NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.
Final Technical Report
Appendix

ANALYTICAL AERIAL TRIANGULATION ERROR ANALYSIS AND APPLICATION OF COMPENSATING EQUATIONS TO THE GENERAL BLOCK TRIANGULATION AND ADJUSTMENT PROGRAM

MARCH 1960 TO FEBRUARY 1962
DEPARTMENT OF THE ARMY TASK NO. 8T35-11-001-05
CONTRACT NO. DA-44-009 ENG 4420

U.S. Army Engineer
Geodesy, Intelligence, and Mapping Research and Development Agency

SCHOOL OF ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge 39, Massachusetts
THE VIEWS CONTAINED HEREIN REPRESENT ONLY THE VIEWS OF THE PREPARING AGENCY AND HAVE NOT BEEN APPROVED BY THE DEPARTMENT OF THE ARMY.

ASTIA AVAILABILITY NOTICE
Qualified requestors may obtain copies of this report from ASTIA.
ANALYTICAL AERIAL TRIANGULATION ERROR ANALYSIS

and

APPLICATION OF COMPENSATING EQUATIONS

to

THE GENERAL BLOCK TRIANGULATION AND ADJUSTMENT PROGRAM.

APPENDIX.

U. S. Army Engineer
Geodesy, Intelligence, and Mapping
Research and Development Agency

CIVIL ENGINEERING SYSTEMS LABORATORY
Department of Civil Engineering
Research Report R6244
Massachusetts Institute of Technology
Cambridge, Massachusetts
These investigations were carried out under the authority contained in Contract No. DA-44-009 ENG 4420, "Analytical Aerial Triangulation Error Analysis and Application of Compensating Equations to the General Block Triangulation Adjustment Program."

The investigation was conducted under the direction of Professor Charles L. Miller and Mr. E. Phillip Gladding, Instructor, Department of Civil Engineering. The investigation was conducted, from March 10, 1960 to March 10, 1962, by Messrs. Luis Andrew R., Ziad M. Elias, and Frank S. Greatorex, Research Assistants in the Department of Civil Engineering. Also contributing to the investigation were Messrs. Daniel R. Schurz, Instructor, Armen Gabrielian, Student Assistant, and Lawrence Kalman, Student Assistant.
ABSTRACT

The objective of the activities reported is to effect improved accuracy in the supplied General Block Triangulation digital computer program through incorporation in the program means of error adjustment and compensation. The first volume of the report presents:

1. The nature of random and systematic errors and the basic techniques for treating their effects as applicable to the analytical photogrammetric problem;

2. The basic least squares method and its incorporation in the computer program;

3. Complete mathematical description of the program;

4. Studies of the nature and effects of the important error sources: lens and camera errors, atmospheric refraction, film distortion;

5. The study of various techniques for the solution of simultaneous equations;

6. Operating instructions; and

7. The results, conclusions, and resulting recommendations of test runs of the final computer program.

The second volume contains appendices which consist of the complete flow charts representing the original and final programs.
ABSTRACT

The objective of the activities reported is to effect improved accuracy in the supplied General Block Triangulation digital computer program through incorporation in the program means of error adjustment and compensation. The first volume of the report presents:

(1) the nature of random and systematic errors and the basic techniques for treating their effects as applicable to the analytical photogrammetric problem;

(2) the basic least squares method and its incorporation in the computer program;

(3) complete mathematical description of the program;

(4) studies of the nature and effects of the important error sources: lens and camera errors, atmospheric refraction, film distortion;

(5) the study of various techniques for the solution of simultaneous equations;

(6) operating instructions; and

(7) the results, conclusions, and resulting recommendations of test runs of the final computer program.

The second volume contains the appendices which consist of the complete flow charts representing the original and final programs.
# TABLE OF CONTENTS

## VOLUME II

| Title Page | i |
| Preface | ii |
| Abstract | iii |
| Table of Contents | iv |
| Flow Chart Outline | v |

**Original IBM 704 Computer Program - Flow Chart**

<table>
<thead>
<tr>
<th>Segment</th>
<th>Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment I</td>
<td>Chain 1</td>
</tr>
<tr>
<td>Segment II</td>
<td>Chain 2</td>
</tr>
<tr>
<td>Segment III</td>
<td>Chain 3</td>
</tr>
</tbody>
</table>

**Additions and Modifications to Original Program - Flow Chart**

<table>
<thead>
<tr>
<th>Segment</th>
<th>Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment 2</td>
<td>Chain 2</td>
</tr>
<tr>
<td>Segment 23</td>
<td>Chain 23</td>
</tr>
</tbody>
</table>
FLOW CHART OUTLINE

Original IBM 704 Computer Program - Flow Chart

Segment I - Chain 1
START - Initializations
Read Control cards: J,P
FILE - Input card read routine
ECARD - Preliminary processing and storing of E-card data
GCARD - Preliminary processing and storing of G-card data
DEXFR - Normal Matrix Bookkeeping
DEXPR - Termination of Segment I - tape writing for Segment II and print outs.

