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FAA TECHNICAL CENTER LETTER REPORT

A LORAN-C PROPAGATION MODEL

by

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U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, N.J. 08405

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INTRODUCTION

PURPOSE

Loran-C propagation software was developed to predict signal characteristics at selected airports throughout the continental United States, Alaska and Canada as potential Loran-C non-precision approach sites.

BACKGROUND

Loran-C signals are transmitted as synchronized pulses from a master and two or more secondary stations in the 90-110 kHz frequency band. The receivers are designed to track the ground wave propagated signal. Signal propagation is affected by different combinations of land/sea conductivity paths and to some extent weather (seasons). Skywave signals and spectral interference change the shape of the pulse. Pulse shape as well as signal to noise ratio affect the receiver's ability to accurately determine the proper tracking point.
A distinctive feature of Loran-C is it's combination of range and accuracy. The low radio frequency provides good radio propagation over land and sea, not being restricted by line-of-site transmission.

Atmospheric noise, local noise, ground conductivity and distance from the transmitter all affect Loran-C performance. The transmitter-receiver geometry (crossing angle and line of position gradients) affect the ability to accurately determine user position. This effect is characterized by a figure of merit called geometric dilution of precision (GDOP). The root-mean-square user position errors increase as GDOP increases. The optimum value for GDOP is one. This occurs along a baseline where the line of position crossing angles are perpendicular.

DISCUSSION

This simulation consists of a main program (LORAN-C) and a library file (LORLIB) containing eleven subroutines. The programs were written in Digital Equipment Corporation (DEC) Fortran IV using an RT-11 operating system. The modular structure was designed to allow for easily inserting future modifications and improvements. In addition, data files were created to store data for eight of the major North American group repetition intervals (GRIs) (see appendix A for a list of information contained in each). These files are selected through a user prompt in the main program.

This software was developed as a first generation baseline model to theoretically predict Loran-C propagation characteristics. The simulation software will be improved as additional information is made available. The sources for the equations may be found in the references 1 through 7 and in appendix A.

The main program logic is illustrated in the accompanying flowchart (figure 1). Prompted by the computer, the user enters a desired data file (file names used are related to the GRI). After the file is read and parameters are set, the user is then prompted to enter a location identifier, position coordinates (latitude and longitude), runway heading with respect to magnetic north, magnetic variation, and estimated atmospheric noise. The program calculates and outputs the following parameters using various subroutines:

Great circle distance (transmitter-to-user location)

Initial heading (user-to-transmitter location)

Ground wave field strength (for seawater and poor soil)

Signal-to-noise ratio

Envelope-to-cycle difference

Great circle distance (transmitter-to-system area monitor (SAM))

Double range difference (transmitter-to-user, transmitter-to-SAM)

Gradient

Direction of normal line of position

Time difference

Crossing Angle

Radial fix errors (longest and shortest sides of error parallelogram)

GDOP

Crosstrack and along track errors

The latter seven parameters pertain to master-secondary 1 and master-secondary 2 triad combinations.

Data are divided into three sections and formatted for the line printer. The first section contains transmitter-to-user location information followed by double range difference with the SAMs. Data pertaining to the triad combinations are formatted last. A sample data output may be found in table 1.

REFERENCES

1. Dean, Walt, "Loran-C Simulator Design", Systems Control Technology.

2. Johler, J.R., Kellar, W.J., and Walters, L.C., "Phase of the Low Radiofrequency Ground Wave", National Bureau of Standards Circular 573, U.S. Department of Commerce, National Bureau of Standards, 1956.

3. Pierce, McKenrie and Woodward, Loran, section 3-4, appendix C1.

4. Sodano Equations, as used in FAA Advisory Circular AC-90-45A, U.S. Department of Transportation, Federal Aviation Administration.

5. Swanson, Eric, "Geometric Dilution of Precision (GDOP)", Journal of the Institute of Navigation, Vol, 25, No. 4, Winter 1978-79.

6. U.S. Department of Transporation, U.S. Coast Guard, Specification of the Transmitted Loran-C Signal, comdtinst M16562.4, July 1981.

7. Wild Goose Association, "Loran-C System Characterization", WGA Publication No.1/1976, September 1976.

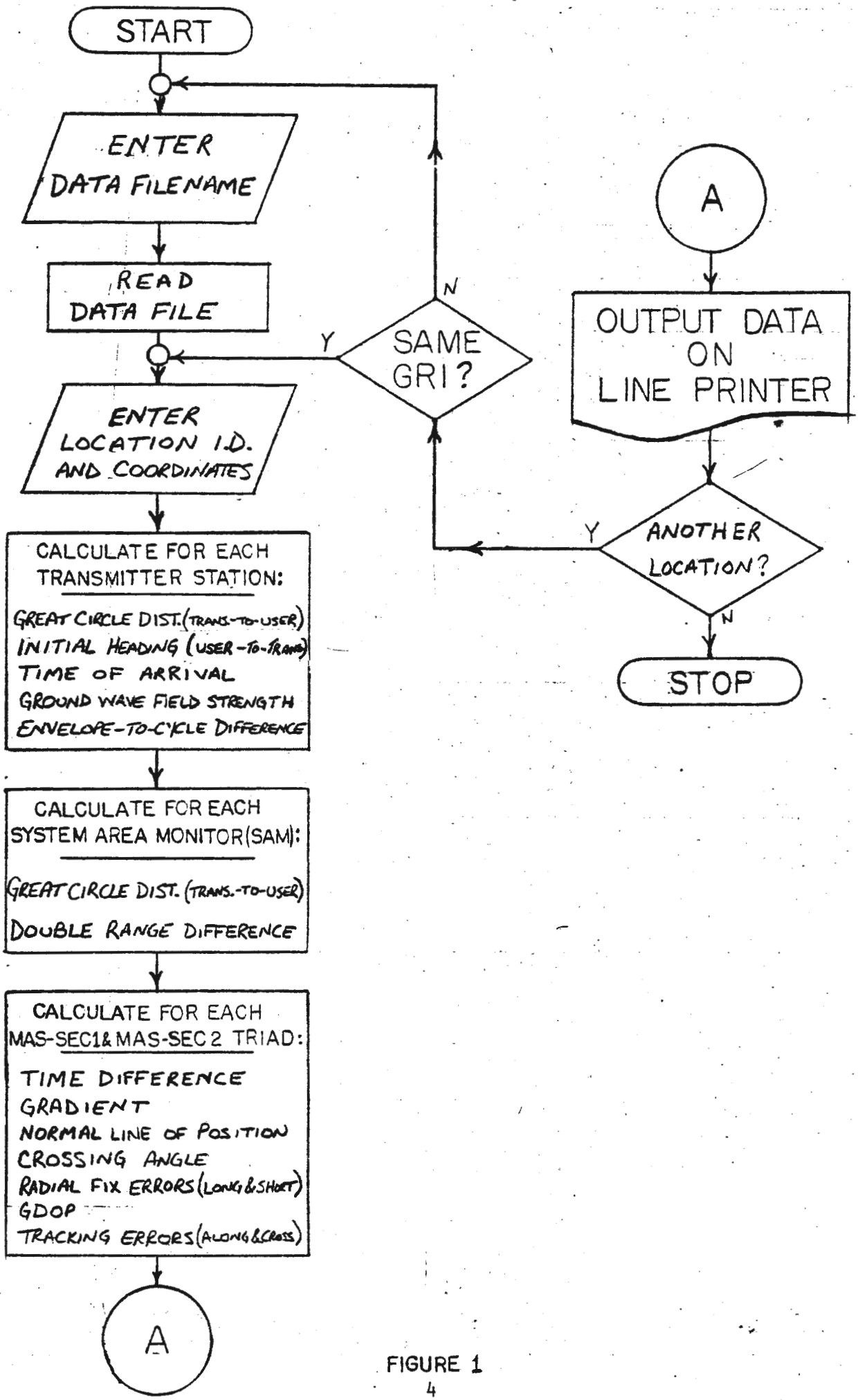
START
ENTER DATA FILENAME
READ DATA FILE
ENTER LOCATION I.D. AND COORDINATES
CALCULATE FOR EACH TRANSMITTER STATION:
GREAT CIRCLE DIST.(TRANS-TO-USER)
INITIAL HEADING (USER-TO-TRANS)
TIME OF ARRIVAL
GROUND WAVE FIELD STRENGTH
ENVELOPE-TO-CYCLE DIFFERENCE
CALCULATE FOR EACH SYSTEM AREA MONITOR(SAM):
GREAT CIRCLE DIST. (TRANS.-TO-USER)
DOUBLE RANGE DIFFERENCE
CALCULATE FOR EACH MAS-SEC1& MAS-SEC 2 TRIAD:
TIME DIFFERENCE
GRADIENT
NORMAL LINE OF POSITION
CROSSING ANGLE
RADIAL FIX ERRORS(LONG&SHORT)
GDOP
TRACKING ERRORS(ALONG&CROSS)
A
SAME GRI?
Y
N
A
OUTPUT DATA ON LINE PRINTER
ANOTHER LOCATION?
Y
N
STOP

FIGURE 1

>>DATA PROCESSED BY: FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER, ATLANTIC CITY AIRPORT, N.J. 08405<<

SELECTED LOCATION:
FAA TECHNICAL CENTER, ATLANTIC CITY AIRPORT, N.J. (RUNWAY 31)
39 27 0.00N 74 35 0.00W

17-DEC-82
08:27:20

RUNWAY HEADING (W/RESPECT TO MAGNETIC NORTH) IN DEGREES: 309.10
MAGNETIC VARIATION ((TRUE NORTH) - (MAGNETIC NORTH)) IN DEGREES: -1.10
ESTIMATED ATMOSPHERIC NOISE (dB ABOVE 1 uv/m): 56.00

GRI: NORTHEAST 19960

TRANSMITTER STATION (LAT./LONG.)	EMISSION DELAY, usec	RAD. POWER, kW	NOM. ECD, usec	DIST, NM	HDG, deg.	TOA, usec	GROUND WAVE FIELD STRENGTH & SNR (dB ABOVE 1 uv/m) SEAWATER (5 mho/m) FS	SEAWATER SNR	POOR SOIL (1 mmho/m) FS	POOR SOIL SNR	ECD usec
M:BENECA 42 42 50.60N 76 49 33.86W	0.00	800.	0.0	220.579	332.4	1363.6840	78.	22.	76.	20.	1.9486
W:CARIBOU 46 48 27.20N 67 55 37.71W	13797.20	350.	0.0	529.006	31.4	3270.8246	60.	4.	49.	-7.	1.1775
X:NANTUCKET 41 15 11.93N 69 58 39.09W	26969.93	275.	0.0	237.288	60.8	1466.9953	73.	17.	70.	14.	1.9068
Y:CAROLINA BEACH 34 3 46.04N 77 54 46.76W	42221.65	550.	0.0	360.448	207.2	2228.5351	69.	13.	64.	8.	1.5989
Z:DANA 39 51 7.54N 87 29 12.14W	57162.06	400.	-0.5	597.942	276.4	3697.1000	58.	2.	46.	-10.	0.5051

MONITOR STATION(SAM) (LAT/LONG)	DOUBLE RANGE DIFFERENCE, (W/ MASTER)
M:SANDYHOOK 40 28 17.04N 74 1 3.71W	0.0000
W:CAPE ELIZABETH 43 33 54.82N 70 11 58.84W	275.8646
X:SANDYHOOK 40 28 17.04N 74 1 3.71W	11.4919
Y:SANDYHOOK 40 28 17.04N 74 1 3.71W	-102.3986
Z:PLUMBROOK 41 22 46.96N 82 39 38.53W	323.1993

****
*
* UNLESS OTHERWISE NOTED, ALL CALCULATIONS *
*
* ASSUME A SEAWATER PATH FOR PROPAGATION. *
*
****

TRIADS	TIME DIFFERENCE usec TDA	TDB	GRADIENT ft/usec & degrees TDA & Angle (m-s)		TDB & Angle (m-s)		NORMAL LOP degrees LOP1	LOP2	XING ANGLE deg.	RADIAL ERROR SHORT feet	LONG	GDOP	TRACKING ERROR CROSS feet	ALONG
M WX	15704.34	27073.24	998.9	58.9	705.0	88.4	91.9	106.6	14.7	143.	665.	9.6	142.	20.
M WY	15704.34	43086.50	998.9	58.9	553.5	125.2	91.9	179.8	87.9	113.	116.	1.7	17.	111.
M WZ	15704.34	59495.47	998.9	58.9	1046.5	56.0	91.9	214.4	122.5	117.	213.	3.1	93.	191.
M XY	27073.24	43086.50	705.0	88.4	553.5	125.2	106.6	179.8	73.2	79.	106.	1.5	8.	79.
M XZ	27073.24	59495.47	705.0	88.4	1046.5	56.0	106.6	214.4	107.8	112.	150.	2.2	98.	114.
M YZ	43086.50	59495.47	553.5	125.2	1046.5	56.0	179.8	214.4	34.6	118.	270.	3.9	108.	48.

