUP,XP,YP,ZP,H,HT,HPROD,XS,YS,ZS,HDOPV,GDOPV
0015        DOUBLE PRECISION WP,TANPHI,COSLAM,SINLAM,COSPHI,SINPHI,ESQU
0016        DATA ESQU/0.006694317778D0/
0017  C  CALCULATE THE TERMS NEEDED TO FILL ENUP MATRIX.
0018        WP=DSQRT(XP**2+YP**2)
0019        TANPHI=ZP/WP
0020        COSLAM=XP/WP
0021        SINLAM=YP/WP
0022        TANPHI=TANPHI/(1.D0-ESQU)
0023        COSPHI=1.D0/DSQRT(1.D0+TANPHI**2)
0024        SINPHI=COSPHI*TANPHI
0025  C  FILL ENUP MATRIX.
0026        ENUP(1,1)=-SINLAM
0027        ENUP(1,2)=COSLAM
0028        ENUP(1,3)=0.D0
0029        ENUP(2,1)=-SINPHI*COSLAM
0030        ENUP(2,2)=-SINPHI*SINLAM
0031        ENUP(2,3)=COSPHI
0032        ENUP(3,1)=COSPHI*COSLAM
0033        ENUP(3,2)=COSPHI*SINLAM
0034        ENUP(3,3)=SINPHI
0035        RETURN
0036        END
```

```
&HTRAN T=00003 IS ON CR00002 USING 00007 BLKS R=0000

0001   FTN4,L,Y
0002   C*************************************************************************
0003   C                                                                        *
0004   C        THIS SUBROUTINE COMPUTES THE TRANSPOSE OF THE H MATRIX.         *
0005   C                                                                        *
0006   C        MICHAEL J. MAGROGAN  CO-OP  ACT-100D  FEBRUARY 1981             *
0007   C                                                                        *
0008   C*************************************************************************
0009         SUBROUTINE HTRAN
0010   C  THIS SUBROUTINE IS PASSED THE H MATRIX FROM THE MAIN PROGRAM(GDOP)
0011   C  AND RETURNS THE TRANSPOSE OF THE H MATRIX(HT).
0012         COMMON /COORD/ ENUP(3,3),XP,YP,ZP,H(4,4),HT(4,4),HPROD(4,4),
0013        +LSAT(4),XS(4),YS(4),ZS(4),HDOPV,GDOPV
0014         DOUBLE PRECISION ENUP,XP,YP,ZP,H,HT,HPROD,XS,YS,ZS,HDOPV,GDOPV
0015   C  COMPUTE THE TRANSPOSE OF THE H MATRIX.
0016         DO 10 I=1,4
0017           DO 20 J=1,4
0018             HT(I,J)=H(J,I)
0019      20 CONTINUE
0020      10 CONTINUE
0021         RETURN
0022         END
```

```
&MLHHT T=00003 IS ON CR00002 USING 00024 BLKS R=0000

0001  FTN4,L,Y
0002  C*****************************************************************
0003  C                                                                *
0004  C        THIS SUBROUTINE MULTILLIES THE H AND H TRANSPOSE MATRICES *
0005  C                                                                *
0006  C        MICHAEL J. MAGROGAN CO-OP ACT-100D FEB 1981             *
0007  C                                                                *
0008  C*****************************************************************
0009        SUBROUTINE MLHHT
0010  C THIS SUBROUTINE IS PASSED THE H AND H TRANSPOSE MATRICES FROM THE
0011  C NAIN PROGRAM (GDOP) AND RETURNS THE PRODUCT MATRIX (HPROD)
0012        COMMON/COORD/ENUP(3,3),XP,YP,ZP,H(4,4),HT(4,4),HPROD(4,4),
0013       +LSAT(4),XS(4),YS(4),ZS(4),HDOPV,GDOPV
0014        DOUBLE PRECISION ENUP,XP,YP,ZP,H,HT,HPROD,XS,YS,ZS,HDOPV,GDOPV
0015  C MULTIPLY THE H AND HT MATRICES
0016        DO 10 I=1,4
0017        DO 10 J=1,4
0018        HPROD(I,J)=0.D0
0019        DO 10 K=1,4
0020        HPROD(I,J)=HPROD(I,J)+HT(I,K)*H(K,J)
0021  10    CONTINUE
0022        RETURN
0023        END
```

```
&INVHP T=00003 IS ON CR00002 USING 00024 BLKS R=0000

0001  FTN4,L,Y
0002  C*****************************************************************
0003  C                                                                *
0004  C       THIS SUBROUTINE WAS WRITTEN BY CHE S. WONG IT IS IN HIS   *
0005  C       PAPER "A GPS ALMANAC", HE CALLS THIS SUBROUTINE "MATI".   *
0006  C                                                                *
0007  C                                                                *
0008  C       MICHAEL J. MAGROGAN  CO-OP  ACT-100D  FEBRUARY 1981      *
0009  C                                                                *
0010  C*****************************************************************
0011        SUBROUTINE INVHP
0012  C  'INVHPR' INVERTS THE H PRODUCT MATRIX AND SUBSTITUTES THE
0013  C  RESULTS BACK INTO THE H PRODUCT MATRIX.
0014  C
0015  C  THIS SUBROUTINE IS PASSED THE H PRODUCT MATRIX(HPROD) FROM THE
0016  C  MAIN PROGRAM(GDOP) AND RETURNS THE MATRIX INVERSE OF THE H
0017  C  PRODUCT MATRIX(HPROD).
0018        COMMON /COORD/ENUP(3,3),XP,YP,ZP,H(4,4),HT(4,4),HPROD(4,4),
0019       +LSAT(4),XS(4),YS(4),ZS(4),HDOPV,GDOPV,DET
0020        DOUBLE PRECISION ENUP,XP,YP,ZP,H,HT,HPROD,XS,YS,ZS,HDOPV,GDOPV
0021        DOUBLE PRECISION PIVOT,ONE,ZERO,T,DET
0022        DIMENSION INDEX(4,2),IPVOT(4),PIVOT(4)
0023        DATA ONE/1.D0/,ZERO/0.D0/
0024        DET=1.D0
0025  C  CLEAR IPVOT VECTOR.
0026        DO 10 I=1,4
0027          IPVOT(I)=0
0028     10 CONTINUE
0029  C  FOLLOWING 12 STATEMENTS SEARCH FOR PIVOT ELEMENT.
0030        DO 20 I=1,4
0031          T=ZERO
0032          DO 30 J=1,4
0033            IF(IPVOT(J)-1) 31,30,31
0034     31     DO 40 K=1,4
0035              IF(IPVOT(K)-1) 41,40,91
0036     41       IF(DABS(T)-DABS(HPROD(J,K))) 42,40,40
0037     42       IROW=J
0038              ICOL=K
0039              T=HPROD(J,K)
0040     40 CONTINUE
0041     30 CONTINUE
0042          IPVOT(ICOL)=IPVOT(ICOL)+1
0043  C  FOLLOWING 15 STATEMENTS PUT PIVOT ELEMENT ON DIAGONAL.
0044          IF(IROW-ICOL) 43,51,43
0045     43   DET=-DET
0046            DO 50 L=1,4
0047              T=HPROD(IROW,L)
0048              HPROD(IROW,L)=HPROD(ICOL,L)
0049     50       HPROD(ICOL,L)=T
0050     51   INDEX(I,1)=IROW
0051          INDEX(I,2)=ICOL
0052          PIVOT(I)=HPROD(ICOL,ICOL)
0053          DET=DET*PIVOT(I)
0054  C  THE FOLLOWING 6 STATEMENTS DIVIDE PIVOT ROW
0055  C  BY PIVOT ELEMENT.
0056          HPROD(ICOL,ICOL)=ONE
0057            DO 60 L=1,4
0058     60       HPROD(ICOL,L)=HPROD(ICOL,L)/PIVOT(I)
```

