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MOMENTS OF INCLINATION ERROR DISTRIBUTION COMPUTER PROGRAM

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TABLE OF CONTENTS

MOMENTS OF INCLINATION ERROR DISTRIBUTION
COMPUTER PROGRAM

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SUMMARY

This report describes a FORTRAN coded computer program which calculates orbital inclination error statistics using a closed-form solution. This solution uses a data base of trajectory errors from actual flights to predict the orbital inclination error statistics. The methods used to generate the error statistics are of general interest since they have other applications. Included in this report are program theory, user instructions, output definitions, subroutine descriptions and detailed FORTRAN coding information.

1.0 INTRODUCTION

Since 1969, flight experience has been used as the basis for predicting Scout orbital accuracy. The data base of flight experience consists of errors in the trajectory parameters at orbit insertion as observed on Scout flights. This data base is used in a Monte Carlo analysis to calculate error statistics in the orbital parameters. The need arose to generate orbital inclination error statistics using a closed-form solution which included the option of considering non-zero mean values and correlation between the variables in the data base. To meet this need, the classical approach of expanding the orbital inclination relationship by a multivariable Taylor series was chosen. The mechanization of this process resulted in computer program Moments of Inclination Error Distribution (acronym MIED) and is described herein.

2.0 DEFINITIONS

2.1 Notation

Symbols used in this report are listed below with their definition and units.

English Alphabet

C_E	east component of position, ft
C_N	north component of position, ft
C_R	crossrange, n.mi.
$E(x)$	expected value of x
i	orbit inclination, deg.
n	number of samples
R	range, n.mi.
r_e	earth radius, ft

Greek Alphabet

α	longitude, deg
Δ	deviation from nominal
ζ	azimuth, deg.
λ	latitude, deg.
μ	statistical moment
σ	standard deviation

Superscripts

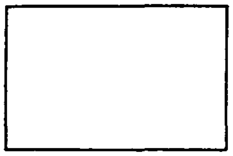
$(')$	adjusted value

Other

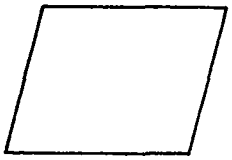
$\frac{\partial x}{\partial y}$	partial derivative of x to y

2.2 Flowchart Conventions

Flowchart conventions used in this report are as follows:

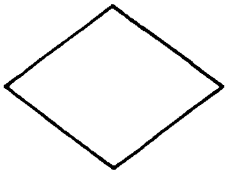


Process



Input/Output

Subroutine



Decision

3.0 PROGRAM DESCRIPTION

This section describes the utilization of the Scout data base, program theory, user instructions and output definitions.

3.1 General

The purpose of computer program MIED is to calculate orbital inclination error statistics from a data base of errors resulting from actual flights. The Scout flight history data base consists of orbit insertion errors in the trajectory parameters - altitude, velocity, flight path angle, flight azimuth, latitude and longitude. This data base is shown in Table 3.1.

The Scout data base includes flights with launch azimuths ranging from easterly to southerly to slightly west of south. Latitude errors, which produce inclination errors, result from crossrange errors on easterly flights and range errors on southerly flights. Therefore, latitude errors of the flight history data base are not a consistent sample set of errors for a given flight azimuth at insertion. Since it is necessary to have a consistent set of sample latitude errors, the data base latitude errors are adjusted for the flight azimuth of interest. Knowing the nominal flight azimuth, latitude and their errors on each flight of the data base, range and crossrange errors are calculated. Since range and crossrange errors are independent of the flight azimuth, these errors can be converted to latitude errors for the flight azimuth of interest. This technique is detailed below:

$$C_N = r_e \, \Delta\lambda$$

$$C_E = r_e \, \Delta\alpha \cos\lambda$$

$$\Delta R = C_N \cos\zeta + C_E \sin\zeta$$

$$\Delta CR = C_N \sin\zeta - C_E \cos\zeta$$

The above relationships are evaluated for each flight sample of the data base, resulting in range and crossrange errors for each flight. Note that latitude and longitude errors are needed to calculate range and crossrange errors. Since the desired end result is inclination error statistics for a specific flight azimuth and latitude at insertion, the above range and crossrange errors are converted to a latitude error applicable to this specific flight azimuth, as shown below.

$$C'_N = \Delta R \cos \zeta' + \Delta CR \sin \zeta'$$

$$\Delta\lambda' = C'_N / r_e$$

where the primed values pertain to the conditions at which the inclination error statistics are desired.

The above process yields a sample set of adjusted latitude errors and are used in conjunction with the azimuth errors of each flight to generate latitude and azimuth error statistics as described in Section 3.2.

3.2 Program Theory

The classical approach to generating statistical moments of a multivariable system is to use a Taylor series expansion. The derivation of the resulting relationships for a system of correlated variables is presented in Appendix 7B of Reference (1). Applying the orbital inclination relationship to the equations of Appendix 7B yields the algorithm used in computer program MIED.

Orbit inclination has the following relationship to trajectory parameters:

$$\cos i = \cos \lambda \sin \zeta$$

Thus, latitude and azimuth are the system variables. This equation is applied at orbit insertion to obtain the final orbit inclination. Adapting the above relationship to the equations given in Appendix 7B for two variables yields the following:

$$\text{Expected value} = E(i) = \cos^{-1} \{\cos [E(\lambda)] \sin [E(\zeta)]\} + \tfrac{1}{2} \frac{\partial 2_i}{\partial \lambda^2} \sigma_\lambda{}^2 + \tfrac{1}{2} \frac{\partial 2_i}{\partial \zeta^2} \sigma_\zeta{}^2 + \frac{\partial 2_i}{\partial \lambda \partial \zeta} E \{[\lambda - E(\lambda)] [\zeta - E(\zeta)]\}$$

$$\text{Variance} = \sigma_\iota^2 = \left(\frac{\partial \iota}{\partial \lambda}\right)^2 \sigma_\lambda^2 + \left(\frac{\partial \iota}{\partial \zeta}\right)^2 \sigma_\zeta^2$$

$$+ 2 \frac{\partial \iota}{\partial \lambda} \frac{\partial \iota}{\partial \zeta} E \left\{[\lambda - E(\lambda)]\,[\zeta - E(\zeta)]\right\}$$

$$+ \frac{\partial \iota}{\partial \lambda} \frac{\partial^2 \iota}{\partial \lambda^2} \mu_3(\lambda) + \frac{\partial \iota}{\partial \zeta} \frac{\partial^2 \iota}{\partial \zeta^2} \mu_3(\zeta)$$

$$+ \frac{\partial \iota}{\partial \lambda} \frac{\partial^2 \iota}{\partial \zeta^2} E \left\{[\lambda - E(\lambda)]\,[\zeta - E(\zeta)]^2\right\}$$

$$+ \frac{\partial^2 \iota}{\partial \lambda^2} \frac{\partial \iota}{\partial \zeta} E \left\{[\lambda - E(\lambda)]^2\,[\zeta - E(\zeta)]\right\}$$

$$+ 2 \frac{\partial \iota}{\partial \lambda} \frac{\partial^2 \iota}{\partial \lambda \partial \zeta} E \left\{[\lambda - E(\lambda)]^2\,[\zeta - E(\zeta)]\right\}$$

$$+ 2 \frac{\partial \iota}{\partial \zeta} \frac{\partial^2 \iota}{\partial \lambda \partial \zeta} E \left\{[\lambda - E(\lambda)]\,[\zeta - E(\zeta)]^2\right\}$$

$$\text{Third moment} = \mu_3(\iota) = \left(\frac{\partial \iota}{\partial \lambda}\right)^3 \mu_3(\lambda) + \left(\frac{\partial \iota}{\partial \zeta}\right)^3 \mu_3(\zeta)$$

$$+ 3 \left(\frac{\partial \iota}{\partial \lambda}\right)^2 \frac{\partial \iota}{\partial \zeta} E \left\{[\lambda - E(\lambda)]^2\,[\zeta - E(\zeta)]\right\}$$

$$+ 3 \frac{\partial \iota}{\partial \lambda} \left(\frac{\partial \iota}{\partial \zeta}\right)^2 E \left\{[\lambda - E(\lambda)]\,[\zeta - E(\zeta)]^2\right\}$$

$$\text{Fourth moment} = \mu_4(\iota) = \left(\frac{\partial \iota}{\partial \lambda}\right)^4 \mu_4(\lambda) + \left(\frac{\partial \iota}{\partial \zeta}\right)^4 \mu_4(\zeta)$$

$$+ 4 \left(\frac{\partial \iota}{\partial \lambda}\right)^3 \frac{\partial \iota}{\partial \zeta} E \left\{[\lambda - E(\lambda)]^3\,[\zeta - E(\zeta)]\right\}$$

$$+ 4 \frac{\partial \iota}{\partial \lambda} \left(\frac{\partial \iota}{\partial \zeta}\right)^3 E \left\{[\lambda - E(\lambda)]\,[\zeta - E(\zeta)]^3\right\}$$

$$+ 6 \left(\frac{\partial \iota}{\partial \lambda}\right)^2 \left(\frac{\partial \iota}{\partial \zeta}\right)^2 E \left\{[\lambda - E(\lambda)]^2\,[\zeta - E(\zeta)]^2\right\}$$

The following equations define the various terms in the inclination statistics relationships shown on the previous pages.

$E(x)$ = expected value of x = mean value of x

$$= \frac{\sum_{i=1}^{n} \Delta X_i}{n}$$

σ_x = standard deviation of x

$$= \left[\frac{\sum_{i=1}^{n} \Delta X_i^2}{n-1} - E(X_i) \right]^{1/2}$$

$E\left\{[X - E(X)]^k [Y - E(Y)]^\ell\right\}$ = expected value of $X^k Y^l$

$$= \frac{\sum_{i=1}^{n} [X_i - E(X)]^k [Y_i - E(Y)]^\ell}{n}$$

$\mu_k(X)$ = kth moment of X

$$= \frac{\sum_{i=1}^{n} [\Delta X_i - E(X)]^k}{n}$$

Differentiating the relationship $i = \cos^{-1} (\cos\lambda \sin\zeta)$, the following partial derivatives are evaluated at the nominal conditions for the desired inclination statistics.

$$\frac{\partial i}{\partial \lambda} = \frac{\sin\lambda \sin\zeta}{\sin i}$$

$$\frac{\partial^2 i}{\partial \lambda^2} = \frac{\cos\lambda \sin\zeta \sin i - \dfrac{\sin^3\zeta \sin^2\lambda \cos\lambda}{\sin i}}{\sin^2 i}$$

$$\frac{\partial \iota}{\partial \zeta} = \frac{-\cos\lambda\cos\zeta}{\sin\iota}$$

$$\frac{\partial^2 \iota}{\partial \zeta^2} = \frac{\cos\lambda\sin\zeta\sin\iota - \dfrac{\cos^3\lambda\cos^2\zeta\sin\zeta}{\sin\iota}}{\sin^2\iota}$$

$$\frac{\partial^2 \iota}{\partial\lambda\partial\zeta} = \frac{\sin\lambda\cos\zeta\sin\iota + \dfrac{\sin\lambda\sin^2\zeta\cos^2\lambda\cos\zeta}{\sin\iota}}{\sin^2\iota}$$

3.3 User Instructions

MIED utilizes both fixed field and a modified FORTRAN NAMELIST for data input. The flight experience data base is input via fixed field format since the data base normally does not change. The remaining data, which normally changes with each program execution, is input via NAMELIST for flexibility of input format.

Data units are feet, degrees and seconds unless otherwise noted.

Subsequent data cases are allowed by providing NAMELIST data only. All input data is retained on subsequent cases.

Sample data cases are provided in Appendix A.

3.3.1 Fixed Field Format - The flight data base is input via fixed field format. For each flight the following parameters are input at orbit insertion.

- o flight identification
- o option specifying usage of latitude, longitude and azimuth errors.
- o nominal altitude
- o nominal latitude
- o nominal flight azimuth
- o observed errors in altitude, velocity, flight path angle, flight azimuth, latitude, longitude.