Segment II - Chain 2
CEQBE - Preliminary initializations
CEQES - General exposure station equation forming routine
ESTYT - Test for type of exposure station and transfer to corresponding equation forming routine
ESTYA, ESTYB, ESTYC, ESTYD, ESTYE, ESTYF, ESTYG, and ESTYH - control for forming of equations by exposure station type
CEQST - Scaling and printing of condition equations
MATFR - Form normal equations
EQ11, EQ12, EQ12A, and EQ13 - Conditional equation forming routine
PHXYZ - Exposure station data processing
CEQFA - General ground point data bookkeeping for equation forming
GPTYB, GPTYC, GPTYD, GPTYE, GPTYF, GPTYG, GPTYH, CEQFJ - control for forming of equations by ground point type
SUB1, SUB2, XYZRA - subroutines for computing quantities used in equation forming
TEFCL - Process type A ground point
SUEFX - Process type C ground point
EQ56 - Equation former for ground point equation 56
EQ1 - Equation former for ground point equation 1
EQ2 - Equation former for ground point equation 2
EQ34 - Equation former for ground points equation 34
EQ5 - Equation former for ground point equation 5
EQ6 - Equation former for ground point equation 6
EQ6A - Equation former for ground point equation 6A
EQ7 - Equation former for ground point equation 7
EQ70 - Equation former for ground point equation 70
EQ 101, 102A - Equation former for ground point equations 101, 102, 103
FCVSQ - Compute sum of squares of right hand sides of the normal equations and print normal matrix and constant vector and transfer to Segment III

Segment III - Chain 3

RESEG3 - Initialize for Chebyshev routine
CEBYA, CEBYB, CEBYC, CEBYD, CEBYE, CEBYF, CEQYG - Chebyshev routine for generating initial values for the Steifel iteration method
STEFB, STEFC, STEFD - Steifel solution initializations for execution of Steifel iteration cycle STEFL
STEF, STEFF, STEFG, STEFM, SSDMT, SSDMD, SSDMP - Post Steifel cycle control routines
STEFZ - Non-convergence print out and control routine

SSVAL - Error print out routine

SSEND - Cycle solution print out routine

CHEBY - Routine used in CEBYF

MXV - Routine used in CEBYB

STEFL - Steifel iteration routine used in STEFD

DPMXV - Routine used in STEFL

SEG3B - Initializations for segment 3B

CMRBE - Testing for sufficient convergences of exposure station position vector

CORMR, CORREC, CMPUTE, AYEBEE, BEET, BB, DD, FF - Routines using Steifel solution to correct position vectors and orientation matrices of exposure stations

CMTSX+3, ITERC, SEGTX - Print out and store on magnetic tape corrected position vectors and orientation matrices of every exposure station, and test for transfer to resection computation or to segment 2.

RESBE - Initializations for resection routine

RESTR, LFXYZ, FXMAT, ..., FULL, PRANG, PREST - Computation, storing, and printing out of exposure station position and orientation parameters

GPRES, GPNL, GPCAL, GBCCB - Print out the given ground point coordinates corresponding to different pairs of photographs. Rewind magnetic tape, halt, and transfer to start a new segment 3 iteration if desired.
Additions and Modifications to Original Program - Flow Chart

Segment 2 - Chain 2

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>THX</td>
<td>Formation of T matrix associated with each image point</td>
<td>B1-B3</td>
</tr>
<tr>
<td>FRBWN</td>
<td>Write on magnetic tape condition equation and control data</td>
<td>B3-B5</td>
</tr>
<tr>
<td>CEQST</td>
<td>Print out coefficients of unknowns as in original program. Compute control words defining equation type</td>
<td>B5-B8</td>
</tr>
<tr>
<td>MFALP</td>
<td>Equation 70 tape writing routine</td>
<td>B8-B9</td>
</tr>
<tr>
<td>SUB1</td>
<td>Modified to include computations introduced by changes in conditional equations</td>
<td>B9-B10</td>
</tr>
<tr>
<td>EQ1</td>
<td>Additions to original EQ1</td>
<td>B11-B12</td>
</tr>
<tr>
<td>EQ2</td>
<td>Additions to original EQ2</td>
<td>B13-B17</td>
</tr>
<tr>
<td>EQ34</td>
<td>Additions to original EQ34</td>
<td>B18-B20</td>
</tr>
<tr>
<td>EQ5</td>
<td>Additions to original EQ5</td>
<td>B21-B22</td>
</tr>
<tr>
<td>EQ6</td>
<td>Additions to original EQ6</td>
<td>B23-B25</td>
</tr>
<tr>
<td>EQ6A</td>
<td>Additions to original EQ6A</td>
<td>B26-B28</td>
</tr>
<tr>
<td>EQ7</td>
<td>Additions to original EQ7</td>
<td>B29-B30</td>
</tr>
<tr>
<td>ESTYA</td>
<td>Additions to original ESTYA</td>
<td>B30-B32</td>
</tr>
<tr>
<td>EQ11</td>
<td>Additions to original EQ11</td>
<td>B32</td>
</tr>
<tr>
<td>EQ12</td>
<td>Additions to original EQ12</td>
<td>B32-B33</td>
</tr>
<tr>
<td>EQ12A</td>
<td>Additions to original EQ12A</td>
<td>B33-B34</td>
</tr>
<tr>
<td>EQ13</td>
<td>Additions to original EQ13</td>
<td>B34</td>
</tr>
<tr>
<td>EQ56</td>
<td>Additions to original EQ56</td>
<td>B35-B38</td>
</tr>
<tr>
<td>EQ101</td>
<td>Additions to original EQ101</td>
<td>B39-B40</td>
</tr>
</tbody>
</table>

Segment 23 - Chain 23

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECHO</td>
<td>Read conditional equations from tape</td>
<td>B41-B43</td>
</tr>
<tr>
<td>FRBWN</td>
<td>Weight matrix and normal equation forming and storing routine</td>
<td>B44-B50</td>
</tr>
</tbody>
</table>