```
0059  C  FOLLWOING 10 STATEMENTS TO REDUCE NON-PIVOT ROWS.
0060               DO 20 LI=1,4
0061                 IF(LI-ICOL) 21,20,21
0062     21          T=HPROD(LI,ICOL)
0063                 HPROD(LI,ICOL)=ZERO
0064                 DO 70 L=1,4
0065     70            HPROD(LI,L)=HPROD(LI,L)-HPROD(ICOL,L)*T
0066     20 CONTINUE
0067  C  FOLLOWING 11 STATEMENTS TO INTERCHANGE COLUMNS.
0068        DO 80 I=1,4
0069        L=4-I+1
0070        IF(INDEX(L,1)-INDEX(L,2))81,80,81
0071  81    JROW=INDEX(L,1)
0072        JCOL=INDEX(L,2)
0073        DO90K=1,4
0074        T=HPROD(K,JROW)
0075             HPROD(K,JROW)=HPROD(K,JCOL)
0076             HPROD(K,JCOL)=T
0077     90 CONTINUE
0078     80 CONTINUE
0079     91 RETURN
0080        END
```

APPENDIX D

EXAMPLES OF DATA FILES

Almanac Files

```
A557    T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001     57.000000       5
0002       0.23045540D-02     0.33177600D+06     0.11124156D+01    -0.61945435D-08
0003       0.51536416D+04     0.56938994D+00    -0.20916948D+01     0.69497383D+00
0004


A657    T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001     57.000000       6
0002       0.15506744D-02     0.33177600D+06     0.11071186D+01     0.64574115D-08
0003       0.51536494D+04    -0.15504746D+01     0.20494380D+01    -0.10743284D+01
0004


A857    T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001     57.000000       8
0002       0.22068024D-02     0.33177600D+06     0.11034214D+01    -0.63431207D-08
0003       0.51536484D+04     0.56528795D+00    -0.19833443D+00     0.35664302D+00
0004


A957    T=00004 IS ON CR00002 USING 00002 BLKS R=0000

0001     57.000000       9
0002       0.81076622D-02     0.33177600D+06     0.11036611D+01    -0.65031278D-08
0003       0.51536670D+04    -0.15456643D+01     0.13524077D+01    -0.11417092D+01
0004
```

URE File

```
U557    T=00004 IS ON CR00002 USING 00024 BLKS R=0000

0001   11
0002       .1050E+02    .1200E+01
0003       .1075E+02    .1330E+01
0004       .1100E+02    .2600E+00
0005       .1125E+02   -.5000E+00
0006       .1150E+02   -.6700E+00
0007       .1175E+02   -.8400E+00
0008       .1200E+02   -.1080E+01
0009       .1225E+02   -.8000E+00
0010       .1250E+02   -.2500E+00
0011       .1275E+02   -.8700E+00
0012       .1300E+02   -.9000E+00
```

PROGRAM *EBGH* VERSION A EXAMPLES OF PROGRAM OUTPUT

```
USER-COORDINATES :
LAT =  39.500000      LON = -74.500000      ALT =  100.00000
XP  =  1317011.6      YP  = -4748990.4      ZP  =  4035321.8
SAT.NO : 1 XS =  -.18330000D+08 YS =  -.19150000D+08 ZS =   .21860000D+07
SAT.NO : 2 XS =  -.28430000D+07 YS =  -.21740000D+08 ZS =   .14930000D+08
SAT.NO : 3 XS =   .97110000D+07 YS =  -.72340000D+07 ZS =   .23660000D+08
SAT.NO : 4 XS =  -.10730000D+08 YS =  -.59120000D+07 ZS =   .23340000D+08

H-MATRIX
 -.93250784D+00  -.28302801D+00   .22433071D+00   .10000000D+01
 -.41485437D+00  -.63121006D-01   .90769576D+00   .10000000D+01
  .34551315D+00   .56740932D+00   .74744052D+00   .10000000D+01
 -.52313791D+00   .71235238D+00   .46784699D+00   .10000000D+01

H-TRANSPOSE-MATRIX
 -.93250784D+00  -.41485437D+00   .34551315D+00  -.52313791D+00
 -.28302801D+00  -.63121006D-01   .56740932D+00   .71235238D+00
  .22433071D+00   .90769576D+00   .74744052D+00   .46784699D+00
  .10000000D+01   .10000000D+01   .10000000D+01   .10000000D+01

HT*H-MATRIX
  .14347276D+01   .11350071D+00  -.57224967D+00  -.15249870D+01
  .11350071D+00   .91348837D+00   .63659009D+00   .93361268D+00
 -.57224967D+00   .63659009D+00   .16517840D+01   .23473140D+01
 -.15249870D+01   .93361268D+00   .23473140D+01   .40000000D+01

