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SCOUT TRAJECTORY ERROR PROPAGATION COMPUTER PROGRAM

T. R. Myler

VOUGHT CORPORATION
P. O. Box 225907
Dallas, Texas 75265

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SCOUT TRAJECTORY ERROR PROPAGATION COMPUTER PROGRAM

by T. R. Myler
Vought Corporation

SUMMARY

This report describes a FORTRAN coded computer program which calculates trajectory error covariance matrices and statistics from a data base of flight experience. The data base consists of trajectory errors resulting from past flights. A covariance matrix is calculated and may be propagated in time and added to a boost covariance matrix of a spin-stabilized stage. A sensitivity matrix is developed from the eigenvalues and eigenvectors of the final propagated covariance matrix. This sensitivity matrix is provided for use by another computer program to randomly sample the matrix using a Monte Carlo technique to yield sample errors which will produce the same covariance matrix.

The theory and methods presented in this report for calculating error statistics and propagating an error covariance matrix are of general interest since they have applications other than those contained herein.

Included in this report are program theory, user instructions, output descriptions, 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 used for calculating the accuracy consists of errors in the trajectory parameters (altitude, velocity, etc.) at stage burnout as observed on Scout flights. Approximately 50 sets of errors are used in a Monte Carlo analysis to generate error statistics in the trajectory parameters. A covariance matrix is formed which may be propagated in time. The mechanization of this process resulted in computer program Scout Trajectory Error Propagation (acronym STEP) and is described herein.

Computer program STEP may be used in conjunction with the Statistical Orbital Analysis Routine (Reference 1) to generate accuracy in the orbit parameters (apogee, perigee, inclination, etc.) based upon flight experience.

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 error, ft
C_N	North component of position error, ft
CR	Crossrange, n.mi.
h	Altitude, n.mi.
n	Number of samples
r_e	Earth radius, ft
R	Range, n.mi.
V	Velocity, fps

Greek Alphabet

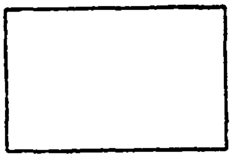
γ	Flight path angle, deg
Δ	Deviation from nominal
ϵ	Random number, unitless
ζ	Velocity azimuth, deg
λ	Latitude, deg
μ	Longitude, deg
$\bar{\mu}$	Statistical mean
ρ	Correlation coefficient
Σ	Summation
σ	Standard deviation

Others

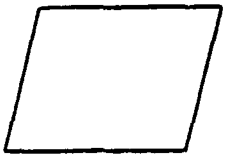
$'$	Adjusted value
$\frac{\partial x}{\partial y}$	Partial derivative of x to y

2.2 Flowchart Conventions

Flowchart conventions used in this report are as follows:

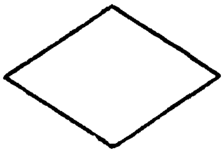


Process

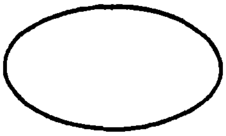


Input/Output

Subroutine



Decision



Subroutine Call

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 STEP is to calculate trajectory error statistics from a data base of errors resulting from actual flights. This data base consists of stage burnout errors in the trajectory parameters - altitude, velocity, flight path angle, flight azimuth, latitude and longitude.

The Scout data base at orbit insertion is shown in Table 3.1. These errors represent flights at various launch azimuths and insertion altitudes. Since errors in latitude and longitude are dependent upon launch azimuth and since errors in altitude, velocity and flight path angle may be dependent upon insertion altitude, adjustments are made to the flight errors in order to provide a consistent data base from which to generate the error statistics. These adjustments are discussed in the following paragraphs.

The Scout data base includes flights with launch azimuths ranging from easterly to southerly to slightly west of south. Latitude and longitude errors, which may produce inclination errors, result from crossrange errors on easterly flights and range errors on southerly flights. Therefore, latitude and longitude errors of the flight history data base are not a consistent set of sample errors for a given launch azimuth. Since it is necessary to have a consistent set of sample errors, the data base latitude and longitude errors are adjusted to the launch azimuth of interest. From the nominal flight azimuth, latitude, longitude 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 new latitude and longitude errors for the flight azimuth of interest by the following transformation.

$$C_N = r_e \Delta\lambda$$

$$C_E = r_e \Delta\mu \cos\lambda$$

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

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

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. The range and crossrange errors are then converted to latitude and longitude errors applicable to the flight azimuth of interest as shown below.

$$C_N = \Delta R \cos\zeta' + \Delta CR \sin\zeta'$$
$$C_E = \Delta R \sin\zeta' - \Delta CR \cos\zeta'$$
$$\Delta\lambda' = C_N'/r_e$$
$$\Delta\mu' = C_E'/r_e/\cos\lambda$$

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

The above process yields latitude and longitude errors which are used in the flight data base for calculating trajectory error statistics.

The second adjustment made to the flight data base is to "normalize" the errors in altitude, velocity and flight path angle to the insertion altitude of interest. The purpose of this adjustment is to obtain the flight errors which would have resulted if all the flights had had the same insertion altitude. This adjustment is accomplished for each flight sample as follows:

$$\Delta V' = \frac{\sigma v'}{\sigma v} \Delta V$$

where $\Delta V'$ = adjusted velocity error at the insertion altitude of interest

ΔV = flight sample velocity error

$\sigma_{V'}$ = standard deviation of velocity at the insertion altitude of interest

σ_V = standard deviation of velocity at the flight sample insertion altitude

Similar expressions are used for altitude and flight path angle errors. Azimuth, latitude and longitude errors are not adjusted for insertion altitude because they are independent of insertion altitude.

The "normalized" deviations in altitude, velocity and flight path angle - the adjusted deviations in latitude and longitude - and the azimuth deviations from the flight samples - are combined to be the flight data base from which error statistics are calculated. This flight data base is applicable only to a trajectory with the insertion altitude and launch azimuth to which the flight errors were adjusted.

The "normalizing" process should be used only when altitude, velocity and flight path angle errors input in the flight data base, are a function of insertion altitude. This relationship is true for Scout because there is a long coast time (300-400 seconds) prior to the last stage boost, which allows the errors to grow. Thus, the error magnitudes at last stage ignition are a function of time and altitude. If the input flight data base corresponds to the stage burnout prior to the long coast time, the errors should not be normalized.

The normalizing equation involves a ratio of standard deviations of the trajectory parameter. These deviations can be obtained by inputting a flight data base at stage burnout prior to the long coast time and propagating the covariance matrix to various insertion altitudes.

3.2 Program Theory

The primary function of STEP is to calculate and/or propagate a covariance matrix of trajectory state parameters - altitude, velocity, flight path angle, azimuth, latitude and longitude. The initial covariance matrix is either input directly or is calculated from input samples of actual flight errors (flight experience). Covariance propagation is optional and is controlled by inputs to the program. If selected, a boost covariance matrix of a spin-stabilized stage is calculated and added to the propagated covariance matrix. The resulting matrix - or the covariance matrix at the input epoch if it is not propagated - provides statistics in the trajectory parameter errors. Also, sensitivity coefficients calculated from the covariance matrix can be used by another computer program to provide a sampling of trajectory errors which can be converted to orbital parameter error statistics. Such a program is the Statistical Orbital Analysis Routine, Reference (1).

The calculation of a covariance matrix from flight results and the calculation of the sensitivity coefficients are discussed below.

Each of the six parameters of the flight data base, as described in Section 3.1, are combined in the manner shown below to yield mean values, standard deviations and correlation coefficients.

$$\bar{\mu}_x = \frac{\sum_{i=1}^{n} \Delta x_i}{n}$$

mean value

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n} \Delta x^2}{n-1} - \bar{\mu}_x^2}$$

standard deviation

$$\rho_{xy} = \frac{\sum_{i=1}^{n} \Delta x \Delta y - n\bar{\mu}_x \bar{\mu}_y}{n \sigma_x \sigma_y}$$

correlation coefficient

where x and y are any two parameters

The error covariance matrix is obtained from the error statistics calculated as shown on the preceding page and has the following form:

$$\begin{bmatrix} \sigma_h^2 & & & \text{Symmetric} & & \\ \rho_{hv}\sigma_h\sigma_v & \sigma_v^2 & & & & \\ \rho_{h\gamma}\sigma_h\sigma_\gamma & \rho_{v\gamma}\sigma_v\sigma_\gamma & \rho_\gamma^2 & & & \\ \rho_{h\zeta}\sigma_h\sigma_\zeta & \rho_{v\zeta}\sigma_v\sigma_\zeta & \rho_{\gamma\zeta}\sigma_\gamma\sigma_\zeta & \rho_\zeta^2 & & \\ \rho_{h\lambda}\sigma_h\sigma_\lambda & \rho_{v\lambda}\sigma_v\sigma_\lambda & \rho_{\gamma\lambda}\sigma_\gamma\sigma_\lambda & \rho_{\zeta\lambda}\sigma_\zeta\sigma_\lambda & \sigma_\lambda^2 & \\ \rho_{h\mu}\sigma_h\sigma_\mu & \rho_{v\mu}\sigma_v\sigma_\mu & \rho_{\gamma\mu}\sigma_\gamma\sigma_\mu & \rho_{\zeta\mu}\sigma_\zeta\sigma_\mu & \rho_{\lambda\mu}\sigma_\lambda\sigma_\mu & \sigma_\mu^2 \end{bmatrix}$$

The error covariance matrix is a real, symmetric matrix and can be diagonalized to obtain the eigenvectors and eigenvalues. A matrix using the eigenvalues is formed as follows:

$$[A]=[\sqrt{EV_1}\ \sqrt{EV_2}\ \sqrt{EV_3}\ \sqrt{EV_4}\ \sqrt{EV_5}\ \sqrt{EV_6}]$$

where EV_i = eigenvalues

The sensitivity matrix is formed from the A matrix and the eigenvector matrix as follows:

$$[S]=[A][ET]^T$$

where $[ET]^T$ is the transpose of the eigenvector matrix.

The S matrix represents a sensitivity matrix of the six trajectory parameters to six independent and uncorrelated error sources and has the following form:

$$[S]=\begin{bmatrix} \frac{\partial h}{\partial E_1} & \frac{\partial V}{\partial E_1} & \frac{\partial \gamma}{\partial E_1} & \frac{\partial \zeta}{\partial E_1} & \frac{\partial \lambda}{\partial E_1} & \frac{\partial \mu}{\partial E_1} \\ \frac{\partial h}{\partial E_2} & \frac{\partial V}{\partial E_2} & \frac{\partial \gamma}{\partial E_2} & \frac{\partial \zeta}{\partial E_2} & \frac{\partial \lambda}{\partial E_2} & \frac{\partial \mu}{\partial E_2} \\ \frac{\partial h}{\partial E_3} & \frac{\partial V}{\partial E_3} & \frac{\partial \gamma}{\partial E_3} & \frac{\partial \zeta}{\partial E_3} & \frac{\partial \lambda}{\partial E_3} & \frac{\partial \mu}{\partial E_2} \\ \frac{\partial h}{\partial E_4} & \frac{\partial V}{\partial E_4} & \frac{\partial \gamma}{\partial E_4} & \frac{\partial \zeta}{\partial E_4} & \frac{\partial \lambda}{\partial E_4} & \frac{\partial \mu}{\partial E_4} \\ \frac{\partial h}{\partial E_5} & \frac{\partial V}{\partial E_5} & \frac{\partial \gamma}{\partial E_5} & \frac{\partial \zeta}{\partial E_5} & \frac{\partial \lambda}{\partial E_5} & \frac{\partial \mu}{\partial E_5} \\ \frac{\partial h}{\partial E_6} & \frac{\partial V}{\partial E_6} & \frac{\partial \gamma}{\partial E_6} & \frac{\partial \zeta}{\partial E_6} & \frac{\partial \lambda}{\partial E_6} & \frac{\partial \mu}{\partial E_6} \end{bmatrix}$$

where E_i = independent, uncorrelated error sources

The sensitivity matrix is used to calculate random errors in the trajectory parameters as follows:

$$\begin{bmatrix} \Delta h \\ \Delta V \\ \Delta \gamma \\ \Delta \zeta \\ \Delta \lambda \\ \Delta \mu \end{bmatrix} = [S] \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \\ \epsilon_5 \\ \epsilon_5 \end{bmatrix}$$

where ϵ_i are random numbers from a normal distribution with a mean value of zero and a standard deviation of one

A covariance matrix is propagated by using a Monte Carlo analysis to: (1) sample the trajectory errors from the sensitivity matrix, (2) add the errors to the nominal values, (3) propagate the state parameters along a conic by a time increment, and (4) subtract the new state parameters from the nominal values at the new epoch. The resulting trajectory errors are combined as described on the preceding pages to yield the mean values, standard deviations and correlation coefficients and, thus, the covariance matrix.

