

Reports of the Department of Geodetic Science

Report Number 87

**LEAST SQUARES ADJUSTMENT
OF SATELLITE OBSERVATIONS
FOR SIMULTANEOUS DIRECTIONS
OR RANGES**

PART 2 of 3: COMPUTER PROGRAMS

by

Edward J. Krakiwsky

Jack Ferrier

Georges Blaha

Prepared for

**National Aeronautics and Space Administration
Washington, D.C.**

Contract No. NSR 36-008-033

OSURF Project No. 1997



**The Ohio State University
Research Foundation
Columbus, Ohio 43212**

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PREFACE

This project is under the direction of Professor Ivan I. Mueller of the Department of Geodetic Science, The Ohio State University; Project Manager is Jerome D. Rosenberg, Geodetic Satellites, Code SAG, NASA Headquarters, Washington, D.C. The contract is administered by the Office of Grants and Research Contracts, Office of Space Science and Applications, NASA Headquarters, Washington, D.C.

The report was written by Edward J. Krakiwsky, Graduate Research Associate. Allen J. Pope acted as a consultant during the development of the computer programs. The majority of the computer programming was performed by Jack Ferrier. Messrs. Blaha and Krakiwsky participated in programming, generation of data for test adjustments, and verification of the computer programs.

Reports related to NASA Contract No. NSR 36-008-033 and published to date are the following:

The Determination and Distribution of Precise Time, Report No. 70 of the Department of Geodetic Science, The Ohio State University.

Proposed Optical Network for the National Geodetic Satellite Program. Report No. 71 of the Department of Geodetic Science, The Ohio State University.

Preprocessing Optical Satellite Observations, Report No. 82 of the Department of Geodetic Science, The Ohio State University.

Least Squares Adjustment of Satellite Observations for Simultaneous Directions or Ranges, Part 1 of 3: Formulation of Equations, Report No. 86 of the Department of Geodetic Science, The Ohio State University.

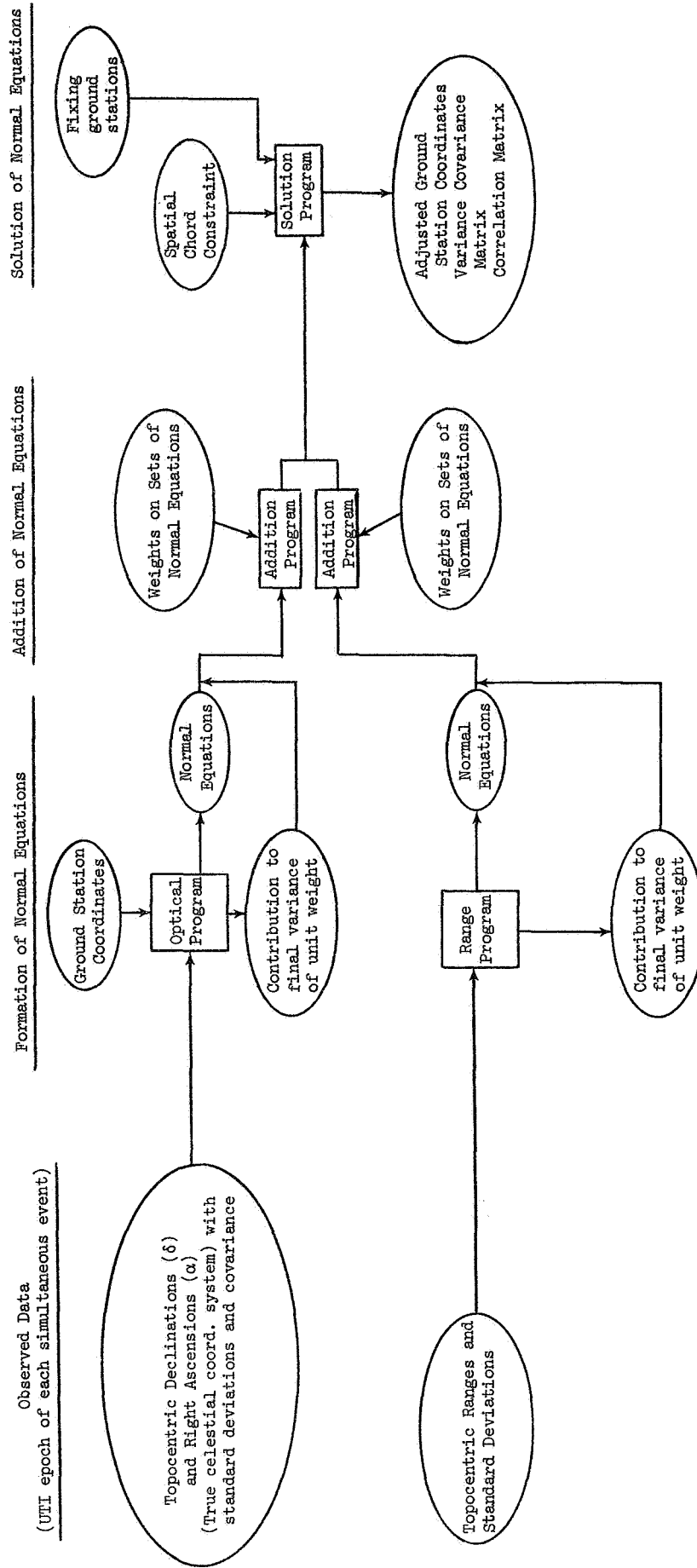
Quarterly Progress Reports, Numbers 1, 2, 3, 4, 5, 6.

ABSTRACT

The purpose of this report is to document the computer programs dealing with the least squares adjustment of satellite observations for simultaneous directions or ranges. The computer programs are based on the theory given in Krakiwsky, Edward J., and Pope, Allen J., Least Squares Adjustment of Satellite Observations for Simultaneous Directions or ranges, Part 1 of 3: Formulation of Equations, Report No. 86 of the Department of Geodetic Science, The Ohio State University, (1967).

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CONCEPT FLOW DIAGRAM OF ADJUSTMENT SYSTEM

GENERAL

Contained herein is the documentation of four separate computer programs; namely,

- (1) Section 1: Formation of Optical Normal Equations,
- (2) Section 2: Formation of Range Normal Equations,
- (3) Section 3: Addition of Normal Equations,
- (4) Section 4: Solution of Normal Equations.

Subroutines used in the above programs are documented in [Krakiwsky et al, in prep.]* All programs and subroutines have been written in "Scatran" - [Numerical Computation Laboratory, 1964]** The programs are based on the theory presented in [Krakiwsky and Pope, 1967].

Together, these programs form the system which is capable of adjusting simultaneous optical or range satellite data. The following concept flow diagram depicts the main phases of the system.

* Krakiwsky, Edward J.; Ferrier, Jack; and Reilly, James P., Least Squares Adjustment of Satellite Observations for Simultaneous Directions or Ranges, Part 3 of 3: Subroutines, Report No. 88 of the Department of Geodetic Science, The Ohio State University, (1967).

**Numerical Computation Laboratory, Scatran Reference Manual, publication of the Department of Computer Science, The Ohio State University, (1964).

SECTION I. FORMATION OF OPTICAL NORMAL EQUATIONS

1.1 Introduction

The general form of the normal equations is [Krakiwsky and Pope, 1967, Eq. 2-44]

$$NX_g + U_g = 0,$$

where N is the symmetric coefficient matrix whose diagonal is composed of the 3 x 3 matrices [Eq. 2-47],

$$N_{kk} = \sum_j m_{kj}^{-1} - \sum_j \left\{ m_{kj}^{-1} \left(\sum_i m_{ij}^{-1} \right)^{-1} m_{kj}^{-1} \right\}, \quad (1)$$

while its off-diagonal portion is composed of the 3 x 3 matrices [Eq. 2-48],

$$N_{k\ell} = - \sum_j \left\{ m_{kj}^{-1} \left(\sum_i m_{ij}^{-1} \right)^{-1} m_{\ell j}^{-1} \right\}. \quad (2)$$

X_g is the vector of unknown corrections to the preliminary Cartesian station coordinates; U_g is the vector of constant terms which is composed of the 3 x 1 vectors [Eq. 2-55],

$$U_k = - \sum_j m_{kj}^{-1} \left\{ \vec{X}_k^0 - \left(\sum_i m_{ij}^{-1} \right)^{-1} \left(\sum_i m_{ij}^{-1} \vec{X}_i^0 \right) \right\}. \quad (3)$$

In the equations above the subscripts have the following meanings:

k and ℓ denote particular ground stations,

j = a particular simultaneous event,

i = any ground station participating in an event j,

$\sum_i$ = the summation over all ground stations involved in event j, and

$\sum_j$ = the summation over all events observed by ground stations k and/or ℓ .

Also

$$m_{ij} = B_{ij} P_{ij}^{-1} B_{ij}',$$

where

P_{ij} is the 3 x 3 weight matrix of any observed direction, and

$$B_{ij} = R_2(-X_p)R_1(-Y_p)R_3(\theta)R_3(\alpha)R_2(-90^\circ + \delta) \begin{bmatrix} 1 & 0 \\ 0 & -1 \\ 0 & -1 \end{bmatrix}$$

(the R's being rotations through two polar motion components, Greenwich apparent sidereal time, topocentric right ascension and declination).

Further

P_k is the 3 x 3 weight matrix associated with a particular ground station, and

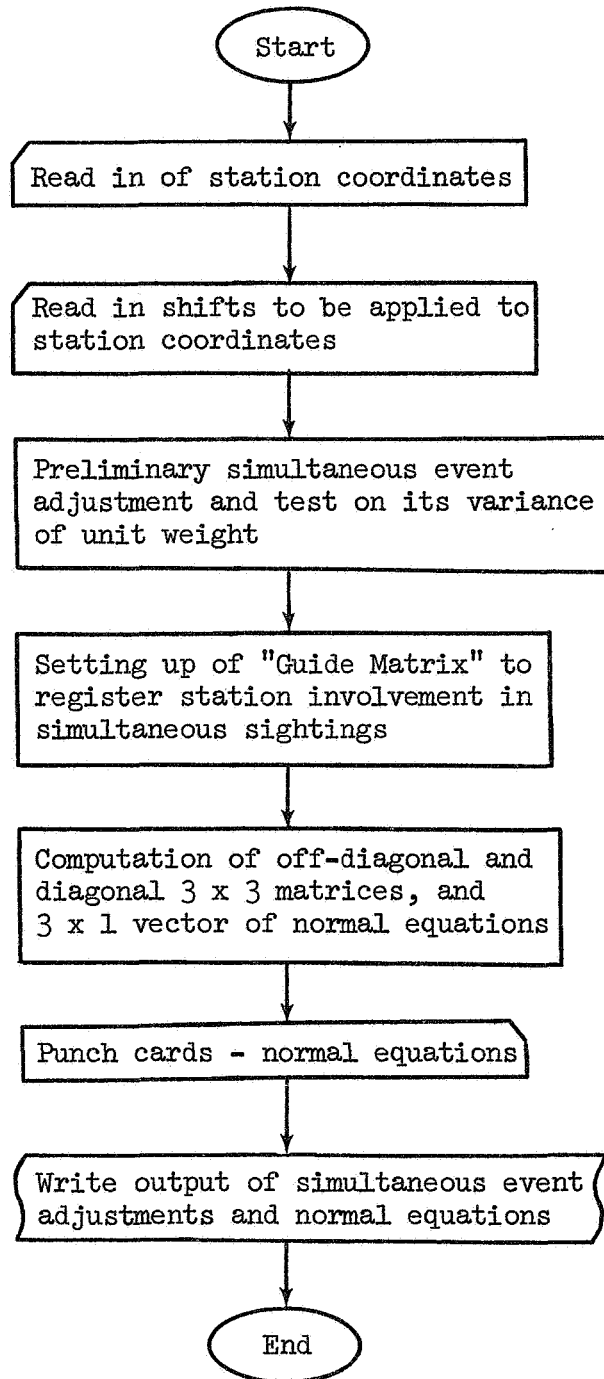
$\vec{X}_i^0$ is the preliminary Cartesian station vector of any ground station.

The computation of Eq. 1 - 3 forms the core of the computer program.

The capacity of the computer program is limited only by the total number of stations, the maximum being 100. There is no restriction on the number of simultaneous events, because of the summation form of the normal equations.

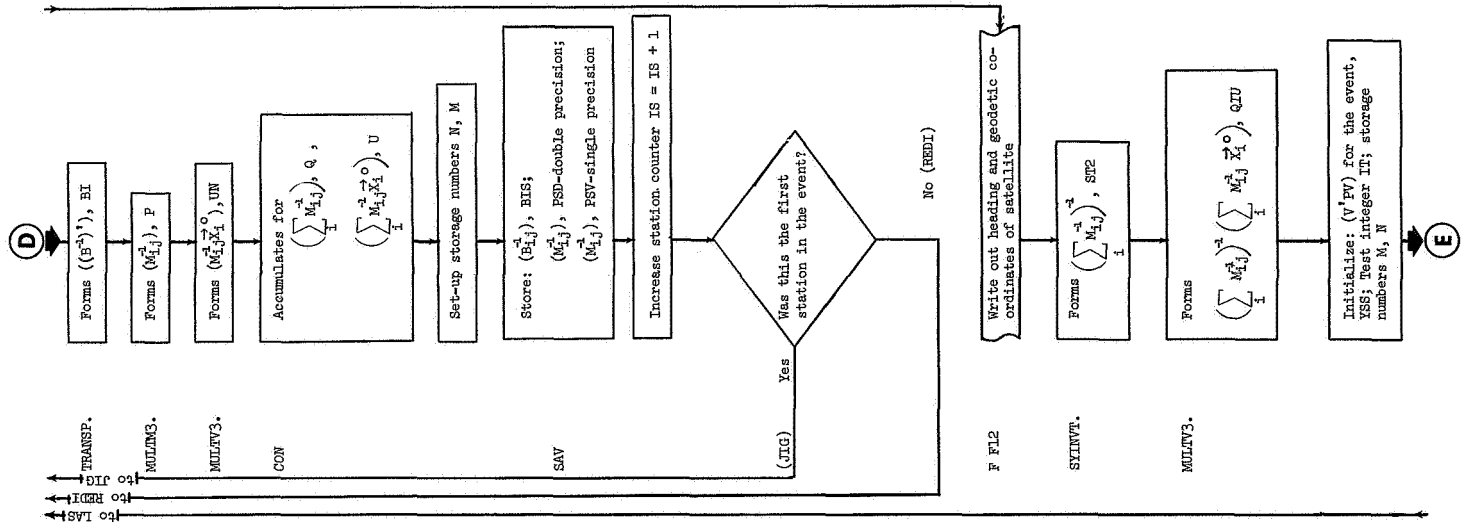
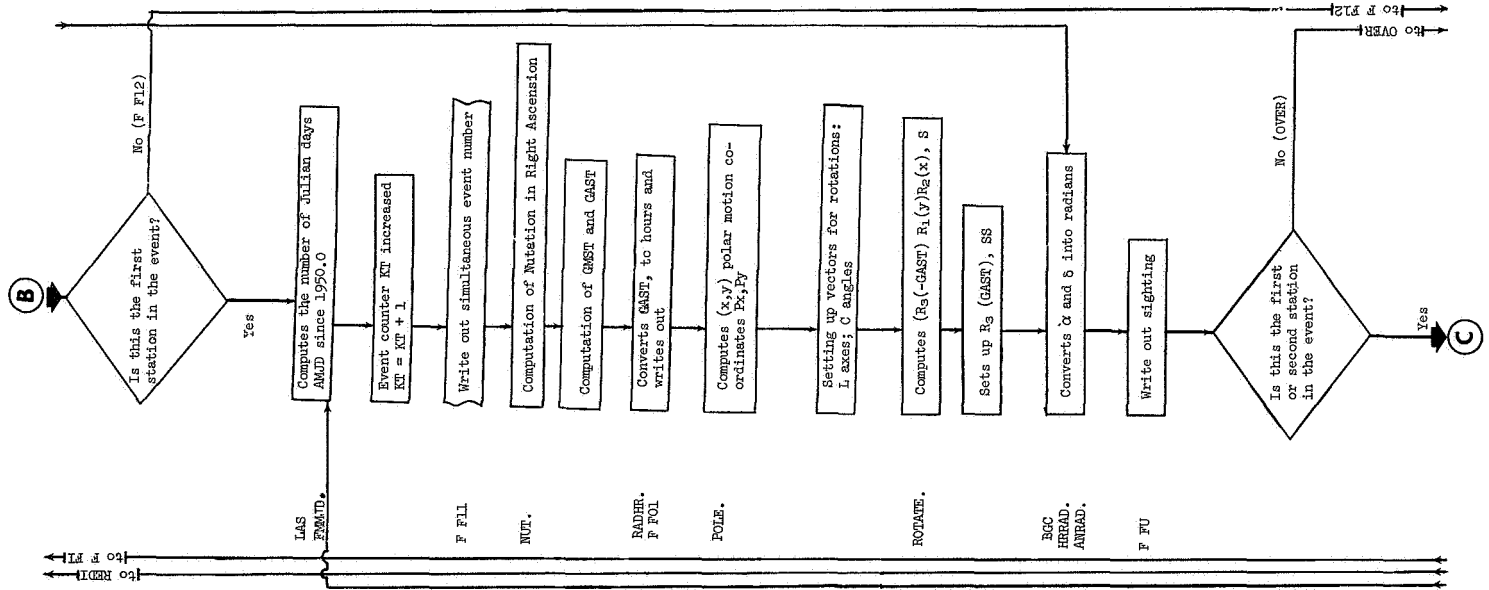
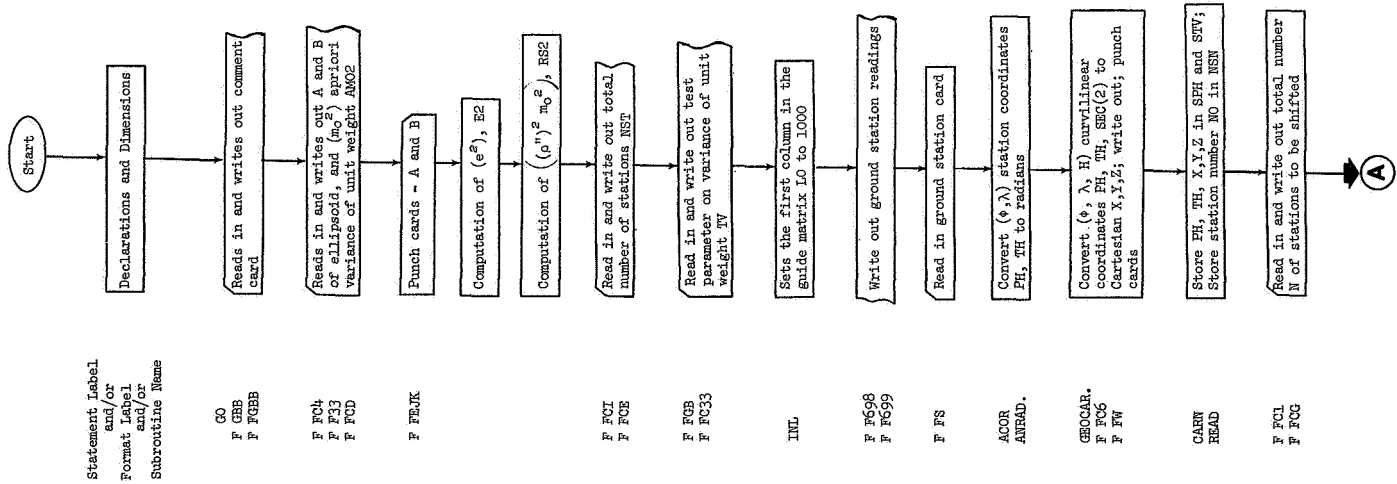
In a study consisting of 40 ground stations (120 unknowns) execution time for the formation of the normal equations on the IBM 7094 was 1.9 minutes.

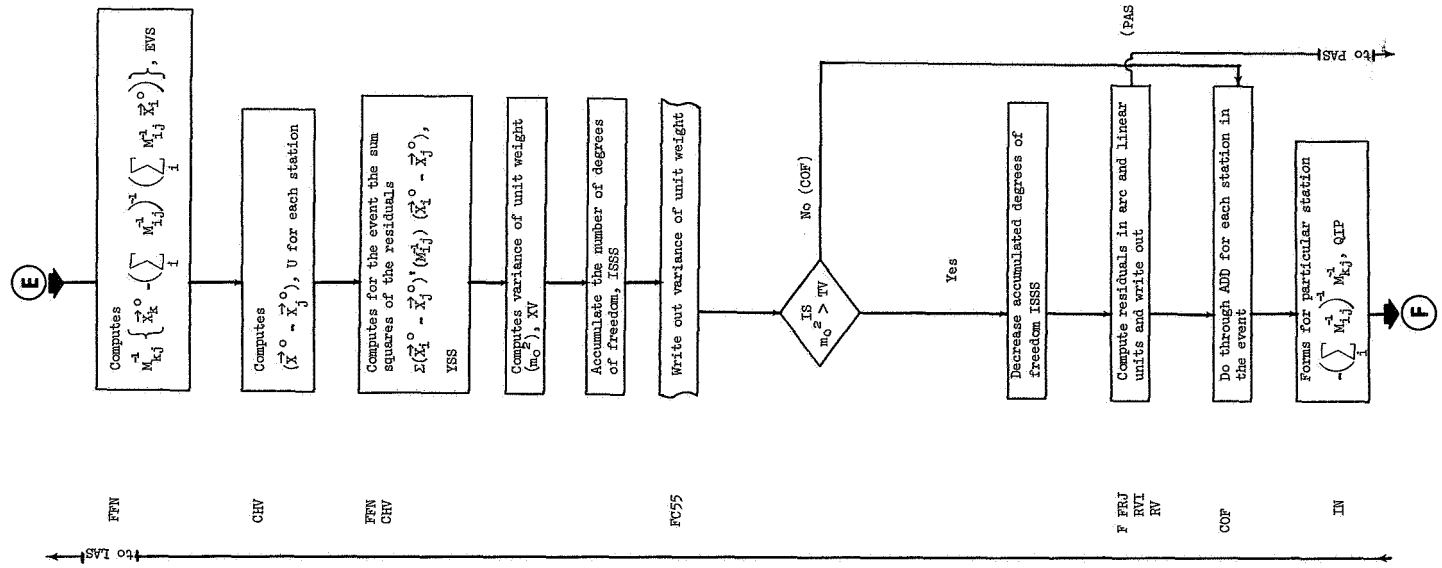
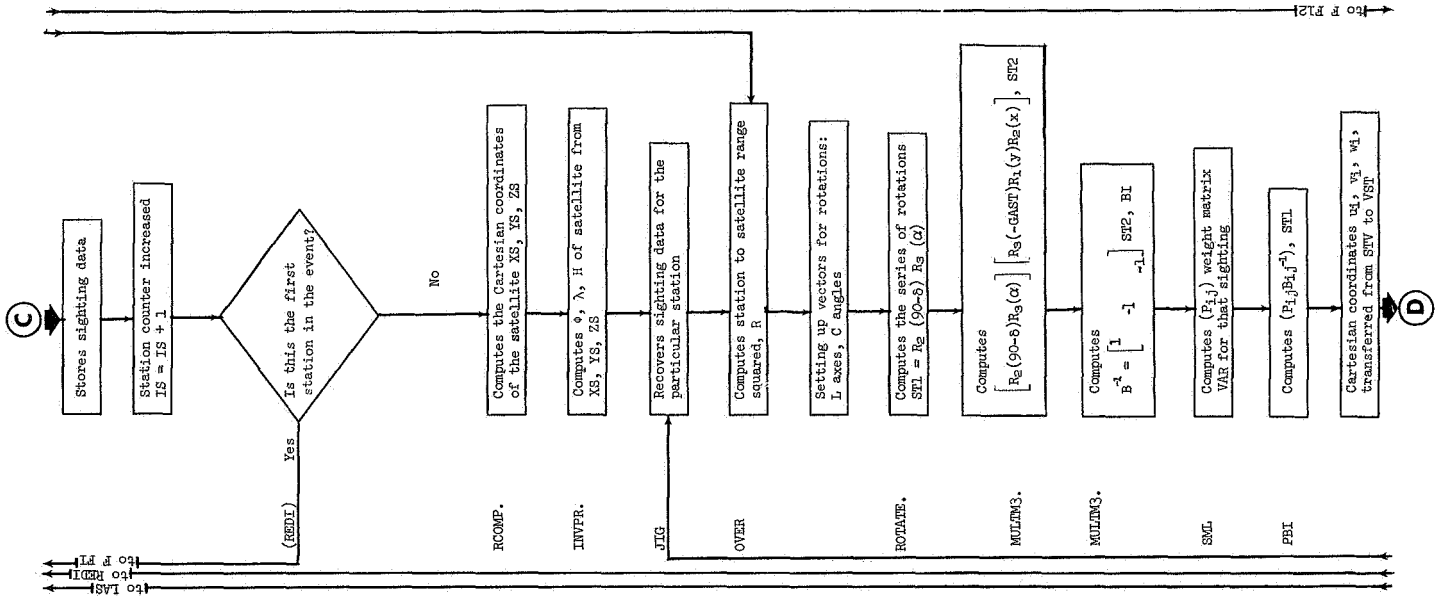
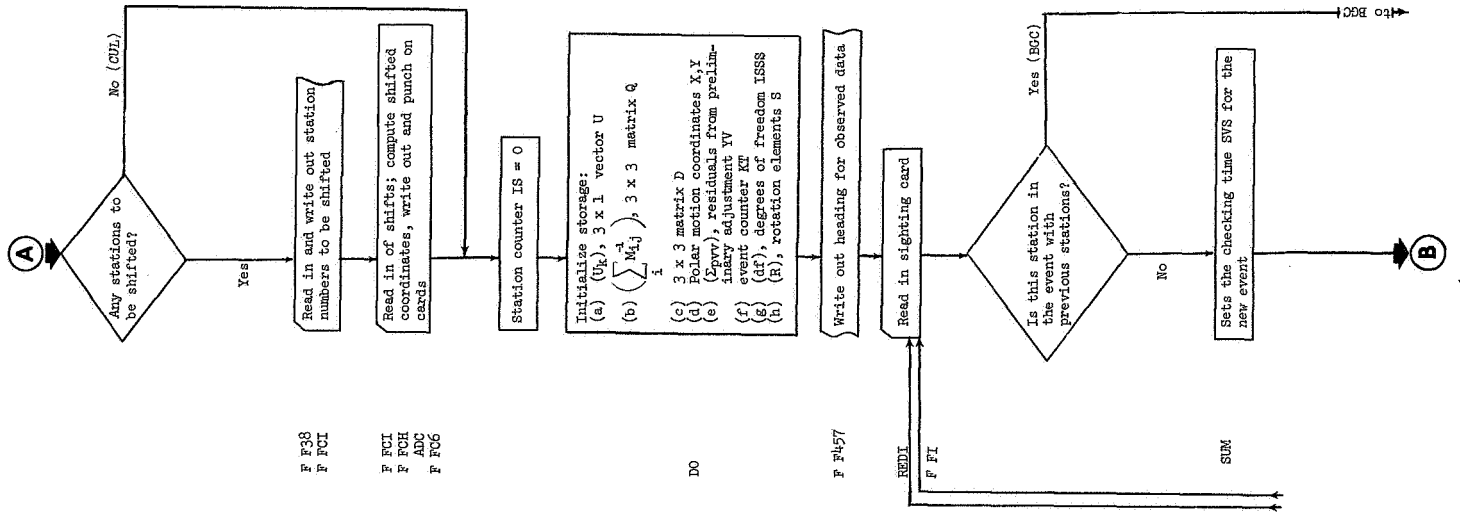
1.2 General Flow Chart