INVERTED H*HT-MATRIX
  .36502949D+01  -.19983312D+01  -.36472862D+01   .39984113D+01
 -.19983312D+01   .25934803D+01   .15117074D+01  -.22542968D+01
 -.36472862D+01   .15117074D+01   .74466003D+01  -.61132306D+01
  .39984113D+01  -.22542968D+01  -.61132306D+01   .58879592D+01
HDOP =    2.49875 PDOP =    3.70005 GDOP =    4.42474
```

PROGRAM *EBGH* VERSION A

```
USER-COORDINATES :
LAT =  39.500000      LON = -74.500000      ALT =  100.00000
XP  =  1317011.6      YP  = -4748990.4      ZP  =  4035321.8
SAT.NO : 1 XS =  -.18330000D+08 YS =  -.19150000D+08 ZS =   .21860000D+07
SAT.NO : 2 XS =  -.28430000D+07 YS =  -.21740000D+08 ZS =   .14930000D+08
SAT.NO : 3 XS =   .97110000D+07 YS =  -.72340000D+07 ZS =   .23660000D+08

H-MATRIX
 -.93250784D+00  -.28302801D+00   .22433071D+00   .10000000D+01
 -.41485437D+00  -.63121006D-01   .90769576D+00   .10000000D+01
  .34551315D+00   .56740932D+00   .74744052D+00   .10000000D+01
  .00000000D+00   .00000000D+00  -.10000000D+01   .00000000D+00

H-TRANSPOSE-MATRIX
 -.93250784D+00  -.41485437D+00   .34551315D+00   .00000000D+00
 -.28302801D+00  -.63121006D-01   .56740932D+00   .00000000D+00
  .22433071D+00   .90769576D+00   .74744052D+00  -.10000000D+01
  .10000000D+01   .10000000D+01   .10000000D+01   .00000000D+00

HT*H-MATRIX
```

```
  .11610544D+01    .48615925D+00  -.32750117D+00  -.10018491D+01
  .48615925D+00    .40604245D+00   .30331817D+00   .22126030D+00
 -.32750117D+00    .30331817D+00   .24329032D+01   .18794670D+01
 -.10018491D+01    .22126030D+00   .18794670D+01   .30000000D+01

INVERTED H*HT-MATRIX
  .54713155D+02  -.77387582D+02  -.29281686D+01   .25813506D+02
 -.77387582D+02   .11217536D+03   .37852890D+01  -.36488319D+02
 -.29281686D+01   .37852890D+01   .10000000D+01  -.18835280D+01
  .25813506D+02  -.36488319D+02  -.18835280D+01   .12824894D+02
HDOP =   12.91853 PDOP =   12.95718 GDOP =   13.44297
```

```
PROGRAM *EBGH*       VERSION B
 ***************

FILENAME : !2/23/

RECORD-NO. :    1
TIME       :     .240295D+05 SEC. ==>    6.4029 HOURS GMT
USERPOSITION  --->      .13124184D+07  -.47538986D+07    .40310172D+07
SATELLITE-POSITIONS :
          XS                YS                ZS
 6  -.27384016D+07  -.24919635D+08    .86777768D+07
 9  -.99460549D+07  -.12005477D+08    .21292195D+08
 8   .14541746D+08  -.34133485D+07    .22000845D+08

H-MATRIX
 -.43966564D+00  -.38309360D+00    .81236286D+00    .10000000D+01
 -.58508400D+00   .49393319D+00    .64320037D+00    .10000000D+01
  .58641386D+00   .55738190D+00    .58774502D+00    .10000000D+01
  .00000000D+00   .00000000D+00  -.10000000D+01    .00000000D+00

H-TRANSPOSE-MATRIX
 -.43966564D+00  -.58508400D+00    .58641386D+00    .00000000D+00
 -.38309360D+00   .49393319D+00    .55738190D+00    .00000000D+00
  .81236286D+00   .64320037D+00    .58774502D+00  -.10000000D+01
  .10000000D+01   .10000000D+01    .10000000D+01    .00000000D+00

HT*H-MATRIX
  .87951037D+00   .20629715D+00  -.38883246D+00  -.43833579D+00
  .20629715D+00   .70140529D+00    .33408543D+00    .66822149D+00
 -.38883246D+00   .33408543D+00    .24190843D+01    .20433082D+01
 -.43833579D+00   .66822149D+00    .20433082D+01    .30000000D+01

INVERTED H*HT-MATRIX
  .15438569D+01  -.84117185D+00    .36562251D-01    .38803629D+00
 -.84117185D+00   .23159976D+01    .19894412D+00  -.77427307D+00
  .36562251D-01   .19894412D+00    .10000000D+01  -.72007348D+00
  .38803629D+00  -.77427307D+00  -.72007348D+00    .10529361D+01
HDOP =    1.96465 PDOP =    2.20451 GDOP =    2.43162


RECORD-NO. :    2
TIME       :     .241645D+05 SEC. ==>    6.4244 HOURS GMT
USERPOSITION  --->      .13137653D+07  -.47567960D+07    .40272182D+07
SATELLITE-POSITIONS :
          XS                YS                ZS
 6  -.27577762D+07  -.25088535D+08    .81721616D+07
 9  -.99341777D+07  -.12380684D+08    .21084965D+08
 8   .14774962D+08  -.32576402D+07    .21870541D+08

H-MATRIX
 -.44157237D+00  -.40434632D+00    .80094812D+00    .10000000D+01
 -.59021561D+00   .47760913D+00    .65079571D+00    .10000000D+01
  .59703183D+00   .55484459D+00    .57939665D+00    .10000000D+01
  .00000000D+00   .00000000D+00  -.10000000D+01    .00000000D+00

H-TRANSPOSE-MATRIX
 -.44157237D+00  -.59021561D+00    .59703183D+00    .00000000D+00
 -.40434632D+00   .47760913D+00    .55484459D+00    .00000000D+00
  .80094812D+00   .65079571D+00    .57939665D+00  -.10000000D+01
  .10000000D+01   .10000000D+01    .10000000D+01    .00000000D+00
```

```
HT*H-MATRIX
  .89978762D+00    .22791568D+00  -.39186811D+00  -.43475615D+00
  .22791568D+00    .69945895D+00   .30844064D+00   .62810740D+00
 -.39186811D+00    .30844064D+00   .24007534D+01   .20311405D+01
 -.43475615D+00    .62810740D+00   .20311405D+01   .30000000D+01