>>NOTE: *= ANGLE BETWEEN MASTER AND SECONDARY IS LESS THAN 20 DEGREES (NEAR BASELINE EXTENSION).

****

```
C*************************************************************************
C
C     >>SOFTWARE FOR LORAN-C NONPRECISION APPROACH TESTING<<
C       ---------------------------------------------
C     WRITTEN BY: ANDREW P. LEONE, DREXEL CO-OP STUDENT
C       DOT/FAA TECHNICAL CENTER, ATLANTIC CITY AIRPORT, N.J.
C                       ACT-100B.2
C
C                 OCTOBER, 1982 - REVISED: 16-DEC-82
C               ------------------------------------
C     PURPOSE: TO EVALUATE LORAN-C PERFORMANCE AT SELECTED
C         AIRPORTS. (RESULTS WILL BE BASED MOSTLY ON GEOMETRIC
C         SOLUTIONS.  IF MEASURED TIME DELAYS(T.D.'S) ARE
C         KNOWN AT A POSITION, ERRORS DUE TO ACTUAL PROPAGATION
C         ERRORS CAN ALSO BE EVALUATED.)
C
C     SUBROUTINES:
C         GREAT- CALULATES GREAT CIRCLE DISTANCE BETWEEN SELECTED
C            SITE OR MONITORS AND LORAN-C TRANSMITTERS IN NAUTICAL
C            MILES; ALSO CALCULATES INITIAL HEADING FROM SELECTED
C            SITE OR MONITORS TO TRANSMITTERS IN DECIMAL DEGREES.
C         DELAY- CALCULATES TIME DELAY(TOA) OF LORAN-C SIGNAL
C            FOR TRANSMITTER TO RECEIVER IN MICROSECONDS.
C         GRDWFS- CALCULATES THE GROUNDWAVE FIELD STRENGTH OVER
C            SEAWATER AND POOR SOIL IN DECIBELS(dB) ABOVE
C            1 MICROVOLT/METER(uV/M) AND SIGNAL-TO-NOISE RATIO(SNR).
C         ETCDIF- CALCULATES THE ENVELOPE-TO-CYCLE DIFFERENCE(ECD)
C            IN MICROSECONDS.
C         TIMDIF- CALCULATES THE TIME DIFFERENCE BETWEEN TWO STATIONS,
C            USUALLY BETWEEN THE MASTER AND A SECONDARY IN MICRO-
C            SECONDS.
C         GRAD- CALCULATES THE ESTIMATES OF POSITIONAL ERROR.  GRADIENT
C            IS IN FEET/MICROSECOND.
C         DOLOP- CALCULATE THE NORMAL TO THE LOP (LINE OF POSITION).
C            DIRECTION IS IN DECIMAL DEGREES.
C         XANGLE- CALCULATES THE CROSSING ANGLE OF A TRIAD; IN DECIMAL
C            DEGREES.
C         DRDIFF- CALCULATES THE DOUBLE RANGE DIFFERENCE BETWEEN
C            SELECTED SITE AND TRANSMITTERS, AND BETWEEN SAM's AND
C            TRANSMITTERS IN NAUTICAL MILES.
C         RFERR- CALCULATES THE SHORTEST AND LONGEST RADIAL FIX
C            ERROR(2DRMS) IN FEET AND GDOP.
C         ELLIPS- CALCULATES THE ALONG TRACK AND CROSS TRACK ERRORS
C            IN FEET.
C         TRIADS- FORMATS DATA PERTAINING TO TRIADS OF SECONDARY
C            TRANSMITTERS FORMED WITH THE MASTER.
C
C     DATA FILES:
C         8 FILES (LC<GRI>.DAT) CONTAINING THE MAJOR NORTHAMERICAN
C            LORAN-C TRANSMITTING CHAINS.  INCLUDED IN EACH FILE:
C                 GRI
C                 TRANSMITTER STATION NAMES & THEIR:
C                      LATITUDE & LONGITUDE
C                      EMISSION DELAY (IN MICROSECONDS)
C                      NOMINAL CODING DELAY (IN MICROSECONDS)
C                      RADIATED POWER (IN KILOWATTS)
C                      NOMINAL ECD (IN MICROSECONDS)
C                 MONITOR STATION NAMES & THEIR:
C                      LATITUDE & LONGITUDE
C                      ECD- CONTROLLING STANDARD
C                      TD- CONTROLLING STANDARD
C                      ECD- TOLERENCE
C                      TD- TOLERENCE
```

```
C
C     REFERENCES:
C         1. SODANO EQUATIONS (AC-90-45A(FAA ADVISORY CIRCULAR),
C             APPENDIX J).
C         2. WGS-72 PARAMETERS (WILD GOOSE ASSOCIATION).
C         3. NATIONAL BUREAU OF STANDARDS CIRCULAR 573 (NBS-573);
C            "PHASE OF THE LOW RADIOFREQUENCY GROUND WAVE", BY JOHLER.
C         4. "SYSTEMS CONTROL TECHNOLOGY"/ WALT DEAN.
C         5. U.S. COAST GUARD;"SPECIFICATIONS OF THE TRANSMITTED
C             LORAN-C SIGNAL", COMDTINST MI6562.4, JULY 1981.
C         6. "LORAN", BY PIERCE, McKENZIE, AND WOODWARD; SECTION 3-4,
C             APPENDIX C1.
C         7. "GEOMETRIC DILUTION OF PRECISION(GDOP)", BY ERIC SWANSON,
C             JOURNAL OF THE INSTITUTE OF NAVIGATION, VOL.25, No.4
C             WINTER 1978-79.
C         8. "LORAN-C SIGNAL STABILITY STUDY: ST. LAWRENCE SEAWAY", BY
C             DANIEL SLAGLE AND ROBERT WENZEL, APPENDIX A, CG-D-39-82.
C         9. ROBERT ERIKSON, U.S. DEPT. OF TRANS.; FEDERAL AVIATION
C             ADMINISTRATION TECHNICAL CENTER, ACT-100B.2,
C             ATLANTIC CITY AIRPORT, N.J.
C
C*******************************************************************************
C*******************************************************************************
C
      PROGRAM LORANC
      COMMON/LOC/P,R
      COMMON/TRIDAT/MW,NN,TOA,ED1,TD,GDT,AL,LOP,XA,WW,W,MN
      COMMON/TRDAT2/RS,RL,GDOP,ATE,CTE,RNWY
      BYTE TRANS(16,5),NAME(72),MON(16,5),QQ(130),WW(130),TIMSTR(8),
     :DATSTR(10)
      INTEGER IREV,Z,O,XX(5,2),YY(5,2),XXM(5,2),YYM(5,2),BB(2),CC(2)
      REAL ECD(5),X(5,3),Y(5,3),RP(5),CDN(5),XM(5,3),YM(5,3),MKR(5),
     :NECD(5),ED(5),CSECD(5),CSTD(5),TECD(5),TTD(5)
      DOUBLE PRECISION TT(2,8),G(5),H(5),B(3),C(3),P(5),R(5),GM(5),
     :TOA(5),LOP(5),XA(6),PM(5),RM(5),HM(5),ED1(5),GDOP(6),
     :RDD(5),RS(6),RL(6),AL(5),FS1(5),FS2(5),SNR1(5),SNR2(5),ATE(6),
     :CTE(6),GDT(5),TD(5)
      LOGICAL U,V,W(5),U1,V1
C
      IREV=20           !REVISION NUMBER--FOR REFERENCE
C
      DATA TT/'NORTHEAS','T  :9960','SOUTHEAS','T  :7980',
     :        'WEST COA','ST :9940','GREAT LA','KES:8970',
     :        'CAN.E.CO','AST:5930','CAN.W.CO','AST:5990',
     :        'ALASKA G','ULF:7960','N. PACIF','IC :9990'/
      NUM=0
      CALL DATE(DATSTR(1))
      CALL TIME(TIMSTR(1))
      WRITE(5,30)(DATSTR(I),I=1,9),(TIMSTR(I),I=1,8)
   30 FORMAT(//////////T30,9A1/T30,8A1//)
      GOTO 60
   40 CONTINUE
      TYPE 50
   50 FORMAT(' DO YOU WISH TO USE THE SAME GRI? YES=1')
      READ(5,*)JJ
      IF (JJ.EQ.1) GOTO 350
   60 DO 80 I=1,8
        WRITE(5,70)(TT(J,I),J=1,2)
   70   FORMAT(1X,2A8)
   80 CONTINUE
  199 TYPE 200
  200 FORMAT(' ENTER DATA FILE SPEC.,LC<GRI>;(ex: LC9960)'/)
      CALL ASSIGN(1,-1,'RD0')
```

```
      READ(1,END=201)GRI                    !TO CALCULATE THE NUMBER OF
      KK=0                                  !STATIONS IN SELECTED GRI
      IF (GRI.EQ.7960.) KK=7
      IF (GRI.EQ.9960.) KK=1
      IF (GRI.EQ.7980.) KK=2
      IF (GRI.EQ.9940.) KK=3
      IF (GRI.EQ.8970.) KK=4
      IF (GRI.EQ.5930.) KK=5
      IF (GRI.EQ.5990.) KK=6
      IF (GRI.EQ.9990.) KK=8
201   IF (KK.NE.0) GOTO 202
      CALL CLOSE (1)
      GOTO 199
202   IF (KK.EQ.7.OR.KK.EQ.5) MM=3          !NUMBER OF STATIONS
      IF (KK.EQ.1.OR.KK.EQ.2) MM=5
      IF (KK.EQ.3.OR.KK.EQ.4.OR.KK.EQ.6.OR.KK.EQ.8) MM=4
      DO 300 I=1,MM                         !READS TRANS-STATIONS
        READ(1,END=301)(TRANS(J,I),J=1,16)      !NAME
        READ(1,END=301)(X(I,K),K=1,3),(Y(I,K),K=1,3)    !LAT/LONG
        READ(1,END=301)ED(I)                !EMISSION DELAY
        READ(1,END=301)NECD(I)              !NOMINAL ECD
        READ(1,END=301)RP(I),CDN(I)         !RAD. POWER,NOM. CODING DELAY
        READ(1,END=301)MKR(I)               !MARKER FOR END OF STATIONS
        XX(I,1)=INT(ABS(X(I,1)))
        XX(I,2)=INT(ABS(X(I,2)))            !TRUNCATES ASBSOLUTE LOCATION
        YY(I,1)=INT(ABS(Y(I,1)))
        YY(I,2)=INT(ABS(Y(I,2)))
        IF (MKR(I).EQ.1.0) GOTO 301
300   CONTINUE
301   CONTINUE
      DO 305 I=1,MM                         !READS MONITOR STATIONS
        READ(1,END=310)(MON(J,I),J=1,16)        !NAME
        READ(1,END=310)(XM(I,J),J=1,3),(YM(I,J),J=1,3)  !LAT/LONG
        READ(1,END=310)CSECD(I)             !CSECD
        READ(1,END=310)CSTD(I)              !CSTD
        READ(1,END=310)TECD(I)              !TOLERENCE ECD
        READ(1,END=310)TTD(I)               !TOLERENCE TD
        XXM(I,1)=INT(ABS(XM(I,1)))
        XXM(I,2)=INT(ABS(XM(I,2)))          !TRUNCATES ABSOLUTE LOCATIONS
        YYM(I,1)=INT(ABS(YM(I,1)))