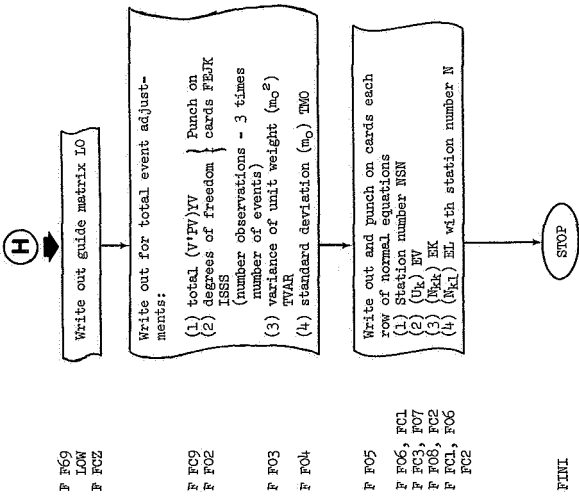
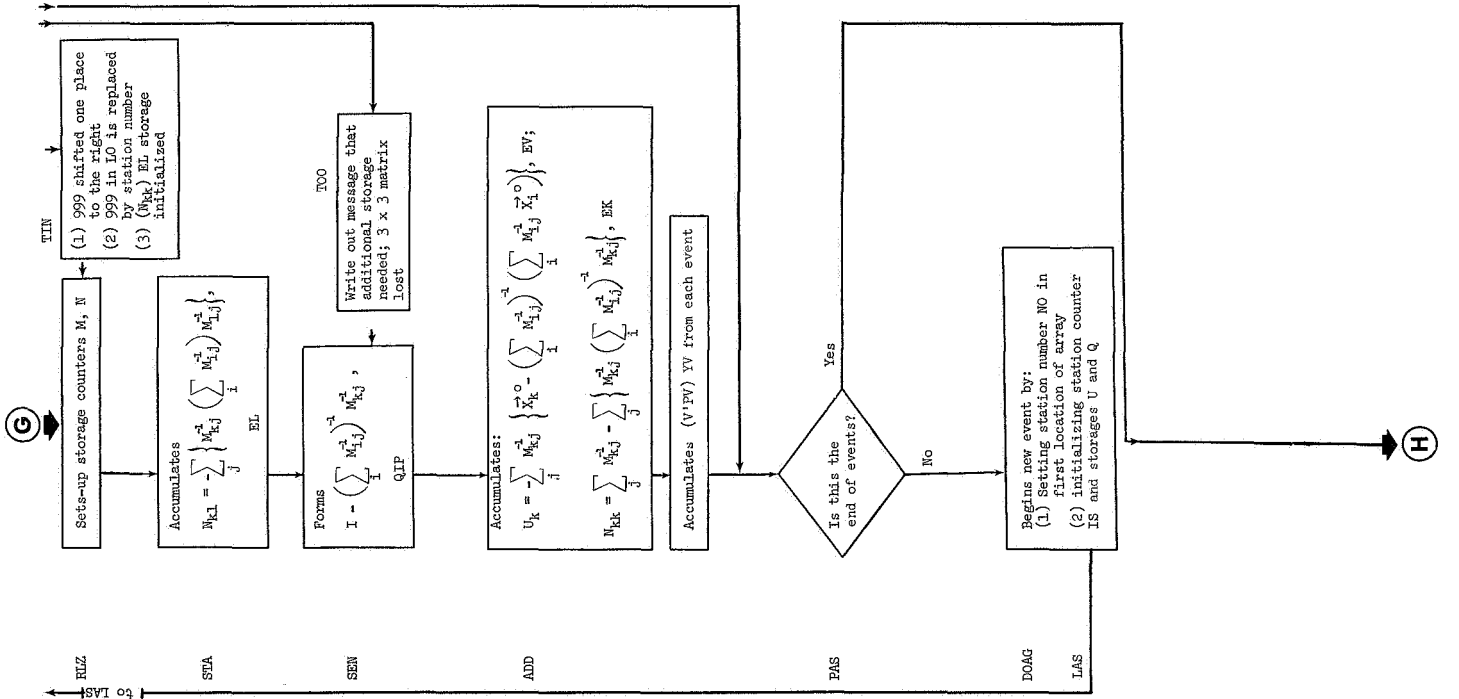
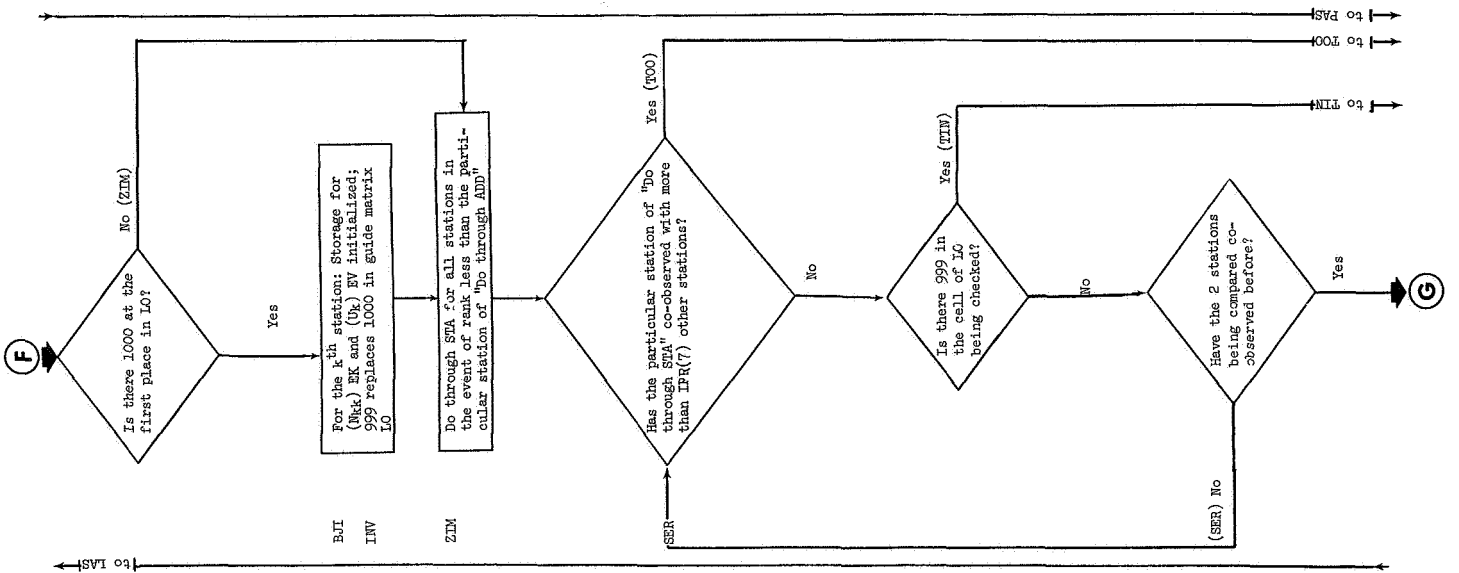


1.3 Specific Flow Chart

1.3 Specific Flow Chart







1.4 STATEMENT LISTING

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 SOURCE LANGUAGE STATEMENTS

```

1 C      THIS PROGRAM FORMS NORMAL EQUATIONS FROM ABSOLUTE SATELLITE DIRECTIONS-
2 C      -
3 C      NOTE THAT THE STATEMENT LISTING SUPERCEDES THE FLOW CHART-
4 C      -
5      DIMENSION (EV(300),STV(300,KDM),EK(900),NSN(100))-
6 C      THIS PROGRAM IS DIMENSIONED FOR 99 STATIONS///NO STATION NUMBER TO HAVE A VALUE GREATER THAN 99-
7 C      SPECIAL PARAMETER FOR DIMENSIONING PURPOSES IS IPR = MAXIMUM NUMBFR OF CO-OBSERVING STATIONS+1-
8 C      THIS PROGRAM IS DIMENSIONED FOR 6 CO-OBSERVING STATIONS , IPR=6+1=7-
9 C      LO AND EL ARE DIMENSIONED ACCORDING TO IPR-
10     DIMENSION (LO(NDIMLO,IPR),EL(NDIMEL))-
11 C      THEIR DIMENSIONS ARE DETERMINED FROM THE FUNCTIONS-
12 C      NDIMLO=100*IPR-
13 C      NDIMEL=500*IPR-
14 C      SO TO INCREASE THE MAXIMUM NUMBER OF CO-OBSERVING STATIONS, SIMPLY CHANGE IPR OF THE PARAMETERS CAR
15     U TO 1 MORE THAN THE NUMBER OF CO-OBSERVING STATIONS DESIRED-
16     DIMENSION (SEC(10),VST(3),QUU(3),U(3),INF(10),ST1(9,KDM),ST2(9,KDM),BI(9,KDM),QIP(9,KDM),PI(
17     9,KDM))-
18     DIMENSION (PSD(100),SPH(100),STH(100),NO(100),PSV(100))-
19     DIMENSION (D(9,KDM),C(5),L(5),EVS(30))-
20     DIMENSION (UN(3),S(9,KDM),BIS(90),V(3),SS(9,KDM))-
21     DIMENSION (VAR(6),SAL(3),SDE(3),R(4),ISTAT(5))-
22     -
23     PRECISION (2,VAR,SAL,SDE,DAR,S1,T,ALS,TVAR,TMO,DSIN,DSQRT.)-
24     PRECISION (2,FMMJD,ANRAD,HRRAD.)-
25     PRECISION (2,RHO,RHOSEC,PI,A,B,E2,AMJD,SVS,P,U,Q,QU)-
26     PRECISION (2,STV,SEC,VST,ST1,ST2,BI,CV,X,Y,Z,AL,DE,TH,PH)-
27     PRECISION (2,UN,S,C,D,PID2,BIS,XV,YV,V,C1,SS)-
28     PRECISION (2,AMO2,PSD,EVS)-
29     -

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28      LITERALS (PID2,1,5707963267948967)-
29      LITERALS (RH0,57,29577951308232,RH0SEC,206264,8062470963,PI,3,141592653589793,KDM,3,LDM,5)-
30 C      -
31 F FS      (1X,I3,20X,L1,2(2I3,DF8.4),DF12.4) -
32 F FI      (I3,2X,I2,I3,DF9.5,I2,I3,I2,2I3,CF9.5,L1,I2,I3,DF8.4,2X,3DF5.2) -
33 F F32      (//) -
34 F F33      (//) -
35 C      -
36 C      -
37 GO      READ INPUT ,GBB,((I1STAT(J),J=0,1,J.L.5))-
38      READ INPUT ,GBB,(POLETE)-
39      IPR3=9*IPR-
40 F GBB      (10L6)-
41      WRITE OUTPUT ,FGBB,((I1STAT(J),J=0,1,J.L.5))-
42 F FGBB      (///20X,10L6)-
43      READ INPUT ,FC4,(A,B,AMC2)-
44      WRITE OUTPUT ,F33-
45      WRITE OUTPUT ,FCD,(A,B,AMC2)-
46      PUNCH CARDS ,FEJK,(A,B)-
47 F FEJK      (2DF25.8) -
48 F FCD      (/Q*      A(ELL.) =*,DF14.4,Q*      B(ELL.) =*,DF14.4,//Q*
              . OF ARC SQUARED) =*,DF8.4//) -
49 F FC4      (2DF25.16,DF10.4) -
50      CAR=1./RH0-
51      TH=B/A-
52      E2=1.-TH*TH-
53      READ INPUT ,FC1,(NST)-
54      WRITE OUTPUT ,FCE,(NST)-
55 F FCE      (Q*      TCTAL NO. OF STATIONS =*,I4)-
56      WRITE OUTPUT ,F32-

```

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57 READ INPUT ,FGB,(TV)-

58 F FGB (3F10.6) -

59 WRITE OUTPUT ,FC33,(TV)-

60 F FC33 (Q* PARAMETER TEST ON VARIANCE OF UNIT WEIGHT*/Q* FOR EACH SIMULTANEOUS EVENT-STATIONS HELD FI
XED (SEC. OF ARC SQUARED) =*,F10.2) -

61 WRITE OUTPUT ,F33-

62 F FC1 (14I5)-

63 DC THROUGH (INL),I=0,1,I.L.L.100-

64 INL LO(I,0)=1000-

65 F FC2 (3E16.8) -

66 WRITE OUTPUT ,F698-

67 F F698 (1H1,///Q* COMPUTED (AND PUNCHED) VALUES*/ - GIVEN VALUES

68 WRITE OUTPUT ,F699-

69 F F699 (Q* NO. LAT. LONG. ELL.HEIGHT X Y Z

70 DC THROUGH (READ),I=0,1,I.L.L.NST-

71 READ INPUT ,FS,(NO,INF,INF(1),INF(2),SEC,INF(3),INF(4),SEC(1),SEC(2))-

72 F FC6 (14,4X,3DF16.6,2F7.4,L2)-

73 ACUR PH=ANRAD.(INF,INF(1),INF(2),SEC)-

74 INN=\$+ \$-

75 TH=ANRAD.(INN,INF(3),INF(4),SEC(1))-

76 CALL SUBROUTINE (X,Y,Z)=GEOCAR.(PH,TH,SEC(2))-

77 PUNCH CARDS ,FC6,(NO,X,Y,Z,PH,TH)-

78 WRITE OUTPUT ,FW,(NO,INF,INF(1),INF(2),SEC,INF(3),INF(4),SEC(1),SEC(2),X,Y,Z,PH,TH)-

79 F FW (1X,13,4X,1,2I3,DF8.4,4X,2I3,DF8.4,DF11.3,8X,3DF14.3,2X,2F7.4) -

80 CARN SPH(NO)=PH-

81 STH(NO)=TH-

82 STV(NO,0)=X-

83 STV(NO,1)=Y-

84 STV(NO,2)=Z-

```

85 READ      NSN(I)=NO-
86          READ INPUT ,FC1,(N)-
87          WRITE OUTPUT ,FCG,(N)-
88 F FCG      (//Q* NO. OF STATIONS TO BE SHIFTED =*,I3//)-
89          PROVIDED (N.E.O), TRANSFER (CUL)-
90          WRITE OUTPUT ,F38-
91 F F38      (Q* STATION NUMBERS OF SHIFTED STATIONS* -
92          READ INPUT ,FC1,((NO(I),I=0,1,I.L.N))-
93          WRITE OUTPUT ,FC1,((NO(I),I=0,1,I.L.N))-
94          WRITE OUTPUT ,F32-
95          N=$AD $-
96          WRITE OUTPUT ,FC1-
97 F FCI      (Q*          SHIFTS          X          Y          Z
          LAT.,LONG.(RAD.)*//) -
98          DO THROUGH (ADC),I=0,1,I.L.N-
99          K=3*NO(I)-
100         READ INPUT ,FCB,(AD1,AD2,AD3)-
101         STV(K)=STV(K)+AD1-
102         STV(K+1)=STV(K+1)+AD2-
103         STV(K+2)=STV(K+2)+AD3-
104         WRITE OUTPUT ,FCH,((NO(I),AD1,AD2,AD3,STV(K),STV(K+1),STV(K+2),SPH(NO(I)),STH(NO(I))))-
105 F FCH      (I4,I4,3F14.3,1CX,3DF14.3,2X,2F7.4) -
106 ADC        PUNCH CARDS ,FC6,((NO(I),STV(K),STV(K+1),STV(K+2),SPH(NO(I)),STH(NO(I)),M))-
107 CUL        WRITE OUTPUT ,F33-
108          IS=0-
109          INS=99-
110          DO THROUGH (DO),I=0,1,I.L.3-
111          U(I)=0.0-
112          DO THROUGH (DO),J=0,1,J.L.3-

```

SHIFTED (AND PUNCHED) VALUES*//C* NO.
X Y Z

```

113      D(I,J)=0.0-
114      Q(I,J)=0.0-
115      D=1.0-
116      D(2,2)=-1.C-
117 C      SET POLAR MOTION COORDINATES TO ZERO-
118      X=C.C-
119      Y=C.C-
120      YV=0.0-
121      KT=0-
122      ISSS=0-
123      S(2,2)=1.0-
124      S(0,2)=0.0-
125      S(1,2)=0.0-
126      S(2,0)=0.0-
127      S(2,1)=0.0-
128      SS(2,2)=1.0-
129      SS(0,2)=0.0-
130      SS(1,2)=0.0-
131      SS(2,0)=0.0-
132      SS(2,1)=0.0-
133      WRITE OUTPUT ,F457-
134 F F457      (1H,///Q*
135      REDI      CONTINUE -
136      READ INPUT ,FI,(NO(I5),INF,INF(1),SEC,(INF(1),I=2,1,I.L.7),SEC(1),INF(7),INF(8),INF(9),SEC(2),SEC(3)
,SEC(4),SEC(5))-
137 C      TRANSFER TO(SUM) IF ALL DATA FOR THE EVENT HAS BEEN READ IN-
138      PROVIDED (.ABS.(SEC-SVS).G..0001.OR.INF(1).NE.INS), TRANSFER (SUM)-
139 F FC3      (3(E16.8,5X)) -
140      BGC      AL=HRRAD.(INF(5),INF(6),SEC(1))-
141      DE=ANRAD.(INF(7),INF(8),INF(9),SEC(2))-

```

OBSERVATIONAL DATA*//)

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142      WRITE OUTPUT ,FU,(NO(IS),INF,INF(1),SEC,(INF(1),I=2,1,I.L.7),SEC(1),INF(7),INF(8),INF(9),SEC(2),SEC(
3),SEC(4),SEC(5))-

143 F FU      (I5,4X,I2,I4,DF9.4,3X,I2,I3,I2,2X,2I4,DF9.4,4X,I1,I2,I4,DF9.4,3X,30F8.2)-

144 C      IF THE OBSERVATIONS FROM THE FIRST TWO STATIONS HAVE ALREADY BEEN READ IN SKIP OVER SATELLITE COORDIN
ATE COMPUTATION-

145      PROVIDED (IS.G.1), TRANSFER (OVER)-

146 C      SAVE THE DEC. AND RIGHT ASC. FROM THE FIRST TWO STATIONS IN THE EVENT-

147      SAL(IS)=AL-

148      SDE(IS)=DE-

149 C      SAVE THE PRECISION ESTIMATES OF THE FIRST STATION IN THE EVENT-

150      PROVIDED (IS.NE.0), TRANSFER IC (MISTOK)-

151      SEC(IS+6)=SEC(3)-

152      SEC(IS+7)=SEC(4)-

153      SEC(IS+8)=SEC(5)-

154 MISTOK      CONTINUE -

155      IS=IS+1-

156 C      READ IN DATA FROM SECOND STATION IN THE EVENT-

157      PROVIDED (IS.E.1), TRANSFER (REDI)-

158      CALL SUBROUTINE (XS,YS,ZS)=KCOMP.(NO,STV,SAL,SDE,SS)-

159      ASP=.HCP.A-

160      E2SP=.HOP.E2-

161      CALL SUBROUTINE (FF,XLAM,HP)=INVPR.(ASP,E2SP,XS,YS,ZS)-

162 C      NOW TO PROCESS ALL STATIONS IN THE EVENT-

163      IS=0-

164 C      RECOVER OBSERVATIONS

CF THE FIRST TWO STATIONS-

165 JIG      AL=SAL(IS)-

166      DE=SDE(IS)-

167      PROVIDED (IS.NE.0), TRANSFER IC (OVER)-

168 C      RECOVER PRECISION ESTIMATES FROM THE FIRST STATION IN THE EVENT-

169      SEC(3)=SEC(IS+6)-

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170 SEC(4)=SEC(15+7)-
171 SEC(5)=SEC(15+8)-
172 OVER R=XS-.HOP.STV(NO(15),0)-
173 R(1)=YS-.HOP.STV(NO(15),1)-
174 R(2)=ZS-.HOP.STV(NO(15),2)-
175 RIJ2=R*R(1)*R(1)+R(2)*R(2)-
176 Y=C.O-
177 X=C.C-
178 C -
179 C SET-UP L AND C VECTORS FOR COMPUTATION OF ST1(R2 ROTATION OF 90-DEC TIMES R3 OF RIGHT ASCENSION)-
180 L=2-
181 L(1)=2-
182 L(2)=4-
183 C=AL-
184 C(1)=PID2-DE-
185 CALL SUBROUTINE (ST1)=RCATE.(C,L)-
186 CALL SUBROUTINE (ST1)=DF3X3.(ST1)-
187 CALL SUBROUTINE (ST2)=MULTM3.(ST1,S)-
188 CALL SUBROUTINE (ST2)=DF3X3.(ST2)-
189 C COMPUTATION OF BIJ INVERSE WITHOUT THE C-MATRIX(EQU.2-11)- CORRECTED)-
190 D(1,1)=-1.-
191 CALL SUBROUTINE (D)=DF3X3.(D)-
192 C COMPUTATION OF BIJ INVERSE(EQU.2-10)-
193 CALL SUBROUTINE (BI)=MULTM3.(D,ST2)-
194 CALL SUBROUTINE (BI)=DF3X3.(BI)-
195 SML CONTINUE -
196 C COMPUTATION OF 2X2 WEIGHT MATRIX PIJ(EQU.2-19)-
197 C FIRST CONVERT PRECISION ESTIMATES INTO LINEAR UNITS (METERS)-
198 RRH02=RIJ2/(.HOP.RH0SEC*.HOP.RH0SEC)-

```

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199 C ACCORDING TO(CORRECTED)EQU.2-16 TO 2-18-

200 SIGD=RRHO2*SEC(4)*SEC(4)-

201 HOPDE=.HOP.DE-

202 SIGA=RRHO2*COS.(HOPDE)*COS.(HOPDE)*SEC(3)*SEC(3)-

203 SIGDA=RRHO2*SEC(5)*COS.(HOPDE)-

204 C NOW GET INVERSE OF 2X2 BY FIRST FINDING THE DETERMINANT-

205 DETIJ=SIGD*SIGA-SIGDA*SIGDA-

206 C WEIGHT MATRIX IS,AFTER CONSIDERING THE APRIORI VARIANCE OF UNIT WEIGHT(AM02)-

207 HOPAM0=.HOP.AM02-

208 VAR=HOPAM0*SIGA/DETIJ-

209 VAR(2)=HOPAM0*SIGD/DETIJ-

210 VAR(1)=HOPAM0*(-SIGDA)/DETIJ-

211 WRITE OUTPUT ,WEIGHT,(VAR,VAR(2),VAR(1))-

212 F WEIGHT (1H,5X,///,3F15.8) -

213 C NOW COMPUTE PIJ*BIJ INVERSE (EQU.2-46)-

214 DO THROUGH (PBI),I=0,1,1.L.2-

215 DO THROUGH (PBI),J=0,1,J.L.3-

216 PBI ST1(I,J)=VAR(1)*BI(I,J)+VAR(I+1)*BI(I,J)-

217 ST1(2,0)=0.0-

218 ST1(2,1)=0.0-

219 ST1(2,2)=0.0-

220 CALL SUBROUTINE (ST1)=DF3X3.(ST1)-

221 RB VST=STV(NO(1S),0)-

222 VST(1)=STV(NO(1S),1)-

223 VST(2)=STV(NO(1S),2)-

224 CALL SUBROUTINE (BI)=TRANSP.(KCM)-

225 CALL SUBROUTINE (BI)=DF3X3.(BI)-

226 C NOW COMPUTE MIJ INVERSE(EQU.2-46)-

227 CALL SUBROUTINE (P)=MULTM3.(BI,ST1)-

```

228      CALL SUBROUTINE (P)=DF3X3.(P)-
229 C      COMPUTE MIJ INVERSE*XI(EQU.2-55)-
230      CALL SUBROUTINE (UN)=MULTV3.(P,VST)-
231      CALL SUBROUTINE (UN)=DF3X1.(UN)-
232 C      COMPUTE SUMMATION OVER I MIJ INVERSE*XI(EQU.2-55)-
233      DO THROUGH (CON),I=0,1,I.L.3-
234      U(I)=U(I)+UN(I)-
235      CALL SUBROUTINE (U)=DF3X1.(U)-
236 C      COMPUTE SUMMATION OVER I MIJ INVERSE(EQU.2-55)-
237      DO THROUGH (CON),J=0,1,J.L.3-
238      Q(I,J)=Q(I,J)+P(I,J)-
239      CALL SUBROUTINE (Q)=DF3X3.(Q)-
240      N=IS*9-
241      M=N-3-
242 C      SAVE RIJ INVERSE IN BIS---ANDMIJ INVERSE IN PSD AND PSV-
243      DO THROUGH (SAV),I=0,1,I.L.3-
244      M=M+3-
245      DO THROUGH (SAV),J=0,1,J.L.3-
246      BIS(M+J)=BI(J,I)-
247      PSD(M+J)=P(I,J)-
248      PSV(M+J)=HOP.P(I,J)-
249      CALL SUBROUTINE (BIS)=DF3X3.(BIS)-
250      CALL SUBROUTINE (PSD)=DF3X3.(PSD)-
251      CALL SUBROUTINE (PSV)=F3X3.(PSV)-
252      IS=IS+1-
253 C      TRANSFER IN ORDER TO DO COMPUTATION FOR THE SECOND STATION IN THE EVENT-
254      PROVIDED (IS.E.1), TRANSFER (JIG)-
255 C      TRANSFER IN ORDER TO READ IN DATA FROM THE REMAINING STATIONS IN THE EVENT-
256      TRANSFER TO (REDI)-

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257  CONTINUE -
258  SVS=SEC-
259  INS=INF(1)-
260  C IF IT IS THE FIRST OBSERVATION ,GO TO COMPUTE GAST-
261  PROVIDED (IS.E.O), TRANSFER (LAS)-
262  F F12 (/Q* GEOD. COORD. OF SATELLITE. LAT.(DEG.)=*,F8.3,Q* LONG.(DEG.)=*,F8.3,Q* ELL.HI.(MET.)=*,F1
      0.1/) -
263  WRITE OUTPUT ,F12,(FF,XLAM,HP)-
264  C COMPUTE SUMMATION OVER I MIJ INVERSE ALL INVERTED(EQU.2-55)-
265  CALL SUBROUTINE (ST2)=SYINVT.(Q)-
266  CALL SUBROUTINE (ST2)=DF3X3.(ST2)-
267  C COMPUTE XJ(P47) OR 2 ND TERM IN EQU.2-55-
268  CALL SUBROUTINE (QIU)=MULTV3.(ST2,U)-
269  WRITE OUTPUT ,XSYSZS,(XS,YS,ZS)-
270  F XSYSZS (1H ,/,10X,Q*CARTESIAN COORDINATES OF SATELLITE (X,Y,Z IN METERS)*,/,10X,
      1CX,3F20.4) -
      Q*AS OBTAINED VIA THE VECTORS FROM THE FIRST TWO STATIONS IN THE EVENT*,/,
271  WRITE OUTPUT ,SATXYZ,(QIU,QIU(1),QIU(2))-
272  F SATXYZ (1H ,/,10X,Q*CARTESIAN COORDINATES OF SATELLITE (X,Y,Z IN METERS) FROM EVENT ADJUSTMENT*,/,10X,30F20.4
      ,/) -
273  YSS=0.C-
274  IT=0-
275  N=-3-
276  M=-3-
277  C COMPUTATION OF VARIANCE OF UNIT WEIGHT FOR EVENT ADJUSTMENT (EQU.2-64)-
278  DO THROUGH (CHV),I=0,1,I.L.IS-
279  N=N+3-
280  U=STV(NO(I),0)-QIU-
281  U(1)=STV(NO(1),1)-QIU(1)-
282  U(2)=STV(NO(1),2)-QIU(2)-
283  DO THROUGH (FFN),J=0,1,J.L.3-

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284 N=N+3-

285 FFN EVS(M+J)=PSD(N)*U+PSD(N+1)*U(1)+PSD(N+2)*U(2)-

286 YS=EVS(M)*U+EVS(M+1)*U(1)+EVS(M+2)*U(2)-

287 C COMPUTE QUADRATIC FORM OF RESIDUALS, NUMERATOR EQU.2-64-

288 CHV YSS=YSS+YS-

289 XV=YSS/(IS*2-3)-

290 C COMPUTE DEGREES OF FREEDOM-

291 ISSS=ISSS+IS*2-3-

292 PROVIDED (XV.G.TV.OR.XV.L.-0.01),IT=4-

293 F FC5 (10X,IS,5DF16.2) -

294 WRITE OUTPUT ,FC55,(XV)-

295 F FC55 (Q* VARIANCE OF UNIT WEIGHT (SEC. OF ARC SQUARED) =*,F10.3//) -

296 PROVIDED (IT.E.0), TRANSFER (COF)-

297 ISSS=ISSS-IS*2+3-

298 WRITE OUTPUT ,FRJ-

299 F FRJ (Q* THIS SIMULTANEOUS EVENT REJECTED, RESIDUALS - */12X,C*NO. V(R.A.)(MET.) V(DE.)(MET.) RAN
GE(MET.) V(R.A.)(SEC.) V(DE.)(SEC.)*)-

300 N=-3-

301 DO THROUGH (RV),I=0,1,I.L.IS-

302 K=3*NO(I)-

303 U=STV(K)-QIU-

304 U(1)=STV(K+1)-QIU(1)-

305 U(2)=STV(K+2)-QIU(2)-

306 DO THROUGH (RV),J=0,1,J.L.3-

307 N=N+3-

308 RV1 V(J)=BIS(N)*U+BIS(N+1)*U(1)+BIS(N+2)*U(2)-

309 XVS=.HOP.RH0SEC/V(2)-

310 XV=V*XVS-

311 XVS=V(1)*XVS-

312 RV WRITE OUTPUT ,FC5,(NO(I),V,V(1),V(2),XV,XVS)-

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313	KRAKINSKY, E.					
314	COF	TRANSFER (PAS)-				
315		IV=-1-				
316		DC THROUGH (ADD),IT=0,1,IT.L,IS-				
317		N=9*IT-				
318		DO THROUGH (IN),I=0,1,I.L,3-				
319		DO THROUGH (IN),J=0,1,J.L,3-				
320		K=N+J-				
321	IN	QIP(I,J)=-.HOP.STI2(I,0)*PSV(K)-.HOP.STI2(I,1)*PSV(K+3)-.HOP.STI2(I,2)*PSV(K+6)-				
322	ZIM	PROVIDED (LO(NO(IT),0).E.1000), TRANSFER (BJI)-				
323		DO THROUGH (STA),JT=0,1,JT.L,IT-				
324	SER	M=-1-				
325		M=M+1-				
326		PROVIDED (M.E.IPR), TRANSFER (IOO)-				
327		PROVIDED (LO(NO(JT),M).E.999), TRANSFER (TIN)-				
328		PROVIDED (NC(IT).NE.LO(NO(JT),M)), TRANSFER (SER)-				
329	RLZ	N=IPR3*NO(JT)+9*M-3-				
330		M=5*JT-3-				
331		DC THROUGH (STA),I=0,1,I.L,3-				
332		N=N+3-				
333		M=M+3-				
334		DC THROUGH (STA),J=0,1,J.L,3-				
335	STA	L=N+J-				
336	SEN	EL(L)=EL(L)+PSV(M)*QIP(O,J)+PSV(M+1)*QIP(1,J)+PSV(M+2)*QIP(2,J)-				
337		QIP=QIP+1.C-				
338		QIP(1,1)=QIP(1,1)+1.0-				
339		QIP(2,2)=QIP(2,2)+1.0-				
340		LM=3*NO(IT)-				
341		N=9*IT-3-				
342		DO THROUGH (ADD),I=0,1,I.L,3-				