The spin-stabilized stage boost covariance matrix is also formed using a Monte Carlo analysis. The boost error sources are sampled as shown below and combined as shown previously in this section.

$$\begin{bmatrix} \Delta h \\ \Delta V \\ \Delta \gamma \\ \Delta \zeta \\ \Delta \lambda \\ \Delta \mu \end{bmatrix} = \begin{bmatrix} \frac{\partial h}{\partial E_1} & \frac{\partial h}{\partial E_2} & \frac{\partial h}{\partial E_3} & \frac{\partial h}{\partial E_4} \\ \frac{\partial V}{\partial E_1} & \frac{\partial V}{\partial E_2} & \frac{\partial V}{\partial E_3} & \frac{\partial V}{\partial E_4} \\ \frac{\partial \gamma}{\partial E_1} & \frac{\partial \gamma}{\partial E_2} & \frac{\partial \gamma}{\partial E_3} & \frac{\partial \gamma}{\partial E_4} \\ \frac{\partial \zeta}{\partial E_1} & \frac{\partial \zeta}{\partial E_2} & \frac{\partial \zeta}{\partial E_3} & \frac{\partial \zeta}{\partial E_4} \\ \frac{\partial \lambda}{\partial E_1} & \frac{\partial \lambda}{\partial E_2} & \frac{\partial \lambda}{\partial E_3} & \frac{\partial \lambda}{\partial E_4} \\ \frac{\partial \mu}{\partial E_1} & \frac{\partial \mu}{\partial E_2} & \frac{\partial \mu}{\partial E_3} & \frac{\partial \mu}{\partial E_4} \end{bmatrix} \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \end{bmatrix}$$

where E_i = boost error sources

$\frac{\partial \chi}{\partial E_i}$ = partial derivative of respective trajectory parameter to a one sigma magnitude of the error source

ϵ_i = a random number defined as follows

For motor performance error source

$\epsilon_1 = \chi_{n_1}$

For pitch tipoff error source

$\epsilon_2 = |\chi_{n_2}| \cos(\chi_u * 360°)$

$\epsilon_3 = |\chi_{n_2}| \sin(\chi_u * 360°)$

$\epsilon_4 = \chi_{n_3}$

χ_{n_i} = a normally distributed random number with a mean value of 0 and a standard deviation of 1.

χ_u = a uniformly distributed random number from 0 to 1.

3.3 User Instructions

STEP 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 in order to utilize a flexible input format.

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 an epoch.

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

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 below 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 all statistics. = 3 if flight is to be used for azimuth statistics only. = 4 is flight is not to be used for statistics.
10-16	Nominal altitude, n.mi.
17-23	Altitude error, n.mi.
24-30	Velocity error, fps
31-37	Path angle error, deg
38-44	Azimuth error, deg
45-52	Latitude error, deg
53-60	Longitude error, deg
61-70	Nominal latitude, deg
71-80	Nominal azimuth, deg

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

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, followed by a value, followed by a comma, e.g., NSAMP=1000,

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

6. Titling information may be input by the appropriate title names, e.g., TITLE1= LOW ALTITUDE TRAJECTORY ERROR STATISTICS
   TITLE1 must begin in column 2.

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

8. Complete data arrays are input in the following form:
   name = value, value, value, ...,
   Data values may be continued on the next line, but the last character on every line must be a comma, excluding title cards.

9. Repeated data values may be input by using a repetition factor and an asterisk, e.g., DATAG = 0.4, 4*0.45, 0.5, 0.65,

10. One or more specific elements of an array may be input, e.g., EMAG(2)= 1.2, 1.6,

Subsequent data cases are allowed by providing additional sets of NAMELIST data. All input data is retained for subsequent cases but can be changed by inputting new values.

A sample data case is included as Appendix A to exemplify data case setup.

Definitions of specific NAMELIST inputs to STEP are shown below. Default values are shown when they are set by the program prior to reading input data. Data units are feet, degrees and seconds unless otherwise noted.

NAMELIST Input Definitions

COV	Covariance matrix of altitude, velocity, flight path angle, azimuth, latitude and longitude. Input when IERROR = 4
DATAG	Standard deviation in flight path angle, used to normalize flight errors. Array of 7 values. Independent variable is HINJ. (0.428, 0.428, 0.428, 0.430, 0.434, 0.442, 0.453 built-in)
DATAH	Standard deviation in altitude, used to normalize flight errors. Array of 7 values. Independent variable is HINJ. (3.35, 4.85, 5.80, 6.45, 6.90, 7.20, 7.30 built-in)
DATAV	Standard deviation in velocity, used to normalize flight errors. Array of 7 values. Independentl8ariable is HINJ. (75.6, 84.6, 88.8, 91.3, 92.5, 93.0, 93.0 built-in)
EMAG	Values for error sources used to calculate covariance matrix of a spin stabilized stage. Array of 4 values. Input when propagation is used. (1) = ratio of standard deviation desired to the standard deviation used to determine SEN1 for the motor performance error source. (2) = same as above except for determining SEN2 for the pitch tipoff error source. (3) = same as above except for determining SEN3 for the yaw tipoff error source. (4) = same as above except for determining SEN4 for the timer error source.
HINJ	Altitude used to normalize flight errors. Array of 7 values. Dependent variables are DATAG, DATAH, DATAV. (100., 200., 300., 400., 500., 600., 700. built-in)
IERROR	Option for inputting data errors = 1 Input flight results of altitude, velocity and path angle errors, 100 samples or less. Errors are input in fixed field format prior to NAMELIST data. = 2 Input flight results of altitude, velocity path angle, azimuth, latitude and longitude, 100 samples or less. Errors are input in fixed field format prior to NAMELIST data. (2 built-in)

	= 3 Input standard deviations (SIG) and correlation coefficients (RHO) of altitude, velocity, path angle azimuth, latitude and longitude. = 4 Input covariance matrix (COV) of altitude, velocity, path angle, azimuth, latitude and longitude.
NERROR	Number of error sources of the spin stabilized stage. (3 built-in)
NORM	Non-zero value normalizes altitude, velocity and path angle errors of the flight data base to the altitude of S1. (1 built-in)
NSAMP	Number of samples used in Monte Carlo analyses. (5000 built-in)
RHO	Correlation coefficients in order of altitude velocity, path angle, azimuth, latitude and longitude. Array of 15 values. Input when IERROR = 3.
SEN1	Sensitivity of spin stabilized stage burnout state parameters to one sigma motor performance error source. Units are state parameter units/sigma. Array of 6 values. Order of state parameters are altitude, velocity, path angle, azimuth, latitude and longitude.
SEN2	Same as SEN1 except error source is pitch tipoff. Units are state parameter units/deg.
SEN3	Same as SEN1 except error source is yaw tipoff. Units are state parameter units/deg.
SEN4	Same as SEN1 except error source is stage ignition time. Units are state parameter units/sec.
SIG	Standard deviation of altitude, velocity, path angle, azimuth, latitude and longitude. Array of 6 values. Input when IERROR = 3.
S1	Nominal state parameters at last stage burnout if covariance matrix propagation is not selected. If propagation is selected, S1 is state at burnout of next to last stage. Array of 6 values. Order is altitude, velocity, path angle, azimuth, latitude and longitude.
S2	Nominal state parameters at last stage burnout. Input if TCOAST is non-zero. Array of 6 values. Order is altitude, velocity, path angle, azimuth, latitude and longitude.

TCOAST	Nominal coast time to propagate covariance matrix. Input zero if propagation is not desired. (0. built-in)
TITLE1 TITLE2	Title information printed at top of each page of output. 72 characters maximum each.

3.4 Output Description

Both the fixed field and NAMELIST input data are listed verbatim on the output listing. These lists provide a quick check of the input data for format correctness and validity.

Following the input data lists, the flight experience data are provided in a labeled format. The next page provides the flight experience data after the altitude, velocity, path angle errors have been normalized and the latitude, longitude errors have been adjusted.

The following page provides error statistics for only those flights with latitude and longitude errors. The next page provides error statistics based upon all flight samples provided. The altitude, velocity, path angle and azimuth error statistics are obtained from those flight samples identified for that purpose. The latitude and longitude error statistics are derived from only those flights available for latitude and longitude statistics. Unless the covariance matrix is propagated, the final error covariance matrix is included on this page. Following the covariance matrix, the sensitivity matrix is provided, which when properly sampled will produce the covariance matrix.

If the covariance matrix is propagated, additional matrices are shown on the next two pages. The sensitivity matrix obtained from the final error covariance matrix is also included.

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	383.8	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	582.7	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	213.5	-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 description of each subroutine of STEP.

4.1 STEP (Main Program)

The main program initializes the input data defaults; calls the two input subroutines; normalizes the errors in altitude, velocity and flight path angle; adjusts the errors in latitude and longitude; calculates the error covariance matrix at the input epoch; calculates the sensitivity matrix; calculates the boost covariance matrix; propagates the covariance matrix; and outputs the results.

4.2 CARDS

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

4.3 CONIC

Subroutine CONIC initializes a conic path from an input trajectory state (altitude, velocity, flight path angle, azimuth, latitude and longitude) for subsequent propagation of the state along the conic path by an input time increment. CONIC verifies that the conic path is elliptical and, if so, calculates the orbital elements and coordinate transformations from the spherical state to inertial cartesian components . CONIC is called one time per conic path.

4.4 CORCO

Subroutine CORCO calculates mean values, standard deviations and the correlation coefficient of two independent variables from random samples of each. On option, the mean values may be set to zero.

4.5 COVR

Subroutine COVR generates a symmetric error covariance matrix of six parameters. COVR is called as each set of error samples is generated. COVR1 (an entry point) is called after all sets of samples have been generated and a covariance matrix is desired.

4.6 EIGEN

Subroutine EIGEN calculates the eigenvalues and eigenvectors of a real symmetric matrix. These values are used in STEP to generate a sensitivity matrix of six pseudo, independent, uncorrelated error sources to the six trajectory parameters.

4.7 INIT

Subroutine INIT initializes constants used by several of the subroutines, which are available to the subroutines via labeled common DIG. Entry point INIT1 initializes the parameters used to obtain random numbers. These parameters are available to the subroutines via labeled common BLK4.

4.8 INPUT

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

4.9 INTER

Subroutine INTER is a second-order interpolater of two variables. It selects the four closest data points to the desired value of the independent variable and interpolates or extrapolates for the value of the dependent variable.

4.10 NEWTON

Subroutine NEWTON iterates for the eccentric anomaly corresponding to a value of time along a conic. If the interation fails, a diagnostic is written. If the iteration is successful, the radius and true anomaly are calculated.

4.11 NORRAN

Subroutine NORRAN generates a normally distributed random number from the set of numbers which have a mean value and standard deviation as supplied to the subroutine.

4.12 TSTEP

Subroutine TSTEP propagates a trajectory state along a conic by a given time increment. Subroutine CONIC is used to initialize the conic from the initial state parameters. Subroutine NEWTON is used to iterate on eccentric anomaly. TSTEP updates the trajectory state parameters at the new time. TSTEP is called each time the trajectory state is to be propagated.

4.13 UNIRAN

Subroutine UNIRAN generates a uniformally distributed random number between zero and one. This random number is used when analyzing tipoff error sources.

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 STEP and in making modifications to the program.

5.1 Subroutine Flowcharts

Flowcharts are presented in Figures 5.1 through 5.9. The flowchart conventions used are defined in Section 2.0 of this report.

5.2 FORTRAN Listings

STEP 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.