        YYM(I,2)=INT(ABS(YM(I,2)))
305   CONTINUE
310   CONTINUE
      CALL CLOSE (1)
      IF (MKR(MM).NE.1.0) GOTO 199
      DO 320 I=1,MM
        P(I)=X(I,1)+X(I,2)/60+X(I,3)/3600       !CONVERTS TRANS-STAT
        R(I)=Y(I,1)+Y(I,2)/60+Y(I,3)/3600       !LAT/LONG TO DECIMAL
320   CONTINUE
350   CONTINUE
      DO 355 NO=1,5
        ED1(NO)=ED(NO)
355   CONTINUE
      DO 999 Z=1,MM
        IF (Z.GT.1) GO TO 440
380     DO 390 N=1,130
          QQ(N)='*'
          WW(N)='-'
390     CONTINUE
        IF(NUM.EQ.0) GOTO 399
        WRITE(6,395)                        !TOP OF FORM FOR EACH NEW
395     FORMAT('1')                         !SELECTED SITE
399     CONTINUE
```

```
      WRITE(6,400)(QQ(N),N=1,130)
400   FORMAT('+',130(A1))
      WRITE(6,4001)
4001  FORMAT(T10'>>DATA PROCESSED BY: FEDERAL AVIATION ADMINISTRA',
     :'TION TECHNICAL CENTER, ATLANTIC CITY AIRPORT, N.J. 08405<<')
      WRITE(6,4002)(WW(N),N=1,106)
4002  FORMAT(T10,106A1)
      WRITE(6,*)' '
      IF (NUM.EQ.0) GOTO 402
      TYPE 401
401   FORMAT(//' SAME LOCATION NAME?(Y=1)')
      READ(5,*)IQU
      IF (IQU.EQ.1) GOTO 4051
402   DO 403 N=1,72
        NAME(N)=' '
403   CONTINUE
      TYPE 404
404   FORMAT(//' ENTER NAME OF LOCATION OF SELECTED SITE',
     :'(72 CHAR.MAX.)')
      READ(5,405)MMM,(NAME(N),N=1,72)
405   FORMAT(Q,72A1)
C*************************************************************************
C     INPUT  LOCATION OF SELECTED POINT.
C     IT WILL BE ASSUMED THAT NORTH AND WEST ARE POSITIVE QUANTITIES.
C*************************************************************************
      IF (NUM.EQ.0) GOTO 407
4051  TYPE 406
406   FORMAT(//' SAME LOCATION COORDINATES?(Y=1)'//)
      READ(5,*)IREP
      IF (IREP.EQ.1) GOTO 4301
407   WRITE(5,408)
408   FORMAT(//1X,'NORTH & WEST ARE POSITIVE, SOUTH & EAST ARE',
     :' NEGATIVE')
      WRITE(5,410)
410   FORMAT(/1X,'ENTER LATITUDE-DEG MIN SEC ',
     :'(LV. SPACE BETW. EACH)')
      READ(5,415)(B(N),N=1,3)
415   FORMAT(F5.0,F4.0,F6.2)
      WRITE(5,420)
420   FORMAT(/1X,'ENTER LONGITUDE-DEG MIN SEC ',
     :'(LV. SPACE BETW. EACH)')
      READ(5,425)(C(N),N=1,3)
425   FORMAT(F5.0,F4.0,F6.2)
      IF (B(1).LT.0) GOTO 426 !ASSIGNS NORTH OR SOUTH TO LOCATION
      U1='N'                  !       OF SELECTED SITE
      GOTO 427
426   U1='S'
427   CONTINUE
      IF (C(1).LT.0) GOTO 428 !ASSIGNS WEST OR EAST TO LOCATION
      V1='W'                  !       OF SELECTED SITE
      GOTO 429
428   V1='E'
429   CONTINUE
      DO 430 N=1,2
        BB(N)=INT(ABS(B(N)))
        CC(N)=INT(ABS(C(N)))
430   CONTINUE
      IF (NUM.EQ.0) GOTO 4312
4301  WRITE(5,4311)
4311  FORMAT(' SAME RUNWAY HEADING, VARIATION, & ATMOS. NOISE?',
     :'(Y=1)')
      READ(5,*)IREP2
      IF (IREP2.EQ.1) GOTO 4319
```

```
 4312   WRITE(5,4313)
 4313   FORMAT(//' ENTER RUNWAY HEADING (W/RESPECT TO MAGNETIC ',
     :  'NORTH)')
        READ(5,4314)RH
 4314   FORMAT(F7.3)
        WRITE(5,4315)
 4315   FORMAT(//' ENTER MAGNETIC VARIATION (TRUE NORTH - MAGNETIC ',
     :  'NORTH)')
        READ(5,4316)VAR
 4316   FORMAT(F7.3)
        RNWY=RH+VAR
        WRITE(5,4317)
 4317   FORMAT(//' ENTER ESTIMATED ATMOSPHERIC NOISE (dB ABOVE ',
     :  '1 uv/m)')
        READ(5,4318)ATNO
 4318   FORMAT(F7.3)
C*************************************************************************
C     HEADER FORMAT
C*************************************************************************
 4319   CALL DATE(DATSTR(1))                        !DATE ENTERED AND
        CALL TIME(TIMSTR(1))              !TIME READ FROM COMPUTER FOR PRINT OUT
        WRITE(6,432)(DATSTR(III),III=1,9)
 432    FORMAT(1X,'SELECTED LOCATION:',T80,9A1)
        WRITE(6,433)(NAME(K),K=1,72),TIMSTR
 433    FORMAT('  ',72A1,T80,8A1)
        WRITE(6,435)(BB(NB),NB=1,2),B(3),U1,(CC(NB),NB=1,2),C(3),V1
 435    FORMAT(1X,I4,I3,F6.2,A1,3X,1X,I4,I3,F6.2,A1)
        WRITE(6,*)' '
        WRITE(6,437)RH
 437    FORMAT(' RUNWAY HEADING (W/RESPECT TO MAGNETIC NORTH) IN ',
     :  'DEGREES: ',T66,F6.2)
        WRITE(6,438)VAR
 438    FORMAT(' MAGNETIC VARIATION ({TRUE NORTH} - {MAGNETIC ',
     :  'NORTH}) IN DEGREES: ',T66,F6.2)
        WRITE(6,439)ATNO
 439    FORMAT(' ESTIMATED ATMOSPHERIC NOISE (dB ABOVE 1 uv/m): ',T66,
     :  F6.2)
        WRITE(6,*)' '
 440    CONTINUE
C*************************************************************************
C     SUBROUTINES CALLED
C*************************************************************************
        CALL GREAT(Z,B,C,G(Z),H(Z))      !G.C. DIST.&HEAD.;TRANS-SITE
        CALL DELAY(G(Z),TOA(Z))          !TIME DELAY
        CALL GRDWFS(G(Z),RP(Z),FS1(Z),FS2(Z),SNR1(Z),SNR2(Z),ATNO)
        CALL ETCDIF(G(Z),NECD(Z),ECD(Z))  !ENVELOP TO CYCLE DIFFERENCE
C*************************************************************************
 999  CONTINUE
      WRITE(6,443)(TT(N,KK),N=1,2)
 443  FORMAT(1X,'GRI: ',2A8,T83,'GROUND WAVE FIELD STRENGTH & SNR')
      WRITE(6,445)
 445  FORMAT(T90,'(dB ABOVE 1 uv/m)')
      WRITE(6,447)
 447  FORMAT(32X,'EMISSION',3X,'RAD.',3X,'NOM.',T87,'SEAWATER',7X,
     :'POOR SOIL')
      WRITE(6,450)
 450  FORMAT(3X,'TRANSMITTER STATION',11X,'DELAY,',3X,
     :'POWER,',2X,'ECD,',5X,'DIST,',4X,'HDG,',4X,'TOA,',T87,
     :'(5 mho/m)',T102,'(1 mmho/m)',T117,'ECD')
      WRITE(6,452)
 452  FORMAT(3X,'(LAT./LONG.)',18X,'usec',6X,'kW',5X,
     :'usec',6X,'NM',6X,'deg.',4X,'usec',T88,'FS',4X,'SNR',5X,'FS',4X,
     :'SNR',T117,'usec')
```

```
      WRITE(6,455)(WW(NN),NN=1,130)
 455  FORMAT(1X,130(A1))
      WRITE(6,*)' '
C*************************************************************************
C     DATA FORMAT
C*************************************************************************
      DO 470 NV=1,MM
        IF (P(NV).LT.0) GO TO 460        !ASSIGNS NORTH OR SOUTH TO
        U='N'                            ! LOCATION OF TRANS-STAT
        GO TO 461
 460    U='S'
 461    CONTINUE
        IF (R(NV).LT.0) GO TO 462        !ASSIGNS WEST OR SOUTH TO
        V='W'                            ! LOCATION OF TRANS-STAT
        GO TO 463
 462    V='E'
 463    CONTINUE
        WRITE(6,465)(TRANS(J,NV),J=1,16),ED(NV),RP(NV),NECD(NV),
     :  G(NV),H(NV),TOA(NV),FS1(NV),SNR1(NV),FS2(NV),SNR2(NV),ECD(NV)
 465    FORMAT(1X,16A1,15X,F8.2,3X,F5.0,F6.1,2X,F9.3,F7.1,2X,F9.4,
     :  T88,F3.0,T92,F5.0,T102,F3.0,T106,F5.0,T115,F7.4)
        WRITE(6,467)(XX(NV,K),K=1,2),X(NV,3),U,(YY(NV,K),K=1,2),Y(NV,3),
     :  V
 467    FORMAT(1X,I4,I3,F6.2,A1,I4,I3,F6.2,A1)
 470  CONTINUE
      WRITE(6,*)' '
      WRITE(6,*)' '
C*************************************************************************
C     HEADER (MONITOR STATIONS) FORMAT
C*************************************************************************
      WRITE(6,495)
 495  FORMAT(T40,'DOUBLE RANGE')
      WRITE(6,500)
 500  FORMAT(3X,'MONITOR STATION(SAM)',T40,'DIFFERENCE,')
      WRITE(6,505)
 505  FORMAT(3X,'(LAT/LONG)',T40,'(W/ MASTER)')
      WRITE(6,510)(WW(NN),NN=1,55),(QQ(NN),NN=1,49)
 510  FORMAT(1X,55(A1),T75,49A1)
      WRITE(6,511)(QQ(NN),NN=1,2)
 511  FORMAT(T75,A1,T123,A1)
      DO 513 Z=1,MM
        DO 512 KL=1,3
           PM(KL)=XM(Z,KL)
           RM(KL)=YM(Z,KL)
 512    CONTINUE
C*************************************************************************
      CALL GREAT(Z,PM,RM,GM(Z),HM(Z))    !G.C. DIST.;TRANS-SAM
C*************************************************************************
 513  CONTINUE
C*************************************************************************
      CALL DRDIFF(MM,G,GM,RDD)           !DOUBLE RANGE DIFFERENCE
C*************************************************************************
C     MONITOR DATA FORMAT
C*************************************************************************
      DO 550 NV=1,MM
        IF (XM(NV,1).LT.0) GOTO 520      !ASSIGNS NORTH OR SOUTH TO
        U='N'                            !LOCATION OF MONITOR