* Additions
APPENDIX A

ORIGINAL IBM 704 COMPUTER PROGRAM - FLOW CHART
ANALYTIC AEROTRIANGULATION, JOB

PRINT ON LINE OR TAPE
SWITCH = TAPE

RAW ON
RAW+1 = NO

- (ECLER+11) = XRX

ECLER = 19

AC = GEOID

RAW+2 = AC
AC = RAW+3 = AC

AC = FOCAL

FROM 6H IN AC
AC = STERAD

- (ECLER+24) = XRX

ECLER = 26

AC = EXSTN+11

FROM 20N IN AC
AC = EXSTD

- (ECLER+35) = XRX

- (ECLER+34) = XRX

FILE

"P" CARD

IMAGES IN BUFFER (A1, A2, ...
ARRANGED AC

CL.1 = CL1
CL. 3-12 = RAW
CL. 14-33 = RAW+1
CL. 35-52 = RAW+2
CL. 54-63 = RAW+3
CL. 65-84 = RAW+4
CL. 87-106 = RAW+5
CL. 109-128 = RAW+6
CL. 131-150 = RAW+7
CL. 153-172 = RAW+8
CL. 175-194 = RAW+9

PCARD+1

CHECK TO INSURE CARD WAS A "P" CARD

YES

START

PAGE A1

1

FILE

AC = FOCUS (FOCAL-LENGTH AS A FLOATING PT NUM IN FOCAL) (IS NEGATIVE [-1])

FROM 6H IN AC

AC = STERAD

- (ECLER+24) = XRX

ECLER = 26

AC = EXSTN+11

FROM 20N IN AC

AC = EXSTD

- (ECLER+35) = XRX

- (ECLER+34) = XRX

FILE

"P" CARD

IMAGES IN BUFFER (A1, A2, ...
ARRANGED AC

CL.1 = CL1
CL. 3-12 = RAW
CL. 14-33 = RAW+1
CL. 35-52 = RAW+2
CL. 54-63 = RAW+3
CL. 65-84 = RAW+4
CL. 87-106 = RAW+5
CL. 109-128 = RAW+6
CL. 131-150 = RAW+7
CL. 153-172 = RAW+8
CL. 175-194 = RAW+9

PCARD+1

CHECK TO INSURE CARD WAS A "P" CARD

YES

START

PAGE A1

1
THE NORMAL MATRIX WILL BE \( n \times n \) IN SIZE AND WILL CONTAIN \( n^2 \) \( n \times n \) BLOCKS. THE BASE IS \( 1 \) BLOCK PER PHOTO PLUS \( n^2 \) \( n \times n \) BLOCKS FOR EACH POSSIBLE PAIR. NOW THERE ARE \( n(n-1) \) POSSIBLE PAIRS OF PHOTOS (OR, THINK OF THEM AS OFF-DIAGONAL BLOCKS). SINCE THE NORMAL MATRIX IS SYMMETRICAL, ONE NEEDS ONLY TO WORK ABOUT THE \( n \) DISTINCT BLOCKS AND \( n(n-1) \) OFF-DIAGONAL BLOCKS. FOR THIS PROGRAM

\[ N_{\text{MAX}} = (n^2) \quad n(n-1) = 4980 \]

**EXAMPLE, FOR \( N = 6 \)**

\[ \begin{array}{c|c|c|c|c|c|c}
\hline
N & 1 & 2 & 3 & 4 & 5 & 6 \\
\hline
1 & 2 & 3 & 4 & 5 & 6 & i \\
2 & 1 & 3 & 4 & 5 & 6 & j \\
3 & 1 & 2 & 4 & 5 & 6 & k \\
4 & 1 & 2 & 3 & 5 & 6 & l \\
5 & 1 & 2 & 3 & 4 & 6 & m \\
6 & 1 & 2 & 3 & 4 & 5 & n \\
\hline
\end{array} \]

**NOTATION INSIDE IS FOR MATDex ADDRESSING**

\[ \text{MATDex} = \left[ n-q+1 + \sum_{j=1}^{15} j \right] \]

**M IS MATRIX**

**MATDex - 1 TO MATDex - 4980 COME IN AS ZEROST IF NOT RELAYE TO PROBLEM**

**EXIST WITH SUCCESSIVE JUMPS IN VALUES OF N**

**EXAMPLE, ASSUME MATDex \((19,12,16,9,8,7,5,4,2)\) CONTAIN ZEROS, THEN**

**MATDex - 1**

\[ \begin{align*}
1 & = 36 \\
-2 & = 0 \\
-3 & = 92 \\
-4 & = 0 \\
-5 & = 0 \\
-6 & = 0 \\
-7 & = 0 \\
-8 & = 0 \\
-9 & = 0 \\
-10 & = 0 \\
-11 & = 144 \\
-12 & = 0 \\
-13 & = 0 \\
-14 & = 180 \\
-15 & = 0 \\
\end{align*} \]

**[MATDex - j]_P = MULTIPLES OF 36 (ONLY FOR PERTINENT ODD)**

- PROVIDES A BOOKING SYSTEM FOR STORING THE BLOCKS - GOES BACKWARDS.

**[MATDex - j]_A = NUMBER OF GROUND PTS. CONTRIBUTING TO THIS ODD**

\[ \begin{align*}
36 \cdot N & = (36 \cdot q) \\
4 \cdot AC & = (36 \cdot N + 36 \cdot q) \times (\text{MAX SIZE THIS ODD})
\end{align*} \]
[12]

**EQ 12**

**LONGITUDE (\(L\)) KNOWN**

**FLOATING DONE VIA**

**FLOAT SUBROUTINE**

\[ 2 dR_{xx} + 2 dR_{yy} + 2 dR_{zz} + 2 \cos L_{xx} + 2 \cos L_{yy} + 2 \cos L_{zz} = 2 \times \text{TERM} \]

\[ \text{TERM} = \text{TERM} + 3 \]

\[ X = \text{TERM} + 3 \]

\[ Y = \text{TERM} + 5 \]

\[ Z = \text{TERM} + 7 \]

\[ \text{RES} = 3 - X \]

\[ \text{FLOAT THE AC} \]

\[ X = X_2 \]

\[ \text{YES} \]

\[ X = X_1 \]

\[ \text{YES} \]

\[ X = X_0 \]

\[ \text{NO} \]

\[ X = X_0 \]

\[ \text{RES} = 3 - X \]

\[ \text{FLOAT THE AC} \]

\[ X = X_2 \]

\[ \text{YES} \]

\[ X = X_1 \]

\[ \text{YES} \]

\[ X = X_0 \]

\[ \text{NO} \]

\[ X = X_0 \]
VIA DOT SUBROUTINE
OBTAIN
\( [R_{m1} + E_{m1} + E_{m2}] \)
in AC.