ALT	Nominal altitude, n.mi.
BEST	Array equivalenced to SEN1, SEN2, SEN3, SEN4
CE	East component of position error, ft
CLAT	Cosine of nominal latitude
CMAT1	Error covariance matrix of last stage boost
CMAT2	Error covariance matrix after propagation

CN	North component of position error, ft
CON	Radians per degree, .0174532925
COV	Input data
CP1 CP2 CP3	Working arrays for correlation coefficients
CZ	Cosine of azimuth error
CZET	Cosine of nominal azimuth
D	Working array
DATAG DATAH DATAV	Input data for normalizing input flight errors
DCR	Crossrange error, n.mi.
DELT	Time increment for propagation of state parameters, sec
DEVG1 DEVG2	Interpolated values of DATAG
DEVH1 DEVH2	Interpolated values of DATAH
DEVV1 DEVV2	Interpolated values of DATAV
DG1 DG2	Path angle errors of flight sample
DH1 DH2	Altitude errors of flight sample
DLG1	Longitude error of flight sample
DL1	Latitude error of flight sample
DR	Range error, n.mi.
DV1 DV2	Velocity errors of flight sample
DX	Working array of trajectory parameter errors
DZ1 DZ2	Azimuth errors of flight sample
EMAG	Input data
EPAR	Array of normally distributed random numbers

EXIC	Working array of trajectory parameter errors
FT	Feet per n.mi., 6076.11549
GAUSS	Normally distributed random number
GM	Earth gravitational constant, 1.4076576E16 ft^3/sec^2
GN	Random numbers used in random number generator
HINJ	Input data
ICNT	Counter used in subroutine NORRAN
ICODE	Value of flag input with flight sample
IERROR	Input data
IWORD	Array of flags input with flight samples
KERR	Diagnostic flag set in subroutine NEWTON
MEAN	Flag for calculating mean values
MEANG	Mean value of path angle, deg
MEANH	Mean value of altitude, n.mi.
MEANL	Mean value of latitude, deg
MEANLG	Mean value of longitude, deg
MEANV	Mean value of velocity, fps
MEANZ	Mean value of azimuth, deg
N	Number of flight samples
NDATA	Number of data values of HINJ
NERROR	Input data
NFLAG	Working flag
NORM	Input data
NPROB	Case number
NSAMP	Input data
N1	Number of flight samples with ICODE = 1 or 2
N2	Number of flight samples with ICODE = 2 or 3

N3	Number of flight samples with ICODE = 1, 2 or 3
PI	3.1415927
R	Eigenvectors
RAD	Degrees per radian, 57.2957795
RE	Earth equatorial radius, 20925741 ft
RHO	Input data
RHOGL	Correlation coefficient of path angle and latitude
RHOGLG	Correlation coefficient of path angle and longitude
RHOGZ	Correlation coefficient of path angle and azimuth
RHOHG	Correlation coefficient of altitude and path angle
RHOHL	Correlation coefficient of altitude and latitude
RHOHLG	Correlation coefficient of altitude and longitude
RHOHV	Correlation coefficient of altitude and velocity
RHOHZ	Correlation coefficient of altitude and azimuth
RHOLLG	Correlation coefficient of latitude and longitude
RHOVG	Correlation coefficient of velocity and path angle
RHOVL	Correlation coefficient of velocity and latitude
RHOVLG	Correlation coefficient of velocity and longitude
RHOVZ	Correlation coefficient of velocity and azimuth
RHOZL	Correlation coefficient of azimuth and latitude
RHOZLG	Correlation coefficient of azimuth and longitude
ROTATE	Earth rotation rate, 7.29211E-5 radians per sec.
RR	Equivalenced to R
SC	Sensitivity coefficients
SEN1 SEN2 SEN3 SEN4	Input data

SIG	Input data
SIGALT	Standard deviation of altitude, n.mi.
SIGG	Standard deviation of path angle, deg
SIGH	Standard deviation of altitude, ft
SIGL	Standard deviation of latitude, deg
SIGLG	Standard deviation of longitude, deg
SIGMA	Standard deviation of normally distributed random numbers. Used in subroutine NORRAN
SIGV	Standard deviation of velocity, fps
SIGZ	Standard deviation of azimuth, deg
SS	Input state S1 propagated by TCOAST
STATE	Trajectory state to be propagated
SUMSQ1 SUMSQ2 SUMSQ3	Working arrays of summation of errors squared
SUM1 SUM2 SUM3	Working arrays of summation of errors
SZ	Sine of azimuth error
SZET	Sine of nominal azimuth
S1	Input data
S2	Input data
T	Time of propagated state referenced to TZERO, sec.
TCALL	Time of propagated state referenced to perigee, sec.
TCOAST	Input data
THET	Random direction of tipoff, deg
TITLE1 TITLE2	Input data
TOMAG	Random value of tipoff magnitude, deg.
TZERO	Initial time of state to be propagated, sec.

W	Working array for sensitivity matrix
WORD	Array of flight sample data
X	Random values of error sources
XALT	Nominal altitude of flight sample, n.mi.
XG	Path angle error of flight sample, deg.
XH	Altitude error of flight sample, ft
XL	Latitude error of flight sample, deg.
XLAT	Nominal latitude of flight sample, deg.
XLG	Longitude error of flight sample, deg.
XMU	Mean value of normally distributed random numbers
XV	Velocity error of flight sample, fps
XZ	Azimuth error of flight sample, deg.
ZET	Nominal azimuth, deg.
ZRAN	Uniformly distributed random number