This flight data base, consisting of the parameters shown above, was developed specifically for orbit accuracy calculations for the Scout launch vehicle. Although the use of MIED is not limited to the Scout vehicle, MIED was designed to accept this data base without change even though only nominal latitude, azimuth and observed errors in latitude, longitude and azimuth are used in the MIED calculations. If it becomes desirable to create a new data base, the unused parameters need not be included; but the parameters which are used must remain within the same column ranges as shown on the next page.

Fixed field data must either be right justified in the field or contain a decimal point.

The flight experience data base is input in the order shown on the next page for each flight. Data may be input for up to 100 flights. Preceding the flight data, one title card is used for identification purposes only. Following the flight data, an END card beginning in column 1 is used to specify the end of the flight data.

Fixed Field Input Definition

Column Range	Definition
1-5	Flight Number
6-9	Flag = 1 if flight is to be used for latitude and longitude statistics only. = 2 if flight is to be used for latitude, longitude and azimuth statistics. = 3 if flight is to be used for azimuth statistics only. = 4 if flight is not to be used for statistics.
10-16	Nominal altitude, n.mi.
17-23	Altitude error, n.mi.
24-30	Velocity error
31-37	Path angle error
38-44	Azimuth error
45-52	Latitude error
53-60	Longitude error
61-70	Nominal latitude
71-80	Nominal azimuth

3.3.2 NAMELIST Format - A modified FORTRAN NAMELIST is used for inputting data to MIED. NAMELIST is used because of its readability and simplicity of inputting data. The following rules apply to NAMELIST input to MIED:

1. First card of a data group or case is $INPUTD beginning in column 2. Blanks are not allowed.

2. Last card of a data group or case is $END beginning in column 2. Blanks are not allowed.

3. Blanks may not be used within names but may be used elsewhere.

4. Variable names are followed by an equal sign which is followed by a value which is followed by a comma, e.g., AZIMUTH = 181.5,

5. Only columns 2-72, inclusive, are used.

6. Titling information may be input by the appropriate title names, e.g., TITLE1= THIS CASE PROVIDES INCLINATION ERROR STATISTICS

7. Any number of names and values may be on a single card or line.

Definitions of specific NAMELIST inputs to MIED are shown below. Default values are shown when they are set by the program prior to reading input data.

NAMELIST Input Definitions

AZMUTH	Nominal geocentric inertial flight azimuth. (0. built-in)
ICOR	Non-zero value results in calculation and and inclusion of correlation terms in the inclination error statistics. (1. built-in)
IMEAN	Non-zero value results in calculation and inclusion of mean values in latitude, longitude and azimuth in the inclination error statistics. (1. built-in)
LAT	Nominal geocentric latitude. (0. built-in)
SIGAZ	If zero, the standard deviation of azimuth is calculated from the flight experience sample set (0. built-in). If non-zero, this value is used for the standard deviation in azimuth.
TITLE1 TITLE2	Title information printed at top of each page of output. 72 characters maximum.

3.4 Output Description

Both the fixed field and NAMELIST input data are listed verbatim on the output listing (shown in Appendix A on pages A1 and A2). These lists provide a quick check of the input data for format correctness and validity.

Following the input data lists, output pages 1 and 2 contain information related to the calculation of latitude error statistics. Page 1 shows those flights with known latitude and longitude errors and the resulting errors in range and crossrange. These range and crossrange errors are along and perpendicular to the nominal azimuth of each flight.

Output page 2 contains adjusted errors in latitude, longitude and inclination for each sample on page 1. The range - crossrange errors of each flight on page 1 are converted to latitude - longitude errors for the nominal flight azimuth input by NAMELIST and shown on page 2. These adjusted errors provide a consistent set of sample errors from which to calculate error statistics involving latitude and longitude. The azimuth errors shown on page 2 are those observed on the flights as input.

Output page 3 contains flight observed azimuth errors. This sample set is used to calculate error statistics involving azimuth.

Output page 4 contains self-explanatory parameters of the inclination error statistics calculations.

Sample data cases are presented in Appendix A.

TABLE 3.1

SCOUT FLIGHT EXPERIENCE
AT ORBIT INSERTION

		ERROR FROM PREDICTED					
VEHICLE	INSERTION ALTITUDE N.MI.	ALTITUDE N.MI.	VELOCITY FPS	PATH ANGLE DEG	AZIMUTH DEG	LATITUDE DEG	LONGITUDE DEG
S-136	562.8	9.7	-58.5	.77	.28		
S-131	612.5	6.9	-280.0	-.36	-.15		
S-138	383.6	3.2	-107.9	.15	.77		
S-139	404.3	8.9	-29.2	.05	.19		
S-140	506.8	-.2	67.2	-.37	-.91		
S-142	487.1	4.1	142.9	-.86	-.29		
S-143	482.2	4.2	112.3	.14	-.28		
S-145	200.1	-3.5	15.0	-.75	.48		
S-146	495.2	-3.7	-24.3	-.63	0.00		
S-147	350.6	3.8	11.1	-.98	-.24		
S-148	197.7	2.8	-31.4	-.17	-.55		
S-149	576.3	0.0	-38.6	.16	-1.18		
S-150	178.5	1.0	-31.1	-.63	-.14	.0638	.0339
S-154	577.0	-.7	-57.5	.12	.26	-.0473	-.0361
S-153	117.1	-.5	-56.9	-.63	-.13		
S-155	279.4	-5.5	94.3	-.06	.18	-.1042	.0115
S-156	592.7	2.0	-53.4	-.05	-.43	-.0108	.3134
S-157	565.9	2.8	-34.4	-.15	-.73	-.0429	.3543
S-158	235.3	-2.1	8.0	-.17	.70	-.0729	-.0749
S-162	581.2	-1.7	-29.1	-.41	-.07	-.2190	.4662
S-161	190.5	-5.8	17.0	-.46	-1.08	-.0774	.0137
S-165	375.8	-2.3	72.4	-.72	-1.36	-.0345	.1321
S-167	147.2	.4	30.7	-.57	-.25	-.0300	.0690
S-172	216.0	-5.2	-91.1	-.13	-.93	-.0801	.0344
S-169	214.7	-1.3	-35.0	-.13	.31	-.0152	.0477
S-176	588.3	-10.1	2.0	-1.01	.02	-.0233	.1267
S-174	169.9	-3.1	-38.2	-.17	-.69	-.0656	-.0159
S-175	294.4	-.7	7.6	-.07	.11	-.2135	.0215
S-173	115.5	4.5	-93.0	-.08	-1.05		
S-177	323.3	.6	-79.4	-.63	-.54	.2250	.0386
S-180	486.0	4.7	-202.0	-.24	.06	.2448	-.1021
S-163	120.0	-.4	-129.0	.49	-.12	.1882	.7061
S-183	297.0	-9.2	47.0	-.47	0.00	.0015	.0170
S-184	263.5	6.7	-8.0	.26	.32	-.1355	-.0692
S-182	449.6	8.0	-177.0	-.02	.13	.2266	.1281
S-170	299.7	0.0	-29.5	-.76	-.60	.2533	-.0426
S-185	151.2	-3.5	70.5	-1.14	.34	-.0743	-.0523
S-181	129.5	-3.4	84.2	-.41	-.28	-.0777	.0682
S-178	604.4	14.5	-220.2	-.03	.17	.3180	.0550
S-190	123.1	2.4	58.2	.03	.07	-.0017	.0943
S-188	405.0	-2.9	149.5	-.47	-.62	-.1845	.1735
S-191	215.2	.6	45.7	-.56	-.20	-.0857	-.2038
S-186	124.2	-4.2	3.9	-.24	.69	-.0147	-.5603
S-189	210.5	-5.0	61.1	-.05	.28	.0101	-.3837
S-197	270.2	4.0	39.1	.15	0.00	.0601	.1696
S-194	271.0	.8	14.1	.03	-.43	.1489	.0124
S-195	194.8	3.4	-25.8	-.09	.77	.0623	-.1025

NOTE: LATITUDE, LONGITUDE ERRORS NOT SHOWN ARE NOT AVAILABLE

4.0 SUBROUTINE DESCRIPTIONS

This section provides a brief explanation of each subroutine of MIED.

4.1 MIED (Main Program)

Data is initialized - sample error sets are placed in appropriate arrays - partial derivatives are evaluated at nominal conditions - range and crossrange errors are calculated and converted to latitude and longitude errors - inclination error statistics are calculated.

4.2 CARDS

Subroutine CARDS reads fixed field data in alphanumeric format, writes the data on the output file as read, and writes the data on unit 8 for subsequent reading by the main program in floating point format. CARDS also counts the number of samples input and writes error messages if there are no samples or if they exceed the maximum of 100.

4.3 CORSIG

Subroutine CORSIG calculates statistical means, standard deviations and correlation coefficients from a sample error set of two variables.

4.4 INPUT

Subroutine INPUT reads input data cards in a modified NAMELIST format. Titling information on title cards are placed in appropriate arrays. Non-title cards are written on unit 8 for a NAMELIST read from the main program.

4.5 STAT

Subroutine STAT calculates statistical expected values and moments from a sample error set of two variables.

5.0 PROGRAM CODING

This section presents details about the program coding. Included are flowcharts of each subroutine, FORTRAN listings of each subroutine and definitions of the FORTRAN variables. The information presented in this section is intended to be helpful in developing a thorough understanding of MIED and in making modifications to the program.

5.1 Subroutine Flowcharts

Flowcharts are presented in Figures 5.1 through 5.5. The flowchart conventions used are defined in Section 2.0 of this report.

5.2 FORTRAN Listings

MIED is coded in FORTRAN IV, Reference (2), on the CDC CYBER 175 computer with the NOS/BE 1.4 operating system. Listings of the FORTRAN coding are presented in Appendix B.

5.3 FORTRAN Variable Definition

Definitions of the FORTRAN variables are presented below. This information is normally used only when making modifications to the program.

Definition of FORTRAN Variables
Main Program

Variables	Definition
ALPHA3	Skewness of inclination
ALPHA4	Kurtosis of inclination
AZMUTH	Input azimuth, deg
AZR	AZMUTH, rad
CAZ	Cosine of AZMUTH
CEAST	Easterly component of position error, ft
CLAT	Cosine of LAT

CNORTH	Northerly component of position error, ft
COV	Covariance matrix of latitude, longitude, azimuth, deg
CZ	Cosine of azimuth of flight sample
DAZ	Azimuth error of input sample data, deg
DCR	Crossrange error, nm
DEG	Degrees per radian
DI	Inclination error, deg
DLAT	Adjusted latitude error, deg
DLG	Longitude error of input sample data, deg
DLONG	Adjusted longitude error, deg
DLT	Latitude error of input sample data, deg
DR	Range error, nm
DZ	Azimuth error of input sample data, deg
EI	Expected value of inclination, deg
ELZ, ELZ2, ELZ3 EL2Z, EL2Z2, EL3Z	Expected values of correlation of latitude and azimuth
FTNM	Feet per nautical mile
ICODE	Option of input sample data
ICOR	Input correlation option
IMEAN	Input mean value option
INCL	Inclination, deg
INCLR	Inclination, rad
IPAGE	Page number
IVEH	Identifier of input sample data
IVEH2	Identifier of input sample data. Applies to latitude, longitude error samples only
IWORD	Word 1 of input sample data
KASE	Case number
LAT	Input latitude, deg

LATR	LAT, rad
LGMEAN	Mean value of longitude, deg
LT	Latitude of input sample data, deg
LTMEAN	Mean value of latitude, deg
MEANI	Mean value of inclination, deg
M3I	Third moment of inclination error, deg^3
M3L	Third moment of latitude error, deg^3
M3Z	Third moment of azimuth error, deg^3
M4I	Fourth moment of inclination error, deg^4
M4L	Fourth moment of latitude error, deg^4
M4Z	Fourth moment of azimuth error, deg^4
NFLT	Number of samples
NFLTX	Number of samples or zero if SIGAZ is input non-zero
NFLT2	Number of samples. Applies to latitude, longitude error samples only
NMAX	Dimension of error samples
NSAMP	Number of input sample cards read
PIL	Partial derivative of inclination to latitude
PILZ	Partial derivative of inclination to latitude and azimuth
PIL2	Second partial derivative of inclination to latitude
PIZ	Partial derivative of inclination to azimuth
PIZ2	Second partial derivative of inclination to azimuth
RE	Earth radius, ft
RHOLL	Correlation coefficient of latitude to longitude
RHOLOZ	Correlation coefficient of longitude to azimuth
RHOLZ	Correlation coefficient of latitude to azimuth