\(-AC + \text{TEMP} + 7 \rightarrow \text{CSQF} + 24\)

REGC \( \rightarrow XRM\)

\(-1 \rightarrow XRM\)

DOT IS ENTERED WITH TWO
VECTORS. 
12a VECTOR IN TEMP + (0,1,2)
24a VECTOR IN TEMP + (3,4,5)
RESULTS IN AC

(SEEN NOTE LAST PAGE)
\( \begin{align*}
\frac{1}{3} \cdot (4R_{m1} + 4R_{m1} + 6R_{m2}) & \rightarrow \text{CSQF} + 24 \text{ [FLOATING]} \end{align*} \)

\[ \text{[12A]} \]

LATITUDE KNOWN \( \phi \)
(10A MORE MINUTES FROM EQUATOR)

\( \text{EQ} \ 12A \)

\( \begin{align*}
XRM \rightarrow \text{REGC} \rightarrow XRM
\end{align*} \)

\( \begin{align*}
\text{MAP} + 3 \rightarrow \text{COMMON} + 4
\end{align*} \)

\( \begin{align*}
\text{EQ}12A + 3 \rightarrow XRM
\end{align*} \)

\( \begin{align*}
\text{GETN} \text{ uses X SQRT places} \frac{3}{8} \text{ in MQ & COMMONS}
\end{align*} \)

\( \begin{align*}
\text{EQ}12A + 5 \rightarrow XRM
\end{align*} \)

\( \begin{align*}
\text{BE}^2 \sin^2 \phi
\end{align*} \)

\( \begin{align*}
(1 - \text{CEQ} + \phi) \text{ FORMED}
\end{align*} \)

\( \begin{align*}
\text{IN AC, IS FLOATED, AND}
\end{align*} \)

\( \begin{align*}
\text{STORED IN COMMON + 11}
\end{align*} \)

\( \begin{align*}
[\text{EQ} + R_{m1}] \text{ IN COMMON + 11}
\end{align*} \)

\( \begin{align*}
\text{FLOATING}
\end{align*} \)

\( \begin{align*}
2 \rightarrow XRM
\end{align*} \)

\( \begin{align*}
12A XRM
\end{align*} \)

\( \begin{align*}
\text{MAP} + 5 \rightarrow XRM
\end{align*} \)

\( \begin{align*}
\text{AC FLOATED}
\end{align*} \)

\( \begin{align*}
\text{AC} \rightarrow \text{COMMON} + 9 \rightarrow XRM
\end{align*} \)

\( \begin{align*}
\text{EQ}12A + 9 \rightarrow \text{AC}
\end{align*} \)

\( \begin{align*}
\text{AC FLOATED}
\end{align*} \)

\( \begin{align*}
\text{AC} \rightarrow \text{COMMON} + 4 \rightarrow XRM
\end{align*} \)

\( \begin{align*}
\text{XR2} \rightarrow \text{XR2}
\end{align*} \)

\( \begin{align*}
\text{AC} \rightarrow \text{MS} + 8
\end{align*} \)

\( \begin{align*}
\text{AC} + 12 \rightarrow \text{ACHA} \rightarrow \text{AC}
\end{align*} \)

\( \begin{align*}
\text{MS} + 8 \rightarrow \text{AC}
\end{align*} \)

\( \begin{align*}
2 \cdot R_{m1} \text{ transferes to CSQF + 8}
\end{align*} \)

\( \begin{align*}
\text{FLOATING}
\end{align*} \)

\( \begin{align*}
2 \cdot R_{m6} \rightarrow \text{CSQF + 9}
\end{align*} \)

\( \begin{align*}
\text{FLOATING}
\end{align*} \)

\( \begin{align*}
V_{c} \rightarrow W
\end{align*} \)

\( \begin{align*}
W \rightarrow V_{c}
\end{align*} \)

A32
\begin{align*}
\text{Flowchart:} \\
\begin{array}{c}
\text{Input: } V_1, V_2 \\
\text{Flow: } AC \rightarrow [\text{CEQCF} + 5 - XR2] \\
\text{IF } XR2 \text{ THEN } \text{NO} \\
\text{ELSE } \text{YES} \\
\text{Flow: } \frac{L + R_{RF}}{L + R_{RF}} \text{ FORMED IN AC, STORED INTO COMMON + 1.7} \\
\text{Flow: } \frac{2(L + R_{RF})}{\tan^2 \theta} \text{ FORMED IN AC, STORED INTO CEQCF + 5} \\
\text{Flow: } (L + R_{RF}) \text{ FORMED IN AC, STORED INTO COMMON + 1.8} \\
\text{Flow: } R_{RF} \text{ FORMED IN AC, STORED IN COMMON + 1.6} \\
\text{Flow: } \frac{(L + R_{RF}) - (R_{RF} + R_{RF})}{(L + R_{RF})} \text{ FORMED IN AC, IS DIVIDED BY LTP7 AND STORED IN CEQCF + 2A} \\
\text{Flow: } 3 \rightarrow XR2 \\
\text{Flow: } (\text{CEQCF} + 6 - XR2) / \text{LTP7} \rightarrow [\text{CEQCF} + 6 - XR2] \\
\text{IF } XR2 \text{ THEN } \text{NO} \\
\text{ELSE } \text{YES} \\
\text{Flow: } \frac{\text{REGC} - XR2}{\text{XR2 - XR2}} \\
\text{Flow: } 1 - XR4 \\
\end{array}
\end{align*}
IF AC is NO OVERFLOW
LTS. ON - TURN OFF