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KRAKINSKY, E.          JOB   SCA200      08/28/68      R07026  PAGE   24
371  TOBLI=ONEAN+FOBL/3600.-
372  EQE=FLON*DCOS.(TOBLI/RHO)-
373  GAST=((GMST+EQE/54000.)*15.)/RHC-
374  MMM=GAST/(2.*PI)-
375  GAST=GAST-MMM*(2.*PI)-
376  CALL SUBROUTINE (IALH, IALM, ALS)=RADHR.(GAST)-
377  PROVIDED (POLETE.LQ.$NO $), TRANSFER (SUN)-
378  CALL SUBROUTINE (PX, PY)=POLE.(AMJD)-
379  SUN      FUNX=PX*RHOSEC-
380          FUNY=PY*RHOSEC-
381  WRITE OUTPUT ,FO1,(IALH, IALM, ALS, FUNX, FUNY)-
382 F FO1  (Q*   AT GAST =*,213,DF8.4,19X,Q*THE VALUES FOR POLAR MOTION ARE X =*,DF8.4,Q* Y =*,DF8.4//) -
383  WRITE OUTPUT ,FCJ-
384 F FCJ  (Q* SIGHTINGS*/Q* NO.   H   M   SEC.   DATE   R.A.   DEC.   STD(RA)
          STD(DEC) COVAR(RA,DEC)*/) -
385 C      COMPUTATION OF R3((-GAST)*R1(Y)*R2(X)-
386          L(C)=2-
387          L(1)=1-
388          L(2)=3-
389          L(3)=5-
390          C(C)=PX-
391          C(1)=PY-
392          C(2)=-GAST-
393  CALL SUBROUTINE (S)=ROTATE.(C,L)-
394 C      SET-UP OF APPROXIMATE 3-DIMENSIONAL ROTATION THROUGH GAST-
395          SS=DCOS.(GAST)-
396          SS(C,1)=DSIN.(GAST)-
397          SS(1,0)=-S(0,1)-
398          SS(1,1)=SS-
399          TRANSFER TO (BGC)-

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400 TIN      LO(NO(JT),M)=NO(IT)-
401          PROVIDED (M,L,IPR-1),LO(NO(JT),M+1)=999-
402          N=IPR3*NO(JT)+9*M-3-
403          M=N+10-
404          DO THROUGH (INT),I=N+3,3,I,L,M-
405          DO THROUGH (INT),J=0,1,J,L,3-
406 INT      EL(I+J)=0,C-
407          TRANSFER TO (RLZ)-
408 BJI      DO THROUGH (INV),I=0,1,I,L,3-
409          LM=NO(IT)*3-
410          L=LM+I-
411          EV(L)=C,C-
412          K=3*L-
413          DO THROUGH (INV),J=0,1,J,L,3-
414 INV      EK(K+J)=0,C-
415          LO(NO(IT),C)=999-
416          TRANSFER TO (ZIM)-
417 TOO      WRITE OUTPUT ,FI,(NO(IT))-
418 F FI      (Q* ADDITIONAL STORAGE FOR OFF DIAGONAL COEFFICIENTS FOR STATION NO. *,I5,W* IS NEEDED*) -
419          TRANSFER TO (SEN)-
420 OUT      PROVIDED (IV,E,0,0), TRANSFER (FINI)-
421          WRITE OUTPUT ,F69-
422 F F69      (IH1,///Q*      GUIDE MATRIX - GROUND STATIONS INVOLVED IN SIMULTANEOUS SIGHTINGS.*//) -
423          DO THROUGH (LOW),I=0,1,I,L,NST-
424 LOW      WRITE OUTPUT ,FCZ,(NSN(I),LO(NSN(I),J),J=0,1,J,L,IPR))-
425 F FCZ      (20X,I5,5X,I2I5) -
426          WRITE OUTPUT ,FC9,(YV)-
427 F FC9      (//Q*      TOTAL SUMMATION OF PVV - GROUND STATIONS HELD FIXED (I.E. PLL ) (SEC. OF ARC SQUARED) =
          *,F11.3//) -
428          WRITE OUTPUT ,F02,(ISSS)-

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429 F F02 (Q* CORRESPONDING TOTAL NO. OF DEGREES OF FREEDOM =*,15/)-
430 SSS=ISS-
431 PUNCH CARDS ,EJK,(SSS,YV)-
432 F EJK (16X,2E16.8)-
433 TVAR=YV/SSS-
434 WRITE OUTPUT ,F03,(TVAR)-
435 F F03 (Q* CORRESPONDING TOTAL VARIANCE OF UNIT WEIGHT (SEC.OF ARC SQUARED) =*,DF10.4/)-
436 TMC=DSORT.(TVAR)-
437 WRITE OUTPUT ,F04,(TMC)-
438 F F04 (Q* CORRESPONDING TOTAL STAN.DEV. OF UNIT WEIGHT (SEC. OF ARC) =*,DF10.4/)-
439 WRITE OUTPUT ,F05-
440 F F05 (1H1,/,Q* NORMAL EQUATIONS (SEE GUIDE MATRIX)*/)-
441 DO THROUGH (POU),I=0,1,I.L.NST-
442 PUNCH CARDS ,FC1,(NSN(I))-
443 WRITE OUTPUT ,F06,(NSN(I))-
444 F F06 (//15)-
445 K=NSN(I)-
446 N=3*K-
447 M=9*K-3-
448 PUNCH CARDS ,FC3,((EV(N+J),J=0,1,J.L.3))-
449 WRITE OUTPUT ,F07,((EV(N+J),J=0,1,J.L.3))-
450 F F07 (/3(F16.10,5X)) -
451 DO THROUGH (OKV),J=0,1,J.L.3-
452 M=M+3-
453 WRITE OUTPUT ,F08,((EK(M+L),L=0,1,L.L.3))-
454 F F08 (3F16.10) -
455 OKV PUNCH CARDS ,FC2,((EK(M+L),L=0,1,L.L.3))-
456 LM=1PR3*K-9-
457 J=C-

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458 ONP      N=LO(K,J)-
459          PUNCH CARDS ,FC1,(N)-
460          WRITE OUTPUT ,FO6,(N)-
461          PROVIDED (N=E.999), TRANSFER (POU)-
462          LM=LM+5-
463          DO THROUGH (OK),N=0,3,N=L.9-
464          M=LM+N-
465          WRITE OUTPUT ,FO8,((EL(M+L),L=0,1,L.L.3))-
466          PUNCH CARDS ,FC2,((EL(M+L),L=0,1,L.L.3))-
467          J=J+1-
468          PROVIDED (J=L.IPR), TRANSFER (CNP)-
469          CONTINUE -
470          CALL SUBROUTINE ( )=ENDJCB.( )-
471 C          -
472 C          -
473 C          *****SUBROUTINES-
474          SUBROUTINE (G)=TRANSP.(N)-
475          PRECISION (2,G,P)-
476          DIMENSION (G(O,N))-
477          I=0-
478          CONJ      J=I+1-
479          JC        P=G(I,J)-
480          G(I,J)=G(J,I)-
481          G(J,I)=P-
482          J=J+1-
483          PROVIDED (J=L.N), TRANSFER TO (JC)-
484          I=I+1-
485          PROVIDED (I=L.N-1), TRANSFER TO (CONJ)-
486          NORMAL EXIT -

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487      END SUBPROGRAM -
488      SUBROUTINE (A)=SYNVT.(B)-
489      DIMENSION (A(0,KDM),B(0,KDM),S(10))-
490      LITERALS (KDM,3)-
491      PRECISION (2,A,B,S)-
492      DO THROUGH (CH),I=0,1,I.L.3-
493      K=2*I-
494      DO THROUGH (CH),J=1,1,J.L.3-
495      CH      S(K+J)=R(I,J)-
496      S(5)=S(1)*S(1)-
497      S(7)=S(2)*S(2)-
498      S(8)=S(4)*S(4)-
499      S(9)=S*S(3)*S(6)+2.*S(1)*S(2)*S(4)-S(3)*S(7)-S(6)*S(5)-
500      A=(S(3)*S(6)-S(8))/S(9)-
501      A(C,1)=(S(2)*S(4)-S(1)*S(6))/S(9)-
502      A(C,2)=(S(1)*S(4)-S(2)*S(3))/S(9)-
503      A(1,1)=(S*S(6)-S(7))/S(9)-
504      A(1,2)=(S(1)*S(2)-S*S(4))/S(9)-
505      A(2,2)=(S*S(3)-S(5))/S(9)-
506      A(1,0)=A(C,1)-
507      A(2,0)=A(C,2)-
508      A(2,1)=A(1,2)-
509      NORMAL EXIT -
510      END SUBPROGRAM -
511      FUNCTION (G)=ANRAD.(I,M,N,C)-
512      PRECISION (2,G,C,RHO,D)-
513      LITERALS (RHO,57.29577951308232)-
514      D=60.-
515      G=(M+N/D+C/(D*D))/RHO-

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516		PROVIDED (I.LQ.\$-	\$),G=-G-			
517		NORMAL EXIT -				
518		END SUBPROGRAM -				
519		FUNCTION (AMJD)=FMMJD.(LHR,LMN,ASC,LMO,LDA,LYR)-				
520		PRECISION (2,ASC,AMJD)-				
521		CONDITIONAL (MON)-				
522		PROVIDED (LMO.LQ.\$JAN	\$) OTHERWISE (MON1)-			
523		KMC=1-				
524	MON1	OR PROVIDED (LMO.LQ.\$FEB	\$) OTHERWISE (MON2)-			
525		KMC=31-				
526	MON2	OR PROVIDED (LMO.LQ.\$MAR	\$) OTHERWISE (MON3)-			
527		KMC=59-				
528	MON3	OR PROVIDED (LMO.LQ.\$APR	\$) OTHERWISE (MON4)-			
529		KMC=90-				
530	MON4	OR PROVIDED (LMO.LQ.\$MAY	\$) OTHERWISE (MON5)-			
531		KMC=121-				
532	MON5	OR PROVIDED (LMO.LQ.\$JUN	\$) OTHERWISE (MON6)-			
533		KMC=151-				
534	MON6	OR PROVIDED (LMO.LQ.\$JUL	\$) OTHERWISE (MON7)-			
535		KMC=181-				
536	MON7	OR PROVIDED (LMO.LQ.\$AUG	\$) OTHERWISE (MON8)-			
537		KMC=212-				
538	MON8	OR PROVIDED (LMO.LQ.\$SEP	\$) OTHERWISE (MON9)-			
539		KMC=242-				
540	MON9	OR PROVIDED (LMO.LQ.\$OCT	\$) OTHERWISE (MON10)-			
541		KMC=272-				
542	MON10	OR PROVIDED (LMO.LQ.\$NOV	\$) OTHERWISE (MON11)-			
543		KMC=304-				
544		END CONDITIONAL -				

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545	MON11	KMO=334-
546	MON	M=LYR/4-
547		PROVIDED (LYR-4*M.E.O.AND.KMO.L.59),KMO=KMO-1-
548		AMJD=-3663.0+(LYR-40)*365+KMO+LDA+M+(LHR+(LMN+ASC/60.)/60.)/24.-
549		NORMAL EXIT -
550		END SUBPROGRAM -
551		SUBROUTINE (X,Y,Z)=GEOCAR.(C,G,H)-
552		UNIVERSAL (A,E2)-
553		PRECISION (2,X,Y,Z,C,G,H,P,DSIN.,DCOS.,BI)-
554		BI=DSIN.(C)-
555		P=A/(1.-E2*BI.P.2).P..5-
556		X=(P+H)*DCOS.(C)-
557		Y=X*DSIN.(G)-
558		X=X*DCOS.(G)-
559		Z=(P*(1.-E2)+H)*BI-
560		NORMAL EXIT -
561		END SUBPROGRAM -
562		SUBROUTINE (R)=ROTATE.(C,L)-
563		LITERALS (KDM,3)-
564		DIMENSION (R(0,KDM),G(9,KDM),Q(2))-
565		PRECISION (2,R,G,C,DSIN.,DCOS.,Q)-
566		K=C-
567	INT0	CONDITIONAL (SWING)-
568		PROVIDED (L(K),E.1) OTHERWISE (SWING1)-
569		G(C,0)=1-
570		G(1,1)=DCOS.(C(K))-
571		G(1,2)=DSIN.(C(K))-
572		G(2,1)=-G(1,2)-
573		G(2,2)=G(1,1)-

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574			G(1)=0.0-				
575			G(2)=0.0-				
576			G(3)=0.0-				
577			G(4)=0.0-				
578	SWING1		OR PROVIDED (L(K).E.2) OTHERWISE (SWING2)-				
579			G(0,0)=DCOS.(C(K))-				
580			G(2,0)=DSIN.(C(K))-				
581			G(1,1)=1-				
582			G(0,2)=-G(2,0)-				
583			G(2,2)=G(0,0)-				
584			G(1)=0.0-				
585			G(3)=0.0-				
586			G(5)=0.0-				
587			G(7)=0.0-				
588	SWING2		OR PROVIDED (L(K).I.3) OTHERWISE (SWING3)-				
589			G(0,0)=DCOS.(C(K))-				
590			G(0,1)=DSIN.(C(K))-				
591			G(1,0)=-G(0,1)-				
592			G(1,1)=G(0,0)-				
593			G(2,2)=1-				
594			G(2)=0.0-				
595			G(5)=0.0-				
596			G(6)=0.0-				
597			G(7)=0.0-				
598			END CONDITIONAL -				
599	SWING3		NORMAL EXIT -				
600	SWING		K=K+1-				
601			PROVIDED (K.G.1); TRANSFER TO (COMP)-				
602			DO THROUGH (GET),I=0,1,I.L.3-				

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603      DO THROUGH (GET),J=0,1,J.L.3-
604      GET      R(I,J)=G(I,J)-
605              TRANSFER TO (INTO)-
606      COMP      DO THROUGH (MULT),I=0,1,I.L.3-
607              Q(C)=R(O,I)-
608              Q(1)=R(1,I)-
609              DO THROUGH (MULT),J=0,1,J.L.3-
610      MULT      R(J,I)=Q(O)*G(J,O)+Q(1)*G(J,1)+R(2,I)*G(J,2)-
611              TRANSFER TO (INTO)-
612      END SUBPROGRAM -
613      SUBROUTINE (R)=MULTM3.(A,B)-
614      PRECISION (2,A,B,R)-
615      LITERALS (KDM,3)-
616      DIMENSION (A(C,KDM),B(O,KDM),R(O,KDM))-
617      DO THROUGH (MULT),I=0,1,I.L.3-
618      DO THROUGH (MULT),J=0,1,J.L.3-
619      MULT      R(I,J)=A(I,O)*B(O,J)+A(I,1)*B(1,J)+A(I,2)*B(2,J)-
620      NCRMAL EXIT -
621      END SUBPROGRAM -
622      SUBROUTINE (R)=MULTIV3.(A,B)-
623      PRECISION (2,A,B,R)-
624      LITERALS (KDM,3)-
625      DIMENSION (A(O,KDM))-
626      DO THROUGH (MULT),I=0,1,I.L.3-
627      MULT      R(I)=A(I,O)*B(O)+A(I,1)*B(1)+A(I,2)*B(2)-
628      NORMAL EXIT -
629      END SUBPROGRAM -
630      FUNCTION (B)=HRRAD.(I,J,A)-
631      LITERALS (T,0.2617993877991494)-

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632 PRECISION (2,B,A,T)-
633 B=I*T+J*T/60.+A*T/3600.-
634 NORMAL EXIT -
635 END SUBPROGRAM -
636 SUBROUTINE (XS,YS,ZS)=RCOMP.(NC,STAXYZ,RA,DEC,R3)-
637 LITERALS (RH0,57.295779513)-
638 DIMENSION (VX(3),VY(3))-
639 DIMENSION (R3(0,L))-
640 DIMENSION (V1(3),V2(3),V12(3),STAXYZ(0,L))-
641 PRECISION (2,R3,DEC,RA,STAXYZ)-
642 LITERALS (L,3)-
643 C=.HOP.DEC-
644 D=.HOP.RA-
645 VX=COS.(C)-
646 VX(1)=SIN.(D)*VX-
647 VX=COS.(D)*VX-
648 VX(2)=SIN.(C)-
649 C=.HOP.DEC(1)-
650 D=.HOP.RA(1)-
651 VY=COS.(C)-
652 VY(1)=SIN.(D)*VY-
653 VY=COS.(D)*VY-
654 VY(2)=SIN.(C)-
655 DO THROUGH (VZERT),I=0,1,1.L.3-
656 V2(1)=C.-
657 V1(1)=0.-
658 DO THROUGH (V1ROT),I=0,1,1.L.3-
659 DO THROUGH (V1ROT),J=0,1,1.L.3-
660 V2(1)=V2(1)+.HOP.R3(1,J)*VY(J)-

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661 VIROT      V1(I)=V1(I)+.HOP.R3(I,J)*VX(J)-
662            V12(0)=.HOP.STAXYZ(N0(1),0)-.HOP.STAXYZ(N0(0),0)-
663            V12(1)=.HOP.STAXYZ(N0(1),1)-.HOP.STAXYZ(N0(0),1)-
664            V12(2)=.HOP.STAXYZ(N0(1),2)-.HOP.STAXYZ(N0(0),2)-
665            R12=SQRT.(V12(0).P.2+V12(1).P.2+V12(2).P.2)-
666            V12(0)=V12(0)/R12-
667            V12(1)=V12(1)/R12-
668            V12(2)=V12(2)/R12-
669            CAT=-V2*V12-V2(1)*V12(1)-V2(2)*V12(2)-
670            SINA2=SQRT.(1.-CAT.P.2)-
671            CAT1=V1*V2+V1(1)*V2(1)+V1(2)*V2(2)-
672            SINA3=SQRT.(1.-CAT1.P.2)-
673            R1S=R12*SINA2/SINA3-
674            XS=.HOP.STAXYZ(N0(0),0)+R1S*V1(0)-
675            YS=.HOP.STAXYZ(N0(0),1)+R1S*V1(1)-
676            ZS=.HOP.STAXYZ(N0(0),2)+R1S*V1(2)-
677            NORMAL EXIT -
678            END SUBPROGRAM -
679            SUBROUTINE (I,J,A)=RADHR.(THETA)-
680            PRECISION (2,PI,A,THETA)-
681            PI=3.141592653589793238-
682            A=THETA*12./PI-
683            I=A-
684            A=(A-I)*60.-
685            J=A-
686            A=(A-J)*60.-
687            NORMAL EXIT -
688            END SUBPROGRAM -
689            SUBROUTINE (FF,XLAM,H)=INVPR.(A,EE,X,Y,Z)-

```

```

690      R0=57.29578-
691      PI=3.1415927-
692      TLAM=Y/X-
693      XLAM=ATAN.(TLAM)-
694      PROVIDED (Y.GE.O.), TRANSFER (L10)-
695      PROVIDED (X.GE.O.), XLAM=XLAM+2.*PI-
696      PROVIDED (X.L.O.), XLAM=XLAM+PI-
697      TRANSFER (L20)-
698      L10      PROVIDED (X.GE.O.), XLAM=XLAM-
699      PROVIDED (X.L.O.), XLAM=XLAM+PI-
700      L20      XLAM=XLAM*R0-
701      TERM1=SQRT.(X*X+Y*Y)-
702      TERM1=Z/TERM3-
703      TERM2=TERM1/(1-EE)-
704      FF=ATAN.(TERM2)-
705      SFI=SIN.(FF)-
706      XN=A/SQRT.(1.-EE*SFI*SFI)-
707      TFI=TERM1*(1.+EE*XN*SFI/Z)-
708      FI1=ATAN.(TFI)-
709      FI1D=FI1*R0-
710      SFI=SIN.(FI1)-
711      H=Z/SFI-XN*(1.-EE)-
712      FF=FI1D-
713      NORMAL EXIT -
714      END SUBPROGRAM -
715      SUBROUTINE (FUNA,FUNB)=POLE.(TIEV)-
716      C      WHEN MORE VALUES OF X AND Y ARE NEEDED,
717      C      CHANGE THE FOLLOWING DIMENSION CARD -
718      DIMENSION (T(180),X(180),Y(180))-

```

PRECISION (2,DELOX,DELIX,DEL2X,DELL ,DELLIX,FUNX,DELOY,DEL1Y,DEL2Y,DELLOY,DELL1Y,FUNY,TIEV)-

PRECISION (2,FUNA,FUNB)-

PRECISION (2,TEV,BY,A,AN,B)-

LITERALS (T(0),0.,1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,
24.,25.,26.,27.,28.,29.,30.,31.,32.,33.,34.,35.,36.,37.,38.,39.,40.,41.,42.,43.,44.,45.,46.,47.,
48.,49.,50.,51.,52.,53.,54.,55.,56.,57.,58.,59.,60.,61.,62.,63.,64.,65.,66.,67.,68.,69.,70.,71.,
72.,73.,74.,75.,76.,77.,78.,79.,80.,81.,82.,83.,84.,85.,86.,87.,88.,89.)-

LITERALS (T(90),90.,91.,92.,93.,94.,95.,96.,97.,98.,99.,100.,101.,102.,103.,104.,105.,106.,107.,108.,
109.,110.,111.,112.,113.,114.,115.,116.,117.,118.,119.,120.,121.,122.,123.,124.,125.,126.,127.,
128.,129.,130.,131.,132.,133.,134.,135.,136.,137.,138.,139.,140.,141.,142.,143.,144.,145.,146.,1
47.,148.,149.,150.,151.,152.,153.,154.,155.,156.,157.,158.,159.,160.,161.,162.,163.,164.,165.,16
6.,167.,168.,169.,170.,171.,172.,173.,174.,175.,176.,177.,178.,179.)-

LITERALS (X(0),-.173,-.215,-.235,-.237,-.218,-.162,-.097,-.032,.036,.111,.188,.237,.348,.398,.398,.3
68,.330,.280,.218,.144,.069,.000,-.062,-.112,-.140,-.153,-.151,-.126,-.086,-.037,.026,.092,.161,
223,.272,.299,.308,.296,.261,.202,.135,.073,.046,.035,.013,-.026,-.072,-.096,-.107,-.103,-.087,
-.039,.004,.040,.070,.080,.109,.117,.117,.109)-

LITERALS (X(60),.092,.074,.065,.064,.062,.057,.046,.034,.030,.032,.040,.043,.042,.041,.039,.028,.019
-.010,-.027,-.021,-.009,.008,.027,.047,.071,.095,.120,.144,.162,.173,.171,.157,.128,.094,.056,.
017,-.019,-.054,-.086,-.110,-.121,-.119,-.105,-.076,-.038,.009,.070,.134,.191,.239,.274,.301,.28
1,.237,.176,.112,.048,-.011,-.069,-.122)-

LITERALS (X(120),-.171,-.206,-.194,-.169,-.139,-.101,-.055,.004,.074,.164,.214,.240,.241,.239,.255,.
250,.219,.161,.099,.042,-.012,-.067,-.120,-.160,-.185,-.196,-.194,-.174,-.130,-.072,-.063,.071,.
127,.168,.201,.221,.227,.220,.194,.138,.075,.033,.000,-.029,-.058,-.086,-.105,-.116,-.119,-.115,
-.104,-.086,-.057,-.010,.052,.096,.117,.125,.123,.115)-

LITERALS (Y(0),.022,.098,.187,.265,.328,.389,.443,.478,.493,.478,.447,.411,.365,.307,.235,.165,.097,
.043,-.007,-.038,-.057,-.064,-.057,-.025,.032,.120,.211,.285,.340,.372,.393,.406,.410,.401,.370,
320,.260,.201,.143,.090,.043,.007,-.012,-.007,-.025,.059,.094,.123,.153,.182,.209,.238,.263,.288
300,.306,.301,.288,.271,.249)-

LITERALS (Y(60),.220,.189,.161,.150,.151,.158,.161,.160,.155,.153,.150,.151,.154,.157,.165,.174,.191
212,.242,.276,.297,.309,.314,.312,.304,.290,.271,.246,.214,.175,.132,.092,.068,.060,.067,.083,
104,.128,.160,.200,.248,.295,.329,.356,.376,.388,.387,.375,.349,.307,.251,.193,.139,.091,.046,.
008,-.020,.005,.041,.078)-

LITERALS (Y(120),.120,.168,.230,.294,.353,.412,.455,.467,.459,.436,.394,.339,.275,.219,.168,.123,.08
5,.060,.046,.043,.049,.069,.103,.153,.226,.286,.334,.374,.408,.434,.444,.433,.399,.349,.303,.259
221,.186,.156,.131,.114,.103,.098,.100,.108,.124,.149,.181,.215,.255,.298,.330,.344,.345,.337,
324,.308,.291,.273,.253)-

LITERALS (RH0SEC,206264.8062470963)-

TEV=TIEV+2433282.500-

BY=(TEV-1721060.133)/365.2422-

A=(BY-1958.0)*20.-

L=A+1.-

AN=(A-T(L-1))/(T(L)-T(L-1))-


```

2.,0.,2.,1.,0.,2.,2.,2.,2.,0.,2.,-2.,2.,0.,0.,-2.,1.,0.,0.,2.,2.,1.,1.,0.,2.,-2.,1.,0.,0.,0.,0.,
1.,0.,)-
762 LITERALS (AM(270),0.,1.,0.,-2.,0.,1.,-1.,0.,0.,0.,1.,0.,-2.,0.,2.,0.,0.,1.,1.,0.,2.,0.,0.,1.,1.,
.,0.,0.,1.,-1.,2.,0.,2.,-2.,0.,0.,1.,-1.,0.,2.,-2.,1.,2.,0.,0.,0.,1.,-1.,-1.,2.,2.,2.,0.,-
1.,2.,2.,2.,1.,0.,0.,0.,2.,1.,1.,2.,0.,2.,3.,0.,2.,0.,2.,)-
763 LITERALS (CS,-172327.,2088.,45.,10.,-4.,-3.,-2.,-12729.,1261.,-497.,214.,124.,45.,-21.,16.,-15.,-15.,
.,-10.,-5.,-5.,4.,3.,-3.,-2037.,675.,-342.,-261.,-149.,114.,60.,58.,-57.,-52.,-44.,-32.,28.,26.,-
26.,25.,19.,14.,-13.,-9.,-7.,7.,6.,-6.,6.,-5.,-5.,5.,-4.,-4.,4.,4.,-4.,3.,-3.,-3.,-2.,-2.,-2.,-2.,-2.,-2.,)-
764 LITERALS (CC,92100.,-904.,-24.,0.,2.,2.,0.,5522.,0.,216.,-93.,-66.,0.,0.,6.,8.,7.,5.,3.,3.,-2.,-2.,0.,
.,884.,0.,183.,113.,0.,-50.,0.,-31.,30.,22.,23.,14.,0.,-11.,11.,0.,-10.,-7.,7.,5.,0.,-3.,0.,3.,3.,
.,3.,-2.,3.,3.,-3.,0.,0.,0.,2.,)-
765 BOOLEAN (B)-
766 L=1-
767 LL=5-
768 K=49-
769 LITERALS (RHO,57.29577951308232)-
770 DII=DD/1000-
771 I=CD/36525-
772 A(C)=296.104603+13.3649924465*DD+0.0006890*DII+0.000000295*DII*DII*DII-
773 A(I)=553.475833+0.9856002669*DD-0.0000112*DII*DII-0.000000068*DII*DII*DII-
774 A(2)=11.250889+13.2293504490*DD-0.0002407*DII*DII-J.000000007*DII*DII*DII-
775 A(3)=350.737486+12.1907491914*DD-0.0001076*DII*DII+0.000000039*DII*DII*DII-
776 A(4)=259.183275-0.05295539222*DD+0.0001557*DII*DII+0.000000046*DII*DII*DII-
777 DC THROUGH (TWO),I=0,1,1,LE.4-
778 MM=A(I)/360-
779 TWO A(I)=A(I)-MM*360.-
780 C=C-
781 E=C-
782 CCS(0)=-173.7*I-
783 CCS(1)=0.2*I-
784 CCS(7)=-1.3*I-
785 CCS(8)=-3.1*I-

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KRAKIWSKY, E.