SAZ	Sine of AZMUTH
SI	Sine of inclination
SIGAZ	Input value of standard deviation of azimuth, deg
SIGI	Standard deviation of inclination, deg
SIGL	Standard deviation of latitude, deg
SIGLON	Standard deviation of longitude, deg
SIGZ	Standard deviation of azimuth, deg
SIGZET	Standard deviation of azimuth of latitude, longitude error samples only, deg
SI2	Square of sine of inclination
SLAT	Sine of LAT
SZ	Sine of azimuth of an individual sample
VARI	Variance of inclination, deg^2
WORD	Array of sample error set data
ZETA	Array of azimuths of the sample set
ZM	Mean value of azimuth of the latitude, longitude error samples only
ZMEAN	Mean value of azimuth of all error samples

Figure 5.1

FLOWCHART OF MAIN PROGRAM MIED

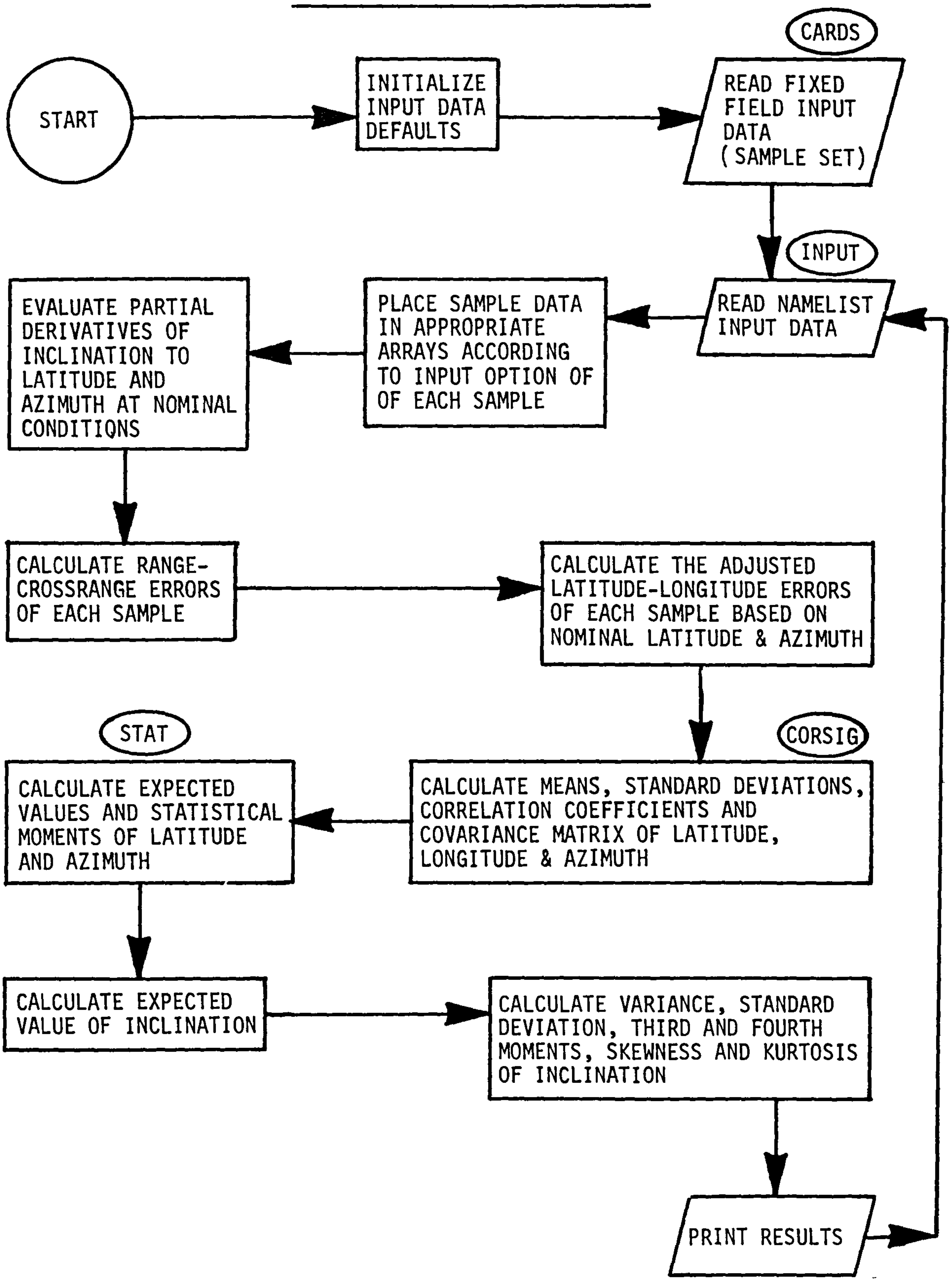


Figure 5.2

FLOWCHART OF SUBROUTINE CARDS

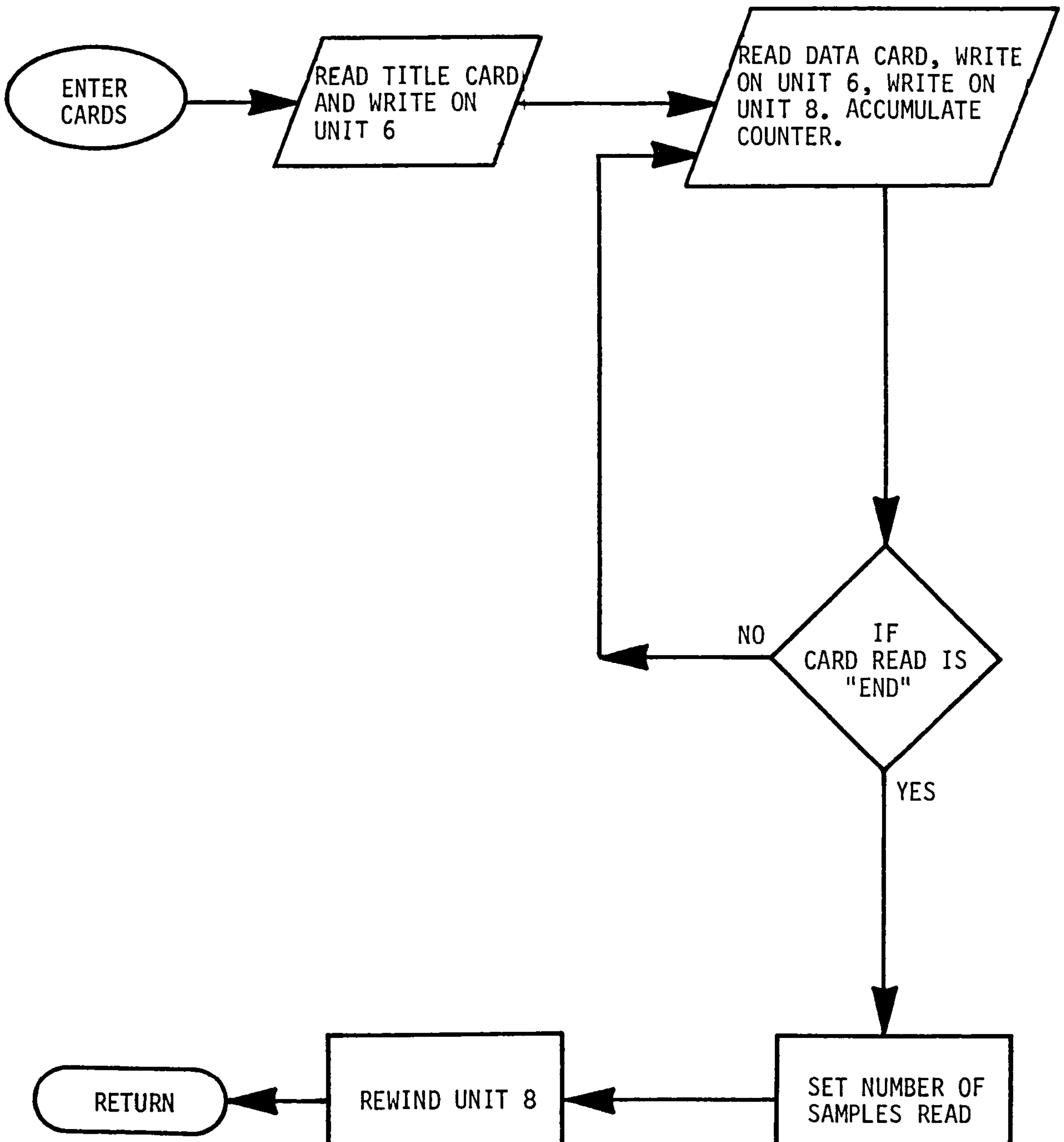


Figure 5.3

FLOWCHART OF SUBROUTINE INPUT

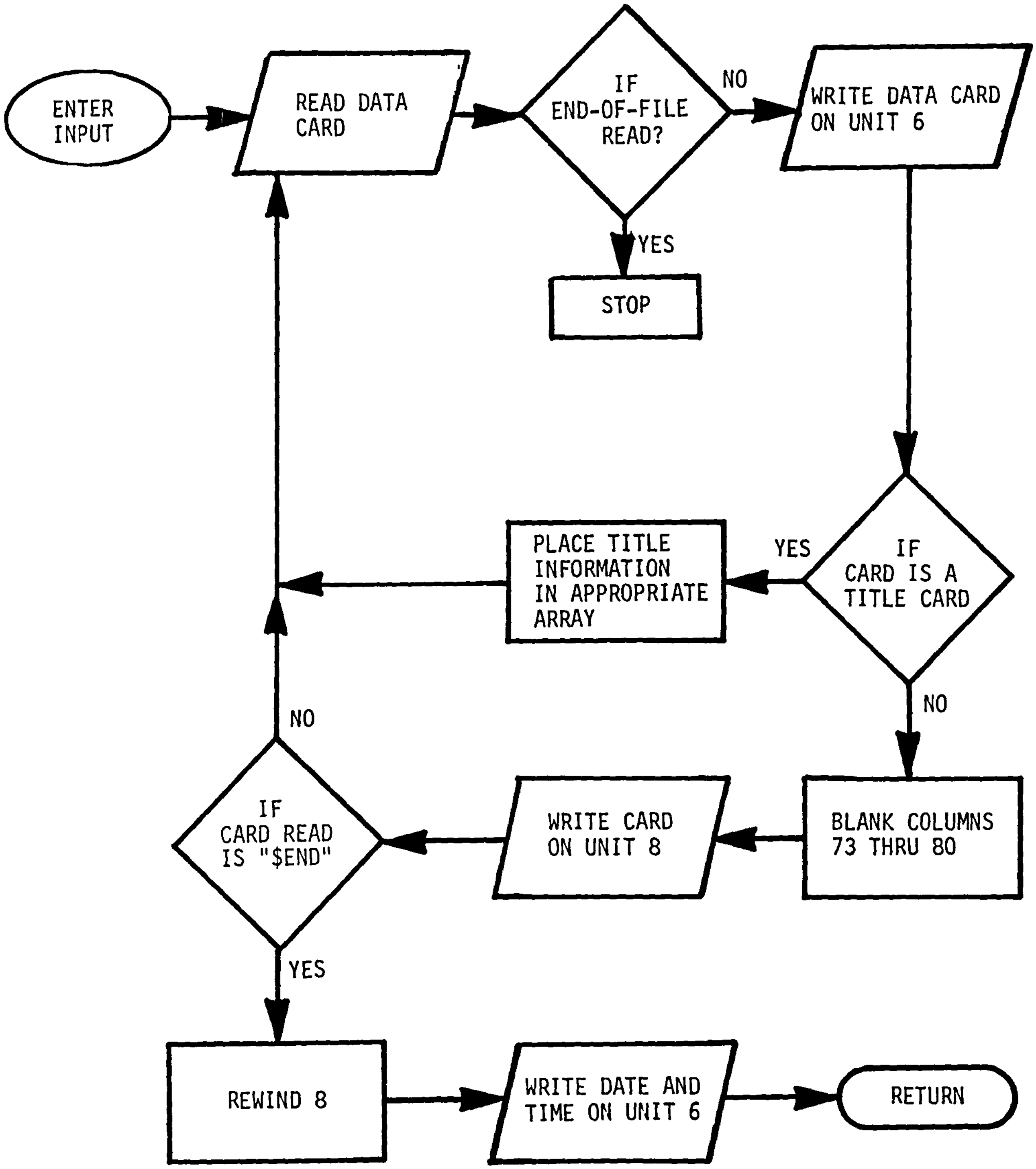


Figure 5.4

FLOWCHART OF SUBROUTINE CORSIG

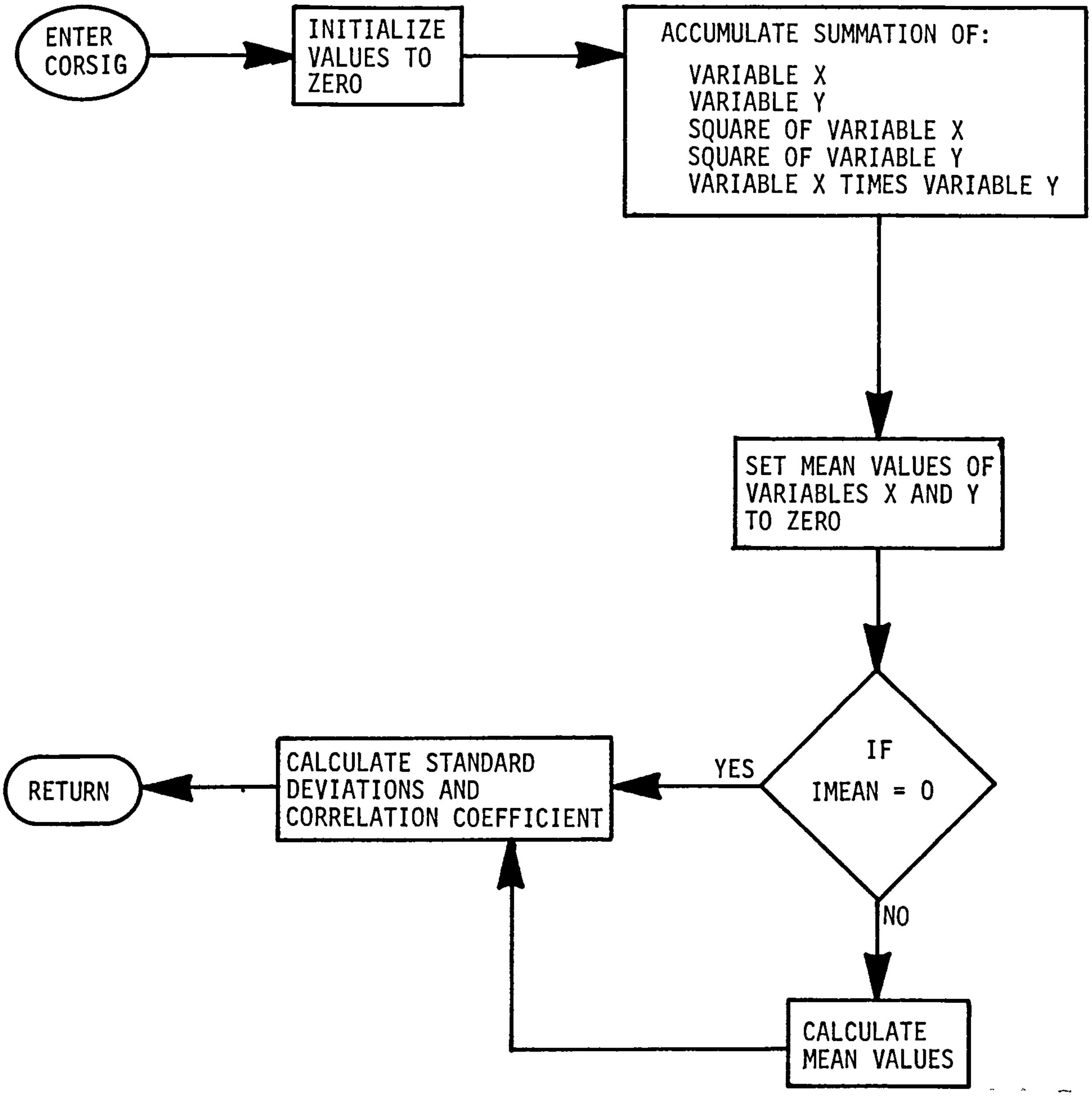
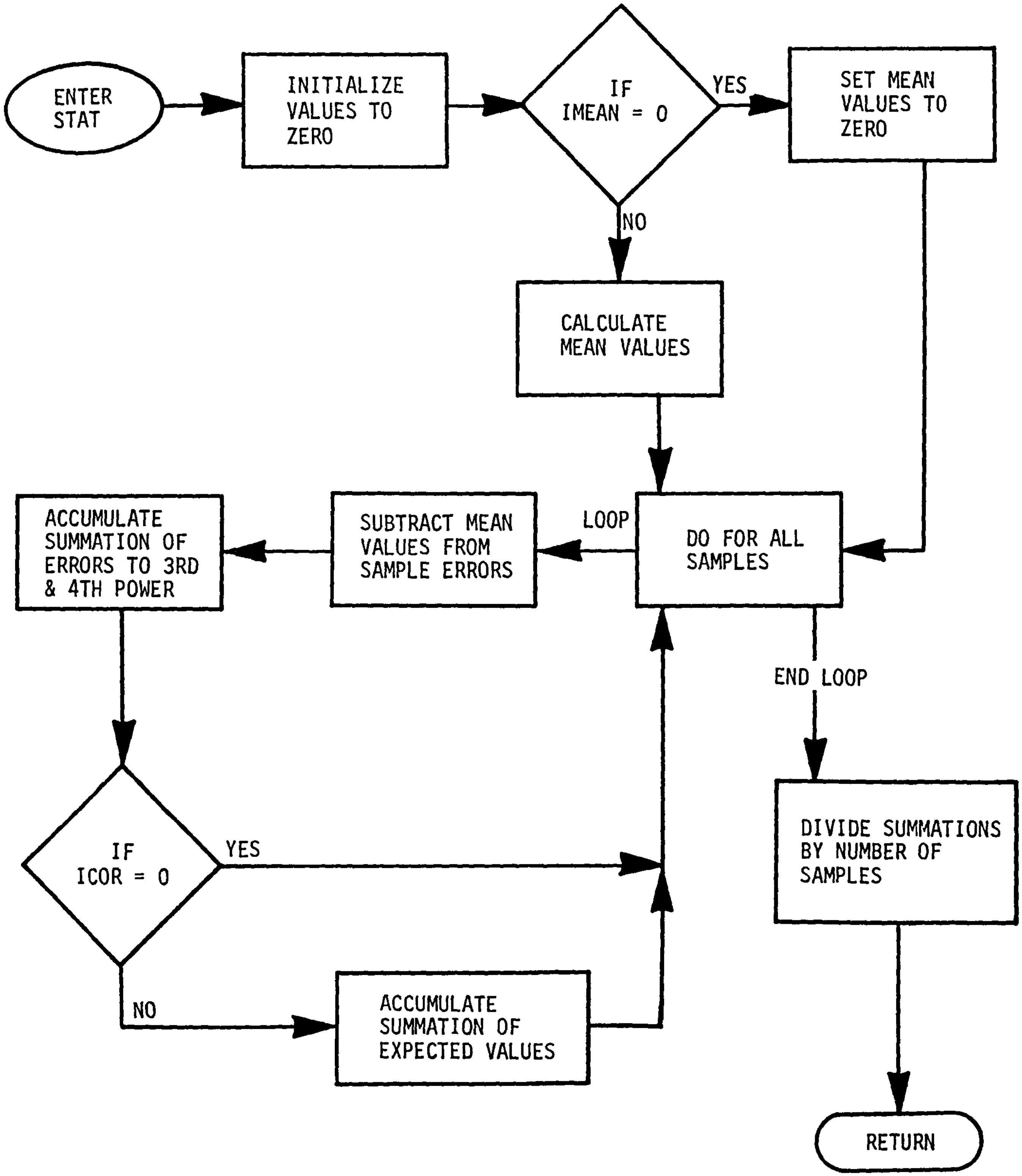


Figure 5.5

FLOWCHART OF SUBROUTINE STAT



6.0 OTHER APPLICATIONS

Various applications can be made of the information provided in this report other than that which computer program MIED was designed to do. As described in Section 3.2, the orbital inclination relationship was applied to the general expressions for moments of a system of components of correlated variables. Since these expressions are general, other relationships of correlated variables can be applied in like manner to yield the expected value, variance, standard deviation and the third and fourth moments.

The concept of using flight experience errors to predict errors of future flights can also be applied to flight parameters other than those presented in this report. An example of another application is Reference (2), which uses flight experience to predict errors in the trajectory and orbital parameters.

Additionally, subroutines STAT, CORSIG and INPUT are written in general form and can be used in other computer programs.

REFERENCES

1. Hahn, Gerald J. and Shapiro, Samuel S.: "Statistical Models in Engineering", John Wiley & Sons, Inc., 1967.

2. Control Data Corporation, "FORTRAN Extended Version 4 Reference Manual", Revision C, dated 15 April 1977.

Sample Data Cases

45 FLIGHT EXPERIENCE

S-115	3.	395.3	18.7	-27.8	0.24	0.58				
S-118	3.	396.4	0.0	-129.3	-0.03	0.78				
S-120	3.	397.5	8.5	-115.6	0.14	-0.003				
S-113	3.	223.1	9.7	2.5	0.74	-0.338				
S-122	3.	322.1	2.4	-357.7	0.25	0.114				
S-127	3.	152.0	9.7	-188.0	0.42	-0.44				
S-125	3.	479.8	-1.2	-122.7	0.33	0.455				
S-134	3.	538.2	6.1	-114.5	-0.38	-0.190				
S-123	3.	495.2	-8.7	146.0	0.39	-0.317				
S-133	3.	247.7	9.5	-62.4	0.49	-0.061				
S-135	3.	285.0	4.8	36.4	-0.17	-0.382				
S-137	3.	115.4	0.5	121.4	-0.41	0.398				
S-136	3.	562.8	9.7	-58.5	0.766	0.277				
S-131	3.	612.5	6.9	-280.0	-0.362	-0.151				
S-138	3.	383.8	3.2	-107.9	0.153	0.77				
S-139	3.	404.3	8.9	-29.2	0.050	0.188				
S-140	3.	506.8	-0.2	67.2	-0.372	-0.906				
S-142	3.	487.1	4.1	142.9	-0.863	-0.29				
S-143	3.	482.2	4.2	112.3	0.135	-0.28				
S-145	3.	200.1	-3.5	15.0	-0.752	0.475				
S-146	3.	495.2	-3.7	-24.3	-0.633	-0.004				
S-147	3.	350.6	3.8	11.1	-0.975	-0.244				
S-148	3.	197.7	2.8	-31.4	-0.168	-0.545				
S-149	3.	576.3	0.0	-38.6	0.161	-1.180				
S-150	2.	178.5	1.0	-31.1	-0.631	-0.136	0.0638	0.0339	20.7161	171.556
S-154	2.	577.0	-0.7	-57.5	0.124	0.260	-0.0473	-0.0361	12.1787	180.000
S-153	3.	117.1	-0.5	-56.9	-0.632	-0.134				
S-155	2.	279.4	-5.5	94.3	-0.055	0.180	-0.1042	0.0115	15.0825	169.640
S-156	2.	582.7	2.0	-53.4	-0.049	-0.430	-0.0108	0.3134	12.0870	180.000
S-157	2.	565.9	2.8	-34.4	-0.151	-0.727	-0.0429	0.3543	12.1900	180.001
S-158	2.	235.3	-2.1	8.0	-0.166	0.701	-0.0729	-0.0749	18.2632	179.999
S-162	2.	581.2	-1.7	-29.1	-0.405	-0.067	-0.2190	0.4662	12.2504	180.000
S-161	2.	190.5	-5.8	17.0	-0.459	-1.083	-0.0774	0.0137	22.0366	188.853
S-165	2.	376.8	-2.3	72.4	-0.716	-1.361	-0.0345	0.1321	13.4573	171.761
S-167	2.	147.2	0.4	30.7	-0.569	-0.250	-0.0300	0.0690	23.1376	184.350
S-172	2.	216.0	-5.2	-91.1	-0.130	-0.929	-0.0801	0.0344	20.8663	175.719
S-169	2.	214.7	-1.3	-35.0	-0.13	0.31	-0.0152	0.0477	17.7236	193.313
S-176	2.	588.3	-10.1	2.0	-1.01	0.02	-0.0233	0.1267	11.9576	180.000
S-174	2.	169.9	-3.1	-38.2	-0.164	-0.688	-0.0656	-0.0159	35.5464	103.438
S-175	2.	294.4	-0.7	7.6	-0.072	0.109	-0.2135	0.0215	-2.7201	88.955
S-173	3.	115.5	4.6	-92.4	-0.074	-1.043				
S-177	2.	323.3	0.6	-79.0	-0.63	-0.54	0.2250	0.0386	23.3147	137.246
S-180	2.	486.0	4.7	-202.	-0.24	0.06	0.2448	-0.1021	23.5077	135.496
S-163	2.	120.0	-0.4	-129.	0.49	-0.12	0.1882	0.7061	-3.3437	90.865
S-183	2.	297.0	-9.2	47.0	-0.47	0.	0.0015	0.0170	15.4234	172.737

