2up

UILU-ENG-74-2004

CIVIL ENGINEERING STUDIES

PHOTOGRAMMETRY SERIES NO. 39

CR 134208

THREED—A COMPUTER PROGRAM FOR THREE DIMENSIONAL TRANSFORMATION OF COORDINATES

(NASA-CR-134208) THREED: A COMPUTER PROGRAM FOR THREE DIMENSIONAL TRANSFORMATION OF COORDINATES Photogrammetry Series No. 39 (Illinois Univ.) ~~112~~ 110 p HC $8.75 CSCL 08B G3/14 N74-20014 Unclas 33467

By

K. W. WONG

A Report on a Study

Sponsored by

NASA-LYNDON B. JOHNSON SPACE CENTER

Contract No. NAS 9-12446

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

URBANA, ILLINOIS

JANUARY 1974

UILU-ENG-74-2004

THREED - A Computer Program for Three Dimensional Transformation of Coordinates

by

Dr. Kam W. Wong
Associate Professor of Civil Engineering

January 1974

A Report on a Study
Sponsored by
NASA - Lyndon B. Johnson Space Center
Contract No. NAS 9-12446

University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

TABLE OF CONTENTS

I. INTRODUCTION

THREED is the code name of a computer program which has been developed for performing absolute orientation by the method of three-dimensional projective transformation. It has the capability of performing complete error analysis on the computed transformation parameters as well as the transformed coordinates.

The accuracy of absolute orientation depends on the following factors:
1) accuracy of the model coordinates,
2) accuracy of the ground controls,
3) density and distribution of control points,
4) size of the area, and
5) scale of the stereo model.

Program THREED was coded in FORTRAN IV computer language for the IBM System 360/75 computer at the University of Illinois at Urbana-Champaign. It may be used to perform any one of the following functions:

1. To perform absolute orientation.

   The program takes as input the model coordinates of a set of model points and the ground coordinates of a group of control points. Both the model and the ground coordinates of the control points can be weighted individually according to their variance-covariance matrices. The program computes the seven transformation parameters (X_T, Y_T, Z_T, ω, ϕ, κ and scale) and their estimated standard errors. The program also transforms the model coordinates of any pass point into the ground reference system and determines the standard errors of the transformed coordinates.

2. To study accuracy of absolute orientation by simulation.

   In simulation application, the program takes as input 1) the ground coordinates of a set of control points; 2) the variances of the ground control coordinates; 3) the variances of the model coordinates; and 4) the scale of the model. The program then generates a set of model coordinates for the given ground points and perturbs them according to the specified accuracy of the model points. It then performs a regular absolute orientation solution and outputs the estimated standard errors of the seven absolute orientation parameters.

3. To determine the uncertainty in the orientation of the surface defined by a set of triangulated pass points.

The direct output of a phototriangulation solution is the ground coordinates of a set of pass points and their standard errors. Program THREED can be used to determine the uncertainty in the orientation (X_T, Y_T, Z_T, ω, ϕ, κ and scale) of the surface defined by the set of pass points. The program takes as input the pass point coordinates and their standard errors. It then generates fictitious ground control coordinates which are translated, rotated and may have different scale with respect to the pass point coordinates. The pass point coordinates are then treated as model coordinates and transformed into the ground system. By assigning very small standard errors to the fictitious ground coorindates, the standard errors of the computed transformation parameters then reflect the uncertainity in the orientation of the surface defined by the set of pass points.

Program THREED was developed for the purpose of a research study on the treatment of control data in lunar phototriangulation. The project was sponsored by NASA - Lyndon B. Johnson Space Center under Contract No. NAS 9-12446. The application of program THREED in studying the accuracy the lunar phototriangulation was reported in the final technical report of this project (1). Nick G. Yacoumelos, presently an Assistant Professor at Lowell Institute of Technology, was the research assistant on this project and was responsible for the coding and testing of program THREED.

2. MATHEMATICAL FORMULATION

The program THREED is based on the equations for three-dimensional projective transformation which are as follows:

---

(1) Wong, K. W., "Treatment of Control Data in Lunar Phototriangulation," Civil Engineering Studies, Photogrammetry Series No. 37, University of Illinois at Urbana-Champaign, Urbana, Illinois, 61801, January 1974.

$$\begin{bmatrix} x_j \\ y_j \\ z_j \end{bmatrix} = \lambda \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \begin{bmatrix} X_j - X_T \\ Y_j - Y_T \\ Z_j - Z_T \end{bmatrix} \tag{2.1}$$

where

x_j, y_j, z_j	model coordinates of point j
X_j, Y_j, Z_j	ground coordinates of point j
X_T, Y_T, Z_T	three translations
λ	scale factor

$m_{11} = \cos\phi \cos\kappa$

$m_{12} = \cos\omega \sin\kappa + \sin\omega \sin\phi \cos\kappa$

$m_{13} = \sin\omega \sin\kappa - \cos\omega \sin\phi \cos\kappa$

$m_{21} = -\cos\phi \sin\kappa$

$m_{22} = \cos\omega \cos\kappa - \sin\omega \sin\phi \sin\kappa$

$m_{23} = \sin\omega \cos\kappa + \cos\omega \sin\phi \sin\kappa$

$m_{31} = \sin\phi$

$m_{32} = -\sin\omega \cos\phi$

$m_{33} = \cos\omega \cos\phi$

After linearization by first-order approximation, Eq. (2.1) may be expressed as follows:

$$\begin{bmatrix} V_{x_j} \\ V_{y_j} \\ V_{z_j} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} & b_{16} & b_{17} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} & b_{26} & b_{27} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} & b_{36} & b_{37} \end{bmatrix} \begin{bmatrix} \Delta X_T \\ \Delta Y_T \\ \Delta Z_T \\ \Delta\omega \\ \Delta\phi \\ \Delta\kappa \\ \Delta\lambda \end{bmatrix} + \begin{bmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{bmatrix} \begin{bmatrix} \Delta X_j \\ \Delta Y_j \\ \Delta Z_j \end{bmatrix} = \begin{bmatrix} \varepsilon_{X_j} \\ \varepsilon_{Y_j} \\ \varepsilon_{Z_j} \end{bmatrix}$$

$$\text{i.e.} \quad \dot{V}_j + \dot{B}_j\dot{\Delta} + \ddot{B}_j\ddot{\Delta}_j = \dot{\varepsilon}_j \tag{2.2}$$

The model coordinates of each control point generates one set of equations as in Eq.(2.2). For m control points, the complete set of observation equations may be expressed as follows:

$$\begin{bmatrix} \dot{V}_1 \\ \dot{V}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{V}_m \end{bmatrix} \begin{bmatrix} \dot{B}_1 \\ \dot{B}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{B}_m \end{bmatrix} \Delta + \begin{bmatrix} \ddot{B}_1 & & & & \\ & \ddot{B}_2 & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & \cdot \\ & & & & & \ddot{B}_m \end{bmatrix} \begin{bmatrix} \ddot{\Delta}_1 \\ \ddot{\Delta}_2 \\ \cdot \\ \cdot \\ \cdot \\ \ddot{\Delta}_m \end{bmatrix} = \begin{bmatrix} \dot{\varepsilon}_1 \\ \dot{\varepsilon}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{\varepsilon}_m \end{bmatrix}$$

i.e. $$\dot{V} + \ddot{B}\Delta + \ddot{\ddot{B}}\ddot{\Delta} = \dot{\varepsilon} \qquad (2.3)$$

In order to permit flexible weighting of the seven transformation parameters as well as the ground control coordinates, one set of observation equations is introduced for each. The set of observation equations for the transformation parameters are as follows:

$$\begin{aligned}
\ddot{V}_{X_T} - \Delta X_T &= X_T^o - X_T^{oo} \\
\ddot{V}_{Y_T} - \Delta Y_T &= Y_T^o - Y_T^{oo} \\
\ddot{V}_{Z_T} - \Delta Z_T &= Z_T^o - Z_T^{oo} \\
\ddot{V}_{\omega} - \Delta\omega &= \omega^o - \omega^{oo} \\
\ddot{V}_{\phi} - \Delta\phi &= \phi^o - \phi^{oo} \\
\ddot{V}_{\kappa} - \Delta\kappa &= \kappa^o - \kappa^{oo} \\
\ddot{V}_{\lambda} - \Delta\lambda &= \lambda^o - \lambda^{oo}
\end{aligned}$$

where X_T^o, Y_T^o, ... and λ^o are approximated parameters; and X_T^{oo}, Y_T^{oo}, ... and λ^{oo} are measured parameters. In matrix notation, this set of equations may be simply written as follows:

$$\underset{(7,1)}{\ddot{V}} - \underset{(7,1)}{\dot{\Delta}} = \underset{(7,1)}{\ddot{\varepsilon}} \qquad (2.4)$$

The observation equations for the jth ground control point are as follows:

$$\begin{bmatrix} \dddot{V}_{X_j} \\ \dddot{V}_{Y_j} \\ \dddot{V}_{Z_j} \end{bmatrix} - \begin{bmatrix} X_j \\ Y_j \\ Z_j \end{bmatrix} = \begin{bmatrix} X_j^o - X_j^{oo} \\ Y_j^o - Y_j^{oo} \\ Z_j^o - Z_j^{oo} \end{bmatrix} \tag{2.5}$$

Again, the superscript (o) denotes approximation parameters and the superscript (oo) denotes measured parameters. Equation (4.5) may be simply written as

$$\dddot{V}_j - \ddot{\Delta}_j = \dddot{\varepsilon}_j$$

The complete set of observation equations for all control points are as follows:

$$\begin{bmatrix} \dddot{V}_1 \\ \dddot{V}_2 \\ \cdot \\ \cdot \\ \vdots \\ \dddot{V}_m \end{bmatrix} - \begin{bmatrix} \ddot{\Delta}_1 \\ \ddot{\Delta}_2 \\ \cdot \\ \cdot \\ \vdots \\ \ddot{\Delta}_m \end{bmatrix} = \begin{bmatrix} \dddot{\varepsilon}_1 \\ \dddot{\varepsilon}_2 \\ \cdot \\ \cdot \\ \vdots \\ \dddot{\varepsilon}_m \end{bmatrix}$$

i.e. $$\dddot{V} - \ddot{\Delta} = \dddot{\varepsilon} \tag{2.6}$$

Combining Eqs. (2.3), (2.4) and (2.6) yields the following observation model:

$$\begin{bmatrix} \dot{V} \\ \ddot{V} \\ \dddot{V} \end{bmatrix} + \begin{bmatrix} \dot{B} & \ddot{B} \\ -I & 0 \\ 0 & -I \end{bmatrix} \begin{bmatrix} \dot{\Delta} \\ \\ \ddot{\Delta} \end{bmatrix} = \begin{bmatrix} \dot{\varepsilon} \\ \ddot{\varepsilon} \\ \dddot{\varepsilon} \end{bmatrix}$$

i.e. $$V + B\Delta = C \tag{2.7}$$

The normal equation is then as follows:

$$(B^TWB)\Delta = B^TWC \tag{2.8}$$

where W is the weight matrix for the observations. An iterative solution procedure must be followed. An initial set of approximate values is assigned to all unknown transformations parameters. The solution solved for the corrections and then apply the corrections to the approximations. The solution is iterated until a stable solution is reached.

After the last iteration, the variance-covariance matrix (σ_T) of the computed transformation parameters is computed by the following expression:

$$\sigma_T = \sigma_o^2 (B^T W B)^{-1} \tag{2.9}$$

where σ_o^2 is the variance of unit weight. The ground coordinates of all other model points and the corresponding standard errors are computed by the following expressions:

$$X_j = \frac{1}{\lambda} (m_{11}x_j + m_{21}y_j + m_{31}z_j) + X_T$$

$$Y_j = \frac{1}{\lambda} (m_{12}x_j + m_{22}y_j + m_{32}z_j) + Y_T$$

$$Z_j = \frac{1}{\lambda} (m_{13}x_j + m_{23}y_j + m_{33}z_j) + Z_T$$

$$\begin{aligned}
{\sigma_{X_j}}^2 = {} & (m_{11}x_j + m_{21}y_j + m_{31}z_j)^2 \lambda^{-4} {\sigma_{\lambda_j}}^2 \\
& + [-(\sin\phi\cos\kappa)x_j + (\sin\phi\sin\kappa)y_j + \cos\phi z_j]^2 \lambda^{-2} {\sigma_\phi}^2 \\
& + [-\cos\phi\sin\kappa x_j - \cos\phi\cos\kappa y_j]^2 \lambda^{-2} {\sigma_\kappa}^2 \\
& + m_{11}^2 \lambda^{-2} {\sigma_{X_j}}^2 + m_{21}^2 \lambda^{-2} {\sigma_{Y_j}}^2 + m_{31}^2 \lambda^{-2} {\sigma_{Z_j}}^2 + {\sigma_{X_T}}^2
\end{aligned}$$

$$\begin{aligned}
{Y_j}^2 = {} & (m_{12}x_j + m_{22}y_j + m_{32}z_j)^2 \lambda^{-4} {\sigma_{\lambda_j}}^2 \\
& + [(-\sin\omega\sin\kappa + \cos\omega\sin\phi\cos\kappa)x_j + (-\sin\omega\cos\kappa - \cos\omega\sin\phi\sin\kappa)y_j \\
& - \cos\omega\cos\phi z_j]^2 \lambda^{-2} {\sigma_\omega}^2 \\
& + [(\sin\omega\cos\phi\cos\kappa)x_j - (\sin\omega\cos\phi\sin\kappa)y_j + \sin\omega\sin\phi z_j]^2 \lambda^{-2} {\sigma_\phi}^2
\end{aligned}$$

$$+ [(\cos\omega\cos\kappa - \sin\omega\sin\phi\sin\kappa)x_j - (\cos\omega\sin\kappa + \sin\omega\sin\phi\cos\kappa)y_j]^2\lambda^{-2}\sigma_\kappa^{\ 2}$$

$$+ m_{12}^2\lambda^{-2}\sigma_{X_j}^{\ 2} + m_{22}^2\lambda^{-2}\sigma_{Y_j}^{\ 2} + m_{32}^2\lambda^{-2}\sigma_{Z_j}^{\ 2} + \sigma_{Y_T}^{\ 2}$$

$$\sigma_{Z_j}^{\ 2} = (m_{13}x_j + m_{23}y_j + m_{33}z_j)^2\lambda^{-4}\sigma_\lambda^{\ 2}$$

$$+ [(\cos\omega\sin\kappa + \sin\omega\sin\phi\cos\kappa)x_j + (\cos\omega\cos\kappa - \sin\omega\sin\phi\sin\kappa)y_j$$

$$- \sin\omega\cos\phi z_j]^2\lambda^{-2}\sigma_\omega^{\ 2}$$

$$+ [(-\cos\omega\cos\phi\cos\kappa)x_j + (\cos\omega\cos\phi\sin\kappa)y_j - \cos\omega\sin\phi z_j]^2\lambda^{-2}\sigma_\phi^{\ 2}$$

$$+ [(\sin\omega\cos\kappa + \cos\omega\sin\phi\sin\kappa)x_j + (-\sin\omega\sin\kappa + \cos\omega\sin\phi\cos\kappa)y_j]^2\lambda^{-2}\sigma_\kappa^{\ 2}$$

$$+ m_{13}^2\lambda^{-2}\sigma_{X_j}^{\ 2} + m_{23}^2\lambda^{-2}\sigma_{Y_j}^{\ 2} + m_{33}^2\lambda^{-2}\sigma_{Z_j}^{\ 2} + \sigma_{Z_T}^{\ 2} \qquad (2.10)$$

The m_{ij} terms in the above equations are defined as in Eq. (2.1).

3. INSTRUCTION FOR DATA INPUT

The first three cards in the data deck are the same for all three applications of the program THREED. These cards are specified as follows:

Card 1. Parameter CArd (6I10)

Col.

1-10 JJ To specify type of problem

= 1 to study accuracy of absolute orientation by simulation

= 2 to perform absolute orientation

= 3 to determine uncertainty in the orientation of a surface defined by a set of triangulated pass points.

11-20	NP	Total number of points in the model, including both control points and points to be transformed into the ground reference system.
21-30	NCP	Number of control points, i.e. points for which the model and ground coordinates are both known.
31-40	MAXITR	Maximum number of iterations allowed.
41-50	JPRINT	= 0 Full variance-covariance matrix to be input for ground coordinates. = 1 Diagonal elements of variance-covariance matrix to be input for ground coordinates
51-60	IPRINT	= 0 Full variance-covariance matrix to be input for model coordinates = 1 Diagonal elements of variance-covariance matrix to be input for model coordinates

Card 2. (F20.10)

Col.

1-20	SIGO	Standard error of unit weight

Card 3. Variances of Input Transformation Parameters (7E10.3)

Col.

1-10	σ^2_{scale}	Variance of input scale
11-20	$\sigma^2_{X_T}$	Variance of X-translation
21-30	$\sigma^2_{Y_T}$	Variance of Y-translation
31-40	$\sigma^2_{Z_T}$	Variance of Z-translation
41-50	σ^2_{ω}	Variance of ω-rotation
51-60	σ^2_{ϕ}	Variance of ϕ-rotation
61-70	σ^2_{κ}	Variance of κ-rotation

The contents of the remaining input cards will depend on the purpose for which program THREED is to be used. The input data format for the three different applications of the program will be described separately on the following sections.

3.1 To Perform Absolute Orientation (JJ = 2 in Card 1)

Subroutine INPUT2 governs the data input for this application.

Card 4. ID numbers of the four corner control points (4I10)

Col.		
1-10	N1	A control point located at the upper left-hand corner of the area
11-20	N2	A control point at the upper right-hand corner
21-30	N3	A control point at the lower right-hand corner
31-40	N4	A control point at the lower left-hand corner

These control points will be used by the program to compute preliminary approximations to the transformation parameters.

Card 5 Sequence. Ground Coordinates of the Control Points (I5,3F15.3)

There should be one card for each control point giving a total of NCP cards in this sequence, with NCP being specified in Card 1 of the deck.

Col.		
1-5	ID	ID number of control point
6-20	X	X-coordinate
21-35	Y	Y-coordinate
36-50	Z	Z-coordinate

Card 6 Sequence. Model Coordinates of All Points (I5,F16.3,F14.3,F15.3,28X,I2)

There should be one card for each model point giving a total of NP cards in this sequence.

Col.

1-5	ID	ID number of model point
6-21	x	x-coordinate
22-35	y	y-coordinate
36-50	z	z-coordinate
79-80	II	= 1 if this is the last card in the sequence.

Card 7 Sequence. Variance-covariance Matrix of the Ground Coordinates (I5,9E8.2,I3)

There should be one card for each ground control point giving a total of NCP cards in this sequence.

Col.

1-5	ID	ID number of control point
6-13	σ_X^2	
14-21	σ_{XY}	
22-29	σ_{XZ}	
30-37	σ_{XY}	
38-45	σ_Y^2	
46-53	σ_{YZ}	
54-61	σ_{XZ}	
62-69	σ_{YZ}	
70-78	σ_Z^2	
79-80	II	= 1 for last card in the sequence

Card 8 Sequence. Variance-Covariance Matrix of Model Coordiantes (I5,9E8.2,I3)

There should be one card for each model point, and a total of NP cards. Same format description as in the Card 7 Sequence.

3.2 To Study Accuracy of Absolute Orientation by Simulation (JJ = 1 in Card 1)

Subroutine INPUT1 governs the data input for this application.

Card 4. Parameter Card
(F10.5,I10)

Col.		
1-10	GSCAL	Scale of model coordinates with respect to ground coordinates
11-20	IAREXP	Integer power of 10 which multiplies input ground coordinates to give the desired dimension on the ground coordinates for the purpose of simulation.

The factor IAREXP provides a means of varying the dimension of the area without having to change the input ground coordinates. For example, by letting IAREXP = 2, the program multiplies all input ground coordinates in Card 5 sequence below by a factor of 10^2.

Card 5 Sequence. Ground Coordinates of Data Points (3F15.5)

Each card will define the approximate location of one point. There should be NP cards in this sequence, with NP being specified in Card 1.

Col.		
1-15	X	X-coordinate
16-30	Y	Y-coordinate
31-45	Z	Z-coordinate

Card 6. Variances of the Model Coordinates (3E10.3)

Col.	
1-10	σ_x^2
11-20	σ_y^2
21-30	σ_z^2

These variances will be used to compute the weights for the model coordinates (x, y, z).

Card 7. Variances of the Ground Control Coordinates (3E10.3)

Col.	
1-10	σ_X^2
11-20	σ_Y^2
21-30	σ_Z^2

These variances will be used to compute the weights of the ground control coordinates.

Card 8. Translations and Rotations of Model Coordinates with Resepct to Ground Coordinates (10X,6F10.5)

Col.		
11-20	XC	X-translation
21-30	YC	Y-translation
31-40	ZC	Z-translation
41-50	OME	ω-rotation
51-60	PHI	ϕ-rotation
61-70	CAPA	κ-rotation

The ground coordinates given in Card 5 sequence above will be translated and rotated according to these factors to generate the fictitious model coordinates (x, y, z).

Card 9. Seeds and Standard Deviations for the Random Realignment of the Ground Coordinates 2(I10,F15.5)

Col.		
1-10	IX1	A seed number for generating random numbers. It should be an odd integer with up to 9 digits.
11-25	S1	Standard deviation of the random perturbation to be applied to the X and Y coordinates of the ground controls.
26-35	IX2	A second seed number
36-50	S2	Standard deviation of the random perturbation to be applied to the Z-coordinates of the ground controls.

The ground coordinates in Card 5 sequence are perturbed by the above standard deviations to derive the ground control coordinates for the simulation. These perturbations serve to create a slightly irregular pattern to the distribution of the ground controls.

Card 10. Seeds for the Perturbation of Model and Ground Coordinates (6I10)

Col.

1-10	IX3
11-20	IX4
21-30	IX5
31-40	IX6
41-50	IX7
51-60	IX8

These seed numbers will be used to generate random perturbations to the model and ground coordinates in the simulation. These perturbations represent random errors in the measurements of the model and ground coordinates. They will follow a normal distribution with the variances defined in cards 6 and 7 above.

Card 11. Perturbations of the Seven Transformation Parameters (7F10.6)

Col.

1-10	DSCAL	Scale perturbation
11-20	DXC	X-translation perturbation
21-30	DYC	Y-translation perturbation
31-40	DZC	Z-translation perturbation
41-50	DOME	ω-rotation perturbation
51-60	DPHI	ϕ-rotation perturbation
61-70	DCAPA	κ-rotation perturbation

These perturbations are applied to the true values of the transformation parameters to derive realistic initial approximations to these parameters.

3.3 To Determine the Uncertainty in the Orientation of the Surface Defined By a Set of Triangulated Pass Points. (JJ = 3 in Card 1)

Card 4. Four seed numbers (4I10)

Col.

1-10	IX1
11-20	IX2
21-30	IX3
31-40	IX4

All seed numbers must be odd integers with up to 9 digits.

Card 5 Sequence. Pass point coordinates from triangulation solution (I10,3F15.2)

There should be one card for each pass point, and a total of NP (=NCP) cards with NP being specified in Card 1.

Col.		
1-10	ID	ID number of pass point
11-25	x	x-coordinate
26-40	y	y-coordinate
41-55	z	z-coordinate

Card 6 Sequence. Standard errors of pass point coordinates (I10,3F20.10,8X,I2)

There should be one card for each of the pass points in the card 5 sequence above.

Col.		
1-10	ID	ID number of pass point
11-30	σ_x	
31-50	σ_y	
51-70	σ_z	
79-80	II	= 1 to indicate last card in this sequence

Card 7. Mean and standard deviation for the rotation parameters (2F10.5)

Col.		
1-10	DEG1	Mean rotations (ω,ϕ and κ) in radians to be applied to the fictitious ground coordinates
11-20	DEG2	Standard deviation within which a random perturbation is to be generated for each of the ω, ϕ and κ rotations.

The parameters DEG1 and DEG2 define the distribution from which fictitious values are generated for the three rotations ω, ϕ and κ. A set of fictitious ground control coordinates will be generated to have such rotations with respect to the pass point coordinates in card sequence 5.

Card 8. Mean and standard deviation for the translation parameters. (2F10.5)

Col.		
1-10	ATRA	Mean translations in X, Y and Z
11-20	DTRA	Standard deviation of the random perturbations

These parameters are used to generate fictitious translations.

Card 9. Mean and deviation of the model scale. (2F10.5)

Col.

1-10 ASCAL Mean scale

11-20 DSCAL Standard deviation of random perturbation.

Card 10. Variances of the ground coordinates 3(E10.3,5X)

Col.

1-10 σ_X^2

11-20 σ_Y^2

21-30 σ_Z^2

These parameters should be assigned very small values, e.g. $\sigma_X^2 = \sigma_Y^2 = \sigma_Z^2 = 1.000$ E-10.