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786      DCS(9)=1.2*I-
787      DCS(10)=-0.5*I-
788      DCS(11)=0.1*I-
789      DCS(14)=-0.1*I-
790      DCS(16)=0.1*I-
791      DCS(23)=-0.2*I-
792      DCS(24)=0.1*I-
793      DCS(25)=-0.4*I-
794      DCC(0)=9.1*I-
795      DCC(1)=0.4*I-
796      DCC(7)=-2.9*I-
797      DCC(9)=-0.6*I-
798      DCC(10)=0.3*I-
799      DCC(23)=-0.5*I-
800      DCC(26)=-0.1*I-
801      CALL SUBROUTINE (B,AMA)=DMTPY.(AM,A,K,LL,L)-
802      DO THROUGH (ABLE),I=0,1,I.L.69-
803      N=AMA(I)/360-
804      AMA(I)=AMA(I)-N*360.-
805      TCS(I)=CS(I)+DCS(I)-
806      TCC(I)=CC(I)+DCC(I)-
807      C=C+TCS(I)*DSIN.(AMA(I)/RHO)-
808      E=E+TCC(I)*DCOS.(AMA(I)/RHO)-
809      E=E/10000.-
810      C=C/10000.-
811      NORMAL EXIT -
812      END SUBPROGRAM -
813      SUBROUTINE (X31)=DF3X1.(X31)-
814      DIMENSION (X31(3))-

```

```

815      PRECISION (2,X31)-
816      WRITE OUTPUT ,FX31,(X31,X31(1),X31(2))-
817 F FX31      (1H,5X,///,3DF15.8)      -
818      NCRMAL EXIT -
819      END SUBPROGRAM -
820 C      -
821      SUBROUTINE (X33)=DF3X3.(X33)-
822      DIMENSION (X33(9,L3))-
823      PRECISION (2,X33)-
824      L3=3-
825      DO THROUGH (XOUT),I=0,1,I.L.3-
826      XOUT      WRITE OUTPUT ,F33,(X33(I,0),X33(I,1),X33(I,2))-
827 F F33      (1H,5X,///,3DF15.8)      -
828      NCRMAL EXIT -
829      END SUBPROGRAM -
830 C      -
831      SUBROUTINE (X33)=F3X3.(X33)-
832      DIMENSION (X33(9,L3))-
833      L3=3-
834      DO THROUGH (XOUT),I=0,1,I.L.3-
835      XOUT      WRITE OUTPUT ,F33,(X33(I,0),X33(I,1),X33(I,2))-
836 F F33      (1H,5X,///,3DF15.8)      -
837      NCRMAL EXIT -
838      END SUBPROGRAM -
839 C      -
840      END PROGRAM (GO)-

```

1.5 Input to Optical Program

	Columns
Card Set 1: (10L6) Comment card.	2 - 30
Card Set 1A: (10L6) "YES" or "NO" for polar motion computation (right adjusted).	
Card Set 2: (2 DF 25.16, DF 10.4) (1) Semi-major axis of reference ellipsoid. (2) Semi-minor axis of reference ellipsoid. (3) Apriori variance of unit weight (units of arc seconds squared)	1 - 25 26 - 50 51 - 60
Card Set 3: (14I5) Total number of ground stations. (maximum 100)	1 - 5
Card Set 4: (3F10.6) Test parameter on the variance of unit weight arising from each preliminary simultaneous event adjustment.	1 - 10
Card Set 5: (1X, I3, 20X, L1, 2(2I3, DF8.4), DF12.4) (1) Station number. (2) Sign of latitude (3) Degrees of latitude (4) Minutes of latitude (5) Seconds of latitude (6) Degrees of longitude (+ East) (7) Minutes of longitude (8) Seconds of longitude (9) Ellipsoidal height	2 - 4 25 26 - 28 29 - 31 32 - 39 40 - 42 43 - 45 46 - 53 54 - 65
Card Set 6: (14I5) Total number of station whose coordinates are to be shifted.	1 - 5
Card Set 7: (14I5) Station numbers of stations to be shifted. 1-5, 5-10, ..., 66-70 (continue on new card if necessary)	
Card Set 8: (3F10.6) Card 1. Three shift values in meters to be applied to the three respective Cartesian coordinates u, v, w. 1-10, 11-20, 21-30	

Card 2. Repeat the above for the second station.
(Continue for all stations to be shifted)

Card Set 9: (I3, 2X, I2, I3, DF9.5, I2, L3, I2, 2I3,
DF9.5, L1, I2, I3, DF8.4, 2X, 3DF5.2)

(1) Ground station number	1 - 3
(2) Hours of UT1 epoch of observation	6 - 7
(3) Minutes of UT1 epoch of observation	8 - 10
(4) Seconds of UT1 epoch of observation	11 - 19
(5) Day of month.	20 - 21
(6) Month.	22 - 14

Note: January = JAN	July = JUL
February = FEB	August = AUG
March = MAR	September = SEP
April = APR	October = OCT
May = MAY	November = NOV
June = JUN	December = DEC

(7) Last two digits of year since 1900.	25 - 26
** (8) Hours of topocentric right ascension	27 - 29
** (9) Minutes of topocentric right ascension	30 - 32
** (10) Seconds of topocentric right ascension	33 - 41
(11) Sign of topocentric declination	42
** (12) Degrees of topocentric declination	43 - 44
** (13) Minutes of topocentric declination	45 - 47
** (14) Seconds of topocentric declination	48 - 55
(15) Standard deviation (arc seconds) in the right ascension.	58 - 62
(16) Standard deviation (arc seconds) in the declination.	63 - 67
(17) Covariance between declination and right ascension.	68 - 72

(Repeat (1) - (17) on a new card for each station
in the event; minimum two stations per event.)
(No limit on the number of events)

Card Set 10:

Control card containing 99 designating end of events.	9 - 10
--	--------

** Refer to the True Topocentric Celestial Coordinate System

SECTION II: FORMATION OF RANGE NORMAL EQUATIONS

2.1 Introduction

The general form of the normal equations is the same as before; i.e.,

$$NX_g + U_g = 0,$$

where N is the symmetric coefficient matrix whose diagonal is composed of the 3 x 3 matrices [Krakiwsky and Pope, 1967, Eq. 3 - 14],

$$N_{kk} = \sum_j a'_{kj} P_{kj} a_{kj} - \sum_j \left\{ a'_{kj} P_{kj} a_{kj} \left(\sum_i a'_{ij} P_{ij} a_{ij} \right)^{-1} a'_{kj} P_{kj} a_{kj} \right\}, \quad (4)$$

while its off-diagonal portion is composed of the 3 x 3 matrices [Eq. 3 - 15],

$$N_{k\ell} = - \sum_j \left\{ a'_{kj} P_{kj} a_{kj} \left(\sum_i a'_{ij} P_{ij} a_{ij} \right)^{-1} a'_{\ell j} P_{\ell j} a_{\ell j} \right\}; \quad (5)$$

X_g is the vector of unknown corrections; U_g is the vector of constant terms which is composed of the 3 x 1 vectors [Eq. 3 - 19],

$$U_k = - \sum_j a'_{kj} P_{kj} \bar{v}_{kj}. \quad (6)$$

The subscripts and symbols in Eq. (4) - (6) have the same meaning as before, except in the following:

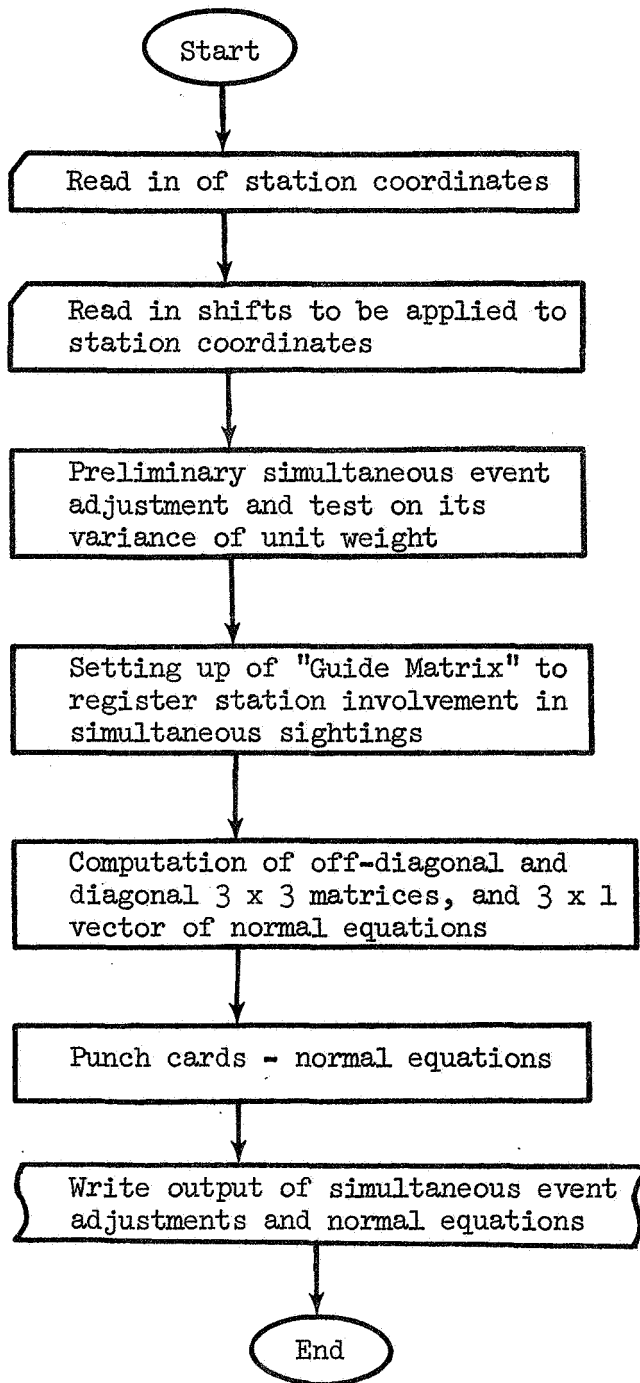
P_{ij} is the weight of any observed range,

$$a_{ij} = \begin{bmatrix} \frac{u_j^\circ - u_i^\circ}{r_{ij}} & \frac{v_j^\circ - v_i^\circ}{r_{ij}} & \frac{w_j^\circ - w_i^\circ}{r_{ij}} \end{bmatrix},$$

$u^\circ, v^\circ, w^\circ$ are the approximate Cartesian coordinates in the average terrestrial coordinate system, $\bar{v}_{ij}$ is the residual of any observed range from a particular station (resulting from a preliminary least square adjustment of any simultaneous event with the stations held fixed). The computation of Eq. 4 - 6 is the core at the computer program.

All comments made in Section 1.1 about the computer program apply for the ranging case also.

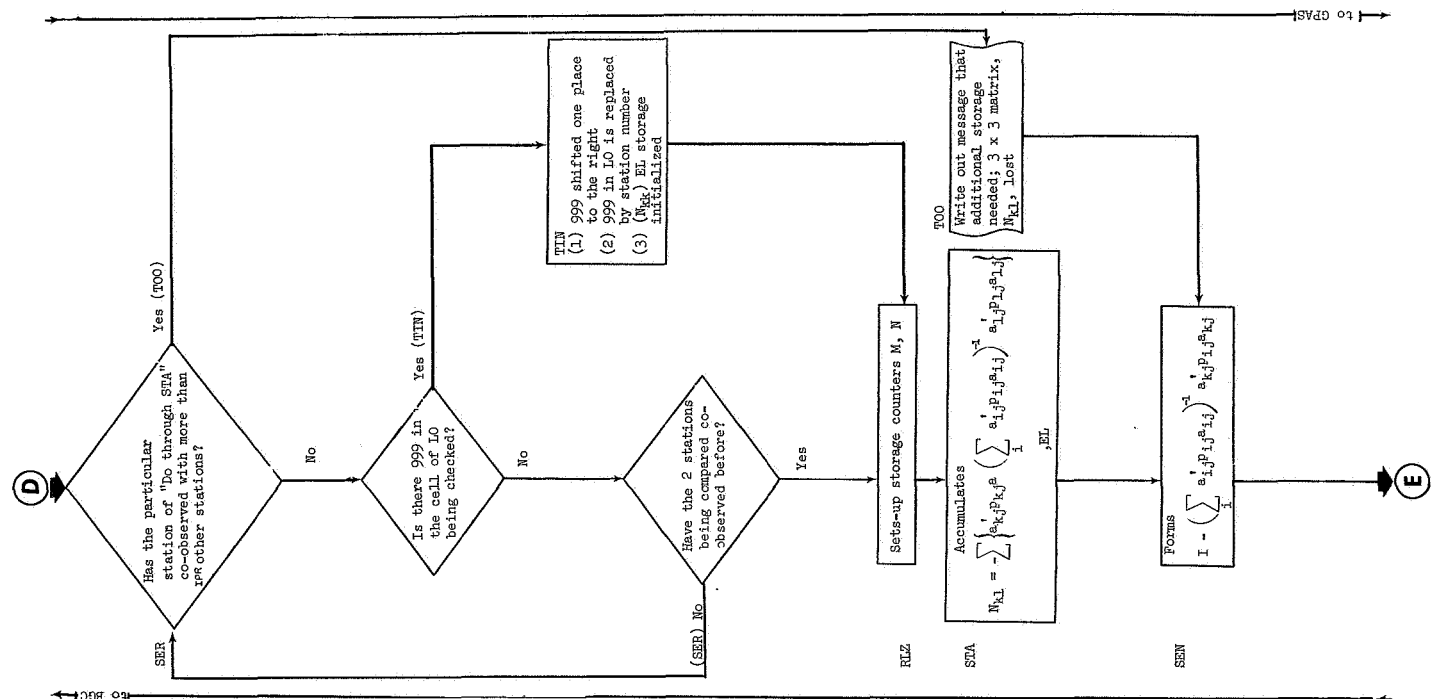
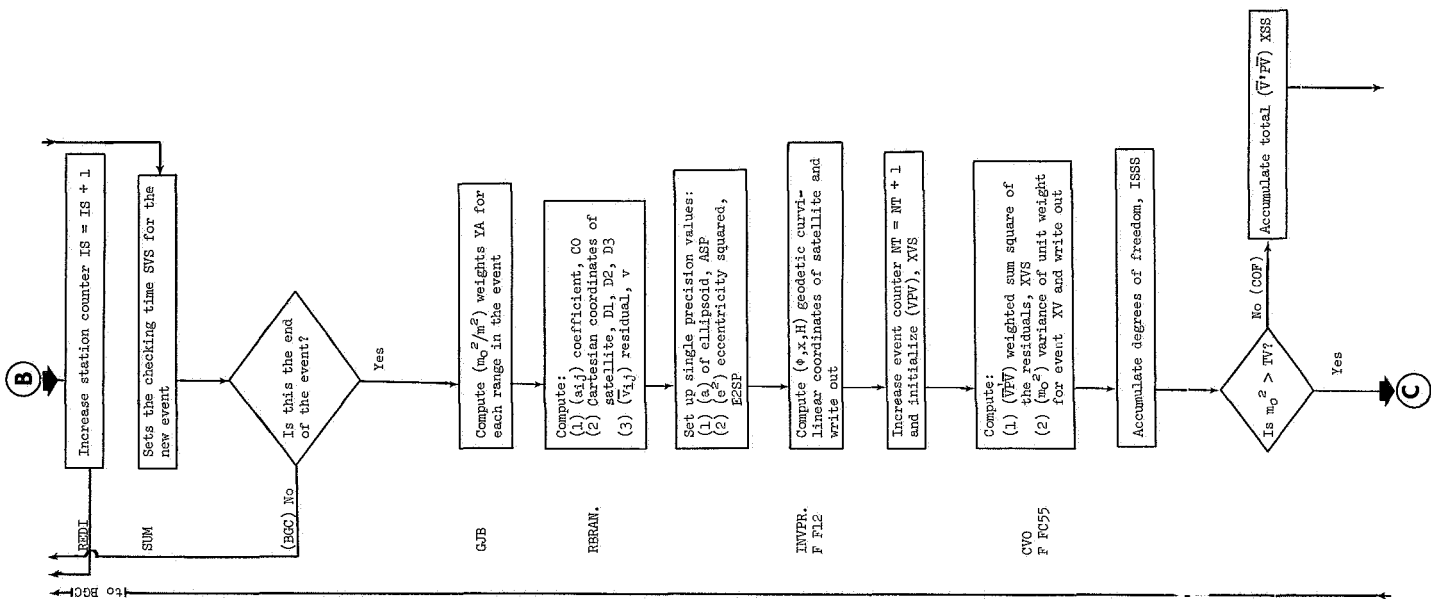
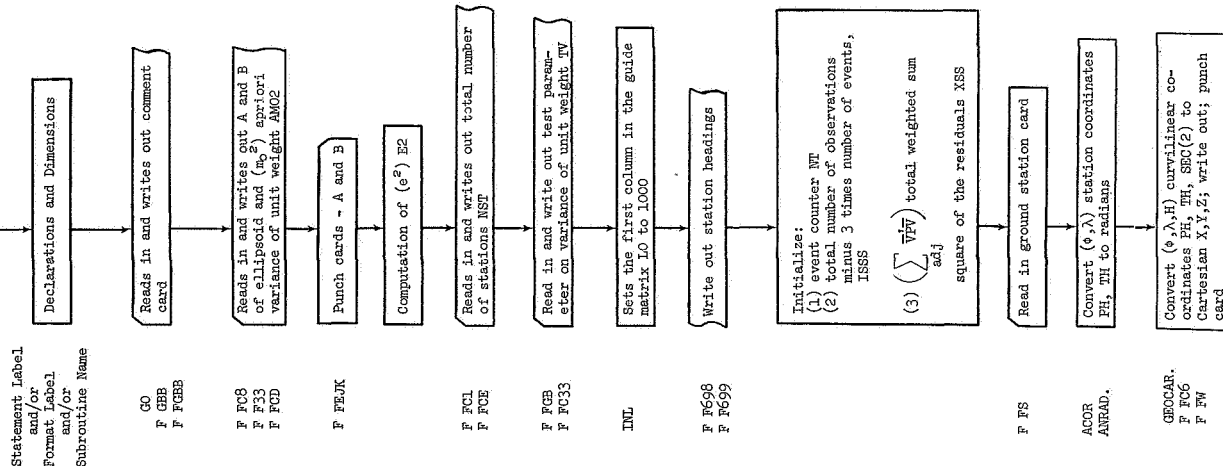
2.2 General Flow Chart

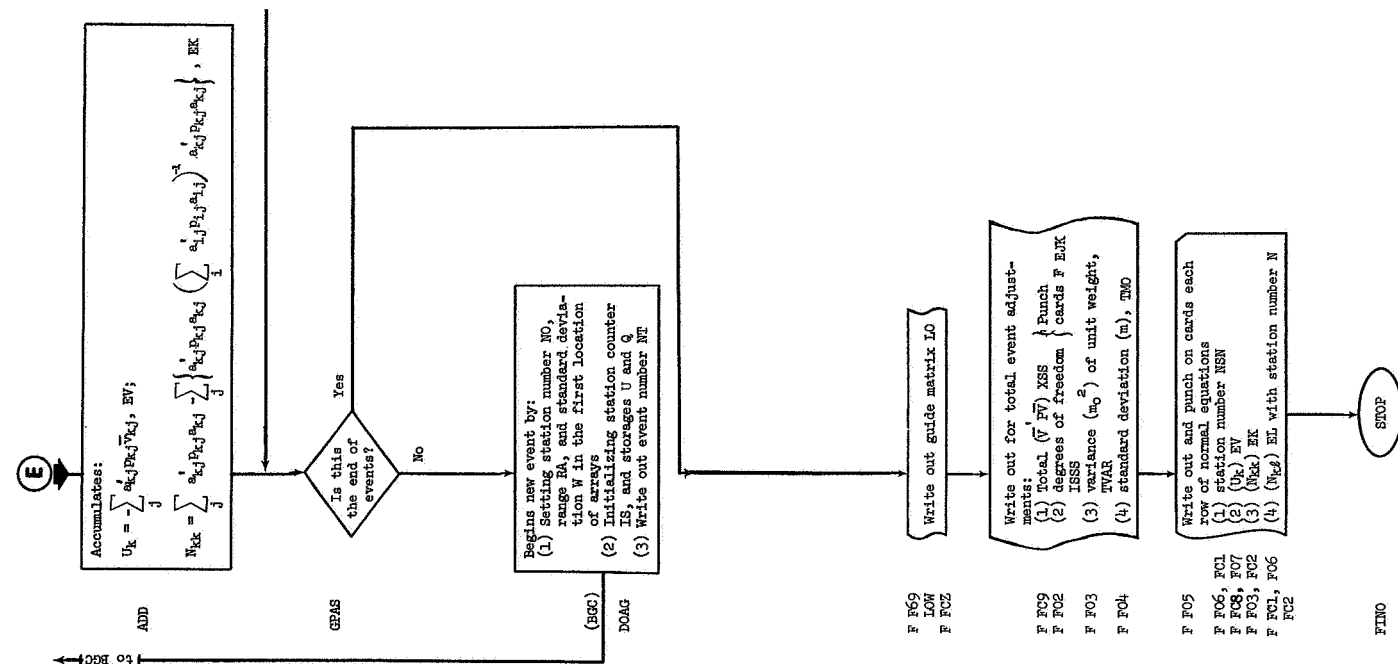
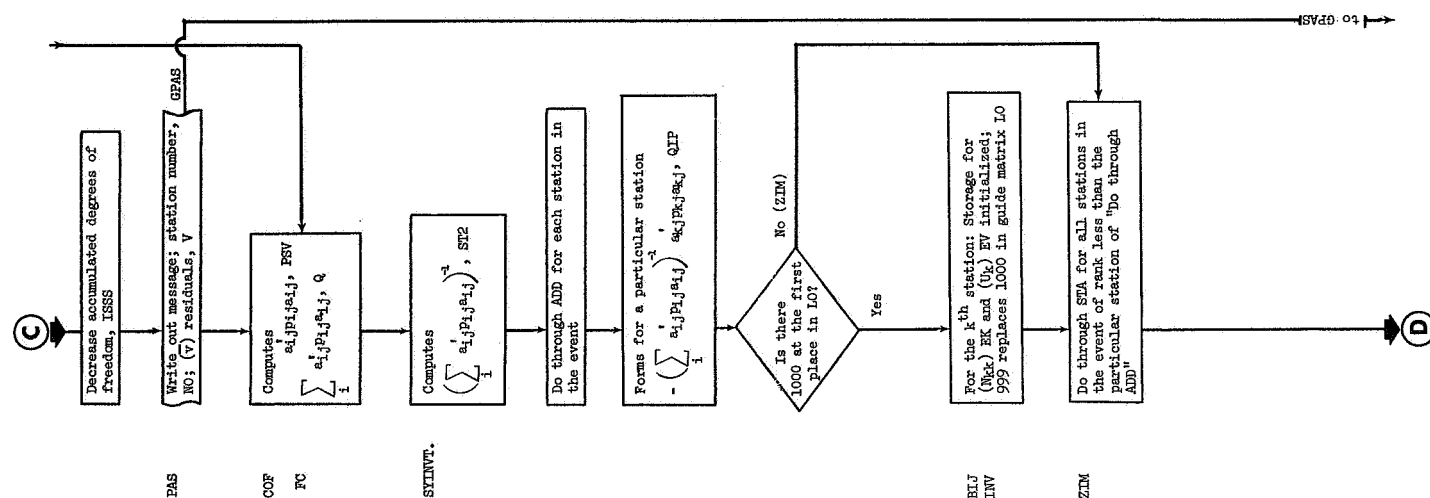
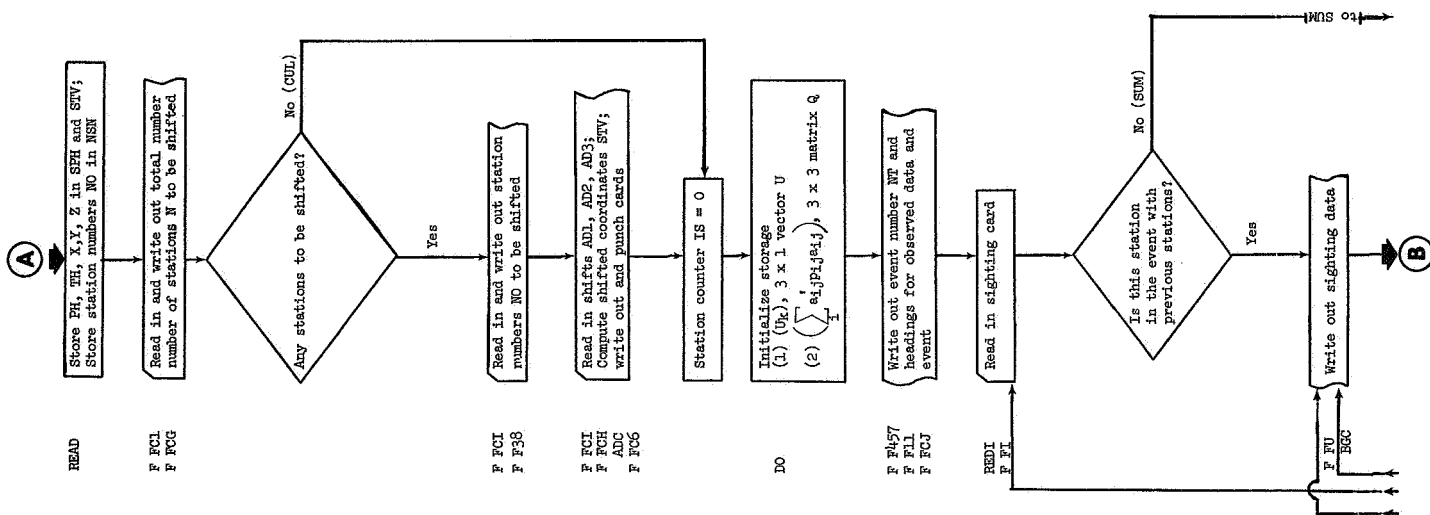


2.3 Specific Flow Chart

2.3 Specific Flow Chart

Statement Label
and/or
Format Label
and/or
Subroutine Name





2.4 STATEMENT LISTING

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KRAKIWSKY, E.      JOB   SCA200      05/23/68      C25009   PAGE    7
SOURCE LANGUAGE STATEMENTS
1 C      THIS PROGRAM FORMS NORMAL EQUATIONS FROM SATELLITE RANGES-
2 C      THIS PROGRAM IS DIMENSIONED FOR 99 STATIONS///NO STATION NUMBER TO HAVE A VALUE GREATER THAN 99-
3 C      SPECIAL PARAMETER FOR DIMENSIONING PURPOSES IS IPR = MAXIMUM NUMBER OF CO-OBSERVING STATIONS+1-
4 C      THIS PROGRAM IS DIMENSIONED FOR 13 CO-OBSERVING STATIONS , IPR=13+1=14-
5 C      LO AND EL ARE DIMENSIONED ACCORDING TO IPR-
6      DIMENSION (LO(NDIMLG,IPR),EL(NDIMEL))-
7 C      THEIR DIMENSIONS ARE DETERMINED FROM THE FUNCTIONS-
8 C      NDIMLG=100*IPR-
9 C      NDIMEL=900*IPR-
10 C      SO TO INCREASE THE MAXIMUM NUMBFR OF CO-OBSERVING STATIONS, SIMPLY CHANGE IPR OF THE PARAMETERS CARL
      TO 1 MORE THAN THE NUMBER OF CO-OBSERVING STATIONS DESIRED-
11      DIMENSION (SEC(10),VST(3),QIU(3),U(3),INF(10),NO(100),ST1(9,KDM),ST2(9,KDM),QIP(9,KDM),PSV(
      100),P(9,KDM))-
12      LITERALS (RHO,57.29577951308232,RHUSEC,206264.8062470963,PI,3.141592653589793,KDM,3,LDM,7)-
13      DIMENSION (CV(300),STV(300,KDM),EK(900),NSN(100))-
14      DIMENSION (SAA(10),UN(3))-
15      PRECISION (2,STV,SEC,VST,ST1,X,Y,Z,AL,DE,TH,PH)-
16      PRECISION (2,D1,D2,D3)-
17      DIMENSION (D4(10),YA(10))-
18      PRECISION (2,RHO,RHUSEC,PI,A,B,E2)-
19      PRECISION (2,ANRAD.,RA)-
20      DIMENSION (CO(30,KDM),RA(10),SPH(100),STH(100),W(10),V(10),ISTAT(5))-
21      PRECISION (2,TVAR)-
22 F FS      (IX,I3,20X,L1,2(2I3,DF8.4),DF12.4) -
23 F FI      (I3,2X,I2,I3,DF9.5,I2,L3,I2,DF15.5,I4X,F5.2)
24 F F33      (//) -
25 F F32      (/) -
26 F FC8      (2DE25.16,DF10.4) -
27 GO      READ INPUT ,GBB,((ISTAT(J),J=0,1,J.L.5))-