INVERTED H*HT-MATRIX
  .15228542D+01  -.84519400D+00   .48530776D-01   .36479000D+00
 -.84519400D+00   .22720379D+01   .17842872D+00  -.71898363D+00
  .48530776D-01   .17842872D+00   .10000000D+01  -.70737127D+00
  .36479000D+00  -.71898363D+00  -.70737127D+00   .10156547D+01
HDOP =    1.94805 PDOP =    2.18972 GDOP =    2.41051


RECORD-NO. :   3
TIME       :    .242855D+05 SEC. ==>   6.4445 HOURS GMT
USERPOSITION  --->     .13146833D+07  -.47595232D+07   .40237264D+07
SATELLITE-POSITIONS :
         XS               YS               ZS
 6  -.27734586D+07  -.25213739D+08   .77753730D+07
 9  -.99268982D+07  -.12705524D+08   .20897338D+08
 8   .15109884D+08  -.30452386D+07   .21672668D+08

H-MATRIX
 -.44289760D+00  -.42060457D+00   .79179133D+00   .10000000D+01
 -.59473423D+00   .46314714D+00   .65710419D+00   .10000000D+01
  .61219330D+00   .55030335D+00   .56779009D+00   .10000000D+01
  .00000000D+00   .00000000D+00  -.10000000D+01   .00000000D+00

H-TRANSPOSE-MATRIX
 -.44289760D+00  -.59473423D+00   .61219330D+00   .00000000D+00
 -.42060457D+00   .46314714D+00   .55030335D+00   .00000000D+00
  .79179133D+00   .65710419D+00   .56779009D+00  -.10000000D+01
  .10000000D+01   .10000000D+01   .10000000D+01   .00000000D+00

HT*H-MATRIX
  .92464773D+00    .24772732D+00  -.39388755D+00  -.42543853D+00
  .24772732D+00    .69424725D+00   .28376167D+00   .59284592D+00
 -.39388755D+00    .28376167D+00   .23811050D+01   .20166856D+01
 -.42543853D+00    .59284592D+00   .20166856D+01   .30000000D+01

INVERTED H*HT-MATRIX
  .14885525D+01  -.84347279D+00   .62223630D-01   .33595049D+00
 -.84347279D+00   .22502180D+01   .16309441D+00  -.67392952D+00
  .62223630D-01   .16309441D+00   .10000000D+01  -.69563438D+00
  .33595049D+00  -.67392952D+00  -.69563438D+00   .98177950D+00
HDOP =    1.93359 PDOP =    2.17687 GDOP =    2.39177


RECORD-NO. :   4
TIME       :    .244363D+05 SEC. ==>   6.4717 HOURS GMT
USERPOSITION  --->     .13116254D+07  -.47538321D+07   .40296685D+07
SATELLITE-POSITIONS :
         XS               YS               ZS
 6  -.27913019D+07  -.25319994D+08   .74149243D+07
 9  -.99219754D+07  -.13107162D+08   .20654291D+08
 8   .15474265D+08  -.28247174D+07   .21444534D+08

H-MATRIX
```

```
 -.44368457D+00  -.43720261D+00   .78230293D+00   .10000000D+01
 -.60048559D+00   .44268187D+00   .66592028D+00   .10000000D+01
  .62875741D+00   .54316541D+00   .55644898D+00   .10000000D+01
  .00000000D+00   .00000000D+00  -.10000000D+01   .00000000D+00

H-TRANSPOSE-MATRIX
 -.44368457D+00  -.60048559D+00   .62875741D+00   .00000000D+00
 -.43720261D+00   .44268187D+00   .54316541D+00   .00000000D+00
  .78230293D+00   .66592028D+00   .55644898D+00  -.10000000D+01
  .10000000D+01   .10000000D+01   .10000000D+01   .00000000D+00

HT*H-MATRIX
  .95277482D+00   .26967525D+00  -.39709986D+00  -.41541275D+00
  .26967525D+00   .68214202D+00   .25500978D+00   .54864466D+00
 -.39709986D+00   .25500978D+00   .23650832D+01   .20046722D+01
 -.41541275D+00   .54864466D+00   .20046722D+01   .30000000D+01

INVERTED H*HT-MATRIX
  .14554206D+01  -.84986195D+00   .77120096D-01   .30542400D+00
 -.84986195D+00   .22516961D+01   .14601366D+00  -.62704469D+00
  .77120096D-01   .14601366D+00   .10000000D+01  -.68424838D+00
  .30542400D+00  -.62704469D+00  -.68424838D+00   .94753181D+00
HDOP =    1.92539 PDOP =    2.16959 GDOP =    2.37795


RECORD-NO. :   5
TIME       :    .245579D+05 SEC. ==>   6.4918 HOURS GMT
USERPOSITION  --->     .13157679D+07  -.47542795D+07   .40295002D+07
SATELLITE-POSITIONS :
          XS                YS                ZS
 6  -.28158738D+07  -.25466048D+08   .68916140D+07
 9  -.99226391D+07  -.13435843D+08   .20444894D+08
 8   .15755228D+08  -.26559606D+07   .21261766D+08

H-MATRIX
 -.44603845D+00  -.45832357D+00   .76875823D+00   .10000000D+01
 -.60568836D+00   .42700231D+00   .67142433D+00   .10000000D+01
  .64110224D+00   .53800090D+00   .54730518D+00   .10000000D+01
  .00000000D+00   .00000000D+00  -.10000000D+01   .00000000D+00

H-TRANSPOSE-MATRIX
 -.44603845D+00  -.60568836D+00   .64110224D+00   .00000000D+00
 -.45832357D+00   .42700231D+00   .53800090D+00   .00000000D+00
  .76875823D+00   .67142433D+00   .54730518D+00  -.10000000D+01
  .10000000D+01   .10000000D+01   .10000000D+01   .00000000D+00

HT*H-MATRIX
  .97682077D+00   .29071318D+00  -.39869106D+00  -.41062457D+00
  .29071318D+00   .68183643D+00   .22881041D+00   .50667964D+00
 -.39869106D+00   .22881041D+00   .23413428D+01   .19874877D+01
 -.41062457D+00   .50667964D+00   .19874877D+01   .30000000D+01