XR4 --- OEX0
XR4 --- OEX8
XR4 --- ORCA
1B --- XR2

[1-XR4] --- AC

[NO STEP (1)]

BUFFY + 12 --- NO

[COMMON (LAST DATA THIS BCP)]

[COMMON (LAST DATA THIS BCP)]

AC --- XR4

[NO (XR4)]

XR4+1 --- XR4
XR4+3 --- XR4
XR4 ORIGINAL

[COMMON + 3 - XR4] --- [DOS+12 - XR2]

[COMMON + 3 - XR4] --- [DOS+12 - XR2]

AMPLER

XR1 --- XR2
XR2 --- AMVC+1
I P U T

X

YES

X2.1 → X2

NO

6 → X2

AZDOT

[CONSTA + 6 - X2] → [TEMP + 6 - X2]

X2.1 → YES

X2.1 → X2

NO

-(AZDOT + 3) → X4

DOT

AC → INPUTO

6 → X2

BYDOT

[CONSTA + 9 - X2] → [TEMP + 9 - X2]

X2.1 → YES

X2.1 → X2

NO

-(BYDOT + 3) → X6

DOT

AC → INPUTO + 1

[\(A^* \cdot A^*\) placed into INPUTO (floating)]

C0DOT

[CONSTA + 15 - X2] → [TEMP + 15 - X2]

X2.1 → YES

X2.1 → X2

NO

-(C0DOT + 31) → X4

DOT

AC → INPUTO + 2

[\(A^* \cdot A^*\) placed into INPUTO + 1 (floating)]

G0DOT

[CONSTA + 21 - X2] → [TEMP + 21 - X2]

X2.1 → YES

X2.1 → X2

K3

6 → X2
\[
\frac{(R_a + R_b + x)^2}{\text{TEMP} + 4} = \frac{(R_a + R_b + x)^2}{\text{TEMP} + 4} - \frac{(R_a + R_b + x)^2}{\text{TEMP} + 4}
\]

\[
\text{EQT}
\]

\[
\text{XAR} \rightarrow \text{REGC}
\]

\[
\text{(-EQT+1) \rightarrow XAR} \quad \text{(SUB1)}
\]

\[
\text{MAPS} \rightarrow \text{COMMON4}
\]

\[
\text{AC FLOATED AND STORED IN TTEE}
\]

\[
\text{COMMON4} \rightarrow \text{AC}
\]

\[
\text{AC IS FLOATED AND STORED IN TEEE}
\]

\[
\text{MAPS} \rightarrow \text{AC}
\]

\[
\text{AC IS FLOATED AND RESULTS IN AC}
\]

\[
\text{AC + TEEE} \rightarrow \text{DENOM}
\]

\[
\text{3} \rightarrow \text{XRI}
\]

\[
\text{XRI} + \text{D20} \rightarrow \text{XRI} \quad \text{(XRI + D20 \rightarrow XRI)}
\]

\[
\text{XRI} + \text{XRI} \rightarrow \text{XRI}
\]

\[
\text{TTEE/\text{DENOM}} \rightarrow \text{MQ} = \frac{3}{(\text{XRI})}
\]
SUMMARY OF EQUATION TO

\[
\left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) \cdot \left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) + \left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) + \left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) = 0
\]

\[\text{NOTE THE /10^6 WORKING FACTOR}\]

\[
\left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) \cdot \left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) + \left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) + \left(\frac{[\text{a}_{1,2} \cdot \text{a}_{2,0} \cdot \text{a}_{0,1} \cdot \text{a}_{1,0}]}{\text{a}_{1,1}}\right) = 0
\]
\[ \text{OECT} = \frac{x}{e} \]

Where \( e \) is a normal equation value.

- **MATHEX** \(\rightarrow\) XRX
- 0 \(\rightarrow\) OECT
- IF OVERT-EXT LT. ON TURN OFF
- SUMR
- [OVERT-EXT] \(\rightarrow\) [OVERT-EXT]
- ORECT \(\rightarrow\) ORECT
- NO
- ORPTION
- NO
- YES
- [SUMR] \(\rightarrow\) XRX
- CLEAR
- PAGE 1/2
- CLEAR (CONT)
- TURN LTS. OFF
- OUT 5 \(\rightarrow\) REMARKS
- 0 \(\rightarrow\) COMMON
- [MATHEX] \(\rightarrow\) COMMON (\(=34(N+4)\))
- [ORECT] \(\rightarrow\) XRX
- PRINT OUT
- "NORMAL MATRIX (N)" "PHOTOS" \([34(N+4)]" ELEMENTS"
- 0 \(\rightarrow\) COMMON
- [MATHEX] \(\rightarrow\) KRI
- PREDIT
- \(N\) \(\rightarrow\) MATHEX
- [KRI] \(\rightarrow\) XRX
- PRINT OUT
- ALL THE NORMAL MATRIX (NON-ZERO BLOCKS) ELEMENTS
- YES
- [KRI] \(\rightarrow\) XRX
- 0 \(\rightarrow\) COMMON
- \(\rightarrow\) COMMON \((=44)\)
- AC \(\rightarrow\) XRI (KRI = 4)
- PRINT OUT
- "VECTOR, ORDER" \((=4)\)
- [KRI] \(\rightarrow\) XRI
- PRINT OUT
- ALL THE APPROPRIATE VALUES \((N)\)
FLOWCHART