Figure 5.1

FLOWCHART OF MAIN PROGRAM STEP

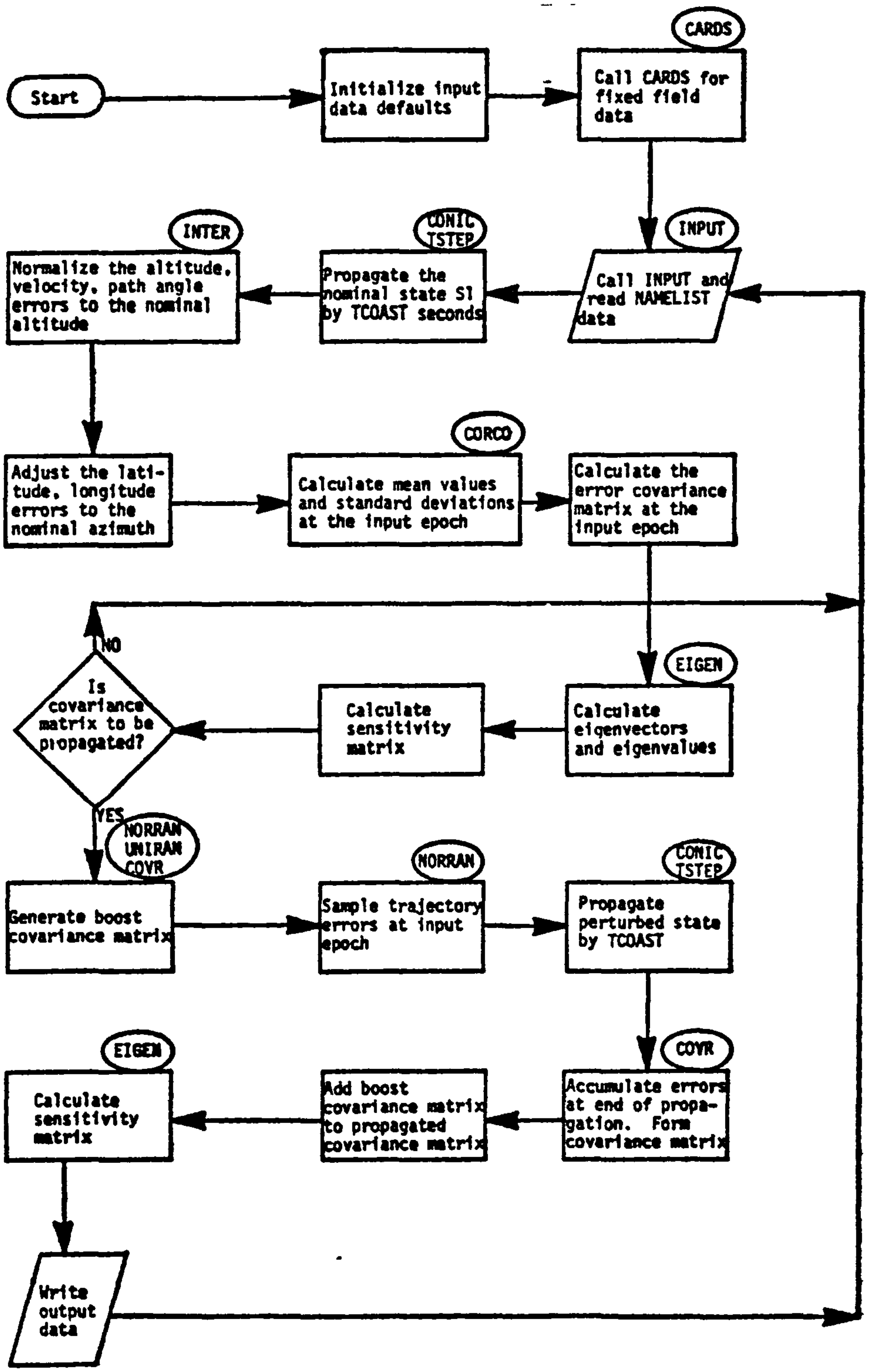


Figure 5.2

FLOWCHART OF SUBROUTINE CARDS

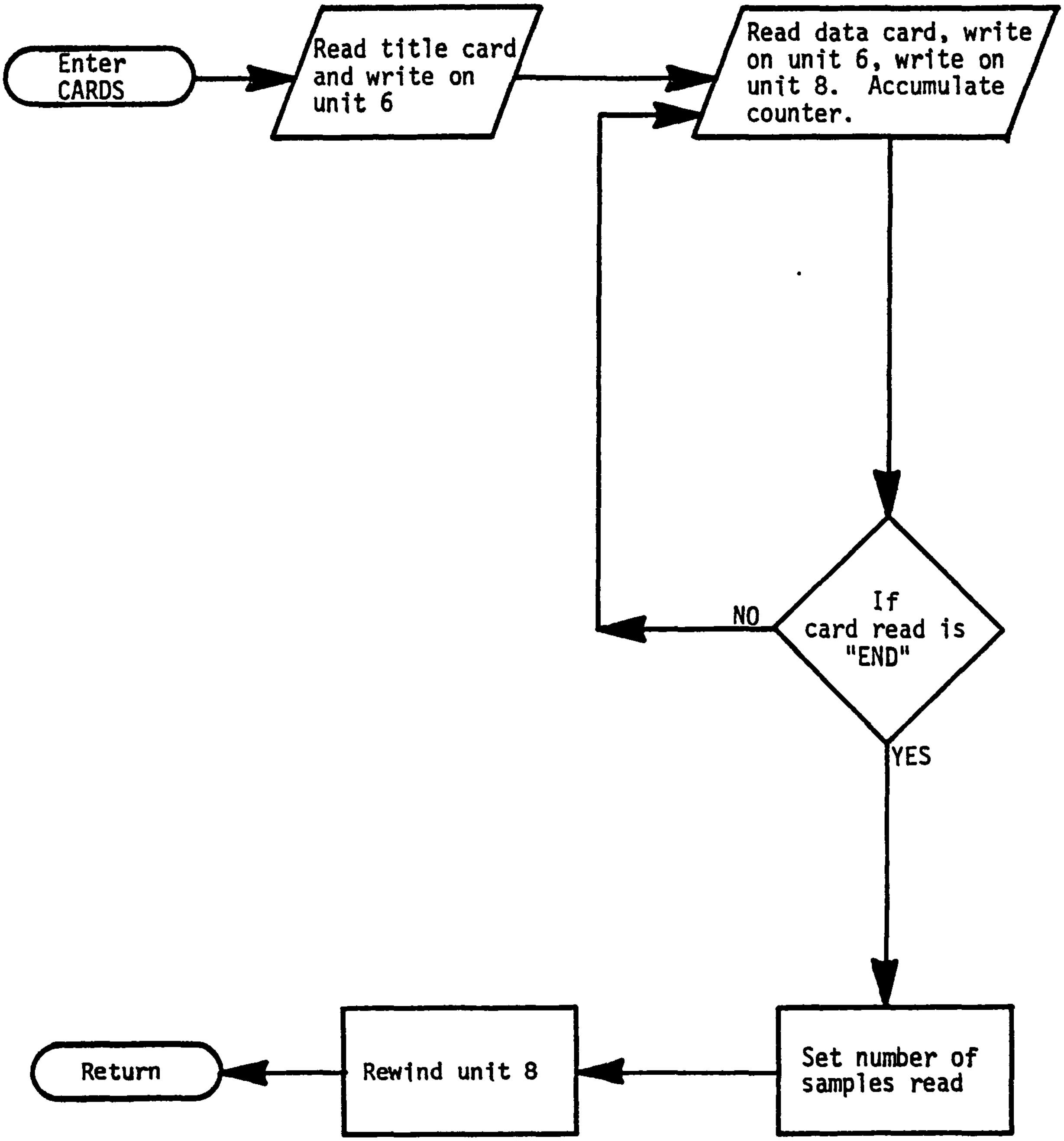


Figure 5.3

FLOWCHART OF SUBROUTINE CONIC

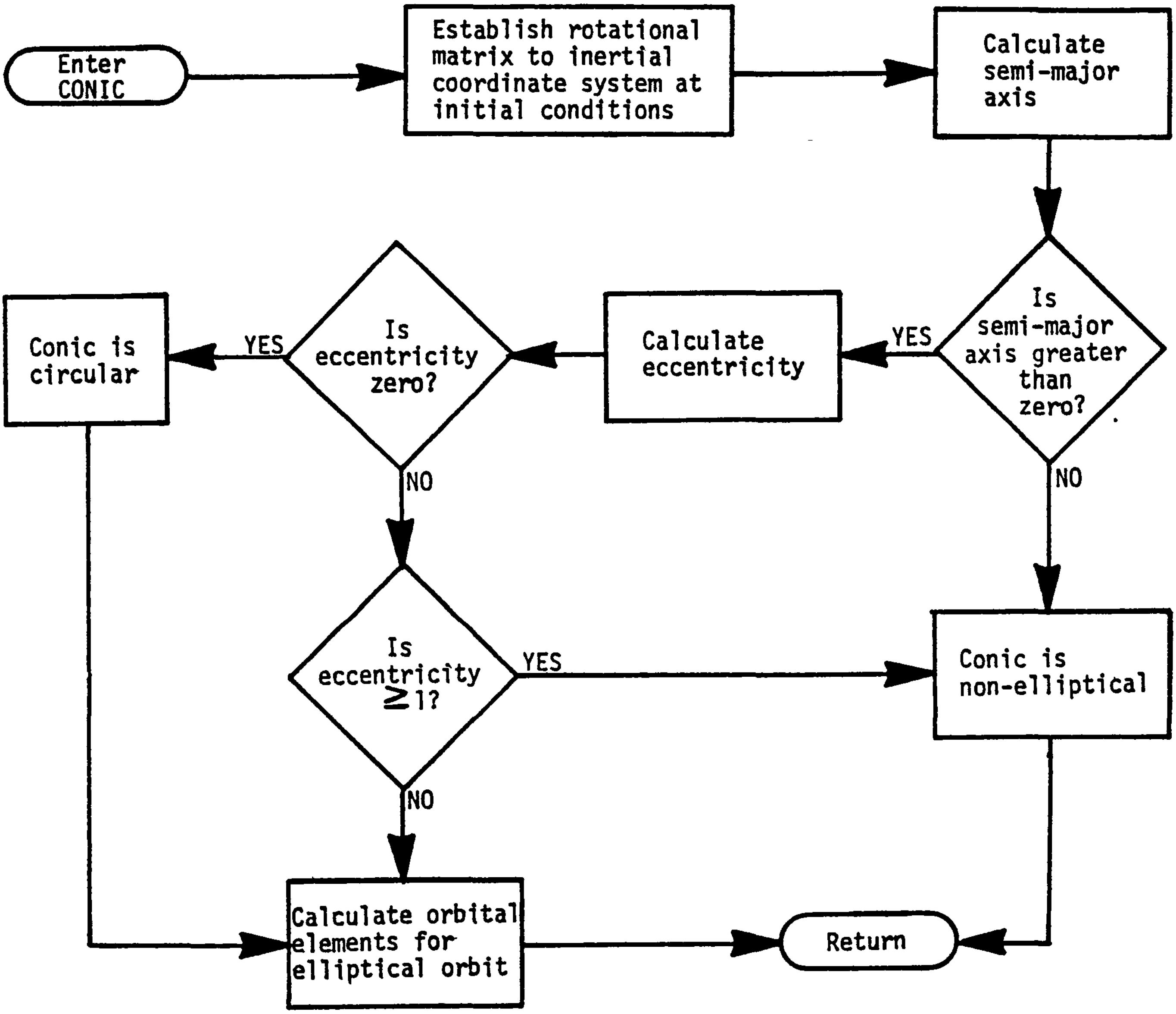


Figure 5.4

FLOWCHART OF SUBROUTINE CORCO

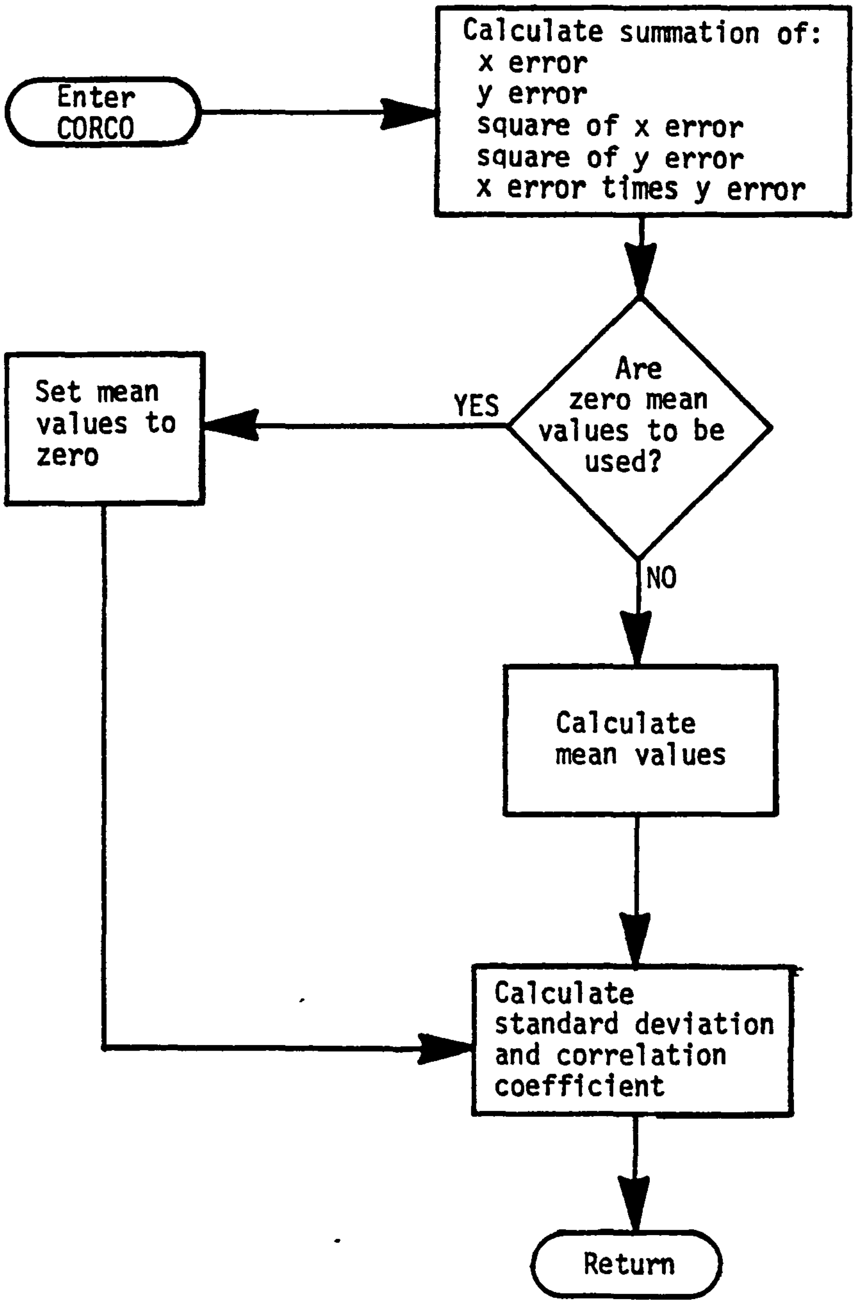


Figure 5.5

FLOWCHART OF SUBROUTINE COVR

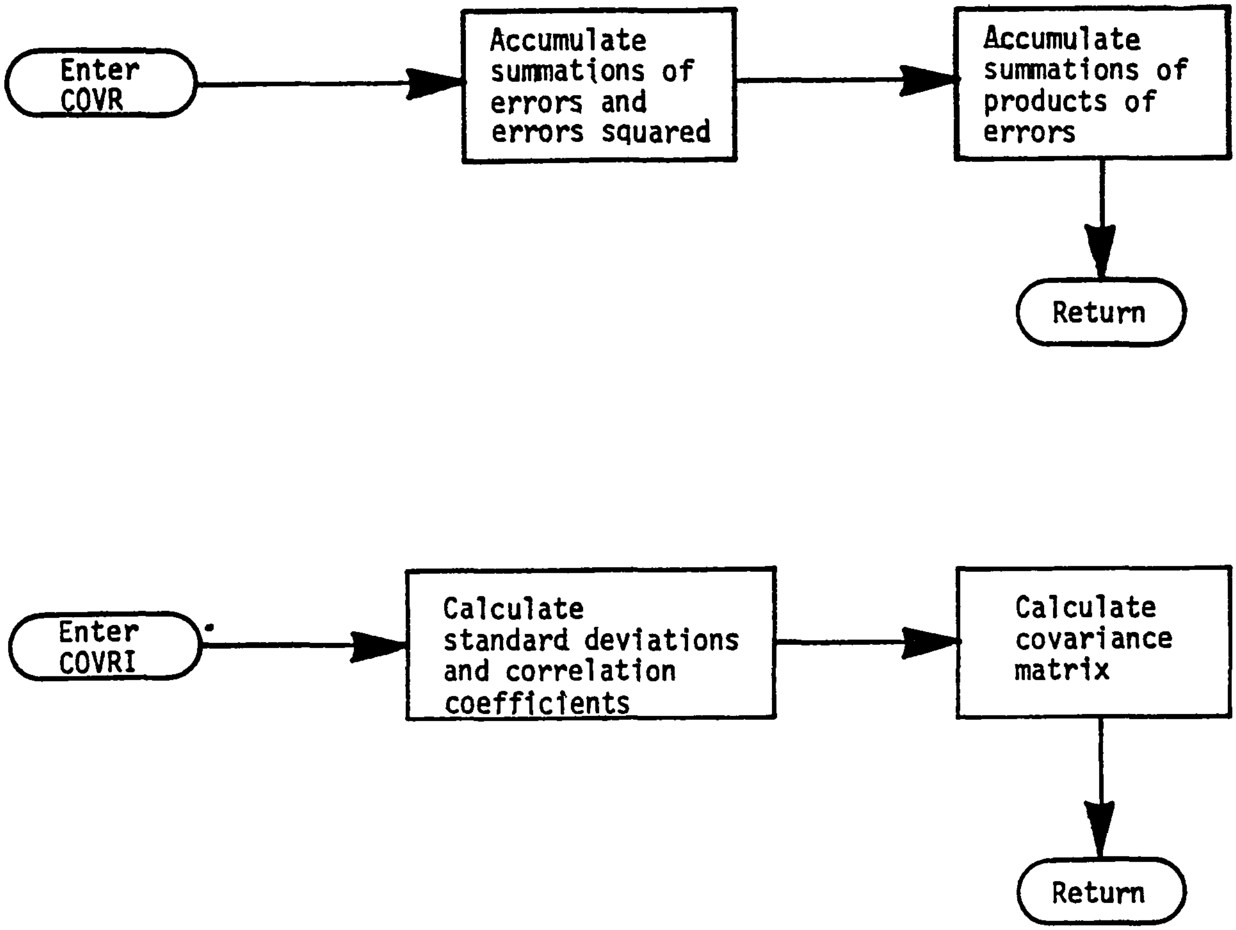


Figure 5.6

FLOWCHART OF SUBROUTINE INPUT

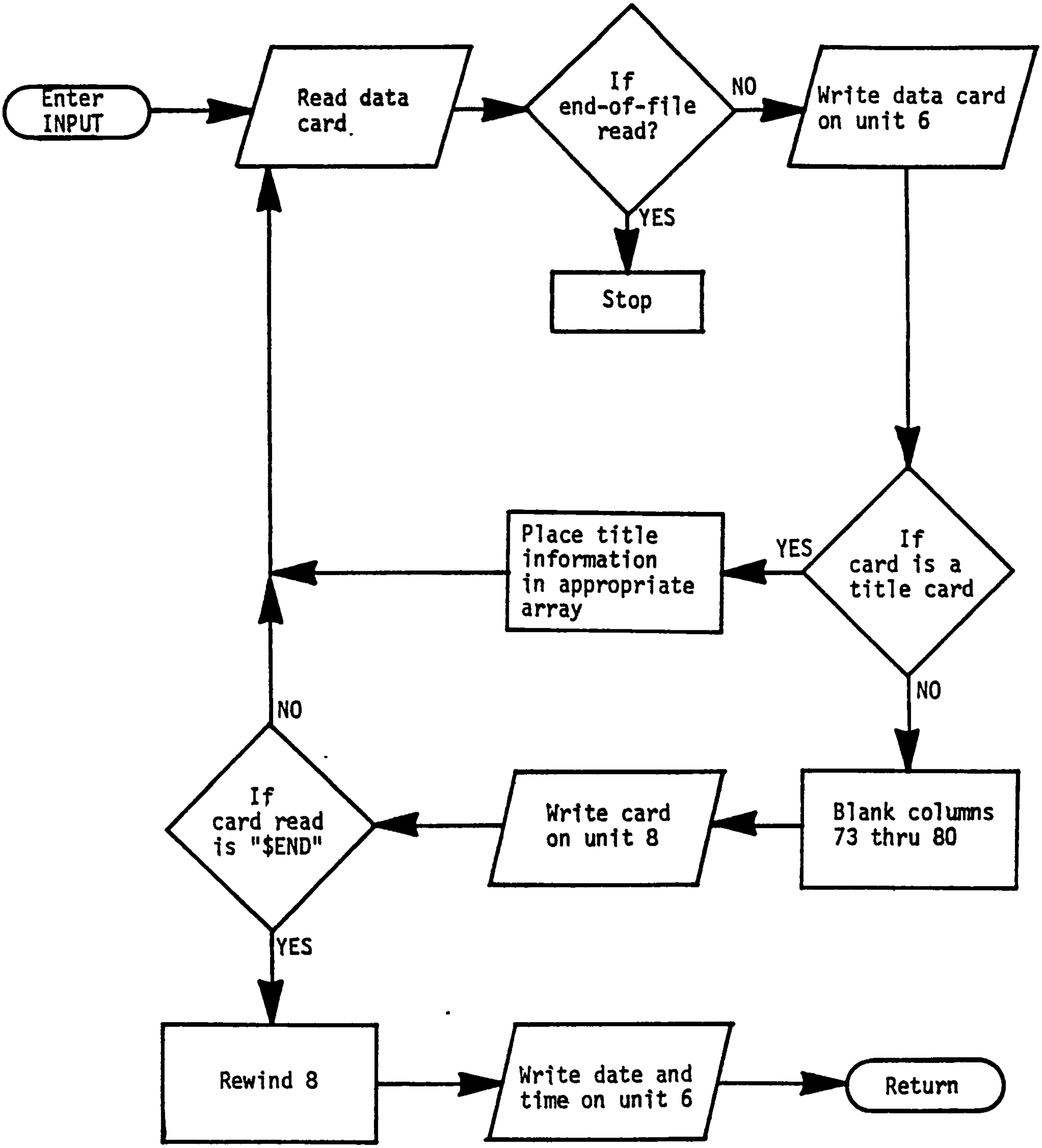