3.4 CONTROL CARDS USAGE

3.4.1 CONTROL CARDS TO LOAD THREED ON DISK

```
/*ID TIME=(2,00),LINES=4000,IOREQ=4000,REGION=300K
// EXEC  DUMMY
//B DD UNIT=DISK,VOL=SER=UIUSR4,DSN=USER.P4677.THREED,
//              DISP=(,CATLG),SPACE=(TRK,(30,5,2))
// EXEC FORT,REGION=250K
//FORT.SYSIN    DD   *

*****  SOURCE DECK *****

/*
// EXEC LKGOFORT,GOFILE="USER.P4677.THREED(THREED)",REGION.GO=250K
//GO.SYSIN DD *

***** TEST DATA SET *****

/*
```

3.4.2 CONTROL CARDS TO USE THREED FROM DISK

```
/*ID TIME=(1,0),LINES=1000,REGION=232K
// EXEC PROGFORT,PROG=THREED,REGION=232K
//STEPLIB  DD  DSN=USER.P4677.THREED,DISP=SHR
//GO.SYSIN  DD  *

***** DATA SET *****

/*
```

3.4.3 CONTROL CARDS TO UPDATE THREED ON DISK

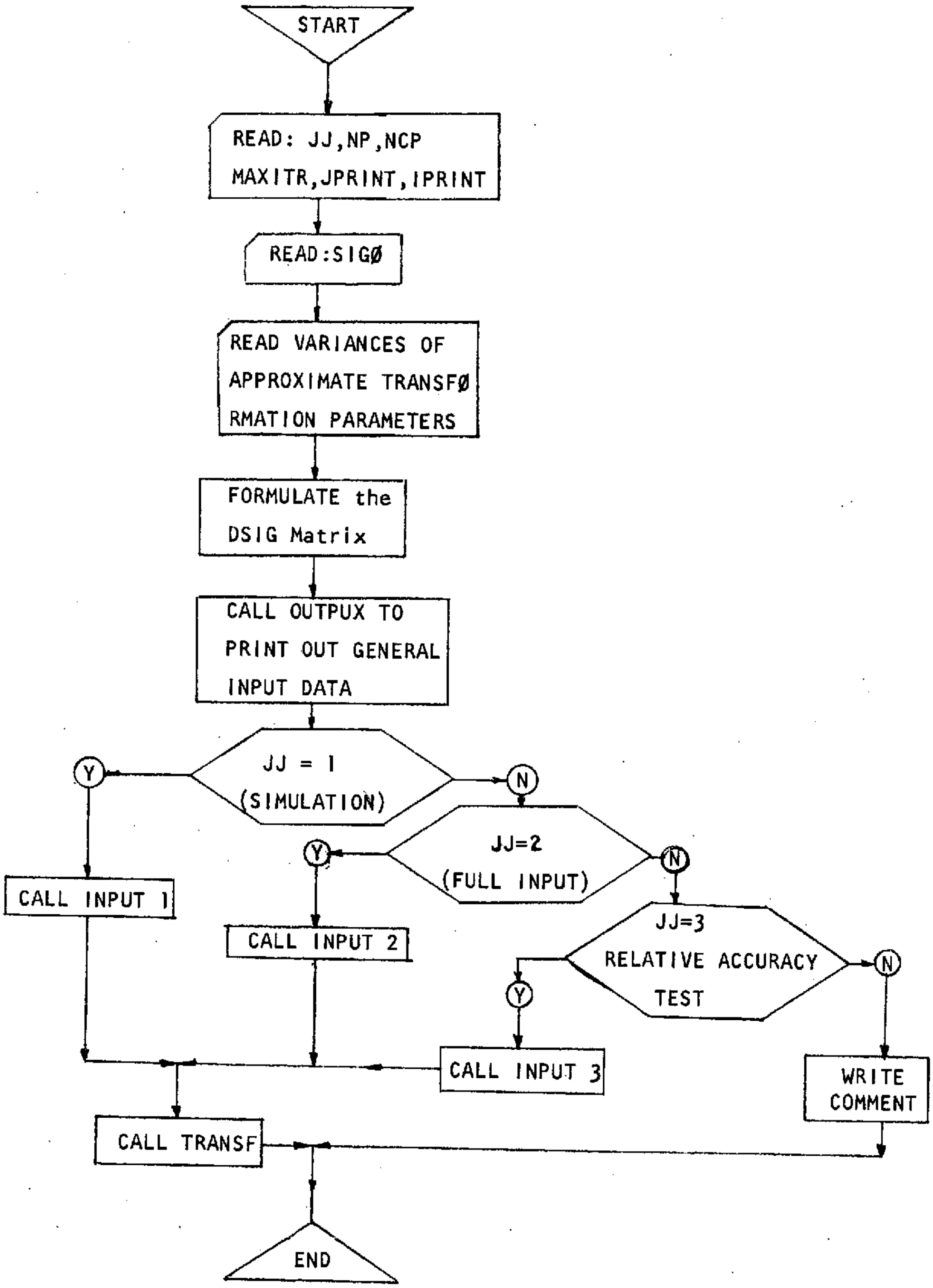
```
/*ID TIME=(1,00),LINES=1500,REGION=250K
// EXEC FORT,REGION=250K
//FORT.SYSIN DD *

***** REVISED SUBROUTINES *****

/*
// EXEC LKGOFORT,GOFILE="USER.P4677.THREED"
//LKED.SYSIN DD *
   INCLUDE SYSLMOD(THREED)
   ENTRY MAIN
   NAME THREED(R)
/*
//  EXEC COMPRESS
//SYSPDS  DD  DSN=USER.P4677.THREED,DISP=OLD
/*
```

3.4.4 CONTROL CARDS TO RUN THREED WITH SOURCE DECK

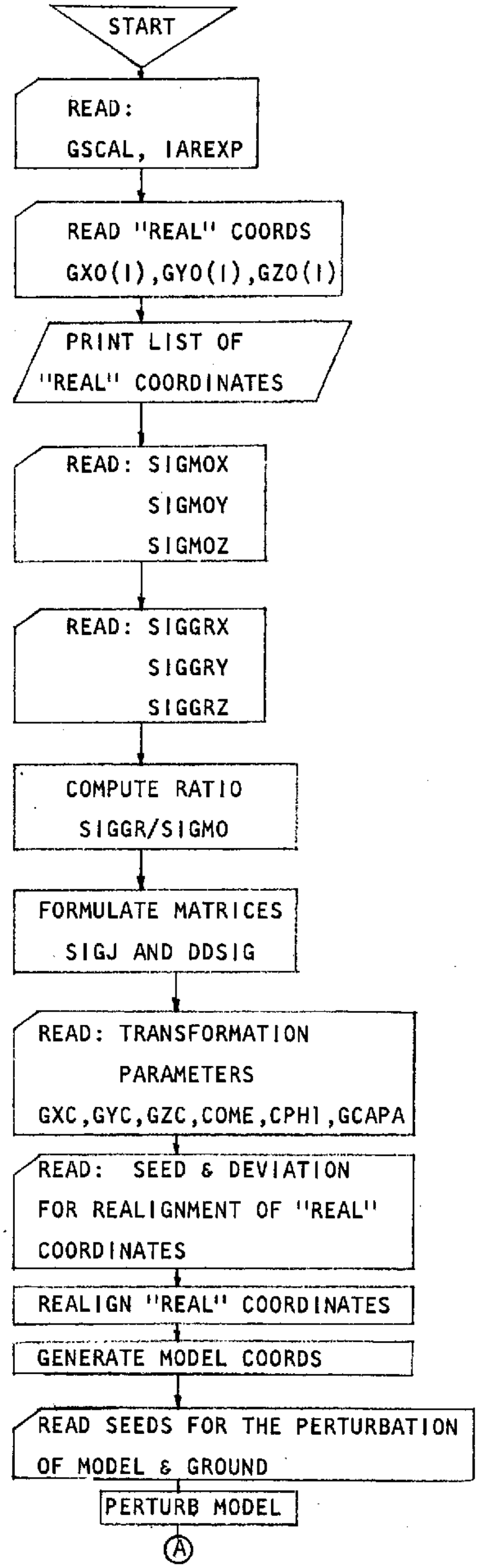
```
/*ID TIME=(1,0),LINES=1000,REGION=232K
// EXEC FORTLDGO,PARM.FORT="NOSOURCE,NOMAP",REGION.GO=232K
//FORT.SYSIN  DD  *

***** SOURCE DECK *****

/*
//GO.SYSIN  DD  *

***** DATA SET *****

/*
```

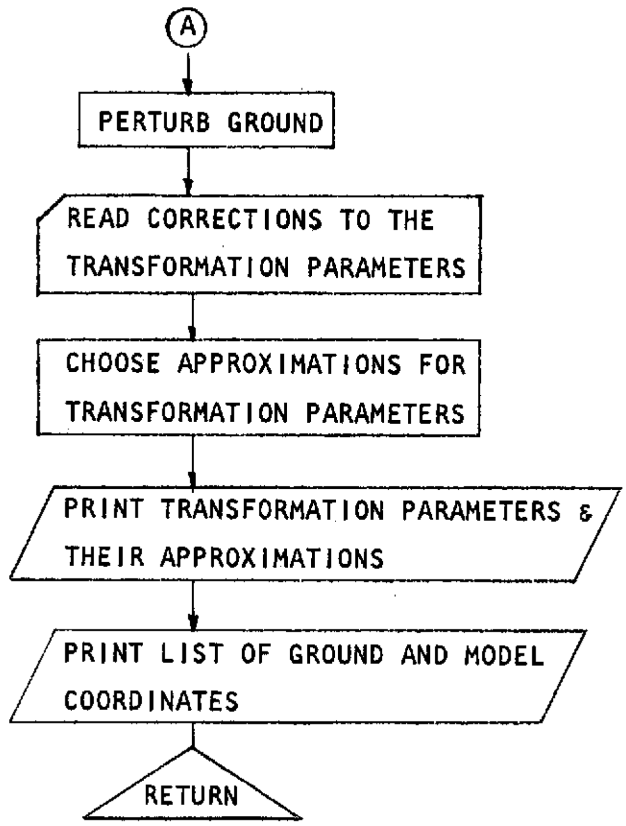
4. FLOW CHARTS

4.1 Flow chart of THREED-MAIN

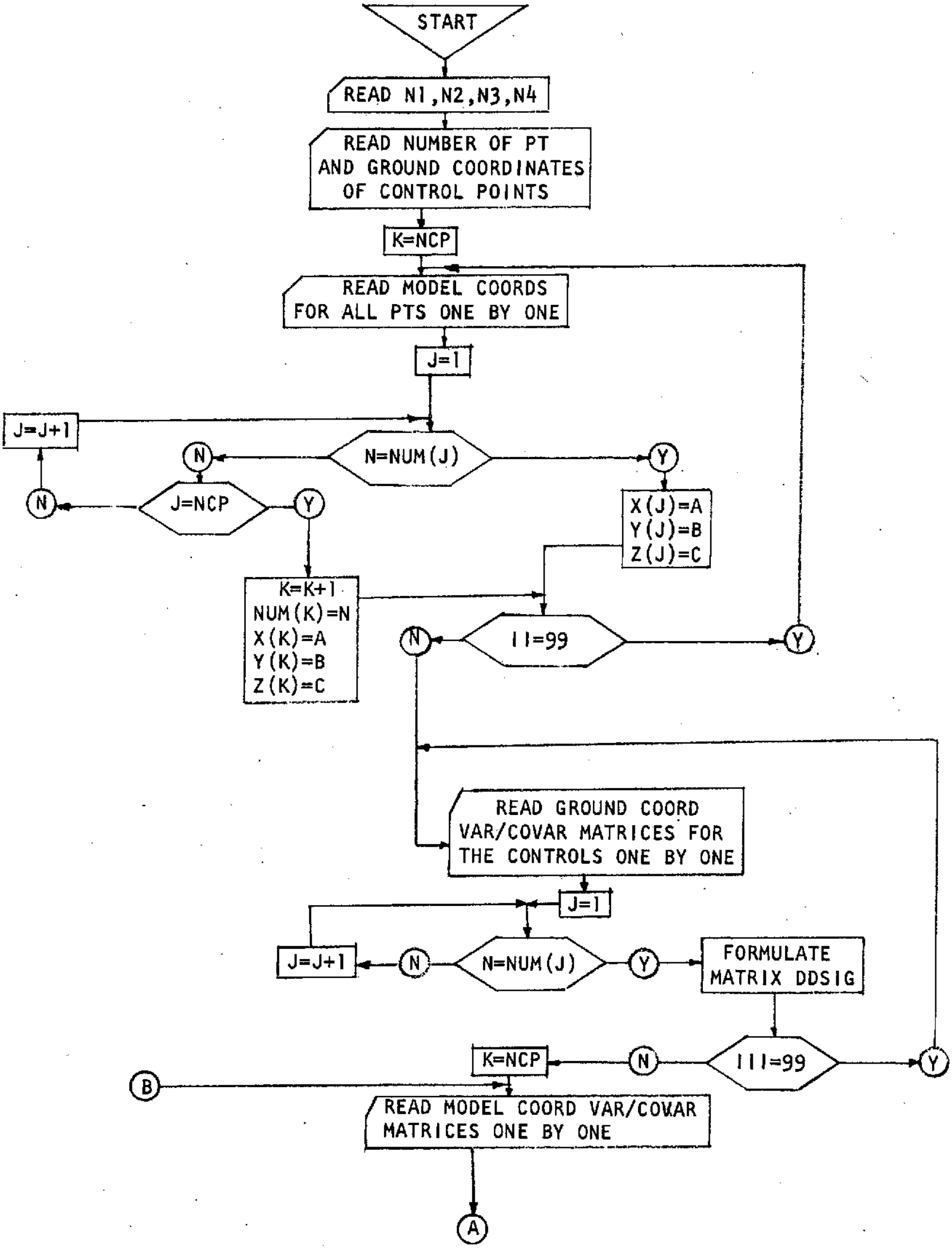


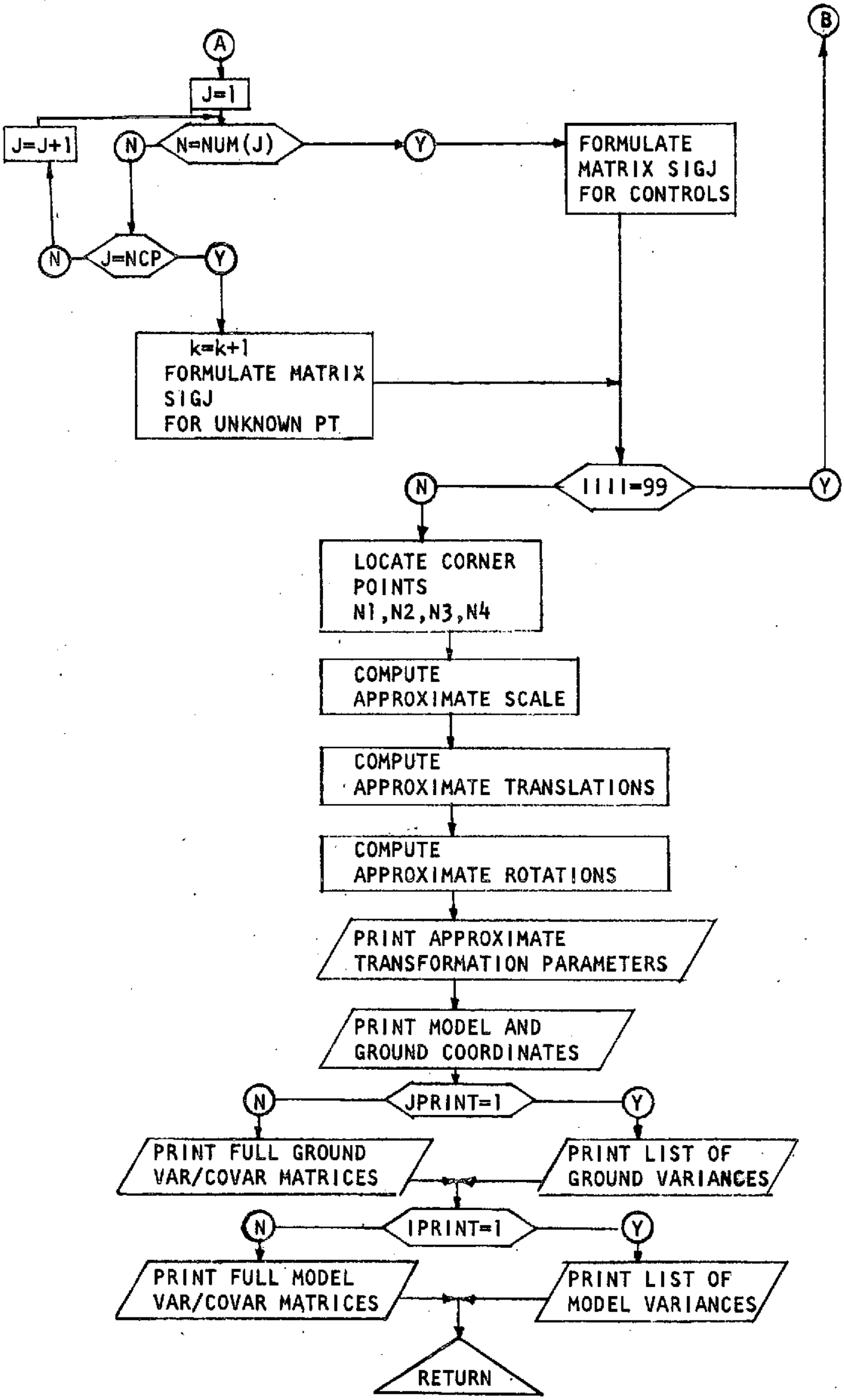
4.2 Flow chart of INPUT1



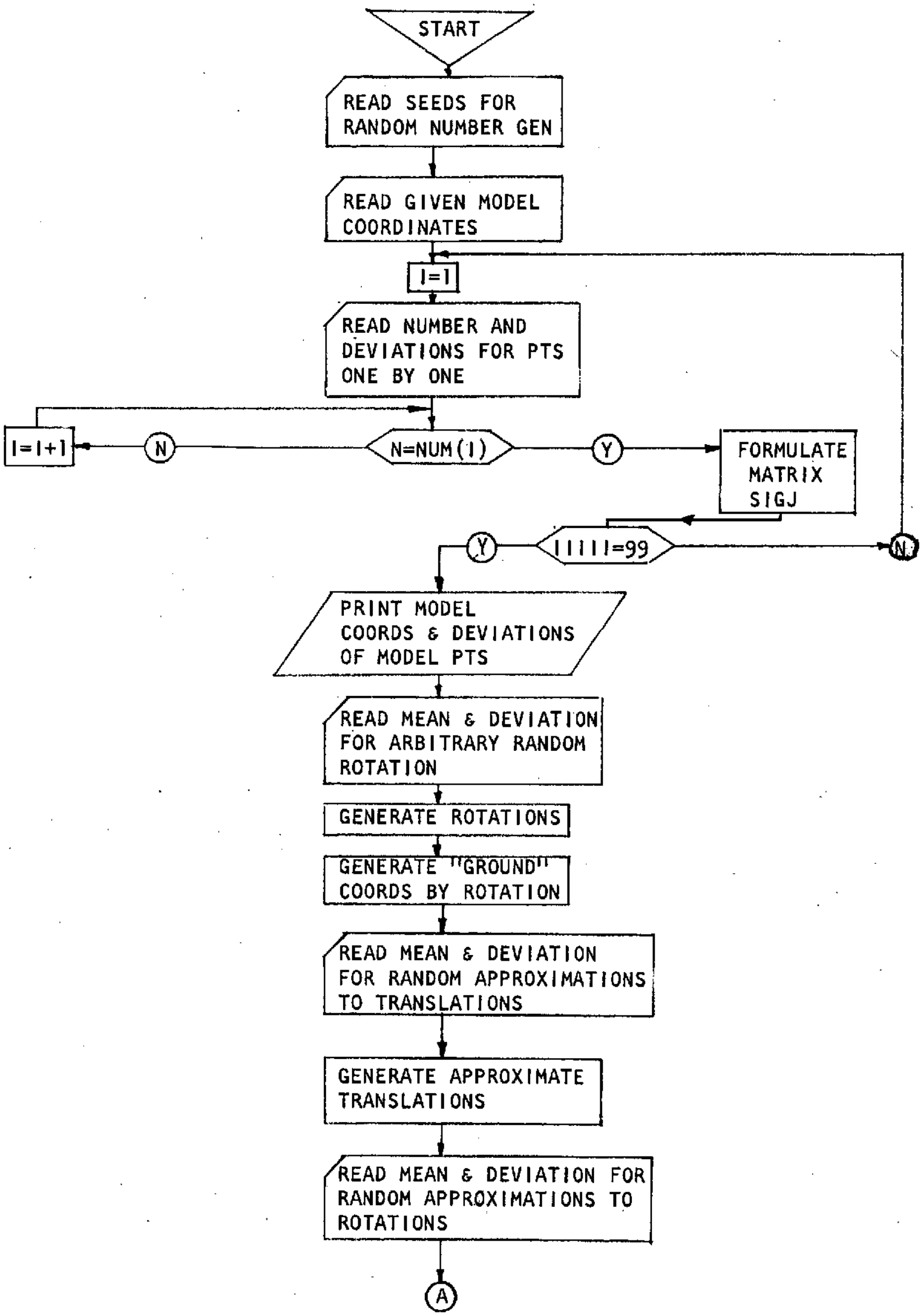

A
PERTURB GROUND
READ CORRECTIONS TO THE TRANSFORMATION PARAMETERS
CHOOSE APPROXIMATIONS FOR TRANSFORMATION PARAMETERS
PRINT TRANSFORMATION PARAMETERS & THEIR APPROXIMATIONS
PRINT LIST OF GROUND AND MODEL COORDINATES
RETURN

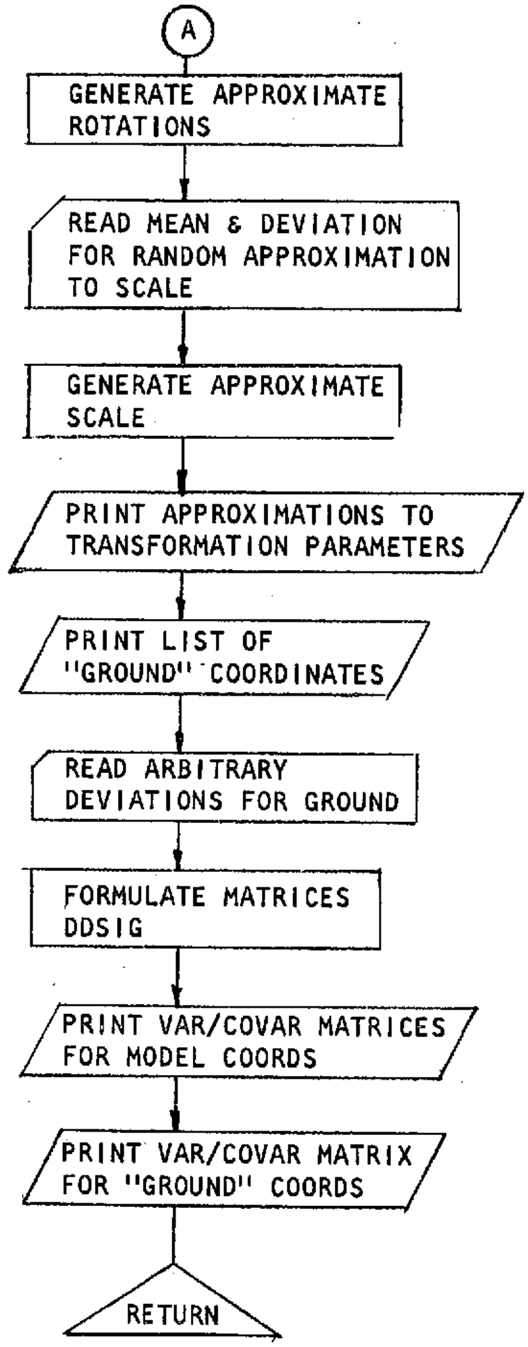
4.3 Flow chart of INPUT2



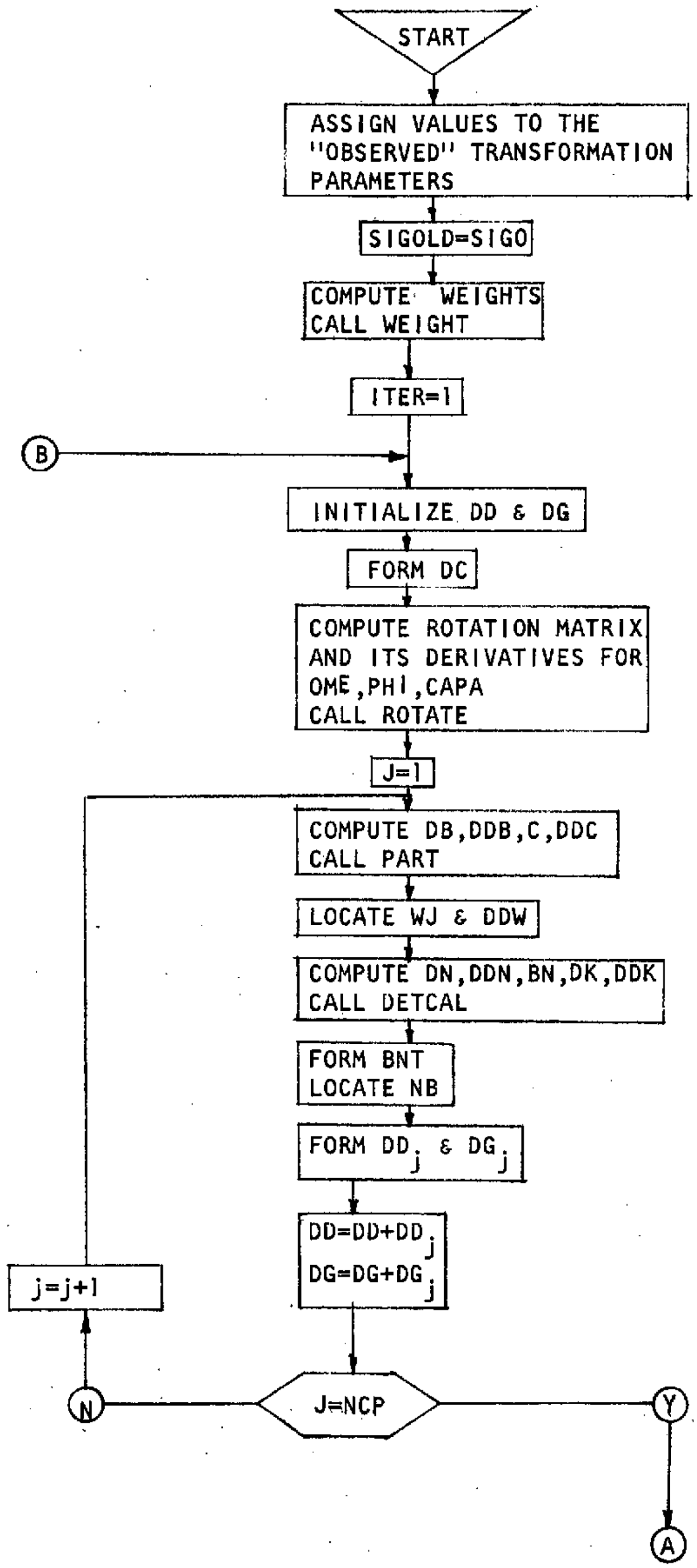

A
B
J=1
J=J+1
N
N=NUM(J)
Y
FORMULATE MATRIX SIGJ FOR CONTROLS
N
J=NCP
Y
k=k+1
FORMULATE MATRIX SIGJ FOR UNKNOWN PT
N
IIII=99
Y
LOCATE CORNER POINTS N1,N2,N3,N4
COMPUTE APPROXIMATE SCALE
COMPUTE APPROXIMATE TRANSLATIONS
COMPUTE APPROXIMATE ROTATIONS
PRINT APPROXIMATE TRANSFORMATION PARAMETERS
PRINT MODEL AND GROUND COORDINATES
N
JPRINT=1
Y
PRINT FULL GROUND VAR/COVAR MATRICES
PRINT LIST OF GROUND VARIANCES
N
IPRINT=1
Y
PRINT FULL MODEL VAR/COVAR MATRICES
PRINT LIST OF MODEL VARIANCES
RETURN

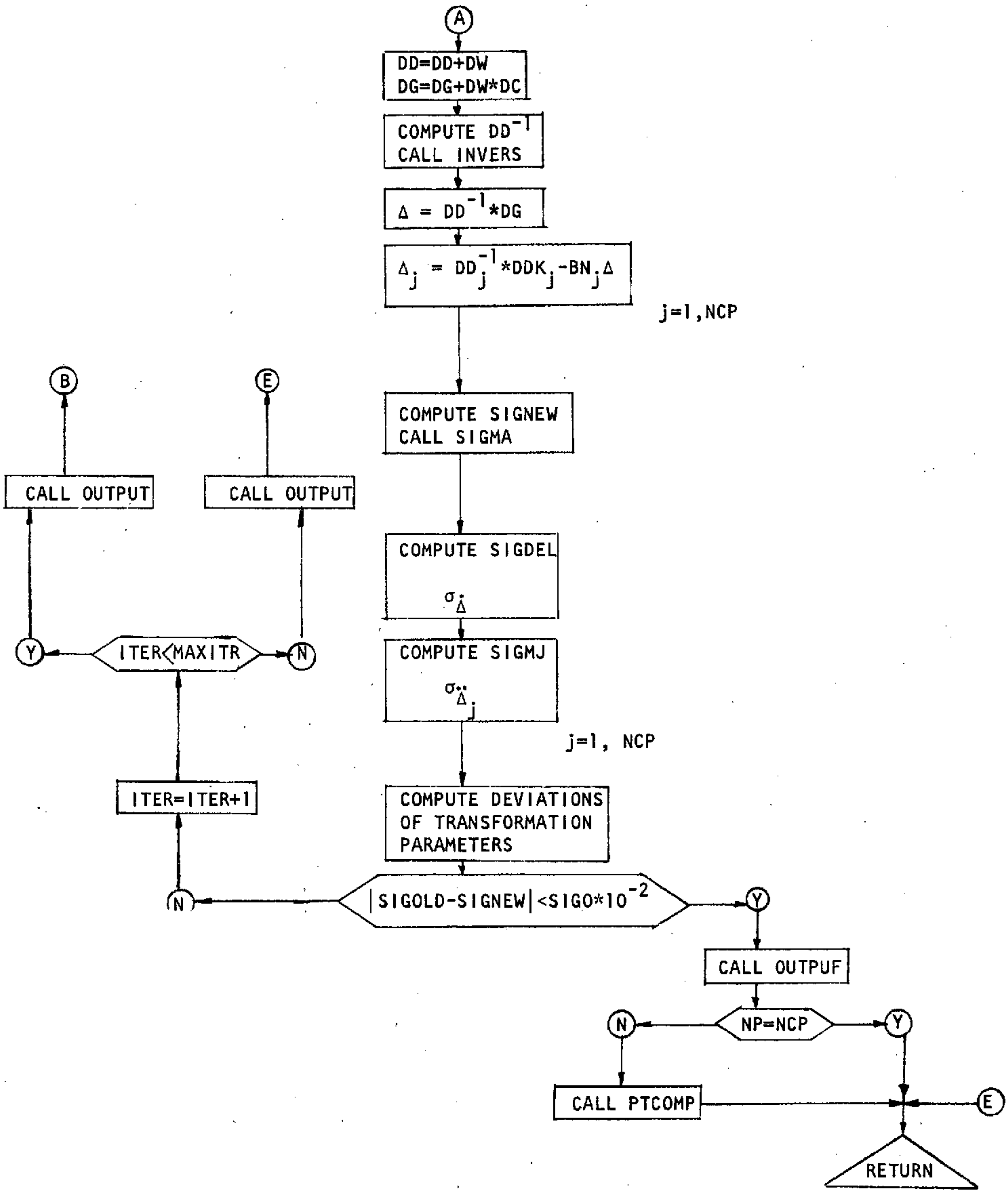
4.4 Flow chart of INPUT3



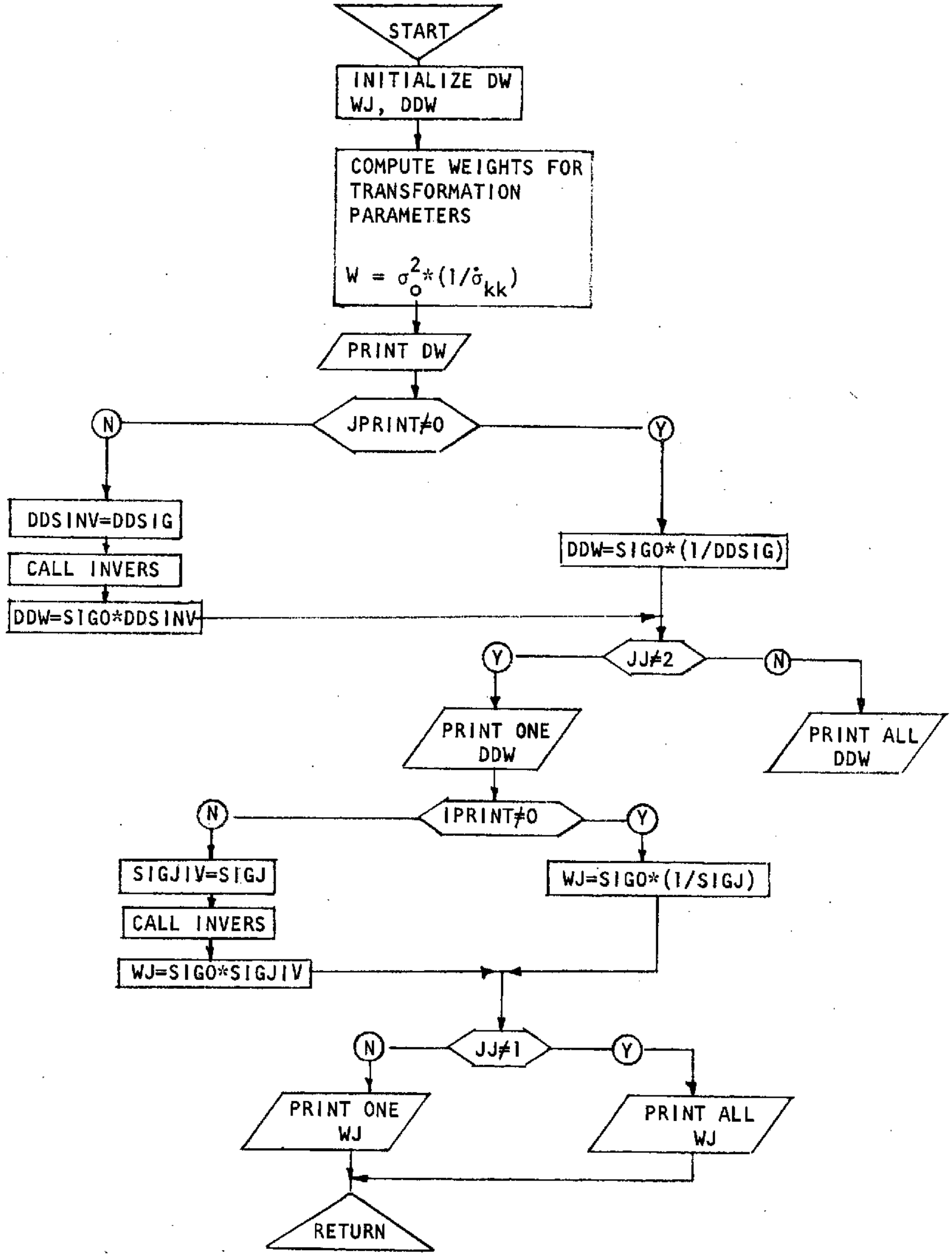

A
GENERATE APPROXIMATE ROTATIONS
READ MEAN & DEVIATION FOR RANDOM APPROXIMATION TO SCALE
GENERATE APPROXIMATE SCALE
PRINT APPROXIMATIONS TO TRANSFORMATION PARAMETERS
PRINT LIST OF "GROUND" COORDINATES
READ ARBITRARY DEVIATIONS FOR GROUND
FORMULATE MATRICES DDSIG
PRINT VAR/COVAR MATRICES FOR MODEL COORDS
PRINT VAR/COVAR MATRIX FOR "GROUND" COORDS
RETURN