        GOTO 525
 520    U='S'
 525    CONTINUE
        IF (YM(NV,1).LT.0) GOTO 530      !ASSIGNS WEST OR EAST TO
        V='W'                            !LOCATION OF MONITOR
        GOTO 535
```

```
530     V='E'
535     CONTINUE
        IF (NV.EQ.1) GOTO 537
        IF (NV.EQ.2) GOTO 538
        IF (NV.EQ.3) GOTO 539
536     WRITE(6,540)(MON(J,NV),J=1,16),RDD(NV)
        GOTO 542
537     WRITE(6,541)(MON(J,NV),J=1,16),RDD(NV)
        GOTO 543
538     WRITE(6,5411)(MON(J,NV),J=1,16),RDD(NV)
        GOTO 543
539     WRITE(6,5412)(MON(J,NV),J=1,16),RDD(NV),(QQ(NN),NN=1,49)
540     FORMAT(1X,16A1,T42,F9.4)
541     FORMAT(1X,16A1,T42,F9.4,T75,'*    UNLESS OTHERWISE NOTED, ',
     :  'ALL CALCULATIONS   *')
5411    FORMAT(1X,16A1,T42,F9.4,T75,'*    ASSUME A SEAWATER PATH FOR',
     :  ' PROPAGATION.    *')
5412    FORMAT(1X,16A1,T42,F9.4,T75,49A1)
542     WRITE(6,545)(XXM(NV,K),K=1,2),XM(NV,3),U,(YYM(NV,K),K=1,2),
     :  YM(NV,3),V
        GOTO 549
543     WRITE(6,546)(XXM(NV,K),K=1,2),XM(NV,3),U,(YYM(NV,K),K=1,2),
     :  YM(NV,3),V,(QQ(NN),NN=1,2)
545     FORMAT(1X,I4,I3,F6.2,A1,I4,I3,F6.2,A1)
546     FORMAT(1X,I4,I3,F6.2,A1,I4,I3,F6.2,A1,T75,A1,T123,A1)
549     CONTINUE
550   CONTINUE
      WRITE(6,*)' '
      WRITE(6,*)' '
      MW=MM
C*******************************************************************************
      CALL GRAD(H,GDT,AL,MW,W)            !GRADIENTS
      CALL DOLOP(H,LOP,MW)                !NORM TO LOP(LINE OF POSITION)
      CALL TIMDIF(TOA,ED1,TD,MW)          !TIME DIFFERENCE
      CALL XANGLE(LOP,XA,MW,KK,NN,MN)     !CROSSING ANGLE
      MW=MM
      CALL RFERR(XA,H,MW,NN,RS,RL,GDOP) !RADIAL ERRORS(SHORT & LONG)
      CALL ELLIPS(MW,NN,H,RNWY,ATE,CTE) !TRACKING ERRORS(ALONG & CROSS)
      CALL TRIADS                         !TRIADS FORMATTED
C*******************************************************************************
      WRITE(5,600)
600   FORMAT(//1X,'CONTINUE?(YES=99)')
      READ(5,610)O
610   FORMAT(I2)
      WRITE (6,620)(QQ(NE),NE=1,127),IREV
620   FORMAT(1X,127(A1),I3)
      NUM=NUM+1
      IF (O.EQ.99) GO TO 40
      CALL DATE(DATSTR(1))
      CALL TIME(TIMSTR(1))
      WRITE(5,630)(DATSTR(I),I=1,9),(TIMSTR(I),I=1,8)
630   FORMAT(/////////T30,9A1//T30,8A1/////////)
      CALL EXIT
      END
```

```
      SUBROUTINE GREAT(TS,B,C,GCD,HDG)
C
C*************************************************************************
C        SUBROUTINE GREAT CALCULATES THE GREAT CIRCLE DISTANCE
C     BETWEEN A SELECTED SITE OR MONITOR AND A TRANSMITTER, AND ALSO
C     THE INITIAL HEADING FROM THE SELECTED SITE TO THE TRANSMITTER
C     OR MONITOR.
C
C     B= LATITUDE OF SELECTED SITE OR MONITOR STATIONS.
C     C= LONGITUDE OF SELECTED SITE OR MONITOR STATIONS.
C     P= LATITUDE OF TRANSMITTER STATIONS.
C     R= LONGITUDE OF TRANSMITTER STATIONS.
C     GCD= THE GREAT CIRCLE DISTANCE BETWEEN THE SELECTED SITE
C        AND THE LORAN-C TRANSMITTER OR MONITOR STATION SELECTED IN
C        NAUTICAL MILES.
C     HDG(A12)= IS THE AZIMUTH (GREAT CIRCLE) FROM THE SELECTED
C        POINT TO THE LORAN-C TRANSMITTER OR MONITOR STATION LOCATION;
C        e.g. INITIAL HEADING FROM SELECTED SITE TO TRANSMITTER.
C     A21= THE AZIMUTH OF GEODESIC FROM THE TRANSMITTER OR MONITOR
C        STATION TO THE SELECTED SITE.
C     TS= STATION NUMBER
C
C        THIS SUBROUTINE USES THE SODANO EQUATIONS AS DESCRIBED IN
C     AC-90-45A(APPENDIX J) WITH WGS-72 PARAMETERS:
C           F=3.3528E-3
C           AX=3443.917387(SEMIMAJOR AXIS OF THE EARTH)
C*************************************************************************
      INTEGER TS
      COMMON/LOC/P,R
      DOUBLE PRECISION B1,L1,B2,L2,BE1,BE2,LP,L,LR,PH,Q,AL,M,GR,S1,SS,
     :ST,S,X,H,LB,LA,SI,A12,A21,LD,LC,V,GCD,HDG,A,HR,X1,PI,AX,F,
     :B(3),C(3),P(5),R(5)
      PI=3.14159265360000
      AX=3443.91738700000        !SEMIMAJOR AXIS OF THE EARTH
      F=3.3528D-3
C*************************************************************************
C        B1 & L1 IS THE PRESENT POSITION(LAT/LONG) OF THE SELECTED
C     SITE ENTERED OR THE LORAN-C MONITOR STATION(SAM) CHOSEN;
C     AND CONVERTED FROM DEG MIN SEC TO DEGREES.
C        B2 & L2 IS THE POSITION(LAT/LONG) OF THE LORAN-C TRANSMITTER
C     STATION CHOSEN CONVERTED FROM DEG MIN SEC TO DEGREES.
C*************************************************************************
      B1=(B(1)+B(2)/60+B(3)/3600)        !LAT OF SITE OR MON.(DEGREES)
      B1=B1*PI/180                       !LAT OF SITE OR MON.(RADIANS)
      L1=C(1)+C(2)/60+C(3)/3600          !LONG OF SITE OR MON.(DEGREES)
      B2=(P(TS))*PI/180                  !LAT OF TRANSMITTER(RADIANS)
      L2=R(TS)                           !LONG OF TRANSMITTER(DEGREES)
C*************************************************************************
C     SODANO EQUATIONS
C     **NOTE: DEGREES ARE CONVERTED TO RADIANS FOR COMPUTATION
C           OF TRIG. FUNCTIONS
C*************************************************************************
      BE1=DATAN((1-F)*(DSIN(B1)/DCOS(B1)))
      BE2=DATAN((1-F)*(DSIN(B2)/DCOS(B2)))
      A=DSIN(BE1)*DSIN(BE2)
      LP=L1-L2                           !DIFF. IN LONG.(DEGREES)
      IF (DABS(LP).GT.180.0) GOTO 20
      L=LP
      GOTO 40
   20 L=LP+(360*(DABS(LP))/LP)
   40 CONTINUE
      LR=L*PI/180                        !DIFF. IN LONG.(RADIANS)
      PH=(DSIN(BE1)*DSIN(BE2))+(DCOS(BE1)*DCOS(BE2)*DCOS(LR))
```

```
      Q=(DSIN(BE2)*DCOS(BE1)-DSIN(BE1)*DCOS(BE2)*DCOS(LR))**2
      AL=DSQRT((DSIN(LR))**2*(DCOS(BE2))**2+Q)
      M=(AL**2-(DSIN(LR))**2*(DCOS(BE1))**2*(DCOS(BE2)**2))/AL**2
      GR=DATAN(AL/PH)
      S1=GR+(F**2+F)/2*(GR*(2-M)+AL*(2*A-M*PH))
        SS=8*GR**2*(M-1)*(A+AL*(DCOS(GR)/DSIN(GR)))
        ST=SS+AL**2*PH*(8*A*(M*PH-A)+(1-2*PH**2))
      S1=S1+F**2/(16*AL)*(ST+AL*GR)
      S=(1-F)*AX*S1                          !GREAT CIRCLE DISTANCE
      X1=GR*(F+F**2)-A*F**2/(2*AL)*(AL**2+2*GR**2)
      X=X1+M*F**2/4*(AL*PH-5*GR+4*GR**2*(DCOS(GR)/DSIN(GR)))
      HR=(DSIN(L)*DCOS(BE1)*DCOS(BE2)/AL)*X+LR
      LB=DSIN(BE2)*DCOS(BE1)-DCOS(HR)*DSIN(BE1)*DCOS(BE2)
      LA=DSIN(HR)*DCOS(BE2)
      IF ((DATAN(LA/LB)*180/PI).LT.0) GOTO 60
      SI=DATAN(LA/LB)*180/PI
      GOTO 80
   60 SI=DATAN(LA/LB)*180/PI+180
   80 CONTINUE
      IF (L.LT.0) GOTO 100
      A12=SI
      GOTO 120
  100 A12=SI+180
  120 CONTINUE
      LD=DSIN(BE2)*DCOS(BE1)*DCOS(HR)-DSIN(BE1)*DCOS(BE2)
      LC=DSIN(HR)*DCOS(BE1)
      IF ((DATAN(LC/LD)*180/PI).LT.0) GOTO 140
      V=DATAN(LC/LD)*180/PI
      GOTO 160
  140 V=180+DATAN(LC/LD)*180/PI
  160 CONTINUE
      IF (L.GT.0) GOTO 180
      A21=V
      GOTO 200
  180 A21=V+180
  200 CONTINUE
      GCD=S
      HDG=A12                    !INITIAL HEADING; SITE TO TRANSMITTER
      RETURN
      END
```

```
      SUBROUTINE DELAY(R,TOA)
C
C*****************************************************************************
C     SUBROUTINE DELAY CALCULATES THE TIME DELAY OF THE LORAN-C
C     SIGNAL FOR A TRANSMITTER TO RECEIVER TRANSMISSION.
C     THE SOURCE OF THIS EQUATION IS  FIGURE 3 IN NBS-573 DOCUMENT
C     (FOR SEAWATER).
C     EQUATION IS A 5TH ORDER POLYNOMIAL DEVELOPED BY TASC.
C
C     R= RANGE IN NAUTICAL MILES
C     N= REFRACTIVE INDEX
C     VL= VELOCITY OF LIGHT IN NM/usec
C     TOA= TIME DELAY OF LORAN-C SIGNAL FOR TRANSMITTER TO RECEIVER
C*****************************************************************************
      REAL N
      DOUBLE PRECISION TOA,R,VL,T,A,B,C,D,E,Q,W
      DATA N/1.000338/
      VL=.161874977300000
      IF (R.GT.8.7.AND.R.LE.86.9) GO TO 20
      IF (R.GT.86.9.AND.R.LT.1303.0) GO TO 40
      IF (R.LE.7.8.OR.R.GE.1303.0) GO TO 60
   20 A=0.107109D3                !FOR 8.7 < RANGE <= 86.9
      B=-0.104986D1
      C=0.415597D-1
      D=0.625429D-4
      E=0.333305D-6
      GO TO 80
   40 A=-0.966958D5               !FOR 86.9 < RANGE < 1303.0