```

```

28 F GBB      (10L6)-
29      WRITE OUTPUT ,FGBB,((ISTAT(J),J=0,1,J.L.5))-
30 F FGBB      (//20X,10L6)-
31      READ INPUT ,FC8,(A,B,AM02)-
32      WRITE OUTPUT ,F33-
33      WRITE OUTPUT ,FCD,(A,B,AM02)-
34      PUNCH CARDS ,FEJK,(A,B)-
35 F FEJK      (2DF25.8) -
36 F FCD      (/Q*      A(ELL.) =*,DF14.4,Q*      B(ELL.) =*,DF14.4,//Q*      APRIORI VARIANCE OF UNIT WEIGHT ( IN
METERS SQUARED) =*,DF8.4//) -
37      TH=B/A-
38      E2=L.-TH*TH-
39      READ INPUT ,FCL,(NST)-
40      WRITE OUTPUT ,FCE,(NST)-
41 F FCE      (Q*      TOTAL NO. OF STATIONS =*,I4)-
42      WRITE OUTPUT ,F32-
43      READ INPUT ,FGB,(TV)-
44 F FGB      (3F10.6) -
45      WRITE OUTPUT ,FC33,(TV)-
46 F FC33      (Q*      PARAMETER TEST ON VARIANCE OF UNIT WEIGHT*/Q*      FOR EACH SIMULTANEOUS EVENT-STATIONS HFLO F1
XED (METERS SQUARED) =*,F10.2)-
47      WRITE OUTPUT ,F33-
48 F FC1      (1415)-
49      DO THROUGH (INL),I=0,1,I.L.100-
50 INL      LO(1,0)=1000-
51      WRITE OUTPUT ,F698-
52 F F698      (1H1,///Q*      GROUND STATIONS*/Q*      GIVEN VALUES
COMPUTED (AND PUNCHED) VALUES*/) -
53      WRITE OUTPUT ,F699-
54 F F699      (Q* NO.      LAT.      LONG.      ELL.HEIGHT      X      Y      Z
LAT.,LONG.(RAD.)*//) -

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KRAKINSKY, E.	JOB	SCA200	05/23/68	C25009	PAGE	9
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55	NT=1-	
56	ISSS=0-	
57	XSS=0.0-	
58	DO THROUGH (READ),I=0,1,I.L.NST-	
59	READ INPUT ,FS,(NO,INF,INF(1),INF(2),SEC,INF(3),INF(4),SEC(1),SEC(2))-	
60	F FC6 (I4,4X,3DF16.6,2F7.4,L2)-	
61	ACOR PH=ANRAD.(INF,INF(1),INF(2),SEC)-	
62	INN=\$+ \$-	
63	TH=ANRAD.(INN,INF(3),INF(4),SEC(1))-	
64	CALL SUBROUTINE (X,Y,Z)=GEUCAR.(PH,TH,SEC(2))-	
65	PUNCH CARDS ,FC6,(NO,X,Y,Z,PH,TH)-	
66	WRITE OUTPUT ,FW,(NO,INF,INF(1),INF(2),SEC,INF(3),INF(4),SEC(1),SEC(2),X,Y,Z,PH,TH)-	
67	F FW (1X,I3,4X,L1,2I3,DF8.4,4X,2I3,DF8.4,DF11.3,8X,3DF14.3,2X,2F7.4) -	
68	SPH(NO)=PH-	
69	STH(NO)=TH-	
70	STV(NO,0)=X-	
71	STV(NO,1)=Y-	
72	STV(NO,2)=Z-	
73	READ NSN(I)=NO-	
74	READ INPUT ,FCL,(N)-	
75	WRITE OUTPUT ,FCG,(N)-	
76	F FCG (//Q* NO. OF STATIONS TO BE SHIFTED =*,I3//)-	
77	PROVIDED (N.E.0), TRANSFER (CUL)-	
78	WRITE OUTPUT ,F38-	
79	F F38 (Q* STATION NUMBERS OF SHIFTED STATIONS*) -	
80	READ INPUT ,FCL,((NO(I),I=0,1,I.L.N))-	
81	WRITE OUTPUT ,FCL,((NO(I),I=0,1,I.L.N))-	
82	WRITE OUTPUT ,F32-	
83	M=\$AD \$-	

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84      WRITE OUTPUT ,FCI-
85 F FCI  {Q*      X      Y      Z      SHIFTS      X      Y      Z      SHIFTS
      LAT.,LONG.(RAD.)*/ ) -      X      Y      Z      SHIFTS
86      DO THROUGH (ADC),I=0,1,I.L.N-      X      Y      Z      SHIFTS
87      K=3*NO(I)-      X      Y      Z      SHIFTS
88      READ INPUT ,FCB,(AD1,AD2,AD3)-      X      Y      Z      SHIFTS
89      STV(K)=STV(K)+AD1-      X      Y      Z      SHIFTS
90      STV(K+1)=STV(K+1)+AD2-      X      Y      Z      SHIFTS
91      STV(K+2)=STV(K+2)+AD3-      X      Y      Z      SHIFTS
92      WRITE OUTPUT ,FCH,(NO(I),AD1,AD2,AD3,STV(K),STV(K+1),STV(K+2),SPH(N0(I)),SPH(N0(I))) -
93 F FCH  {I4,Ix,3F14.3,10X,3DF14.3,2X,2F7.4} -      X      Y      Z      SHIFTS
94 ADC      PUNCH CARDS ,FC6,(NO(I),STV(K),STV(K+1),STV(K+2),SPH(N0(I)),STH(N0(I)),M)-      X      Y      Z      SHIFTS
95 CUL      WRITE OUTPUT ,F33-      X      Y      Z      SHIFTS
96      IS=0-      X      Y      Z      SHIFTS
97      INS=99-      X      Y      Z      SHIFTS
98      DO THROUGH (DO),I=0,1,I.L.3-      X      Y      Z      SHIFTS
99      U(I)=0.0-      X      Y      Z      SHIFTS
100      DO THROUGH (DO),J=0,1,J.L.3-      X      Y      Z      SHIFTS
101 DO      Q(I,J)=0.0-      X      Y      Z      SHIFTS
102      WRITE OUTPUT ,F457-      X      Y      Z      SHIFTS
103 F F457  {IHL,///Q*      X      Y      Z      SHIFTS
104 F F11  (/Q*      X      Y      Z      SHIFTS
105      WRITE OUTPUT ,F11,(INT)-      X      Y      Z      SHIFTS
106      WRITE OUTPUT ,FCJ-      X      Y      Z      SHIFTS
107 F FCJ  {Q* SIGHTINGS*/Q* NO.      H      M      SEC.      DATE      RANGE(METERS)      STD.DEV.(MET.)*/)
108 REDI      CONTINUE -      X      Y      Z      SHIFTS
109      READ INPUT ,FI,(NO(1S),INF,INF(1),SEC,INF(2),INF(3),INF(4),RA(1S),W(1S))-      X      Y      Z      SHIFTS
110 F FC2  {3E16.8} -      X      Y      Z      SHIFTS
111 F FC3  {3(E16.8,5X)}      X      Y      Z      SHIFTS

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112      PROVIDED (.ABS.(SEC-SVS).G..0001.DR.INF(1).NE.INS.OR.INF.NE.IOS), TRANSFER (SUM)-
113 F FU      (I5,4X,I2,I4,DF9.4,3X,I2,I3,I2,6X,DF13.4,9X,F5.2)      -
114 BGC      WRITE OUTPUT ,FU,(NO(IS),INF,INF(1),SEC,INF(2),INF(3),INF(4),RA(IS),W(IS))-
115      IS=IS+1-
116      TRANSFER TO (REDI)-
117 SUM      CONTINUE -
118      SVS=SEC-
119      INS=INF(1)-
120      IOS=INF-
121      PROVIDED (IS.E.0), TRANSFER TO (BGC)-
122      DO THROUGH (GJB),I=0,1,I.L.IS-
123 GJB      YA(1)=AM02/(W(1)*W(1))-
124      CALL SUBROUTINE (CO,D1,D2,D3,D4,V,KJE)=RBRAN.(IS,SPH,STH,STV,NU,RA,YA)-
125      WRITE OUTPUT ,FXYZS,{D1,D2,D3}-
126 F FXYZS    (1H ,/,20X,Q*CARTESIAN COORDINATES OF SATELLITE{XS,YS,ZS IN METERS)*,/,10X,30F20.5)-
127      ASP=.HCP.A-
128      E2SP=.HOP.E2-
129      CALL SUBROUTINE (FF,XLAM,HP)=INVPR.(ASP,E2SP,D1,D2,D3)-
130      WRITE OUTPUT ,F12,(FF,XLAM,HP)-
131 F F12      (/Q*   GEOD. COORD. OF SATELLITE.   LAT.(DEG.)=*,F8.3,Q*   LONG.(DEG.)=*,F8.3,Q*   ELL.(IT.(MET.)=*,F1
              2.1/) -
132      WRITE OUTPUT ,FKJE,(KJE)-
133 F FKJE      (1H ,Q*   NUMBER OF ITERATIONS FOR SIMULTANEOUS EVENT ADJUSTMENT   = *,I10,/)   -
134 F FC5      (3DE25.16,I10)      -
135      NT=NT+1-
136      XVS=0.0-
137      DO THROUGH (CVU),I=0,1,I.L.IS-
138 CVU      XVS=XVS+V(I)*V(I)*YA(I)-
139      XV=XVS/(IS-3)-
140      WRITE OUTPUT ,FC55,(XV)-

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141 F FC55 (Q* VARIANCE OF UNIT WEIGHT (METERS SQUARED) =*,F10.3//)-
142 ISSS=ISSS+IS-3-
143 PROVIDED (XV.G.TV), TRANSFER (PAS)-
144 XSS=XSS+XVS-
145 TRANSFER (COF)-
146 PAS WRITE OUTPUT ,FC7-
147 F FC7 (Q* THIS SIMULTANEOUS EVENT WAS REJECTED, RESIDUALS - */12X,Q*NO. V(MET.)*)-
148 ISSS=ISSS-IS+3-
149 F F1234 (10X,I5,DF16.2) -
150 DO THROUGH (PAS11),I=0,1,I.L.IS-
151 PAS11 WRITE OUTPUT ,F1234,(NO(I),V(I))-
152 TRANSFER (GPAS)-
153 COF CONTINUE -
154 DO THROUGH (FC),K=0,1,K.L.IS-
155 L=9*K-3-
156 DO THROUGH (FC),I=0,1,I.L.3-
157 L=L+3-
158 DO THROUGH (FC),J=0,1,J.L.3-
159 PSV(L+J)=CO(K,I)*CO(K,J)*YA(K)-
160 FC Q(I,J)=Q(I,J)+PSV(L+J)-
161 CALL SUBROUTINE (ST2)=SYINVT.(0)-
162 DO THROUGH (ADD),IT=0,1,IT.L.IS-
163 N=9*IT-
164 DO THROUGH (IN),I=0,1,I.L.3-
165 DO THROUGH (IN),J=0,1,J.L.3-
166 K=N+J-
167 IN QIP(I,J)=-ST2(I,0)*PSV(K)-ST2(I,1)*PSV(K+3)-ST2(I,2)*PSV(K+6)-
168 PROVIDED (LO(NO(IT),0).E.1000), TRANSFER (BJI)-
169 ZIM DO THROUGH (STA),JT=0,1,JT.L.IT-

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170 M=-1-
171 SER M=M+1-
172 PROVIDED (M.E.IPR), TRANSFER TO (TOO)-
173 PROVIDED (LO(NO(JT),M).E.999), TRANSFER (TIN)-
174 PROVIDED (NO(IT).NE.LO(NO(JT),M)), TRANSFER (SER)-
175 IPR3=9*IPR-
176 N=IPR3*NO(JT)+9*M-3-
177 RLZ M=9*JT-3-
178 DO THROUGH (STA),I=0,1,I.L.3-
179 N=N+3-
180 M=M+3-
181 DO THROUGH (STA),J=0,1,J.L.3-
182 L=N+J-
183 STA EL(L)=EL(L)+PSV(M)*QIP(0,J)+PSV(M+1)*QIP(1,J)+PSV(M+2)*QIP(2,J)-
184 SEN QIP=QIP+1.0-
185 QIP(1,1)=QIP(1,1)+1.0-
186 QIP(2,2)=QIP(2,2)+1.0-
187 LM=3*NO(IT)-
188 N=9*IT-3-
189 DO THROUGH (ADD),I=0,1,I.L.3-
190 N=N+3-
191 M=LM+1-
192 K=3*M-
193 EV(M)=EV(M)-CO(IT,1)*V(IT)*YA(IT)-
194 DO THROUGH (ADD),J=0,1,J.L.3-
195 L=K+J-
196 ADD EK(L)=EK(L)+PSV(N)*QIP(0,J)+PSV(N+1)*QIP(1,J)+PSV(N+2)*QIP(2,J)-
197 GPAS PROVIDED (INS.E.99), TRANSFER (OUT)-
198 NO(0)=NO(1S)-

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199 RA=RA(IS)-
200 W=W(IS)-
201 IS=0-
202 DO THROUGH (DOAG),I=0,1,I.L.3-
203 U(I)=0.0-
204 DO THROUGH (DOAG),J=0,1,J.L.3-
205 DOAG Q(I,J)=0.0-
206 WRITE OUTPUT ,F11,(INT)-
207 WRITE OUTPUT ,FCJ-
208 TRANSFER TO (BGC)-
209 TIN LO(NO(JT),M)=NO(IT)-
210 PROVIDED (M.L.IPR-1),LO(NO(JT),M+1)=999-
211 N=IPR3*NO(JT)+9*M-3-
212 M=N+10-
213 DO THROUGH (INT),I=N+3,3,I.L.M-
214 DO THROUGH (INT),J=0,1,J.L.3-
215 INT EL(I+J)=0.0-
216 TRANSFER TO (RLZ)-
217 BJI DO THROUGH (INV),I=0,1,I.L.3-
218 LM=NO(IT)*3-
219 L=LM+1-
220 EV(L)=0.0-
221 K=3*L-
222 DO THROUGH (INV),J=0,1,J.L.3-
223 INV EK(K+J)=0.0-
224 LO(NO(IT),0)=999-
225 TRANSFER TO (ZIM)-
226 TGO WRITE OUTPUT ,FT,(NO(IT))-
227 F FT (Q* ADDITIONAL STORAGE FOR OFF DIAGONAL COEFFICIENTS FOR STATION NO. *,15,Q* IS NEEDED*) -

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257 PUNCH CARDS ,FC3,((EVIN+J),J=0,1,J.L.3))-
258 WRITE OUTPUT ,F07,((EVIN+J),J=0,1,J.L.3))-
259 F F07 (/3(F16.10,5X)) -
260 DO THROUGH (OKV),J=0,1,J.L.3-
261 M=M+3-
262 WRITE OUTPUT ,F08,((EK(M+L),L=0,1,L.L.3))-
263 F F08 (3F16.10) -
264 OKV PUNCH CARDS ,FC2,((EK(M+L),L=0,1,L.L.3))-
265 LM=IPR3*K-9-
266 J=0-
267 ONP N=LO(K,J)-
268 PUNCH CARDS ,FC1,(N)-
269 WRITE OUTPUT ,F06,(N)-
270 PROVIDED (N.E.999), TRANSFER (POU)-
271 LM=LM+9-
272 DO THROUGH (OK),N=0,3,N.L.9-
273 M=LM+N-
274 WRITE OUTPUT ,F08,((EL(M+L),L=0,1,L.L.3))-
275 OK PUNCH CARDS ,FC2,((EL(M+L),L=0,1,L.L.3))-
276 J=J+1-
277 PROVIDED (J.L.IPR), TRANSFER (ONP)-
278 PCU CONTINUE -
279 FINC CALL SUBROUTINE ( )=ENDJOB.( )-
280 SUBROUTINE (G)=TRANSP.(N)-
281 PRECISION (2,G,P)-
282 DIMENSION (G(0,N))-
283 I=0-
284 CONJ J=I+1-
285 JC P=G(I,J)-

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286      G(I,J)=G(J,I)-
287      G(J,I)=P-
288      J=J+1-
289      PROVIDED (J.L.N), TRANSFER TO (JC)-
290      I=I+1-
291      PROVIDED (I.L.N-1), TRANSFER TO (CONJ)-
292      NORMAL EXIT -
293      END SUBPROGRAM -
294      SUBROUTINE (A)=SYINVT.(B)-
295      DIMENSION (A(O,KDM),B(O,KDM),S(10))-
296      LITERALS (KDM,3)-
297      DO THROUGH (CH),I=0,1,I.L.3-
298      K=2*I-
299      DO THROUGH (CH),J=I,1,J.L.3-
300      CH
301      S(K+J)=B(I,J)-
302      S(5)=S(1)*S(1)-
303      S(7)=S(2)*S(2)-
304      S(8)=S(4)*S(4)-
305      S(9)=S*(3)*S(6)+2.*S(1)*S(2)*S(4)-S(3)*S(7)-S*(8)-S(6)*S(5)-
306      A=(S(3)*S(6)-S(8))/S(9)-
307      A(0,1)=(S(2)*S(4)-S(1)*S(6))/S(9)-
308      A(0,2)=(S(1)*S(4)-S(2)*S(3))/S(9)-
309      A(1,1)=(S*(6)-S(7))/S(9)-
310      A(1,2)=(S(1)*S(2)-S*(4))/S(9)-
311      A(2,2)=(S*(3)-S(5))/S(9)-
312      A(1,0)=A(0,1)-
313      A(2,0)=A(0,2)-
314      A(2,1)=A(1,2)-
315      NORMAL EXIT -

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315  END SUBPROGRAM -
316  FUNCTION (G)=ANRAD.(I,M,N,C)-
317  PRECISION (2,G,C,RHO,D)-
318  LITERALS (RHO,57.29577951308232)-
319  D=60.-
320  G=(M+N/D+C/(D*D))/RHO-
321  PROVIDED (I,LQ,$- $),G=-G-
322  NORMAL EXIT -
323  END SUBPROGRAM -
324  SUBROUTINE (X,Y,Z)=GEOCAR.(C,G,H)-
325  UNIVERSAL (A,E2)-
326  PRECISION (2,X,Y,Z,C,G,H,P,DSIN.,DCOS.,BI)-
327  BI=DSIN.(C)-
328  P=A/(1.-E2*BI.P.2).P..5-
329  X=(P+H)*DCOS.(C)-
330  Y=X*DSIN.(G)-
331  X=X*DCOS.(G)-
332  Z=(P*(1.-E2)+H)*BI-
333  NORMAL EXIT -
334  END SUBPROGRAM -
335  SUBROUTINE (ACOE,XS,YS,ZS,FL,V,K)=RBRAN.(NS,FLAT,FLON,STAXYZ,NU,RO,YA)-
336  DIMENSION (FL(10))-
337  PRECISION (2,STAXYZ,RO)-
338  DIMENSION (FN(9,L),C(9,L),ACOE(0,L),STAXYZ(0,L),U(3),D(3),ST(10),ACOE(30,L))-
339  PRECISION (2,R,XS,YS,ZS,DSQRT.,DX,DY,DZ,GEOCAR.,FLATM,FLONM,HS)-
340  L=3-
341  CALL SUBROUTINE (XS,YS,ZS)=WTRI.(STAXYZ(NO(0),0),STAXYZ(NO(1),0),STAXYZ(NO(2),0),STAXYZ(NO(0),1),STA
      XYZ(NO(1),1),STAXYZ(NO(2),1),STAXYZ(NO(0),2),STAXYZ(NO(1),2),STAXYZ(NO(2),2),RU(0),RO(1),RO(2))-
342  K=0-
343  DO THROUGH (ZER1),I=0,1,I.L.3-

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344 DO THROUGH (ZER1),J=0,1,J.L.3-
345 U(I)=0.-
346 C(I,J)=0.-
347 DO THROUGH (NORMAL),I=0,1,I.L.NS-
348 DX=XS-STAXYZ(NO(I),0)-
349 DY=YS-STAXYZ(NO(I),1)-
350 DZ=ZS-STAXYZ(NO(I),2)-
351 R=DSQRT.(DX.P.2+DY.P.2+DZ.P.2)-
352 FL(I)=R-RO(I)-
353 AC0EE(I,0)=DX/R-
354 AC0EE(I,1)=DY/R-
355 AC0EE(I,2)=DZ/R-
356 AC0EF(I,0)=AC0EE(I,0)*YA(I)-
357 AC0EF(I,1)=AC0EE(I,1)*YA(I)-
358 AC0EF(I,2)=AC0EE(I,2)*YA(I)-
359 C=C+AC0EF(I,0)*AC0EE(I,0)-
360 C(I,1)=C(I,1)+AC0EF(I,1)*AC0EE(I,1)-
361 C(2,2)=C(2,2)+AC0EF(I,2)*AC0EE(I,2)-
362 C(0,1)=C(0,1)+AC0EF(I,0)*AC0EE(I,1)-
363 C(1,2)=C(1,2)+AC0EF(I,1)*AC0EE(I,2)-
364 C(0,2)=C(0,2)+AC0EF(I,0)*AC0EE(I,2)-
365 U(0)=U(0)+AC0EF(I,0)*FL(I)-
366 U(1)=U(1)+AC0EF(I,1)*FL(I)-
367 NGRMAL U(2)=U(2)+AC0EF(I,2)*FL(I)-
368 CALL SUBROUTINE (FN)=SYINVT.(C)-
369 D(0)=0.-
370 D(1)=0.-
371 D(2)=0.0-
372 DO THROUGH (XVECT),I=0,1,I.L.3-

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373      DO THROUGH (XVECT),J=0,1,J.L.3-
374      D(I)=D(I)-FN(I,J)*U(J)-
375      XS=XS+D(I)-
376      YS=YS+D(I)-
377      ZS=ZS+D(I)-
378      DO THROUGH (ZERO),I=0,1,I.L.3-
379      DO THROUGH (ZERO),J=0,1,J.L.3-
380      U(I)=0.-
381      C(I,J)=0.-
382      K=K+1-
383      CHECKING TO SEE IF TOO MANY ITERATIONS ARE BEING PERFORMED-
384      PROVIDED (K.G.10), TRANSFER TO (LOOP)-
385      TRANSFER TO (RCOMP) PROVIDED (.ABS.D.G.0.01.OR..ABS.D(1).G.0.01.OR..ABS.D(2).G.0.01)-
386      DO THROUGH (VCOMP),I=0,1,I.L.NS-
387      V(I)=FL(I)+ACOE(I,0)*D(0)+ACOE(I,1)*D(1)+ACOE(I,2)*D(2)-
388      NORMAL EXIT -
389      WRITE OUTPUT ,FLUOP-
390      F FLUOP      (IH ,Q*THE PROGRAM IS IN A LOOP IN SUBROUTINE RBRAN.-CHECK DATA FOR SIMULTANEOUS EVENT -AND FURTHER CU
                     PUTATIONS MADE*) -
391      TRANSFER TO (TIXE)-
392      NORMAL EXIT -
393      END SUBPROGRAM -
394      SUBROUTINE (FF,XLAM,H)=INVPR.(A,EE,X,Y,Z)-
395      RQ=57.29578-
396      PI=3.1415927-
397      TLAM=Y/X-
398      XLAM=ATAN.(TLAM)-
399      PROVIDED (Y.GE.0.), TRANSFER (L10)-
400      PROVIDED (X.GE.0.),XLAM=XLAM+2.*PI-
401      PROVIDED (X.L.0.),XLAM=XLAM+PI-

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402 TRANSFER (L20)-
403 L10 PROVIDED (X.GE.O.),XLAM=XLAM-
404 PROVIDED (X.L.O.),XLAM=XLAM+PI-
405 L20 XLAM=XLAM*RO-
406 TERM3=SQRT.(X*X+Y*Y)-
407 TERM1=Z/TERM3-
408 TERM2=TERM1/(1-EE)-
409 FF=ATAN.(TERM2)-
410 SFI=SIN.(FF)-
411 XN=A/SQRT.(1.-EE*SFI*SFI)-
412 TFI=TERM1*(1.+EE*XN*SFI/Z)-
413 FI1=ATAN.(TFI)-
414 FI1D=FI1*RO-
415 SFI=SIN.(FI1)-
416 H=Z/SFI-XN*(1.-EE)-
417 FF=FI1D-
418 NORMAL EXIT -
419 END SUBPROGRAM -
420 SUBROUTINE (XS1,YS1,ZS1)=WTRI.(X1,X2,X3,Y1,Y2,Y3,Z1,Z2,Z3,R1,R2,R3)-
421 PRECISION (2,XS1,XS2,YS1,YS2,ZS1,ZS2,GR1,GR2,X1,X2,X3,Y1,Y2,Y3,Z1,Z2,Z3,R1,R2,R3,B1,B2,B3,R,A1,A2,C1
,C2,D,E,F,G,FI1,FI2,FI3,QUADA,QUADB,QUADC,QUADD,QUADD2,TEMP1,TEMP2,TEMP3,TEMP4,DSQRT.)-
422 TI1=X1*X1+Y1*Y1+Z1*Z1-(R1*R1)-
423 TI2=X2*X2+Y2*Y2+Z2*Z2-(R2*R2)-
424 TI3=X3*X3+Y3*Y3+Z3*Z3-(R3*R3)-
425 B1=TI1-TI2-
426 B2=TI2-TI3-
427 B3=TI3-TI1-
428 A1=-{(Y3*B1+Y1*B2+Y2*B3)-
429 A2=X1*B2+X2*B3+X3*B1-
430 C1=2.*{(Y1*(Z2-Z3)+Y2*(Z3-Z1)+Y3*(Z1-Z2))-

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431 C2=2.*(X1*(Z3-Z2)+X2*(Z1-Z3)+X3*(Z2-Z1))-
432 B=2.*(X1*(Y2-Y3)+X2*(Y3-Y1)+X3*(Y1-Y2))-
433 D=A1/B-
434 E=C1/B-
435 F=A2/B-
436 G=C2/B-
437 QUADA=E+E+G+1.-
438 QUADB=2.*(E*(D-X1)+G*(F-Y1)-Z1)-
439 QUADC=D*(D-2.*X1)+F*(F-2.*Y1)+T11-
440 QUADD2=QUADB*QUADB-4.*QUADA*QUADC-
441 QUADD=DSQRT.(QUADD2)-
442 ZS1=(-QUADB+QUADD)/(2.*QUADA)-
443 ZS2=(-QUADB-QUADD)/(2.*QUADA)-
444 XS1=D+E*ZS1-
445 XS2=D+E*ZS2-
446 YS2=F+G*ZS2-
447 YS1=F+G*ZS1-
448 GR1=(XS1*XS1+YS1*YS1+ZS1*ZS1)*P.(0.5)-
449 GR2=(XS2*XS2+YS2*YS2+ZS2*ZS2)*P.(0.5)-
450 PROVIDED (GR1.GE.GR2), TRANSFER TO (OVER1)-
451 TEMP1=XS1-
452 TEMP2=YS1-
453 TEMP3=ZS1-
454 TEMP4=GR1-
455 XS1=XS2-
456 YS1=YS2-
457 ZS1=ZS2-
458 GR1=GR2-
459 XS2=TEMP1-

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460	YS2=TEMP2-					
461	ZS2=TEMP3-					
462	GR2=TEMP4-					
463	OVER1	NORMAL EXIT -				
464		END SUBPROGRAM -				
465		END PROGRAM (GU)-				

2.5 Input to Range Program

	Columns
Card Set 1: (10L6) Comment card	2 - 30
Card Set 2: (2 DF 25.16, DF 10.4) (1) Semi-major axis of reference ellipsoid (2) Semi-minor axis of reference ellipsoid (3) Apriori variance of unit weight	1 - 25 26 - 50 51 - 60
Card Set 3: (14I5) Total number of ground stations (maximum 100)	1 - 5
Card Set 4: (3F10.6) Test parameter on the variance of unit weight arising from each preliminary simultaneous event adjustment	1 - 10
Card Set 5: (1X, I3, 20X, L1, 2(2I3, DF8.4), DF12.4) (1) Station number (2) Sign of latitude (3) Degrees of latitude. (4) Minutes of latitude. (5) Seconds of latitude. (6) Degrees of longitude (+ East). (7) Minutes of longitude (8) Seconds of longitude. (9) Ellipsoidal height.	2 - 4 25 26 - 28 29 - 31 32 - 39 40 - 42 43 - 45 46 - 53 54 - 65
Card Set 6: (14I5) Total number of stations whose coordinates are to be shifted.	1 - 5
Card Set 7: (14I5) Station numbers of stations to be shifted. 1 - 5, 6 - 10, . . . , 66 - 70 (continue on new card if necessary)	

Card Set 8: (3 F10.6)

- Card 1. Three shift values in meters to be applied to the three respective Cartesian coordinates u, v, w, of the first station. 1 - 10, 11 - 20, 21 - 30
- Card 2. Repeat the above for second station.
(Continue for all stations to be shifted)

Card Set 9: (I3, 2X, I2, I3, DF9.5, I2, L3, I2, DF15.5, 14X, F5.2)

- | | |
|--|---------|
| (1) Ground station number | 1 - 3 |
| (2) Hours of UTI epoch of observation. | 6 - 7 |
| (3) Minutes of UTI epoch of observation. | 8 - 10 |
| (4) Seconds of UTI epoch of observation | 11 - 19 |
| (5) Day of month. | 20 - 21 |
| (6) Month. | 22 - 24 |

Note: January = JAN July = JUL
February = FEB August = AUG
March = MAR September = SEP
April = APR October = OCT
May = MAY November = NOV
June = JUN December = DEC

- | | |
|---|---------|
| (7) Last two digits of year since 1900. | 25 - 26 |
| (8) Topocentric range. | 42 - 55 |
| (9) Standard deviation of range. | 56 - 60 |

(Repeat (1) - (9) on a new card for each station in the event; minimum of three stations per event.)
(No limit on the number of events.)

Card Set 10:

Control card containing 99 designating end of events	9 - 10
--	--------

SECTION III. ADDITION OF NORMAL EQUATIONS

3.1 Introduction

The addition of n sets of normal equations is represented by [Krakiwsky and Pope, 1967, Eq. 4 - 3],

$$(N_1 + P_{12}N_2 + \cdots + P_{1n}N_n)X + (U_1 + P_{12}U_2 + \cdots + P_{1n}U_n) = 0 ,$$

where N_1 to N_n are the coefficient matrices, U_1 to U_n are the constant vectors, and P_{12} to P_{1n} are the weights relative to the first set of normal equations. Weights are also applied to the quadratic form of the weighted residuals.

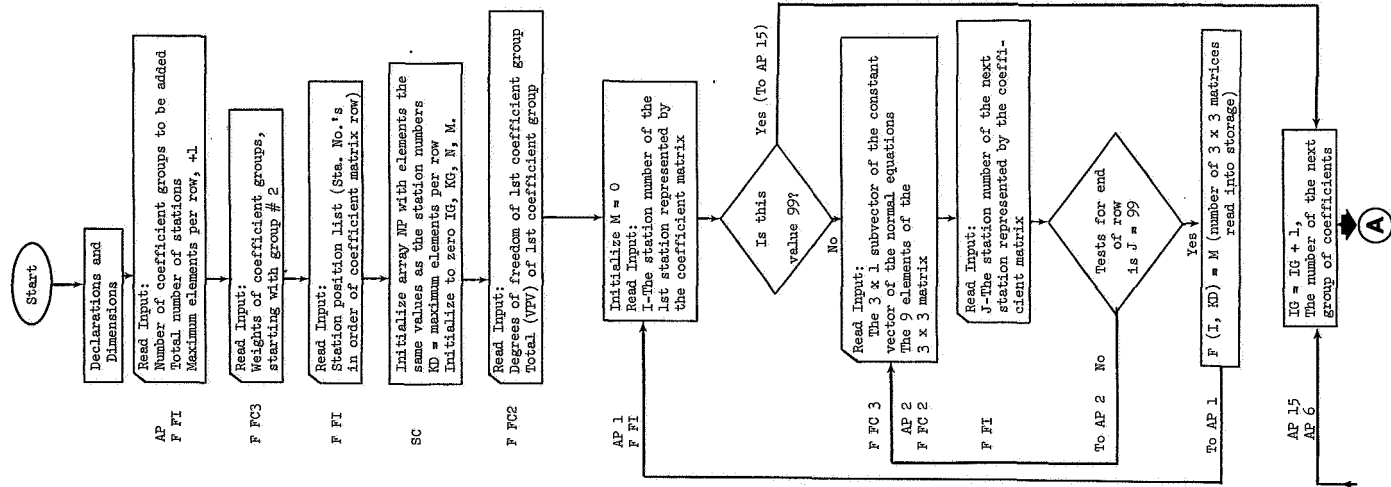
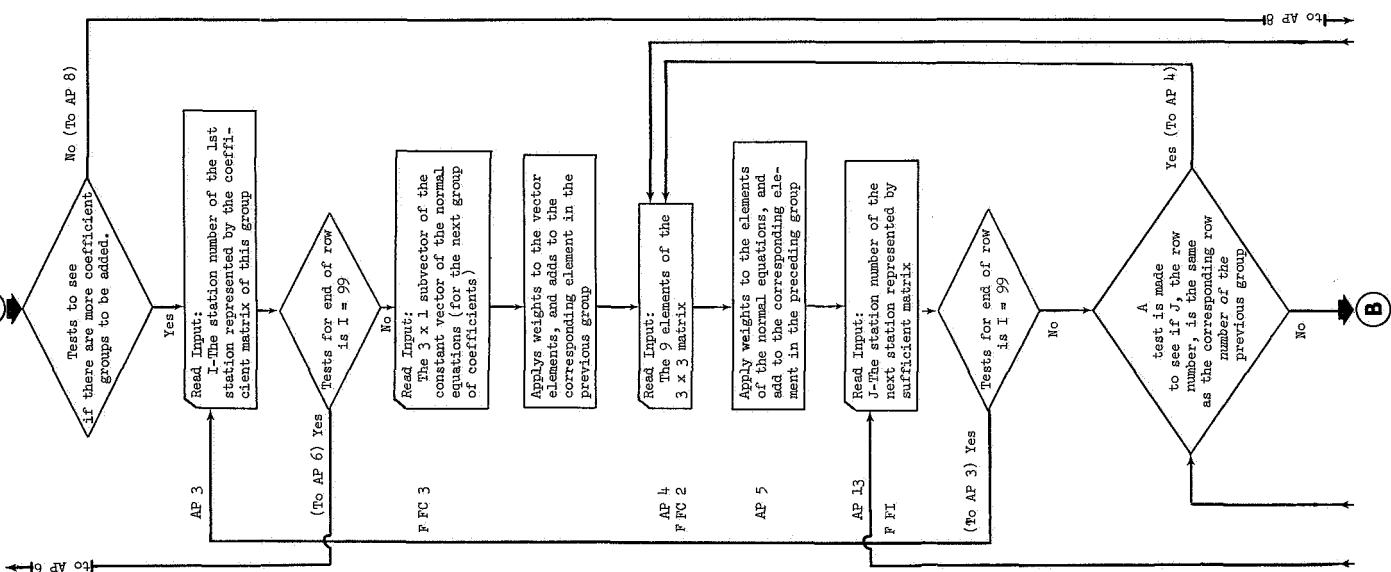
The above equation is the core of the computer program.

3.2 Specific Flow Chart