4.5 Flow chart of TRANSF

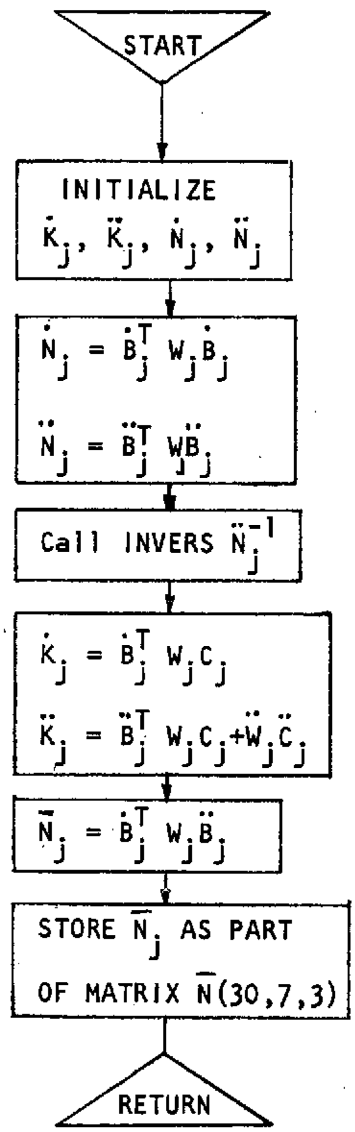



A
DD=DD+DW
DG=DG+DW*DC
COMPUTE DD^{-1}
CALL INVERS
$\Delta = DD^{-1}*DG$
$\Delta_j = DD_j^{-1}*DDK_j - BN_j\Delta$
j=1,NCP
B
E
CALL OUTPUT
CALL OUTPUT
COMPUTE SIGNEW
CALL SIGMA
COMPUTE SIGDEL
$\sigma_{\dot{\Delta}}$
Y
ITER<MAXITR
N
COMPUTE SIGMJ
$\sigma_{\ddot{\Delta}_j}$
j=1, NCP
ITER=ITER+1
COMPUTE DEVIATIONS OF TRANSFORMATION PARAMETERS
N
$|SIGOLD-SIGNEW|<SIGO*10^{-2}$
Y
CALL OUTPUF
N
NP=NCP
Y
CALL PTCOMP
E
RETURN