END

```
 $INPUTD
 TITLE1=TEST CASE
 TITLE2=WITH MEAN      WITH CORRELATION
 IMEAN=1,ICOR=1,
 LAT=15.263,AZMUTH=187.274,
 $END
```

```
DATE IS  12/15/80
TIME IS  12.36.45
```

TEST CASE
WITH MEAN WITH CORRELATION

FLIGHT EXPERIENCE ERRORS

ONLY SAMPLES WITH LATITUDE, LONGITUDE ERRORS

	VEHICLE	LATITUDE DEG	LONGITUDE DEG	AZIMUTH DEG	RANGE NMI	C-RANGE NMI
1	S-150	.064	.034	-.136	-3.513	2.448
2	S-154	-.047	-.036	.260	2.843	-2.121
3	S-155	-.104	.012	.180	6.281	-.470
4	S-156	-.011	.313	-.430	.649	18.420
5	S-157	-.043	.354	-.727	2.578	20.816
6	S-158	-.073	-.075	.701	4.382	-4.275
7	S-162	-.219	.466	-.067	13.164	27.384
8	S-161	-.077	.014	-1.083	4.479	1.470
9	S-165	-.035	.132	-1.361	3.159	7.345
10	S-167	-.030	.069	-.250	1.509	3.940
11	S-172	-.080	.034	-.929	4.945	1.567
12	S-169	-.015	.048	.310	.260	2.868
13	S-176	-.023	.127	.020	1.401	7.450
14	S-174	-.066	-.016	-.688	.160	-4.016
15	S-175	-.214	.022	.109	1.057	-12.854
16	S-177	.225	.039	-.540	-8.484	10.746
17	S-180	.245	-.102	.060	-14.439	6.301
18	S-163	.188	.706	-.120	42.194	11.951
19	S-183	.002	.017	0.000	.035	.989

TEST CASE
WITH MEAN WITH CORRELATION

ADJUSTED ERRORS

ONLY SAMPLES WITH LATITUDE, LONGITUDE ERRORS

AZIMUTH= 187.274 DEG

	LATITUDE DEG	LONGITUDE DEG	AZIMUTH DEG	INCLINATION DEG
1	.053	.050	-.136	-.133
2	-.042	-.042	.260	.252
3	-.103	-.022	.180	.177
4	-.050	.314	-.430	-.413
5	-.086	.350	-.727	-.698
6	-.063	-.083	.701	.678
7	-.275	.440	-.067	-.056
8	-.077	.015	-1.083	-1.042
9	-.068	.119	-1.361	-1.311
10	-.033	.064	-.250	-.240
11	-.085	.016	-.929	-.893
12	-.010	.048	.310	.299
13	-.039	.124	.020	.021
14	.006	-.069	-.688	-.664
15	.010	-.222	.109	.105
16	.117	.202	-.540	-.524
17	.225	.139	.060	.050
18	-.722	.112	-.120	-.092
19	-.003	.017	0.000	.000

COVARIANCE MATRIX BASED ON 19 FLIGHTS
LATITUDE-LONGITUDE-AZIMUTH-DEG

.035163	-.005174	.000343
-.005174	.025925	-.020693
.000343	-.020693	.281815

TEST CASE
WITH MEAN WITH CORRELATION

AZIMUTH DEVIATIONS(DEG)
FLIGHT EXPERIENCE

1	S-115	.580
2	S-118	.780
3	S-120	-.003
4	S-113	-.338
5	S-122	.114
6	S-127	-.440
7	S-125	.455
8	S-134	-.190
9	S-123	-.317
10	S-133	-.061
11	S-135	-.382
12	S-137	.398
13	S-136	.277
14	S-131	-.151
15	S-138	.770
16	S-139	.188
17	S-140	-.906
18	S-142	-.290
19	S-143	-.280
20	S-145	.475
21	S-146	-.004
22	S-147	-.244
23	S-148	-.545
24	S-149	-1.180
25	S-150	-.136
26	S-154	.260
27	S-153	-.134
28	S-155	.180
29	S-156	-.430
30	S-157	-.727
31	S-158	.701
32	S-162	-.067
33	S-161	-1.083
34	S-165	-1.361
35	S-167	-.250
36	S-172	-.929
37	S-169	.310
38	S-176	.020
39	S-174	-.688
40	S-175	.109
41	S-173	-1.043
42	S-177	-.540
43	S-180	.060
44	S-163	-.120
45	S-183	0.000

TEST CASE
WITH MEAN WITH CORRELATION

NOMINAL VALUES	
INCLINATION, DEG	97.0161
LATITUDE, DEG	15.2630
AZIMUTH, DEG	187.274
INCLINATION STATISTICS	
MEAN, DEG	-.151370
VARIANCE, DEG	.248552
STANDARD DEVIATION, DEG	.498550
THIRD MOMENT	-.292903E-06
SKEWNESS	-.444597
FOURTH MOMENT	.142631E-07
KURTOSIS	2.48812
MEAN VALUES	
LATITUDE, DEG	-.655065E-01
LONGITUDE, DEG	.827947E-01
AZIMUTH(19 FLIGHTS), DEG	-.246895
AZIMUTH(45 FLIGHTS), DEG	-.159156
STANDARD DEVIATIONS	
LATITUDE, DEG	.187518
LONGITUDE, DEG	.161012
AZIMUTH(19 FLIGHTS), DEG	.530862
AZIMUTH(45 FLIGHTS), DEG	.517076
CORRELATION COEFFICIENTS	
LATITUDE-AZIMUTH	.344954E-02
LATITUDE-LONGITUDE	-.171356
LONGITUDE-AZIMUTH	-.242089

TERMS OF THE INCLINATION STATISTICAL EQUATIONS
(I=INCLINATION; L=LATITUDE; Z=AZIMUTH)

PARTIAL DERIVATIVES UNITLESS		EXPECTED VALUES RADIANS	
PIL	-.335827E-01	ELZ	.104602E-06
PIL2	-.122931E+00	EL2Z	.232265E-07
PIZ	.964183E+00	ELZ2	.141576E-07
PIZ2	-.865801E-02	EL2Z2	.112616E-09
PILZ	-.267087E+00	EL3Z	-.153411E-09
		ELZ3	.144715E-09

MOMENTS RADIANS		VARIANCE TERMS RADIANS	
M3L	-.721875E-07	TERM1	.120801E-07
M4L	.955417E-09	TERM2	.757152E-04
M3Z	-.325381E-06	TERM3	-.677401E-08
M4Z	.165228E-07	TERM4	-.298017E-09
		TERM5	.271625E-08
		TERM6	.411645E-11
		TERM7	-.275300E-08
		TERM8	.416660E-09
		TERM9	-.729172E-08

```
$INPUTD
TITLE2=  NO MEAN      WITH CORRELATION
IMEAN=0,ICOR=1,
$END
```

```
DATE IS  12/15/80
TIME IS  12.36.47
```

TEST CASE
NO MEAN WITH CORRELATION

FLIGHT EXPERIENCE ERRORS

ONLY SAMPLES WITH LATITUDE, LONGITUDE ERRORS

	VEHICLE	LATITUDE DEG	LONGITUDE DEG	AZIMUTH DEG	RANGE NMI	C-RANGE NMI
1	S-150	.064	.034	-.136	-3.513	2.448
2	S-154	-.047	-.036	.260	2.843	-2.121
3	S-155	-.104	.012	.180	6.281	-.470
4	S-156	-.011	.313	-.430	.649	18.420
5	S-157	-.043	.354	-.727	2.578	20.816
6	S-158	-.073	-.075	.701	4.382	-4.275
7	S-162	-.219	.466	-.067	13.164	27.384
8	S-161	-.077	.014	-1.083	4.479	1.470
9	S-165	-.035	.132	-1.361	3.159	7.345
10	S-167	-.030	.069	-.250	1.509	3.940
11	S-172	-.080	.034	-.929	4.945	1.567
12	S-169	-.015	.048	.310	.260	2.868
13	S-176	-.023	.127	.020	1.401	7.450
14	S-174	-.066	-.016	-.688	.160	-4.016
15	S-175	-.214	.022	.109	1.057	-12.854
16	S-177	.225	.039	-.540	-8.484	10.746
17	S-180	.245	-.102	.060	-14.439	6.301
18	S-163	.188	.706	-.120	42.194	11.951
19	S-183	.002	.017	0.000	.035	.989

TEST CASE
NO MEAN WITH CORRELATION

ADJUSTED ERRORS

ONLY SAMPLES WITH LATITUDE, LONGITUDE ERRORS

AZIMUTH= 187.274 DEG

	LATITUDE DEG	LONGITUDE DEG	AZIMUTH DEG	INCLINATION DEG
1	.053	.050	-.136	-.133
2	-.042	-.042	.260	.252
3	-.103	-.022	.180	.177
4	-.050	.314	-.430	-.413
5	-.086	.350	-.727	-.698
6	-.063	-.083	.701	.678
7	-.275	.440	-.067	-.056
8	-.077	.015	-1.083	-1.042
9	-.068	.119	-1.361	-1.311
10	-.033	.064	-.250	-.240
11	-.085	.016	-.929	-.893
12	-.010	.048	.310	.299
13	-.039	.124	.020	.021
14	.006	-.069	-.688	-.664
15	.010	-.222	.109	.105
16	.117	.202	-.540	-.524
17	.225	.139	.060	.050
18	-.722	.112	-.120	-.092
19	-.003	.017	0.000	.000