Figure 5.7

FLOWCHART OF SUBROUTINE INTER

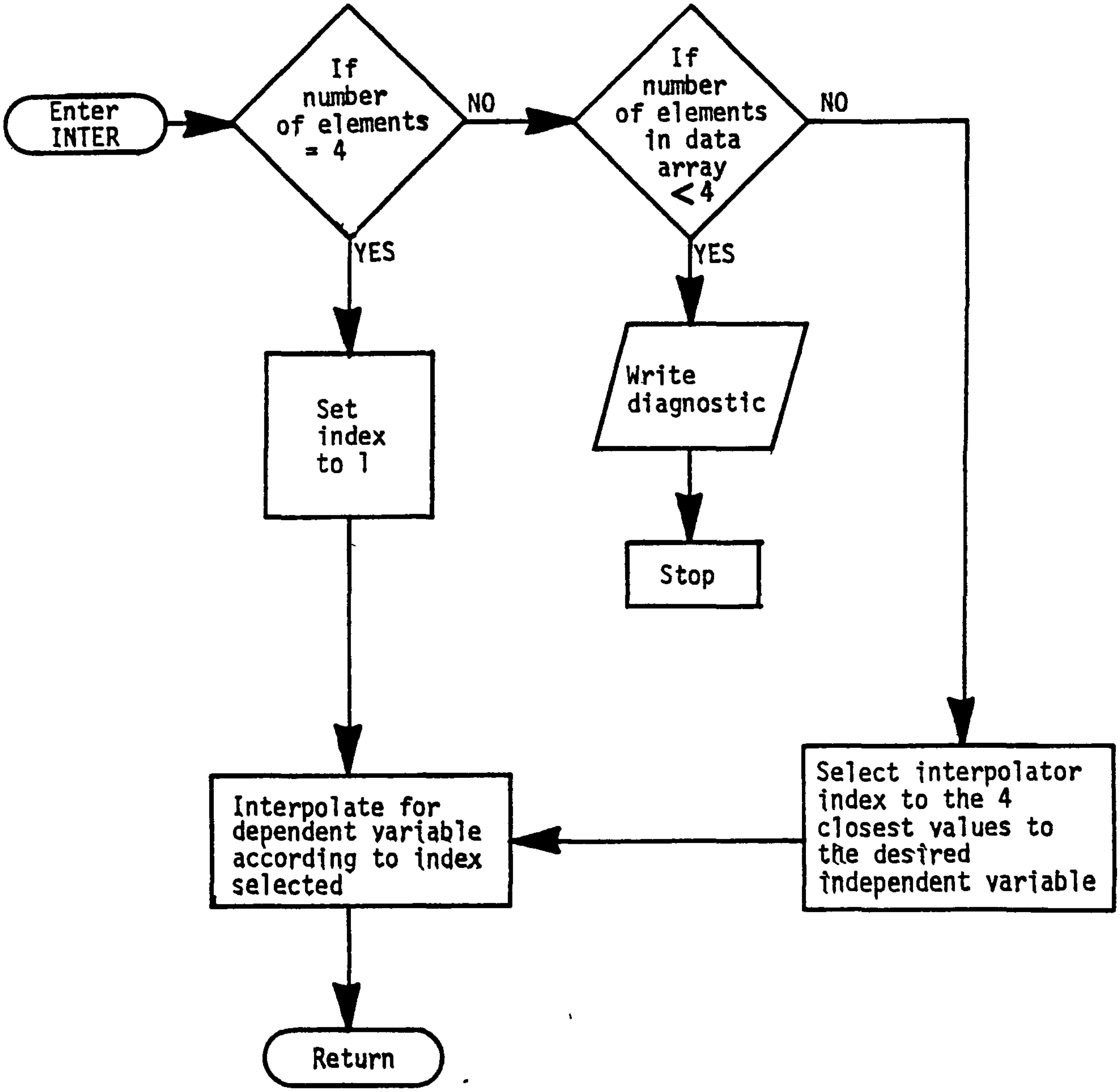


Figure 5.8

FLOWCHART OF SUBROUTINE NEWTON

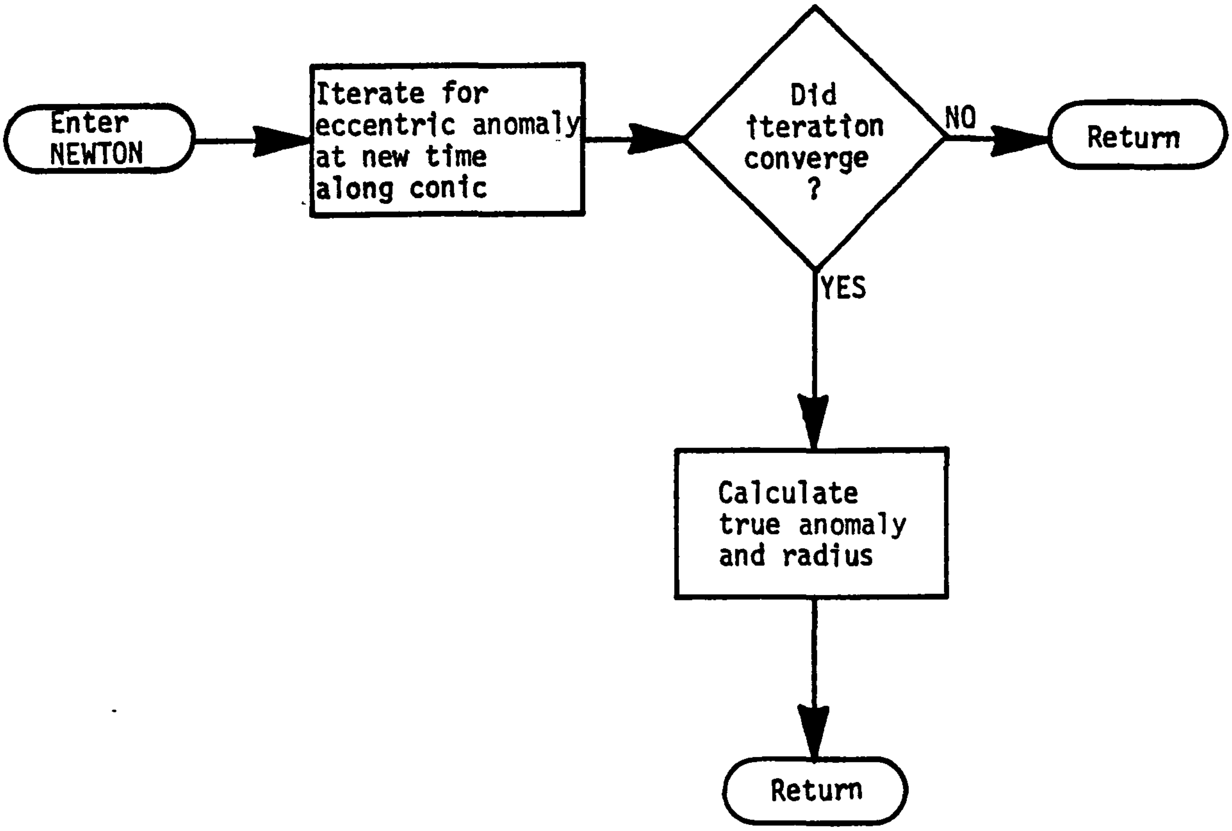
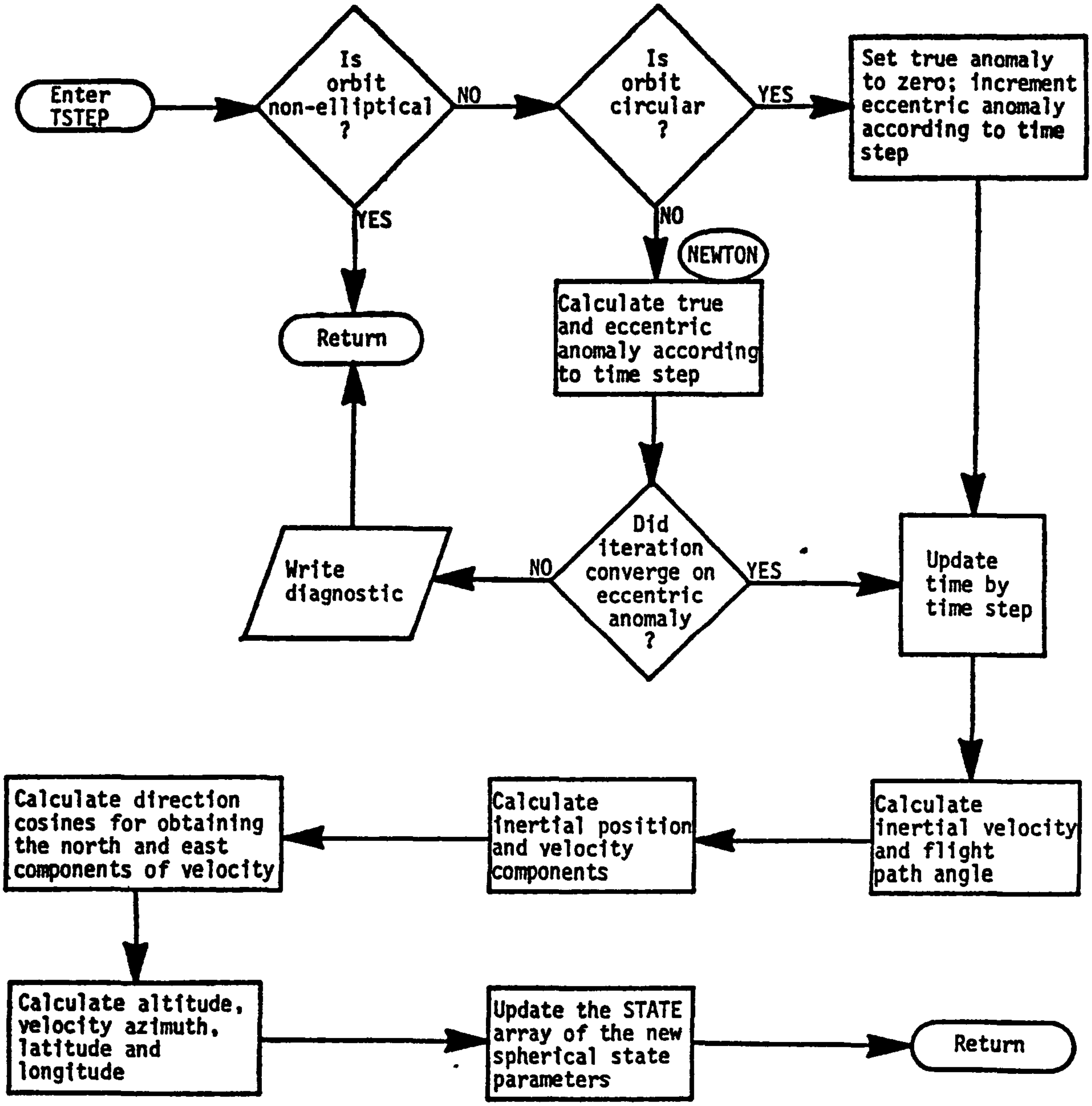


Figure 5.9

FLOWCHART OF SUBROUTINE TSTEP



REFERENCES

1. Vought Corporation Report No. 23.478, "The Statistical Orbital Analysis Routine" dated 19 March 1971.
2. Control Data Corporation, "FORTRAN Extended Version 4 Reference Manual," Revision C, dated 15 April 1977.