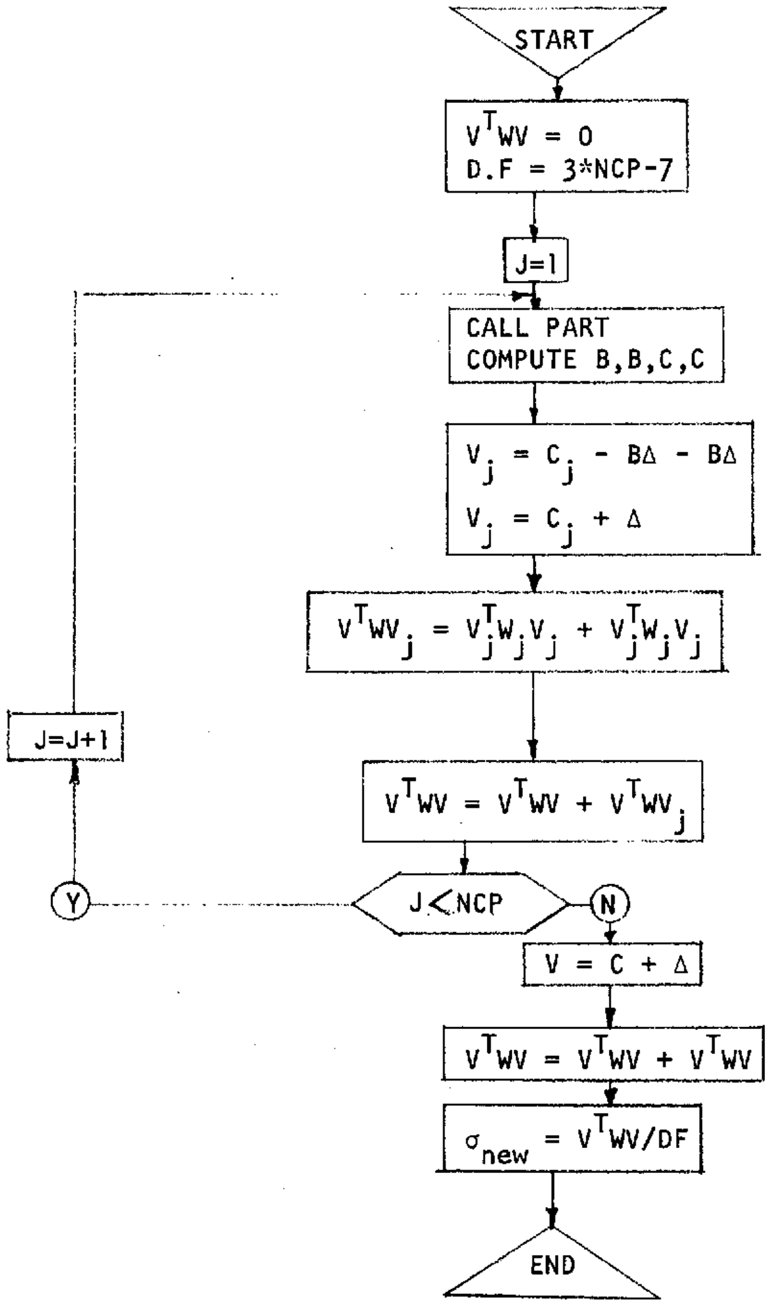
4.6 Flow chart of WEIGHT



4.7 Flow chart for DETCAL



4.8 Flow chart for SIGMA



V. PROGRAM LISTING

```
C************* T H R E E D  -  M A I N **********************************
C
C     THIS PROGRAM PERFORMS A THREE DIMENSIONAL TRANSFORMATION BY A LEAST
C     SQUARE FIT OF THE TWO MODELS.
C     THE COORDINATES OF THE POINTS OF THE TWO MODELS ARE ASIGNED WEIGHTS
C     WHICH MIGHT DIFFER FOR EACH INDIVIDUAL POINT AND/OR EACH OF THE COO
C     RDINATES OF THE POINTS. CORRELATION AMONG THE COORDINATES OF THE PO
C     INTS OF EITHER MODEL IS ALSO ACCEPTAPLE.
C
C     THE PROGRAM ALLOWS EACH MODEL PLASTIC FREEDOM AS PRESCRIBED BY THE
C     INPUT VARIANCES, THUS NOT FORCING EITHER TO THE OTHER.
C
C
C              ****************************************************
C              *                                                  *
C              *        THE PROGFAM ACCEPTS A MAXIMUM NUMBER OF   *
C              *                                                  *
C              *                     ONE HUNDRED                  *
C              *                                                  *
C              *        POINTS (TOTAL CONTROLS AND UNKNOWN).FOR   *
C              *        A LARGER NUMBER OF POINTS IT HAS TO BE    *
C              *             R E D I M E N S I O N E D            *
C              *                                                  *
C              ****************************************************
C
C     THE MAIN PROGRAM GOVERNS THE INPUT OF THE PACKAGE AND WILL ACCEPT
C     ANY NUMBER OF INPUT SUBROUTINES TO BE INCORPORATED TO IT, THEREFORE
C     SUBROUTINE TRANSF IS THE BASIC OPERATIONAL PART OF THE PACKAGE.
C
C     THE FOLLOWING SUBROUTINES ARE INCLUDED IN THE PACKAGE AT PRESENT
C          1.  INPUT1 - FICTITIOUS DATA GENERATOR FOR SIMULATION
C          2. INPUT2 - READS DATA FROM AEROTRIANGULATION OUTPUTS
C          3. INPUT3 - READS MODEL COORDINATES AND VAR-COVAR INFORMATION
C                      FROM AEROTRIANGULATION OUTPUTS AND SIMULATES CONTRO
C                      LS FOR RELATIVE ACCURACY TEST.
C          4. TRANSF - LEAST SQUARE SOLUTION OF THE TRANSFORMATION
C          5. ROTATE - COMPUTES ROTATION MATRIX AND ITS DERIVATIVES WITH
C                      RESPECT TO THE ROTATION ANGLES
C          6. GAUSS  - COMPUTES NORMALLY DISTRIBUTED RANDOM NUMBERS WITH
C                      GIVEN MEAN AND DEVIATION
C          7. RANDU  - COMPUTES UNIFORMELY DISTRIBUTED RANDOM NUMBERS
C          8. WEIGHT - COMPUTES THE WEIGHTS OF THE GIVEN POINTS FROM THE
C                      INPUT VAR-COVAR MATRICES AND ESTIMATED SIGMA ZERO.
C          9. DETCAL - COMPUTES THE CONTIBUTION OF EACH POINT TO THE
C                      NORMAL EQUATIONS
C         10. PART   - COMPUTES THE CONTRIBUTION OF EACH POINT TO THE
C                      OBSERVATION EQUATIONS
C         11. MXMULT - MULTIPLIES TWO MATRICES
C         12. INVERS - COMPUTES THE INVERSE OF A SQUARE MATRIX BY DESTROY-
C                      ING THE ORIGINAL.
C         13. SIGMA  - COMPUTES THE SIGMA ZERO OF THE SOLUTION
C         14. RTODMS - TRANSFORMS RADIANS TO DEGREES-MIN-SEC.
C         15. OUTPUT - AN OUTPUT SUBROUTINE FOR EACH ITERATION
```

```
C        16. OUTPUF - FINAL OUTPUT OF THE SOLUTION
C
C
C
C.......................................................................
C
C
      DIMENSION       NUM(100),XO(100),YO(100),ZO(100),XOO(100),YOO(100)
     1,ZOO(100),X(100),Y(100),Z(100),WJ(100,3,3),DDW(100,3,3),DDNINV(100
     1,3,3),SIGJ(100,3,3),DDSIG(100,3,3),DDELTA(100,3),DDK(100,3),BN(100
     1,7,3),SIGMJ(100,3,3),DX(100),DY(100),DZ(100),XM(100),YM(100),ZM(10
     10),DEVIA(100,3,3)
      DIMENSION DBT(7,3),DDBT(3,3),DBTWJ(7,3),DDBTWJ(3,3),Q(7,3),DDK1(3)
     1,DDK2(3),R(7,7),QQ(7),BNJ(7,3),BNT(3,7),DDNIVT(7,7),H1(3,7),H2(3,7
     1),H3(7,3),A(3,3)        ,DB(3,7),DDB(3,3),C(3),DDC(3),DW(7,7),AWJ(3
     1,3),ADDW(3,3),DDN(3,3),DDNINJ(3,3),DG(7),DD(7,7),DC(7),DCD(7),DDJ(
     17,7),DN(7,7),DK(7),DDINV(7,7),DELTA(7),DWDC(7),F(3,3),SIGDEL(7,7),
     1DSIG(7,7),COR(7),PAR(7),SIGPAR(7),DEVPAR(7,7),AS(3,3),SIGGR(3),SIG
     1MO(3),V(3),IDEG(3),MIN(3),SEC(3)
      DIMENSION AT(3,3),MOCOUR(100,3),GRCOOR(100,3),ATX(100,3),TRANSL(3)
C
C
C  BASIC INPUT READING AND PRINTING
C
C
      READ(5,100) JJ,NP,NCP,MAXITR,JPRINT,IPRINT
  100 FORMAT( 6I10 )
      READ(5,110) SIGO
  110 FORMAT(F20.10)
      READ(5,150) ( SIGPAR(K), K=1,7 )
  150 FORMAT(7E10.3)
      DO 160 K=1,7
      DO 160 L=1,7
      IF ( K - L ) 161,162,161
  161 DSIG(K,L) = 0.0
      GO TO 160
  162 IF (K.EQ.1) DSIG(K,L) = SIGPAR(1)
      IF (K.EQ.2) DSIG(K,L) = SIGPAR(2)
      IF (K.EQ.3) DSIG(K,L) = SIGPAR(3)
      IF (K.EQ.4) DSIG(K,L) = SIGPAR(4)
      IF (K.EQ.5) DSIG(K,L) = SIGPAR(5)
      IF (K.EQ.6) DSIG(K,L) = SIGPAR(6)
      IF (K.EQ.7) DSIG(K,L) = SIGPAR(7)
  160 CONTINUE
C
C
      CALL OUTPUX (JJ,NP,NCP,MAXITR,JPRINT,IPRINT,SIGO,DSIG)
C
C
      IF(JJ.EQ.1) GO TO 200
      IF(JJ.EQ.2) GO TO 300
      IF(JJ.EQ.3) GO TO 400
      WRITE(6,500)
  500 FORMAT("1",///////,10X," ERROR = WRONG PARAMETER GOVERNING INPUT,(
     1JJ)",/,10X," CHECK THE FIRST PARAMETER ON COLUMN 10 OF THE FIRST D
     1ATA CARD")
      GO TO 1000
  200 CALL INPUT1      (NCP,XO,YO,ZO,X,Y,Z,SCAL,OME,PHI,CAPA,XC,YC,ZC,NUM
     1,SIGJ,DDSIG )
      GO TO 999
  300 CALL        INPUT2 ( NP,NCP,XO,YO,ZO,X,Y,Z,SIGO,SCAL,XC,YC,ZC,OME,P
     1HI,CAPA,JPRINT,IPRINT,SIGJ,DDSIG ,NUM)
```

```
      GO TO 999
  400 CALL        INPUT3(NCP,NUM,XO,YO,ZO,Y,Y,Z,SCAL,OME,PHI,CAPA,XC,YC,Z
     1C,DDSIG,SIGJ)
      GO TO 999
  999 CALL        TRANSF ( NCP,NP,NUM,XO,YO,ZO,X,Y,Z,SCAL,OME,PHI,CAPA,SI
     1GJ,DSIG,DDSIG,SIGO,JJ,MAXITR,JPRINT,IPRINT ,XC,YC,ZC)
 1000 CONTINUE
      STOP
      END
      SUBROUTINE INPUT1(NP,XO,YO,ZO,X,Y,Z,SCAL,OME,PHI,CAPA,XC,YC,ZC,NUM
     1,SIGJ,DDSIG )
C.......................................................................
C
C   PURPOSE
C      GENERATES MODEL AND GROUND COORDINATES OF GIVEN STANDARD DEVIATION
C      FOR A SET OF IDEAL POINTS. THE TRANSFORMATION PARAMETERS ARE ALSO
C      RANDOMLY GENERATED AND THEIR APPROXIMATIONS ARE RANDOMLY CHOSEN
C
C
C   DESCRIPTION OF PARAMETERS
C      1. INPUTS  NP   = NUMBER OF POINTS USED
C                 GXO  =
C                 GYO  = LIST OF "TRUE" COORDINATES OF POINTS
C                 GZO  =
C               SIGGRX =
C               SIGGRY = VARIANCE OF GROUND COORDINATES OF POINTS
C               SIGGRZ =
C               SIGMOX =
C               SIGMOY = VARIANCE OF MODEL COORDINATES OF POINTS
C               SIGMOZ =
C      2. OUTPUTS XO   =
C                 YO   = PERTURBED GROUND COORDINATES
      CONTINUE
C                 ZO   =
C                 X    =
C                 Y    = PERTURBED MODEL COORDINATES
C                 Z    =
C                SCAL  = APPROXIMATE SCALE OF THE MODEL
C                 XC   =
C                 YC   = APPROXIMATE TRANSLATIONS OF THE MODEL
C                 ZC   =
C                 OME  = APPROXIMATE ROTATION ABOUT X AXIS
C                 PHI  = APPROXIMATE ROTATION ABOUT Y AXIS
C                CAPA  = APPROXIMATE ROTATION ABOUT Z AXIS
C   REMARKS
C      THE SUBROUTINE WORKS ONLY FOR UNIFORM GROUND AND MODEL ACCURACY.
C      IT ALLOWS FOR DIFFERENT ACCURACIES IN EACH OF THE THREE BASIC DI-
C      MENSIONS FOR BOTH MODEL AND GROUND.
C
C   SUBROUTINES REQUIRED
C      GAUSS ( NORMALLY DISTRIBUTED NUMBER GENERATOR )
C      RANDU ( UNIFORMLY DISTRIBUTED NUMBER GENERATOR )
C      ROTATE ( COMPUTES THE ROTATION MATRIX FOR 3-D TRANSFORMATION )
C
C.......................................................................
      DIMENSION GXO(100),GYO(100),GZO(100),XO(100),YO(100),ZO(100),X(100
     1),Y(100),Z(100),XM(100),YM(100),ZM(100),A(3,3),AS(3,3),NUM(100),DS
     1IG(7,7),SIGJ(100,3,3),DDSIG(100,3,3),PAR(7),COR(7),DX(100),DY(100)
     1,DZ(100)
C
C
      READ(5,20) GSCAL,IAREXP
```

```
 20 FORMAT(F10.5,I10)
    WRITE(6,30)
 30 FORMAT("1"," ************************  PRINT OUT OF THE INPUT  ****
   1********************")
    DO 35 J=1,NP
 35 READ(5,45) GXO(J),GYO(J),GZO(J)
 45 FORMAT( 3F15.5 )
    WRITE(6,50)
 50 FORMAT(/////,3X," LIST OF TRUE COORDINATES OF POINTS USED IN THE S
   1OLUTION",/,16X," POINT",23X," COORDINATES",/,15X," NUMBER",13X," X
   1",12X," Y",12X," Z")
    DO 60 J=1,NP
 60 WRITE(6,70) J,GXO(J),GYO(J),GZO(J)
 70 FORMAT(16X,I3,12X,F9.3,2(5X,F9.3))
    WRITE(6,75)
 75 FORMAT("1",////," ********************  VARIANCE-COVARIANCE MATRIC
   1ES  ********************",//)
    WRITE(6,80)
 80 FORMAT(    3X," THE VARIANCE-COVARIANCE MATRICES FOR MODEL COORDIN
   1ATES",///)
    READ(5,85) SIGMOX,SIGMOY,SIGMOZ
    READ(5,85) SIGGRX,SIGGRY,SIGGRZ
 85 FORMAT( 3E10.3 )
    SGX = SQRT(SIGGRX)
    SGY = SQRT(SIGGRY)
    SGZ = SQRT(SIGGRZ)
    SMX = SQRT(SIGMOX)
    SMY = SQRT(SIGMOY)
    SMZ = SQRT(SIGMOZ)
    RATIOX = SGX * ( GSCAL/SMX )
    RATIOY = SGY * ( GSCAL/SMY )
    RATIOZ = SGZ * ( GSCAL/SMZ )
    DO 90 J=1,NP
    DO 90 K=1,3
    DO 90 L=1,3
    IF( K-L ) 91,92,91
 91 SIGJ(J,K,L) = 0.0
    GO TO 90
 92 IF(K.EQ.1) SIGJ(J,K,L) = SIGMOX
    IF(K.EQ.2) SIGJ(J,K,L) = SIGMOY
    IF(K.EQ.3) SIGJ(J,K,L) = SIGMOZ
 90 CONTINUE
    DO 95 J=1,NP
 95 NUM(J) = J
    J = 1
    DO 100 K=1,3
100 WRITE(6,130)(SIGJ(J,K,L),L=1,3)
130 FORMAT(8X,3(E10.3,5X))
    WRITE(6,190)
190 FORMAT(///,3X," THE VARIANCE-COVARIANCE MATRICES FOR GROUND COORDI
   1NATES",///)
    DO 200 J=1,NP
    DO 200 K=1,3
    DO 200 L=1,3
    IF( K-L ) 201,202,201
201 DDSIG(J,K,L) = 0.0
    GO TO 200
202 IF(K.EQ.1)DDSIG(J,K,L) = SIGGRX
    IF(K.EQ.2)DDSIG(J,K,L) = SIGGRY
    IF(K.EQ.3)DDSIG(J,K,L) = SIGGRZ
200 CONTINUE
    J = 1
```

```
      DO 205 K = 1,3
  205 WRITE(6,130) (DDSIG(J,K,L),L=1,3)
      WRITE(6,210)  RATIOX
      WRITE(6,211) RATIOY
      WRITE(6,212) RATIOZ
  210 FORMAT(/," THE RATIO SIGMA GROUND TO SIGMA MODEL, FOR THE X COORDI
     1NATES, AT THE GROUND SCALE IS",F15.7)
  211 FORMAT(/," THE RATIO SIGMA GROUND TO SIGMA MODEL, FOR THE Y COORDI
     1NATES, AT THE GROUND SCALE IS",F15.7)
  212 FORMAT(/," THE RATIO SIGMA GROUND TO SIGMA MODEL, FOR THE Z COORDI
     1NATES, AT THE GROUND SCALE IS",F15.7)
C
C
C  GENERATE TRANSFORMATION PARAMETERS
C
C
      READ(5,230)GXC,GYC,GZC,GOME,GPHI,GCAPA
  230 FORMAT(10X,6F10.5)
C
C
C  REALIGN GROUND POINTS
C
C
      READ(5,315) IX1,S1,IX2,S2
  315 FORMAT(2(I10,F15.5))
      AM = 0.0
      IX = IX1
      S = S1
      DO 310 I= 1,NP
      CALL GAUSS (IX,S,AM,CORGPX)
      GXO(I) =(GXO(I) + CORGHX)*10.**IAREXP
      CALL GAUSS (IX,S,AM,CORGPY)
  310 GYO(I) =(GYO(I) + CORGHY)*10.**IAREXP
      IX = IX2
      S = S2
      DO 320 I= 1,NP
      CALL GAUSS (IX,S,AM,CORGPZ)
  320 GZO(I) =(GZO(I) + CORGHZ)*80.
C
C
C  GENERATE MODEL COORDINATES
C
C
      CALL ROTATE ( GOME,GPHI,GCAPA,A,AS )
      DO 340 I=1,NP
      DX(I) = GXO(I)-GXC
      DY(I) = GYO(I)-GYC
      DZ(I) = GZO(I)-GZC
      XM(I) = (A(1,1)*DX(I)+A(1,2)*DY(I)+A(1,3)*DZ(I))*GSCAL
      YM(I) = (A(2,1)*DX(I)+A(2,2)*DY(I)+A(2,3)*DZ(I))*GSCAL
  340 ZM(I) = (A(3,1)*DX(I)+A(3,2)*DY(I)+A(3,3)*DZ(I))*GSCAL
C
C
C  PERTURB THE MODEL COORDINATES
C
C
      READ(5,345) IX3,IX4,IX5,IX6,IX7,IX8
  345 FORMAT(6I10)
      SMX = SQRT(SIGMOX)
      SMY = SQRT(SIGMOY)
      SMZ = SQRT(SIGMOZ)
      DO 350 I=1,NP
```

```
      CALL GAUSS   (IX3,SMX,AM,VMX)
      X(I) = XM(I) + VMX
      CALL GAUSS   (IX4,SMY,AM,VMY)
      Y(I) = YM(I) + VMY
      CALL GAUSS   (IX5,SMZ,AM,VMZ)
  350 Z(I) = ZM(I) + VMZ
C
C
C  PERTURB GROUND COORDINATES
C
C
      DO 360 I=1,NP
      SGX = SQRT(SIGGRX)
      SGY = SQRT(SIGGRY)
      SGZ = SQRT(SIGGRZ)
      CALL GAUSS   (IX6,SGX,AM,VGX)
      XO(I) = GXO(I) + VGX
      CALL GAUSS   (IX7,SGY,AM,VGY)
      YO(I) = GYO(I) + VGY
      CALL GAUSS   (IX8,SGZ,AM,VGZ)
  360 ZO(I) = GZO(I) + VGZ
C
C
C  CHOOSE APPROXIMATIONS FOR THE TRANSFORMATION PARAMETERS
C
C
      READ(5,370)DSCAL,DXC,DYC,DZC,DOME,DPHI,DCAPA
  370 FORMAT(7F10.6)
      SCAL = GSCAL + DSCAL
      OME = GOME + DOME
      PHI = GPHI + DPHI
      CAPA = GCAPA + DCAPA
      XC = GXC + DXC
      YC = GYC + DYC
      ZC = GZC + DZC
      WRITE(6,400)
  400 FORMAT("1"," *********************  OUTPUT OF SUBROUTINE INPUT1  *
     1******************",///,10X," T R A N S F O R M A T I O N   P A R
     1A M E T E R S",/,10X," =========================================
     1========",///,5X," PARAMETER",12X," GENERATED",5X," CORRECTIONS",2X
     1," APPROXIMATIONS",/)
      WRITE(6,410) GSCAL,DSCAL,SCAL
  410 FORMAT(5X," SCALE",17X,F10.5,2(5X,F10.5))
      WRITE(6,420) GXC,DXC,XC
  420 FORMAT(5X," TRANSLATION IN X",5X,F11.5,2(4X,F11.4))
      WRITE(6,430) GYC,DYC,YC
  430 FORMAT(5X," TRANSLATION IN Y",5X,F11.5,2(4X,F11.4))
      WRITE(6,440) GZC,DZC,ZC
  440 FORMAT(5X," TRANSLATION IN Z",5X,F11.5,2(4X,F11.4))
      WRITE(6,450) GOME,DOME,OME
  450 FORMAT(5X," ANGLE OME",13X,3(F10.5,5X))
      WRITE(6,460) GPHI,DPHI,PHI
  460 FORMAT(5X," ANGLE PHI",13X,3(F10.5,5X))
      WRITE(6,470) GCAPA,DCAPA,CAPA
  470 FORMAT(5X," ANGLE CAPA",12X,3(F10.5,5X))
      WRITE(6,475)
  475 FORMAT(/,5X," ANGLES IN DEGREES")
      CALL RTODMS(GOME,IDGOME,MIGOME,SEGOME)
      CALL RTODMS(DOME,IDEGDO,MIDOME,SEDOME)
      CALL RTODMS(OME,IDEGO,MINO,SECO)
      CALL RTODMS(GPHI,IDGPHI,MIGPHI,SEGPHI)
      CALL RTODMS(DPHI,IDEGDP,MIDPHI,SEDPHI)
```

```
      CALL RTODMS(PHI,IDEGP,MINP,SECP)
      CALL RTODMS(GCAPA,IDGCPA,MIGCPA,SEGCPA)
      CALL RTODMS(DCAPA,IDEGDC,MIDCPA,SEDCPA)
      CALL RTODMS(CAPA,IDEGC,MINC,SECC)
      WRITE(6,476) IDGOME,MIGOME,SEGOME,IDEGDO,MIDOME,SEDOME,IDEGO,MINO,
     1SECO
  476 FORMAT(5X," ANGLE OMEGA",5X, 3(2X,I3,I3,F6.2,1X))
      WRITE(6,477) IDGPHI,MIGPHI,SEGPHI,IDEGDP,MIDPHI,SEDPHI,IDEGP,MINP,
     1SECP
  477 FORMAT(5X," ANGLE PHI",  7X,3(2X,I3,I3,F6.2,1X))
      WRITE(6,478) IDGCPA,MIGCPA,SEGCPA,IDEGDC,MIDCPA,SEDCPA,IDEGC,MINC,
     1SECC
  478 FORMAT(5X," ANGLE CAPA", 6X,3(2X,I3,I3,F6.2,1X))
      WRITE(6,480)
  480 FORMAT(////,20X," M O D E L   C O O R D I N A T E S",/,20X," -----
     1------------------------------",//,6X," POINT",14X," GENERATED",23X,
     1" PERTURBED",/,5X," NUMBER",7X," X",9X," Y",9X," Z",9X," X",9X," Y
     1",9X," Z",/)
      DO 490 J=1,NP
  490 WRITE(6,500) J,XM(J),YM(J),ZM(J),X(J),Y(J),Z(J)
  500 FORMAT(7X,I3,5X,6(F9.2,2X))
      WRITE(6,510)
  510 FORMAT("1",18X," G R O U N D   C O O R D I N A T E S",/,18X," ----
     1--------------------------------",//,6X," POINT",14X," GENERATED",2
     13X," PERTURBED",/,5X," NUMBER",7X," X",9X," Y",9X," Z",9X," X",9X,
     1" Y",9X," Z",/)
      DO 520 J=1,NP
  520 WRITE(6,500) J,GXO(J),GYO(J),GZO(J),XO(J),YO(J),ZO(J)
      RETURN
      END
      SUBROUTINE INPUT2 ( NP,NCP,XO,YO,ZO,X,Y,Z,SIGO,SCAL,XC,YC,ZC,OME,P
     1HI,CAPA,JPRINT,IPRINT,SIGJ,DOSIG ,NUM)
C
C.......................................................................
C
C       PURPOSE
C
C       1. READS MODEL COORDINATES OF ALL POINTS (KNOWN AND UNKNOWN ) AT
C       ANY SEQUENCE.
C       2. READS THE GROUND COORDINATES OF THE CONTROLS AT ANY SEQUENCE.
C       3. READS VARIANCE-COVARIANCE MATRICES ( FULL 3 X 3 MATRICES ) FOR
C       BOTH GROUND AND MODEL COORDINATES OF THE CONTROLS AND OF THE MODEL
C       COORDINATES OF THE UNKNOWN POINTS.
C       4. SEPARATES CONTROLS FROM UNKNOWN POINTS AND PUTS THE MODEL COORD
C       INATES IN THE ORDER OF THE CONTROL POINTS.
C       5. PUTS IN ORDER THE VARIANCE-COVARIANCE MATRICES
C       6. COMPUTES APPROXIMATION OF THE TRANSFORMATION PARAMETERS.
C
C       DESCRIPTION OF PARAMETERS
C
C       1. INPUT
C
C           NP - NUMBER OF MODEL POINTS
C          NCP - NUMBER OF CONTROL POINTS
C     N1 TO N4 - NUMBERS OF THE CORNER POINTS OF THE MODEL TO BE USED FOR
C                THE COMPUTATION OF THE TRANSFORMATION PARAMETERS.
C          NUM - ID NUMBER OF THE POINTS
C     XO,YO,ZO - GROUND COORDINATES OF THE CONTROLS
C        A,B,C - MODEL COORDINATES OF THE MODEL POINTS IN ARBITRARY ORDER
C         SIGO - ESTIMATED VARIANCE OF UNIT WEIGHT
      CONTINUE
C     SS1-SS9 - ELEMENTS OF THE VAR-COVAR MATRICES OF THE MODEL POINTS BY
```

```
C              ROW IN ARBITRARY ORDER
C       S1-S9 - ELEMENTS OF THE VAR/COVAR MATRICES OF THE GROUND COORDINA-
C               TES OF THE CONTROLS BY ROW IN ARBITRARY ORDER
C        DSIG - VAR/COVAR MATRIX FOR THE APPROXIMATE TRANSFORMATION PARAM.
C
C       2. OUTPUT
C
C   X0,Y0,Z0 - GROUND COORDINATES FOR THE CONTROLS
C       X,Y,Z - MODEL COORDS FOR ALL MODEL POINTS IN CORRECT ORDER
C        SIGJ - VAR/COVAR MATRICES OF THE MODEL COORDS IN CORRECT ORDER-
C               ( NP,3,3 )
C       DDSIG - VAR/COVAR MATRICES FOR THE GROUND COORDS OF THE CONTROL
C               POINTS IN CORRECT ORDER ( NCP,3,3 )
C        SCAL - APPROXIMATE SCALE OF THE MODEL
C   XC,YC,ZC - APPROXIMATE TRANSLATIONS OF THE MODEL
      CONTINUE
C         OME - APPROXIMATE ROTATION OF THE MODEL ARROUND THE X AXIS
C         PHI - APPROXIMATE ROTATION OF THE MODEL ARROUND THE Y AXIS
C        CAPA - APPROXIMATE ROTATION OF THE MODEL ARROUND THE Z AXIS
C
C       REMARKS
C          *  THE SCALE IS COMPUTED AS THE MEAN OF THE SCALES OF THE TWO
C             DIAGONALS OF THE MODEL
C          * THE TRANSLATIONS ARE COMPUTED AS THE DIFFERENCES IN X,Y, AND
C             Z OF THE CENTER OF GRAVITY OF ALL CONTROL POINTS
C          * THE FOUR CORNER POINTS N1,N2,N3,N4 ARE USED FOR THE COMPUTA-
C            TION OF THE ROTATIONS.
C
C.......................................................................
C
      DIMENSION X0(100),Y0(100),Z0(100),X(100),Y(100),Z(100),NUM(100), D
     1DSIG(100,3,3),SIGJ(100,3,3)
C
C     READ THE GROUND COORDINATES OF THE CONTROL POINTS
C
      READ(5,10) N1,N2,N3,N4
   10 FORMAT(4I10)
      DO 110 I=1,NCP
  110 READ(5,100) NUM(I),X0(I),Y0(I),Z0(I)
  100 FORMAT(I5,3F15.3)
C
C     READ THE  MODEL COORDINATES OF THE POINTS
C
      K = NCP
  400 READ(5,450) N,A,B,C,II
  450 FORMAT(I5,F16.3,F14.3,F15.3,28X,I2)
      J = 1
  310 IF(N.EQ.NUM(J)) GO TO 200
      IF(J.GT.NCP) GO TO 300
      J = J + 1
      GO TO 310
  200 X(J) = A
      Y(J) = B
      Z(J) = C
  350 IF(II.NE.99) GO TO 400
      GO TO 500
  300 K = K + 1
      NUM(K)=N
      X(K) = A
      Y(K) = B
      Z(K) = C
      GO TO 350
```

```
  500 CONTINUE
C
C      READ AND PUT IN ORDER THE VAR/COVAR MATRICES OF THE CONTROLS
C
  600 FORMAT(I5,9E8.2,I3)
      READ(5,600) N,S1,S2,S3,S4,S5,S6,S7,S8,S9,III
      J = 1
  620 IF(N.EQ.NUM(J)) GO TO 610
      J = J + 1
      GO TO 620
  610 DDSIG(J,1,1) = S1
      DDSIG(J,1,2) = S2
      DDSIG(J,1,3) = S3
      DDSIG(J,2,1) = S4
      DDSIG(J,2,2) = S5
      DDSIG(J,2,3) = S6
      DDSIG(J,3,1) = S7
      DDSIG(J,3,2) = S8
      DDSIG(J,3,3) = S9
      IF (III.NE.99) GO TO 500
C
C      READ AND PUT IN ORDER THE VAR/COVAR MATRICES OF THE MODEL POINTS
C
      K = NCP
  700 READ(5,600) N,SS1,SS2,SS3,SS4,SS5,SS6,SS7,SS8,SS9,IIII
      J = 1
  730 IF(N.EQ.NUM(J)) GO TO 710
      J = J + 1
      GO TO  730
  710 SIGJ(J,1,1) = SS1
      SIGJ(J,1,2) = SS2
      SIGJ(J,1,3) = SS3
      SIGJ(J,2,1) = SS4
      SIGJ(J,2,2) = SS5
      SIGJ(J,2,3) = SS6
      SIGJ(J,3,1) = SS7
      SIGJ(J,3,2) = SS8
      SIGJ(J,3,3) = SS9
  750 IF(IIII.NE.99) GO TO 700
      GO TO 740
  740 CONTINUE
C
C
C      COMPUTATION OF APPROXIMATIONS FOR THE TRANSFORMATION PARAMETERS
C
C
      DO 900 J = 1,NCP
      IF(NUM(J).EQ.N1) K=J
      IF(NUM(J).EQ.N3) L=J
      IF(NUM(J).EQ.N2) M=J
  900 IF(NUM(J).EQ.N4) N=J
C
C      COMPUTATION OF APPROXIMATE SCALE
C
      DM1 = ABS(SQRT((X(K)-X(L))**2+(Y(K)-Y(L))**2+(Z(K)-Z(L))**2))
      DM2 = ABS(SQRT((X(M)-X(N))**2+(Y(M)-Y(N))**2+(Z(M)-Z(N))**2))
      DG1=ABS(SQRT((XO(K)-XO(L))**2+(YO(K)-YO(L))**2+(ZO(K)-ZO(L))**2))
      DG2=ABS(SQRT((XO(M)-XO(N))**2+(YO(M)-YO(N))**2+(ZO(M)-ZO(N))**2))
      SCAL = ((DM1/DG1) + (DM2/DG2))/2
C
C      COMPUTATION OF APPROXIMATE TRANSLATIONS
C
```

```
      SUMXM = 0.
      SUMYM = 0.
      SUMZM = 0.
      SUMXG = 0.
      SUMYG = 0.
      SUMZG = 0.
      DO 910 I = 1,NCP
      SUMXM = SUMXM + X(I)
      SUMYM = SUMYM + Y(I)
      SUMZM = SUMZM + Z(I)
      SUMXG = SUMXG + XO(I)
      SUMYG = SUMYG + YO(I)
  910 SUMZG = SUMZG + ZO(I)
      XC= (SUMXG - SUMXM)/NCP
      YC=(SUMYG - SUMYM)/NCP
      ZC=(SUMZG- SUMZM)/NCP
C
C     COMPUTATION OF ROTATION CAPA
C
      DXKL = X(K) - X(L)
      DYKL = Y(K) - Y(L)
      DXOKL = XO(K) - XO(L)
      DYOKL = YO(K) - YO(L)
      DYOMN = YO(M) - YO(N)
      DXOMN = XO(M) - XO(N)
      DXMN = X(M) - X(N)
      DYMN = Y(M) - Y(N)
      THETM1 = ATAN2(DYKL,DXKL)
      THETG1 = ATAN2(DYOKL,DXOKL)
      THETM2 = ATAN2(DYMN,DXMN)
      THETG2 = ATAN2(DYOMN,DXOMN)
      CAPA = ( THETG1+THETG2-THETM1-THETM2)/2
C
C     COMPUTATION OF ROTATION PHI
C
      DZMK = Z(M)-Z(K)
      DZLN = Z(L)-Z(N)
      XYMK = SQRT((X(M)-X(K))**2 + (Y(M)-Y(K))**2)
      XYLN = SQRT((X(L)-X(N))**2 + (Y(L)-Y(N))**2)
      DZOMK = ZO(M)-ZO(K)
      DZOLN = ZO(L)-ZO(N)
      XYOMK = SQRT((XO(M)-XO(K))**2 + (YO(M)-YO(K))**2)
      XYOLN = SQRT((XO(L)-XO(N))**2 + (YO(L)-YO(N))**2)
      PHIM2 = ATAN2(DZLN,XYLN)
      PHIM1 = ATAN2(DZMK,XYMK)
      PHIG1 = ATAN2(DZOMK,XYOMK)
      PHIG2 = ATAN2(DZOLN,XYOLN)
      PHI = ( PHIG1 + PHIG2 - PHIM1 - PHIM2 ) / 2
C
C     COMPUTATION OF ROTATION OMEGA
C
      DZKN = Z(K) - Z(N)
      DZML = Z(M) - Z(L)
      XYKN = SQRT((X(K)-X(N))**2 + (Y(K)-Y(N))**2)
      XYML = SQRT((X(M)-X(L))**2 + (Y(M)-Y(L))**2)
      DZOKN=ZO(K)-ZO(N)
      DZOML=ZO(M)- ZO(L)
      XYOKN = SQRT((XO(K)-XO(N))**2 + (YO(K)-YO(N))**2)
      XYOML = SQRT((XO(M)-XO(L))**2 + (YO(M)-YO(L))**2)
      OMEM1 = ATAN2(DZKN,XYKN)
      OMEM2 = ATAN2(DZML,XYML)
      OMEG1 = ATAN2(DZOKN,XYOKN)
```

```
      OMEG2 = ATAN2(DZOML,XYOML)
      OME = ( OMEG1 + OMEG2 -OMEM1 - OMEM2 ) / 2
      CALL RTODMS(OME,IDOME,MOME,SOME)
      CALL RTODMS(PHI,IDPHI,MPHI,SPHI)
      CALL RTODMS(CAPA,IDCAPA,MCAPA,SCAPA)
C
C     PRINT OUT OF THE OUTPUT OF SUBROUTINE INPUT2
C
      WRITE(6,1000)
 1000 FORMAT("1"," ********************** OUTPUT OF SUBROUTINE INPUT2 *
     1******************",///,10X," T R A N S F O R M A T I O N   P A R
     1A M E T E R S",/,10X," ----------------------------------------
     1--------",///,5X," PARAMETER",20X," COMPUTED APPROXIMATIONS",/,38X,
     1" IN RAD",9X," IN DEGREES",/)
      WRITE(6,1010) SCAL,XC,YC,ZC
 1010 FORMAT( 9X," SCALE",30X,F10.5,/, 9X," TRANSLATION IN X",18X,F11.3,
     1/,9X," TRANSLATION IN Y",18X,F11.3,/,9X," TRANSLATION IN Z",18X,F1
     11.3)
      WRITE(6,1020)  OME,IDOME,MOME,SOME
 1020 FORMAT( 9X," ROTATION OMEGA",11X,F10.5,9X,2(I3,1X),F7.3)
      WRITE(6,1030) PHI,IDPHI,MPHI,SPHI
 1030 FORMAT( 9X," ROTATION PHI   ",11X,F10.5,9X,2(I3,1X),F7.3)
      WRITE(6,1040) CAPA,IDCAPA,MCAPA,SCAPA
 1040 FORMAT( 9X," ROTATION CAPA ",11X,F10.5,9X,2(I3,1X),F7.3)
      WRITE(6,1100)
 1100 FORMAT(////,20X," M O D E L   C O O R D I N A T E S",/,20X," -----
     1-----------------------------",//,6X," 1. CONTROL POINTS",//,
     16X," NUMBER",5X," POINT",10X," X",10X," Y",10X,"Z",/)
      DO 1120 J=1,NCP
 1120 WRITE(6,1130) J,NUM(J),X(J),Y(J),Z(J)
 1130 FORMAT( 5X,I5,8X,I5,3F12.4 )
      IF(NP.EQ.NCP) GO TO 1160
      WRITE(6,1140)
 1140 FORMAT(//,6X," 2. UNKNOWN POINTS",//,
     16X," NUMBER",5X," POINT",10X," X",10X," Y",10X,"Z",/)
      NCPP1=NCP+1
      DO 1150 J=NCPP1,NP
 1150 WRITE(6,1130) J,NUM(J),X(J),Y(J),Z(J)
 1160 WRITE(6,1170)
 1170 FORMAT("1",18X," G R O U N D   C O O R D I N A T E S",/,18X," ----
     1---------------------------------",//,6X," CONTROL POINTS",//,
     16X," NUMBER",5X," POINT",10X," X",10X," Y",10X,"Z",/)
      DO 1180 J=1,NCP
 1180 WRITE(6,1130) J,NUM(J),XO(J),YO(J),ZO(J)
      IF(JPRINT.EQ.1) GO TO 1500
      WRITE(6,1310)
 1310 FORMAT("1",3X," THE VARIANCE-COVARIANCE MATRICES FOR GROUND COORDI
     1NATES",///)
      DO 1320 J =1,NCP
 1320 WRITE(6,1330)    NUM(J),((DDSIG(J,K,L),K=1,3),L=1,3)
 1330 FORMAT(3X," POINT",I5,2X,3(2X,F13.6),/,2(16X,3(2X,F13.6),/))
      GO TO 1340
 1500 WRITE(6,1510)
 1510 FORMAT("1",///,3X," THE LIST OF VARIANCES FOR GROUND COORDINATES",
     1//,5X," NUMBER",3X," POINT",7X," VAR X",8X," VAR Y",8X," VAR Z")
      DO 1520 J=1,NCP
 1520 WRITE(6,1530)J,NUM(J),(DDSIG(J,K,K),K=1,3)
 1530 FORMAT(I10,5X,I5,5X,3(E12.5,2X))
 1340 IF(IPRINT.EQ.1) GO TO 1700
      WRITE(6,1610)
 1610 FORMAT("1",3X," THE VARIANCE-COVARIANCE MATRICES FOR MODEL COORDIN
     1ATES",///)
```

```
      DO 1620 J =1,NP
 1620 WRITE(6,1330)   NUM(J),(( SIGJ(J,K,L),K=1,3),L=1,3)
      GO TO 1640
 1700 WRITE(6,1710)
 1710 FORMAT("1",///,3X," THE LIST OF VARIANCES FOR  MODEL COORDINATES",
     1//,5X," NUMBER",3X," POINT",7X," VAR X",8X," VAR Y",8X," VAR Z")
      DO 1720 J=1,NP
 1720 WRITE(6,1530)J,NUM(J),( SIGJ(J,K,K),K=1,3)
 1640 CONTINUE
      RETURN
      END
      SUBROUTINE INPUT3(NCP,NUM,XO,YO,ZO,X,Y,Z,SCAL,OME,PHI,CAPA,XC,YC,Z
     1C,DDSIG,SIGJ)
C
C.......................................................................
C
C     THIS SUBROUTINE READS OUTPUT FROM ANY TRIANGULATION PROGRAM ( MO-
C     DEL COORDINATES AND THEIR DEVIATIONS )0
C     IT ROTATES THE MODEL BY SMALL ROTATION ANGLES AND THE COMPUTED
C     COORDINATES ARE CONSIDERED TO BE FICTITIOUS "GROUND" CONTROLS.
C     THE GROUND IS ASSIGNED ARBITRARILY HIGH WEIGHTS AND THE PROGRAM
C     COMPUTES THE ADJUSTED TRANSFORMATION PARAMETERS AND THEIR DEVIA-
C     TIONS, WHICH ARE REPRESENTING THE UNCERTAINTY OF THE MODEL AS A
C     WHOLE.
C
C     THE INPUT COORDINATES AND DEVIATIONS NEED NOT BE IN THE SAME ORDER
C
C.......................................................................
C
      DIMENSION  NUM(100),XO(100),YO(100),ZO(100),X(100),Y(100),Z(100),
     1 DDSIG(100,3,3),SIGJ(100,3,3),IDEG(3),MIN(3),SEC(3),A(3,3),AS(3,3)
     1 ,V(3),SIGGR(3)
C
C     READ INPUT
C
      READ(5,5) IX1,IX2,IX3,IX4
    5 FORMAT(4I10)
      DO 10 J=1,NCP
   10 READ(5,20) NUM(J), X(J), Y(J), Z(J)
   20 FORMAT(I10,3F15.2)
   35 I = 1
      READ(5,40) N,S1,S2,S3,IIIII
   40 FORMAT(I10,3F20.10,8X,I2)
   45 IF(N.EQ.NUM(I)) GO TO 30
      I = I + 1
      GO TO 45
   30 SIGJ(I,1,1) = S1
      SIGJ(I,1,2) = 0.0
      SIGJ(I,1,3) = 0.0
      SIGJ(I,2,1) = 0.0
      SIGJ(I,2,2) = S2
      SIGJ(I,2,3) = 0.0
      SIGJ(I,3,1) = 0.0
      SIGJ(I,3,2) = 0.0
      SIGJ(I,3,3) = S3
      IF(IIIII.NE.99) GO TO 35
C
C     PRINT THE READ INPUT
C
      WRITE(6,50)
   50 FORMAT("1",///,5X," THE GIVEN MODEL  COORDINATES OF THE CONTROL PO
     1INTS",///,5X," NUMBER",11X," X",17X," Y",17X," Z",/)
```

```
      DO 60 I=1,NCP
   60 WRITE(6,70) I,NUM(I), X(I), Y(I), Z(I)
   70 FORMAT(2I5,9X,3(F11.2,8X))
      WRITE(6,80)
   80 FORMAT("1",///,5X," THE DEVIATIONS OF THE MODEL  COORDINATES OF TH
     1E CONTROL POINTS",////, 5X," NUMBER",8X," SIGMA X",9X," SIGMA Y",9X
     1," SIGMA Z")
      DO 90 I=1,NCP
   90 WRITE(6,100) I,NUM(I),( SIGJ(I,K,K),K=1,3)
  100 FORMAT(2I5,9X,3(F11.7,6X))
C
C     GENERATE ARBITRARY ROTATIONS
C
      READ(5,105) DEG1,DEG2
  105 FORMAT(2F10.5)
      IX = IX1
      AM = DEG1/57.2957795131
       S = DEG2/57.2957795131
      DO 110 I=1,3
      CALL GAUSS(IX,S,AM,V(I))
  110 CALL RTODMS(V(I),IDEG(I),MIN(I),SEC(I))
      OME = V(1)
      PHI = V(2)
      CAPA = V(3)
      WRITE(6,120)
  120 FORMAT("1","************************  PRINT OUT OF INPUT3  ********
     1****************",/////,5X," THE ARBITRARY ROTATIONS OF THE MODEL",
     1//,30X," IN RAD",9X," IN DEGREES",/)
      WRITE (6,130)  V(1),IDEG(1),MIN(1),SEC(1)
  130 FORMAT(9X," OMEGA",13X,F10.7,7X,2(I3,1X),F7.3)
      WRITE (6,131)  V(2),IDEG(2),MIN(2),SEC(2)
  131 FORMAT(9X," PHI   ",13X,F10.7,7X,2(I3,1X),F7.3)
      WRITE (6,132)  V(3),IDEG(3),MIN(3),SEC(3)
  132 FORMAT(9X," CAPA ",13X,F10.7,7X,2(I3,1X),F7.3)
C
      CALL ROTATE(OME,PHI,CAPA,A,AS)
C
      DO 170 I=1,NCP
      XO(I)= A(1,1)* X(I) + A(1,2)* Y(I) + A(1,3)* Z(I)
      YO(I)= A(2,1)* X(I) + A(2,2)* Y(I) + A(2,3)* Z(I)
      ZO(I)= A(3,1)* X(I) + A(3,2)* Y(I) + A(3,3)* Z(I)
  170 CONTINUE
C
C     ASIGN VALUES TO APPROXIMATE TRANSFORMATION PARAMETERS
C
      READ(5,105) ATRA,DTRA
      IX =IX2
      AM = ATRA
      S = DTRA
      DO 200 I=1,3
  200 CALL GAUSS(IX,S,AM,V(I))
      XC = V(1)
      YC = V(2)
      ZC = V(3)
      IX = IX3
      READ(5,105) DEG3,DEG4
      AM = DEG3/57.2957795131
      S  = DEG4/57.2957795131
      DO 210 I=1,3
      CALL GAUSS(IX,S,AM,V(I))
      V(I) = -V(I)
  210 CALL RTODMS (V(I),IDEG(I),MIN(I),SEC(I))
```

```
      OME = V(1)
      PHI = V(2)
      CAPA = V(3)
      IX = IX4
      READ(5,105) ASCAL,DSCAL
      AM = ASCAL
      S = DSCAL
      CALL GAUSS ( IX,S,AM,SCAL )
      WRITE(6,220)
  220 FORMAT(////////, 5X," APPROXIMATIONS FOR THE TRANSFORMATION PARAME
     1TERS",///,10X," PARAMETER",24X," APPROXIMATION",/,38X," IN RAD", 9X
     1," IN DEGREES",/)
      WRITE(6,230) SCAL,XC,YC,ZC
  230 FORMAT( 9X," SCALE",30X,F10.5,/, 9X," TRANSLATION IN X",18X,F11.5,
     1/,9X," TRANSLATION IN Y",18X,F11.5,/,9X," TRANSLATION IN Z",18X,F1
     11.5)
      WRITE(6,231)                    V(1),IDEG(1),MIN(1),SEC(1)
  231 FORMAT( 9X," ROTATION OMEGA",11X,F10.5,9X,2(I3,1X),F7.3)
      WRITE(6,232)                    V(2),IDEG(2),MIN(2),SEC(2)
  232 FORMAT( 9X," ROTATION PHI   ",11X,F10.5,9X,2(I3,1X),F7.3)
      WRITE(6,233)                    V(3),IDEG(3),MIN(3),SEC(3)
  233 FORMAT( 9X," ROTATION CAPA ",11X,F10.5,9X,2(I3,1X),F7.3)
      WRITE(6,180)
  180 FORMAT("1",/////,5X," GROUND COORDINATES - (GENERATED BY ROTATION O
     1F THE GIVEN MODEL COORDINATES)",                  ///,5X," NUMBER",1
     11X," X",17X," Y",17X," Z",/)
      DO 190 I=1,NCP
  190 WRITE(6,70) I,NUM(I),XO(I),YO(I),ZO(I)
      READ(5,250) (SIGGR(K),K=1,3)
  250 FORMAT(3(E10.3,5X))
      DO 260 J=1,NCP
      DO 260 K=1,3
      DO 260 L=1,3
      IF (K-L) 261,262,261
  261 DDSIG(J,K,L) = 0.0
      GO TO 260
  262 DDSIG(J,K,L) = SIGGR(K)**2
  260 CONTINUE
      DO 160 J=1,NCP
      DO 160 K=1,3
      DO 160 L=1,3
      IF (K-L) 166,167,166
  166  SIGJ(J,K,L) = 0.0
      GO TO 160
  167 SIGJ(J,K,L) = SIGJ(J,K,K)**2
  160 CONTINUE
      WRITE(6,700)
  700 FORMAT("1", ///," *********************  VARIANCE-COVARIANCE MATRIC
     1ES  *********************",//)
      WRITE(6,710)
  710 FORMAT(     3X," THE VARIANCE-COVARIANCE MATRICES FOR MODEL COORDIN
     1ATES",///)
      DO 720 J=1,NCP
  720 WRITE(6,730) NUM(J),((SIGJ(J,K,L),K=1,3),L=1,3)
  730 FORMAT(3X," POINT",I5,2X,3(2X,E13.6),/,2(16X,3(2X,E13.6),/))
      WRITE(6,750)
  750 FORMAT(///,3X," THE VARIANCE-COVARIANCE MATRICES FOR GROUND COORDI
     1NATES",///)
      WRITE(6,760)          (( DDSIG(J,K,L),K=1,3),L=1,3)
  760 FORMAT(                              3(16X,3(2X,E13.6),/))
      RETURN
      END
```

```
      SUBROUTINE TRANSF ( NCP,NP,NUM,XO,YO,ZO,X,Y,Z,SCAL,OME,PHI,CAPA,SI
     1GJ,DSIG,DDSIG,SIGO,JJ,MAXITR,JPRINT,IPRINT ,XC,YC,ZC)
C
C.......................................................................
C
C      PURPOSE
C         PERFORMS THE LEAST SQUARE FIT OF ONE DIGITAL MODEL TO AN OTHER
C
C         FOR REASONS OF CONVENSION THE ONE MODEL IS CALLED "MODEL" AND
C         THE OTHER "GROUND".
C
C      DEFINITION OF VARIABLES
C                     NP,NCP - TOTAL NUMBER OF POINTS AND NUMBER OF CONTROLS
C                        NUM - ID NUMBER OF POINTS
C                   XO,YO,ZO - GROUND COORDINATES OF THE CONTROLS
C                      X,Y,Z - MODEL COORDINATES OF ALL POINTS
C                       SCAL - THE APPROXIMATE SCALE OF THE MODEL
C                   XC,YC,ZC - APPROXIMATE TRANSLATIONS OF THE MODEL
C               OME,PHI,CAPA - APPROXIMATE ROTATIONS OF THE MODEL
C                       SIGO - ESTIMATED MEAN SQUARE ERROR OF UNIT WEIGHT
C               SIGJ(NP,3,3) - VAR/COVAR MATRICES OF THE MODEL COORDS
C                              OF ALL THE POINTS
C             DDSIG(NCP,3,3) - VAR/COVAR MATRICES OF THE GROUND COORDS
C                              OF THE CONTROL POINTS
C                  DSIG(7,7) - VAR/COVAR MATRIX OF THE TRANSFORMATION PARA-
C                              METERS
C                     MAXITR - MAXIMUM NUMBER OF ITERATIONS ALLOWED
C
C.......................................................................
      DIMENSION         NUM(100),XO(100),YO(100),ZO(100),XOO(100),YOO(100)
     1,ZOO(100),X(100),Y(100),Z(100),WJ(100,3,3),DDW(100,3,3),DDNINV(100
     1,3,3),SIGJ(100,3,3),DDSIG(100,3,3),DDELTA(100,3),DDK(100,3),BN(100
     1,7,3),SIGMJ(100,3,3),DX(100),DY(100),DZ(100),XM(100),YM(100),ZM(10
     10),DEVIA(100,3,3)
      DIMENSION DBT(7,3),DDBT(3,3),DBTWJ(7,3),DDBTWJ(3,3),Q(7,3),DDK1(3)
     1,DDK2(3),R(7,7),QQ(7),BNJ(7,3),BNT(3,7),DDNIVT(7,7),H1(3,7),H2(3,7
     1),H3(7,3),A(3,3)        ,DB(3,7),DDB(3,3),C(3),DDC(3),DW(7,7),AWJ(3
     1,3),ADDW(3,3),DDN(3,3),DDNINJ(3,3),DG(7),DD(7,7),DC(7),DGJ(7),DDJ(
     17,7),DN(7,7),DK(7),DDINV(7,7),DELTA(7),DWDC(7),F(3,3),SIGDEL(7,7),
     1DSIG(7,7),COR(7),PAR(7),SIGPAR(7),DEVPAR(7,7),AS(3,3),SIGGR(3),SIG
     1MO(3),V(3),IDEG(3),MIN(3),SEC(3)
C
C
C      ASIGN APPROXIMATIONS TO THE TRANSFORMATION PARAMETERS FOR THE
C      FIRST ITERATION
C
      SCALO = SCAL
      XCO = XC
      YCO = YC
      ZCO = ZC
      OMEO = OME
      PHIO = PHI
      CAPAO = CAPA
      DO 5   J=1,NCP
      XOO(J) = XO(J)
      YOO(J) = YO(J)
    5 ZOO(J) = ZO(J)
C
C
      SIGOLD = SIGO
C
C
```

```
C  COMPUTE THE WEIGHT MATRICES
C
C
      CALL       WEIGHT (NP,NCP,JJ,NUM,JPRINT,IPRINT,SIGO,SIGJ,DSIG,DDSI
     1G,SCAL,WJ,DW,DDW )
C
C
      ITER=1
C
C
C  INITIALIZE  MATRICES DD AND DG
C
C
  470 DO 10  K=1,7
      DG(K) = 0.0
      DO 10  L=1,7
   10 DD(K,L) = 0.0
C
C
C  COMPUTATION OF ELEMENTS OF DC ( RIGHT HAND FOR TRANSFORMATION PARAME-
C  TERS OBSERVATION EQUATIONS )
C
C
      DC(1) = SCAL-SCALO
      DC(2) = XC-XCO
      DC(3) = YC-YCO
      DC(4) = ZC-ZCO
      DC(5) = OME-OMEO
      DC(6) = PHI-PHIO
      DC(7) = CAPA-CAPAO
C
C
C  COMPUTE THE ROTATION MATRIX AND THE DERIVATIVE FOR PHI