COVARIANCE MATRIX BASED ON 19 FLIGHTS
LATITUDE-LONGITUDE-AZIMUTH-DEG

.039454	-.010597	.016517
-.010597	.032780	-.041134
.016517	-.041134	.342772

TEST CASE
NO MEAN WITH CORRELATION

AZIMUTH DEVIATIONS(DEG)
FLIGHT EXPERIENCE

1	S-115	.580
2	S-118	.780
3	S-120	-.003
4	S-113	-.338
5	S-122	.114
6	S-127	-.440
7	S-125	.455
8	S-134	-.190
9	S-123	-.317
10	S-133	-.061
11	S-135	-.382
12	S-137	.398
13	S-136	.277
14	S-131	-.151
15	S-138	.770
16	S-139	.188
17	S-140	-.906
18	S-142	-.290
19	S-143	-.280
20	S-145	.475
21	S-146	-.004
22	S-147	-.244
23	S-148	-.545
24	S-149	-1.180
25	S-150	-.136
26	S-154	.260
27	S-153	-.134
28	S-155	.180
29	S-156	-.430
30	S-157	-.727
31	S-158	.701
32	S-162	-.067
33	S-161	-1.083
34	S-165	-1.361
35	S-167	-.250
36	S-172	-.929
37	S-169	.310
38	S-176	.020
39	S-174	-.688
40	S-175	.109
41	S-173	-1.043
42	S-177	-.540
43	S-180	.060
44	S-163	-.120
45	S-183	0.000

TEST CASE
NO MEAN WITH CORRELATION

NOMINAL VALUES	
INCLINATION, DEG	97.0161
LATITUDE, DEG	15.2630
AZIMUTH, DEG	187.274
INCLINATION STATISTICS	
MEAN, DEG	-.141433E-03
VARIANCE, DEG	.271297
STANDARD DEVIATION, DEG	.520862
THIRD MOMENT	-.128516E-05
SKEWNESS	-1.71064
FOURTH MOMENT	.269679E-07
KURTOSIS	3.94864
MEAN VALUES	
LATITUDE, DEG	0.
LONGITUDE, DEG	0.
AZIMUTH(19 FLIGHTS), DEG	0.
AZIMUTH(45 FLIGHTS), DEG	0.
STANDARD DEVIATIONS	
LATITUDE, DEG	.198630
LONGITUDE, DEG	.181052
AZIMUTH(19 FLIGHTS), DEG	.585467
AZIMUTH(45 FLIGHTS), DEG	.541016
CORRELATION COEFFICIENTS	
LATITUDE-AZIMUTH	.142028
LATITUDE-LONGITUDE	-.294676
LONGITUDE-AZIMUTH	-.388058

TERMS OF THE INCLINATION STATISTICAL EQUATIONS
(I=INCLINATION; L=LATITUDE; Z=AZIMUTH)

PARTIAL DERIVATIVES UNITLESS		EXPECTED VALUES RADIANS	
PIL	-.335827E-01	ELZ	.503125E-05
PIL2	-.122931E+00	EL2Z	-.260757E-07
PIZ	.964183E+00	ELZ2	-.998382E-07
PIZ2	-.865801E-02	EL2Z2	.198581E-09
PILZ	-.267087E+00	EL3Z	.233801E-09
		ELZ3	.161858E-08

MOMENTS RADIANS		VARIANCE TERMS RADIANS	
M3L	-.108251E-06	TERM1	.135543E-07
M4L	.136630E-08	TERM2	.828885E-04
M3Z	-.144411E-C5	TERM3	-.325823E-06
M4Z	.314280E-07	TERM4	-.446900E-09
		TERM5	.120553E-07
		TERM6	-.290289E-10
		TERM7	.309070E-08
		TERM8	-.467772E-09
		TERM9	.514208E-07