APPENDIX A

SAMPLE DATA CASES

```
46 FLIGHT SAMPLES AT STAGE 4 BURNOUT
S-136  3.  562.8    9.7  -58.5   0.77   0.28
S-131  4.  612.5    6.9 -280.0  -0.36  -0.15
S-138  3.  383.8    3.2 -107.9   0.15   0.77
S-139  3.  404.3    8.9  -29.2   0.05   0.19
S-140  3.  506.8   -0.2   67.2  -0.37  -0.91
S-142  3.  487.1    4.1  142.9  -0.86  -0.29
S-143  3.  482.2    4.2  112.3   0.14  -0.28
S-145  3.  200.1   -3.5   15.0  -0.75   0.48
S-146  3.  495.2   -3.7  -24.3  -0.63   0.0
S-147  3.  350.6    3.8   11.1  -0.98  -0.24
S-148  3.  197.7    2.8  -31.4  -0.17  -0.55
S-149  3.  576.3    0.0  -38.6   0.16  -1.18
S-150  2.  178.5    1.0  -31.1  -0.63  -0.14  0.0638  0.0339   20.7161   171.556
S-154  2.  577.0   -0.7  -57.5   0.12   0.26 -0.0473 -0.0361   12.1787   180.000
S-153  3.  117.1   -0.5  -56.9  -0.63  -0.13
S-155  2.  279.4   -5.5   94.3  -0.06   0.18 -0.1042  0.0115   15.0825   169.640
S-156  2.  582.7    2.0  -53.4  -0.05  -0.43 -0.0108  0.3134   12.0870   180.000
S-157  2.  565.9    2.8  -34.4  -0.15  -0.73 -0.0429  0.3543   12.1900   180.001
S-158  2.  235.3   -2.1    8.0  -0.17   0.70 -0.0729 -0.0749   18.2632   179.999
S-162  2.  581.2   -1.7  -29.1  -0.41  -0.07 -0.2190  0.4662   12.2504   180.000
S-161  2.  190.5   -5.8   17.0  -0.46  -1.08 -0.0774  0.0137   22.0366   188.853
S-165  2.  376.8   -2.3   72.4  -0.72  -1.36 -0.0345  0.1321   13.4573   171.761
S-167  2.  147.2    0.4   30.7  -0.57  -0.25 -0.0300  0.0690   23.1376   184.350
S-172  2.  216.0   -5.2  -91.1  -0.13  -0.93 -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  -0.17  -0.69 -0.0656 -0.0159   35.5464   103.438
S-175  2.  294.4   -0.7    7.6  -0.07   0.11 -0.2135  0.0215   -2.7201    88.955
S-173  3.  115.5    4.5  -93.0  -0.08  -1.05
S-177  2.  323.3    0.6  -79.4  -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
S-184  2.  263.5    6.7   -8.0   0.26   0.32 -0.1355 -0.0692   34.3083   106.662
S-182  2.  449.6    8.0 -177.0  -0.02   0.13  0.2266  0.1281   13.4634   180.000
S-170  2.  299.7   -0.0  -29.5  -0.76  -0.60  0.2533 -0.0426   -1.6043    89.260
S-185  2.  151.2   -3.5   70.5  -1.14   0.34 -0.0743 -0.0523   22.3683   180.860
S-181  2.  129.5   -3.4   84.2  -0.41  -0.28 -0.0777  0.0682   22.1681   187.780
S-178  2.  604.4   14.5 -220.2  -0.03   0.17  0.3180  0.0550   11.5952   180.020
S-190  2.  123.1    2.4   58.2   0.03   0.07 -0.0017  0.0943   -2.8471    89.370
S-188  2.  405.0   -2.9  149.5  -0.47  -0.62 -0.1845  0.1735   13.8902   188.650
S-191  2.  215.2    0.6   45.7  -0.56  -0.20 -0.0857 -0.2038   14.2879   179.896
S-186  2.  124.2   -4.2    3.9  -0.24   0.69 -0.0147 -0.5603   21.9731   187.336
S-189  2.  210.5   -5.0   61.1  -0.05   0.28  0.0101 -0.3837   13.0322   187.980
S-187  2.  270.2    4.0   39.1   0.15   0.00  0.0601  0.1696   -2.7540    89.026
S-194  2.  271.0    0.8   14.1   0.03  -0.43  0.1489  0.0124   -2.6565    88.795
S-195  2.  194.8    3.4  -25.8  -0.09   0.77  0.0623 -0.1025   15.0391   179.991
END
```

```
                                                                  ROUTINE STEP
                                                                  DTD MAR 1981
                                                                  PROB. NO.  1
TRAJECTORY TO 200 NM ALTITUDE
WITH PROPAGATION     500 SAMPLES

          FLIGHTS FOR SCOUT FLIGHT EXPERIENCE ACCURACY

STANDARD DEVIATIONS
ALT-VEL-GAM-ZET-LAT-LONG (FT,FPS,DEG)

    29297.      80.4       .402       .525      .1641      .2239
     4.822 NM

MEAN VALUES
ALT-VEL-GAM-ZET-LAT-LONG
     2391.     -11.5      -.260      -.152     -.0347      .0427


CORRELATION COEFFICIENTS
ALT-VEL-GAM-ZET-LAT-LONG

   -.43278    .43300     .11934     .40168     .14018
             -.32800    -.10826    -.33822    -.20859
                         .16758    -.21837    -.11681
                                    .07191    -.47921
                                              -.07939

                     COVARIANCE MATRIX (A MATRIX)
  ALT             VEL             GAM             ZET             LAT             LONG

 .85830E+09
-.10200E+07    .64719E+04
 .51043E+04   -.10618E+02     .16191E+00
 .18355E+04   -.45721E+01     .35398E-01      .27558E+00
 .19316E+04   -.44661E+01    -.14423E-01      .61961E-02      .26943E-01
 .91966E+03   -.37578E+01    -.10525E-01     -.56335E-01     -.29183E-02      .50149E-01


                              EIGENVALUES
 .85830E+09    .52597E+04     .28973E+00      .13160E+00      .35253E-01      .11113E-01

                              EIGENVECTORS

 .10000E+01    .11884E-02    -.21914E-05     -.39473E-05     -.11341E-06     -.31095E-05
-.11884E-02    .10000E+01     .44569E-03      .61192E-03      .39731E-03      .80723E-03
 .59470E-05   -.86539E-03     .16123E+00      .95227E+00      .40492E-02      .25918E+00
 .21385E-05   -.45458E-03     .95546E+00     -.17894E+00      .22700E+00      .59516E-01
 .22505E-05   -.41268E-03    -.72590E-02     -.23903E+00     -.39090E+00      .88883E+00
 .10715E-05   -.50665E-03    -.24707E+00     -.63533E-01      .89199E+00      .37319E+00

                     SENSITIVITY COEFFICIENTS
                     ALT-VEL-GAM-ZET-LAT-LONG (TOP TO BOTTOM)

 .29297E+05    .86188E-01    -.11795E-05     -.14319E-05     -.21294E-07     -.32780E-06
-.34816E+02    .72524E+02     .23990E-03      .22198E-03      .74598E-04      .85096E-04
 .17423E+00   -.62761E-01     .86785E-01      .34545E+00      .76026E-03      .27322E-01
 .62651E-01   -.32968E-01     .51429E+00     -.64912E-01      .42622E-01      .62740E-02
 .65933E-01   -.29929E-01    -.39073E-02     -.86710E-01     -.73394E-01      .93698E-01
 .31391E-01   -.36744E-01    -.13299E+00     -.23047E-01      .16748E+00      .39340E-01
```

```
                                                                ROUTINE STEP
                                                                OTD MAR 1981
                                                                PROB. NO.  1
   TRAJECTORY TO 200 NM ALTITUDE
   WITH PROPAGATION    500 SAMPLES



   COVARIANCE MATRIX OF LAST STAGE BOOST

       ALT          VEL          GAM          ZET          LAT          LONG
  .44472E+08
 -.97678E+05   .41439E+03
  .61046E+04  -.13451E+02   .83797E+00
 -.17595E+03  -.63128E+01  -.24474E-01   .78739E+00
  .15782E+02  -.11740E-01   .21447E-02   .44487E-02   .57817E-04
  .33073E+02   .30522E-01   .44994E-02   .21484E-02   .77457E-04   .13641E-03


   SAMPLED COVARIANCE MATRIX AT INPUT EPOCH

       ALT          VEL          GAM          ZET          LAT          LONG
  .91102E+09
 -.13486E+07   .76936E+04
  .55736E+04  -.13026E+02   .17963E+00
  .19986E+04  -.12525E+01   .25690E-01   .27893E+00
  .24830E+04  -.68055E+01  -.14711E-01   .97317E-02   .31043E-01
  .98971E+03  -.57254E+01  -.30337E-02  -.61651E-01  -.25342E-02   .52863E-01


   COVARIANCE MATRIX AFTER PROPAGATION

       ALT          VEL          GAM          ZET          LAT          LONG
  .31132E+10
 -.44132E+07   .12580E+05
  .18540E+05  -.20220E+02   .15571E+00
  .38874E+04  -.43581E+01   .22484E-01   .22453E+00
  .47692E+04  -.15010E+02  -.57539E-02   .12444E-01   .50500E-01
 -.12004E+04  -.29157E+01  -.20754E-01  -.11936E+00  -.18270E-02   .10248E+00
```

```
                                                                   ROUTINE STEP
                                                                   DTD MAR 1981
                                                                   PROB. NO.  2
     TRAJECTORY TO 200 NM ALTITUDE
     NO PROPAGATION      500 SAMPLES


       NORMALIZED DEVIATIONS AND ADJUSTED LATITUDE, LONGITUDE DEVIATIONS
                             ALTITUDE=     90.0 N MI
                             AZIMUTH=   178.900 DEG
                             LATITUDE=  30.6500 DEG


 SAMPLE      ALT         VEL      GAMMA      ZETA       LAT       LONG       CODE
 NUMBER       FT         FPS       DEG        DEG       DEG        DEG

    1      58938.       -58.5      .770       .280    0.0000    0.0000          3
    2      19444.      -107.9      .150       .770    0.0000    0.0000          3
    3      54077.       -29.2      .050       .190    0.0000    0.0000          3
    4      -1215.        67.2     -.370      -.910    0.0000    0.0000          3
    5      24912.       142.9     -.860      -.290    0.0000    0.0000          3
    6      25520.       112.3      .140      -.280    0.0000    0.0000          3
    7     -21266.        15.0     -.750       .480    0.0000    0.0000          3
    8     -22482.       -24.3     -.630      0.000    0.0000    0.0000          3
    9      23089.        11.1     -.980      -.240    0.0000    0.0000          3
   10      17013.       -31.4     -.170      -.550    0.0000    0.0000          3
   11          0.       -38.6      .160     -1.180    0.0000    0.0000          3
   12       6076.       -31.1     -.630      -.140     .0592     .0460          2
   13      -4253.       -57.5      .120       .260    -.0480    -.0400          2
   14      -3038.       -56.9     -.630      -.130    0.0000    0.0000          3
   15     -33419.        94.3     -.060       .180    -.1046    -.0068          2
   16      12152.       -53.4     -.050      -.430    -.0049     .3564          2
   17      17013.       -34.4     -.150      -.730    -.0362     .4034          2
   18     -12760.         8.0     -.170       .700    -.0743    -.0810          2
   19     -10329.       -29.1     -.410      -.070    -.2102     .5344          2
   20     -35241.        17.0     -.460     -1.080    -.0740     .0301          2
   21     -13975.        72.4     -.720     -1.360    -.0502     .1432          2
   22       2430.        30.7     -.570      -.250    -.0238     .0767          2
   23     -31596.       -91.1     -.130      -.930    -.0818     .0321          2
   24      -7899.       -35.0     -.130       .310    -.0034     .0555          2
   25     -61369.         2.0    -1.010       .020    -.0209     .1446          2
   26     -18836.       -38.2     -.170      -.690    -.0039    -.0776          2
   27      -4253.         7.6     -.070       .110    -.0217    -.2481          2
   28      27343.       -93.0     -.080     -1.050    0.0000    0.0000          3
   29       3646.       -79.4     -.630      -.540     .1446     .2046          2
   30      28558.      -202.0     -.240       .060     .2422     .1165          2
   31      -2430.      -129.0      .490      -.120    -.6980     .2467          2
   32     -*5900.        47.0     -.470      0.000    -.0003     .0191          2
   33      40710.        -8.0      .260       .320     .0131    -.1703          2
   34      48609.      -177.0     -.020       .130     .2289     .1397          2
   35          0.       -29.5     -.760      -.600     .0442     .2941          2
   36     -21266.        70.5    -1.140       .340    -.0759    -.0532          2
   37     -20659.        84.2     -.410      -.280    -.0670     .0865          2
   38      88104.      -220.2     -.030       .170     .3190     .0554          2
   39      14583.        58.2      .030       .070    -.0942    -.0011          2
   40     -17621.       149.5     -.470      -.620    -.1533     .2293          2
   41       3646.        45.7     -.560      -.200    -.0891    -.2278          2
   42     -25520.         3.9     -.240       .690    -.0908    -.5949          2
   43     -30381.        61.1     -.050       .280    -.0490    -.4309          2
   44      24304.        39.1      .150      0.000    -.1693     .0703          2
   45       4861.        14.1      .030      -.430    -.0127     .1731          2
   46      20659.       -25.8     -.090       .770     .0604    -.1164          2
```

```
                                                               ROUTINE STEP
                                                               DTD MAR 1981
                                                               PROB. NO.  2
  TRAJECTORY TO 200 NM ALTITUDE
  NO PROPAGATION      500 SAMPLES


            FLIGHTS WITH LATITIUDE/LONGITUDE DEVIATIONS
                      33 FLIGHT SAMPLES
  STANDARD DEVIATIONS
  ALT-VEL-GAM-ZET-LAT-LONG (FT,FPS,DEG) -

      29603.      83.4      .361      .505     .1641     .2239
       4.872 NM

  MEAN VALUES
  ALT-VEL-GAM-ZET-LAT-LONG
      -2799.     -13.2     -.265     -.123    -.0347     .0427


  CORRELATION COEFFICIENTS
  ALT-VEL-GAM-ZET-LAT-LONG

     -.56673    .40712    .16499    .40168    .14018
               -.30939   -.08451   -.33822   -.20859
                          .25407   -.21837   -.11681
                                    .07191   -.47921
                                             -.07939


                 COVARIANCE MATRIX (A MATRIX)
    ALT         VEL         GAM         ZET         LAT         LONG

 .87636E+09
-.13999E+07   .69624E+04
 .43566E+04 -.93318E+01   .13067E+00
 .24649E+04 -.35585E+01   .46347E-01   .25467E+00
 .19518E+04 -.46323E+01 -.12957E-01   .59564E-02   .26943E-01
 .92929E+03 -.38976E+01 -.94556E-02 -.54156E-01 -.29183E-02   .50149E-01
```