STARTING VECTOR

\[
\begin{align*}
\begin{cases}
E & = E' \\
F & = F' \\
G & = G' \\
H & = H' \\
I & = I' \\
J & = J'
\end{cases}
\end{align*}
\]

WHERE A IS MATRIX \( \{ \ldots \} \)

\begin{align*}
& (R \times A) \text{ PLACED INTO DVECT - (LEN TO 1) (FLOATING)} \\
& [E(F^*)] \times \text{DVECT} = 0 \text{ (FLOATING)}
\end{align*}

\begin{align*}
& \text{NUMBER OF CYCLES OF CHEBYSHEV IN CYCLE} \quad \text{(INT)}
\end{align*}

\[ (\text{LEN} = \text{N}) \]
OCTON-AC NO (EOF
CNEr)

FCAQ(AC
-t
-PLCE
14r TR

SA
o~ KqO SS E.OCN 0

PAGE
108

\[ E \frac{v}{g} \text{ placed into TEMP} \]

\[ XRS \rightarrow XRS \text{ (only if all } f_{x} < g \leq c) \]

\[ \text{STEP M} \]

\[ \text{PRINT OUT} \]

"STIEL - CYCLE, MOD OR RESID" (CYCLE) (TEMP)

\[ \text{CYC} \rightarrow \text{AC} \]

\[ \text{CYCLE} \rightarrow \text{MQ} \]

\[ \text{MQ} \rightarrow \text{AC} \]

\[ \text{AC} \rightarrow \text{CYC} \]

\[ \text{TIME FOR STOP} \]

\[ \text{WRITE DATA TO TAPE 149} \]

\[ \text{LOCATIONS LAST TO CYC} \]

\[ \text{PAGE 481} \]
FINAL PRODUCT IS A
$(n+1)$ VECTOR
STORED IN VECT-{$(n+1)$} [MAJOR]
LEVEL-{$(n+1)$} [MINOR]
AC
MQ

AC
NO

12.3
COMM

COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COMMON
COM
APPENDIX B

ADDITIONS AND MODIFICATIONS TO ORIGINAL PROGRAM - FLOW CHART
**Formation of T Matrix**

BUFFY + 15, = M (O7 PHOTO) This SET - STRIP
BUFFY + 15, = M (O8 IMAGES THIS SET - STRIP)
BUFFY + 15, = M (O9 PHOTO) THIS SET - STRIP
BUFFY + 15, = M (O8 IMAGES THIS SET - STRIP 2)
BUFFY + 15, = M (O8 PHOTO) - M ORIGIN

COMMON + I, = M (O8 IMAGES)
COMMON + I, = M (O8 PHOTO) - M ORIGIN

PHOTO = M (O8 IMAGES)

PHOTO = M (O8 PHOTO) - M ORIGIN

O STORED IN TEMP (O TO 17)

X,1 = X,2
X,2 = X,3
X,3 = X,4
X,4 = X,5

M,1 = X,4
M,2 = X,5
M,3 = X,6
M,4 = X,7
M,5 = X,8
M,6 = X,9

M,1 = TEMP + 6
M,2 = TEMP + 4
M,3 = TEMP + 2
M,4 = TEMP + 1
M,5 = TEMP + 3
M,6 = TEMP + 5

M,1 = TEMP + 6
M,2 = TEMP + 4
M,3 = TEMP + 2
M,4 = TEMP + 1
M,5 = TEMP + 3
M,6 = TEMP + 5
CHANGE TO CEQST

WETFR PERFORMS SAME FUNCTION NOW AS IT DID IN THE OLD PROGRAM EXCEPT THAT 32 COEFF. #1 EQ. VALUE ARE DIVIDED BY THE LARGEST COEFF.

PRINT OUT
"COEFF. OF COND. EQ. CALLED FROM" (ABSOLUTE MACHINE ADDRESS) "PHOTO: ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ `_
EQ 70 TAPE WRITING ROUTINE

WRITE ON TAPE B1 AS ONE RECORD (BINARY)

\[
\begin{align*}
\text{TEMP} & \rightarrow 6 \\
\text{TEMP} + 5 & \rightarrow 6 \\
\text{TEMP} + 4 & \rightarrow 6 \\
\text{TEMP} + 3 & \rightarrow 15 \text{ PHOTO} \\
\text{TEMP} + 2 & \rightarrow 15 \text{ PHOTO} \\
\text{COEFF} & \rightarrow 0 \text{ to 25}
\end{align*}
\]

\[
\begin{align*}
\text{TEMP} + 5 & \rightarrow \text{CHECK SUM}
\end{align*}
\]
ADDITIONS TO SUB 1

SUB 1

STENTH

YES

XRO > 0

NO

XRO ≤ 0

YES

BY PASS SWITCH

G ← XRI

[KENST + L7 - XRI] - [TEMP + G - XRI]

[XRI] (1)

YES

XRI - → XRI

NO

-XRI (T)