```

graph TD
    Start(( )) --> AP9[AP 9]
    AP9 --> Decision1{Since  
the row number  
are not the same, is  
this value of J less than  
the next row number  
of the previous  
group}
    Decision1 -- Yes --> AP10[Increase the row number  
of the previous group  
by a factor of 1]
    AP10 --> Decision1
    Decision1 -- No --> Decision2{The  
row number  
is greater than the  
next row # in the  
preceding group.  
A test is made on the storage  
number F(I,KD) to see  
if too many elements  
are in storage}
    Decision2 -- Yes --> AP11[AP 11  
AP 12  
AP 17]
    AP11 --> AP17[AP 17]
    Decision2 -- No --> AP12[Make modifications to  
storage numbers  
  
(To AP 4)]
    AP12 --> AP4[AP 4]
    AP4 --> AP10
    AP10 --> AP13[Prints Error Message:  
The compacted column dimension  
has been exceeded on Row 2  
I , by column J , of  
additions group IG]
    AP13 --> AP16[Read Input:  
The 9 elements of the  
next 3 x 3 matrix]
    AP16 --> AP13
    AP16 --> AP8[AP 8  
F F FC9, FCZ  
Low  
F F FC2, FC9  
F F FC2, FC2  
AP 15  
F F FC6, F07  
F F FI, F06]
    AP8 --> Output[Prints & Punches Output Data  
Guide Matrix  
Σ VVW  
Degrees of Freedom  
Normal Equations in the format  
acceptable for the solution program]
    Output --> End([END])

```



3.3 STATEMENT LISTING

```

        DIMENSION (E(5500),AD(10),NO(100),NOSU(100),L(700,10),F(70
0,10),EK(300),NP(100))-
        INTEGERS (F)-
        DIMENSION (W(10))-
F FI      (1415)-
F FC2     (3E16.8) -
F FC3     (3(E16.8,5X)) -
AP        READ INPUT ,FI,(NG,NST,ID)-
C          NG - THE NUMBER OF COEFFICIENT GROUPS TO BE ADDED. -
C          NST - TOTAL NUMBER OF STATIONS. -
C          ID - MAXIMUM ELEMENTS PER ROW. +1 -
        READ INPUT ,FC3,((W(I),I=1,1,I.L.NG))-
C          W(I) - WEIGHTS OF COEFFICIENT GROUPS, STARTING WITH GROUP NO. 2 -
        READ INPUT ,FI,((NO(I),I=0,1,I.L.NST))-
C          NO(I) - STATION POSITION LIST (STA. NO'S IN ORDER OF COEFFICIENT -
C          MATRIX ROW. -
        DO THROUGH (SC),I=0,1,I.L.NST-
C          SETTING UP THE ARRAY NP WITH SUBSCRIPTS (NO(I)) -
C          BEING THE STATION NUMBERS. -
SC        NP(NO(I))=I-
        NP(99) = 99 -
        KD=ID-1-
C          KD = MAXIMUM ELEMENTS PER ROW. -
        IG=0-
        KG=0-
        N=0-
        READ INPUT,FC2,(ALI,EQU,VPV) -
AP1        M=0-
C          READ THE FIRST CARD OF THE FIRST GROUP OF NORMAL EQUATIONS. -
        READ INPUT ,FI,(I,MOSU)-
        TRANSFER TO (APG,AP15,AP15) PROVIDED (I-99 )-
APG        L(I,0)=I-
        LM=3*I-
C          READ IN THE VECTOR. -
        READ INPUT ,FC3,(EK(LM),EK(LM+1),EK(LM+2))-
C          READ THE NINE (9) ELEMENTS ( THE FIRST 3X3 SUBMATRIX ) -
AP2        READ INPUT ,FC2,((E(N+K),K=0,1,K.L.9))-
        F(I,M)=N-
        M=M+1-
        N=N+9-
        READ INPUT ,FI,(J)-
C          THE L ARRAY CONTAINS STA. NUMBERS , NOT RANK NUMBERS. -
        L(I,M)=J-
C          TEST FOR END OF ROW. -
        PROVIDED (J.NE.99 ), TRANSFER (AP2)-
        F(I,KD)=M-
C          M - THE NUMBER OF 3X3 MATRICES IN A PARTICULAR ROW. -
        NOSU(KG)=MOSU-
        TRANSFER (AP1)-
C          THE SECOND 999 CARD ( AFTER THE NORMAL EQUATIONS . CAUSES THE -
C          TRANSFER TO AP15. -
AP15       CONTINUE -
AP6        IG=IG+1-
        PROVIDED (IG.E.NG), TRANSFER (AP8)-
        READ INPUT,FC2,(ALI2,EQU2,VPV2) -
        EQU = EQU + EQU2 -
        VPV = VPV + W(IG) * VPV2 -
C          READ THE FIRST CARD OF THE NEXT GROUP OF NORMAL EQUATIONS. -
AP3        READ INPUT ,FI,(I)-
        TRANSFER TO (APH,AP6,AP6) PROVIDED (I-99 )-
APH        LM=3*I-
        M=0-
C          READ IN THE VECTOR. -
        READ INPUT ,FC3,(AD,AD(1),AD(2))-

```

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C      APPLY WEIGHTS TO THE VECTOR ELEMENTS, AND ADD TO THE CORRESPONDING-
C      ELEMENT IN THE PRECEDING GROUP. -
      EK(LM)=EK(LM)+W(IG)*AD-                                0040
      EK(LM+1)=EK(LM+1)+W(IG)*AD(1)-                          0041
      EK(LM+2)=EK(LM+2)+W(IG)*AD(2)-                          0042
C      READ THE NINE (9) ELEMENTS. -
AP4      READ INPUT ,FC2,((AD(K),K=0,1,K.L.9))-              0043
      LM=F(I,M)-                                              0044
      DO THROUGH (AP5),K=0,1,K.L.9-                          0045
C      APPLY WEIGHTS TO THE ELEMENTS OF THE NORMAL EQUATIONS, AND ADD -
C      TO THE CORRESPONDING ELEMENTS IN THE PRECEDING GROUP. -
AP5      E(LM+K)=E(LM+K)+W(IG)*AD(K)-                        0046
C      READ THE FIRST CARD OF THE NEXT ROW. -
AP13     READ INPUT ,FI,(J)-                                  0047
      PROVIDED (J.E.99 ), TRANSFER (AP3)-
AP9      M=M+1-                                              0049
      TRANSFER TO (AP7,AP4,AP9) PROVIDED (NP(J)-NP(L(I,M)))- 0050
C      NP(J) AND NP(L(I,M)) MUST BE THE SAME NUMBER BEFORE THE ELEMENTS -
C      OF THE NORMALS CAN BE READ. -
C      IF NP(J) IS GREATER THAN NP(L(I,M)), TRANSFER TO AP9, WHICH -
C      INCREASES M BY +1 AND THEN TESTS THE VALUE AGAIN. -
C      IF NP(J) IS LESS THAN NP(L(I,M)), THIS MEANS THAT A NEW STATION -
C      AND THE NEW DATA PUT IN THE PROPER LOCATION. -
AP7      PROVIDED (F(I,KD).G.KD-1), TRANSFER (AP10)-         0051
C      (KD-1) IS THE MAXIMUM NUMBER OF 3X3 MATRICES, LESS 1. -
      F(I,KD)=F(I,KD)+1-                                     0052
      L(I,KD)=L(I,KD-1)-                                     0053
      K=KD-1-                                                0054
      TRANSFER (AP11)-                                       0055
AP12     LM=K-1-                                             0056
      L(I,K)=L(I,LM)-                                       0057
      F(I,K)=F(I,LM)-                                       0058
      K=K-1-                                                0059
AP11     PROVIDED (K.G.M), TRANSFER (AP12)-                 0060
      L(I,M)=J-                                             0061
      F(I,M)=N-                                             0062
      DO THROUGH (AP17),LM=0,1,LM.L.9-                     0063
AP17     E(N+LM)=0.0-                                       0064
      N=N+9-                                                0065
      TRANSFER (AP4)-                                       0066
AP10     WRITE OUTPUT ,FE,(I,J,IG)-                          0067
F FE     (Q* THE COMPACTED COLUMN DIMENSION HAS BEEN EXCEEDED ON RO 0068
      W *,I5,Q*, BY COLUMN *,I5,Q*, OF ADDITION GROUP *,I5) - 0069
      READ INPUT ,FC2,((AD(K),K=0,1,K.L.9))-              0070
      M=M-1-                                                0071
      TRANSFER (AP13)-                                       0072
AP8      CONTINUE -
      WRITE OUTPUT ,F69-                                     0365
F F69    (IH1,///Q* GUIDE MATRIX - GROUND STATIONS INVOLVED 0366
      IN SIMULTANEOUS SIGHTINGS.*/) -                      0367
      DO THROUGH (LOW),I=0,1,I.L.NST -
      WRITE OUTPUT,FCZ,((L(NO(I),K),K=0,1,K.L.ID)) -
F FCZ    (20X,I5,5X,8I5) -                                  0370
      PUNCH CARDS,FC2,(ALI,EQU,VPV) -
      WRITE OUTPUT,FC9,(VPV) -
F FC9    (//Q* TOTAL SUMMATION OF PVV - GROUND STATIONS HELD 0372
      FIXED (I.E. PLL ) (SEC. OF ARC SQUARED) =*,F11.3/) - 0373
      WRITE OUTPUT,F02,(EQU) -
F F02    (Q* CORRESPONDING TOTAL NO. OF DEGREES OF FREEDOM = 0375
      *, F10.5/) -
      WRITE OUTPUT ,F05-                                     0388
F F05    (IH1,///Q* NORMAL EQUATIONS (SEE GUID 0389
      E MATRIX)*/)-                                         0390
      DO THROUGH (AP14),I=0,1,I.L.NST-                     0073

```

	K=3*NO(I)-	0074
	M=0-	0075
	KG=F(NO(I),KD)-	0076
	PUNCH CARDS ,FI,(NO(I),NOSU(I))-	0077
	WRITE OUTPUT,F06,(NO(I)) -	
F F06	(//15)-	0394
	PUNCH CARDS ,FC3,(EK(K),EK(K+1),EK(K+2))-	0078
	WRITE OUTPUT,F07,(EK(K),EK(K+1),EK(K+2)) -	
F F07	(/3(F16,10,5X)) -	0400
AP16	LM=F(NO(I),M)-	0079
	PUNCH CARDS ,FC2,((E(LM+K),K=0,1,K,L,9))-	0080
	WRITE OUTPUT,F08,((E(LM+K),K=0,1,K,L,9)) -	
F F08	(3F16,10) -	0404
	N=M+1-	0081
	PUNCH CARDS ,FI,(L(NO(I),M))-	0082
	WRITE OUTPUT,F06,(L(NO(I),M)) -	
	PROVIDED (M,NE,KG), TRANSFER (AP16)-	0083
	CONTINUE -	
AP14	CALL SUBROUTINE ()=ENDJOB.()-	0085
	END PROGRAM (AP)-	0086

3.4 Input to Addition Program

Columns:

Card Set 1: (14I5)	
(1) Number of coefficients groups	1-5
(2) Total number of ground stations	6-10
(3) Maximum number of elements per row + 1	11-15
Card Set 2: (3(E 16.8, 5X))	
Weights of coefficient groups, starting with group # 2	
(1) Weight of group # 2	1-16
Weight of group # 3	17-32
Weight of group # 4	33-48
(2) Weight of group # 5	1-16
etc.	
Card Set 3: (14I5)	
Station Position List	
Station numbers in order of location of coefficient matrix rows	
(1) First station	1-5
Second station	6-10
etc.	
Card Set 4: (3E16.8)	
(1) Degrees of freedom of coefficient group	17-32
Σ VPV for coefficient group	33-48
Card Set 5:	
(1) Card (1) Row number (station number) of normal equations (14I5)	1-5
(2) Card (2) U_k Vector (3(E16.8, 5X)	1-16
1-16, 22-37, 43-58	22-37
	43-58
(3) Cards (3)-(5) N_{kk} Matrix (3E 16.8)	1-16
	17-32
	33-48
(4) Card (6) Station Number (14I5)	1-5
(5) Cards (7)-(9) N_{kl} Matrix (3E 16.8)	1-16
	17-32
	33-48
(repeated for up to 7 N_{kl} 's)	
(6) Last card in row contains 999 (14I5)	1-5
((1)-(6) repeated for the required number of stations)	
(7) Last card after all rows contains 999 (14I5)	1-5

Card Set 6:

Repeat of card sets 4 and 5, for each group of coefficients, but not to exceed the total number of groups, specified on card #1, Card Set 1.

SECTION IV. SOLUTION OF NORMAL EQUATION

4.1 Introduction

The reduction of N and U is carried out as follows (all quantities are either 3 x 3 matrices or 3 x 1 vectors) [Krakiwsky and Pope, 1967, Eq. 5 - 9 and 5 - 10]:

$$\begin{aligned} \bar{n}_{ij} &= \bar{n}_{ij} - \bar{n}'_{ki} \bar{n}_{kk}^{-1} \bar{n}_{kj} & k &= 1, 2, \dots, n \\ \bar{u}_i &= \bar{u}_i - \bar{n}'_{ki} \bar{n}_{kk}^{-1} \bar{u}_k & i &= k+1, k+2, \dots, n \\ & & j &= i, i=1, \dots, n \end{aligned}$$

and further

$$\begin{aligned} \bar{n}_{ii} &= I & j &= i, \\ \bar{n}_{ij} &= \bar{n}_{ij} \bar{n}_{ij}^{-1}, & j &= i+1, i+2, \dots, n, \\ \bar{u}_i &= \bar{n}_{ii}^{-1} \bar{u}_i, & i &= 1, 2, \dots, n. \end{aligned}$$

The back solution for Xg is [Eq. 5 - 12].

$$X_i = \sum_{k=i+1}^n \bar{n}_{ik} X_k + \bar{u}_i.$$

The formation of N^{-1} is [Eq. 5 - 24]

$$n^{ij} = \sum_{k=i+1}^n \bar{n}_{ik} n^{kj} + \delta_{ij} \bar{n}_{ii}^{-1},$$

where

$$\delta_{ij} = 0 \quad \text{for } i \neq j,$$

$$\delta_{ij} = 1 \quad \text{for } i = j,$$

and

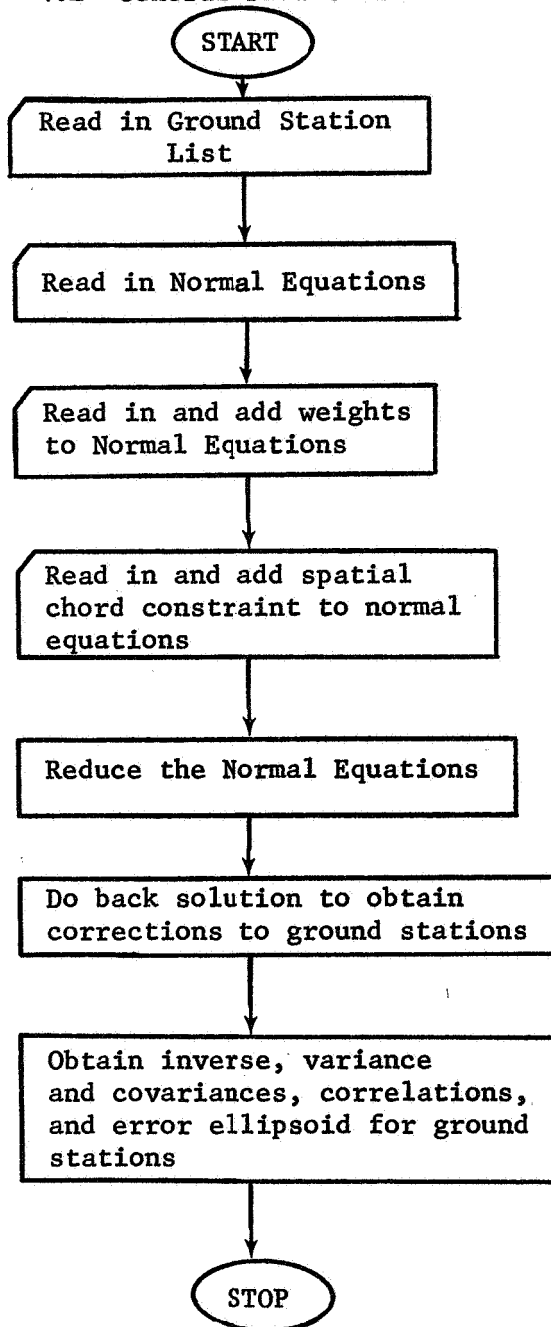
$$n^{ij} = (n^{ji})'.$$

The reduction, back solution, and the formation of the inverse is the core of this computer program.

The capacity of the computer program is determined by the total number of stations. The maximum number of ground stations is also about 100.

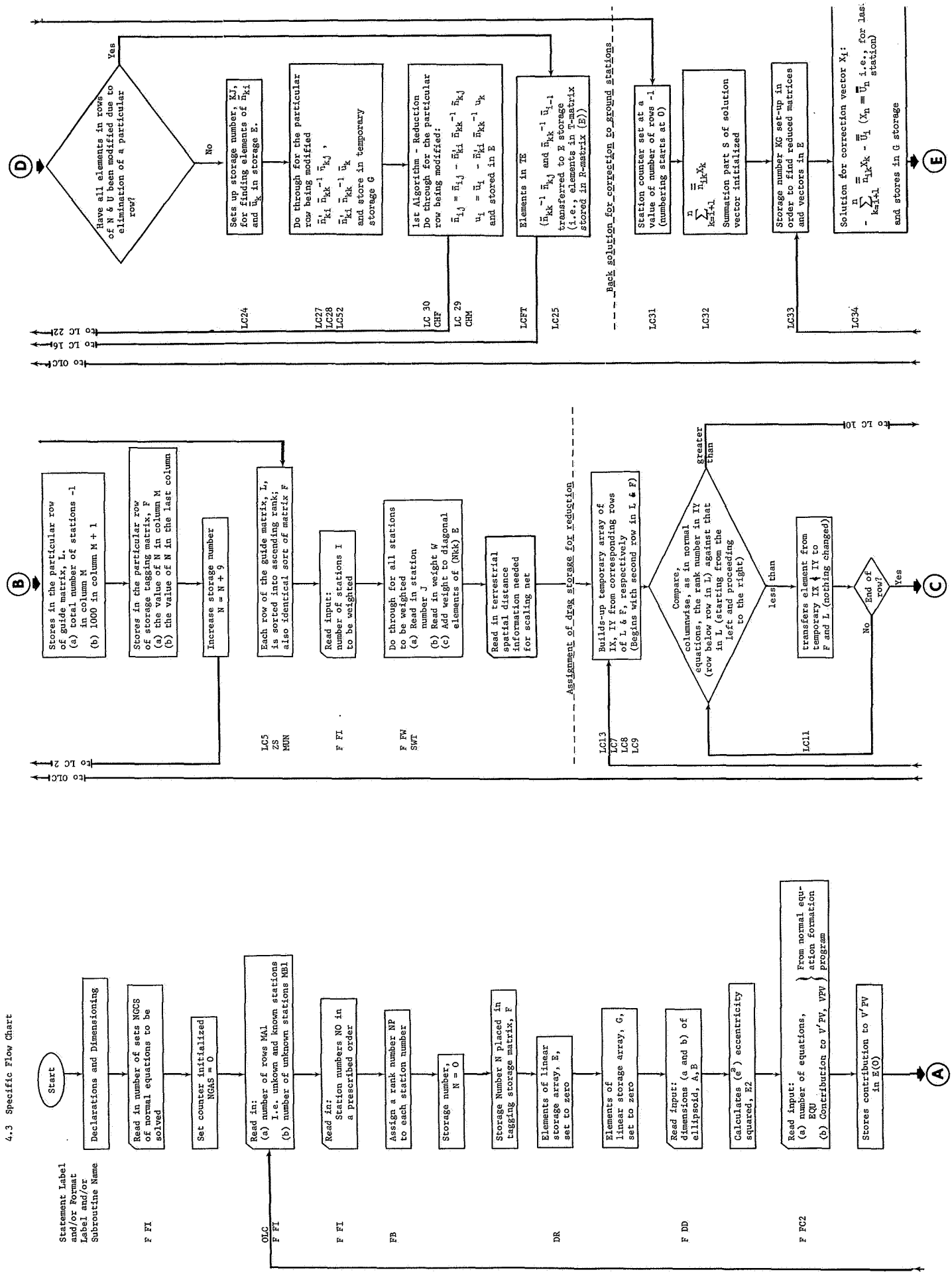
In a study consisting of 40 ground stations (120 unknowns) execution time on the IBM 7094 was 1.8 minutes; this included the determination of all correlation coefficients.