C
C
      CALL ROTATE ( OME,PHI,CAPA,A,AS )
C
C
C  COMPUTE THE CONTRIBUTION OF EACH POINT TO THE DD AND DG MATRICES
C
C
      DO 20  J=1,NCP
C
C
      CALL PART(  A,AS,XO(J),YO(J),ZO(J),XOO(J),YOO(J),ZOO(J),XC,YC,ZC,
     1SCAL,DB,DDB,C,DDC,X(J),Y(J),Z(J))
C
C
      DO 30  K=1,3
      DO 30  L=1,3
      AWJ(K,L) =WJ(J,K,L)
   30 ADDW(K,L) = DDW(J,K,L)
C
C
      CALL DETCAL(NP,J,DB,DDB,DC,DDC,C,AWJ,DW,ADDW,DN,DDN,DK,DDK,BN,
     1DDNINV,DDNINJ)
C
C
      DO 40  K=1,3
      DO 40  L=1,7
   40 BNT(K,L) = BN(J,L,K)
      DO 50  K=1,7
```

```
      DO 50  L=1,3
   50 BNJ(K,L) = BN(J,K,L)
C
      CALL MXMULT(BNJ,DDNINJ,Q,7,3,3)
      CALL MXMULT(Q,BNT,R,7,7,3)
      DO  60 K=1,7
      DO  60 L=1,7
   60 DDJ(K,L) = DN(K,L)-R(K,L)
      DO 70  K=1,7
      QQ(K) = 0.0
      DO  70 L=1,3
   70 QQ(K) = QQ(K) + Q(K,L)*DDK(J,L)
      DO  80 K=1,7
   80 DGJ(K) = DK(K) - QQ(K)
C
C
C   CONTRIBUTION OF POINT J TU NORMAL EQUATIONS
C
C
      DO  90 K=1,7
      DG(K)=DG(K)+DGJ(K)
      DO  90 L=1,7
   90 DD(K,L)=DD(K,L)+DDJ(K,L)
C
   20 CONTINUE
C
C
C   FORMULATION OF  NORMAL EQUATIONS
C
C
      DO 300 K=1,7
      DWDC(K) = 0.0
      DO 300 L=1,7
  300 DWDC(K) = DWDC(K) + DW(K,L)*DC(L)
      DO 310 K=1,7
      DG(K) = DG(K) + DWDC(K)
      DO 310 L=1,7
  310 DD(K,L) = DD(K,L) + DW(K,L)
C
C
C    SOLUTION OF THE NORMAL EQUATIONS TO OBTAIN CORRECTIONS FOR THE
C    TRANSFORMATION PARAMETERS
C
C
      DO 320 K=1,7
      DO 320 L=1,7
  320 DDINV(K,L)=DD(K,L)
C
C
      CALL INVERS ( DDINV,7,II )
C
C
      DO 330 K=1,7
      DELTA(K)=0.0
      DO 330 L=1,7
  330 DELTA(K) = DELTA(K)+DDINV(K,L)*DG(L)
C
C
C   COMPUTATION OF CORRECTIONS FOR THE GROUND COORDINATES OF EACH POINT
C
C
      DO 340 J=1,NCP
```

```
      DO 340 K=1,3
      SUM1=0.0
      SUM2=0.0
      DO 350 M=1,3
      SUM1= SUM1+DDNINV(J,K,M)*DDK(J,M)
      DO 350 N=1,7
  350 SUM2=SUM2+DDNINV(J,K,M)*PN(J,N,M)*DFLTA(N)
  340 DDELTA(J,K) = SUM1 -SUM2
C
C
C  ERROR ANALYSIS
C
C
      CALL SIGMA (NCP,XO,YO,ZO,XOO,YOO,ZOO,XC,YC,ZC,SCAL,DELTA,DDELTA,
     1A,AS,X,Y,Z,DC,WJ,DDW,DW,SIGNEW )
C
C
      DO 360 K=1,7
      DO 360 L=1,7
  360 SIGDEL(K,L) = SIGNEW*DDINV(K,L)
C
C   COMPUTATION OF THE VARIANCF-COVARIANCF MATRICES FOR EACH POINT
C
      DO 410 J=1,NCP
      DO 370 K=1,7
      DO 370 L=1,3
  370 BNT(L,K) = BN(J,K,L)
      DO 380 K=1,3
      DO 380 M=1,3
  380 DDNINJ(M,K) = DDNINV(J,M,K)
C
C
      CALL MXMULT ( DDNINJ,BNT,H1,3,7,3  )
      CALL MXMULT ( H1,DDINV,H2,3,7,7 )
C
C
      DO 390 K=1,7
      DO 390 L=1,3
  390 H3(K,L) = H1(L,K)
C
C
      CALL MXMULT ( H2,H3,F,3,3,7 )
C
C
      DO 400 K=1,3
      DO 400 L=1,3
  400 SIGMJ(J,K,L)= SIGNEW*(DDNINJ(K,L)+F(K,L))
  410 CONTINUE
      ASIGN = SQRT(SIGNEW)
      DO 405 K=1,7
  405 DEVPAR(K,K) = SQRT(SIGDEL(K,K))
      CALL RTODMS(DEVPAR(5,5),IDDEVO,MIDEVO,SEDEVO)
      CALL RTODMS(DEVPAR(6,6),IDDEVP,MIDEVP,SEDEVP)
      CALL RTODMS(DEVPAR(7,7),IDDEVC,MIDEVC,SEDEVC)
C
C
C   CONVERGENCY CRITERION
C
C
      IF(ABS(SIGOLD-SIGNEW)-SIGO*1.E-2)       420,430,430
  430 CALL        OUTPUT ( ITER,ASIGN,DELTA,SCAL,XC,YC,ZC,OME,PHI,CAPA,
     1DEVPAR )
```

```
      ITER = ITER+1
      IF ( ITER-MAXITR ) 440,440,450
C
C
C  UPDATE VARIABLES
C
C
  440 SCAL=SCAL+DELTA(1)
      XC   =XC   +DELTA(2)
      YC   =YC   +DELTA(3)
      ZC   =ZC   +DELTA(4)
      OME  =OME  +DELTA(5)
      PHI  =PHI  +DELTA(6)
      CAPA=CAPA+DELTA(7)
      DO 460 J=1,NCP
      XO(J) = XO(J) + DDELTA(J,1)
      YO(J) = YO(J) + DDELTA(J,2)
  460 ZO(J) = ZO(J) + DDELTA(J,3)
      SIGOLD = SIGNEW
      GO TO 470
  450 WRITE(6,640)     MAXITR
  640 FORMAT("1", 4(///////),20X," *******************************",/,20X
     1," *",27X," *",/,20X" * SOLUTION DOES NOT CONVERGE *",/,
     120X," *      AFTER",I5," ITERATIONS    *",/,20X," *",27X,
     1   " *",/,20X," *******************************",4(///////))
      GO TO 1000
  420 CALL         OUTPUF ( ITER,ASIGN,DELTA,SCAL,XC,YC,ZC,OME,PHI,CAPA,DE
     1VPAR,SIGDEL,XO,YO,ZO,DDELTA,NUM, NCP,SIGMJ)
      IF(NP.EQ.NCP) GO TO 1000
      CALL         PTCOMP ( NP,NCP,SCAL,XC,YC,ZC,OME,PHI,CAPA,X,Y,Z,NUM,
     1 DEVPAR,SIGJ)
 1000 CONTINUE
      RETURN
      END
      SUBROUTINE WEIGHT (NP,NCP,JJ,NUM,JPPINT,IPRINT,SIGO,SIGJ,DSIG,DDSI
     1G,SCAL,WJ,DW,DDW )
C
C.......................................................................
C
C    THIS SUBROUTINE COMPUTES THE WEIGHT MATRICES FOR THE COORDINATES OF
C    ALL THE GROUND CONTROL POINTS AND THE MODEL - CONTROL AND UNKNOWN -
C    POINTS AND FOR THE APPROXIMATE TRANSFORMATION PARAMETERS. IT ACCEPTS
C    FULL VARIANCE-COVARIANCE MATRICES.
C
C       INPUTS
C                     NP,NCP - TOTAL NUMBER OF POINTS AND NUMBER OF CONTROL
C                        NUM - ID NUMBER OF POINTS
C          JJ,JPPINT,IPRINT - INPUT PARAMETERS ( SEE MAIN )
C                       SCAL - APPROXIMATE SCALE OF THE MODEL
C                       SIGO - ESTIMATED MEAN SQUARE ERROR OF UNIT WEIGHT
C              SIGJ(NP,3,3) - VAR/COVAR MATRICES OF THE MODEL COORDS
C                             OF ALL THE POINTS
C            DDSIG(NCP,3,3) - VAR/COVAR MATRICES OF THE GROUND COORDS
C                             OF THE CONTROL POINTS
C                 DSIG(7,7) - VAR/COVAR MATRIX OF THE TRANSFORMATION PARA-
C                             METERS
C
C       OUTPUTS
C
      CONTINUE
C                WJ(NP,3,3) = THE WEIGHT MATRICES OF THE MODEL COORDS OF
C                             ALL THE POINTS
```

```
C                  DW(7,7) - THE WEIGHT MATRIX OF THE TRANSFORMATION PARA
C                            METERS
C             DDW(NCP,3,3) - THE WEIGHT MATRICES OF THE GROUND COORDS OF
C                            THE CONTROL POINTS
C
C........................................................................
C
      DIMENSION DW(7,7),DSIG(7,7),SIGJIN(3,3),DDSINV(3,3),DSIGIN(7,7)
      DIMENSION WJ(100,3,3),DDW(100,3,3),DDSIG(100,3,3),SIGJ(100,3,3),NU
     1M(100)
C
C     INITIALIZE THE WEIGHT MATRICES
C
      DO 100 K=1,7
      DO 100 L=1,7
  100 DW(K,L)=0.
      DO 110 J=1,NP
      DO 110 K=1,3
      DO 110 L=1,3
  110 WJ(J,K,L)=0.
      DO 115 J=1,NCP
      DO 115 K=1,3
      DO 115 L=1,3
  115 DDW(J,K,L)=0.
C
C     COMPUTE WEIGHTS OF THE TRANSFORMATION PARAMETERS
C
      DO 200 K=1,7
  200 DW(K,K) = SIGO*(1/DSIG(K,K))
C
C     PRINT MATRIX FOR TRANSFORMATION PARAMETERS
C
      WRITE(6,145)
  145 FORMAT("1",////," ***********************  WEIGHTS USED IN SOLUTION
     1  ***********************",//)
      WRITE(6,220)
  220 FORMAT(////,3X," THE WEIGHT MATRIX FOR THE TRANSFORMATION PARAMETE
     1RS",///)
      DO 230 K = 1,7
  230 WRITE(6,240)( DW(K,L),L=1,7)
  240 FORMAT(2X,7E10.3)
C
C     COMPUTE WEIGHTS FOR GROUND AND MODEL POINTS
C
      IF (JPRINT.NE.0 ) GO TO 400
      DO 320 J=1,NCP
      DO 310 K=1,3
      DO 310 L=1,3
  310 DDSINV(K,L) = DDSIG(J,K,L)
      CALL INVERS (DDSINV,3,II)
      DO 320 K=1,3
      DO 320 L=1,3
  320 DDW(J,K,L) = SIGO*DDSINV(K,L)
      GO TO 500
  400 DO 420 J=1,NCP
      DO 420 K=1,3
  420 DDW(J,K,K) = SIGO*(1/DDSIG(J,K,K))
  500 IF (JJ.EQ.2 ) GO TO 550
      J = 1
      WRITE(6,520)
  520 FORMAT(////, 3X," THE GROUND COORDINATE WEIGHT MATRIX",///)
      DO 525 K=1,3
```

```
  525 WRITE(6,530) (DDW(J,K,L),L=1,3)
  530 FORMAT(8X,3(E11.4,5X))
      GO TO 562
  550 WRITE(6,555)
  555 FORMAT(////,3X," THE WEIGHT MATRICES FOR THE GROUND COORDINATES OF
     1 THE CONTROL POINTS",///)
      J = 1
  570 WRITE(6,560) NUM(J),(DDW(J,1,L),L=1,3),(DDW(J,2,L),L=1,3),(DDW(J,3
     1,L),L=1,3)
  560 FORMAT(3X," POINT",I5,3(E11.4,2X),/,2(14X,3(E11.4,2X),/))
      IF(J-NCP) 561,562,562
  561 J = J + 1
      GO TO 570
  562 IF(IPRINT.NE.0) GO TO 800
      DO 720 J =1,NP
      DO 710 K=1,3
      DO 710 L=1,3
  710 SIGJIN(K,L) = SIGJ(J,K,L)
      CALL INVERS (SIGJIN,3,II)
      DO 720 K=1,3
      DO 720 L=1,3
  720 WJ(J,K,L) = SIGO*SIGJIN(K,L)
      GO TO 900
  800 DO 820 J = 1,NP
      DO 820 K=1,3
  820 WJ(J,K,K) = SIGO*(1/SIGJ(J,K,K))
  900 IF(JJ.NE.1) GO TO 1100
 1000 WRITE(6,1020)
 1020 FORMAT(     ////, 3X," THE MODEL COORDINATE WEIGHT MATRIX",///)
      J = 1
      DO 1025 K=1,3
 1025 WRITE(6,530) (WJ(J,K,L),L=1,3)
      GO TO 1130
 1100 WRITE(6,1120)
 1120 FORMAT(///,3X," THE WEIGHT MATRICES FOR THE COORDINATES OF THE MOD
     1DEL POINTS ( CONTROL AND UNKNOWN) ",//// )
      J = 1
 1140 WRITE(6,560) NUM(J),(WJ(J,1,L),L=1,3),(WJ(J,2,L),L=1,3),(WJ(J,3,L)
     1,L=1,3)
      IF(J-NP) 1125,1130,1130
 1125 J=J+1
      GO TO 1140
 1130 CONTINUE
      RETURN
      END
      SUBROUTINE PART(  A,AS,XO,YO,ZO,XOO,YOO,ZOO,XC,YC,ZC,SCAL,DB,DDB,C
     1,DDC,X,Y,Z)
      DIMENSION DB(3,7),DDB(3,3),C(3),DDC(3),A(3,3),AS(3,3)
C
C  COMPUTES THE CONTRIBUTION OF EACH  POINT TO THE OBSERVATION EQUATIONS
C
      DX=XO-XC
      DY=YO-YC
      DZ=ZO-ZC
      DB(1,1)=-A(1,1)*DX-A(1,2)*DY-A(1,3)*DZ
      DB(2,1)=-A(2,1)*DX-A(2,2)*DY-A(2,3)*DZ
      DB(3,1)=-A(3,1)*DX-A(3,2)*DY-A(3,3)*DZ
      DB(1,2)= SCAL*A(1,1)
      DB(2,2)= SCAL*A(2,1)
      DB(3,2)= SCAL*A(3,1)
      DB(1,3)= SCAL*A(1,2)
      DB(2,3)= SCAL*A(2,2)
```

```
      DB(3,3)= SCAL*A(3,2)
      DB(1,4)= SCAL*A(1,3)
      DB(2,4)= SCAL*A(2,3)
      DB(3,4)= SCAL*A(3,3)
      DB(1,5)= SCAL*(A(1,3)*DY-A(1,2)*DZ)
      DB(2,5)= SCAL*(A(2,3)*DY-A(2,2)*DZ)
      DB(3,5)= SCAL*(A(3,3)*DY-A(3,2)*DZ)
      DB(1,6)=-SCAL*(AS(1,1)*DX+AS(1,2)*DY+AS(1,3)*DZ)
      DB(2,6)=-SCAL*(AS(2,1)*DX+AS(2,2)*DY+AS(2,3)*DZ)
      DB(3,6)=-SCAL*(AS(3,1)*DX+AS(3,2)*DY+AS(3,3)*DZ)
      DB(1,7)=-SCAL*(A(2,1)*DX+A(2,2)*DY+A(2,3)*DZ)
      DB(2,7)= SCAL*(A(1,1)*DX+A(1,2)*DY+A(1,3)*DZ)
      DB(3,7)= 0.0
      DO 10 K=1,3
      DO 10 L=1,3
   10 DDB(K,L)=-SCAL*A(K,L)
      DDC(1) = XO-XOO
      DDC(2) = YO-YOO
      DDC(3) = ZO-ZOO
      C(1) = SCAL*(A(1,1)*DX+A(1,2)*DY+A(1,3)*DZ)-X
      C(2) = SCAL*(A(2,1)*DX+A(2,2)*DY+A(2,3)*DZ)-Y
      C(3) = SCAL*(A(3,1)*DX+A(3,2)*DY+A(3,3)*DZ)-Z
      RETURN
      END
      SUBROUTINE DETCAL(NP,J,DB,DDB,DC,DDC,C,WJ,DW,DDW,DN,DDN,DK,DDK,BN,
     1DDNINV,DDNINJ)
C
C.......................................................................
C
C     THIS SUBROUTINE COMPUTES THE CONTRIBUTION OF EACH POINT TO THE NO-
C     RMAL EQUATIONS OF THE FORM
C              DN * DD +  BN * DDD =  DK
C             BNT * DD + DDN * DDD = DDK
C     MATRICES COMPUTED BY THIS SUBROUTINE = DN,DDN,BN,DK,DDK
C
C     INPUTS
C
C             DB,DDB,DDC,C - ELEMENTS OF THE OBSERVATION EQUATIONS
C                            COMPUTED IN SUBROUTINE PART
C                       DC - ELEMENT OF THE OBSERVATION EQUATIONS COMPU-
C                            TED IN SUBROUTINE 3DTRAN
C               WJ,DW,DDW - WEIGHT MATRICES OF THE MODEL COORDS, THE TRA-
C                            NSFORMATION PARAMETERS AND THE GROUND COORDS
C                        J - NUMBER OF THE POINT
C
C     OUTPUTS
C
C            DN,DDN,DK,DDK - ELEMENTS OF THE NORMAL EQUATIONS FOR THE
C                            INDIVIDUAL POINT J
C                       BN - ELEMENT OF THE NORMAL EQUATIONS STORED IN A
C                            NCP*3*3 MATRIX FOR FUTURE USE
C                   DDNINV - INVERSE OF DDN STORED IN A NCP*3*3 MATRIX
C                   DDNINJ - INVERSE OF DDN OF THE INDIVIDUAL POINT J
C
C.......................................................................
C
      DIMENSION DK(7),DN(7,7),DDC(3),DDN(3,3),DB(3,7),WJ(3,3),DW(7,7),
     1C(3),DC(7),DDB(3,3),DDNINJ(3,3),DDW(3,3)
      DIMENSION DBT(7,3),DDBT(3,3),DBTWJ(7,3),DDBTWJ(3,3),BNJ(7,3),DDK1(
     13),DDK2(3)
      DIMENSION DDNINV(100,3,3),BN(100,7,3),DDK(100,3)
C
```

```
C   COMPUTES THE CONTRIBUTION OF EACH POINT TO THE NORMAL EQUATIONS
C
C
C
C   INITIALIZE ELEMENTS OF ON DDN,DK,DDK
C
        DO 10 K=1,7
        DK(K)=0.0
        DO 10 L=1,7
   10   DN(K,L) = 0.0
        DO 20 K=1,3
        DDK(J,K)=0.
        DO 20 L=1,3
   20   DDN(K,L) = 0.0
C
C
C   CONSTRUCT MATRICES DBT(7,3) AND DDBT(3;3)
C
C
        DO 30 K=1,3
        DO 30 L=1,3
   30   DDBT(K,L) = DDB(L,K)
        DO 40 K=1,7
        DO 40 L=1,3
   40   DBT(K,L) = DB(L,K)
C
C   COMPUTE DN(7,7) AND DDN(3,3)
C
        CALL MXMULT(DBT,WJ,DBTWJ,7,3,3)
        CALL MXMULT(DBTWJ,DB,DN,7,7,3)
C
        CALL MXMULT(DDBT,WJ,DDBTWJ,3,3,3)
        CALL MXMULT(DDBTWJ,DDB,DDN,3,3,3)
        DO 50 K=1,3
        DO 50 L=1,3
        DDN(K,L) = DDN(K,L) + DDW(K,L)
   50   DDNINJ(K,L) = DDN(K,L)
C
        CALL INVERS ( DDNINJ,3,II )
C
        DO 60 K=1,3
        DO 60 L=1,3
   60   DDNINV(J,K,L) = DDNINJ(K,L)
C
C   COMPUTATION OF DK(7) AND DDK(J,3)
C
        DO 70 K=1,7
        DO 70 L=1,3
   70   DK(K) = DK(K) + DBTWJ(K,L)*C(L)
        DO 80 K=1,3
        DDK1(K) = 0.0
        DO 80 L=1,3
   80   DDK1(K) = DDK1(K) + DDBTWJ(K,L)*C(L)
        DO 90 K=1,3
        DDK2(K) = 0.0
        DO 90 L=1,3
   90   DDK2(K)=DDK2(K)+ DDW(K,L)*DDC(L)
        DO 100 K=1,3
  100   DDK(J,K) = DDK1(K) - DDK2(K)
C
C   COMPUTATION OF BN(J,7,3)
C
```

```
      CALL MXMULT ( DBTWJ,DDB,BNJ,7,3,3)
      DO 110 K=1,7
      DO 110 L=1,3
  110 BN(J,K,L) = BNJ(K,L)
      RETURN
      END
      SUBROUTINE SIGMA ( NP,XO,YO,ZO,XOO,YOO,ZOO,XC,YC,ZC,SCAL,DELTA,
     1DDELTA,A,AS,X,Y,Z,DC,WJ,DDW,DW,SIGNEW )
C
C.......................................................................
C
C      THIS SUBROUTINE COMPUTES THE MEAN SQUARE ERROR OF UNIT WEIGHT OF
C      EACH ITERATION,  CALLED SIGNEW, BY SOLVING THE OBSERVATION EQUA-
C      TIONS FOR THE COMPUTATION OF THE RESIDUALS.
C
C      INPUTS
C                      NP(NCP) - THE NUMBER OF CONTROLS
C                     XO,YO,ZO - THE GROUND COORDS OF THE CONTROLS
C                 XOO,YOO,ZOO,
C                 XOO,YOO,ZOO - APPROXIMATIONS TO THE GROUND COORDS OF THE
C                               CONTROLS AS USED IN THE FIRST ITERATION
C                        X,Y,Z - MODEL COORDINATES OF THE POINTS
C                         SCAL - THE APPROXIMATE SCALE OF THE MODEL
C                     XC,YC,ZC - APPROXIMATE TRANSLATIONS OF THE MODEL
C              OME,PHI,CAPA - APPROXIMATE ROTATIONS OF THE MODEL
C                         A,AS - THE ROTATION MATRIX AND ITS DERIVATIVES
C                 DELTA(7,1) - THE COMPUTED TRANSFORMATION PARAMETERS
C            DDELTA(NCP,3) - THE COMPUTED  GROUND COORDS OF THE CONTROLS
      CONTINUE
C                           DC - THE RIGHT HAND MATRIX OF THE OBSERVATION
C                               EQUATIONS ( FROM SUBROUTINE 3DTRAN )
C                  WJ,DW,DDW - WEIGHT MATRICES OF THE MODEL COORDS, THE TRA-
C                               NSFORMATION PARAMETERS AND THE GROUND COORDS
C
C      OUTPUTS
C
C                       SIGNEW - THE NEW MEAN SQUARE ERROR OF UNIT WEIGHT OF
C                               THE SPECIFIC ITERATION
C
C.......................................................................
      DIMENSION DB(3,7),DDB(3,3),C(3),DDC(3),A(3,3),AS(3,3),DW(7,7)
      DIMENSION  DELTA(7),               DC(7),V(3),DDV(3),DV(7)
      DIMENSION  XOO(100),XO(100),YO(100),ZO(100),X(100),Y(100),Z(100),
     1YOO(100),ZOO(100),WJ(100,3,3),DDW(100,3,3),DDELTA(100,3)
C
C
      VTWV=0.0
      NDF = 3*NP-7
C
C
      J=1
  999 CALL PART(  A,AS,XO(J),YO(J),ZO(J),XOO(J),YOO(J),ZOO(J),XC,YC,ZC,
     1SCAL,DB,DDB,C,DDC,X(J),Y(J),Z(J))
      DO 100 K=1,3
      S1=0.0
      S2=0.0
      DO 110 L=1,7
  110 S1=S1+DB(K,L)*DELTA(L)
      DO 120 L=1,3
  120 S2=S2+DDB(K,L)*DDELTA(J,L)
      V(K)=C(K)-S1-S2
  100 DDV(K)=DDC(K)+DDELTA(J,K)
```

```
      S1=0.0
      S2=0.0
      DO 130 K=1,3
      DO 130 L=1,3
      S1=S1+V(K)*WJ(J,K,L)*V(L)
  130 S2=S2+DDV(K)*DDW(J,K,L)*DDV(L)
      VTWV=VTWV+S1+S2
      IF(J-NP) 131,132,132
  131 J=J+1
      GO TO 999
  132 DO 140 K=1,7
  140 DV(K)=DC(K)+DELTA(K)
      DO 141 K=1,7
      DO 141 L=1,7
  141 VTWV=VTWV+DV(K)*DW(K,L)*DV(L)
      SIGNEW = VTWV/NDF
      RETURN
      END
      SUBROUTINE ROTATE (OME,PHI,CAPA,A,AS)
C
C  COMPUTES THE ROTATION MATRIX FOR GIVEN ROTATION ANGLES AND THE
C  PARTIAL DERIVATIVES OF THE ROTATION MATRIX ELEMENTS FOR PHI
C
      DIMENSION A(3,3),AS(3,3)
      SINO = SIN(OME)
      COSO = COS(OME)
      SINP = SIN(PHI)
      COSP = COS(PHI)
      SINC = SIN(CAPA)
      COSC = COS(CAPA)
      A(1,1) = COSP*COSC
      A(1,2)= COSO*SINC+SINO*SINP*COSC
      A(1,3)=  SINO*SINC-COSO*SINP*COSC
      A(2,1)=  -COSP*SINC
      A(2,2)=  COSO*COSC-SINO*SINP*SINC
      A(2,3)=  SINO*COSC+COSO*SINP*SINC
      A(3,1)=  SINP
      A(3,2)=  -SINO*COSP
      A(3,3)=  COSO*COSP
      AS(1,1) = -SINP*COSC
      AS(1,2) = SINO*COSP*COSC
      AS(1,3) = -COSO*COSP*COSC
      AS(2,1) = SINP*SINC
      AS(2,2) = -SINO*COSP*SINC
      AS(2,3) = COSO*COSP*SINC
      AS(3,1) = COSP
      AS(3,2) = SINO*SINP
      AS(3,3) = -COSO*SINP
      RETURN
      END
      SUBROUTINE OUTPUF ( ITER,ASIGN,DELTA,SCAL,XC,YC,ZC,OME,PHI,CAPA,DE
     1VPAR,SIGDEL,XO,YO,ZO,DDELTA,NUM,NCP,SIGMJ)
C
C.....................................................................
C
C     THIS SUBROUTINE PRINTS OUT THE RESULTS OF THE TRANSFORMATION
C     AFTER THE SOLUTION HAS CONVERGED.. IT ALSO PRINTS OUT THE ADJUSTED
C     VALUES OF THE GROUND COORDINATED OF THE CONTROL POINTS AND THEIR
C     DEVIATIONS.
C
C.....................................................................
C
```

```
      DIMENSION DELTA(7),DEVPAR(7,7),SIGDFL(7,7)
      DIMENSION XD(100),YD(100),ZD(100),DDELTA(100,3),DEVIA(100,3,3)
      DIMENSION SIGMJ(100,3,3),NUM(100)
C
C
      WRITE(6,480) ITER
  480 FORMAT("1"," ******************************** FINAL OUTPUT **********
     1********************",//,12X," THE SOLUTION CONVERGES AFTER ITERATI
     1ON NUMBER",I3,/,12X," --------------------------------------------
     1----",//)
      WRITE(6,490) ASIGN
  490 FORMAT(////,20X," ***********************************",/,20X," *",29X
     1," *",/,20X," *",3X," SIGMA ZERO=",F11.4,3X," *",/,20X," *",29X,"
     1*",/,20X," ***********************************",//)
      ASCAL = SCAL + DELTA(1)
      AXC = XC + DELTA(2)
      AYC = YC + DELTA(3)
      AZC = ZC + DELTA(4)
      AOME = OME + DELTA(5)
      APHI = PHI + DELTA(6)
      ACAPA = CAPA + DELTA(7)
      CALL RTODMS(OME ,IDEOME,MINOME,SECOME)
      CALL RTODMS(PHI ,IDEPHI,MINPHI,SECPHI)
      CALL RTODMS(CAPA,IDCAPA,MICAPA,SECAPA)
      CALL RTODMS(DELTA(5),IDDOME,MDOME ,SDOME )
      CALL RTODMS(DELTA(6),IDDPHI,MDPHI ,SDPHI )
      CALL RTODMS(DELTA(7),IDDCPA,MDCAPA,SDCAPA)
      CALL RTODMS(AOME ,IDAOME,MAOME ,SAOME )
      CALL RTODMS(APHI ,IDAPHI,MAPHI ,SAPHI )
      CALL RTODMS(ACAPA,IDACPA,MACAPA,SACAPA)
      CALL RTODMS(DEVPAR(5,5),IDDEVO,MIDEVO,SEDEVO)
      CALL RTODMS(DEVPAR(6,6),IDDEVP,MIDEVP,SEDEVP)
      CALL RTODMS(DEVPAR(7,7),IDDEVC,MIDEVC,SEDEVC)
      WRITE(6,500)
  500 FORMAT(/,10X," T R A N S F O R M A T I O N   P A R A M E T E R S",
     1/,10X," -----------------------------------------------------",//,25X,
     1" OLD VALUE",3X," CORRECTION",2X," FINAL VALUE",3X," DEVIATION",/)
      WRITE(6,510)SCAL,DELTA(1),ASCAL,DEVPAR(1,1)
  510 FORMAT(5X," SCALE FACTOR",4X,2(2X,F11.5,2X,E11.4))
      WRITE(6,520)XC   ,DELTA(2),AXC,DEVPAR(2,2)
  520 FORMAT(5X," TRANSLATION IN X",2(2X,F11.3,2X,E11.4))
      WRITE(6,530)YC   ,DELTA(3),AYC,DEVPAR(3,3)
  530 FORMAT(5X," TRANSLATION IN Y",2(2X,F11.3,2X,E11.4))
      WRITE(6,540)ZC   ,DELTA(4),AZC,DEVPAR(4,4)
  540 FORMAT(5X," TRANSLATION IN Z",2(2X,F11.3,2X,E11.4))
      WRITE(6,550) IDEOME,MINOME,SECOME,IDDOME,MDOME ,SDOME ,IDAOME,
     1MAOME ,SAOME,IDDEVO,MIDEVO,SEDEVO
  550 FORMAT(5X," ANGLE OMEGA",5X, 4(1X,I3,I3,F6.2))
      WRITE(6,560) IDEPHI,MINPHI,SECPHI,IDDPHI,MDPHI ,SDPHI ,IDAPHI,
     1MAPHI ,SAPHI,IDDEVP,MIDEVP,SEDEVP
  560 FORMAT(5X," ANGLE PHI",  7X,4(1X,I3,I3,F6.2))
      WRITE(6,570) IDCAPA,MICAPA,SECAPA,IDDCPA,MDCAPA,SDCAPA,IDACPA,
     1MACAPA,SACAPA,IDDEVC,MIDEVC,SEDEVC
  570 FORMAT(5X," ANGLE CAPA", 6X,4(1X,I3,I3,F6.2))
      WRITE(6,580)
  580 FORMAT(///,10X," THE VARIANCE-COVARIANCE MARTIX OF THE TRANSFORMAT
     1ION",//)
      DO 590 K=1,7
  590 WRITE(6,600) ( SIGDEL(K,L),L=1,7)
  600 FORMAT(" ",7E11.4 )
      WRITE(6,610)
  610 FORMAT("1",//,18X," LIST OF ADJUSTED GROUND COORDINATES",/,18X," -
```

```
     1-----------------------------------",//," NUMBER",6X," X",11X," Y",
     111X," Z",8X," SIG(X)",4X," SIG(Y)",4X," SIG(Z)",//)
      DO 620 J=1,NCP
      XO(J) = XO(J) + DDELTA(J,1)
      YO(J) = YO(J) + DDELTA(J,2)
      ZO(J) = ZO(J) + DDELTA(J,3)
      DO 625 K=1,3
  625 DEVIA(J,K,K) = SQRT(SIGMJ(J,K,K))
  620 WRITE(6,630) NUM(J),XO(J),YO(J),ZO(J),DEVIA(J,1,1),DEVIA(J,2,2),DE
     1VIA(J,3,3)
  630 FORMAT(I5,3(2X,F11.3),3(2X,E11.4))
  650 CONTINUE
      RETURN
      END

      SUBROUTINE OUTPUT ( ITER,ASIGN,DELTA,SCAL,XC,YC,ZC,OME,PHI,CAPA,
     1DEVPAR )
C
C......................................................................
C
C
C     THIS SUBROUTINE PRINTS OUT THE RESULTS OF EACH ITERATION EXCEPT
C     THE LAST AND FINAL ONE.
C
C......................................................................
C
      DIMENSION DELTA(7),DEVPAR(7,7)
      WRITE(6,10) ITER
   10 FORMAT("1"," ************************  ITERATION NUMBER",I4,2X,
     1" ************************")
      WRITE(6,20)  ASIGN
   20 FORMAT(////,20X," *********************************",/,20X," *",29X
     1," *",/,20X," *",3X," SIGMA ZERO=",F11.4,3X," *",/,20X," *",29X,"
     1*",/,20X," *********************************",//)
      ASCAL = SCAL + DELTA(1)
      AXC = XC + DELTA(2)
      AYC = YC + DELTA(3)
      AZC = ZC + DELTA(4)
      AOME = OME + DELTA(5)
      APHI = PHI + DELTA(6)
      ACAPA = CAPA + DELTA(7)
      CALL RTODMS(OME ,IDEOME,MINOME,SECOME)
      CALL RTODMS(PHI ,IDEPHI,MINPHI,SECPHI)
      CALL RTODMS(CAPA,IDCAPA,MICAPA,SECAPA)
      CALL RTODMS(DELTA(5),IDDOME,MDOME ,SDOME )
      CALL RTODMS(DELTA(6),IDDPHI,MDPHI ,SDPHI )
      CALL RTODMS(DELTA(7),IDDCPA,MDCAPA,SDCAPA)
      CALL RTODMS(AOME ,IDAOME,MAOME ,SAOME )
      CALL RTODMS(APHI ,IDAPHI,MAPHI ,SAPHI )
      CALL RTODMS(ACAPA,IDACPA,MACAPA,SACAPA)
      CALL RTODMS(DEVPAR(5,5),IDDEVO,MIDEVO,SEDEVO)
      CALL RTODMS(DEVPAR(6,6),IDDEVP,MIDEVP,SEDEVP)
      CALL RTODMS(DEVPAR(7,7),IDDEVC,MIDEVC,SEDEVC)
      WRITE(6,30)
   30 FORMAT(/,10X," T R A N S F O R M A T I O N   P A R A M E T E R S",
     1/,10X," ------------------------------------------------",//,25X,
     *" OLD VALUE",3X," CORRECTION",3X," NEW VALUE",3X," DEVIATION",/)
      WRITE(6,40) SCAL,DELTA(1),ASCAL,DEVPAR(1,1)
   40 FORMAT(5X," SCALE FACTOR",4X,2(2X,F11.5,2X,E11.4))
      WRITE(6,50) XC   ,DELTA(2),AXC   ,DEVPAR(2,2)
   50 FORMAT(5X," TRANSLATION IN X",2(2X,F11.3,2X,E11.4))
      WRITE(6,60) YC   ,DELTA(3),AYC   ,DEVPAR(3,3)
```

```
 60 FORMAT(5X," TRANSLATION IN Y",2(2X,F11.3,2X,E11.4))
    WRITE(6,70) ZC   ,DELTA(4),AZC   ,DEVPAR(4,4)
 70 FORMAT(5X," TRANSLATION IN Z",2(2X,F11.3,2X,E11.4))
    WRITE(6, 80) IDEOME,MINOME,SECOME,IDDOME,MDOME ,SDOME ,IDAOME,
   1MAOME ,SAOME,IDDEVO,MIDEVO,SEDEVO
 80 FORMAT(5X," ANGLE OMEGA",5X, 4(1X,I3,I3,F6.2))
    WRITE(6, 90) IDEPHI,MINPHI,SECPHI,IDDPHI,MDPHI ,SDPHI ,IDAPHI,
   1MAPHI ,SAPHI,IDDEVP,MIDEVP,SEDEVP
 90 FORMAT(5X," ANGLE PHI",  7X,4(1X,I3,I3,F6.2))
    WRITE(6,100) IDCAPA,MICAPA,SECAPA,IDDCPA,MDCAPA,SDCAPA,IDACPA,
   1MACAPA,SACAPA,IDDEVC,MIDEVC,SEDEVC
100 FORMAT(5X," ANGLE CAPA", 6X,4(1X,I3,I3,F6.2))
    WRITE(6,110)
110 FORMAT(//,5X," ROTATIONS IN RADIANS",//)
    WRITE(6,120) OME,DELTA(5),AOME,DEVPAR(5,5)
120 FORMAT(5X," ANGLE OMEGA",5X,2(2X,F11.8,2X,E11.4))
    WRITE(6,130) PHI,DELTA(6),APHI,DEVPAR(6,6)
130 FORMAT(5X," ANGLE PHI  ",5X,2(2X,F11.8,2X,F11.4))
    WRITE(6,140) CAPA,DELTA(7),ACAPA,DEVPAR(7,7)
140 FORMAT(5X," ANGLE CAPA ",5X,2(2X,F11.8,2X,F11.4))
    RETURN
    END
    SUBROUTINE OUTPUX(JJ,NP,NCP,MAXITR,JPRINT,IPRINT,SIGO,DSIG)
C
C     THIS SUPRUUTINE PRINTS THE INPUT OF THE MAIN/THREED
C
C     TEMPORARY WRITE-UP
C
      DIMENSION DSIG(7,7)
C
      WRITE(6,10) NCP,MAXITR
   10 FORMAT("1",10X," GENERAL DATA",//10X," NUMBER OF POINTS USED IN TH
     1E SOLUTION",10X,I5,/,10X," MAXIMUM NUMBER OF ITERATIONS ALLOWED",1
     11X,I5)
      WRITE(6,140)
  140 FORMAT(////,3X," THE VARIANCE-COVARIANCE MATRIX FOR THE TRANSFORMA
     1TION PARAMETERS",//,10X," (ORDER OF VARIABLES = SCALE,DX,DY,DZ,OME
     1,PHI,CAPA)",///)
      DO 170 K=1,7
  170 WRITE(6,180) (DSIG(K,L),L=1,7)
  180 FORMAT(2X,7E10.3)
      ASIGO = SQRT(SIGO)
      WRITE(6,110) ASIGO
  110 FORMAT(////,20X," ***********************************",/,20X," *",29X
     1," *",/,20X," *",4X," SIGMA ZERO=",F9.5,4X," *",/,20X," *",29X," *
     1",/,20X," ***********************************",//)
C
      RETURN
      END
      SUBROUTINE RANDU(IX,IY,YFL)
C
C     ...................................................................
C
C        SUBROUTINE RANDU
C
C        PURPOSE
C           COMPUTES UNIFORMLY DISTRIBUTED RANDOM REAL NUMBERS BETWEEN
C           0 AND 1.0 AND RANDOM INTEGERS BETWEEN ZERO AND
C           2**31. EACH ENTRY USES AS INPUT AN INTEGER RANDOM NUMBER
C           AND PRODUCES A NEW INTEGER AND REAL RANDOM NUMBER.
C
C        USAGE
```

```
C           CALL RANDU(IX,IY,YFL)
C
C        DESCRIPTION OF PARAMETERS
C           IX - FOR THE FIRST ENTRY THIS MUST CONTAIN ANY ODD INTEGER
C                NUMBER WITH NINE OR LESS DIGITS. AFTER THE FIRST ENTRY,
C                IX SHOULD BE THE PREVIOUS VALUE OF IY COMPUTED BY THIS
C                SUBROUTINE.
C           IY - A RESULTANT INTEGER RANDOM NUMBER REQUIRED FOR THE NEXT
C                ENTRY TO THIS SUBROUTINE. THE RANGE OF THIS NUMBER IS
     CONTINUE
C                BETWEEN ZERO AND 2**31
C           YFL- THE RESULTANT UNIFORMLY DISTRIBUTED, FLOATING POINT,
C                RANDOM NUMBER IN THE RANGE 0 TO 1.0
C
C        REMARKS
C           THIS SUBROUTINE IS SPECIFIC TO SYSTEM/360 AND WILL PRODUCE
C           2**29 TERMS BEFORE REPEATING.  THE REFERENCE BELOW DISCUSSES
C           SEEDS (65539 HERE), RUN PROBLEMS, AND PROBLEMS CONCERNING
C           RANDOM DIGITS USING THIS GENERATION SCHEME.  MACLAREN AND
C           MARSAGLIA, JACM 12, P. 83-89, DISCUSS CONGRUENTIAL
C           GENERATION METHODS AND TESTS.  THE USE OF TWO GENERATORS OF
C           THE RANDU TYPE, ONE FILLING A TABLE AND ONE PICKING FROM THE
C           TABLE, IS OF BENEFIT IN SOME CASES.  65549 HAS BEEN
C           SUGGESTED AS A SEED WHICH HAS BETTER STATISTICAL PROPERTIES
C           FOR HIGH ORDER BITS OF THE GENERATED DEVIATE.
C           SEEDS SHOULD BE CHOSEN IN ACCORDANCE WITH THE DISCUSSION
C           GIVEN IN THE REFERENCE BELOW.  ALSO, IT SHOULD BE NOTED THAT
C           IF FLOATING POINT RANDOM NUMBERS ARE DESIRED,AS ARE
C           AVAILABLE FROM RANDU, THE RANDOM CHARACTERISTICS OF THE
C           FLOATING POINT DEVIATES ARE MODIFIED AND IN FACT THESE
     CONTINUE
C           DEVIATES HAVE HIGH PROBABILITY OF HAVING A TRAILING LOW
C           ORDER ZERO BIT IN THEIR FRACTIONAL PART.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           POWER RESIDUE METHOD DISCUSSED IN IBM MANUAL C20-8011,
C           RANDOM NUMBER GENERATION AND TESTING
C
C     ..................................................................
C
      IY=IX*65539
      IF(IY)5,6,6
    5 IY=IY+2147483647+1
    6 YFL=IY
      YFL=YFL*.4656613E-9
      RETURN
      END
      SUBROUTINE GAUSS(IX,S,AM,V)
C
C     ..................................................................
C
C        SUBROUTINE GAUSS
C
C        PURPOSE
C           COMPUTES A NORMALLY DISTRIBUTED RANDOM NUMBER WITH A GIVEN
C           MEAN AND STANDARD DEVIATION
C
C        USAGE
C           CALL GAUSS(IX,S,AM,V)
```

```
C
C        DESCRIPTION OF PARAMETERS
C           IX -IX MUST CONTAIN AN ODD INTEGER NUMBER WITH NINE OR
C                LESS DIGITS ON THE FIRST ENTRY TO GAUSS. THEREAFTER
C                IT WILL CONTAIN A UNIFORMLY DISTRIBUTED INTEGER RANDOM
C                NUMBER GENERATED BY THE SUBROUTINE FOR USE ON THE NEXT
C                ENTRY TO THE SUBROUTINE.
C           S  -THE DESIRED STANDARD DEVIATION OF THE NORMAL
      CONTINUE
C                DISTRIBUTION.
C           AM -THE DESIRED MEAN OF THE NORMAL DISTRIBUTION
C           V  -THE VALUE OF THE COMPUTED NORMAL RANDOM VARIABLE
C
C        REMARKS
C           THIS SUBROUTINE USES RANDU WHICH IS MACHINE SPECIFIC
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           RANDU
C
C        METHOD
C           USES 12 UNIFORM RANDOM NUMBERS TO COMPUTE NORMAL RANDOM
C           NUMBERS BY CENTRAL LIMIT THEOREM. THE RESULT IS THEN
C           ADJUSTED TO MATCH THE GIVEN MEAN AND STANDARD DEVIATION.
C           THE UNIFORM RANDOM NUMBERS COMPUTED WITHIN THE SUBROUTINE
C           ARE FOUND BY THE POWER RESIDUE METHOD.
C
C     ..................................................................
C
      A=0.0
      DO 50 I=1,12
      CALL RANDU(IX,IY,Y)
      IX=IY
   50 A=A+Y
      V=(A-6.0)*S+AM
      RETURN
      END
      SUBROUTINE INVERS(A,M,II)
C
C   II = 1   DIVIDION BY ZERO
C   THIS ROUTINE COMPUTES THE INVERSE OF AN M X M MATRIX,
C   AND DESTROYS THE ORIGINAL MATRIX.
C   A ZERO DIAGONAL ELEMENT WILL CAUSE A DIVISION BY ZERO
C   WHICH WILL STOP THE PROGRAM.
C
      DIMENSION A(M,M)
      II = 0
   40 DO 7 L=1,M
C ROW L IS PIVOTAL ROW
      IF(A(L,1) .LT. 1.0E-15)  GO TO 8
      FMN= 1.0/A(L,1)
      DIV = A(L,1)
      DO 4 J=2,M
    4 A(L, J-1)= A(L,J)/DIV
      A(L,M)= FMN
C PIVOTAL ROW HAS BEEN MODIFIED , NOW OTHER ROWS TO BE MODIFIED
      DO 7 J=1, M
      IF(J-L) 5, 7,5
    5 FMULT = A(J,1)
      DO 6 K=2, M
    6 A(J, K-1) =(A(J,K)-((FMULT)*(A(L,K-1))))
      A(J,M)= -FMN * FMULT
    7 CONTINUE
```

```
      RETURN
    8 II= 1
      RETURN
      END
      SUBROUTINE RTODMS ( ANGLE, IDEG, MIN, SEC )
C
C  PURPOSE
C     TRANSFORMS ANGLES FROM RADIANS TO DEGREES,MINUTES,SECONDS
C
C  DESCRIPTION OF VARIABLES
C     ANGLE - THE INPUT ANGLE TO BE TRANSFORMED
C     IDEG - THE DEGREES ( INTEGER )
C     MIN - THE MINUTES ( INTEGER ))
C     SEC - THE SECONDS ( REAL )
C
      ANG = ANGLE* ( 57.2957795131 )
      IDEG = INT( ANG)
      DEG = IDEG
      FMIN = ( ANG - DEG )* 60.0
      MIN= INT( FMIN)
      TMIN = MIN
      SEC= ( FMIN - TMIN)* 60.0
      RETURN
      END
      SUBROUTINE MXMULT ( A,B,C,K,L,M )
C
C.....................................................................
C
C     THE SUBROUTINE MULTIPLIES TWO MATRICES
C     A    PREMULTIPLIER MATRIX WITH DIMENSIONS K BY M
C     B    POSTMULTIPLIER MATRIX WITH DIMENSIONS M BY L
C     C    RESULT MATRIX WITH DIMENSIONS K BY L
C
C.....................................................................
C
      DIMENSION A(K,M),B(M,L),C(K,L)
C
C
      DO 10 I=1,K
      DO 10 J=1,L
      C(I,J) =0.0
      DO 10 N=1,M
   10 C(I,J) = C(I,J) + A(I,N)*B(N,J)
      RETURN
      END
      SUBROUTINE PTCOMP ( NP,NCP,SCAL,XC,YC,ZC,OME,PHI,CAPA,X,Y,Z,NUM,
     1  DEVPAR,SIGJ)
C
C.....................................................................
C
C     THIS SUBROUTINE WILL COMPUTE THE TRANSFORMED COORDS FOR THE
C     UNKNOWN POINTS AFTER THE ADJUSTMENT OF THE TRANSFORMATION
C
C.....................................................................
C
      DIMENSION NUM(100),X(100),Y(100),Z(100),A(3,3),AS(3,3)
     1  ,DEVPAR(7,7), SIGJ(100,3,3)
      DIMENSION AT(3,3),XMCOOR(100,3),GRCOOR(100,3),ATX(100,3),TRANSL(3)
C
C     COMPUTE AND TRANSPOSE THE ROTATION MATRIX
C
      CALL ROTATE(OME,PHI,CAPA, A,AS)
```

```
      DO 10 I=1,3
      DO 10 J=1,3
   10 AT(I,J) = A(J,I)
C
C     FORMULATE MODEL COORDINATE AND TRANSLATION VECTORS
C
      DO 20 J=NCP,NP
      XMCOOR(J,1) = X(J)
      XMCOOR(J,2) = Y(J)
   20 XMCOOR(J,3) = Z(J)
      TRANSL(1) = XC
      TRANSL(2) = YC
      TRANSL(3) = ZC
C
C     ROTATE MODEL
C
      DO 30 J=NCP,NP
      DO 30 K=1,3
      ATX(J,K) = 0.
      DO 30 L=1,3
   30 ATX(J,K) = ATX(J,K) + AT(K,L)*XMCOOR(J,L)
C
C     COMPUTE GROUND COORDINATES OF THE UNKNOWN POINTS
C
      DO 40 J = NCP,NP
      DO 40 I =1,3
   40 GRCOOR(J,I) = (1/SCAL)*ATX(J,I) + TRANSL(I)
C
C     PRINT THE GROUND COORDINATES OF THE UNKNOWN POINTS
C
      VL= DEVPAR(1,1) *DEVPAR(1,1)
      VXT= DEVPAR(2,2) *DEVPAR(2,2)
      VYT=DEVPAR(3,3) *DEVPAR(3,3)
      VZT= DEVPAR(4,4) *DEVPAR(4,4)
      VO=DEVPAR(5,5) *DEVPAR(5,5)
      VP=DEVPAR(6,6)* DEVPAR(6,6)
      VC= DEVPAR(7,7) *DEVPAR(7,7)
      WRITE(6,50)
   50 FORMAT(*1*,////,10X,* LIST OF COMPUTED GROUND COORDINATES OF UNKNO
     1WN POINTS*,//,10X,* ================================================
     1========*,//,5X,* NUMBER*,10X,* X*,15X,* Y*,15X,* Z*,
     1 10X,*SIGMA X*,10X,*SIGMA Y*,10X,*SIGMA Z*, /)
      DO 80 J = NCP,NP
      XM= XMCOOR(J,1)
      YM=XMCOOR(J,2)
      ZM=XMCOOR(J,3)
      VXM=SIGJ(J,1,1)
      VYM= SIGJ(J,2,2)
      VZM= SIGJ(J,3,3)
      VX=((A(1,1)*XM + A(2,1)*YM + A(3,1)*ZM)**2) *VL /(SCAL**4) +
     1   ((1.0/SCAL)**2)*(((AS(1,1)*XM + AS(2,1)*YM +AS(3,1)*ZM)**2)
     1   *VP + ((-A(2,1)*XM - A(1,1)*YM)**2)*VC +(A(1,1)**2)*VXM
     1   + (A(2,1)**2)*VYM + (A(3,1)**2)*VZM ) + VXT
      VX=SQRT(VX)
      VY= ((A(1,2)*XM +A(2,2)*YM + A(3,2)*ZM)**2)*VL /(SCAL**4)
     1                                                + ((1.0/SCAL)**2)*
     1    (((-A(1,3)*XM - A(2,3)*YM -A(3,3)*ZM)**2)*VO
     1     +((AS(1,2)*XM + AS(2,2)*YM + AS(3,2)*ZM)**2)*VP
     1     +((A(2,2)*XM - A(1,2)*YM)**2)*VC
     1     + (A(1,2)**2) * VXM + (A(2,2)**2)*VYM + (A(3,2)**2)*VZM)
     1     + VYT
      VY= SQRT(VY)
```

```
      VZ= ((A(1,3)*XM +A(2,3)*YM + A(3,3)*ZM)**2)*VL /(SCAL**4)
     1                                                + ((1.0/SCAL)**2)*
     1     (((A(1,2)*XM + A(2,2)*YM + A(3,2)*ZM)**2) *VO
     1   +((AS(1,3)*XM +AS(2,3)*YM + AS(3,3)*ZM)**2) *VP
     1      +((A(2,3)*XM - A(1,3)*YM)**2)*VC
     1      + (A(1,3)**2)*VXM + (A(2,3)**2)*VYM + (A(3,3)**2)*VZM)
     1      + VZT
      VZ=SQRT(VZ)
   80 WRITE(6,90) NUM(J),( GRCOOR(J,I),I=1,3),VX,VY,VZ
   90 FORMAT(5X,I5,6(6X,F11.3))
      RETURN
      END
```