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                                                             ROUTINE STEP
                                                             DTD MAR 1981
                                                             PROB. NO.  1
TRAJECTORY TO 200 NM ALTITUDE
WITH PROPAGATION    500 SAMPLES


          FLIGHTS WITH LATITIUDE/LONGITUDE DEVIATIONS
                    33 FLIGHT SAMPLES
STANDARD DEVIATIONS
ALT-VEL-GAM-ZET-LAT-LONG (FT,FPS,DEG)

    29603.      83.4       .361       .505      .1641      .2239
     4.872 NM

MEAN VALUES
ALT-VEL-GAM-ZET-LAT-LONG
    -2799.     -13.2      -.265      -.123     -.0347      .0427


CORRELATION COEFFICIENTS
ALT-VEL-GAM-ZET-LAT-LONG

   -.56673    .40712    .16499    .40168    .14018
             -.30939   -.08451   -.33822   -.20859
                        .25407   -.21837   -.11681
                                  .07191   -.47921
                                            -.07939


                    COVARIANCE MATRIX (A MATRIX)
  ALT           VEL            GAM           ZET           LAT           LONG

 .87636E+09
-.13999E+07   .69624E+04
 .43566E+04  -.93318E+01   .13C67E+00
 .24649E+04  -.35585E+01   .46347E-01   .25467E+00
 .19518E+04  -.46323E+01  -.12957E-01   .59564E-02   .26943E-01
 .92929E+03  -.38976E+01  -.94556E-02  -.54156E-01  -.29183E-02   .50149E-01
```

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                                                                    ROUTINE STEP
                                                                    DTD MAR 1981
                                                                    PROB. NO.  1
   TRAJECTORY TO 200 NM ALTITUDE
   WITH PROPAGATION    500 SAMPLES


   COVARIANCE MATRIX AT LAST STAGE BURNOUT

        ALT           VEL           GAM           ZET           LAT          LONG
    .31576E+10
   -.45109E+07    .12995E+05
    .24645E+05   -.33671E+02    .99368E+00
    .37114E+04   -.10671E+02   -.19893E-02    .10119E+01
    .47850E+04   -.15021E+02   -.36091E-02    .16893E-01    .50558E-01
   -.11674E+04   -.28852E+01   -.16255E-01   -.11721E+00   -.17495E-02    .10262E+00


                                EIGENVALUES
    .31576E+10    .65504E+04    .10225E+01    .79928E+00    .83924E-01    .30506E-01

                                EIGENVECTORS

    .10000E+01    .14286E-02    .88576E-06   -.81140E-05    .12497E-05   -.10137E-07
   -.14286E-02    .10000E+01    .76165E-03   -.21010E-03    .65864E-03    .13090E-02
    .78047E-05    .23448E-03   -.13018E+00    .99012E+00    .80103E-02    .51511E-01
    .11754E-05   -.81974E-03    .98333E+00    .12774E+00    .12904E+00    .96536E-02
    .15154E-05   -.12497E-02    .10391E-01   -.49461E-01   -.10453E+00    .99324E+00
   -.36969E-06   -.69504E-03   -.12653E+00   -.30003E-01    .98608E+00    .10361E+00

                          SENSITIVITY COEFFICIENTS
                          ALT-VEL-GAM-ZET-LAT-LONG (TOP TO BOTTOM)

    .56193E+05    .11562E+00    .89567E-06   -.72542E-05    .36203E-06   -.17704E-08
   -.80276E+02    .80934E+02    .77017E-03   -.18784E-03    .19081E-03    .22864E-03
    .43857E+00    .18978E-01   -.13163E+00    .88519E+00    .23206E-02    .89969E-02
    .66048E-01   -.66346E-01    .99434E+00    .11420E+00    .37384E-01    .16861E-02
    .85154E-01   -.10114E+00    .10508E-01   -.44220E-01   -.30283E-01    .17348E+00
   -.20774E-01   -.56253E-01   -.12794E+00   -.26823E-01    .28566E+00    .18096E-01
```

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                                                              ROUTINE STEP
                                                              DTD MAR 1981
                                                              PROB. NO.  1
          TRAJECTORY TO 200 NM ALTITUDE
          WITH PROPAGATION    500 SAMPLES

           NORMALIZED DEVIATIONS AND ADJUSTED LATITUDE, LONGITUDE DEVIATIONS
                                 ALTITUDE=     90.0 N MI
                                 AZIMUTH=   178.900 DEG
                                 LATITUDE=  30.6500 DEG

        SAMPLE        ALT        VEL      GAMMA        ZETA       LAT       LONG     CODE
        NUMBER         FT        FPS        DEG         DEG       DEG        DEG

           1       58938.      -58.5       .770        .280    0.0000     0.0000       3
           2       19444.     -107.9       .150        .770    0.0000     0.0000       3
           3       54077.      -29.2       .050        .190    0.0000     0.0000       3
           4       -1215.       67.2      -.370       -.910    0.0000     0.0000       3
           5       24912.      142.9      -.860       -.290    0.0000     0.0000       3
           6       25520.      112.3       .140       -.280    0.0000     0.0000       3
           7      -21266.       15.0      -.750        .480    0.0000     0.0000       3
           8      -22482.      -24.3      -.630       0.000    0.0000     0.0000       3
           9       23089.       11.1      -.980       -.240    0.0000     0.0000       3
          10       17013.      -31.4      -.170       -.550    0.0000     0.0000       3
          11           0.      -38.6       .160      -1.180    0.0000     0.0000       3
          12        6076.      -31.1      -.630       -.140     .0592      .0460       2
          13       -4253.      -57.5       .120        .260    -.0480     -.0400       2
          14       -3038.      -56.9      -.630       -.130    0.0000     0.0000       3
          15      -33419.       94.3      -.060        .180    -.1046     -.0068       2
          16       12152.      -53.4      -.050       -.430    -.0049      .3564       2
          17       17013.      -34.4      -.150       -.730    -.0362      .4034       2
          18      -12760.        8.0      -.170        .700    -.0743     -.0810       2
          19      -10329.      -29.1      -.410       -.070    -.2102      .5344       2
          20      -35241.       17.0      -.460      -1.080    -.0740      .0301       2
          21      -13975.       72.4      -.720      -1.360    -.0502      .1432       2
          22        2430.       30.7      -.570       -.250    -.0238      .0767       2
          23      -31596.      -91.1      -.130       -.930    -.0818      .0321       2
          24       -7899.      -35.0      -.130        .310    -.0034      .0555       2
          25      -61369.        2.0     -1.010        .020    -.0209      .1446       2
          26      -18836.      -38.2      -.170       -.690    -.0039     -.0776       2
          27       -4253.        7.6      -.070        .110    -.0217     -.2481       2
          28       27343.      -93.0      -.080      -1.050    0.0000     0.0000       3
          29        3646.      -79.4      -.630       -.540     .1446      .2046       2
          30       28558.     -202.0      -.240        .060     .2422      .1165       2
          31       -2430.     -129.0       .490       -.120    -.6980      .2467       2
          32      -55900.       47.0      -.470       0.000    -.0003      .0191       2
          33       40710.       -8.0       .260        .320     .0131     -.1703       2
          34       48609.     -177.0      -.020        .130     .2289      .1397       2
          35           0.      -29.5      -.760       -.600     .0442      .2941       2
          36      -21266.       70.5     -1.140        .340    -.0759     -.0532       2
          37      -20659.       84.2      -.410       -.280    -.0670      .0865       2
          38       88104.     -220.2      -.030        .170     .3190      .0554       2
          39       14583.       58.2       .030        .070    -.0942     -.0011       2
          40      -17621.      149.5      -.470       -.620    -.1533      .2293       2
          41        3646.       45.7      -.560       -.200    -.0891     -.2278       2
          42      -25520.        3.9      -.240        .690    -.0908     -.5949       2
          43      -30381.       61.1      -.050        .280    -.0490     -.4309       2
          44       24304.       39.1       .150       0.000    -.1693      .0703       2
          45        4861.       14.1       .030       -.430    -.0127      .1731       2
          46       20659.      -25.8      -.090        .770     .0604     -.1164       2
```

TRAJECTORY TO 200 NM ALTITUDE
WITH PROPAGATION 500 SAMPLES

FLIGHT RESULTS AT INPUT TIME

SAMPLE NUMBER	VEHICLE NUMBER	PREDALT - N.MI.	DELTA ALT N.MI.	DELTA VEL FPS	DELTA GAM DEG	DELTA AZ DEG	DELTA LAT DEG	DELTA LONG DEG
1	S-136	562.8	9.700	-58.5	.770	.280	0.0000	0.0000
2	S-131	612.5	6.900	-280.0	-.360	-.150	0.0000	0.0000
3	S-138	383.8	3.200	-107.9	.150	.770	0.0000	0.0000
4	S-139	404.3	8.900	-29.2	.050	.190	0.0000	0.0000
5	S-140	506.8	-.200	67.2	-.370	-.910	0.0000	0.0000
6	S-142	487.1	4.100	142.9	-.860	-.290	0.0000	0.0000
7	S-143	482.2	4.200	112.3	.140	-.280	0.0000	0.0000
8	S-145	200.1	-3.500	15.0	-.750	.480	0.0000	0.0000
9	S-146	495.2	-3.700	-24.3	-.630	0.000	0.0000	0.0000
10	S-147	350.6	3.800	11.1	-.980	-.240	0.0000	0.0000
11	S-148	197.7	2.800	-31.4	-.170	-.550	0.0000	0.0000
12	S-149	576.3	0.000	-38.6	.160	-1.180	0.0000	0.0000
13	S-150	178.5	1.000	-31.1	-.630	-.140	.0638	.0339
14	S-154	577.0	-.700	-57.5	.120	.260	-.0473	-.0361
15	S-153	117.1	-.500	-56.9	-.630	-.130	0.0000	0.0000
16	S-155	279.4	-5.500	94.3	-.060	.180	-.1042	.0115
17	S-156	582.7	2.000	-53.4	-.050	-.430	-.0108	.3134
18	S-157	565.9	2.800	-34.4	-.150	-.730	-.0429	.3543
19	S-158	235.3	-2.100	8.0	-.170	.700	-.0729	-.0749
20	S-162	581.2	-1.700	-29.1	-.410	-.070	-.2190	.4662
21	S-161	190.5	-5.800	17.0	-.460	-1.080	-.0774	.0137
22	S-165	376.8	-2.300	72.4	-.720	-1.360	-.0345	.1321
23	S-167	147.2	.400	30.7	-.570	-.250	-.0300	.0690
24	S-172	216.0	-5.200	-91.1	-.130	-.930	-.0801	.0344
25	S-169	214.7	-1.300	-35.0	-.130	.310	-.0152	.0477
26	S-176	588.3	-10.100	2.0	-1.010	.020	-.0233	.1267
27	S-174	169.9	-3.100	-38.2	-.170	-.690	-.0656	-.0159
28	S-175	294.4	-.700	7.6	-.070	.110	-.2135	.0215
29	S-173	115.5	4.500	-93.0	-.080	-1.050	0.0000	0.0000
30	S-177	323.3	.600	-79.4	-.630	-.540	.2250	.0386
31	S-180	486.0	4.700	-202.0	-.240	.060	.2448	-.1021
32	S-163	120.0	-.400	-129.0	.490	-.120	.1882	.7061
33	S-183	297.0	-9.200	47.0	-.470	0.000	.0015	.0170
34	S-184	263.5	6.700	-8.0	.260	.320	-.1355	-.0692
35	S-182	449.6	8.000	-177.0	-.020	.130	.2266	.1281
36	S-170	299.7	0.000	-29.5	-.760	-.600	.2533	-.0426
37	S-185	151.2	-3.500	70.5	-1.140	.340	-.0743	-.0523
38	S-181	129.5	-3.400	84.2	-.410	-.280	-.0777	.0682
39	S-178	604.4	14.500	-220.2	-.030	.170	.3180	.0550
40	S-190	123.1	2.400	58.2	.030	.070	-.0017	.0943
41	S-188	405.0	-2.900	149.5	-.470	-.620	-.1845	.1735
42	S-191	215.2	.600	45.7	-.560	-.200	-.0857	-.2038
43	S-186	124.2	-4.200	3.9	-.240	.690	-.0147	-.5603
44	S-189	210.5	-5.000	61.1	-.050	.280	.0101	-.3837
45	S-187	270.2	4.000	39.1	.150	0.000	.0601	.1696
46	S-194	271.0	.800	14.1	.030	-.430	.1489	.0124
47	S-195	194.8	3.400	-25.8	-.090	.770	.0623	-.1025