      B=0.394614D3
      C=-0.594986D0
      D=0.683632D-3
      E=-0.228463D-8
      GO TO 80
   60 WRITE(5,70)R                !FOR RANGE <= 8.7 OR RANGE => 1303.0;
      WRITE(6,70)R                !ERROR: CAN'T BE CALCULATED
   70 FORMAT(1X,'TIME DELAY CAN NOT BE CALULATED WITH GIVEN RANGE:'/,
     :15X,F10.4/)
      TOA=0.0000
      GO TO 100
   80 CONTINUE
      T=6.1797777*R
      TOA=N/VL*R+A/T**2+B/T+C+D*T+E*T**2
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GRDWFS(R,RP,FS1,FS2,SNR1,SNR2,ATNO)
C
C*************************************************************************
C     SUBROUTINE GRDWFS CALCULATES THE GROUNDWAVE FIELD STRENGTH
C        OVER SEAWATER IN dB ABOVE 1 MICROVOLT/METER.
C     THE SOURCE OF THIS EQUATION(SEAWATER) IS FROM "SYSTEMS CONTROL
C        TECHNOLOGY"/ BY WALT DEAN.
C
C     R= RANGE IN NAUTICAL MILES
C     RP= PEAK RADIATED POWER OF TRANSMITTER IN KILOWATTS
C     FS1= GROUNDWAVE FIELD STRENGTH dB ABOVE 1 uV/METER(SEAWATER)
C     FS2= GROUNDWAVE FIELD STRENGTH dB ABOVE 1 uV/METER(POOR SOIL)
C     ATNO= ESTIMATED ATMOSPHERIC NOISE
C     SNR1= SIGNAL-TO-NOISE RATIO(SEAWATER)
C     SNR2= SIGNAL-TO-NOISE RATIO(POOR SOIL)
C*************************************************************************
      DOUBLE PRECISION R,FS1,FS2,AO,SNR1,SNR2,A(7)
      AO=104.0+10*DLOG10(RP)-6.0        !-6.0 dB TO MAKE FIELD STRENGTH
      IF (R.LT.150.0) GOTO 10           !AT 3RD CYCLE, NOT PEAK.
      IF (R.GE.150.0.AND.R.LE.450.0) GOTO 20
      IF (R.GT.450.0) GOTO 30
      WRITE(5,5)R
    5 FORMAT(/' ERROR IN GIVEN RANGE:'/6X,F9.4/)
   10 FS1=AO-20*DLOG10(R)                         !RANGE < 150 N.M.
      GOTO 40
   20 FS1=AO-20*DLOG10(R)-0.024*(R-150.0)         !150  <= RANGE <= 450
      GOTO 40
   30 FS1=AO-60-0.04*(R-450.0)                    !450 N.M. < RANGE
   40 CONTINUE
      A(1)=93.25469556205636            !112.65788228;
      A(2)=-.645430294                  !A(1) TERM FOR 6TH ORDER POLYN'L
      A(3)=.00391649001                 !IN WGA DOCUMENT, POWER=400kW
      A(4)=-1.26649335000D-5
      A(5)=2.07557395000D-8
      A(6)=-1.65834993000D-11
      A(7)=5.12575970000D-15
      FS2=A(7)*R**6+A(6)*R**5+A(5)*R**4+A(4)*R**3+A(3)*R**2
      FS2=FS2+A(2)*R+A(1)+(10*DLOG10(RP))
      SNR1=FS1-ATNO
      SNR2=FS2-ATNO
      RETURN
      END
```

```
      SUBROUTINE ETCDIF(R,NECD,ECD)
C
C*****************************************************************************
C     SUBROUTINE ETCDIF CALCULATES THE ENVELOPE-TO-CYCLE DIFFERENCE.
C
C     SOURCE: USCG, SPECIFICATION OF THE TRANSMITTED LORAN-C
C        SIGNAL, COMDTINST MI6562.4, JULY 1981.
C
C     NOTE: FURTHER CHECKING IS NECESSARY TO DETERMINE IF THE
C        2.5 usec CONSTANT SHIFT IS WITH RESPECT TO THE ANTENNA
C        CURRENT OR THE FAR FIELD WAVE FORM.
C        ----------------------------------------------------
C       R= RANGE IN NAUTICAL MILES
C       NECD= NOMINAL ECD OF TRANSMITTING STATION
C       ECD= ECD OF TRANSMITTING STATION
C*****************************************************************************
C
      REAL NECD
      DOUBLE PRECISION ECD,R
      ECD=2.5-(0.0025*R)+NECD
      RETURN
      END
```

```
      SUBROUTINE DRDIFF(I,G,GM,RDD)
C
C*****************************************************************************
C        SUBROUTINE DRDIFF CALULATES THE DOUBLE RANGE DIFFERENCE
C     BETWEEN SELECTED SITE AND TRANSMITTER STATIONS, AND TRANSMITTER
C     STATIONS AND MONITOR STATIONS (SAM's).
C
C        DOUBLE RANGE DIFF.= {[G(N)-G(1)]-[GM(N)-GM(1)]}
C     WHERE:
C        G(N)= GREAT CIRCLE DIFFERENCE FROM N th SECONDARY TO USER.
C        G(1)= GREAT CIRCLE DIFFERENCE FROM MASTER TO USER.
C        GM(N)= GREAT CIRCLE DIFFERENCE FROM N th SECONDARY TO SAM.
C        GM(1)= GREAT CIRCLE DIFFERENCE FROM MASTER TO SAM.
C        RDD= DOUBLE RANGE DIFFERENCE.
C        I= NUMBER OF STATIONS.
C
C     SOURCE: EQUATION PER TASC REPORT.
C
C*****************************************************************************
      DOUBLE PRECISION G(5),GM(5),RDD(5)
      DO 10 N=2,I
        RDD(N)=((G(N)-G(1))-(GM(N)-GM(1)))
   10 CONTINUE
      RDD(1)=0.0
      RETURN
      END
```

```
      SUBROUTINE TIMDIF(TOA,ED,TD,MM)
C
C*********************************************************************
C     SUBROUTINE TIMDIF CALCULATES THE TIME DIFFERENCE(T.D.)
C       BETWEEN TWO STATIONS.
C
C       TD= TIME DIFFERENCE.
C       TOA= TIME OF ARRIVAL OF SIGNAL FROM TRANSMITTER TO RECEIVER
C          IN MICROSECONDS.
C       ED= PUBLISHED NOMINAL EMISSION DELAY IN MICROSECONDS
C       S1- FOR MASTER DEPENDENT SYSTEMS, S1 WILL BE THE MASTER. FOR
C          MASTER INDEPENDENT SYSTEMS, S1 WILL BE THE SECONDARY WITH
C          THE SMALLEST EMISSION DELAY.
C       S2- IS THE SECOND STATION REQUIRED TO FORM THE DESIRED LINE
C          OF POSITION.
C       MM= NUMBER OF STAIONS.
C*********************************************************************
      DOUBLE PRECISION TOA(5),ED(5),TD(5),EDS1,EDS2,TOAS1,TOAS2
      MM=MM-1
      DO 10 N=1,MM
      I=N+1
C     **         !TD=(TOAS2-TOAS1)+(EDS2-EDS1)
      TD(I)=(TOA(I)-TOA(1))+(ED(I)-ED(1))
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GRAD(HDG,GDT,AL,MM,W)
C
C*********************************************************************
C     SUBROUTINE GRAD CALCULATES THE ESTIMATES OF POSITIONAL ERROR
C     IN ft/usec.
C
C        GRADIENT = K*csc(1/2*SI)
C
C     SI= THE ANGLE BETWEEN THE DIRECTIONS FROM THE POINT TO
C        THE TWO LORAN-C STATIONS.
C     K= A CONSTANT NECESSARY TO CONVERT THE EXPRESSION TO THE
C        PROPER UNITS.  THE CONSTANT IS EQUAL TO 1/2 THE SIGNAL
C        PROPAGATION.  IF K EQUALS 1 THE RESULT IS IN MICROSECONDS.
C              VALUES OF K (ft/usec):
C                 FREE SPACE          491.62
C                 SEA WATER           491.45
C                 AVERAGE GROUND      491.22
C                 FROZEN GROUND       491.17
C
C     GDT= GRADIENT
C     HDG= INITIAL HEADING FROM SELECTED SITE TO TRANSMITTER.
C     AL= ANGLE BETWEEN MAIN AND SECONDARY
C     MM= NUMBER OF STATIONS.
C     W= POSSIBLE ERROR IN CALCULATION; INDICATOR FOR FORMATTING.
C
C     SOURCE: LORAN; BY PIERCE,McKENZIE,WOODWARD; SECTION 3-4,
C        APPENDIX C1.
C*********************************************************************
      DOUBLE PRECISION HDG(5),GDT(5),AL(5),SI
      LOGICAL W(5)
      DO 10 N=2,MM
        AL(N)=DABS(HDG(1)-HDG(N))
        IF (AL(N).GT.180.0) AL(N)=360.0-AL(N)
        SI=AL(N)*3.1415926536/180
        W(N)=' '
        IF (AL(N).LT.20.0) W(N)='*'
        GDT(N)=491.45*(1/DSIN(.5*SI))
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DOLOP(HDG,LOP,MM)
C
C*********************************************************************
C     SUBROUTINE DOLOP CALCULATES THE NORMAL TO THE LOP (LINE OF
C        POSITION).
C     FROM THE ABOVE SOURCE AN LOP IS FORMED AT 1/2 THE GEODESIC
C        ANGLE BETWEEN THE TWO STATIONS OF INTEREST WITH THE VERTEX
C        AT THE SELECTED POSITION.  THE TECHNIQUE DOES NOT INCLUDE
C        THE EFFECTS OF DIFFERENT PROPAGATION DELAYS FOR EACH
C        TRANSMITTER TO RECEIVER PATH.  ONE WOULD EXPECT THE LOP'S
C        TO SHIFT PARALLEL TO THOSE OBTAINED USING CONSTANT PROPAGATION
C        DELAYS EXCEPT IN AREAS OF LARGE GRADIENTS.
C     ** NO STUDY WILL BE CONDUCTED AT PRESENT TO OBTAIN ERROR BOUNDS.
C
C     NORMAL TO LOP= DIRECTION OF LOP + OR - 90 DEGREES, SIGN IS
C        REQUIRED TO POINT VECTOR IN DIRECTION OF SECONDARY OR
C        INCREASING TIME DELAY'S.
C     * TRIG. IDENTITY: Sin(180-a)=Sin(a), THEREFORE EITHER CLOCKWISE
C        OR COUNTER CLOCKWISE ANGLE BETWEEN MASTER AND SECONDARY YIELDS
C        THE SAME RESULT.
C
C     HDG= INITIAL HEADING FROM SELECTED SITE TO TRANSMITTER.
C     LOP= LINE OF POSITION.
C     MM= NUMBER OF STATIONS.
C
C     SOURCE: "GEOMETRIC DILUTIONS OF PRECISION", BY ERIC SWANSON,