INVERTED H*HT-MATRIX
  .14299077D+01  -.84764592D+00   .88344820D-01   .28035198D+00
 -.84764592D+00   .22115435D+01   .12587245D+00  -.57292608D+00
  .88344820D-01   .12587245D+00   .10000000D+01  -.67166273D+00
  .28035198D+00  -.57292608D+00  -.67166273D+00   .91344361D+00
HDOP =    1.90826 PDOP =    2.15440 GDOP =    2.35688
```

```
PROGRAM *EBGD1*
^^^^^^^^^^^^^^^


H-MATRIX
  .100000000D+01    .000000000D+00    .000000000D+00    .100000000D+01
 -.500000000D+00    .866025000D+00    .000000000D+00    .100000000D+01
 -.500000000D+00   -.866025000D+00    .000000000D+00    .100000000D+01
  .000000000D+00    .000000000D+00    .100000000D+01    .100000000D+01

H-TRANSPOSE-MATRIX
  .100000000D+01   -.500000000D+00   -.500000000D+00    .000000000D+00
  .000000000D+00    .866025000D+00   -.866025000D+00    .000000000D+00
  .000000000D+00    .000000000D+00    .000000000D+00    .100000000D+01
  .100000000D+01    .100000000D+01    .100000000D+01    .100000000D+01

HT*H-MATRIX
  .200000000D+01    .500000000D+00    .500000000D+00    .100000000D+01
  .500000000D+00    .199999930+01     .500000700+00     .100000000D+01
  .500000000D+00    .500000700+00     .199999930+01     .100000000D+01
  .100000000D+01    .100000000D+01    .100000000D+01    .200000000D+01

INVERTED HT*H-MATRIX
  .666666670+00   -.346944700-17    .000000000D+00   -.333333330+00
 -.346944700-17    .666666980+00   -.310833620-06   -.333333330+00
  .000000000D+00   -.310833620-06    .666666980+00   -.333333330+00
 -.333333330+00   -.333333330+00   -.333333330+00    .100000000D+01
HDOP =       1.15470076 GDOP =       1.73205090
PROGRAM *EBGD1*
^^^^^^^^^^^^^^^


H-MATRIX
  .100000000D+01    .000000000D+00    .000000000D+00    .100000000D+01
 -.500000000D+00    .866000000D+00    .000000000D+00    .100000000D+01
 -.500000000D+00   -.866000000D+00    .000000000D+00    .100000000D+01
  .100000000D+01    .000000000D+00    .000000000D+00    .100000000D+01

H-TRANSPOSE-MATRIX
  .100000000D+01   -.500000000D+00   -.500000000D+00    .100000000D+01
  .000000000D+00    .866000000D+00   -.866000000D+00    .000000000D+00
  .000000000D+00    .000000000D+00    .000000000D+00    .000000000D+00
  .100000000D+01    .100000000D+01    .100000000D+01    .100000000D+01

HT*H-MATRIX
  .200000000D+01    .500000000D+00    .500000000D+00    .200000000D+01
  .500000000D+00    .199995600+01     .500044000+00     .500000000D+00
  .500000000D+00    .500044000+00     .199995600+01     .500000000D+00
  .200000000D+01    .500000000D+00    .500000000D+00    .200000000D+01
****************************************
*HT*H-MATRIX IS SINGULAR (DETERMINANT=0.)*
****************************************
PROGRAM *EBGD1*
^^^^^^^^^^^^^^^


AZIMUTH          ELEVATION
  .0000D+00     .1000D+02
  .2400D+03     .1000D+02
  .1200D+03     .1000D+02
```

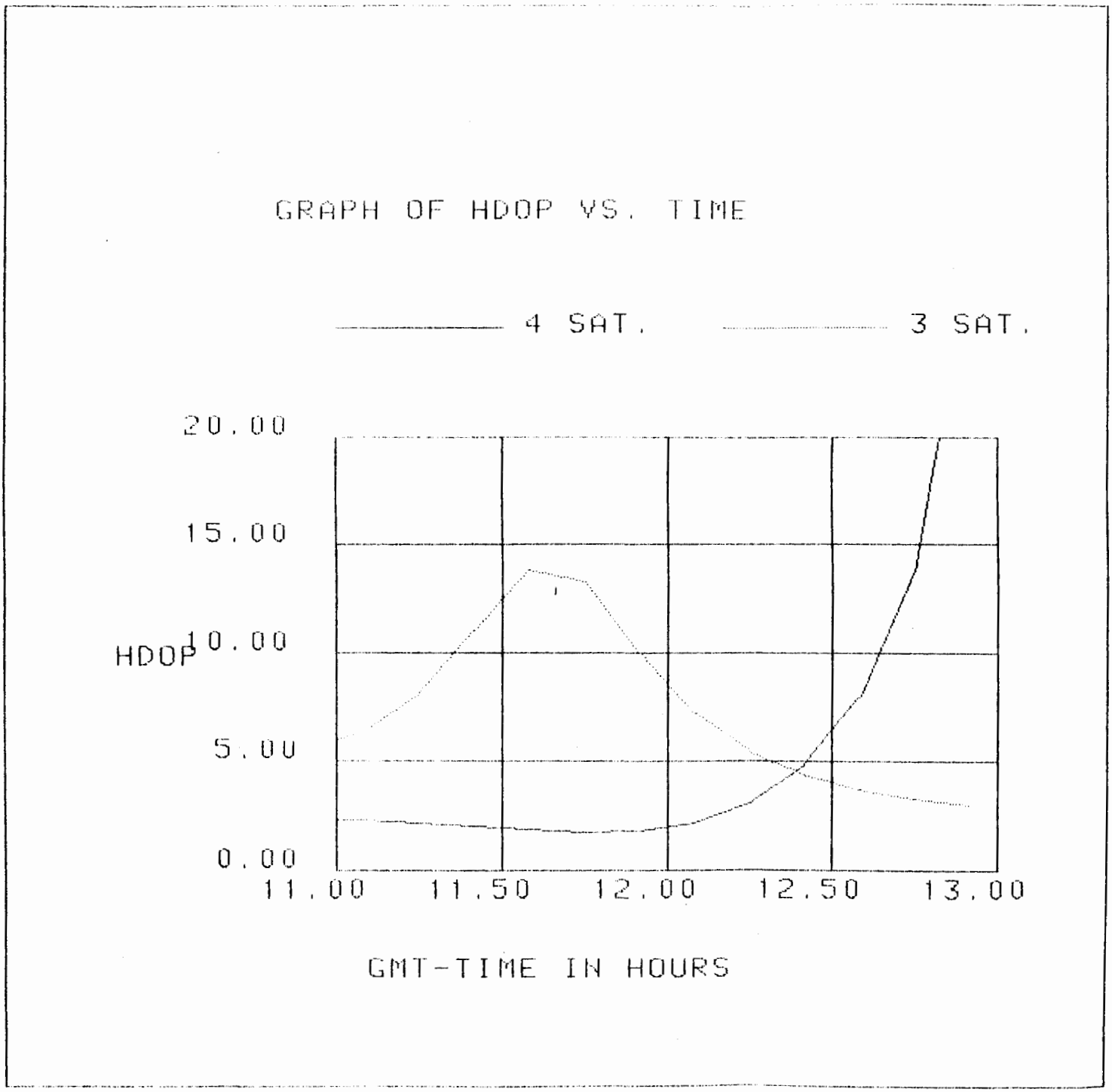
```
   .0000D+00    .9000D+02