STENTH + S → XRA

DOT

C/on TRANSFERS TO TEMP + 0

C/lyL x = TEMP + 1

C/la x = TEMP + 2

B/ow x = TEMP + 3

B/ly x = TEMP + 4

B/1 x = TEMP + 5

C/15 x 3 2 in AC
ADDITIONS TO EQ 1

IN CALLING SEQUENCE

PHOTOS
1,2,3,4,5,6,7,8

SQ20A = 15 13 9 7
SQ20B = 13 15 18 12
SQ20C = 16 30 18 12

EQ 1

3 → XRA

1ST LOOP

C4M transferred to TEMP + 3
C3M = TEMP + 4
C2M = TEMP + 5

V ← TEMP, 2

2ND LOOP

C1M transferred to TEMP
C0M = TEMP + 1
C1M = TEMP + 2
C2M = TEMP + 3

AC = C4M + C3M + C1M + C0M

XRA-1 → XRA

 búffy + XRA → XRA-1

DOF

ZGA, → XRA

AC → MD

NG + VI → [GEOF + 26 - XRA]

XRA-1 → XRA

1ST LOOP

C4M transferred to TEMP
C3M = TEMP + 1
C2M = TEMP + 2

2ND LOOP

C1M transferred to TEMP
C0M = TEMP + 1
C1M = TEMP + 2
C2M = TEMP + 3
ADDITIONS TO EQ 2.

EQ 2.

\[ \text{CONST} + 72 \times \text{XR}1 \rightarrow \text{AC} \]

\[ \text{CONST} + 75 \times \text{XR}1 \rightarrow \text{MQ} \]

\[ \text{AC} \rightarrow \text{CONST} + 75 \times \text{XR}1 \]

\[ \text{MQ} \rightarrow \text{CONST} + 72 \times \text{XR}1 \]

\[ X R 1 > 1 \rightarrow \text{YES} \]

\[ X R 1 > 0 \rightarrow \text{XR}1 \rightarrow \text{XR}1 \]

\[ X R 1 < 1 \rightarrow \text{NO} \]

\[ Z \rightarrow \text{XR}2 \]

\[ S \rightarrow \text{XR}1 \]

1ST LOOP

2ND LOOP

\[ \text{STORE} + 2 \times \text{XR}2 \] \rightarrow \text{TEMP} + 3 \times \text{XR}2 \]

\[ \text{CONST} + 73 \times \text{XR}2 \] \rightarrow \text{TEMP} + 4 \times \text{XR}2 \]

\[ \text{XR}2 \rightarrow \text{XR}2 \]

\[ X R 2 \rightarrow X R 2 \]

\[ X R 4 \rightarrow X R 4 \]

\[ \text{DOT} \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]

\[ \text{CONF} + 2 \times \text{XR}4 \] \rightarrow \text{CONF} + 2 \times \text{XR}4 \]
In calling sequence:

<table>
<thead>
<tr>
<th>PHOTO</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQWQ</td>
<td>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WWII</td>
<td>34 33 32 31 30</td>
<td>34 33 32 31 30</td>
<td>34 33 32 31 30</td>
<td>34 33 32 31 30</td>
<td>34 33 32 31 30</td>
</tr>
<tr>
<td>SQWSA</td>
<td>19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOUNG</td>
<td>4 3 2 1 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</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EQ 3, 4**

\[ \text{EQ: } \]

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 5**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 6**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 7**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 8**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 9**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 10**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 11**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 12**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 13**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 14**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 15**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 16**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 17**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]

**EQ 18**

\[ \begin{align*}
\text{AC} & \rightarrow \text{AC} \\
\text{[BUFFER]} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\text{[WRITE]-FLOAT} & \rightarrow \text{AC} \\
\text{[WRITE]-OCT} & \rightarrow \text{AC} \\
\end{align*} \]
ADDENDS TO EQ 6

EQ 6

\[ (D_1 + 18) \cdot \text{SECDF}, 35 \] (EQ 6 VALUE)

\[ 3 \rightarrow XRI \]

\[ \text{LDXL} \]
\[ \text{DELAST} = 3 \cdot XRI \rightarrow \text{TEMP} + 3 \cdot XRI \]
\[ \text{GCONST} = 3 \cdot XRI \rightarrow \text{TEMP} + 6 \cdot XRI \]

\[ \text{IF XRI} \]
\[ \text{YES} \rightarrow \text{XRI} \rightarrow \text{EXIT} \]
\[ \text{NO} \]

\[ -(LMX + 8) \rightarrow XRA \]
\[ \text{DOT} \]

\[ AC \rightarrow \text{WW} + 9 \]

\[ 1 \rightarrow XRA \]
\[ 0 \rightarrow XRA \]
\[ 2 \rightarrow XRA \]

\[ \text{LDXL} \]
\[ \text{BUFFy} = 4 \cdot XRI \rightarrow \text{TEMP} + 4 \cdot XRI \]
\[ \text{XRA} \rightarrow XRL \]

\[ \text{IF XRI} \]
\[ \text{YES} \rightarrow \text{XRI} \rightarrow \text{EXIT} \]
\[ \text{NO} \]

\[ 3 \rightarrow XRI \]

\[ \text{LDXL} \]
\[ \text{MM} + 3 \cdot XRI \rightarrow \text{TEMP} + 6 \cdot XRI \]
\[ \text{XRA} \rightarrow \text{XRI} \]

\[ \text{IF XRI} \]
\[ \text{YES} \rightarrow \text{XRI} \rightarrow \text{EXIT} \]
\[ \text{NO} \]

\[ XRA \rightarrow ZG4 \]

\[ -(LMX + 9) \rightarrow XRA \]
\[ \text{DOT} \]
\[ ZG4 \rightarrow XRA \]

\[ AC \cdot \text{WW} + 9 \rightarrow \text{SECDF}, 35 \cdot XRI \]

\[ 3 \rightarrow XRI \]

\[ D_1 \]
EQ 8, 9, 10

![Flowchart Diagram]
ADDITIONS TO EQ 11

$$\text{EQ 11}$$

$$\text{AC} \rightarrow \text{CEQF + 32}$$  (EQ. VALUE)