C        JOURNAL OF THE INSTITUTDE OF NAVIGATION, VOL.25, No.4
C        WINTER 1978-79.
C
C*********************************************************************
      DOUBLE PRECISION HDG(5),LOP(5)
      DO 10 N=2,MM
        LOP(N)=HDG(1)-((HDG(1)-HDG(N))/2)
        IF (HDG(1).LT.HDG(N)) LOP(N)=LOP(N)+90.0
        IF (HDG(1).GT.HDG(N)) LOP(N)=LOP(N)-90.0
        IF (LOP(N).GT.360.0) LOP(N)=LOP(N)-360.0
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE XANGLE(LOP,XA,MM,KK,NN,MN)
C
C*********************************************************************
C     SUBROUTINE XANGLE CALCULATES THE CROSSING ANGLE OF THE TRIAD.
C
C     ** THE EQUATION USED DOES NOT INCLUDE ANY EFFECTS DUE TO
C          DIFFERENCE IN PROPAGATION DELAY RATES FOR EACH PATH.
C
C     SOURCE: "GEOMETRIC DILUTION OF PRECISION(GDOP)," BY ERIC SWANSON,
C       JOURNAL OF THE INSTITUTE OF NAVIGATION, VOL. 25, NO. 4,
C       WINTER 1978-79.
C
C       XA= CROSSING ANGLE.
C       LOP= THE NORMAL TO THE LINE OF POSITION.
C       MM= NUMBER OF STATIONS.
C       KK= STATION IDENTIFIER.
C       NN= NUMBER OF TRIADS.
C       MN= FORMAT SPECIFIER.
C
C*********************************************************************
      DOUBLE PRECISION LOP(5),XA(6)
      IF (KK.EQ.1.OR.KK.EQ.2) MN=1
      IF (KK.EQ.3.OR.KK.EQ.4) MN=2
      IF (KK.EQ.6.OR.KK.EQ.8) MN=3
      IF (KK.EQ.5.OR.KK.EQ.7) MN=4
      IF (MN.EQ.1) NN=6
      IF (MN.EQ.2.OR.MN.EQ.3) NN=3
      IF (MN.EQ.4) NN=1
      DO 20 I=2,4
        M=I-1
        N=I+1
        XA(M)=DABS(LOP(2)-LOP(N))
        IF (XA(M).GT.180.0) XA(M)=360.0-XA(M)
        IF (M.EQ.NN.AND.NN.EQ.1) GOTO 40
        IF (M.EQ.(NN-1)) GOTO 20
   20 CONTINUE
      DO 30 J=4,5
        XA(J)=DABS(LOP(3)-LOP(J))
        IF (XA(J).GT.180.0) XA(J)=XA(J)-180.0
        IF (J.EQ.(NN+1)) GOTO 40
   30 CONTINUE
      XA(6)=DABS(LOP(4)-LOP(5))
      IF (XA(6).GT.180.0) XA(6)=XA(6)-180.0
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RFERR(XA,HDG,MM,NN,RES,REL,GDOP)
C
C*********************************************************************
C     SUBROUTINE RFERR CALCULATES THE RADIAL FIX ERROR FOR BOTH
C        THE SHORTEST AND LONGEST DISTANCE IN FEET.
C
C     SOURCES:
C      "GEOMETRIC DILUTION OF PRECISION(GDOP)," BY ERIC SWANSON,
C         (EQUATION 10), JOURNAL OF THE INSTITUTE OF NAVIGATION,
C         VOL. 25, NO. 4, WINTER 1978-79.
C       "LORAN", BY PIERCE, McKENZIE, AND WOODWARD; SECTION 3-4,
C         APPENDIX C1.
C
C       RES= RADIAL FIX ERROR (2DRMS); SHORTEST DISTANCE
C       REL= RADIAL FIX ERROR (2DRMS); LONGEST DISTANCE
C       GDOP= GEOMETRIC DILUTION OF PRECISION
C       XA=  CROSSING ANGLE
C       XB=  ACUTE CROSSING ANGLE
C       HDG= INITIAL HEADING
C       SIG= STANDARD DEVIATION IN T.D. MEASUREMENT
C       S=   SCALE FACTOR
C       A=   ANGLE BETWEEN MASTER AND SECONDARY 1;CONVERTED TO RADIANS
C       B=   ANGLE BETWEEN MASTER AND SECONDARY 2;CONVERTED TO RADIANS
C       MM=  NUMBER OF STATIONS
C       NN=  NUMBER OF TRIADS
C
C*********************************************************************
      DOUBLE PRECISION XA(6),XB(6),HA(5),HDG(5),A,B,RES(6),REL(6),
     :SUB1,SUB2,PI,SUB21,GDOP(6)
      PI=3.1415926536
      SIG=.1
      S=491.45
      DO 5 L=1,NN
        IF (XA(L).LT.90.0) GOTO 3
        XB(L)=180.0-XA(L)               !CROSSING ANGLE MUST BE ACUTE
        GOTO 4
    3   XB(L)=XA(L)
    4 CONTINUE
      IF (NN.EQ.3) XB(4)=XB(3)
    5 CONTINUE
      DO 10 N=2,MM
        HA(N)=DABS(HDG(1)-HDG(N))       !ANGLE BETW MASTER & SECONDARY
        IF (HA(N).GT.180.0) HA(N)=360.0-HA(N)
   10 CONTINUE
      DO 20 J=2,4
        I=J-1
        M=J+1
        A=HA(2)*PI/180.0
        B=HA(M)*PI/180.0
        SUB1=1/(DSIN(B/2))**2+1/(DSIN(A/2))**2
        SUB1=SUB1-2*DCOS(XB(I)*PI/180.0)/(DSIN(B/2)*DSIN(A/2))
        RES(I)=SIG*S/DSIN(XB(I)*PI/180.0)*DSQRT(SUB1) !RAD.ERR.(SHORT)
        SUB2=1/(DSIN(B/2))**2+1/(DSIN(A/2))**2
        SUB2=SUB2+2*DCOS(XB(I)*PI/180.0)/(DSIN(A/2)*DSIN(B/2))
        REL(I)=SIG*S/DSIN(XB(I)*PI/180.0)*DSQRT(SUB2) !RAD.ERR.(LONG)
        GDOP(I)=1.0/(DSQRT(2.0)*DSIN(XB(I)*PI/180.0))*DSQRT(SUB2)
        IF (I.EQ.NN.AND.NN.EQ.1) GOTO 40
        IF (I.EQ.(NN-1)) GOTO 25
   20 CONTINUE
   25 DO 30 I=4,5
        A=HA(3)*PI/180.0
        B=HA(I)*PI/180.0
        SUB1=1/(DSIN(B/2))**2+1/(DSIN(A/2))**2
```

```
      SUB1=SUB1-2*DCOS(XB(I)*PI/180.0)/(DSIN(B/2)*DSIN(A/2))
      RES(I)=SIG*S/DSIN(XB(I)*PI/180.0)*DSQRT(SUB1) !RAD.ERR.(SHORT)
      SUB2=1/(DSIN(B/2))**2+1/(DSIN(A/2))**2
      SUB2=SUB2+2*DCOS(XB(I)*PI/180.0)/(DSIN(A/2)*DSIN(B/2))
      REL(I)=SIG*S/DSIN(XB(I)*PI/180.0)*DSQRT(SUB2) !RAD.ERR.(LONG)
      GDOP(I)=1.0/(DSQRT(2.0)*DSIN(XB(I)*PI/180.0))*DSQRT(SUB2)
      IF (I.EQ.(NN+1)) GOTO 40
30 CONTINUE
      A=HA(4)*PI/180.0
      B=HA(5)*PI/180.0
      SUB1=1/(DSIN(B/2))**2+1/(DSIN(A/2))**2
      SUB1=SUB1-2*DCOS(XB(6)*PI/180.0)/(DSIN(B/2)*DSIN(A/2))
      RES(6)=SIG*S/DSIN(XB(6)*PI/180.0)*DSQRT(SUB1) !RAD.ERR.(SHORT)
      SUB2=1/(DSIN(B/2))**2+1/(DSIN(A/2))**2
      SUB2=SUB2+2*DCOS(XB(6)*PI/180.0)/(DSIN(A/2)*DSIN(B/2))
      REL(6)=SIG*S/DSIN(XB(6)*PI/180.0)*DSQRT(SUB2) !RAD.ERR.(LONG)
      GDOP(6)=1.0/(DSQRT(2.0)*DSIN(XB(6)*PI/180.0))*DSQRT(SUB2)
40 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE ELLIPS(MM,NN,H,RNWY,ATE,CTE)
C*****************************************************************
C     SUBROUTINE ELLIPS CALCULATES ALONG AND CROSS TRACK ERRORS
C       IN FEET.
C
C     SOURCE: "LORAN-C SIGNAL STABILITY STUDY: ST. LAWRENCE SEAWAY",
C       BY DANIEL SLAGLE AND ROBERT WENZEL, APPENDIX A, CG-D-39-82.
C
C     V= SPEED OF SIGNAL
C     DELTA= DELTA TIME DIFFERENCE
C     ATE= ALONG TRACK ERROR
C     CTE= CROSS TRACK ERROR
C*****************************************************************
      DOUBLE PRECISION H(5),A11,A12,A21,A22,AI11,AI12,AI21,AI22,D,
     :XTD1,XTD2;ATE(6),CTE(6),PI
      PI=3.141592653589793
      V=983.24
      DELTA=.1
      DO 10 J=2,4
        I=J-1
        M=J+1
        A11=DSIN(H(2)*PI/180.0)-DSIN(H(1)*PI/180.0)
        A12=DCOS(H(2)*PI/180.0)-DCOS(H(1)*PI/180.0)
        A21=DSIN(H(M)*PI/180.0)-DSIN(H(1)*PI/180.0)
        A22=DCOS(H(M)*PI/180.0)-DCOS(H(1)*PI/180.0)
        D=(A11*A22)-(A12*A21)
        AI11=A22/D
        AI12=-A12/D
        AI21=-A21/D
        AI22=A11/D
        XTD1=-V*((AI11*DELTA)+(AI12*DELTA))
        XTD2=-V*((AI21*DELTA)+(AI22*DELTA))
        ATE(I)=(DSIN(RNWY*PI/180.0)*XTD1)+(DCOS(RNWY*PI/180.0)*XTD2)
        CTE(I)=(-DCOS(RNWY*PI/180.0)*XTD1)+(DSIN(RNWY*PI/180.0)*XTD2)
        IF (I.EQ.NN.AND.NN.EQ.1) GOTO 30
        IF (I.EQ.(NN-1)) GOTO 15
   10 CONTINUE
   15 DO 20 I=4,5
        A11=DSIN(H(3)*PI/180.0)-DSIN(H(1)*PI/180.0)
        A12=DCOS(H(3)*PI/180.0)-DCOS(H(1)*PI/180.0)
        A21=DSIN(H(I)*PI/180.0)-DSIN(H(1)*PI/180.0)
        A22=DCOS(H(I)*PI/180.0)-DCOS(H(1)*PI/180.0)
        D=(A11*A22)-(A12*A21)
        AI11=A22/D
        AI12=-A12/D
        AI21=-A21/D
        AI22=A11/D
        XTD1=-V*((AI11*DELTA)+(AI12*DELTA))
        XTD2=-V*((AI21*DELTA)+(AI22*DELTA))
        ATE(I)=(DSIN(RNWY*PI/180.0)*XTD1)+(DCOS(RNWY*PI/180.0)*XTD2)
        CTE(I)=(-DCOS(RNWY*PI/180.0)*XTD1)+(DSIN(RNWY*PI/180.0)*XTD2)
        IF (I.EQ.(NN+1)) GOTO 30
   20 CONTINUE
        A11=DSIN(H(4)*PI/180.0)-DSIN(H(1)*PI/180.0)
        A12=DCOS(H(4)*PI/180.0)-DCOS(H(1)*PI/180.0)
        A21=DSIN(H(5)*PI/180.0)-DSIN(H(1)*PI/180.0)
        A22=DCOS(H(5)*PI/180.0)-DCOS(H(1)*PI/180.0)
        D=(A11*A22)-(A12*A21)
        AI11=A22/D
        AI12=-A12/D
        AI21=-A21/D
        AI22=A11/D
        XTD1=-V*((AI11*DELTA)+(AI12*DELTA))
```

```
      XTD2=-V*((AI21*DELTA)+(AI22*DELTA))
      ATE(6)=(DSIN(RNWY*PI/180.0)*XTD1)+(DCOS(RNWY*PI/180.0)*XTD2)
      CTE(6)=(-DCOS(RNWY*PI/180.0)*XTD1)+(DSIN(RNWY*PI/180.0)*XTD2)
30 CONTINUE
   DO 40 I=1,6
      ATE(I)=DABS(ATE(I))
      CTE(I)=DABS(CTE(I))