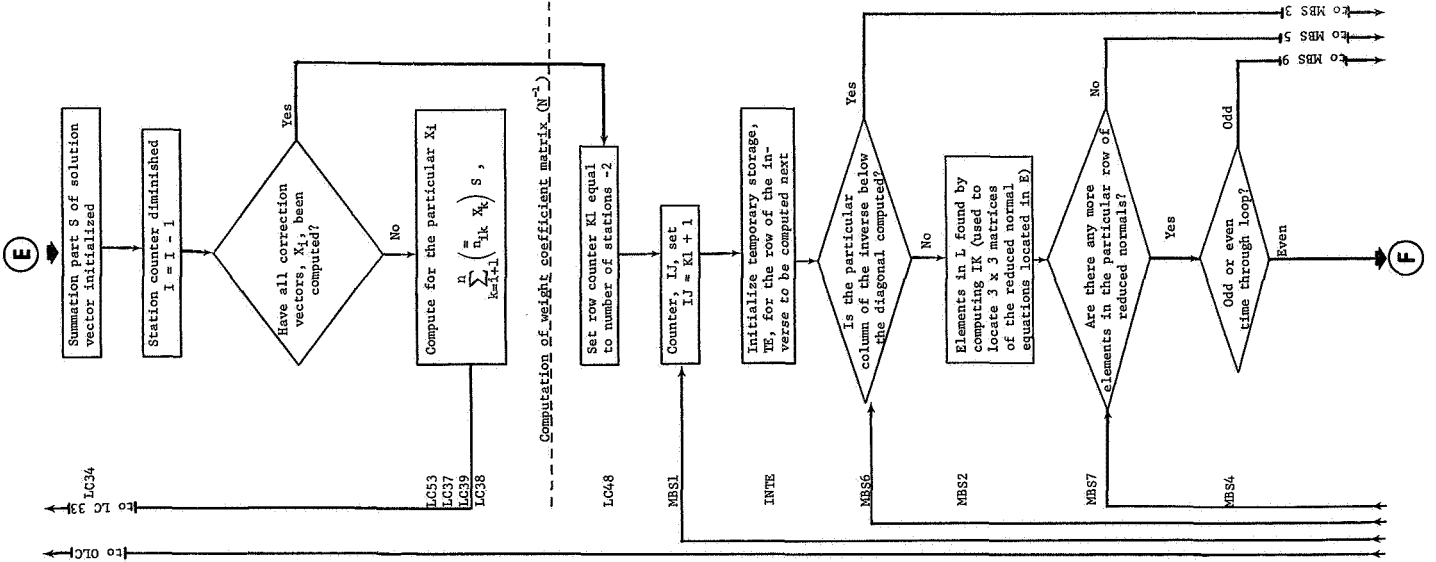
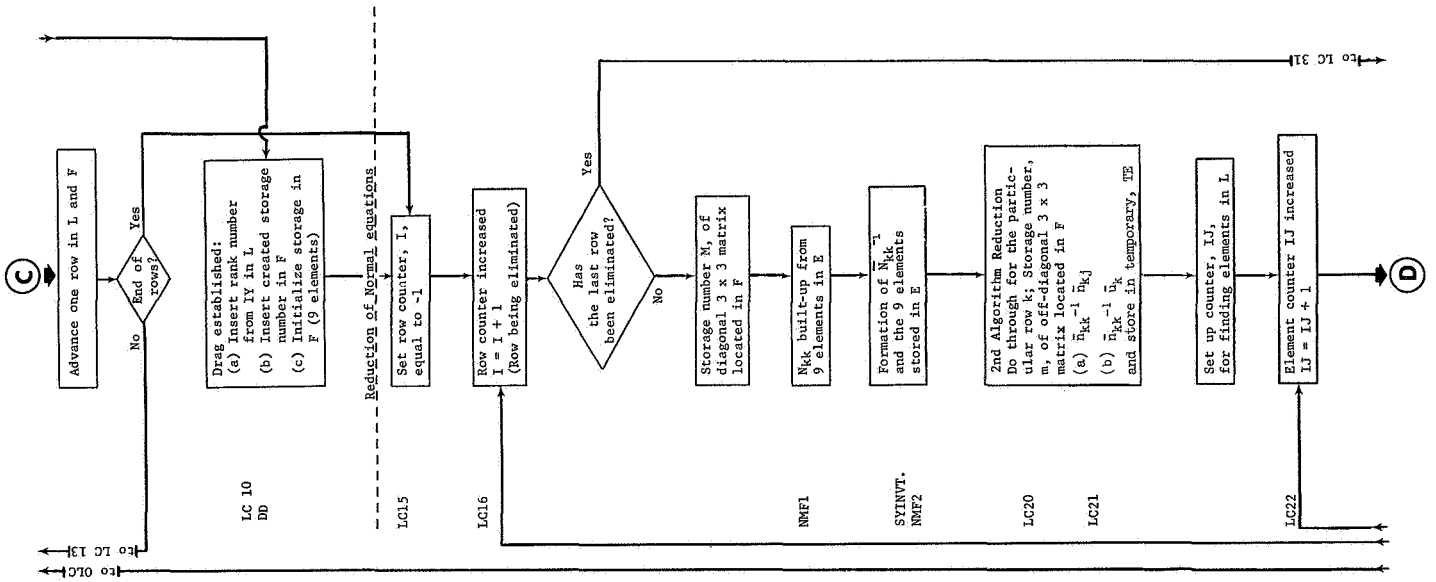
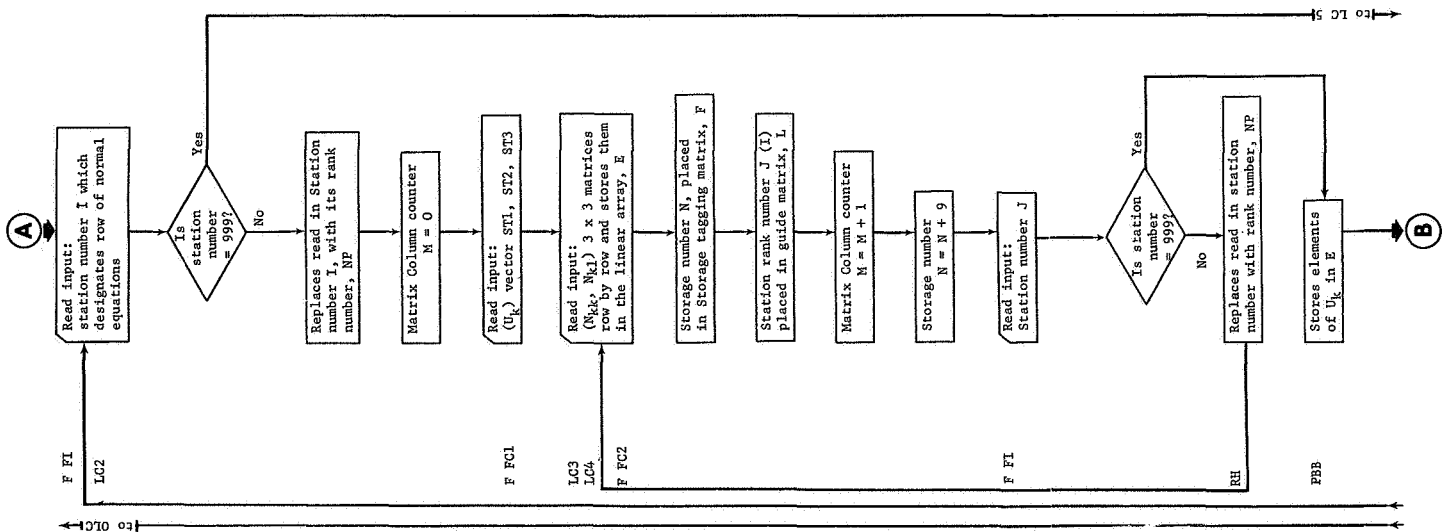
4.2 General Flow Chart

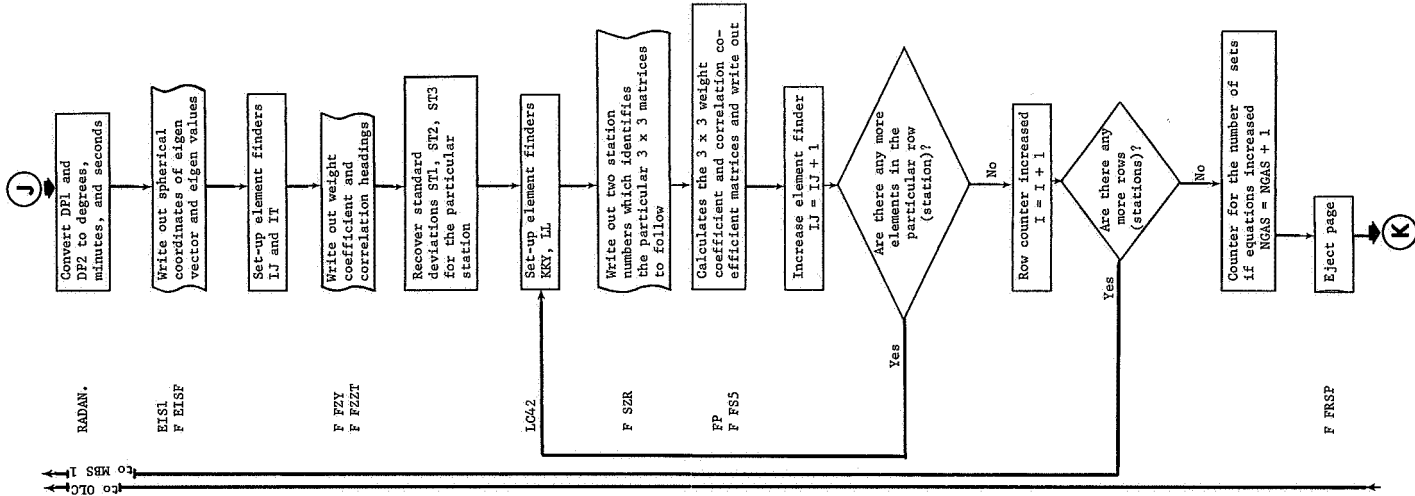
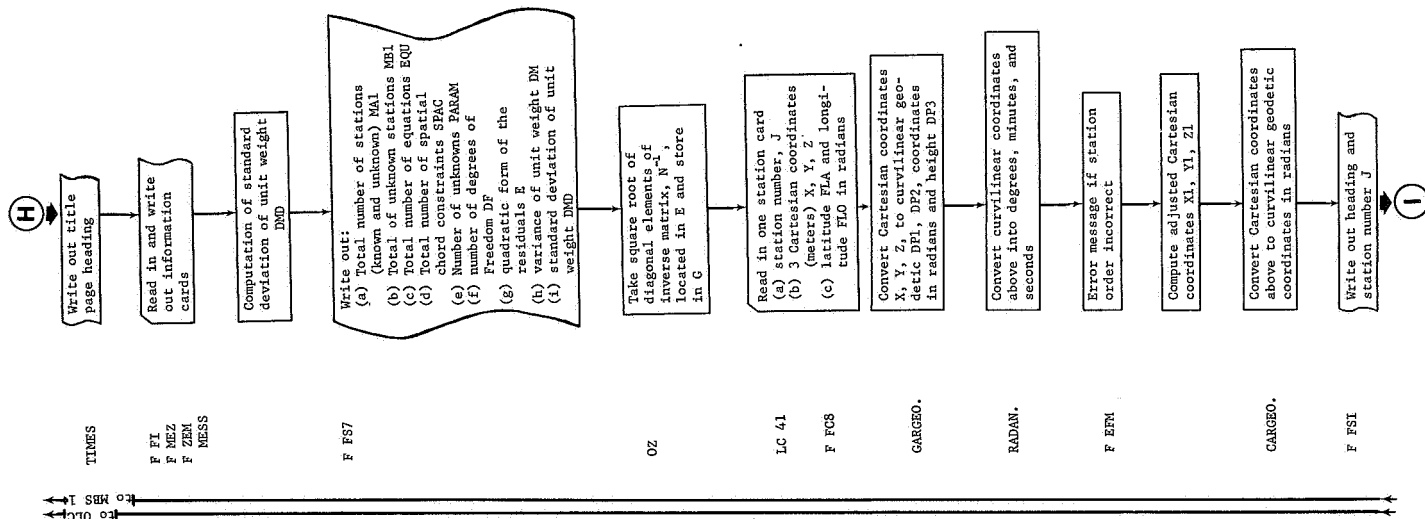
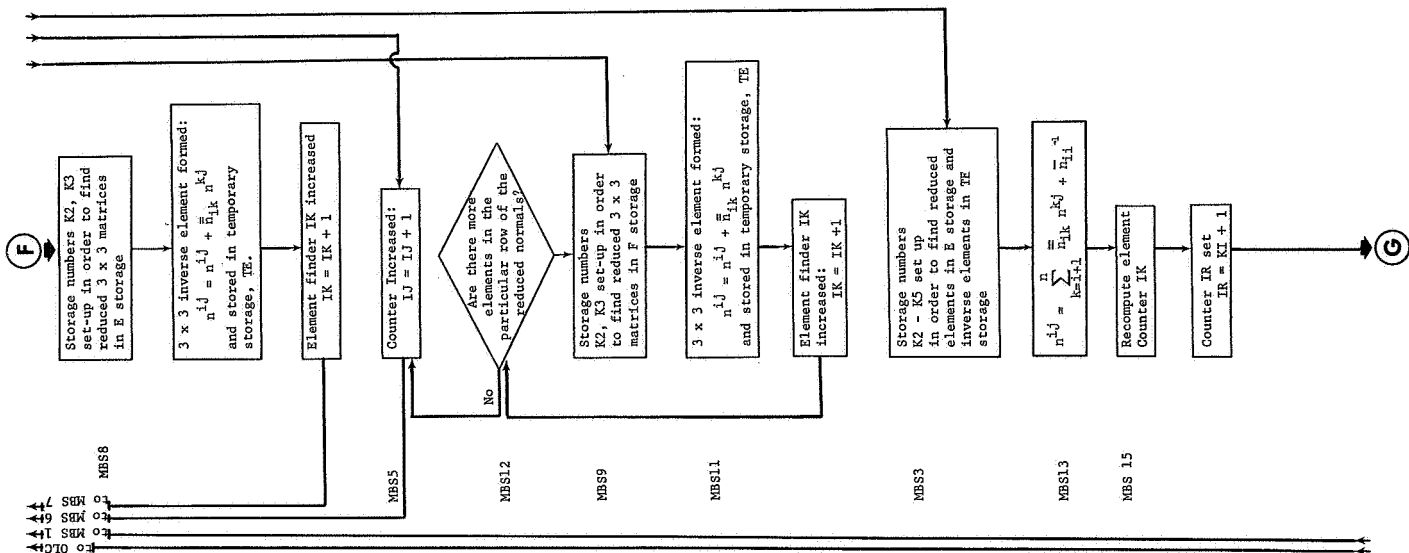


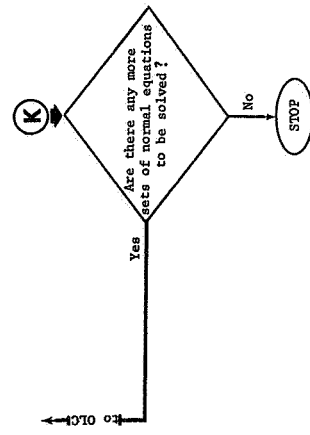
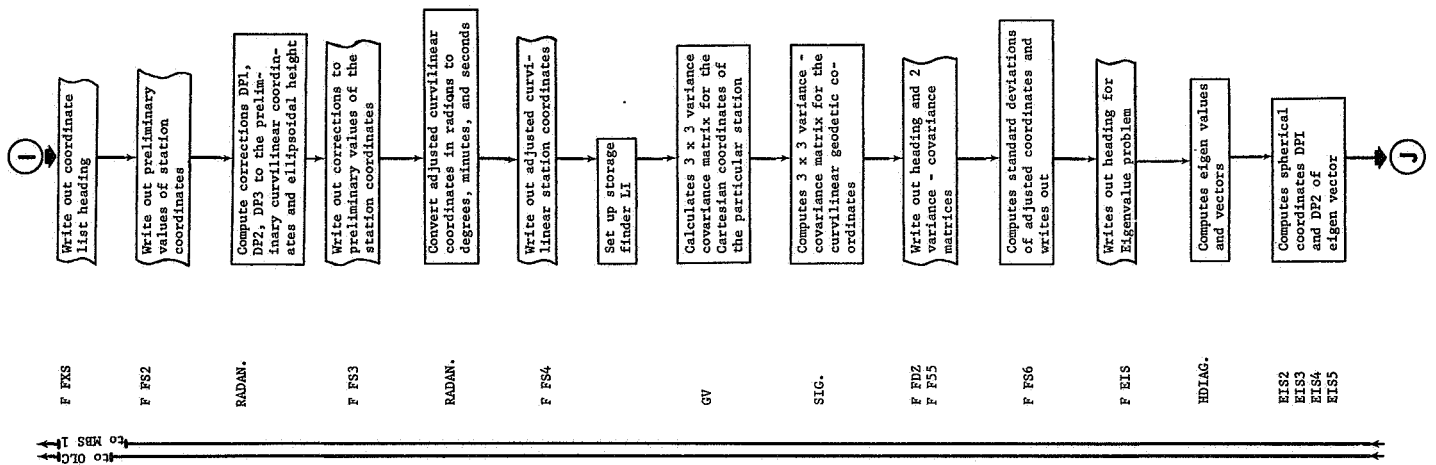
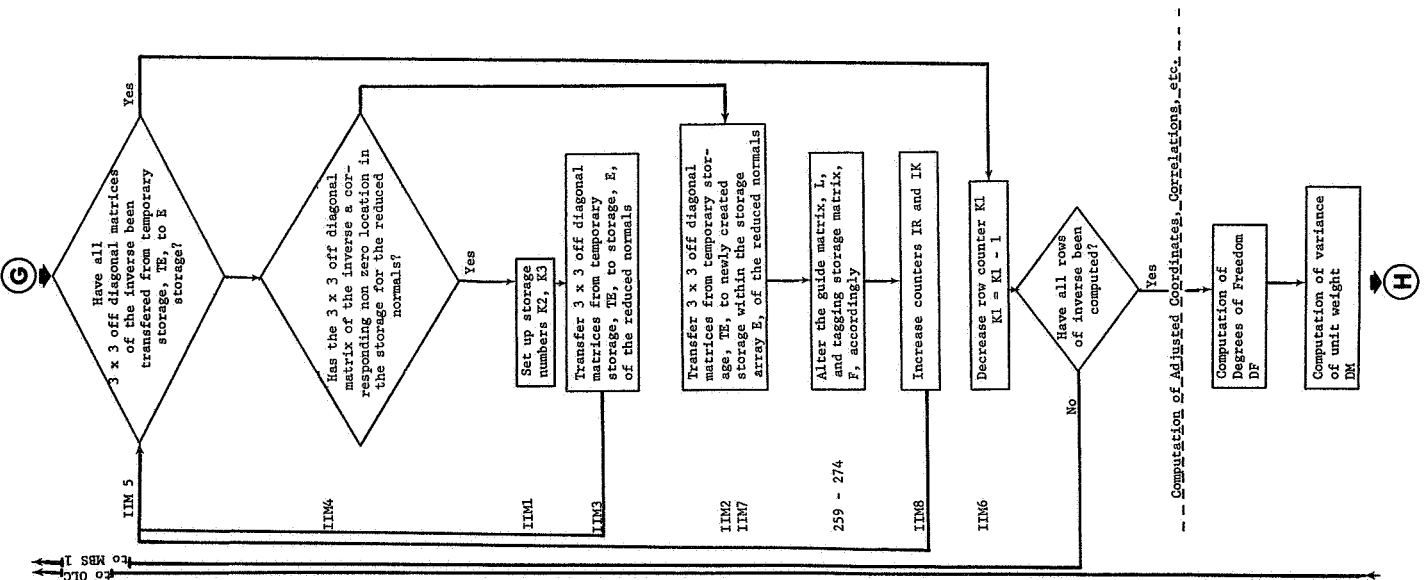
4.3 Specific Flow Chart

4.3 Specific Flow Chart









4.4 STATEMENT LISTING

SOURCE LANGUAGE STATEMENTS

```

1 C *****STATIONS*****THIS PROGRAM IS NOW DIMENSIONED FOR 37 (M
2 C MAXNST,PARAMETER,GIVES THE MAXIMUM NUMBER OF STATIONS , FOR DIMENSION PURPOSES.
3 C NDIME, PARAMETER, = 5*MAXNST*MAXNST + 5*MAXNST.
4 C NDIMG, PARAMETER= 9*MAXNST.
5 C NDIMST, PARAMETER, = 3*MAXNST.
6 C NDIMF, PARAMETER, = MAXNST*MAXNST+3*MAXNST+2.
7 C
8 INTEGERS (F).
9 C THIS PROGRAM HAS A BUILT-IN WEIGHT OF 0.1 FOR THE TERRESTRIAL SPATIAL DISTANCE SUBROUTINE GHCON.
10 C
11 PRECISION (2,XX1,YY1,ZZ1,XX2,YY2,ZZ2,RR).
12 DIMENSION (N11(9,KDM),N22(9,KDM),N12(9,KDM)).
13 FLGATING=(N11,N22,N12).
14 DIMENSION (TF(360),T1(3),T2(3)).
15 DIMENSION (E(NDIME),G(NDIMG),F(NDIMF,10),L(NDIME,10),NG(MAXNST),STV(NDIMST,KDM),NP(MAXNST),IX(MAXNST),IY(MAXNST)).
16 PRECISION (2,STV).
17 DIMENSION (S(9)).
18 DIMENSION (S1(9,KDM),S2(9,KDM),S3(9,KDM)).
19 PRECISION (2,X,Y,Z,X1,Y1,Z1,DP1,DP2,DP3,DP4,DP5,DP6,A,B,E2).
20 LITERALS (KDM,3,PI,3.141592653589793).
21 PRECISION (2,PI).
22 C
23 C
24 LC CONTINUE.
25 READ INPUT ,FI,(NGS).
26 NGS=0.
27 OLC READ INPUT ,FI,(M1,M11).

```

```

28 MAC=MA1*
29 NST=MA1*
30 NUNKST=MB1*
31 MBA=MA1-1*
32 ID=MAC+2*
33 READ INPUT ,FI,((NO(I),I=0,1,I.LE.MAC))*
34 DO THROUGH (FB),I=0,1,I.LE.MAC*
35 FB NP(NO(I))=I*
36 MAX=ID-1*
37 N=0*
38 DO THROUGH (IMT),I=MBA+1,1,I.LE.MAC*
39 F(I,0)=N*
40 DO THROUGH (DR),J=0,1,J.L.9*
41 DR E(N+J)=0.0*
42 N=N+9*
43 IMT L(I,0)=MAC*
44 J=9*MAC*
45 DO THROUGH (IG),I=0,1,I.L.J*
46 IG G(I)=0.0*
47 READ INPUT ,FDD,{A,B}*
48 F FDD {20E25.16} *
49 DP1=B/A*
50 E2=1.-DP1*DP1*
51 READ INPUT ,FC2,{ALI,EQU,E(0)}*
52 F FI (1415)*
53 C *

```

```

54 C *****READ IN AND STORING OF NORMAL EQUATIONS*

```

```

55 LC2 READ INPUT ,FI,{I}*
56 PROVIDED (I.E.999), TRANSFER (LC5)*

```

57	I=NP(I)'
58	M=0'
59	J=I'
60	READ INPUT ,FC1,(ST1,ST2,ST3)'
61	F FC1 (3(E16.8,5X)) '
62	LC3 DO THROUGH (LC4),K=N,3,K.L,N+9'
63	LC4 READ INPUT ,FC2,(E(K),E(K+1),E(K+2))'
64	F(I,M)=N'
65	L(I,M)=J'
66	M=M+1'
67	N=N+9'
68	READ INPUT ,FI,(J)'
69	TRANSFER TO (PC1,PC1,RH) PROVIDED (999-J)'
70	RH J=NP(J)'
71	TRANSFER (LC3)'
72	F FC2 (3E16.8) '
73	PC1 CONTINUE '
74	PBB F(N)=ST1'
75	E(N+3)=ST2'
76	E(N+6)=ST3'
77	E(N+1)=0.0'
78	E(N+2)=0.0'
79	E(N+4)=0.0'
80	E(N+5)=0.0'
81	E(N+7)=0.0'
82	E(N+8)=0.0'
83	L(I,M)=MAC'
84	F(I,M)=N'
85	F(I,MAX)=N'

```

86      L(I,M+1)=1000*
87      N=N+9*
88      TRANSFER (LC2)*
89 C
90 C *****SORTING L AND F*****
91 LC5  DO THROUGH (MUN),I=0,1,I.LE.MBA*
92      DO THROUGH (MUN),J=0,1,L(I,J+1).NE.MAC*
93      DO THROUGH (MUN),K=J+1,L(I,K).NE.MAC*
94      TRANSFER TO (MUN,MUN,ZS) PROVIDED (L(I,J)-L(I,K))*
95 ZS   K1=L(I,K)*
96      K2=F(I,K)*
97      L(I,K)=L(I,J)*
98      F(I,K)=F(I,J)*
99      L(I,J)=K1*
100     F(I,J)=K2*
101 MUN  CONTINUE *
102      WRITE OUTPUT ,FLF1*
103 F FLF1 (I1,10X,/,Q*THE GUIDE MATRIX L(SHOWS THE RANK NUMBER OF THE NON-ZERO 3X3 SUB-MATRICES OF THE NORMAL
          EQUATIONS),/,10X,Q*AND THE F MATRIX(SHOWS THE STORAGE NUMBERS OF THE 3X3 MATRICES) FOLLOW*,/,/
          )
104 C   WRITEOUT F AND L AFTER SORTING ELEMENTS IN EACH ROW OF L IN INCREASING RANK*
105      WRITE OUTPUT ,FLF3*
106 F FLF3 (I1 ,/,10X,Q*L AND F AFTER SORTING ELEMENTS IN EACH ROW OF LIN INCREASING RANK*,/) *
107      CALL SUBROUTINE (F,L)=FLOUT,(ID,NST)*
108 C
109 C *****READ IN AND APPLY WEIGHTS TO GROUND STATI
          GNS*
110     READ INPUT ,FI,II*
111     DO THROUGH (SWT),K=0,1,K.L.I*
112     READ INPUT ,FW,IJ,W*
113     WRITE OUTPUT ,FFW,IJ,W*

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114 F FFW      (1H, 20X, Q*STATION *, I6, 1X, Q*WEIGHTED BY *, F10.3) *
115      J=NP(J) *
116      M=F(J, 0) *
117      E(M)=E(M)+W *
118      E(M+4)=E(M+4)+W *
119      E(M+8)=E(M+8)+W *
120      WRITE OUTPUT, CIND *
121 F CIND      (1H, 10X, Q* 3 X 3 MATRIX OF WEIGHTED STATION FOLLOWS (WEIGHT ADDED TO THE 3 DIAGONAL ELEMENTS)*)
122      WRITE OUTPUT, CAMB, (E(M), E(M+1), E(M+2)) *
123      WRITE OUTPUT, CAMC, (E(M+3), E(M+4), E(M+5)) *
124      WRITE OUTPUT, CAMD, (E(M+6), E(M+7), E(M+8)) *
125 F CAMB      (1H, //, 20X, 3(F12.7, 5X)) *
126 F CAMC      (20X, 3(F12.7, 5X)) *
127 F CAMD      (20X, 3(F12.7, 5X), //, //) *
128      SWT      CCNTINUE *
129 F FW      (15, F16.8) *
130 C
131 C      *****DETERMINATION OF CONTRIBUTION OF TERRESTRIAL SPATIAL DISTANCES TO THE NORMAL EQUATIONS*****
132      SPAC=0. *
133 CHORD      READ INPUT, MMM, (ICC1, XX1, YY1, ZZ1) *
134 F MMN      (14, 4X, 3D F16.6) *
135      TRANSFER TO (LC6) PROVIDED (ICC1.E.0) *
136      SPAC=SPAC+1. *
137      READ INPUT, MMM, (ICC2, XX2, YY2, ZZ2) *
138      CALL SUBROUTINE (N11, N22, N12, RR)=CHCON. (ICC1, ICC2, XX1, XX2, YY1, YY2, ZZ1, ZZ2) *
139      WRITE OUTPUT, CIND, (ICC1, ICC2, RR) *
140 F CIND      (1H, //, 10X, Q*SPATIAL CHORD BETWEEN STATIONS*, I8, 0* AND*, I8, Q* FIXED AT *, DF15.3, Q* METERS*/ )
141      WRITE OUTPUT, CIND1 *

```

142 F CINO1 (1H, //, 20X, Q*3-3X3 MATRICES FOLLOW, 2 DIAGONAL AND ONE OFF-DIAGONAL TO BE ADDED*//) *

143 DO THROUGH (CON1), J=0,1,J.L.3*

144 CON1 WRITE OUTPUT, QAZI, (N11(J,0), N11(J,1), N11(J,2), N22(J,0), N22(J,1), N22(J,2), N12(J,1), N12(J,2))

145 F QAZI (1H, //, 20X, 3F12.7, 2X, 3F12.7, 2X, 3F12.7) *

146 K1=NP(I*CC1) *

147 K2=NP(I*CC2) *

148 AC3 DO THROUGH (AC3), I=1,1,I(L(K1,I), NE, K2 *

149 K3=F(NP(I*CC1), 0) *

150 DO THROUGH (AC4), J=0,1,J.L.9 *

151 AC4 F(K3+J)=E(K3+J)+N11(J) *

152 K4=F(NP(I*CC2), 0) *

153 DO THROUGH (AC5), J=0,1,J.L.9 *

154 AC5 F(K4+J)=E(K4+J)+N22(J) *

155 K5=F(K1,I) *

156 DO THROUGH (AC6), J=0,1,J.L.9 *

157 AC6 E(K5+J)=E(K5+J)+N12(J) *

158 WRITE OUTPUT, Z33 *

159 F Z33 (1H, //, 9X, 0*NORMAL EQUATION SUBMATRICES AFTER ADDITION OF THE ABOVE*//) *

160 DO THROUGH (AFTAD), K=0,3,K.L.9 *

161 AFTAD WRITE OUTPUT, QAZI, ((E(K3+J3), J3=K,1,J3.L.K+3), (E(K4+J4), J4=K,1,J4.L.K+3), (E(K5+J5), J5=K,1,J5.L.K+3))

162 TRANSFER TO (CHORD) *

163 C *

164 C *****ASSIGN DRAG STORAGE TO BE NEEDED IN THE REDUCTION OF THE NORMAL EQUATIONS*****

165 LC6 IU=C *

166 IT=MAC *

167 LC13 IL=IU+1 *

168 J=-1 *

169 LC7 J=J+1 *

170	IX(J)=F(IL,J)*				
171	IY(J)=L(IL,J)*				
172	PROVIDED (IY(J).NE.MAC), TRANSFER (LC7)*				
173	JU=1*				
174	JL=C*				
175	J=-1*				
176	J=J+1*				
177	TRANSFER TO (LC12,LC11,LC10) PROVIDED (IY(JL)-L(IU,JU))*				
178	F(IL,J)=IX(JL)*				
179	L(IL,J)=IY(JL)*				
180	K=JL*				
181	JL=JL+1*				
182	JU=JU+1*				
183	PROVIDED (IY(K).L.MAC), TRANSFER (LC9)*				
184	IU=IU+1*				
185	L(IL,J+1)=1000*				
186	TRANSFER TO (LC13,LC13,LC15) PROVIDED (IU-IT)*				
187	LC12 F(IL,J)=IX(JL)*				
188	L(IL,J)=IY(JL)*				
189	JL=JL+1*				
190	TRANSFER (LC9)*				
191	LC10 L(IL,J)=L(IU,JU)*				
192	F(IL,J)=N*				
193	JU=JU+1*				
194	IK=N+9*				
195	DD E(N)=0.0*				
196	N=N+1*				
197	TRANSFER TO (LC9,LC9,DD) PROVIDED (IK-N)*				
198	LC15 I=-1*				