APPENDIX B

FORTRAN Code Listings

```
      PROGRAM MIED(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE8)
C        CALCULATES ORBITAL INCLINATION STATISTICS FROM A SAMPLE SET
C        OF AZIMUTH, LATITUDE AND LONGITUDE ERRORS OBTAINED FROM FLIGHT
C        EXPERIENCE.  EQUATIONS OBTAINED FROM A TAYLOR SERIES EXPANSION.
C        REFERENCE, ≠STATISTICAL MODELS IN ENGINEERING≠, BY HAHN AND SHAPIRO.
C
C        ****************  FIXED FIELD INPUTS  ************
C        WORD  1 = VEHICLE NUMBER           (COLUMNS 1 - 5)
C        WORD  2 = DATA OPTION              (COLUMNS 6 - 9)
C                 =1 FLIGHT SAMPLE IS USED FOR LATITUDE, LONGITUDE
C                    STATISTICS ONLY
C                 =2 FLIGHT SAMPLE IS USED FOR LATITUDE, LONGITUDE
C                    AND AZIMUTH STATISTICS
C                 =3 FLIGHT SAMPLE IS USED FOR AZIMUTH STATISTICS ONLY
C                 =4 FLIGHT SAMPLE IS NOT USED FOR STATISTICS
C        WORD  3 = NOMINAL ALTITUDE, N.M.   (COLUMNS 10-16)
C        WORD  4 = ALTITUDE ERROR, N.M.     (COLUMNS 17-23)
C        WORD  5 = VELOCITY ERROR, FPS      (COLUMNS 24-30)
C        WORD  6 = PATH ANGLE ERROR, DEG    (COLUMNS 31-37)
C        WORD  7 = AZIMUTH ERROR, DEG       (COLUMNS 38-44)
C        WORD  8 = LATITUDE ERROR, DEG      (COLUMNS 45-52)
C        WORD  9 = LONGITUDE ERROR, DEG     (COLUMNS 53-60)
C        WORD 10 = NOMINAL LATITUDE, DEG    (COLUMNS 61-70)
C        WORD 11 = NOMINAL AZIMUTH, DEG     (COLUMNS 71-80)
C
C        ************** NAMELIST INPUTS *************
C        AZMUTH= NOMINAL GEOCENTRIC INERTIAL AZIMUTH.
C        ICOR  = NON-ZERO VALUE RESULTS IN INCLUSION OF CORRELATION TERMS IN THE
C                INCLINATION STATISTICS.
C        IMEAN = NON-ZERO VALUE RESULTS IN CALCULATON OF MEAN VALUES IN
C                LATITUDE,LONGITUDE,AZIMUTH.  ZERO VALUE ASSUMES ZERO MEANS.
C        LAT   = NOMINAL GEOCENTRIC LATITUDE.
C        SIGAZ = ZERO VALUE RESULTS IN USING INPUT AZIMUTH ERROR SAMPLE SET TO
C                CALCULATE STANDARD DEVIATION.  NON-ZERO VALUE RESULTS IN USING
C                SIGAZ AS STANDARD DEVIATION.
C        TITLE1= TITLE PRINTED AT TOP OF EACH PAGE. 72 CHARACTERS MAXIMUM.
C        TITLE2= TITLE PRINTED AT TOP OF EACH PAGE. 72 CHARACTERS MAXIMUM.
C
C
C
      IMPLICIT REAL (A-H,L,M,O-Z)
      INTEGER TITLE1,TITLE2
      REAL  INCL,INCLR,INCLN
      COMMON /STATS/ ELZ,EL2Z,ELZ2,EL3Z,ELZ3,EL2Z2,M3L,M3Z,M4L,M4Z
      DIMENSION  DR(100),DCR(100),DZ(100),DLAT(100),DLONG(100),
     ^   DAZ(100),DLT(100),DLG(100),ZETA(100),IVEH(100),IVEH2(100),
     ^   LT(100),WORD(11,100),TITLE1(8),TITLE2(8),COV(3,3),DI(100),
     ^   IWORD(100)
      DATA TITLE1,TITLE2/16*10H          /
      DATA DEG/57.29578/, RE/20925741./, FTNM/6076.1155/
      NAMELIST /INPUTD/ LAT,AZMUTH,IMEAN,ICOR,SIGAZ
      INCLN(L,A)=ACOS(COS(L/DEG)*SIN(A/DEG))*DEG
C
C
      WRITE(6,70)
C        INITIALIZE
      AZMUTH=0.
```

```
      ICOR=0
      IMEAN=0
      LAT=0.
      SIGAZ=0.
      NMAX=100
      KASE=0
C
C        READ FIXED FIELD INPUT DATA
      CALL CARDS(NSAMP,NMAX)
      READ(8,80) (IWORD(J),(WORD(I,J),I=2,11),J=1,NSAMP)
C        READ NAMELIST INPUT  DATA
   10 CONTINUE
      KASE=KASE+1
      CALL INPUT (TITLE1,TITLE2)
      READ(8,INPUTD)
C
C
C        PLACE SAMPLE SET DATA IN APPROPIATE ARRAYS
      NFLT=0
      NFLT2=0
      DO 40 I=1,NSAMP
         ICODE=WORD(2,I)
         GOTO (20,20,30,40), ICODE
C         SELECTS SAMPLES TO BE USED FOR LATITUDE, LONGITUDE STATISTICS
   20       NFLT2=NFLT2+1
            IVEH2(NFLT2)=IWORD(I)
            DZ(NFLT2)=WORD(7,I)
            DLT(NFLT2)=WORD(8,I)
            DLG(NFLT2)=WORD(9,I)
            LT(NFLT2)=WORD(10,I)
            ZETA(NFLT2)=WORD(11,I)
            GOTO (40,30,30,40), ICODE
C        SELECTS SAMPLES TO BE USED FOR AZIMUTH STATISTICS
   30          NFLT=NFLT+1
               IVEH(NFLT)=IWORD(I)
               DAZ(NFLT)=WORD(7,I)
   40 CONTINUE
C
C        SET-UP
      AZR=AZMUTH/DEG
      LATR=LAT/DEG
      SAZ=SIN(AZR)
      CAZ=COS(AZR)
      SLAT=SIN(LATR)
      CLAT=COS(LATR)
      INCL=INCLN(LAT,AZMUTH)
      INCLR=INCL/DEG
      SI=SIN(INCLR)
      SI2=SI**2
      NFLTX=NFLT
C
C
C        COMPUTE PARTIAL DERIVATIVES AT NOMINAL CONDITIONS
      PIL=SLAT*SAZ/SI
      PIL2=(CLAT*SAZ*SI-SAZ**3*SLAT**2*CLAT/SI)/SI2
      PIZ=-CLAT*CAZ/SI
      PIZ2=(CLAT*SAZ*SI-CLAT**3*SAZ*CAZ**2/SI)/SI2
```

```
      PILZ=(SLAT*CAZ*SI+SLAT*SAZ**2*CLAT**2*CAZ/SI)/SI2
C
C        CONVERT LATITUDE-LONGITUDE DEVIATIONS TO RANGE-CROSSRANGE DEVIATION
      IPAGE=1
      WRITE(6,90) KASE,IPAGE,TITLE1,TITLE2
      WRITE(6,100)
      DO 50 I=1,NFLT2
         SZ=SIN(ZETA(I)/DEG)
         CZ=COS(ZETA(I)/DEG)
         CNORTH=RE*DLT(I)/DEG
         CEAST=RE*DLG(I)*COS(LT(I)/DEG)/DEG
         DR(I)=(CNORTH*CZ+CEAST*SZ)/FTNM
         DCR(I)=(CNORTH*SZ-CEAST*CZ)/FTNM
         WRITE(6,110) I,IVEH2(I),DLT(I),DLG(I),DZ(I),DR(I),DCR(I)
   50 CONTINUE
C        CONVERT RANGE-CROSSRANGE DEVIATIONS TO LATITUDE-LONGITUDE DEVIATION
      DO 60 I=1,NFLT2
         CNORTH=DR(I)*CAZ+DCR(I)*SAZ
         CEAST=DR(I)*SAZ-DCR(I)*CAZ
         DLAT(I)=CNORTH/RE*FTNM*DEG
         DLONG(I)=CEAST/RE*FTNM/CLAT*DEG
         DI(I)=INCLN(LAT+DLAT(I),AZMUTH+DZ(I)) - INCL
   60 CONTINUE
      IPAGE=2
      WRITE(6,90) KASE,IPAGE,TITLE1,TITLE2
      WRITE(6,120) AZMUTH
      WRITE(6,130) (I,DLAT(I),DLONG(I),DZ(I),DI(I),I=1,NFLT2)
C
C        COMPUTE SIGMA LATITUDE, LONGITUDE, AZIMUTH AND CORRELATIONS (FLT. EXP.)
C        PARAMETERS ARE FOR LATITUDE-LONGITUDE SAMPLES ONLY
      CALL CORSIG (DLAT,DZ,NFLT2,SIGL,SIGZET,RHOLZ,
     ^             LTMEAN,ZM,IMEAN,ICOR)
      CALL CORSIG (DLONG,DZ,NFLT2,SIGLON,SIGZET,RHOLOZ,
     ^             LGMEAN,ZM,IMEAN,ICOR)
      CALL CORSIG (DLAT,DLONG,NFLT2,SIGL,SIGLON,RHOLL,
     ^             LTMEAN,LGMEAN,IMEAN,ICOR)
C        COMPUTE COVARIANCE MATRIX
      COV(1,1)=SIGL**2
      COV(1,2)=RHOLL*SIGL*SIGLON
      COV(1,3)=RHOLZ*SIGL*SIGZET
      COV(2,1)=COV(1,2)
      COV(2,2)=SIGLON**2
      COV(2,3)=RHOLOZ*SIGLON*SIGZET
      COV(3,1)=COV(1,3)
      COV(3,2)=COV(2,3)
      COV(3,3)=SIGZET**2
      WRITE(6,140) NFLT2,((COV(I,J),J=1,3),I=1,3)
C
C        CALCULATE SIGMA AZIMUTH FROM FLIGHT EXPERIENCE(ALL FLIGHTS)
      IPAGE=3
      WRITE(6,90) KASE,IPAGE,TITLE1,TITLE2
      WRITE(6,150) (I,IVEH(I),DAZ(I),I=1,NFLT)
C        ZMEAN = AZIMUTH MEAN OF ALL FLIGHTS
      CALL CORSIG (DAZ,DAZ,NFLT,SIGZ,DUM1,DUM2,ZMEAN,DUM3,IMEAN,ICOR)
      IF (SIGAZ.NE.0.)  SIGZ=SIGAZ
      IF (SIGAZ.NE.0.)  NFLTX=0
      IF (SIGAZ.NE.0.)  ZMEAN=0.
```

```
      SIGL=SIGL/DEG
      SIGZ=SIGZ/DEG
C
C
C        COMPUTE INCLINATION STATISTICS
C
C        COMPUTE LATITUDE, AZIMUTH STATISTICS
      CALL STAT(DLAT,DZ,NFLT2,ICOR,IMEAN)
C
C        COMPUTE EXPECTED VALUE OF INCLINATION
      EI1=INCLN(LAT+LTMEAN,AZMUTH+ZMEAN)/DEG
      EI2=0.5*PIL2*SIGL**2
      EI3=0.5*PIZ2*SIGZ**2
      EI4=PILZ*ELZ
      EI=(EI1+EI2+EI3+EI4)*DEG
      MEANI=EI-INCL
C
C        COMPUTE VARIANCE OF INCLINATION
      TERM1=PIL**2*SIGL**2
      TERM2=PIZ**2*SIGZ**2
      TERM3=2.*PIL*PIZ*ELZ
      TERM4=PIL*PIL2*M3L
      TERM5=PIZ*PIZ2*M3Z
      TERM6=PIL*PIZ2*ELZ2
      TERM7=PIZ*PIL2*EL2Z
      TERM8=2.*PIL*PILZ*EL2Z
      TERM9=2.*PIZ*PILZ*ELZ2
      VARI=TERM1+TERM2+TERM3+TERM4+TERM5+TERM6+TERM7+TERM8+TERM9
      SIGI=SQRT(VARI)*DEG
C
C        COMPUTE THIRD MOMENT AND SKEWNESS OF INCLINATION
      M3I=PIL**3*M3L+PIZ**3*M3Z+3.*PIL**2*PIZ*EL2Z+3.*PIL*PIZ**2*ELZ2
      ALPHA3=M3I/SQRT(VARI**3)
C
C        COMPUTE FOURTH MOMENT AND KURTOSIS OF INCLINATION
      M4I=PIL**4*M4L+PIZ**4*M4Z+4.*PIL**3*PIZ*EL3Z+4.*PIL*PIZ**3*ELZ3+6.
     ^    *PIL**2*PIZ**2*EL2Z2
      ALPHA4=M4I/VARI**2
C
      VARI=VARI*DEG**2
      SIGL=SIGL*DEG
      SIGZ=SIGZ*DEG
      IPAGE=4
      WRITE(6,90) KASE,IPAGE,TITLE1,TITLE2
      WRITE(6,160) INCL,LAT,AZMUTH,MEANI,VARI,SIGI,M3I,ALPHA3,M4I,ALPHA4
      WRITE(6,170) LTMEAN,LGMEAN,NFLT2,ZM,NFLT,ZMEAN,SIGL,SIGLON,
     ^             NFLT2,SIGZET,NFLTX,SIGZ,RHOLZ,RHOLL,RHOLOZ
      WRITE(6,180) PIL,ELZ,PIL2,EL2Z,PIZ,ELZ2,PIZ2,EL2Z2,PILZ,EL3Z,ELZ3
      WRITE(6,190) M3L,TERM1,M4L,TERM2,M3Z,TERM3,M4Z,TERM4,
     ^             TERM5,TERM6,TERM7,TERM8,TERM9
      GOTO 10
C
   70 FORMAT (1H1)
   80 FORMAT (A5,F4.0,5F7.0,2F8.0,2F10.0)
   90 FORMAT (1H1/T66,*VOUGHT CORPORATION*,/T72,*PROGRAM MIED*,/
     ^        T66,*CASE *I2*     PAGE *,I1/  2(10X,8A10/)/)
  100 FORMAT (26X,*FLIGHT EXPERIENCE ERRORS*,//
```

```
     ^        16X,*ONLY SAMPLES WITH LATITUDE, LONGITUDE ERRORS*,//
     ^        11X,*  VEHICLE   LATITUDE   LONGITUDE  AZIMUTH    RANGE*,
     ^        *    C-RANGE*,/
     ^        21X,3(7X,*DEG*),2(7X,*NMI*)/)
110 FORMAT (10X,I2,2X,A5,3X,5F10.3)
120 FORMAT (31X,*ADJUSTED ERRORS*,//
     ^        17X,*ONLY SAMPLES WITH LATITUDE, LONGITUDE ERRORS*,//
     ^        29X,*AZIMUTH=*,F8.3,* DEG*)
130 FORMAT (4(/)23X,*LATITUDE  LONGITUDE  AZIMUTH INCLINATION*,/
     ^        19X,4(7X,*DEG*)//50(18X,I2,4F10.3/))
140 FORMAT (6(/)22X,*COVARIANCE MATRIX BASED ON*,I3,* FLIGHTS*,/
     ^        25X,*LATITUDE-LONGITUDE-AZIMUTH-DEG*,//
     ^        3(15X,3F15.6,/))
150 FORMAT (15X,*AZIMUTH DEVIATIONS(DEG)*,/
     ^        20X,*FLIGHT EXPERIENCE*,//
     ^        100(15X,I2,3X,A5,3X,F7.3,/))
160 FORMAT (  10X,*NOMINAL VALUES                  *,       /
     ^          10X,*   INCLINATION, DEG           *,G15.6/
     ^          10X,*   LATITUDE, DEG              *,G15.6/