6. SAMPLE RUNS

6.1 TO PERFORM ABSOLUTE ORIENTATION

6.1.1 INPUT DATA

```
       2          32           6           6           0           0
 .0001
 1.000E+20 1.000E+20 1.000E+20 1.000E+20 1.000E+20 1.000E+20 1.000E+20 1.000E+20
      27          29          15          14
   27        001806.0      015096.0         310.0
   29        010759.0      021624.0         386.0
   15        014080.0     -009575.0         904.0
   14        008007.0     -006116.0         360.0
   17        008701.0      005200.0         301.0
   30        017232.0      009647.0          347.0
   27        -045.406       058.396       -000.799
   29         014.964       100.865       -000.061
   15         033.930      -107.635        003.133
   14        -006.402      -083.653       -000.215
   17        -000.479      -008.434       -000.704
   30         056.822       020.231       -000.362
    2         049.594       036.132        003.494
   28        -038.419       106.586       -000.420
  175        -008.057      -122.278        000.275
  182         019.160      -117.189        003.096
  190         056.678      -115.561        004.227
  181         019.586      -084.599        001.958
  174        -010.957      -088.442       -000.351
  166        -042.525      -086.624       -000.229
  172        -010.956      -021.763       -000.583
  173        -013.266      -057.254       -000.367
  180         020.133      -050.199        000.056
  188         057.172      -055.845        002.183
  169        -009.653       072.515       -000.170
  177         020.824       075.133       -000.128
  184         054.609       076.321        003.111
  185         058.569       047.865        002.914
  178         026.090       052.083        000.028
  170        -010.685       051.498       -000.236
  163        -041.656       005.040       -000.679
  171        -005.245       018.659       -000.126
  186         054.842       013.650       -000.223
  187         053.032      -014.109        000.507
  199         028.979      -023.733       -001.182
  168        -011.219       108.819       -000.041
  183         058.296       112.773        002.585
  217         023.897       110.495        000.339                     99
  27.225E+03                           .1F+03                   6.25E+02
  29.225E+03                           .1E+03                   6.25E+02
  15.225E+03                           .1F+03                   6.25E+02
```