199 WRITE OUTPUT ,FDRAG*

200 F FDRAG (1H ,/,10X,0*L AND F AFTER REDUCTION DRAG DETERMINED*,/)

201 CALL SUBROUTINE (F,L)=FLOUT,(ID,NST)*

202 C *

203 C *****GAUSSIAN REDUCTION OF NORMAL EQUATIONS*****

204 LC16 I=I+1*

205 PROVIDED (I,G,MBA),TRANSFER (LC31)*

206 M=F(I,0)*

207 DO THROUGH (NMF1),KI=0,1,KI*L*9*

208 NMF1 S1(KI)=E(KI+M)*

209 CALL SUBROUTINE (S2)=SYINVT.(S1)*

210 DO THROUGH (NMF2),KI=0,1,KI*L*9*

211 NMF2 E(KI+M)=S2(KI)*

212 J=1*

213 K=-1*

214 LC20 M=F(I,J)*

215 DO THROUGH (LC21),IR=0,3,IR*L*9*

216 DO THROUGH (LC21),LL=M,1,LL*L*M+3*

217 K=K+1*

218 LC21 IF(K)=S2(IR)*E(LL)+S2(IR+1)*E(LL+3)+S2(IR+2)*E(LL+6)*

219 J=J+1*

220 PROVIDED (L(I,J),LE,MAC),TRANSFER (LC20)*

221 J=0*

222 IJ=ID*I*

223 LC22 J=J+1*

224 IJ=IJ+1*

225 PROVIDED (L(IJ),G,MAC),TRANSFER (LCFJ)*

226 PROVIDED (L(IJ),LE,MBA,OR.L(IJ),GE,MAC-MRO),TRANSFER (LC23)*

227 IT=L(IJ)+MRO*

228		TRANSFER (LC24)*	
229	LC23	IT=MAC*	
230	LC24	KJ=F(IJ)*	
231		IK=IJ-1*	
232		KK=9*J-18*	
233		TRANSFER (LC52)*	
234	LC27	KK=KK+9*	
235		KG=9*L(IK)-1*	
236		NP(L(IK))=-5*	
237		DO THROUGH (LC28),IR=KJ,1,IR.L,KJ+3*	
238		DO THROUGH (LC28),LL=KK,1,LL.L,KK+3*	
239		KG=KG+1*	
240	LC28	G(KG)=E(IR)*TE(LL)+E(IR+3)*TE(LL+3)+E(IR+6)*TE(LL+6)*	
241	LC52	IK=IK+1*	
242		TRANSFER TO (HR,LC27,LC27) PROVIDED (IT-L(IK))*	
243	HR	IR=L(IJ)*	
244		JN=IC*IR*	
245	LC30	TRANSFER TO (CHF,CHM,CHM) PROVIDED (NP(L(JN)))*	
246	CHF	KE=F(JN)*	
247		KG=9*L(JN)-1*	
248		JJ=KE+9*	
249		DO THROUGH (LC29),LL=KE,1,LL.L,JJ*	
250		KG=KG+1*	
251		E(LL)=E(LL)-G(KG)*	
252	LC29	G(KG)=0.0*	
253		NP(L(JN))=5*	
254	CHM	JN=JN+1*	
255		TRANSFER TO (LC30,LC30,LC22) PROVIDED (L(JN)-IT)*	
256	LCFJ	IK=I*ID+1*	

```

257      K1=-1
258      DO THROUGH (LC25),K=IK,1,L(K).LE.MAC
259      K2=F(K)
260      DO THROUGH (LC25),K3=0,1,K3.L.9
261      K1=K1+1
262      LC25  E(K2+K3)=TE(K1)
263      TRANSFER (LC16)
264 C
265 C *****BACK SOLUTION FOR CORRECTION VECTOR*****
266      LC31  I=MBA
267      DO THROUGH (LC32),LK=0,3,LK.L.9
268      LC32  S(LK)=0.0
269      LC33  KG=F(I,MAX)
270      KJ=9*L(I,0)
271      DO THROUGH (LC34),LK=0,3,LK.L.9
272      G(KJ+LK)=-E(KG+LK)-S(LK)
273      LC34  S(LK)=0.0
274      I=I-1
275      TRANSFER TO (LC40,LC53,LC53) PROVIDED (I)
276      LC53  J=1
277      LC37  KJ=9*L(I,J)
278      LC39  KG=F(I,J)
279      DO THROUGH (LC38),LK=0,3,LK.L.9
280      IK=KG+LK
281      LC38  S(LK)=S(LK)+G(KJ)*E(IK)+G(KJ+3)*E(IK+1)+G(KJ+6)*E(IK+2)
282      J=J+1
283      TRANSFER TO (LC37,LC37,LC33) PROVIDED (L(I,J)-MBA)
284 C
285 C *****INVERSE DETERMINATION*****

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286	LC40	K1=MBA-1'				
287	MBS1	IJ=K1+1'				
288		KJ=-1'				
289		J=(MBA-K1)*9'				
290		DO THROUGH (INTE),K=0,1,K.L,J'				
291	INTE	TE(K)=0.0'				
292	MBS6	TRANSFER TO (MBS2,MBS2,MBS3) PROVIDED (IJ-MBA)'				
293	MBS2	IK=K1#ID+1'				
294	MBS7	TRANSFER TO (MBS4,MBS4,MBS5) PROVIDED (L(IK)-MBA)'				
295	MBS4	TRANSFER TO (MBS8,MBS9,MBS9) PROVIDED (L(IK)-IJ)'				
296	MBS8	K2=F(L(IK),IJ-L(IK))'				
297		K3=F(IK)'				
298		KK=KJ'				
299		DO THROUGH (MBS10),K=K3,3,K.L,K3+9'				
300		DO THROUGH (MBS10),J=K2,1,J.L,K2+3'				
301		KK=KK+1'				
302	MBS10	TF(KK)=TE(KK)-E(K)*E(J)-E(K+1)*E(J+3)-E(K+2)*E(J+6)'				
303		IK=IK+1'				
304		TRANSFER (MBS7)'				
305	MBS5	IJ=IJ+1'				
306		KJ=KJ+9'				
307		TRANSFER (MBS6)'				
308	MBS12	TRANSFER TO (MBS9,MBS9,MBS5) PROVIDED (L(IK)-MBA)'				
309	MBS9	K2=F(IJ,L(IK)-IJ)'				
310		K3=F(IK)'				
311		KK=KJ'				
312		DO THROUGH (MBS11),K=K3,3,K.L,K3+9'				
313		DO THROUGH (MBS11),J=K2,3,J.L,K2+9'				
314		KK=KK+1'				

```

315 MBS11 TE(KK)=TE(KK)-E(K)*E(J)-E(K+1)*E(J+1)-E(K+2)*E(J+2)*
316 IK=IK+1*
317 TRANSFER (MBS12)*
318 MBS3 IK=K1*ID+1*
319 K2=F(K1,0)-1*
320 MBS14 K3=K2*
321 K4=F(IK)*
322 K5=(L(IK)-K1-1)*9*
323 DO THROUGH (MBS13),K=K4,3,K,L,K4+9*
324 DO THROUGH (MBS13),J=K5,3,J,L,K5+9*
325 K3=K3+1*
326 MBS13 F(K3)=E(K3)-E(K)*TE(J)-E(K+1)*TE(J+1)-E(K+2)*TE(J+2)*
327 IK=IK+1*
328 TRANSFER TO (MBS14,MBS14,MBS15) PROVIDED (L(IK)-M3A)*
329 MBS15 IK=K1*ID+1*
330 IR=K1+1*
331 K1=-9*
332 IIM5 TRANSFER TO (IIM4,IIM4,IIM6) PROVIDED (IR-M3A)*
333 IIM4 TRANSFER TO (IIM1,IIM1,IIM2) PROVIDED (L(IK)-IR)*
334 IIM1 K2=F(IK)-1*
335 K3=K3+9*
336 DO THROUGH (IIM3),K=0,1,K,L,9*
337 K2=K2+1*
338 IIM3 F(K2)=TE(K3+K)*
339 IR=IR+1*
340 IK=IK+1*
341 TRANSFER (IIM5)*
342 IIM2 K3=K3+9*
343 K2=N-1*

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344 DO THROUGH (IIM7), K=0,1,K.L.9,

345 K2=K2+1,

346 IIM7 E(K2)=TE(K3+K),

347 LL=L(IK),

348 LK=F(IK),

349 DO THROUGH (IIM8), K=IK,1,L(K).LE.MAC,

350 K2=K+1,

351 LL=L(K2),

352 LK1=F(K2),

353 L(K2)=LL,

354 F(K2)=LK,

355 LL=LL1,

356 IIM8 LK=LK1,

357 L(IK)=IR,

358 F(IK)=N,

359 IR=IR+1,

360 IK=IK+1,

361 N=N+9,

362 TRANSFER (IIM5),

363 IIM6 K1=K1-1,

364 TRANSFER TO (FPO,MBS1,MBS1) PROVIDED (K1),

365 FPO CONTINUE,

366 WRITE OUTPUT, FINVER,

367 F FINVER (IH,/,10X,Q#L AND F AFTER INVERSE DETERMINATION*,/),

368 CALL SUBROUTINE (F,L)=FLOUT.(ID,NST),

369 PARAM=3.*(MBS1),

370 DF=EQU+SPAC-PARAM,

371 VPV=E(0),

372 DM=VPV/DF,

```

373 C      '
374 C      SET VARIANCE OF UNIT WEIGHT TO 1 WHEN WORKING WITH ERRORLESS DATA
375      PROVIDED (ALI.E.1),DM=1.0
376 C      '
377      WRITE OUTPUT ,TMES
378      READ INPUT ,FI,(I)
379      DO THROUGH (MESS),K=0,1,K.L.1
380      READ INPUT ,MEZ,((NP(J),J=0,1,J.L.12))
381 MESS      WRITE OUTPUT ,ZEM,((NP(J),J=0,1,J.L.12))
382      DMD=SQRT.(DM)
383      WRITE OUTPUT ,FS7,(M1,M1,EQU,SPAC,PARAM,DF,VPV,DM,DMD)
384 F FS7      (///,33X,Q* NUMBER OF KNOWN AND UNKNOWN GROUND STATIONS = *, I12,/,43X,Q* NUMBER OF UNKNOWN GROUND
              STATIONS=*, I12,/,22X,Q* NUMBER OF OBSERVATIONS-MINUS 3 TIMES NUMBER OF EVENTS = *,F12.4,
              //,43X,Q* NUMBER OF SPATIAL CHORD EQUATIONS =*,F12.4,/,38X,Q* NUMBER OF UNKNOWN IN NORMAL EQ
              UATIONS=*,F12.4,/,48X,Q* NUMBER OF DEGREES OF FREEDOM = *,F12.4,/,36X,Q* QUADRATIC SUM OF A
              LL THE RESIDUALS (VPV) = *,F12.4,/,54X,Q* VARIANCE OF UNIT WEIGHT = *,F12.4,/,43X,Q* STANDARD
              DEVIATION OF UNIT WEIGHT = *,F12.4)
385 F MEZ      (12L6)
386 F ZEM      (723X,12L6)
387 F TMES      (1H1,777777,30X,Q+INITIAL SOLUTION)
388      M=MBA*ID
389      DO THROUGH (OZ),J=0,10,J.LE.M
390      I=9*L(J)
391      G(I+1)=SQRT.(E(F(J))*DM)
392      G(I+4)=SQRT.(E(F(J)+4)*DM)
393 OZ      G(I+7)=SQRT.(E(F(J)+8)*DM)
394      I=0
395 LC41      READ INPUT ,FC8,(J,X,Y,Z,FLA,FLO)
396 C      BUILD-UP ARRAY WITH PRELIMINARY CARTESIAN COORDINATES
397      STV(I,0)=X
398      STV(I,1)=Y
399      STV(I,2)=Z

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Line	Code	Text	Page
400	CALL	SUBROUTINE (DP1,DP2,DP3)=CARGEO.(X,Y,Z)*	22
401	H=	HOP.DP3*	
402	CALL	SUBROUTINE (LL,M,N,ST1)=RADAN.(DP1)*	
403	CALL	SUBROUTINE (KG,KK,K,ST2)=RADAN.(DP2)*	
404	PROVIDED	(J.NE.NG(I)), WRITE OUTPUT ,EFM*	
405	F EFM	(Q* THE STA. POSITION DATA DECK IS IMPROPERLY ARRANGED *) *	
406	F FC8	(I4,4X,3DF16.6,2F7.4) *	
407	F FC9	(I4,20X,LL,2(2I3,F8.4),F9.4) *	
408	LI=	I*9*	
409	X1=	X+G(LI)*	
410	Y1=	Y+G(LI+3)*	
411	Z1=	Z+G(LI+6)*	
412	CALL	SUBROUTINE (DP4,DP5,DP6)=CARGEO.(X1,Y1,Z1)*	
413	FLA=	HOP.DP4*	
414	FLO=	HOP.DP5*	
415	WRITE	OUTPUT ,FS1,(J)*	
416	F FS1	(LH1,///Q* STATION NUMBER - *,I4) *	
417	WRITE	OUTPUT ,FXS*	
418	F FXS	(/26X,Q*X*,15X,Q*Y*,15X,Q*Z*,21X,Q*LAT.*,12X,Q*LONG.(+E) ELL. HT.*)*	
419	WRITE	OUTPUT ,FS2,(X,Y,Z,LL,M,N,ST1,KK,K,ST2,H)*	
420	F FS2	(/Q* PREL. COORD. - *,3DF16.4,10X,LL,2I3,F8.4,I7,I3,F8.4,F12.4) *	
421	DP1=	DP4-DP1*	
422	DP2=	DP5-DP2*	
423	H=	DP6-DP3*	
424	CALL	SUBROUTINE (KG,K,KK,ST1)=RADAN.(DP1)*	
425	CALL	SUBROUTINE (LL,M,N,ST2)=RADAN.(DP2)*	
426	WRITE	OUTPUT ,FS3,(G(LI),G(LI+3),G(LI+6),KG,K,KK,ST1,LL,M,N,ST2,H)*	
427	F FS3	(/Q* CORRECTIONS - *,3F16.4,10X,LL,2I3,F8.4,3X,LL,2I3,F8.4,F12.4)*	
428	CALL	SUBROUTINE (KG,K,KK,ST1)=RADAN.(DP4)*	

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429      CALL SUBROUTINE (LL,M,N,ST2)=RADAN.(DP5)
430      H=.HUP.DP6
431      WRITE OUTPUT ,FS4,(X1,Y1,Z1,KG,K,KK,ST1,M,N,ST2,H)
432 F FS4      (/Q* ADJ. COORD. - *,3DF16.4,10X,11,2I3,F8.4,17,13,F8.4,F12.4)
433      N=1
434      LI=F(N,0)
435      DO THROUGH (GV),J=0,1,J.L.9
436 GV      S3(J)=E(LI+J)*DM
437      CALL SUBROUTINE (S1,S2)=SIG.(S3,FLA,FLC,H)
438      WRITE OUTPUT ,FDZ
439 F FDZ      (/Q* VAR.-COV. MATRICES OF THE STATION POSITION - X,Y,Z (METERS.2.) AND LAT.,LONG.,HT. (SEC..2.,METER
              S.2.,SEC. METERS)/)
440      DO THROUGH (OY),K=0,3,K.L.9
441 OY      WRITE OUTPUT ,FS5,(S3(J),J=K,1,J.L.K+3),(S2(J),J=K,1,J.L.K+3)
442 F FS5      (14X,3F16.6,10X,3F16.6)
443      K=N*9
444      S=SQRT.(S2)
445      S(1)=SQRT.(S2(4))
446      S(2)=SQRT.(S2(8))
447      WRITE OUTPUT ,FS6,(G(K+1),G(K+4),G(K+7),S,S(1),S(2))
448 F FS6      (/Q* STAND. DEV. - *,F15.4,2F16.4,10X,3F16.4)
449      WRITE OUTPUT ,EIS
450 F EIS      (/Q* DIRECTIONS (LAT.,LONG.) OF EIGENVECTORS AND SQUARE ROOT OF EIGENVALUES OF VARIANCE-COVARIANCE MAT
              FIX - *)
451      CALL SUBROUTINE (S3,S1)=HDIAG.(3,3,0,11,T2)
452      IEF=-4
453      DO THROUGH (EIS1),IE=0,1,IE.L.3
454      IEF=IEF+4
455      X=S1(IE)
456      Y=S1(IE+3)

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457      Z=S1(IE+6)*
458      ESR=SQRT.(S3(IEF))*
459      DP1=ATAN.(Y/X)*
460      TRANSFER TO (EIS2,EIS3,EIS3) PROVIDED (Y)*
461      EIS2      DP1=DP1+PI*
462      TRANSFER TO (EIS5,EIS4,EIS4) PROVIDED (X)*
463      EIS3      TRANSFER TO (EIS4,EIS5,EIS5) PROVIDED (X)*
464      EIS4      DP1=DP1+PI*
465      EIS5      DP2=ATAN.(Z/SQRT.(X*X+Y*Y))*
466      CALL SUBROUTINE (KG,K,KK,ST1)=RADAN.(DP2)*
467      CALL SUBROUTINE (LL,M,N1,ST2)=RADAN.(DP1)*
468      EIS1      WRITE OUTPUT ,EISF,(KG,K,KK,ST1,LL,M,N1,ST2,ESR)*
469      F EISF      (/15X,LL,2I3,F8.4,5X,LI,2I3,F8.4,5X,FI2.4)*
470      C      IJ ESTABLISHES THE BEGINNING OF A NEW ROW IN L AND F*
471      IJ=N*ID*
472      IT=MBA*
473      JUN      WRITE OUTPUT ,FZY*
474      F FZY      (/15X,Q* 3X3 WEIGHT COEFFICIENT MATRICES*,43X,*CORRELATION COEFFICIENT*,/)
475      WRITE OUTPUT ,FZZY*
476      F FZZY      (26X,Q*X*,15X,Q*Y*,15X,Q*Z*,25X,Q*X*,15X,Q*Y*,15X,Q*Z*)
477      C      LL ESTABLISHES THE LOCATION OF THE STANCARD DEVIATIONS*
478      C      FOR A PARTICULAR STATION IN THE G ARRAY*
479      LL=9*LI(IJ)+1*
480      KKY=I-1*
481      LC42      LI=9*LI(IJ)+1*
482      C      ST1,ST2,ST3 CHANGE FOR EACH STATION IN THE ROW OF THE
483      C      CORRELATION COEFFICIENT MATRIX*
484      ST1=G(LI)*
485      ST2=G(LI+3)*

```

486 ST3=G(LI+6)*

487 KKY=KKY+1*

488 WRITE OUTPUT ,SZR,(NO(I),NO(KKY))*

489 F SZR I/5X,Q* STA. NO. *,I4,Q* WITH STA. NO. *,I4) *

490 DO THROUGH (FP),K=0,3,K.L.9*

491 C D IS CONSTANT FOR A 3X3 ROW OF THE CORRELATION MATRIX*

492 C HOWEVER VARIES FOR EACH ROW OF THE 3X3 MATRICES*

493 D=G(LL+K)*

494 KK=F(IJ)+K*

495 C THE E VALUES CHANGE FOR EACH ELEMENT*

496 C S,S(1),S(2) ARE THE COVARIANCES FOR A PARTICULAR ROW *

497 S=E(KK)*DM*

498 S(1)=E(KK+1)*DM*

499 S(2)=F(KK+2)*DM*

500 C S(3),S(4),S(5) ARE THE CORRELATION COEFFICIENTS FOR A ROW*

501 S(3)=S/(ST1*D)*

502 S(4)=S(1)/(ST2*D)*

503 S(5)=S(2)/(ST3*D)*

504 FP WRITE OUTPUT ,FS5,(E(KK),E(KK+1),E(KK+2),S(3),S(4),S(5))*

505 IJ=IJ+1*

506 C A TEST FOR MORE STATIONS IN THE ROW OF THE *

507 C CORRELATION MATRIX*

508 TRANSFER TO (LC42,LC42,WN) PROVIDED (L(IJ)-1)*

509 WN I=I+1*

510 C A TEST FOR MORE ROWS TO BE COMPUTED*

511 TRANSFER TO (LC41,LC41,ZO) PROVIDED (I-MBA)*

512 ZO CONTINUE *

513 NGAS=NGAS+1*

514 WRITE OUTPUT ,\$(1H1) \$*

515 PROVIDED (NGAS.L,NGS), TRANSFER TO (OLC)'

516 CALL SUBROUTINE ()=ENDJOB.()'

517 C '

518 C '

519 C ***** SUBROUTINES'

520 C '

521 C '

522 C ***** FLOUT.'

523 SUBROUTINE (F,L)=FLOUT.(ID,NST)'

524 C THIS SUBROUTINE SIMPLY WRITES OUT THE L AND F MATRICES'

525 INTEGERS (F)'

526 DIMENSION (F(0,ID),L(0,ID))'

527 DO THROUGH (OUT1),I=0,1,I.LE.NST'

528 WRITE OUTPUT ,FLF,(I,(L(I,J),J=0,1,J.L.ID))'

529 WRITE OUTPUT ,FLF,(I,(F(I,J),J=0,1,J.L.ID))'

530 F FLF (1H ,15,XX,2015) '

531 NORMAL EXIT '

532 END SUBPROGRAM '

533 C '

534 C '

535 SUBROUTINE (C,G,H)=CARGEO.(X,Y,Z)'

536 UNIVERSAL (A,E2)'

537 LITERALS (PI,3.141592653589793)'

538 PRECISION (2,0,C,G,H,X,Y,Z,CO,DATAN.,P,PI)'

539 PRECISION (2,TANC,TANCO,DSIN.,DCOS.,F,BI,DSQRT.)'

540 F=DSQRT.(X*X+Y*Y)'

541 D=Z/F'

542 TANC=0/(1.-E2)'

543 CO=DATAN.(TANCO)'

```

544      BI=DSIN.(C)*
545      P=A/DSQRT.(1.-E2*BI*BI)*
546  HERM1  TANC=D*(1.+E2*P*BI/Z)*
547      C=DATAN.(TANC)*
548      BI=DSIN.(C)*
549      P=A/DSQRT.(1.-E2*BI*BI)*
550      PROVIDED (.ABS.(C-CG).LE..5.X.-10), TRANSFER TO (HERM2)*
551      CO=C*
552      TRANSFER TO (HERM1)*
553  HERM2  G=DATAN.(Y/X)*
554      PROVIDED (X.L.0.0),G=G+PI*
555      PROVIDED (X.GE.0.0.AND.Y.L.0.0),G=G+2.*PI*
556      H=F/DCOS.(C)-P*
557      NORMAL EXIT *
558      END SUBPRUGRAM *
559      SUBROUTINE (I,M,N,C)=RADAN.(T)*
560      PRECISION (2,G,I,RHC)*
561      G=T*
562      LITERALS (RHD,57.29577951308252)*
563      PROVIDED (G.L.0.0), TRANSFER TO (PLAC1)*
564      I=$+ $*
565      TRANSFER TO (PLAC2)*
566  PLAC1  G=-G*
567      I=$- $*
568  PLAC2  G=G*RHD*
569      M=G*
570      G=(G-M)*60.*
571      N=G*
572      C=(G-N)*60.*

```

```

573      NORMAL EXIT *
574      END SUBPROGRAM *
575      SUBROUTINE (SIGL,SIGM)=SIG.(SIGX,FLAT,FLON,H)*
576      DIMENSION (GSIGX(9,L))*.
577      DIMENSION (SIGX(0,L),SIGL(0,L),G(9,L),GT(9,L),SIGM(0,L),T1(3),T2(3))*.
578      LITERALS (R,6370000.,RHOSEC,206264.81)*
579      L=3*
580      EK1=SIN.(FLAT)*
581      EK2=COS.(FLAT)*
582      FK1=SIN.(FLON)*
583      FK2=COS.(FLON)*
584      G(0,0)=-EK1*FK2*
585      G(0,1)=-EK2*FK1*
586      G(0,2)=EK2*FK2*
587      G(1,0)=-EK1*FK1*
588      G(1,1)=EK2*FK2*
589      G(1,2)=EK2*FK1*
590      G(2,0)=EK2*
591      G(2,1)=0.*
592      G(2,2)=EK1*
593      DO THROUGH (TRN),I=0,1,I.L.3*
594      DO THROUGH (TRN),J=0,1,J.L.3*
595      TRN      GT(I,J)=G(J,I)*
596      CALL SUBROUTINE (E,D,G)=MTINV.(T1,T2,3,3)*
597      CALL SUBROUTINE (E,D,GT)=MTINV.(T1,T2,3,3)*
598      CALL SUBROUTINE (E,GSIGX)=MTMPY.(G,SIGX,3,3,3)*
599      CALL SUBROUTINE (E,SIGL)=MTMPY.(GSIGX,GT,3,3,3)*
600      RHORH=.HOP.RHOSEC/(R+H)*
601      SIGM(0,0)=SIGL(0,0)*RHORH.P.2*

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602      SIGM(1,1)=SIGL(1,1)*RHORH,P,2*
603      SIGM(2,2)=SIGL(2,2)*
604      SIGM(0,1)=SIGL(0,1)*RHORH,P,2*
605      SIGM(1,0)=SIGM(0,1)*
606      SIGM(0,2)=SIGL(0,2)*RHORH*
607      SIGM(2,0)=SIGM(0,2)*
608      SIGM(1,2)=SIGL(1,2)*RHORH*
609      SIGM(2,1)=SIGM(1,2)*
610      NORMAL EXIT *
611      END SUBPROGRAM *
612      SUBROUTINE (A)=SYNVT,(B)*
613      DIMENSION (A(0,KDM),B(0,KDM),S(10))*
614      LITERALS (KDM,3)*
615      DO THROUGH (CH),I=0,1,I,L,3*
616      K=2*I*
617      DO THROUGH (CH),J=1,1,J,L,3*
618      CH      S(K+J)=B(I,J)*
619      S(5)=S(1)*S(1)*
620      S(7)=S(2)*S(2)*
621      S(8)=S(4)*S(4)*
622      S(9)=S*S(3)*S(6)+2*S(1)*S(2)*S(4)-S(3)*S(7)-S*(8)-S(6)*S(5)*
623      A=(S(3)*S(6)-S(8))/S(9)*
624      A(0,1)=(S(2)*S(4)-S(1)*S(6))/S(9)*
625      A(0,2)=(S(1)*S(4)-S(2)*S(3))/S(9)*
626      A(1,1)=(S*S(6)-S(7))/S(9)*
627      A(1,2)=(S(1)*S(2)-S*S(4))/S(9)*
628      A(2,2)=(S*S(3)-S(5))/S(9)*
629      A(1,0)=A(0,1)*
630      A(2,0)=A(0,2)*

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660	NORMAL EXIT					
661	END SUBPROGRAM					
662	END PROGRAM (LC)					

Columns

Number of sets of normal equations to be solved

1 - 5

- (1) Number of unknown and known stations
- (2) Number of unknown stations

1 - 5

6 - 10

Station numbers in the pre-established order.
1 - 5, 6 - 10, ... , 66 - 70
(repeat on new card if necessary)

(1) Semi-major axis of reference ellipsoid
(2) Semi-minor axis of reference ellipsoid

1 - 25

26 - 50

- (1) "1.0" if estimate of variance of unit weight not wanted from adjustment; blank otherwise
- (2) Number of observations minus 3 times the number of events
- (3) Contribution to $V'PV$, namely $W'PW$

33 - 48

- *(1) Card 1. Row number (station number) of normal equations (1415)
- *(2) Card 2. U_k vector [3(E16.8, 5X)] 1 - 16, 22 - 37, 43 - 58
- *(3) Cards 3 - 5. N_{kk} matrix (3E16.8)
- *(4) Card 6. Station number (1415) 1 - 16, 17 - 32, 33 - 48
- *(5) Cards 7 - 9. N_{kl} matrix (3E16.8) 1 - 16, 17 - 32, 33 - 48
- *(6) Last card in row contains 999 (1415)
[(1) - (5) repeated for the required number of stations]
- (7) Last card after all rows contains 999 (1415)

1 - 5

1 - 5

1 - 5

1 - 5

- (1) Card 1. Number of stations to be weighted
(1415) (If none, blank card)
- (2) Card 2.
 - (a) Station number (1415)
 - (b) Weight (E16.8)

1 - 5

1 - 5

6 - 21

Card Set 8:

- *(1) Card 1. (I4, 4X, 3DF16.6)
- (a) First station number of two for fixing of spatial chort (lowest rank of the two) (Blank card if no chord) 1 - 4
 - (b) Three Cartesian rectangular coordinates u, v, w (must be the same values used in forming the normal equations) 16 - 24
25 - 40
41 - 56
- *(2) Card 2. (I4, 4X, 3DF16.6)
- (a) Second station number of two [higher rank than (1) - (a)] 1 - 4
 - (b) As in (1) - (b)
- (Repeat Cards 1 and 2 for the desired number of spatial chords)
- (3) Blank card (not needed if no chord)

Card Set 9:

- (1) Card 1. (I4I5)
The number of comment cards to follow 1 - 5
- (2) Cards 2 - N (I2L6) 2 - 72

*Card Set 10: (I4, 4X, 3DF16.6, 2F7.4)

- (1) Station number 1 - 4
- (2) Three Cartesian coordinates u, v, w 16 - 24
25 - 40
41 - 56
- (3) Latitude and longitude in radians 57 - 63
64 - 70

(Card Set 10 for all stations in the solution)

FOR THE DEPARTMENT OF GEODETIC SCIENCE

Project Supervisor Ivan I. Mueller Date 9.9.68

FOR THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION

Executive Director Robert C. Stephenson Date 9-9-68