     ^          10X,*   AZIMUTH, DEG               *,G15.6/
     ^          10X,*INCLINATION STATISTICS        *,       /
     ^          10X,*   MEAN, DEG                  *,G15.6/
     ^          10X,*   VARIANCE, DEG              *,G15.6/
     ^          10X,*   STANDARD DEVIATION, DEG    *,G15.6/
     ^          10X,*   THIRD MOMENT               *,G15.6/
     ^          10X,*   SKEWNESS                   *,G15.6/
     ^          10X,*   FOURTH MOMENT              *,G15.6/
     ^          10X,*   KURTOSIS                   *,G15.6)
170 FORMAT (  10X,*MEAN VALUES                     *,       /
     ^          10X,*   LATITUDE, DEG              *,G15.6/
     ^          10X,*   LONGITUDE, DEG             *,G15.6/
     ^          10X,*   AZIMUTH(*,I2,* FLIGHTS), DEG   *,G15.6/
     ^          10X,*   AZIMUTH(*,I2,* FLIGHTS), DEG   *,G15.6/
     ^          10X,*STANDARD DEVIATIONS           *,       /
     ^          10X,*   LATITUDE, DEG              *,G15.6/
     ^          10X,*   LONGITUDE, DEG             *,G15.6/
     ^          10X,*   AZIMUTH(*,I2,* FLIGHTS), DEG   *,G15.6/
     ^          10X,*   AZIMUTH(*,I2,* FLIGHTS), DEG   *,G15.6/
     ^          10X,*CORRELATION COEFFICIENTS      *,       /
     ^          10X,*   LATITUDE-AZIMUTH           *,G15.6/
     ^          10X,*   LATITUDE-LONGITUDE         *,G15.6/
     ^          10X,*   LONGITUDE-AZIMUTH          *,G15.6)
180 FORMAT (////10X,*TERMS OF THE INCLINATION STATISTICAL EQUATIONS*/
     ^            10X,*     (I=INCLINATION; L=LATITUDE; Z=AZIMUTH)     */
     ^          / 10X,* PARTIAL DERIVATIVES            EXPECTED VALUES */
     ^            10X,*      UNITLESS                          RADIANS     */
     ^            10X,*PIL    *,E15.6,*       ELZ   *,E15.6 /
     ^            10X,*PIL2   *,E15.6,*       EL2Z  *,E15.6 /
     ^            10X,*PIZ    *,E15.6,*       ELZ2  *,E15.6 /
     ^            10X,*PIZ2   *,E15.6,*       EL2Z2 *,E15.6 /
     ^            10X,*PILZ   *,E15.6,*       EL3Z  *,E15.6 /
     ^            10X,*       *,  15X,*       ELZ3  *,E15.6 )
190 FORMAT (   /10X,*       MOMENTS                     VARIANCE TERMS*/
     ^            10X,*       RADIANS                         RADIANS    */
     ^            10X,*M3L    *,E15.6,*       TERM1 *,E15.6 /
     ^            10X,*M4L    *,E15.6,*       TERM2 *,E15.6 /
     ^            10X,*M3Z    *,E15.6,*       TERM3 *,E15.6 /
```

```
^             10X,*M4Z    *,E15.6,*      TERM4 *,E15.6 /
^             10X,*       *,  15X,*      TERM5 *,E15.6 /
^             10X,*       *,  15X,*      TERM6 *,E15.6 /
^             10X,*       *,  15X,*      TERM7 *,E15.6 /
^             10X,*       *,  15X,*      TERM8 *,E15.6 /
^             10X,*       *,  15X,*      TERM9 *,E15.6 )
 END
```

```
      SUBROUTINE CARDS(NSAMP,NMAX)
C        THIS SUBROUTINE READS FIXED FIELD DATA CARDS IN (A)
C        FORMAT, WRITES ON UNIT 6 FOR PRINTOUT AND WRITES ON
C        UNIT 8 FOR SUBSEQUENT READING IN (F) FORMAT.
C
      IMPLICIT INTEGER(A-Z)
      DIMENSION CARD(8)
C
      NSAMP=0
      MAX=NMAX+1
      READ(5,50) CARD
         IF (EOF(5).NE.0) GOTO 30
      WRITE(6,60) CARD
         DO 10 I=1,MAX
            READ(5,50) CARD
            WRITE(6,60) CARD
            WRITE(8,50) CARD
            IF (CARD(1).EQ.4HEND ) GOTO 20
   10    CONTINUE
      WRITE(6,70) NMAX
      GOTO 40
   20 CONTINUE
      NSAMP=I-1
         IF (NSAMP.LE.0) WRITE(6,80)
         IF (NSAMP.LE.0) GOTO 40
      REWIND 8
      RETURN
   30 CONTINUE
      WRITE(6,90)
   40 STOP
C
   50 FORMAT (8A10)
   60 FORMAT (5X,8A10)
   70 FORMAT (//15X,*SUBROUTINE CARDS - SAMPLES EXCEEDS MAX OF * I4)
   80 FORMAT (//15X,*SUBROUTINE CARDS - NO DATA PROVIDED*)
   90 FORMAT (//15X,*SUBROUTINE CARDS - NO SAMPLES INPUT*)
      END
```

```
      SUBROUTINE INPUT (TITLE1,TITLE2)
C        THIS SUBROUTINE READS MODIFIED NAMELIST FORMATTED DATA.
C        IT READS A CARD ON UNIT 5, WRITES THE CARD ON UNIT 6,
C        WRITES THE CARD ON UNIT 8 (FIRST 72 CHARACTERS ONLY).
C        THE TITLE1 AND TITLE2 CARDS ARE NOT WRITTEN ON UNIT 8
C        BUT THE DATA IS PLACED IN THE TITLE1 AND TITLE2 ARRAYS
C        FOR TRANSFER BACK TO THE CALLING PROGRAM.  TITLE1= AND
C        TITLE2= CARDS MUST BEGIN IN COLUMN 2 WITH NO SPACES.
C        THE CALLING PROGRAM MUST BLANK THE TITLE ARRAYS,
C        CALL INPUT(ARG1,ARG2,), AND READ(8,INPUTD).  NAMELIST
C        DATA MUST BEGIN WITH $INPUTD AND END WITH $END, BOTH
C        BEGINNING IN COLUMN 2.
      IMPLICIT INTEGER(A-Z)
      DIMENSION TITLE1(8), TITLE2(8), CARD(8)
      DATA BLANK/10H          /
C
C
      REWIND 8
      WRITE(6,40)
   10 CONTINUE
         READ(5,50) CARD
         IF (EOF(5).NE.0) STOP
         WRITE(6,60) CARD
C           BLANK COLUMNS 9 AND 10
         ENCODE (10,70,WORD) CARD(1),BLANK
         IF (WORD.NE.10H TITLE1=  ) GOTO 20
C           CARD READ IS A TITLE CARD
            ENCODE (72,80,TITLE1) CARD
            GOTO 10
C
   20    CONTINUE
         IF (WORD.NE.10H TITLE2=  ) GOTO 30
C           CARD READ IS A TITLE CARD
            ENCODE (72,80,TITLE2) CARD
            GOTO 10
C
   30    CONTINUE
C           CARD READ IS NOT A TITLE CARD
C           BLANK COLUMNS 73-80 OF DATA CARD
         ENCODE (10,90,CARD(8)) CARD(8),BLANK
         WRITE(8,50) CARD
      IF (CARD(1).NE.10H $END     ) GOTO 10
C
      REWIND 8
      CALL DATE(DAT)
      CALL TIME(TIM)
      WRITE(6,100) DAT,TIM
      RETURN
C
   40 FORMAT (1H1)
   50 FORMAT (8A10)
   60 FORMAT (10X,8A10)
   70 FORMAT (A8,A2)
   80 FORMAT (R2,7A10)
   90 FORMAT (A2,A8)
  100 FORMAT (/////,10X,*DATE IS *A9/
     ^               10X,*TIME IS *A9)
      END
```

```
      SUBROUTINE CORSIG(X,Y,NSAMP,SIGMAX,SIGMAY,RHOXY,
     ^                  XMEAN,YMEAN,IMEAN,ICOR)
C        CALCULATES MEAN,STANDARD DEVIATION AND CORRELATION COEFFICIENTS
C        OF TWO VARIABLES OF NSAMP SAMPLES.
C
C        *************  INPUT DATA  ***************
C        X       = ARRAY OF SAMPLE VALUES OF VARIABLE X
C        Y       = ARRAY OF SAMPLE VALUES OF VARIABLE Y
C        NSAMP   = NUMBER OF SAMPLE VALUES
C        IMEAN   = 0 IF MEAN VALUES OF VARIABLES X AND Y
C                    ARE TO BE SET TO ZERO.
C                = 1 IF MEAN VALUES OF VARIABLES X AND Y
C                    ARE TO BE CALCULATED.
C
C        *************  OUTPUT DATA  ***************
C        SIGMAX = STANDARD DEVIATION OF VARIABLE X
C        SIGMAY = STANDARD DEVIATION OF VARIABLE Y
C        RHOXY  = CORRELATION COEFFICIENT OF VARIABLES X AND Y
C        XMEAN  = MEAN VALUE OF VARIABLE X
C        YMEAN  = MEAN VALUE OF VARIABLE Y
C
      IMPLICIT REAL (A-H,O-Z)
      DIMENSION X(1),Y(1)
C
C
      XSUM=0.
      YSUM=0.
      XSQSUM=0.
      YSQSUM=0.
      XYSUM=0.
      RHOXY=0.
      SAMPN=NSAMP
      DO 10 I=1,NSAMP
         XSUM=XSUM+X(I)
         YSUM=YSUM+Y(I)
         XSQSUM=XSQSUM+X(I)*X(I)
         YSQSUM=YSQSUM+Y(I)*Y(I)
         XYSUM=XYSUM+X(I)*Y(I)
   10 CONTINUE
      XMEAN=0.
      YMEAN=0.
      IF (IMEAN.NE.0) XMEAN=XSUM/SAMPN
      IF (IMEAN.NE.C) YMEAN=YSUM/SAMPN
      SIGMAX=SQRT(XSQSUM/(SAMPN-1.)-XMEAN**2)
      SIGMAY=SQRT(YSQSUM/(SAMPN-1.)-YMEAN**2)
      IF (ICOR.NE.0)
     ^   RHOXY=(XYSUM-SAMPN*XMEAN*YMEAN)/SAMPN/SIGMAX/SIGMAY
      RETURN
      END
```

```
      SUBROUTINE STAT(DX,DY,NSAMP,ICOR,IMEAN)
C          THIS SUBROUTINE CALCULATES EXPECTED VALUES AND STATISTICAL
C          MOMENTS OF TWO VARIABLES.
C
C            ********** INPUT DATA **********
C     DX   = ARRAY OF SAMPLE VALUES OF VARIABLE X, DEG
C     DY   = ARRAY OF SAMPLE VALUES OF VARIABLE Y, DEG
C     NSAMP= NUMBER OF SAMPLES
C     ICOR = NON-ZERO VALUE RESULTS IN INCLUSION OF CORRELATION
C            TERMS, I.E., EXPECTED VALUES BETWEEN THE TWO VARIABLES
C            ARE CALCULATED.
C     IMEAN= NON-ZERO VALUE RESULTS IN CALCULATION OF MEAN VALUES
C            OF THE TWO VARIABLES.  ZERO VALUE ASSUMES ZERO MEANS.
C
C            ********** OUTPUT DATA **********
C     EXY  = EXPECTED VALUES OF VARIABLES X AND Y
C     M3X  = THIRD MOMENT OF VARIABLE X
C     M3Y  = THIRD MOMENT OF VARIABLE Y
C     M4X  = FOURTH MOMENT OF VARIABLE X
C     M4Y  = FOURTH MOMENT OF VARIABLE Y
C
      IMPLICIT REAL(A-H,M,O-Z)
      COMMON /STATS/ EXY,EX2Y,EXY2,EX3Y,EXY3,EX2Y2,M3X,M3Y,M4X,M4Y
      DIMENSION DX(1),DY(1)
      DATA DEG/57.29578/
C
C
      SAMP=NSAMP
      EXY=0.
      EX2Y=0.
      EXY2=0.
      EX3Y=0.
      EXY3=0.
      EX2Y2=0.
      M3X=0.
      M3Y=0.
      M4X=0.
      M4Y=0.
      XSUM=0.
      YSUM=0.
      EX=0.
      EY=0.
      IF (IMEAN.EQ.0) GOTO 20
      DO 10 I=1,NSAMP
         XSUM=XSUM+DX(I)
         YSUM=YSUM+DY(I)
   10 CONTINUE
      EX=XSUM/SAMP
      EY=YSUM/SAMP
   20 CONTINUE
      DO 30 I=1,NSAMP
         DDX=(DX(I)-EX)/DEG
         DDY=(DY(I)-EY)/DEG
         DX2=DDX**2
         DX3=DDX**3
         DX4=DDX**4
         DY2=DDY**2
```

```
      DY3=DDY**3
      DY4=DDY**4
      M3X=M3X+DX3
      M3Y=M3Y+DY3
      M4X=M4X+DX4
      M4Y=M4Y+DY4
      IF (ICOR.EQ.0) GOTO 30
         EXY=EXY+DDX*DDY
         EX2Y=EX2Y+DX2*DDY
         EXY2=EXY2+DDX*DY2
         EX3Y=EX3Y+DX3*DDY
         EXY3=EXY3+DDX*DY3
         EX2Y2=EX2Y2+DX2*DY2
30 CONTINUE
   M3X=M3X/SAMP
   M3Y=M3Y/SAMP
   M4X=M4X/SAMP
   M4Y=M4Y/SAMP
   EXY=EXY/SAMP
   EX2Y=EX2Y/SAMP
   EXY2=EXY2/SAMP
   EX3Y=EX3Y/SAMP
   EXY3=EXY3/SAMP
   EX2Y2=EX2Y2/SAMP
   RETURN
   END
```