14,225E+03		.1F+03	6,25E+02	
17,225E+03		.1F+03	6,25E+02	
30,225E+03		.1F+03	6,25E+02	99
27	.1E-03	.1F-03	.1E-03	
30	.1E-03	.1F-03	.1E-03	
29	.1E-03	.1F-03	.1E-03	
15	.1E-03	.1F-03	.1E-03	
14	.1E-03	.1F-03	.1E-03	
17	.1E-03	.1F-03	.1E-03	
28	.1E-03	.1F-03	.1E-03	
2	.1F-03	.1F-03	.1E-03	
190	.1E-03	.1F-03	.1E-03	
182	.1E-03	.1F-03	.1F-03	
166	.1F-03	.1F-03	.1E-03	
175	.1E-03	.1F-03	.1E-03	
174	.1E-03	.1F-03	.1F-03	
181	.1E-03	.1F-03	.1E-03	
188	.1E-03	.1E-03	.1E-03	
180	.1F-03	.1F-03	.1E-03	
173	.1E-03	.1E-03	.1E-03	
172	.1E-03	.1F-03	.1E-03	
199	.1F-03	.1F-03	.1E-03	
187	.1E-03	.1F-03	.1E-03	
186	.1E-03	.1E-03	.1E-03	
171	.1E-03	.1F-03	.1E-03	
163	.1E-03	.1F-03	.1E-03	
170	.1E-03	.1F-03	.1E-03	
178	.1E-03	.1F-03	.1E-03	
185	.1E-03	.1F-03	.1E-03	
184	.1E-03	.1F-03	.1E-03	
177	.1F-03	.1F-03	.1E-03	
169	.1E-03	.1F-03	.1E-03	
168	.1E-03	.1F-03	.1E-03	
183	.1E-03	.1F-03	.1E-03	
217	.1E-03	.1F-03	.1E-03	99

6.1.2 OUTPUT

GENERAL DATA

NUMBER OF POINTS USED IN THE SOLUTION	6
MAXIMUM NUMBER OF ITERATIONS ALLOWED	6

THE VARIANCE-COVARIANCE MATRIX FOR THE TRANSFORMATION PARAMETERS

(ORDER OF VARIABLES = SCALE,DX,DY,DZ,OME,PHI,CAPA)

0.100E 21	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.100E 21	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.100E 21	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.100E 21	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.100E 21	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.100E 21	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.100E 21

```
*********************************
*                               *
*     SIGMA ZERO=  0.01000      *
*                               *
*********************************
```

********************** OUTPUT OF SUBROUTINE INPUT2 ******************

T R A N S F O R M A T I O N   P A R A M E T E R S

PARAMETER	COMPUTED APPROXIMATIONS IN RAD		IN DEGREES		
SCALE		0.00667			
TRANSLATION IN X		10088.594			
TRANSLATION IN Y		5982.703			
TRANSLATION IN Z		434.501			
ROTATION OMEGA	0.00022		0	0	46.253
ROTATION PHI	0.00166		0	5	41.500
ROTATION CAPA	0.01614		0	55	29.799

M O D E L   C O O R D I N A T E S

1. CONTROL POINTS

NUMBER	POINT	X	Y	Z
1	27	-45.4060	58.3960	-0.7990
2	29	14.9640	100.8650	-0.0610
3	15	33.9300	-107.6350	3.1330
4	14	-6.4020	-83.6530	-0.2150
5	17	-0.4790	-8.4340	-0.7040
6	30	56.8220	20.2310	-0.3620

2. UNKNOWN POINTS

NUMBER	POINT	X	Y	Z
7	2	49.5940	36.1320	3.4940
8	28	-38.4190	106.5860	-0.4200
9	175	-8.0570	-122.2780	0.2750
10	182	19.1600	-117.1890	3.0960
11	190	56.6780	-115.5610	4.2270
12	181	19.5860	-84.5990	1.9580
13	174	-10.9570	-88.4420	-0.3510
14	166	-42.5250	-86.6240	-0.2290
15	172	-10.9560	-21.7630	-0.5830
16	173	-13.2660	-57.2540	-0.3670
17	180	20.1330	-50.1990	0.0560
18	188	57.1720	-55.8450	2.1830
19	169	-9.6530	72.5150	-0.1700
20	177	20.8240	75.1330	-0.1280
21	184	54.6090	76.3210	3.1110
22	185	58.5690	47.8650	2.9140
23	178	26.0900	52.0830	0.0280
24	170	-10.6850	51.4980	-0.2360
25	163	-41.6560	5.0400	-0.6790
26	171	-5.2450	18.6590	-0.1260
27	186	54.8420	13.6500	-0.2230

28	187	53.0320	-14.1090	0.5070
29	199	28.9790	-23.7330	-1.1820
30	168	-11.2190	108.8190	-0.0410
31	183	58.2960	112.7730	2.5850
32	217	23.8970	110.4950	0.3390

GROUND COORDINATES

CONTROL POINTS

NUMBER	POINT	X	Y	Z
1	27	1806.0000	15096.0000	310.0000
2	29	10759.0000	21624.0000	386.0000
3	15	14080.0000	-9575.0000	904.0000
4	14	8007.0000	-6116.0000	360.0000
5	17	8701.0000	5200.0000	301.0000
6	30	17232.0000	9647.0000	347.0000

THE VARIANCE-COVARIANCE MATRICES FOR GROUND COORDINATES:

POINT	27	0.225000E 03	0.0	0.0
		0.0	0.100000E 03	0.0
		0.0	0.0	0.625000E 03
POINT	29	0.225000E 03	0.0	0.0
		0.0	0.100000E 03	0.0
		0.0	0.0	0.625000E 03
POINT	15	0.225000E 03	0.0	0.0
		0.0	0.100000E 03	0.0
		0.0	0.0	0.625000E 03
POINT	14	0.225000E 03	0.0	0.0
		0.0	0.100000E 03	0.0
		0.0	0.0	0.625000E 03
POINT	17	0.225000E 03	0.0	0.0
		0.0	0.100000E 03	0.0
		0.0	0.0	0.625000E 03
POINT	30	0.225000E 03	0.0	0.0
		0.0	0.100000E 03	0.0
		0.0	0.0	0.625000E 03

THE VARIANCE-COVARIANCE MATRICES FOR MODEL COORDINATES

POINT	27	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	29	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	15	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	14	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	17	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	30	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	2	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	28	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	175	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	182	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	190	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	181	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	174	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	166	0.100000E-03	0.0	0.0
		0.0	0.100000E-03	0.0
		0.0	0.0	0.100000E-03
POINT	172	0.100000E-03	0.0	0.0

		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	173	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	180	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	188	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	169	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	177	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	184	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	185	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	178	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	170	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	163	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	171	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	186	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	187	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000F-03
POINT	199	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0
		0.0	0.0	0.100000E-03
POINT	168	0.100000E-03	0.0	0.0
		0.0	0.100000F-03	0.0

	0.0	0.0	0.100000E-03
POINT 183	0.100000E-03	0.0	0.0
	0.0	0.100000E-03	0.0
	0.0	0.0	0.100000E-03
POINT 217	0.100000E-03	0.0	0.0
	0.0	0.100000E-03	0.0
	0.0	0.0	0.100000E-03

********************** WEIGHTS USED IN SOLUTION **********************

THE WEIGHT MATRIX FOR THE TRANSFORMATION PARAMETERS

0.100E-23	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.100E-23	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.100E-23	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.100E-23	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.100E-23	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.100E-23	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.100E-23

THE WEIGHT MATRICES FOR THE GROUND COORDINATES OF THE CONTROL POINTS

POINT	27	0.4444E-06	0.0	0.0
		0.0	0.1000E-05	0.0
		0.0	0.0	0.1600E-06
POINT	29	0.4444E-06	0.0	0.0
		0.0	0.1000E-05	0.0
		0.0	0.0	0.1600E-06
POINT	15	0.4444E-06	0.0	0.0
		0.0	0.1000E-05	0.0
		0.0	0.0	0.1600E-06
POINT	14	0.4444E-06	0.0	0.0
		0.0	0.1000E-05	0.0
		0.0	0.0	0.1600E-06
POINT	17	0.4444E-06	0.0	0.0
		0.0	0.1000E-05	0.0
		0.0	0.0	0.1600E-06
POINT	30	0.4444E-06	0.0	0.0
		0.0	0.1000E-05	0.0
		0.0	0.0	0.1600E-06

THE WEIGHT MATRICES FOR THE COORDINATES OF THE MODDEL POINTS (CONTROL AND UNKN

POINT	27	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	29	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	15	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	14	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	17	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	30	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	2	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	28	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	175	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	182	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	190	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	181	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	174	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	166	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01
POINT	172	0.1000E 01	0.0	0.0
		0.0	0.1000E 01	0.0
		0.0	0.0	0.1000E 01

```
POINT  173 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  180 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  188 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  169 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  177 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  184 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  185 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  178 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  170 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  163 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  171 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  186 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  187 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  199 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  168 0.1000E 01     0.0             0.0
           0.0            0.1000E 01      0.0
           0.0            0.0             0.1000E 01

POINT  183 0.1000E 01     0.0             0.0
```

	0.0	0.1000E 01	0.0
	0.0	0.0	0.1000E 01
POINT 217	0.1000E 01	0.0	0.0
	0.0	0.1000E 01	0.0
	0.0	0.0	0.1000E 01

************************* IIFPATION NUMBFR 1 *************************

```
**********************************
*                                *
*     SIGMA ZERO= 0,1186E-01     *
*                                *
**********************************
```

T R A N S F O R M A T I O N   P A R A M E T E R S

	OLD VALUE	CORRECTION	NEW VALUE	DEVIATION
SCALE FACTOR	0.00667	-0.1243E-05	0.00667	0.2846E-05
TRANSLATION IN X	10088.594	-0.1334E 04	8754.570	0.7299E 01
TRANSLATION IN Y	5982.703	0.4805F 03	6463.172	0.4896E 01
TRANSLATION IN Z	434.501	-0.2230F 02	412.202	0.1213E 02
ANGLE OMEGA	0 0 46.25	0 -2-23,25	0 -1-37.00	0 3 52.87
ANGLE PHI	0 5 41.50	0 -3-27,10	0 2 14.40	0 8 46.98
ANGLE CAPA	0 55 29.80	0 1 6.19	0 56 35.99	0 1 54.37

ROTATIONS IN RADIANS

ANGLE OMEGA	0.00022424	-0.6945E-03	-0.00047026	0.1129E-02
ANGLE PHI	0.00165564	-0.1004E-02	0.00065161	0.2555E-02
ANGLE CAPA	0.01614332	0.3209F-03	0.01646423	0.5545E-03

******************************* FINAL OUTPUT *******************************

THE SOLUTION CONVERGES AFTER ITERATION NUMBER 2

```
********************************
*                              *
*   SIGMA ZERO= 0.1187E-01     *
*                              *
********************************
```

T R A N S F O R M A T I O N   P A R A M E T E R S

	OLD VALUE	CORRECTION	FINAL VALUE	DEVIATION
SCALE FACTOR	0.00667	0.1067E-07	0.00667	0.2847E-05
TRANSLATION IN X	8754.570	-0.4073E 00	8754.160	0.7332E 01
TRANSLATION IN Y	6463.172	-0.3552E 00	6462.816	0.4957E 01
TRANSLATION IN Z	412.202	-0.1665E 01	410.537	0.1259E 02
ANGLE OMEGA	0 -1-37.00	0 0 0.88	0 -1-36.12	0 3 53.18
ANGLE PHI	0 2 14.40	0 0 1.55	0 2 15.95	0 8 47.42
ANGLE CAPA	0 56 35.99	0 0 -0.05	0 56 35.94	0 1 54.41

THE VARIANCE-COVARIANCE MARTIX OF THE TRANSFORMATION

```
 0.8105E-11 0.1683E-05-0.4428E-06 0.8870E-07 0.6864E-10 0.2105E-10-0.1069E-09
 0.1683E-05 0.5376E 02 0.1055E 00-0.1372E 00 0.2339E-04-0.1147E-03-0.1691E-03
-0.4429E-06 0.1055E 00 0.2457E 02 0.8381E-01 0.8161E-05 0.6086E-04-0.4052E-03
 0.8868E-07-0.1372E 00 0.8379E-01 0.1584E 03-0.2887E-03 0.8453E-02-0.6804E-04
 0.6864E-10 0.2339E-04 0.8161E-05-0.2888E-03 0.1278E-05-0.6755E-06 0.1128E-07
 0.2106E-10-0.1147E-03 0.6086E-04 0.8455E-02-0.6755E-06 0.6538E-05-0.5468E-07
-0.1069E-09-0.1691E-03-0.4052E-03-0.6806E-04 0.1128E-07-0.5468E-07 0.3077E-06
```

LIST OF ADJUSTED GROUND COORDINATES

NUMBER	X	Y	Z	SIG(X)	SIG(Y)	SIG(Z)
27	1802.769	15105.105	291.357	0.9756E 01	0.7646E 01	0.2450E 02
29	10748.652	21621.320	392.987	0.1135E 02	0.8314E 01	0.2182E 02
15	14106.629	-9589.348	884.318	0.1157E 02	0.8437E 01	0.2186E 02
14	8000.918	-6094.605	384.560	0.9973E 01	0.7317E 01	0.1992E 02
17	8703.078	5197.234	305.587	0.7485E 01	0.5175E 01	0.1281E 02
30	17222.941	9636.289	349.190	0.8229E 01	0.6644E 01	0.2304E 02

LIST OF COMPUTED GROUND COORDINATES OF UNKNOWN POINTS

NUMBER	X	Y	Z	SIGMA X	SIGMA Y	SIGMA Z
30	17223.258	9636.402	350.913	8.466	7.122	25.347
2	16100.777	12002.691	928.696	8.731	7.025	23.511
28	2731.707	22347.523	345.682	11.922	9.163	26.839
175	7848.547	-11888.434	462.655	12.623	9.404	24.422
182	11916.590	-11058.113	882.592	12.438	9.280	24.868
190	17537.324	-10721.355	1048.351	12.903	10.241	32.288
181	11899.895	-6171.297	709.674	10.403	7.685	20.721
174	7330.199	-6822.988	366.749	10.500	7.721	19.988
166	2593.102	-6628.355	388.037	10.676	8.351	25.058
172	7165.727	3173.416	327.369	7.729	5.439	13.820
173	6907.047	-2153.035	362.430	8.896	6.434	16.669
180	11896.801	-1012.883	422.066	8.687	6.328	17.224
188	17463.773	-1767.742	737.714	9.633	7.914	27.262
169	7128.383	17310.672	382.670	9.644	7.005	18.120
177	11690.988	17778.391	385.775	9.811	7.267	19.511
184	16753.371	18040.121	868.005	10.411	8.437	27.392
185	17417.273	13783.797	840.036	9.279	7.740	26.830
178	12537.379	14335.777	410.233	8.778	6.521	18.260
170	7025.543	14157.277	374.324	8.661	6.207	15.996
163	2497.066	7115.887	314.164	7.964	6.242	20.426
171	7922.172	9247.543	392.542	7.653	5.334	13.233
186	16942.680	8644.918	372.404	8.328	6.951	24.599
187	16739.922	4478.914	483.950	8.319	6.868	24.138
199	13157.523	2976.610	233.742	7.988	5.920	17.406
168	6804.008	22749.457	399.666	11.784	8.736	22.903
183	17216.086	23514.016	786.261	12.508	10.100	31.629
217	12064.441	23087.430	453.056	11.910	8.975	24.197

6.2 TO STUDY ACCURACY OF ABSOLUTE ORIENTATION BY SIMULATION

6.2.1 INPUT DATA

```
        1          25          25          8          1          1
     .01
 1.000E+06 1.000E+06 1.000E+06 1.000E+06 1.000E+06 1.000E+06 1.000E+06
     1.0          1
  -1000.0        1000.0           745.0
  - 500.0        1000.0           730.0
       .0        1000.0           747.0
    500.0        1000.0           735.0
   1000.0        1000.0           780.0
  -1000.0         500.0           790.0
  - 500.0         500.0          800.0
       .0         500.0           720.0
    500.0         500.0           735.0
   1000.0         500.0           749.0
  -1000.0            .0           713.0
  - 500.0            .0           784.0
       .0            .0           795.0
    500.0            .0           810.0
   1000.0            .0           725.0
  -1000.0       - 500.0           730.0
  - 500.0       - 500.0           747.0
       .0       - 500.0           758.0
    500.0       - 500.0           739.0
   1000.0       - 500.0           729.0
  -1000.0       -1000.0           786.0
  - 500.0       -1000.0           793.0
       .0       -1000.0           749.0
    500.0      -1000.0           763.0
   1000.0       -1000.0           777.0
  1.44E+02  1.44E+02   .25E+02
  1.00E+00  1.00E+00  5.00E+00
            200.0     -200.0    25.0       .33142     -.33142  .67189
    43211    200.0               1431   15.0
   123455    479213      69813        1111  123567891 213456789
   .100     20.0     -15.0     5.0         .01         -0.02       -0.03
```

6.2.2 OUTPUT

GENERAL DATA

```
NUMBER OF POINTS USED IN THE SOLUTION          25
MAXIMUM NUMBER OF ITERATIONS ALLOWED            8
```

THE VARIANCE-COVARIANCE MATRIX FOR THE TRANSFORMATION PARAMETERS

(ORDER OF VARIABLES = SCALE,DX,DY,DZ,OME,PHI,CAPA)

```
0.100E 07 0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.100E 07 0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.100E 07 0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.100E 07 0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.100E 07 0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.100E 07 0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.100E 07
```

```
*******************************
*                             *
*     SIGMA ZERO=  0.10000    *
*                             *
*******************************
```

************************ PRINT OUT OF THE INPUT ************************

LIST OF TRUE COORDINATES OF POINTS USED IN THE SOLUTION

POINT NUMBER	X	COORDINATES Y	Z
1	-1000.000	1000.000	745.000
2	-500.000	1000.000	730.000
3	0.0	1000.000	747.000
4	500.000	1000.000	735.000
5	1000.000	1000.000	780.000
6	-1000.000	500.000	790.000
7	-500.000	500.000	800.000
8	0.0	500.000	720.000
9	500.000	500.000	735.000
10	1000.000	500.000	749.000
11	-1000.000	0.0	713.000
12	-500.000	0.0	784.000
13	0.0	0.0	795.000
14	500.000	0.0	810.000
15	1000.000	0.0	725.000
16	-1000.000	-500.000	730.000
17	-500.000	-500.000	747.000
18	0.0	-500.000	758.000
19	500.000	-500.000	739.000
20	1000.000	-500.000	729.000
21	-1000.000	-1000.000	786.000
22	-500.000	-1000.000	793.000
23	0.0	-1000.000	749.000
24	500.000	-1000.000	763.000
25	1000.000	-1000.000	777.000

********************* VARIANCE-COVARIANCE MATRICES *********************

THE VARIANCE-COVARIANCE MATRICES FOR MODEL COORDINATES

0.144E 03	0.0	0.0
0.0	0.144E 03	0.0
0.0	0.0	0.250E 02

THE VARIANCE-COVARIANCE MATRICES FOR GROUND COORDINATES

0.100E 01	0.0	0.0
0.0	0.100E 01	0.0
0.0	0.0	0.500E 01

THE RATIO SIGMA GROUND TO SIGMA MODEL, FOR THE X COORDINATES, AT THE GROUND SCALE

THE RATIO SIGMA GROUND TO SIGMA MODEL, FOR THE Y COORDINATES, AT THE GROUND SCALE

THE RATIO SIGMA GROUND TO SIGMA MODEL, FOR THE Z COORDINATES, AT THE GROUND SCALE

********************** OUTPUT OF SUBROUTINE INPUT1 ********************

T R A N S F O R M A T I O N   P A R A M E T E R S

PARAMETER	GENERATED	CORRECTIONS	APPROXIMATIONS
SCALE	1,00000	0,10000	1,10000
TRANSLATION IN X	200,00000	20,0000	220,0000
TRANSLATION IN Y	-200,00000	-15,0000	-215,0000
TRANSLATION IN Z	25,00000	5,0000	30,0000
ANGLE OME	0,33142	0,01000	0,34142
ANGLE PHI	-0,33142	-0,02000	-0,35142
ANGLE CAPA	0,67189	-0,03000	0,64189
ANGLES IN DEGREES			
ANGLE OMEGA	18 59 20.23	0 34 22,65	19 33 42.91
ANGLE PHI	-18-59-20.23	-1 -8-45,29	-20 -8 -5,54
ANGLE CAPA	38 29 47.20	-1-43 -7,94	36 46 39.86

M O D E L   C O O R D I N A T E S

POINT NUMBER	GENERATED X	GENERATED Y	GENERATED Z	PERTURBED X	PERTURBED Y	PERTURBED Z
1	22647.64	18898.97	55011.57	22660.36	18926.43	55018.34
2	27240.86	13060.09	48730.49	27228.74	13067.63	48726.67
3	32529.18	11924.55	51076.73	32520.73	11929.30	51064.63
4	33359.00	8150.96	47659.58	33369.06	8165.49	47658.86
5	39274.91	5230.15	50240.33	39279.86	5236.57	50237.13
6	19429.45	11586.27	58169.51	19417.36	11573.68	58168.65
7	30584.44	11915.09	56383.95	30586.27	11915.05	56389.55
8	26841.99	6459.16	51742.48	26862.22	6442.11	51747.32
9	32007.84	2993.38	48519.10	32000.60	3016.47	48513.02
10	36673.04	968.91	48149.18	36662.23	978.30	48146.82
11	17534.02	11929.20	52398.84	17555.44	11931.34	52392.10
12	24069.79	8177.08	57556.79	24081.67	8197.91	57562.21
13	29184.73	5212.50	56570.44	29164.87	5203.15	56576.87
14	32848.06	2939.81	54578.10	32839.83	2947.67	54575.05
15	30021.73	-2274.08	50215.87	30023.14	-2274.26	50207.72
16	15576.11	4449.33	58390.55	15562.32	4461.25	58401.98
17	20033.22	5841.73	55019.64	20030.57	5850.76	55022.61
18	24567.80	6056.96	54833.32	24553.76	6028.88	54835.97
19	29265.78	-2974.55	50120.10	29244.99	-2986.24	50112.75
20	33212.50	-5228.58	49567.02	33219.15	-5237.89	49565.62
21	19868.91	1322.58	60887.37	19873.79	1315.47	60884.85
22	19702.75	1277.97	60458.94	19691.07	1275.43	60459.58
23	23498.14	-4775.02	54559.68	23480.54	-4781.35	54561.93
24	25548.37	-2776.49	58456.63	25543.25	-2766.10	58454.64
25	31565.46	-12087.81	54010.04	31542.93	-12104.13	54009.25

GROUND COORDINATES

POINT NUMBER	GENERATED X	GENERATED Y	GENERATED Z	PERTURBED X	PERTURBED Y	PERTURBED Z
1	-12063.27	9559.49	60446.23	-12064.34	9559.05	60448.75
2	-3183.52	9109.07	56497.87	-3183.07	9110.84	56499.38
3	635.06	10146.43	60868.55	635.86	10145.25	60867.59
4	4582.18	8576.13	57942.81	4583.43	8574.85	57945.02
5	9839.71	8419.86	62688.69	9839.74	8419.20	62689.02
6	-11168.25	1066.59	61381.31	-11166.48	1065.62	61380.26
7	-2525.48	7522.38	64751.07	-2525.70	7521.35	64747.08
8	-573.51	2660.53	58597.32	-573.62	2661.73	58597.84
9	6338.29	3471.53	57786.64	6339.35	3471.84	57784.39
10	11102.75	4313.04	59396.35	11101.42	4312.84	59398.19
11	-10895.13	2159.91	55402.93	-10894.72	2159.19	55401.74
12	-5528.15	854.18	62675.47	-5527.18	854.26	62674.91
13	323.07	1355.10	63874.04	323.47	1356.92	63870.11
14	5020.11	1989.06	63573.26	5021.16	1989.59	63573.28
15	7416.74	-2300.33	58090.63	7418.11	-2301.87	58091.58
16	-9891.12	-6702.27	59419.94	-9890.89	-6701.67	59422.27
17	-6315.31	-2288.80	58469.88	-6315.28	-2290.86	58471.04
18	-3025.53	235.26	60327.27	-3025.05	235.55	60324.16
19	7300.75	-3217.72	57625.63	7301.79	-3214.82	57623.96
20	11728.21	-2868.24	58738.54	11728.29	-2866.50	58737.78
21	-5686.25	-7819.53	63358.16	-5684.55	-7819.11	63361.55
22	-5643.56	-7807.70	62898.61	-5643.34	-7806.80	62899.09
23	2647.53	-8951.65	58924.41	2649.01	-8950.93	58927.04
24	1720.48	-7503.07	63443.93	1719.11	-7500.95	63444.42
25	13100.90	-10596.49	61547.83	13101.68	-10595.79	61547.82

*********************** WEIGHTS USED IN SOLUTION ***********************

THE WEIGHT MATRIX FOR THE TRANSFORMATION PARAMETERS

0.100E-07	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.100E-07	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.100E-07	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.100E-07	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.100E-07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.100E-07	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.100E-07

THE GROUND COORDINATE WEIGHT MATRIX

0.1000E-01	0.0	0.0
0.0	0.1000E-01	0.0
0.0	0.0	0.2000E-02

THE MODEL COORDINATE WEIGHT MATRIX

0.6944E-04	0.0	0.0
0.0	0.6944E-04	0.0
0.0	0.0	0.4000E-03

************************* ITERATION NUMBER 1 *************************

```
*********************************
*                               *
*    SIGMA ZERO= 0.1043E 00     *
*                               *
*********************************
```