40 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE TRIADS
C
C*************************************************************************
C     SUBROUTINE TRIADS FORMATS ALL DATA CONNECTED WITH THE TRIADS
C     OF THE MASTER TRANSMITTER AND ITS SECONDARY TRANSMITTERS.
C
C       TOA= TIME DELAY
C       ED= EMISSION DELAY
C       GDT= GRADIENTS
C       AL= ANGLE BETWEEN MASTER AND SECONDARY
C       LOP= LINE OF POSITION
C       TD= TIME DIFFERENCE
C       XA= CROSSING ANGLE
C       RS= RADIAL ERROR; SHORTEST DISTANCE
C       RL= RADIAL ERROR; LONGEST DISTANCE
C       MM= NUMBER OF STATIONS
C       NN= NUMBER OF TRIADS
C       MN= FORMAT OF TRIADS
C       W= POSSIBLE ERROR IN A CALCULATED GRADIENT
C
C*************************************************************************
      COMMON/TRIDAT/MM,NN,TOA,ED,TD,GDT,AL,LOP,XA,WW,W,MN
      COMMON/TRDAT2/RS,RL,GDOP,ATE,CTE
      REAL*8 ZZ(13),AA(6)
      DOUBLE PRECISION TD(5),TOA(5),ED(5),GDT(5),LOP(5),XA(6),
     :RS(6),RL(6),AL(5),GDOP(6),ATE(6),CTE(6)
      LOGICAL W(5)
      BYTE WW(130)
      DATA ZZ/'M  WX','M  WY','M  WZ','M  XY','M  XZ','M  YZ',
     :'M  WX','M  WY','M  XY','M  XY','M  XZ','M  YZ','M  XY'/
      IF (MN.EQ.1) GOTO 2
      IF (MN.EQ.2) GOTO 4
      IF (MN.EQ.3) GOTO 6
      IF (MN.EQ.4) GOTO 8
    2 DO 3 J=1,6
        AA(J)=ZZ(J)
    3 CONTINUE
      GOTO 10
    4 DO 5 J=1,3
        K=J+6
        AA(J)=ZZ(K)
    5 CONTINUE
      GOTO 10
    6 DO 7 J=1,3
        K=J+9
        AA(J)=ZZ(K)
    7 CONTINUE
      GOTO 10
    8 AA(1)=ZZ(13)
   10 CONTINUE
C*************************************************************************
C     HEADER FORMAT
C*************************************************************************
      WRITE(6,25)
   25 FORMAT(T38,'G R A D I E N T')
      WRITE(6,30)
   30 FORMAT(11X,'TIME DIFFERENCE',T42,'ft/usec',T60,
     :'NORMAL LOP',3X,'XING',4X,'RADIAL ERROR',T97,'GDOP',T104,
     :'TRACKING ERROR')
      WRITE(6,35)
   35 FORMAT(1X,'TRIADS',9X,'usec',T33,'TDA',' & ','Angle',3X,'TDB',
     :' & ','Angle',T61,'degrees',5X,'ANGLE',3X,'SHORT',3X,'LONG',
     :T104,'CROSS    ALONG')
```

```
      WRITE(6,40)
   40 FORMAT(12X,'TDA',6X,'TDB',T39,'(m-s)',9X,'(m-s)',2X,
     :'LOP1',2X,'LOP2',3X,'deg.',85X,'feet',T109,'feet')
      WRITE(6,45)(WW(J),J=1,130)
   45 FORMAT(1X,130A1)
      WRITE(6,*)' '
C*************************************************************************
C     DATA FORMAT
C*************************************************************************
      DO 100 I=1,3
        N=I+2
        WRITE(6,50)AA(I),TD(2),TD(N),GDT(2),W(2),AL(2),GDT(N),
     :  W(N),AL(N),LOP(2),LOP(N),XA(I),RS(I),RL(I),GDOP(I),CTE(I),
     :  ATE(I)
   50   FORMAT(2X,A5,2X,F9.2,F9.2,2X,F8.1,A1,F5.1,F8.1,A1,F5.1,
     :  2X,F5.1,1X,F5.1,2X,F5.1,1X,F7.0,F7.0,3X,F4.1,T103,F6.0,3X,
     :  F6.0)
        IF (I.EQ.(NN-1)) GOTO 200
        IF (I.EQ.NN) GOTO 300
  100 CONTINUE
  200 DO 250 I=4,5
        IA=I
        IF (NN.EQ.2.OR.NN.EQ.3) IA=I-1
        WRITE(6,225)AA(IA),TD(3),TD(I),GDT(3),W(3),AL(3),GDT(I),
     :  W(I),AL(I),LOP(3),LOP(I),XA(I),RS(I),RL(I),GDOP(I),CTE(I),
     :  ATE(I)
  225   FORMAT(2X,A5,2X,F9.2,F9.2,2X,F8.1,A1,F5.1,F8.1,A1,F5.1,
     :  2X,F5.1,1X,F5.1,2X,F5.1,1X,F7.0,F7.0,3X,F4.1,T103,F6.0,3X,
     :  F6.0)
        IF (I.EQ.(NN+1)) GOTO 300
  250 CONTINUE
      WRITE(6,275)AA(6),TD(4),TD(5),GDT(4),W(4),AL(4),GDT(5),W(5),
     :AL(5),LOP(4),LOP(5),XA(6),RS(6),RL(6),GDOP(6),CTE(6),ATE(6)
  275 FORMAT(2X,A5,2X,F9.2,F9.2,2X,F8.1,A1,F5.1,F8.1,A1,F5.1,
     :  2X,F5.1,1X,F5.1,2X,F5.1,1X,F7.0,F7.0,3X,F4.1,T103,F6.0,3X,
     :  F6.0)
  300 CONTINUE
      WRITE(6,*)' '
      WRITE(6,400)
  400 FORMAT(' >>NOTE: *= ANGLE BETWEEN MASTER AND SECONDARY IS LESS',
     :' THAN 20 DEGREES (NEAR BASELINE EXTENSION).')
      WRITE(6,*)' '
      RETURN
      END
```

```
      PROGRAM DATFIL
C
C*********************************************************************
C     THIS PROGRAM IS THE MAIN PROGRAM FOR CREATING,PRINTING
C     AND/OR CHANGING A DATA FILE FOR THE MAIN PROGRAM LORAN-C.
C*********************************************************************
   10 TYPE 20
   20 FORMAT(' DO YOU WISH TO;'/'   CREATE A FILE? Y=1'/
     :'   PRINT A FILE ON PRINTER? Y=2'/
     :'   CHANGE A FILE? Y=3'/'   STOP?Y=0'/)
      ACCEPT 30,N
   30 FORMAT(I2)
      IF (N.EQ.1) GOTO 40
      IF (N.EQ.2) GOTO 50
      IF (N.EQ.3) GOTO 60
      IF (N.EQ.0) GOTO 70
      GOTO 10
   40 CALL NUFILE
      GOTO 10
   50 CALL DMPFIL
      GOTO 10
   60 CALL CHGFIL
      GOTO 10
   70 STOP 'END OF PROGRAM DATFIL'
      END
```

```
      SUBROUTINE NUFILE
C
C*****************************************************************
C     SUBROUTINE NUFILE CREATES DATA FILES OF LORAN-C TRANSMITTER
C     INFORMATION FOR EACH TRANSMITTER STATION; FOR USE IN MAIN
C     PROGRAM LORANC.FOR
C*****************************************************************
      BYTE MESS(16),MON(16)
      INTEGER MSC
      REAL LAT(3),LONG(3),XM(3),YM(3)
    1 CONTINUE
      TYPE 2
    2 FORMAT(' ENTER NEW FILENAME'/)
      CALL ASSIGN (1,,-1,'NEW')          !DATA FILENAME
      TYPE 3
    3 FORMAT(' ENTER GRI')
      READ(5,*)GRI                       !GRI CHAIN
      WRITE(1)GRI
      DO 5 I=1,16
      MESS(I)=' '
    5 CONTINUE
    4 TYPE 6
    6 FORMAT(' ENTER TRANS-STATION(16 CHAR. MAX)'/)
      READ(5,10)MSC,MESS                 !TRANS-STAT. NAME
   10 FORMAT(Q,16A1)
      TYPE 15
   15 FORMAT(' ENTER ED'/)
      ACCEPT 20,ED                       !EMISSION DELAY
   20 FORMAT(F8.2)
      TYPE 25
   25 FORMAT(' ENTER ECD'/)
      ACCEPT 30,ECD                      !ECD
   30 FORMAT(F5.1)
      TYPE 35
   35 FORMAT(' ENTER RP,NCD'/)
      ACCEPT 40,RP,CDN                   !RAD. POWER & NOM. CODING DELAY
   40 FORMAT(F5.0,F6.0)
      TYPE 45
   45 FORMAT(' ENTER LAT/LONG'/)
      ACCEPT 50,(LAT(L),L=1,3),(LONG(L),L=1,3)  !LAT/LONG
   50 FORMAT(F6.1,F4.1,F6.2,F6.1,F4.1,F6.2)
      TYPE 55
   55 FORMAT(' ENTER 1 FOR END OF TRANS-STAT.')
      ACCEPT 60,MKR                      !REFERENCE MARKER
   60 FORMAT(I2)
      WRITE(1)(MESS(N),N=1,16)
      WRITE(1)(LAT(N),N=1,3),(LONG(N),N=1,3)
      WRITE(1)ED
      WRITE(1)ECD
      WRITE(1)RP,CDN
      WRITE(1)MKR
      TYPE 65
   65 FORMAT(' CONTINUE?Y=1')
      ACCEPT 70,IYN
   70 FORMAT(I2)
      IF (IYN.EQ.1) GOTO 4
  100 CONTINUE
      DO 110 I=1,16
      MON(I)=' '
  110 CONTINUE
      TYPE 115
  115 FORMAT(' ENTER LORMONSTA(16 CHAR. MAX)'/)
      READ(5,120)MSC,MON                 !LORMONSTA NAME
```

```
120 FORMAT(Q,16A1)
    TYPE 125
125 FORMAT(' ENTER LAT/LONG'/)
    ACCEPT 130,(XM(K),K=1,3),(YM(K),K=1,3)     !LAT/LONG
130 FORMAT(F6.1,F4.1,F6.2,F6.1,F4.1,F6.2)
    TYPE 135
135 FORMAT(' ENTER CSECD'/)
    ACCEPT 140,CSECD                           !CSECD
140 FORMAT(F6.2)
    TYPE 145
145 FORMAT(' ENTER CSTD'/)
    ACCEPT 150,CSTD                            !CSTD
150 FORMAT(F8.2)
    TYPE 155
155 FORMAT(' ENTER ECD (TOLERANCE)'/)
    ACCEPT 160,TECD                            !TECD
160 FORMAT(F5.1)
    TYPE 165
165 FORMAT(' ENTER TD (TOLERANCE)'/)
    ACCEPT 170,TTD                             !TTD
170 FORMAT(F5.1)
    WRITE(1)(MON(L),L=1,16)
    WRITE(1)(XM(L),L=1,16),(YM(L),L=1,16)
    WRITE(1)CSECD
    WRITE(1)CSTD
    WRITE(1)TECD
    WRITE(1)TTD
    TYPE 180
180 FORMAT(' CONTINUE(MON STAT.)? Y=1'/)
    ACCEPT 185,IYN
185 FORMAT(I2)
    IF (IYN.EQ.1) GOTO 100
    CALL CLOSE(1)
    TYPE 190
190 FORMAT(' CREATE ANOTHER FILE?Y=2')
    ACCEPT 195,INY
195 FORMAT(I2)
    IF (INY.EQ.2) GOTO 1
    CONTINUE
    RETURN
    END
```

```
      SUBROUTINE DMPFIL
C
C*********************************************************************
C     SUBROUTINE DMPFIL DUMPS FILES CREATED BY PROGRAM NUFILE
C     ON TO THE LINE PRINTER
C*********************************************************************