H-MATRIX
   .98480775D+00    .00000000D+00    .17364819D+00    .10000000D+01
  -.49240368D+00   -.85286864D+00    .17364819D+00    .10000000D+01
  -.49240397D+00    .85286847D+00    .17364819D+00    .10000000D+01
  -.86246497D-07    .00000000D+00    .10000000D+01    .10000000D+01

H-TRANSPOSE-MATRIX
   .98480775D+00   -.49240368D+00   -.49240397D+00   -.86246497D-07
   .00000000D+00   -.85286864D+00    .85286847D+00    .00000000D+00
   .17364819D+00    .17364819D+00    .17364819D+00    .10000000D+01
   .10000000D+01    .10000000D+01    .10000000D+01    .10000000D+01

HT*H-MATRIX
   .20000000D+01    .54523073D+00    .54523044D+00    .11736481D+01
   .54523073D+00    .20000000D+01    .54523044D+00    .11736482D+01
   .54523044D+00    .54523044D+00    .20000000D+01    .11736482D+01
   .11736481D+01    .11736482D+01    .11736482D+01    .20000000D+01

INVERTED HT*H-MATRIX
   .78369263D+00    .96298448D-01    .96298605D-01   -.57291028D+00
   .96298448D-01    .78369273D+00    .96298655D-01   -.57291041D+00
   .96298605D-01    .96298655D-01    .78369277D+00   -.57291052D+00
  -.57291028D+00   -.57291041D+00   -.57291052D+00    .15085929D+01
HDOP =       1.25195265 GDOP =       1.96460462
```

```
PROGRAM   * H D 0 0 *
----------------------

USER-POSITION :
  LATITUDE :  39.500000     DEGREE
  LONGITUDE: -74.500000     DEGREE
  ALTITUDE :  100.00000     FEET

ECEF-COORDINATES :       X             Y             Z
------------------  1317011.6     -4748990.4     4035321.8


USERTIMES :
  START (TSTART):   38700.000     SEC. = 10.45 HOURS
  END (TFIN)    :   46800.000     SEC. = 13.00 HOURS
  INCR. (TDEL)  :   600.00000     SEC
  DATE (DTU)    :   57.000000     DAYS

   USED ALMANACS          DTC=   57.   TC=  20000.
   -------------
SAT. ID :   5                  6                  8                  9
          .2305D-02          .1551D-02          .2207D-02          .8108D-02
          .3318D+06          .3318D+06          .3318D+06          .3318D+06
          .1112D+01          .1107D+01          .1103D+01          .1104D+01
         -.6195D-08         -.6457D-08         -.6343D-08         -.6503D-08
          .5154D+04          .5154D+04          .5154D+04          .5154D+04
          .5694D+00         -.1550D+01          .5653D+00         -.1546D+01
         -.2092D+01          .2049D+01         -.1983D+00          .1352D+01
          .6950D+00         -.1074D+01          .3566D+00         -.1142D+01
          .2656D+08          .2656D+08          .2656D+08          .2656D+08
          .4425D+00          .4472D+00          .4505D+00          .4503D+00
          .8968D+00          .8944D+00          .8928D+00          .8929D+00
         -.4977D+00         -.4606D+00          .9804D+00          .2167D+00
         -.8674D+00          .8876D+00         -.1970D+00          .9762D+00
          .1459D-03          .1459D-03          .1459D-03          .1459D-03

OUTPUT OF COMPUTATIONS
----------------------

================================================
! THE PRINTOUT IS ARRANGED AS FOLLOWING EXAMPLE :  !
! ----------------                                 !
! TIME                                             !
!POSITION OF SATELLITES IN ECEF-COORDINATES (X,Y,Z)!
!AND ELEVATION AND AZIMUTH (3-4 LINES)            !
!- - - - - - - - -                                !
!  HDOP AND GDOP                                  !
!------------------                               !
!    ALL VALUES ARE IN METER                       !
================================================
------------------------
TIME : 10.4501 HOURS
   -.1833D+08     -.1915D+08      .2186D+07      .1294D+02      .2531D+03
   -.2843D+07     -.2174D+08      .1493D+08      .6517D+02      .2612D+03
    .9711D+07     -.7234D+07      .2366D+08      .4839D+02      .3139D+02
   -.1073D+08     -.5912D+07      .2334D+08      .2789D+02      .3237D+03
- - - - - - - - - - - - -
 2.4984615          4.4243006
------------------------
------------------------
TIME : 10.5500 HOURS
   -.1824D+08     -.1889D+08      .4249D+07      .1588D+02      .2571D+03
   -.2728D+07     -.2281D+08      .1326D+08      .6319D+02      .2493D+03
    .1104D+08     -.6041D+07      .2341D+08      .4477D+02      .3586D+02
   -.1039D+08     -.7676D+07      .2298D+08      .3173D+02      .3208D+03
- - - - - - - - - - - - -
 2.3736091          4.5147265
------------------------
------------------------
TIME : 11.0500 HOURS
   -.1803D+08     -.1853D+08      .6279D+07      .1877D+02      .2612D+03
   -.2686D+07     -.2376D+08      .1148D+08      .6012D+02      .2396D+03
    .1241D+08     -.4931D+07      .2299D+08      .4126D+02      .4015D+02
   -.1015D+08     -.9419D+07      .2245D+08      .3530D+02      .3172D+03
- - - - - - - - - - - - -
 2.2600505          4.7088703
------------------------
```