T R A N S F O R M A T I O N   P A R A M E T E R S

	OLD VALUE	CORRECTION	NEW VALUE	DEVIATION
SCALE FACTOR	1.10000	-0.1000E 00	0.99996	0.2122E-03
TRANSLATION IN X	220.000	0.3248E 02	252.477	0.1065E 02
TRANSLATION IN Y	-215.000	-0.2085E 02	-235.852	0.1223E 02
TRANSLATION IN Z	30.000	0.9883E 01	39.883	0.1175E 02
ANGLE OMEGA	19 33 42.91	0-31-20.22	19 2 22.66	0 0 39.89
ANGLE PHI	-20 -8 -5.54	1 1 47.42	-19 -6-18.09	0 0 31.35
ANGLE CAPA	36 46 39.26	1 35 28.29	38 22 7.53	0 0 52.24

ROTATIONS IN RADIANS

ANGLE OMEGA	0.34141994	-0.9116E-02	0.33230430	0.1934E-03
ANGLE PHI	-0.35141993	0.1797E-01	-0.33344579	0.1520E-03
ANGLE CAPA	0.64188993	0.2777E-01	0.66966146	0.2533E-03

************************** ITERATION NUMBER 2 **************************

SIGMA ZERO= 0.1031E 00

TRANSFORMATION PARAMETERS

	OLD VALUE	CORRECTION	NEW VALUE	DEVIATION
SCALE FACTOR	0.99998	0.5561E-03	1.00053	0.2098E-03
TRANSLATION IN X	252.477	-0.3349E 02	218.986	0.1134E 02
TRANSLATION IN Y	-235.852	0.2131E 02	-214.538	0.1300E 02
TRANSLATION IN Z	39.883	0.1961E 02	59.494	0.1278E 02
ANGLE OMEGA	19 2 22.66	0 -3-26.71	18 58 55.95	0 0 42.41
ANGLE PHI	-19 -6-18.09	0 6 34.05	-18-59-44.07	0 0 33.41
ANGLE CAPA	38 22 7.53	0 9 11.26	38 31 18.83	0 0 56.42

ROTATIONS IN RADIANS

ANGLE OMEGA	0.33230430	-0.1002E-02	0.33130211	0.2056E-03
ANGLE PHI	-0.33344579	0.1910E-02	-0.33153540	0.1620E-03
ANGLE CAPA	0.66966146	0.2673E-02	0.67233402	0.2735E-03

******************************** FINAL OUTPUT ********************************

THE SOLUTION CONVERGES AFTER ITERATION NUMBER 3

****
*   *
*   SIGMA ZERO= 0,1031E 00   *
*   *
****

T R A N S F O R M A T I O N   P A R A M E T E R S

	OLD VALUE	CORRECTION	FINAL VALUE	DEVIATION
SCALE FACTOR	1,00053	0,5464E-05	1,00054	0,2099E-03
TRANSLATION IN X	218.986	-0.3506E 00	218.635	0.1132E 02
TRANSLATION IN Y	-214.538	0.1443E 00	-214.393	0.1297E 02
TRANSLATION IN Z	59.494	0.1574E 00	59.651	0.1277E 02
ANGLE OMEGA	18 58 55.95	0 0 0.02	18 58 55.95	0 0 42.34
ANGLE PHI	-18-59-44.07	0 0 0.01	-18-59-44.01	0 0 33.37
ANGLE CAPA	38 31 18.83	0 0 -0.46	38 31 18.33	0 0 56.36

THE VARIANCE-COVARIANCE MARTIX OF THE TRANSFORMATION

0.4404E-07	-0.6512E-03	-0.6344E-03	0.2661E-02	-0.1210E-07	0.1033E-07	-0.3351E-08
-0.6512E-03	0.1280E 03	-0.3355E 00	-0.3776E 02	0.5656E-03	-0.1580E-02	0.1707E-02
-0.6344E-03	-0.3352E 00	0.1683E 03	-0.3865E 02	0.2380E-02	-0.3392E-03	-0.9976E-03
0.2661E-02	-0.3776E 02	-0.3865E 02	0.1631E 03	-0.7557E-03	0.6261E-03	-0.1906E-03
-0.1210E-07	0.5656E-03	0.2380E-02	-0.7557E-03	0.4214E-07	-0.7335E-08	0.7780E-08
0.1033E-07	-0.1580E-02	-0.3391E-03	0.6262E-03	-0.7334E-08	0.2617E-07	-0.4897E-08
-0.3351E-08	0.1707E-02	-0.9976E-03	-0.1906E-03	0.7780E-08	-0.4697E-08	0.7465E-07

LIST OF ADJUSTED GROUND COORDINATES

NUMBER	X	Y	Z	SIG(X)	SIG(Y)	SIG(Z)
1	-12064.352	9559.168	60449.133	0.1027E 01	0.1027E 01	0.2173E 01
2	-3183.107	9110.813	56498.746	0.1026E 01	0.1026E 01	0.2158E 01
3	635.918	10145.344	60865.816	0.1026E 01	0.1026E 01	0.2159E 01
4	4583.406	8574.953	57945.219	0.1026E 01	0.1026E 01	0.2156E 01
5	9839.723	8419.285	62688.859	0.1026E 01	0.1027E 01	0.2171E 01
6	-11166.414	1065.517	61379.656	0.1026E 01	0.1026E 01	0.2157E 01
7	-2525.752	7521.273	64748.109	0.1026E 01	0.1026E 01	0.2159E 01
8	-573.482	2661.634	58598.977	0.1026E 01	0.1026E 01	0.2143E 01
9	6339.230	3470.967	57784.301	0.1026E 01	0.1026E 01	0.2149E 01
10	11101.348	4312.840	59397.992	0.1026E 01	0.1026E 01	0.2159E 01
11	-10894.473	2159.314	55401.160	0.1026E 01	0.1027E 01	0.2167E 01
12	-5527.207	854.368	62675.727	0.1026E 01	0.1026E 01	0.2147E 01
13	323.315	1356.696	63871.277	0.1026E 01	0.1026E 01	0.2146E 01
14	5021.102	1989.643	63572.836	0.1026E 01	0.1026E 01	0.2150E 01
15	7418.184	-2301.760	58090.805	0.1026E 01	0.1026E 01	0.2150E 01
16	-9891.016	-6701.730	59423.301	0.1026E 01	0.1027E 01	0.2166E 01
17	-6315.281	-2290.816	58471.195	0.1026E 01	0.1026E 01	0.2151E 01
18	-3025.025	235.296	60324.750	0.1026E 01	0.1026E 01	0.2143E 01
19	7301.754	-3214.919	57623.543	0.1026E 01	0.1026E 01	0.2152E 01
20	11728.320	-2866.526	58738.539	0.1026E 01	0.1026E 01	0.2160E 01
21	-5684.367	-7819.023	63360.453	0.1026E 01	0.1026E 01	0.2159E 01
22	-5643.301	-7806.816	62898.664	0.1026E 01	0.1026E 01	0.2158E 01
23	2648.951	-8951.008	58927.180	0.1026E 01	0.1026E 01	0.2159E 01
24	1719.122	-7500.844	63443.965	0.1026E 01	0.1026E 01	0.2154E 01
25	13101.598	-10595.902	61548.008	0.1027E 01	0.1027E 01	0.2181E 01

6.3 TO DETERMINE THE UNCERTAINTY IN THE ORIENTATION OF THE SURFACE DEFINED BY A SET OF TRIANGULATED PASS POINTS

6.3.1 INPUT DATA

```
        3           9           9          8           1          1
    1.0
 1.000E+06 1.000E+06 1.000E+06 1.000E+06 1.000E+06 1.000E+06 1.000E+06
     12345     1234567         123      54321
         7    -205573.4       -84998.6          84675.1
         8    -183918.4       -89441.8          86030.0
         9    -161431.8       -94340.5          89482.9
        49    -227384.6       -27526.5          84682.8
        50    -204120.1       -32641.7          86455.7
        51    -179883.2       -38225.9          91487.4
        91    -250402.5        35956.8          80707.9
        92    -225748.3        30354.6          82398.3
        93    -199706.4        24186.2          86004.7
         7        6.4               11.3                     16.9
         8        7.1               19.7                     31.2
         9        6.3               10.3                     14.6
        49        6.4                5.3                     16.4
        50        8.0                6.6                     29.4
        51        6.3                5.4                     13.5
        91        8.6               10.4                     20.3
        92       11.4               15.6                     31.7
        93        7.6                9.3                     17.7
    0.5        0.1
   50.0       10.0
    0.5        0.2
    1.0        0.2
 1.000E-10      1.000E-10       1.000E-10
```

GFNERAL DATA

NUMBER OF POINTS USED IN THE SOLUTION 9
MAXIMUM NUMBER OF ITERATIONS ALLOWED 8

THE VARIANCE-COVARIANCE MATRIX FOR THE TRANSFORMATION PARAMETERS

(ORDER OF VARIABLES = SCALE,DX,DY,DZ,OME,PHI,CAPA)

0.100E 07	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.100E 07	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.100E 07	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.100E 07	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.100E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.100E 07	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.100E 07

```
********************************
*                              *
*     SIGMA ZERO=  1.00000     *
*                              *
********************************
```

THE GIVEN MODEL COORDINATES OF THE CONTROL POINTS

	NUMBER	X	Y	Z
1	7	-205573.38	-84998.56	64675.06
2	8	-183918.38	-89441.75	66030.00
3	9	-161431.75	-94340.50	69462.88
4	49	-227384.56	-27526.50	64662.75
5	50	-204120.06	-32641.70	66455.69
6	51	-179883.19	-38225.90	61467.38
7	91	-250402.50	35956.80	60707.88
8	92	-225748.25	30354.60	62396.25
9	93	-199706.38	24186.20	66004.69

THE DEVIATIONS OF THE MODEL COORDINATES OF THE CONTROL POINTS

	NUMBER	SIGMA X	SIGMA Y	SIGMA Z
1	7	6.3999996	11.2999992	16.8999939
2	8	7.0999994	19.6999969	31.1999969
3	9	6.2999992	10.2999992	14.5999994
4	49	6.3999996	5.2999992	16.3999939
5	50	8.0000000	6.5999994	29.3999939
6	51	6.2999992	5.3999996	13.5000000
7	91	8.5999994	10.3999996	20.2999876
8	92	11.3999996	15.5999994	31.6999969
9	93	7.5999994	9.2999992	17.6999969

C-2

************************ PRINT OUT OF INPUT3 ************************

THE ARBITRARY ROTATIONS OF THE MODEL

	IN RAD	IN DEGREES
OMEGA	0,0067688	0 23 16,171
PHI	0,0118747	0 40 49,331
CAPA	0,0118678	0 40 47,901

APPROXIMATIONS FOR THE TRANSFORMATION PARAMETERS

PARAMETER	APPROXIMATION IN RAD		APPROXIMATION IN DEGREES
SCALE		1,04620	
TRANSLATION IN X		39,48483	
TRANSLATION IN Y		47,34769	
TRANSLATION IN Z		27,77567	
ROTATION OMEGA	-0,00326		0 -11 -12,320
ROTATION PHI	-0,01163		0 -39 -59,258
ROTATION CAPA	-0,01065		0 -36 -36,788

GROUND COORDINATES - (GENERATED BY ROTATION OF THE GIVEN MODEL COORDINATES)

	NUMBER	X	Y	Z
1	7	-207558.44	-81965.94	62801.31
2	8	-185975.50	-86656.38	64443.38
3	9	-163591.38	-91797.56	88196.06
4	49	-228680.00	-24240.52	62161.06
5	50	-205500.81	-29619.05	64244.69
6	51	-181393.38	-35455.57	69601.50
7	91	-250889.31	39482.47	77483.56
8	92	-226325.44	33599.91	79504.38
9	93	-200403.44	27147.98	63461.50

```
********************  VARIANCE-COVARIANCE MATRICES  ********************

  THE VARIANCE-COVARIANCE MATRICES FOR MODEL COORDINATES


  POINT     7        0.409600E 02    0.0              0.0
                     0.0             0.127690E 03     0.0
                     0.0             0.0              0.285610E 03

  POINT     8        0.504100E 02    0.0              0.0
                     0.0             0.388090E 03     0.0
                     0.0             0.0              0.973440E 03

  POINT     9        0.396900E 02    0.0              0.0
                     0.0             0.106090E 03     0.0
                   0.0             0.0              0.213160E 03
  POINT    49        0.409600E 02    0.0              0.0
                     0.0             0.280900E 02     0.0
                     0.0             0.0              0.268960E 03

  POINT    50        0.640000E 02    0.0              0.0
                     0.0             0.435600E 02     0.0
                     0.0             0.0              0.864360E 03

  POINT    51        0.396900E 02    0.0              0.0
                     0.0             0.291600E 02     0.0
                     0.0             0.0              0.182250E 03

  POINT    91        0.739600E 02    0.0              0.0
                     0.0             0.108160E 03     0.0
                     0.0             0.0              0.412089E 03

  POINT    92        0.129960E 03    0.0              0.0
                     0.0             0.243360E 03     0.0
                     0.0             0.0              0.100489E 04

  POINT    93        0.577600E 02    0.0              0.0
                     0.0             0.864900E 02     0.0
                     0.0             0.0              0.313290E 03


  THE VARIANCE-COVARIANCE MATRICES FOR GROUND COORDINATES


                     0.100000E-19    0.0              0.0
                     0.0             0.100000E-19     0.0
                     0.0             0.0              0.100000E-19
```

************************ WEIGHTS USED IN SOLUTION ************************

THE WEIGHT MATRIX FOR THE TRANSFORMATION PARAMETERS

0.100E-05	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.100E-05	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.100E-05	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.100E-05	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.100E-05	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.100E-05	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.100E-05

THE GROUND COORDINATE WEIGHT MATRIX

0.1000E 21	0.0	0.0
0.0	0.1000E 21	0.0
0.0	0.0	0.1000E 21

THE WEIGHT MATRICES FOR THE COORDINATES OF THE MODDEL POINTS (CONTROL AND UNK

POINT	7	0.2441E-01	0.0	0.0
		0.0	0.7831E-02	0.0
		0.0	0.0	0.3501E-02
POINT	8	0.1984E-01	0.0	0.0
		0.0	0.2577E-02	0.0
		0.0	0.0	0.1027E-02
POINT	9	0.2520E-01	0.0	0.0
		0.0	0.9426E-02	0.0
		0.0	0.0	0.4691E-02
POINT	49	0.2441E-01	0.0	0.0
		0.0	0.3560E-01	0.0
		0.0	0.0	0.3718E-02
POINT	50	0.1563E-01	0.0	0.0
		0.0	0.2296E-01	0.0
		0.0	0.0	0.1157E-02

POINT	51	0.2520E-01	0.0	0.0
		0.0	0.3429E-01	0.0
		0.0	0.0	0.5487E-02
POINT	91	0.1352E-01	0.0	0.0
		0.0	0.9246E-02	0.0
		0.0	0.0	0.2427E-02
POINT	92	0.7695E-02	0.0	0.0
		0.0	0.4109E-02	0.0
		0.0	0.0	0.9951E-03
POINT	93	0.1731E-01	0.0	0.0
		0.0	0.1156E-01	0.0
		0.0	0.0	0.3192E-02

************************* ITERATION NUMBER 1 *************************

```
**********************************
*                                *
*    SIGMA ZERO= 0.1366E 00      *
*                                *
**********************************
```

T R A N S F O R M A T I O N   P A R A M E T E R S

	OLD VALUE	CORRECTION	NEW VALUE	DEVIATION
SCALE FACTOR	1.04620	-0.4621E-01	0.99999	0.8443E-05
TRANSLATION IN X	39.485	-0.3713E 02	2.354	0.3721E 01
TRANSLATION IN Y	47.348	-0.4529E 02	2.059	0.2569E 01
TRANSLATION IN Z	27.776	-0.2475E 02	3.022	0.8159E 01
ANGLE OMEGA	0-11-12.32	0-11-59.78	0-23-12.10	0 0 4.61
ANGLE PHI	0-39-59.26	0 0-30.43	0-40-29.69	0 0 7.87
ANGLE CAPA	0-36-36.79	0 -4-15.99	0-40-52.76	0 0 1.34

ROTATIONS IN RADIANS

ANGLE OMEGA	-0.00325950	-0.3490E-02	-0.00674911	0.2236E-04
ANGLE PHI	-0.01163193	-0.1475E-03	-0.01177945	0.3814E-04
ANGLE CAPA	-0.01065033	-0.1241E-02	-0.01189142	0.6509E-05

```
************************  ITERATION NUMBER   2  ************************


              ********************************
              *                              *
              *    SIGMA ZERO= 0.1648E-01    *
              *                              *
              ********************************


     T R A N S F O R M A T I O N   P A R A M E T E R S
     -------------------------------------------------

                          OLD VALUE    CORRECTION     NEW VALUE     DEVIATION

  SCALE FACTOR              0.99999    0.6752E-05      1.00000      0.1017E-05
  TRANSLATION IN X            2.354   -0.2526E 01       -0.171      0.4690E 00
  TRANSLATION IN Y            2.059   -0.1879E 01        0.179      0.3242E 00
  TRANSLATION IN Z            3.022   -0.3161E 01       -0.139      0.1029E 01
  ANGLE OMEGA           0-23-12.10    0  0-33.14    0-23-45.24     0  0  0.58
  ANGLE PHI             0-40-29.69    0  0 -2.77    0-40-32.46     0  0  0.99
  ANGLE CAPA            0-40-52.78    0  0-11.64    0-41 -4.42     0  0  0.17

  ROTATIONS IN RADIANS

  ANGLE OMEGA          -0.00674911   -0.1606E-03   -0.00690976    0.2820E-05
  ANGLE PHI            -0.01177945   -0.1344E-04   -0.01179289    0.4810E-05
  ANGLE CAPA           -0.01189142   -0.5643E-04   -0.01194784    0.8180E-06
```

******************************* FINAL OUTPUT *******************************

THE SOLUTION CONVERGES AFTER ITERATION NUMBER 3

```
*********************************
*                               *
*     SIGMA ZERO= 0.1638E-01    *
*                               *
*********************************
```

T R A N S F O R M A T I O N   P A R A M E T E R S

	OLD VALUE	CORRECTION	FINAL VALUE	DEVIATION
SCALE FACTOR	1.00000	0.8061E-06	1.00000	0.1011E-05
TRANSLATION IN X	-0.171	-0.7840E-01	-0.250	0.4663E 00
TRANSLATION IN Y	0.179	-0.2036E 00	-0.024	0.3223E 00
TRANSLATION IN Z	-0.139	-0.3826E-01	-0.177	0.1023E 01
ANGLE OMEGA	0-23-45.24	0 0 -0.05	0-23-45.29	0 0 0.58
ANGLE PHI	0-40-32.46	0 0 0.11	0-40-32.34	0 0 0.99
ANGLE CAPA	0-41 -4.42	0 0 -0.18	0-41 -4.60	0 0 0.17

THE VARIANCE-COVARIANCE MARTIX OF THE TRANSFORMATION

0.1023E-11	-0.2481E-06	-0.1979E-08	-0.2600E-08	-0.4096E-13	0.4372E-12	0.1438E-12
-0.2481E-06	0.2174E 00	0.7156E-01	0.3997E 00	0.7097E-06	-0.1980E-05	0.1033E-07
-0.1980E-08	0.7156E-01	0.1039E 00	0.2118E 00	0.7730E-06	-0.9265E-06	0.1718E-06
-0.2606E-08	0.3997E 00	0.2118E 00	0.1046E 01	0.1981E-05	-0.4834E-05	0.1823E-06
-0.4096E-13	0.7097E-06	0.7730E-06	0.1981E-05	0.7858E-11	-0.8558E-11	0.4640E-12
0.4372E-12	-0.1980E-05	-0.9265E-06	-0.4834E-05	-0.8558E-11	0.2287E-10	-0.7759E-12
0.1438E-12	0.1033E-07	0.1718E-06	0.1823E-06	0.4640E-12	-0.7759E-12	0.6611E-12

LIST OF ADJUSTED GROUND COORDINATES

NUMBER	X	Y	Z	SIG(X)	SIG(Y)	SIG(Z)
7	-207558.438	-81965.938	82801.313	0.1638E-11	0.1638E-11	0.1638E-11
8	-185975.500	-86656.375	84443.375	0.1638E-11	0.1638E-11	0.1638E-11
9	-163591.375	-91797.563	88196.063	0.1638E-11	0.1638E-11	0.1638E-11
49	-228680.000	-24240.516	82161.063	0.1638E-11	0.1638E-11	0.1638E-11
50	-205500.813	-29619.055	84244.688	0.1638E-11	0.1638E-11	0.1638E-11
51	-181393.375	-35455.574	89601.500	0.1638E-11	0.1638E-11	0.1638E-11
91	-250889.313	39482.469	77483.563	0.1638E-11	0.1638E-11	0.1638E-11
92	-226325.438	33599.910	79504.375	0.1638E-11	0.1638E-11	0.1638E-11
93	-200403.438	27147.984	83461.500	0.1638E-11	0.1638E-11	0.1638E-11

CIVIL ENGINEERING STUDIES

PHOTOGRAMMETRY SERIES

The Photogrammetry Series publications are available through the National Technical Information Service, Operations Division, Springfield, Virginia 22151, USA, at $3.00 and up per paper copy and $0.95 per microfiche.

No.				N.T.I.S. Accession No.
1	1963	H. M. Karara	STUDIES IN SPATIAL AEROTRIANGULATION, Technical Report. No. 5, Engineering Experiment Station, University of Illinois.	
2	1965	A. A. Elassal	ANALYTICAL AERIAL TRIANGULATION THROUGH SIMULTANEOUS RELATIVE ORIENTATION OF MULTIPLE CAMERAS. (NSF-G-19749).*	PB 176 458
3	1965	Gordon Gracie	A STATISTICAL INVESTIGATION OF THE PROPAGATION OF RANDOM ERRORS IN ANALOG AEROTRIANGULATION. (NSF-G-19749).	PB 176 459
4	1966	M. F. Madkour	THE EFFECT OF THE ANOMALOUS GRAVITY ON THE DIRECTION OF THE VERTICAL AS DETERMINED BY A MECHANICALLY PERFECT INERTIAL PLATFORM. (NSF-GK-776).	PB 176 460
5	1967	H. F. Soehngen	STRIP AND BLOCK ADJUSTMENTS OF THE I.T.C. BLOCK OF SYNTHETIC AERIAL TRIANGULATION STRIPS. (NSF-GK-776).	PB 176 461
6	1967	D. C. O'Connor	VISUAL FACTORS AFFECTING THE PRECISION OF COORDINATE MEASUREMENT IN AEROTRIANGULATION.	AD 663 821
7	1967	D. E. Moellman	A COMPARATIVE STUDY OF TWO-PHOTO VERSUS THREE-PHOTO RELATIVE ORIENTATION. (NSF-GK-776).	PB 176 462
8	1967	H. F. Soehngen, C. C. Tung & J. W. Leonard	INVESTIGATION OF BLOCK ADJUSTMENTS OF I.T.C. FICTITIOUS BLOCK USING SECTIONS AND THE ITERATIVE AND DIRECT SOLUTIONS OF THE NORMAL EQUATION SYSTEM. (NSF-GK-776).	PB 179 567
9	1967	H. M. Karara	MONO VERSUS STEREO ANALYTICAL PHOTOGRAMMETRY -- Part I. (DA-1338-X).	AD 664 184

---

* Information in parentheses refers to the contract number of the project's sponsor.

CIVIL ENGINEERING STUDIES

PHOTOGRAMMETRY SERIES

(Continued)

No.				N.T.I.S. Accession No.
10	1968	G. Inghilleri	A TREATISE ON ANALYTICAL PHOTOGRAMMETRY (LECTURE NOTES).	PB 182 618
11	1967	S. Weissman	STEREOPHOTOGRAMMETRY AS A MEANS OF ANTHROPOMETRY FOR MENTALLY HANDICAPPED CHILDREN (MH-NB-07346-01A1).	PB 178 125
12	1968	D. E. Moellman & H. M. Karara	A UNIVERSAL DATA REDUCTION SCHEME FOR CLOSE-RANGE PHOTOGRAMMETRY (NSF-GK-1888).	PB 182 204
13	1968	S. Weissman	HORIZON-CONTROLLED ANALYTICAL AEROTRIANGULATION. (NSF-GK-776).	PB 178 030
14	1968	H. M. Karara & G. W. Marks	MONO VERSUS STEREO ANALYTICAL PHOTOGRAMMETRY -- Part II. (DA-1338-X).	AD 828 750
15	1968	H. M. Karara	ON THE PRECISION OF STEREOMETRIC SYSTEMS. (NSF-GK-1888).	PB 179 920
16	1968	K. W. Wong	GEOMETRIC CALIBRATION OF TELEVISION SYSTEMS FOR PHOTOGRAMMETRIC APPLICATIONS.	PB 182 715
17	1968	K. W. Wong	PHOTOGRAMMETRIC QUALITY OF TELEVISION PICTURES.	PB 182 727
18	1968	S. Weissman	ABOUT THE INCORPORATION OF HORIZON PHOTOGRAPHY IN ANALYTICAL AEROTRIANGULATION. (NSF-GK-776).	PB 180 783
19	1968	R. C. Malhotra	GRID PLATE CALIBRATION.	PB 182 728
20	1968	K. W. Wong	THREE COMPUTER PROGRAMS FOR STRIP AEROTRIANGULATION.	PB 186 469
21	1968	L. A. White	GRAPHICAL TRANSFORMATION AND COMPARISON OF PLANE COORDINATE SYSTEMS.	PB 182 716
22	1968	H. M. Karara & G. W. Marks	ANALYTICAL AERIAL TRIANGULATION FOR HIGHWAY LOCATION AND DESIGN (IHR-804).	PB 186 495
23	1969	J. M. Fry	METHODS OF GRAPHICAL AND ANALYTICAL MENSURATION OF SINGLE TERRESTRIAL PHOTOGRAPHS.	PB 183 889
24	1969	R. C. Malhotra	MATRIX TREATMENT OF THE ERROR ELLIPSOID (NSF-GK-1888).	PB 185 560
25	1969	K. W. Wong	GEOMETRIC FIDELITY OF THREE-SPACE TELEVISION SYSTEMS.	PB 187 466
26	1973	W. Faig	MODEL DEFORMATIONS DUE TO RADIAL LENS DISTORTION (NSF-GK-1888 and 11655).	
27	1971	J. J. Del Vecchio	LUNAR CONTROL BY ORBITAL TRIANGULATION--AN ERROR ANALYSIS (RADC-TR-71-)	

CIVIL ENGINEERING STUDIES
PHOTOGRAMMETRY SERIES
(Continued)

No.				N.T.I.S. Accession No.
28	1971	R. C. Malhotra	HIGH-PRECISION STEREOMETRIC SYSTEMS (NSF-GK-1888).	
29	1972	G. W. Marks & H. M. Karara	IMAGE COORDINATE REFINEMENT ANALYSIS (RADC-F30602-20-C-0036)(RADC-TR-72-170).	AD 747 799
30	1971	K. W. Wong & G. Elphingstone	SIMULTANEOUS ADJUSTMENT OF PHOTO-GRAMMETRIC AND GEODETIC OBSERVATIONS (SAPGO) (DA-ARO-D-31-124-G1129).	AD 737 748
31	1971	W. Faig	PHOTOGRAMMETRY AS A TOOL FOR HYDRAULIC SURFACE STUDIES. (University of Illinois Research Board).	PB 202 280
32	1971	W. Faig	DESIGN, CONSTRUCTION AND GEODETIC COORDINATION, OF A CLOSE-RANGE PHOTOGRAMMETRIC TEST FIELD. (NSF-GK-11655).	
33	1971	K. W. Wong, E. V. Gamble & R. E. Riggins	GEOMETRIC ANALYSIS OF THE RBV TELE-VISION SYSTEM. (USGS 14-08-0001-12631).	PB 203 705
34	1971	K. W. Wong & N. G. Yacoumelos	TELEVISION DISPLAY OF TOPOGRAPHIC IN-FORMATION. (USATL-DAAK02-71-C-0045).	AD 734 367
35	1972	K. W. Wong	GEOMETRIC ANALYSIS OF THE RBV TELE-VISION SYSTEM--PHASE II. (USGS 14-08-0001-12631).	
** 36	1973	Y. I. Abdel-Aziz & H. M. Karara	PHOTOGRAMMETRIC POTENTIALS OF NON-METRIC CAMERAS. (NSF-GK-11655).	
37	1974	K. W. Wong	TREATMENT OF CONTROL DATA IN LUNAR PHOTOTRIANGULATION (NAS9-12446).	
38	1974	K. W. Wong	SAPGOA- A COMPUTER PROGRAM FOR THE SIMULTANEOUS ADJUSTMENT OF PHOTO-GRAMMETRIC AND GEODETIC OBSERVA-TIONS (DA-ARO-D-31-124-G1129).	
39	1974	K. W. Wong	THREED- A COMPUTER PROGRAM FOR THREE-DIMENSIONAL TRANSFORMATION OF COORDINATES (NAS9-12446).	

** In preparation.