$$\text{RES} \times (\text{MAP} + 6) \rightarrow (\text{WW} + 9)$$

$$[\text{RES} + 1] \times (\text{MAP} + 5) \times (\text{WW} + 5) \rightarrow \text{AC}$$

$$\text{AC} \rightarrow \text{CEQF + 130}$$

$$\text{REGC2} \rightarrow \text{XRA}$$

$$1 - \text{XRA}$$

$$R_n \cos \theta \times (\text{EQ.}) \text{ stores in WW + 9}$$

$$R_n \cos \theta = R_m \sin \theta \text{ stores in CEQF + 30 (or d.h.)}$$

ADDITIONS TO EQ 12

$$\text{EQ 12}$$

$$\text{AC} \rightarrow \text{CEQF + 32}$$  (EQ. VALUE)

$$\text{RES} \rightarrow \text{AC}$$

$$\text{RES} \times (\text{PG} + 12) \rightarrow \text{XRA}$$  FLOAT

$$[\text{-AC}] \times \text{CEQF + 4} \rightarrow (\text{WW} + 9)$$

$$\text{RES} + 1 \rightarrow \text{AC}$$

$$-R_{1n} \text{ if true, stores in WW + 9}$$
ADDENDA TO EQ 15

EQ 15

\[ MQ \rightarrow [CEQCF + SE] \quad \text{(w. Q2.VALUE)} \]
\[ -LF \rightarrow CEQCF + 3! \quad \text{-1 STORES IN CEQCF + 3! (w.RH)} \]
\[ REGC \rightarrow XRX \]
\[ \text{(1 - XRA)} \]
AT END OF JOB-E ROUTINE

\[ c_y = c_y + S \times c_0 \]

\[ X_0 = X_e + X \]
DISTRIBUTION LIST

ANALYTICAL AERIAL TRIANGULATION ERROR ANALYSIS AND
APPLICATION OF COMPENSATING EQUATIONS TO
THE GENERAL BLOCK TRIANGULATION AND ADJUSTMENT PROGRAM

FINAL TECHNICAL REPORT
VOLUME 2

Civil Engineering Systems Laboratory
Department of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

Contract No. DA44-009 ENG4420

No. of Copies Received: 49

Copies Distribution

1 Director of Tactical Systems, GIMRADA
2 Photogrammetry Division, GIMRADA
3 Scientific Advisor, GIMRADA
4-13 Data Reduction Branch, GIMRADA
14 OCE Liaison Officer
U. S. Army Combat Developments Experimentation Center
Fort Ord, California

15-16 Commanding Officer
Army Map Service
ATTN: Code 4201
Washington 25, D. C.

17 Inter-American Geodetic Survey Liaison Office
c/o Army Map Service
Washington 25, D. C.

18 The Engineer
Headquarters, USAREUR
ATTN: I&M Branch
Engineer Division
APO 403 New York, New York
19
Commanding Officer
U. S. Army Map Service, Far East
ATTN: Chief, O&P Division
APO 67, San Francisco, California

20
Redstone Scientific Information Center
U. S. Army Missile Command
ATTN: Chief, Document Section
Redstone Arsenal, Alabama

21
Headquarters, U. S. Air Force
ATTN: AFOOP-SV-CG
Washington 25, D. C.

22
Commander
Rome Air Development Center
ATTN: RAWIC - Mr. A. Stringham
Griffiss Air Force Base, New York

23
Commander
Rome Air Development Center
ATTN: RAWIC - Mr. A. S. Zieno
Griffiss Air Force Base, New York

24
Commander
Rome Air Development Center (RAALD)
ATTN: Documents Library
Griffiss Air Force Base, New York

25-26
Headquarters
Aeronautical Chart & Information Center (ACOC)
U. S. Air Force
2nd and Arsenal
St. Louis 18, Missouri

27
Commander
Air Force Cambridge Research Laboratories
ATTN: CRZGG
L. G. Hanscom Field
Bedford, Massachusetts

28-29
Headquarters
Strategic Air Command (DICC)
Offutt Air Force Base, Nebraska
30 Headquarters, Tactical Air Command
   Office of Civil Engineering (CE)
   Langley Air Force Base, Virginia

31 Commander
   544th R Technical Group (RTGTMG)
   Offutt Air Force Base, Nebraska

32 Commander
   Air Proving Ground Center (PGAPI)
   Eglin Air Force Base, Florida

33 Commander
   Aeronautical Systems Division (ASNPRO)
   Wright-Patterson Air Force Base, Ohio

34-43 Armed Services Technical Information Agency
   ATTN: Documents Service Center
   Arlington Hall Station
   Arlington 12, Virginia

44 Chief
   Bureau of Naval Weapons (FFRD-5)
   Department of the Navy
   Washington 25, D. C.

45 Director
   Marine Corps Landing Force Development Center
   Marine Corps Schools
   Quantico, Virginia

46 The Director
   U. S. Geological Survey
   ATTN: Mr. Robert C. Eller
   Department of the Interior
   Washington 25, D. C.

47 Director
   Coast and Geodetic Survey
   Washington 25, D. C.

48 MCLAEB, Chief, Air Force Liaison Office, GIMRADA
   Wright-Patterson Air Force Base, Ohio

49 Mr. R. E. Moore
   Air Survey Section
   Department of Mines and Technical Surveys
   Ottawa 4, Canada
Further information concerning this project may be obtained from Mr. R. D. Esten, Chief, Photogrammetry Division, U. S. Army Engineer Geodesy, Intelligence and Mapping Research and Development Agency, Fort Belvoir, Virginia, telephone EDgewater 9-5500, ext. 62140.