```
----------------------
TIME : 11.1500 HOURS
   -.1767D+08     -.1809D+08      .8261D+07      .2161D+02      .2655D+03
   -.2706D+07     -.2457D+08      .9620D+07      .5628D+02      .2320D+03
    .1380D+08     -.3914D+07      .2239D+08      .3785D+02      .4434D+02
   -.9994D+07     -.1112D+08      .2174D+08      .3851D+02      .3128D+03
- - - - - - - - - - -
 2.1423699           5.0271648
----------------------
----------------------
TIME : 11.2500 HOURS
   -.1718D+08     -.1759D+08      .1018D+08      .2439D+02      .2700D+03
   -.2774D+07     -.2524D+08      .7684D+07      .5195D+02      .2261D+03
    .1519D+08     -.2997D+07      .2162D+08      .3456D+02      .4844D+02
   -.9927D+07     -.1277D+08      .2086D+08      .4124D+02      .3075D+03
- - - - - - - - - - -
 2.0113983           5.5042133
----------------------
----------------------
TIME : 11.3500 HOURS
   -.1654D+08     -.1704D+08      .1202D+08      .2712D+02      .2746D+03
   -.2879D+07     -.2576D+08      .5688D+07      .4732D+02      .2215D+03
    .1657D+08     -.2183D+07      .2069D+08      .3136D+02      .5249D+02
   -.9944D+07     -.1435D+08      .1981D+08      .4337D+02      .3014D+03
- - - - - - - - - - -
 1.8709018           6.1925626
----------------------
----------------------
TIME : 11.4501 HOURS
   -.1575D+08     -.1645D+08      .1377D+08      .2981D+02      .2793D+03
   -.3005D+07     -.2611D+08      .3649D+07      .4253D+02      .2179D+03
    .1793D+08     -.1478D+07      .1960D+08      .2827D+02      .5651D+02
   -.1004D+08     -.1584D+08      .1862D+08      .4478D+02      .2946D+03
- - - - - - - - - - -
 1.7567730           7.1692332
----------------------
----------------------
TIME : 11.5500 HOURS
   -.1483D+08     -.1584D+08      .1542D+08      .3245D+02      .2843D+03
   -.3138D+07     -.2631D+08      .1582D+07      .3767D+02      .2150D+03
    .1924D+08     -.8800D+06      .1836D+08      .2525D+02      .6050D+02
   -.1019D+08     -.1722D+08      .1727D+08      .4538D+02      .2873D+03
- - - - - - - - - - -
 1.7786423           8.5484359
----------------------
----------------------
TIME : 12.0500 HOURS
   -.1376D+08     -.1523D+08      .1695D+08      .3506D+02      .2893D+03
   -.3262D+07     -.2634D+08     -.4972D+06      .3282D+02      .2125D+03
    .2049D+08     -.3895D+06      .1698D+08      .2232D+02      .6447D+02
   -.1041D+08     -.1849D+08      .1580D+08      .4513D+02      .2800D+03
- - - - - - - - - - -
 2.1462068           10.507829
----------------------
----------------------
TIME : 12.1500 HOURS
   -.1257D+08     -.1463D+08      .1835D+08      .3763D+02      .2946D+03
   -.3364D+07     -.2621D+08     -.2573D+07      .2801D+02      .2104D+03
    .2166D+08     -.2539D+04      .1547D+08      .1946D+02      .6842D+02
   -.1067D+08     -.1963D+08      .1420D+08      .4407D+02      .2727D+03
- - - - - - - - - - -
 3.0898991           13.345598
----------------------
----------------------
TIME : 12.2500 HOURS
   -.1125D+08     -.1406D+08      .1961D+08      .4018D+02      .3000D+03
   -.3427D+07     -.2592D+08     -.4628D+07      .2329D+02      .2085D+03
    .2273D+08      .2861D+06      .1384D+08      .1665D+02      .7236D+02
   -.1096D+08     -.2063D+08      .1249D+08      .4226D+02      .2659D+03
- - - - - - - - - - -
 4.8538946           17.615520
----------------------
----------------------
TIME : 12.3500 HOURS
   -.9819D+07     -.1353D+08      .2072D+08      .4269D+02      .3056D+03
   -.3439D+07     -.2548D+08     -.6649D+07      .1868D+02      .2067D+03
    .2370D+08      .4837D+06      .1211D+08      .1390D+02      .7627D+02
   -.1127D+08     -.2148D+08      .1069D+08      .3982D+02      .2597D+03
- - - - - - - - - - -
 7.9541551           24.494625
----------------------
```

```
PROGRAM   * H D 0 0 *
----------------------

USER-POSITION :
  LATITUDE :  39.500000     DEGREE
  LONGITUDE: -74.500000     DEGREE
  ALTITUDE :  100.00000     FEET

ECEF-COORDINATES :       X              Y              Z
------------------  1317011.6     -4748990.4     4035321.8


USERTIMES :
  START (TSTART):   38700.000     SEC. = 10.45 HOURS
  END (TFIN)    :   46800.000     SEC. = 13.00 HOURS
  INCR. (TDEL)  :   600.00000     SEC
  DATE (DTU)    :   57.000000     DAYS

   USED ALMANACS          DTC=   57.   TC=  20000.
   -------------
SAT. ID :   5                    6                    9                    0
            .2305D-02            .1551D-02            .8108D-02            .0000D+00
            .3318D+06            .3318D+06            .3318D+06            .0000D+00
            .1112D+01            .1107D+01            .1104D+01            .0000D+00
           -.6195D-08           -.6457D-08           -.6503D-08            .0000D+00
            .5154D+04            .5154D+04            .5154D+04            .0000D+00
            .5694D+00           -.1550D+01           -.1546D+01            .0000D+00
           -.2092D+01            .2049D+01            .1352D+01            .0000D+00
            .6950D+00           -.1074D+01           -.1142D+01            .0000D+00
            .2656D+08            .2656D+08            .2656D+08            .0000D+00
            .4425D+00            .4472D+00            .4503D+00            .0000D+00
            .8968D+00            .8944D+00            .8929D+00            .0000D+00
           -.4977D+00           -.4606D+00            .2167D+00            .0000D+00
           -.8674D+00            .8876D+00            .9762D+00            .0000D+00
            .1459D-03            .1459D-03            .1459D-03            .0000D+00