APPENDIX C

SCIENTIFIC DATA PROCESSING ROUTINE
SUMMARY DOCUMENTATION

IDENTIFICATION

Title Moments of Inclination Error Distribution (MIED)

Routine No. 7229 Date Filed April 70 Security Class. U

Responsible Engineer T. R. Myler

Date Completed April 1970 Source Language: FORTRAN IV Other

Key Words Orbit inclination, statistics

RESOURCE REQUIREMENTS

Typical CPU 10 sec Machine(s) CDC CYBER 175 No. Source Cards 519

Core 42k (octal) Tape none Plot no Graphics none Other

DESCRIPTION

Purpose: To compute inclination error statistics based on flight experience using a closed form solution.

Input: Predicted insertion conditions and observed deviations of past flights; nominal insertion conditions of orbit requiring inclination error statistics.

Output: Mean, standard deviation, variance, third moment, skewness, fourth moment and kurtosis of inclination error; means, standard deviations and correlations of azimuth, latitude and longitude.

Functional Description: A Taylor series expansion is used to generate statistical moments of a multivariable system, which is the relationship of inclination to latitude and azimuth.

DOCUMENTATION

Vought Report 2-53030/1R-52638, "Moments of Inclination Error Distribution Computer Program" dated 1 March 1981.

1 Report No	2 Government Accession No	3 Recipient's Catalog No
NASA CR-165824		

4 Title and Subtitle	5 Report Date
Moments of Inclination Error Distribution Computer Program	December 1981
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7 Author(s)	8 Performing Organization Report No
T. R. Myler	
	10 Work Unit No
9 Performing Organization Name and Address	11 Contract or Grant No
Vought Corporation P. O. Box 225907 Dallas, TX 75265	NAS1-15000
12 Sponsoring Agency Name and Address	13 Type of Report and Period Covered
National Aeronautics and Space Administration Washington, DC 20546	Contractor Report
	14 Sponsoring Agency Code
	490-02-02-77-00

15 Supplementary Notes

Langley Technical Monitor: R. J. Keynton

16 Abstract This report describes a FORTRAN coded computer program which calculates orbital inclination error statistics using a closed-form solution. This solution uses a data base of trajectory errors from actual flights to predict the orbital inclination error statistics. The Scout flight history data base consists of orbit insertion errors in the trajectory parameters - altitude, velocity, flight path angle, flight azimuth, latitude and longitude.

The Scout data base includes flights with launch azimuths ranging from easterly to southerly to slightly west of south. Latitude errors, which produce inclination errors, result from crossrange errors on easterly flights and range errors on southerly flights. Therefore, latitude errors of the flight history data base are not a consistent sample set of errors for a given flight azimuth at insertion. Since it is necessary to have a consistent set of sample latitude errors, the data base latitude errors are adjusted for the flight azimuth of interest. Knowing the nominal flight azimuth, latitude and their errors on each flight of the data base, range and cross-range errors are calculated. Since range and crossrange errors are independent of the flight azimuth, these errors can be converted to latitude errors for the flight azimuth of interest.

The methods used to generate the error statistics are of general interest since they have other applications. Included in this report are program theory, user instructions, output definitions, subroutine descriptions and detailed FORTRAN coding information.

17 Key Words (Suggested by Author(s))	18 Distribution Statement
Orbital: Mechanics, error analysis	FEDD Distribution Subject Category 61

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End of Document