      BYTE MSC(16),MON(16)
      REAL X(3),Y(3),XM(3),YM(3),MKR
      M=0
    1 IF (M.NE.4) GOTO 3
      WRITE(6,2)
    2 FORMAT('1')
      IF (M.EQ.4) M=0
    3 TYPE 10
   10 FORMAT(' ENTER DATA FILE,(ex:<LC9960>)'/)
      CALL ASSIGN(1,,-1,'RDO')
      READ(1,END=200)GRI
      WRITE(6,20)GRI
   20 FORMAT(' GRI:',F6.0)
      DO 100 I=1,10
      READ(1,END=200)(MSC(J),J=1,16)
      READ(1,END=200)(X(J),J=1,3),(Y(K),K=1,3)
      READ(1,END=200)ED
      READ(1,END=200)ECD
      READ(1,END=200)RP,CDN
      READ(1,END=200)MKR
      WRITE(6,50)(MSC(J),J=1,16),(X(J),J=1,3),(Y(K),K=1,3),
     :ED,CDN,RP,ECD,MKR
   50 FORMAT(1X,16A1,1X,F6.1,F5.1,F6.2,3X,F6.1,F5.1,F6.2,
     :1X,F8.2,1X,F6.0,1X,F5.0,1X,F5.1,3X,F3.0)
      IF (MKR.EQ.1.0) GOTO 200
  100 CONTINUE
  200 CONTINUE
      WRITE(6,210)
  210 FORMAT(2X,'LORAN-C MONITOR STATIONS')
      DO 300 N=1,10
      READ(1,END=400)(MON(J),J=1,16)
      READ(1,END=400)(XM(J),J=1,3),(YM(J),J=1,3)
      READ(1,END=400)CSECD
      READ(1,END=400)CSTD
      READ(1,END=400)TECD
      READ(1,END=400)TTD
      WRITE(6,250)(MON(J),J=1,16),(XM(J),J=1,3),(YM(J),J=1,3),
     :CSECD,CSTD,TECD,TTD
  250 FORMAT(1X,16A1,1X,F6.0,F4.0,F6.2,1X,F6.0,F4.0,F6.2,2X,F6.2,
     :2X,F8.2,2X,F5.1,2X,F5.1)
  300 CONTINUE
  400 CALL CLOSE (1)
      WRITE(6,*)' '
      M=M+1
      TYPE 275
  275 FORMAT(' CONTINUE? Y=9')
      READ(5,*)N
      IF (N.EQ.9) GOTO 1
      RETURN
      END
```

```
      SUBROUTINE CHGFIL
C
C*********************************************************************
C     SUBROUTINE CHGFIL ALLOWS CHANGES TO BE MADE IN ANY OF THE
C     FILES CREATED BY PROGRAM NUFILE
C*********************************************************************
      BYTE MSC(16,5),MON(16,5)
      REAL X(5,3),Y(5,3),ED(5),ECD(5),RP(5),CDN(5),MKR(6),
     :XM(5,3),YM(5,3),CSECD(5),CSTD(5),TECD(5),TTD(5)
    1 TYPE 10
   10 FORMAT(' ENTER FILE TO BE CHANGED(ex:<LC9960>)'/)
      CALL ASSIGN(1,,-1,'RDO')                    !OPENS DATA FILE
      READ(1,END=200)GRI                          !OPENS GRI
      DO 100 I=1,10                               !READS TRANS-STATIONS
      READ(1,END=200)(MSC(J,I),J=1,16)
      READ(1,END=200)(X(I,J),J=1,3),(Y(I,J),J=1,3)
      READ(1,END=200)ED(I)
      READ(1,END=200)ECD(I)
      READ(1,END=200)RP(I),CDN(I)
      READ(1,END=200)MKR(I)
      WRITE(5,50)(MSC(J,I),J=1,16),ED(I),CDN(I),RP(I),ECD(I),
     :(X(I,J),J=1,3),(Y(I,J),J=1,3)
   50 FORMAT(1X,16A1,1X,F8.2,1X,F6.0,1X,F5.0,1X,F5.1,1X/,
     :5X,F6.1,F5.1,F6.2,3X,F6.1,F5.1,F6.2)
      IF (MKR(I).EQ.1) GOTO 200
  100 CONTINUE
  200 CONTINUE
      DO 240 N=1,10                               !READS MONITOR STATIONS
      READ(1,END=250)(MON(J,N),J=1,16)
      READ(1,END=250)(XM(N,J),J=1,3),(YM(N,J),J=1,3)
      READ(1,END=250)CSECD(N)
      READ(1,END=250)CSTD(N)
      READ(1,END=250)TECD(N)
      READ(1,END=250)TTD(N)
      WRITE(5,225)(MON(J,N),J=1,16),CSECD(N),CSTD(N),TECD(N),
     :TTD(N),(XM(N,J),J=1,3),(YM(N,J),J=1,3)
  225 FORMAT(1X,16A1,1X,F6.2,1X,F8.2,1X,F5.1,1X,F5.1,1X/,
     :5X,F6.1,F5.1,F6.2,3X,F6.1,F5.1,F6.2)
  240 CONTINUE
  250 CALL CLOSE(1)                               !CLOSES FILE
  290 CONTINUE
      TYPE 300
  300 FORMAT(' CHANGE RECORD NO.?')               !STATION(LINE) TO BE
      READ(5,*)L                                  ! CHANGED
      IF (L.GT.I) GOTO 888
      TYPE 310
  310 FORMAT(' CHANGE: NAME=1,ED=2,NCD=3,RP=4,ECD=5,X=6,Y=7,ALL=8')
      READ(5,*)M1
      IF (M1.EQ.1) GOTO 400             !TRANS-STATION NAME
      IF (M1.EQ.2) GOTO 410             !EMISSION DELAY
      IF (M1.EQ.3) GOTO 420             !NOM. CODING DELAY
      IF (M1.EQ.4) GOTO 430             !RADIATED POWER
      IF (M1.EQ.5) GOTO 440             !ECD
      IF (M1.EQ.6) GOTO 450             !LATITUDE
      IF (M1.EQ.7) GOTO 460             !LONGITUDE
      IF (M1.EQ.8) GOTO 400             !ALL
      GOTO 470
  400 DO 401 J=1,16
      MSC(J,L)=' '
  401 CONTINUE
      ACCEPT 402,JJJ,(MSC(J,L),J=1,16)          !NAME
  402 FORMAT(Q,16A1)
      IF (M1.EQ.8) GOTO 410
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    GOTO 470
410 ACCEPT 411,ED(L)                          !EMISSION DELAY
411 FORMAT(F8.2)
    IF (M1.EQ.8) GOTO 420
    GOTO 470
420 ACCEPT 421,CDN(L)                         !NOM. CODING DELAY
421 FORMAT(F6.0)
    IF (M1.EQ.8) GOTO 430
    GOTO 470
430 ACCEPT 431,RP(L)                          !RADIATED POWER
431 FORMAT(F5.0)
    IF (M1.EQ.8) GOTO 440
    GOTO 470
440 ACCEPT 441,ECD(L)                         !ECD
441 FORMAT(F5.1)
    IF (M1.EQ.8) GOTO 450
    GOTO 470
450 ACCEPT 451,(X(L,J),J=1,3)                 !LAT. (DDD.,MM.,SS.SS)
451 FORMAT(F6.1,F4.1,F6.2)
    IF (M1.EQ.8) GOTO 460
    GOTO 470
460 ACCEPT 461,(Y(L,J),J=1,3)                 !LONG. (DDD.,MM.,SS.SS)
461 FORMAT(F6.1,F5.1,F6.2)
470 CONTINUE
    TYPE 480
480 FORMAT(' CONTINUE?Y=1'/)
    ACCEPT 500,NN
500 FORMAT(I2)
    IF (NN.EQ.1) GOTO 290
    DO 550 K=1,6
    MKR(K)=0.0
550 CONTINUE
    TYPE 600
600 FORMAT(' ENTER NUMBER OF TRANS-STAT. '/)  !ENTER # OF STATIONS
    ACCEPT 610,JJ
610 FORMAT(I2)
    MKR(JJ)=1.0              !END OF TRANS-STATIONS MARKER ASSIGNED
888 TYPE 615
615 FORMAT(' ENTER THE RECORD NO. OF LORMONSTA')
    ACCEPT 616,KK            !MONITOR STATION TO BE CHANGED
616 FORMAT(I2)
617 TYPE 618
618 FORMAT(' CHANGE: MON.NAME=1,X=2,Y=3,CSECD=4,CSTD=5,TECD=6,',
   :'TTD=7,ALL=8'/)
    READ(5,*)M
    IF (M.EQ.1) GOTO 620              !MONITOR NAME
    IF (M.EQ.2) GOTO 630              !LATITUDE
    IF (M.EQ.3) GOTO 640              !LONGITUDE
    IF (M.EQ.4) GOTO 650              !CSECD
    IF (M.EQ.5) GOTO 660              !CSTD
    IF (M.EQ.6) GOTO 670              !ECD(TOLERENCE)
    IF (M.EQ.7) GOTO 680              !TD(TOLERENCE)
    IF (M.EQ.8) GOTO 620              !ALL OF THE ABOVE
    GOTO 690
620 DO 621 J=1,16
    MON(J,KK)=' '
621 CONTINUE
    ACCEPT 625,JJJ,(MON(J,KK),J=1,16)         !MONITOR NAME
625 FORMAT(Q,16A1)
    IF (M.EQ.8) GOTO 630
    GOTO 690
630 ACCEPT 635,(XM(KK,J),J=1,3)               !LAT (DDD.,MM.,SS.SS)
635 FORMAT(F6.1,F5.1,F6.2)
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      IF (M.EQ.8) GOTO 640
      GOTO 690
  640 ACCEPT 645,(YM(KK,J),J=1,3)                !LONG (DDD.,MM.,SS.SS)
  645 FORMAT(F6.1,F5.1,F6.2)
      IF (M.EQ.8) GOTO 650
      GOTO 690
  650 ACCEPT 655,CSECD(KK)                       !CSECD
  655 FORMAT(F6.2)
      IF (M.EQ.8) GOTO 660
      GOTO 690
  660 ACCEPT 665,CSTD(KK)                        !CSTD
  665 FORMAT(F9.2)
      IF (M.EQ.8) GOTO 670
      GOTO 690
  670 ACCEPT 675,TECD(KK)                        !ECD(TOLERENCE)
  675 FORMAT(F5.1)
      IF (M.EQ.8) GOTO 680
      GOTO 690
  680 ACCEPT 685,TTD(KK)                         !TD(TOLERENCE)
  685 FORMAT(F5.1)
  690 TYPE 692
  692 FORMAT(' CONTINUE?Y=1'/)
      ACCEPT 693,NY
  693 FORMAT(I2)
      IF (NY.EQ.1) GOTO 888
      TYPE 694
  694 FORMAT(' ENTER NO. OF LORMONSTA')
      ACCEPT 695,KK                              !ENTER # OF LORMONSTA
  695 FORMAT(I2)
      TYPE 697
  697 FORMAT(' ENTER GRI')
      READ(5,*)GRI
      CALL ASSIGN(1,,-1,'NEW')                   !ASSIGN NEW FILE NAME
      WRITE(1)GRI
      DO 700 II=1,JJ                             !WRITE TRANS-STATIONS
      WRITE(1)(MSC(J,II),J=1,16)
      WRITE(1)(X(II,J),J=1,3),(Y(II,J),J=1,3)
      WRITE(1)ED(II)
      WRITE(1)ECD(II)
      WRITE(1)RP(II),CDN(II)
      WRITE(1)MKR(II)
  700 CONTINUE
      DO 750 JK=1,KK                             !WRITE LORMONSTA
      WRITE(1)(MON(J,JK),J=1,16)
      WRITE(1)(XM(JK,J),J=1,3),(YM(JK,J),J=1,3)
      WRITE(1)CSECD(JK)
      WRITE(1)CSTD(JK)
      WRITE(1)TECD(JK)
      WRITE(1)TTD(JK)
  750 CONTINUE
      CALL CLOSE (1)                             !CLOSE FILE
      TYPE 800
  800 FORMAT(' ANOTHER FILE?Y=1'/)
      READ(5,*)KJ
      IF(KJ.EQ.1) GOTO 1
      RETURN
      END
```