OUTPUT OF COMPUTATIONS
----------------------

=================================================
! THE PRINTOUT IS ARRANGED AS FOLLOWING EXAMPLE :  !
! ---------------                                 !
! TIME                                            !
!POSITION OF SATELLITES IN ECEF-COORDINATES (X,Y,Z)!
!AND ELEVATION AND AZIMUTH (3-4 LINES)            !
!- - - - - - - - -                                !
!  HDOP AND GDOP                                  !
!-----------------                                !
!    ALL VALUES ARE IN METER                      !
=================================================
------------------------
TIME : 10.4501 HOURS
   -.1833D+08    -.1915D+08     .2186D+07     .1294D+02     .2531D+03
   -.2843D+07    -.2174D+08     .1493D+08     .6517D+02     .2612D+03
   -.1073D+08    -.5912D+07     .2334D+08     .2789D+02     .3237D+03
- - - - - - - - - - -
 4.7632762          8.3858993
------------------------
------------------------
TIME : 10.5500 HOURS
   -.1824D+08    -.1889D+08     .4249D+07     .1588D+02     .2571D+03
   -.2728D+07    -.2281D+08     .1326D+08     .6319D+02     .2493D+03
   -.1039D+08    -.7676D+07     .2298D+08     .3173D+02     .3208D+03
- - - - - - - - - - -
 5.3833744          10.201813
------------------------
------------------------
TIME : 11.0500 HOURS
   -.1803D+08    -.1853D+08     .6279D+07     .1877D+02     .2612D+03
   -.2686D+07    -.2376D+08     .1148D+08     .6012D+02     .2396D+03
   -.1015D+08    -.9419D+07     .2245D+08     .3530D+02     .3172D+03
- - - - - - - - - - -
 6.4216688          13.226424
------------------------
```

```
----------------------
TIME : 11.1500 HOURS
   -.1767D+08     -.1809D+08      .8261D+07      .2161D+02      .2655D+03
   -.2706D+07     -.2457D+08      .9620D+07      .5628D+02      .2320D+03
   -.9994D+07     -.1112D+08      .2174D+08      .3851D+02      .3128D+03
- - - - - - - - - - - -
 8.1927780            18.405895
----------------------
----------------------
TIME : 11.2500 HOURS
   -.1718D+08     -.1759D+08      .1018D+08      .2439D+02      .2700D+03
   -.2774D+07     -.2524D+08      .7684D+07      .5195D+02      .2261D+03
   -.9927D+07     -.1277D+08      .2086D+08      .4124D+02      .3075D+03
- - - - - - - - - - - -
 11.009826            26.657326
----------------------
----------------------
TIME : 11.3500 HOURS
   -.1654D+08     -.1704D+08      .1202D+08      .2712D+02      .2746D+03
   -.2879D+07     -.2576D+08      .5688D+07      .4732D+02      .2215D+03
   -.9944D+07     -.1435D+08      .1981D+08      .4337D+02      .3014D+03
- - - - - - - - - - - -
 13.818422            34.879208
----------------------
----------------------
TIME : 11.4501 HOURS
   -.1575D+08     -.1645D+08      .1377D+08      .2981D+02      .2793D+03
   -.3005D+07     -.2611D+08      .3649D+07      .4253D+02      .2179D+03
   -.1004D+08     -.1584D+08      .1862D+08      .4478D+02      .2946D+03
- - - - - - - - - - - -
 13.244735            33.416337
----------------------
----------------------
TIME : 11.5500 HOURS
   -.1483D+08     -.1584D+08      .1542D+08      .3245D+02      .2843D+03
   -.3138D+07     -.2631D+08      .1582D+07      .3767D+02      .2150D+03
   -.1019D+08     -.1722D+08      .1727D+08      .4538D+02      .2873D+03
- - - - - - - - - - - -
 9.9871434            24.453441
----------------------
----------------------
TIME : 12.0500 HOURS
   -.1376D+08     -.1523D+08      .1695D+08      .3506D+02      .2893D+03
   -.3262D+07     -.2634D+08     -.4972D+06      .3282D+02      .2125D+03
   -.1041D+08     -.1849D+08      .1580D+08      .4513D+02      .2800D+03
- - - - - - - - - - - -
 7.1913427            16.689341
----------------------
----------------------
TIME : 12.1500 HOURS
   -.1257D+08     -.1463D+08      .1835D+08      .3763D+02      .2946D+03
   -.3364D+07     -.2621D+08     -.2573D+07      .2801D+02      .2104D+03
   -.1067D+08     -.1963D+08      .1420D+08      .4407D+02      .2727D+03
- - - - - - - - - - - -
 5.4283696            12.201738
----------------------
----------------------
TIME : 12.2500 HOURS
   -.1125D+08     -.1406D+08      .1961D+08      .4018D+02      .3000D+03
   -.3427D+07     -.2592D+08     -.4628D+07      .2329D+02      .2085D+03
   -.1096D+08     -.2063D+08      .1249D+08      .4226D+02      .2659D+03
- - - - - - - - - - - -
 4.3584985            9.3746357
----------------------
----------------------
TIME : 12.3500 HOUR
   -.9819D+07     -.1353D+08      .2072D+08      .4269D+02      .3056D+03
   -.3439D+07     -.2548D+08     -.6649D+07      .1868D+02      .2067D+03
   -.1127D+08     -.1480D+08      .1069D+08      .3982D+02      .2597D+03
- - - - - - - - - - - -
 3.6957639            7.5990681
----------------------
----------------------
TIME : 12.4501
   -.8289D+07     -.1305D+08      .2167D+08      .4518D+02      .3114D+03
   -.3386D+07     -.2489D+08     -.8618D+07      .1419D+02      .2049D+03
   -.1158D+08     -.2218D+08      .8800D+07      .3688D+02      .2542D+03
- - - - - - - - - - - -
 3.2771483            6.4295319
----------------------
```


GRAPH OF HDOP VS. TIME
4 SAT.
3 SAT.
20.00
15.00
10.00
5.00
0.00
HDOP
11.00
11.50
12.00
12.50
13.00
GMT-TIME IN HOURS

GRAPH OF HDOP VS. TIME