```
 $INPUTD
 TITLE1=TRAJECTORY TO 200 NM ALTITUDE
 TITLE2=WITH PROPAGATION    500 SAMPLES
 S1= 546675,18989,13.5,178.9,30.65,-120.86,
 S2=1218031,17899,  .5,179.0,16.48,-121.83,
 TCOAST=300,
 IERROR=2,NORM=0,
 NSAMP=500,
 EMAG=1,3.6,3.6,0,
 NERROR=3,
 SEN1=  20,11.6,-.001,-.001,.005,.010,
 SEN2=2550,-5.6,  .35,    0,.001,.002,
 SEN3=   1,-3.0,    0,  .35,.002,.001,
 $END


DATE IS  06/30/81
TIME IS  13.27.34
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                                                               ROUTINE STEP
                                                               DTD MAR 1981
                                                               PROB. NO.  2
  TRAJECTORY TO 200 NM ALTITUDE
  NO PROPAGATION      500 SAMPLES


           FLIGHTS FOR SCOUT FLIGHT EXPERIENCE ACCURACY

  STANDARD DEVIATIONS
  ALT-VEL-GAM-ZET-LAT-LONG (FT,FPS,DEG)

      29297.      80.4      .402      .525     .1641     .2239
       4.822 NM

  MEAN VALUES
  ALT-VEL-GAM-ZET-LAT-LONG
       2391.     -11.5     -.260     -.152    -.0347     .0427


  CORRELATION COEFFICIENTS
  ALT-VEL-GAM-ZET-LAT-LONG

     -.43278    .43300    .11934    .40168    .14018
              -.32800   -.10826   -.33822   -.20859
                          .16758   -.21837   -.11681
                                    .07191   -.47921
                                             -.07939


                 COVARIANCE MATRIX (A MATRIX)
    ALT         VEL          GAM          ZET          LAT          LONG

 .85830E+09
-.10200E+07   .64719E+04
 .51043E+04  -.10618E+02   .16191E+00
 .18355E+04  -.45721E+01   .35398E-01   .27558E+00
 .19316E+04  -.44661E+01  -.14423E-01   .61961E-02   .26943E-01
 .91966E+03  -.37578E+01  -.10525E-01  -.56335E-01  -.29183E-02   .50149E-01


                       EIGENVALUES
 .85830E+09   .52597E+04   .28973E+00   .13160E+00   .35253E-01   .11113E-01

                       EIGENVECTORS

 .10000E+01   .11884E-02  -.21914E-05  -.39473E-05  -.11341E-06  -.31095E-05
-.11884E-02   .10000E+01   .44569E-03   .61192E-03   .39731E-03   .80723E-03
 .59470E-05  -.86539E-03   .16123E+00   .95227E+00   .40492E-02   .25918E+00
 .21385E-05  -.45458E-03   .95546E+00  -.17894E+00   .22700E+00   .59516E-01
 .22505E-05  -.41268E-03  -.72590E-02  -.23903E+00  -.39090E+00   .88883E+00
 .10715E-05  -.50665E-03  -.24707E+00  -.63533E-01   .89199E+00   .37319E+00

                 SENSITIVITY COEFFICIENTS
                 ALT-VEL-GAM-ZET-LAT-LONG (TOP TO BOTTOM)

 .29297E+05   .86188E-01  -.11795E-05  -.14319E-05  -.21294E-07  -.32780E-06
-.34816E+02   .72524E+02   .23990E-03   .22198E-03   .74598E-04   .85096E-04
 .17423E+00  -.62761E-01   .86785E-01   .34545E+00   .76026E-03   .27322E-01
 .62651E-01  -.32968E-01   .51429E+00  -.64912E-01   .42622E-01   .62740E-02
 .65933E-01  -.29929E-01  -.39073E-02  -.86710E-01  -.73394E-01   .93698E-01
 .31391E-01  -.36744E-01  -.13299E+00  -.23047E-01   .16748E+00   .39340E-01
```

```
$INPUTD
TITLE1=TRAJECTORY TO 200 NM ALTITUDE
TITLE2=NO PROPAGATION      500 SAMPLES
TCOAST=0,
$END


DATE IS  06/30/81
TIME IS  13.27.36
```

ROUTINE STEP
DTD MAR 1981
PROB. NO. 2

TRAJECTORY TO 200 NM ALTITUDE
NO PROPAGATION 500 SAMPLES

FLIGHT RESULTS AT INPUT TIME

SAMPLE NUMBER	VEHICLE NUMBER.	PREDALT N.MI.	DELTA ALT N.MI.	DELTA VEL FPS	DELTA GAM DEG	DELTA AZ DEG	DELTA LAT DEG	DELTA LONG DEG
1	S-136	562.8	9.700	-58.5	.770	.280	0.0000	0.0000
2	S-131	612.5	6.900	-280.0	-.360	-.150	0.0000	0.0000
3	S-138	383.8	3.200	-107.9	.150	.770	0.0000	0.0000
4	S-139	404.3	8.900	-29.2	.050	.190	0.0000	0.0000
5	S-140	506.8	-.200	67.2	-.370	-.910	0.0000	0.0000
6	S-142	487.1	4.100	142.9	-.860	-.290	0.0000	0.0000
7	S-143	482.2	4.200	112.3	.140	-.280	0.0000	0.0000
8	S-145	200.1	-3.500	15.0	-.750	.480	0.0000	0.0000
9	S-146	495.2	-3.700	-24.3	-.630	0.000	0.0000	0.0000
10	S-147	350.6	3.800	11.1	-.980	-.240	0.0000	0.0000
11	S-148	197.7	2.800	-31.4	-.170	-.550	0.0000	0.0000
12	S-149	576.3	0.000	-38.6	.160	-1.180	0.0000	0.0000
13	S-150	178.5	1.000	-31.1	-.630	-.140	.0638	.0339
14	S-154	577.0	-.700	-57.5	.120	.260	-.0473	-.0361
15	S-153	117.1	-.500	-56.9	-.630	-.130	0.0000	0.0000
16	S-155	279.4	-5.500	94.3	-.060	.180	-.1042	.0115
17	S-156	582.7	2.000	-53.4	-.050	-.430	-.0108	.3134
18	S-157	565.9	2.800	-34.4	-.150	-.730	-.0429	.3543
19	S-158	235.3	-2.100	8.0	-.170	.700	-.0729	-.0749
20	S-162	581.2	-1.700	-29.1	-.410	-.070	-.2190	.4662
21	S-161	190.5	-5.800	17.0	-.460	-1.080	-.0774	.0137
22	S-165	376.8	-2.300	72.4	-.720	-1.360	-.0345	.1321
23	S-167	147.2	.400	30.7	-.570	-.250	-.0300	.0690
24	S-172	216.0	-5.200	-91.1	-.130	-.930	-.0801	.0344
25	S-169	214.7	-1.300	-35.0	-.130	.310	-.0152	.0477
26	S-176	588.3	-10.100	2.0	-1.010	.020	-.0233	.1267
27	S-174	169.9	-3.100	-38.2	-.170	-.690	-.0656	-.0159
28	S-175	294.4	-.700	7.6	-.070	.110	-.2135	.0215
29	S-173	115.5	4.500	-93.0	-.080	-1.050	0.0000	0.0000
30	S-177	323.3	.600	-79.4	-.630	-.540	.2250	.0386
31	S-180	486.0	4.700	-202.0	-.240	.060	.2448	-.1021
32	S-163	120.0	-.400	-129.0	.490	-.120	.1882	.7061
33	S-183	297.0	-9.200	47.0	-.470	0.000	.0015	.0170
34	S-184	263.5	6.700	-8.0	.260	.320	-.1355	-.0692
35	S-182	449.6	8.000	-177.0	-.020	.130	.2266	.1281
36	S-170	299.7	0.000	-29.5	-.760	-.600	.2533	-.0426
37	S-185	151.2	-3.500	70.5	-1.140	.340	-.0743	-.0523
38	S-181	129.5	-3.400	84.2	-.410	-.280	-.0777	.0682
39	S-178	604.4	14.500	-220.2	-.030	.170	.3180	.0550
40	S-190	123.1	2.400	58.2	.030	.070	-.0017	.0943
41	S-188	405.0	-2.900	149.5	-.470	-.620	-.1845	.1735
42	S-191	215.2	.600	45.7	-.560	-.200	-.0857	-.2038
43	S-186	124.2	-4.200	3.9	-.240	.690	-.0147	-.5603
44	S-189	210.5	-5.000	61.1	-.050	.280	.0101	-.3837
45	S-187	270.2	4.000	39.1	.150	0.000	.0601	.1696
46	S-194	271.0	.800	14.1	.030	-.430	.1489	.0124
47	S-195	194.8	3.400	-25.8	-.090	.770	.0623	-.1025

APPENDIX B

FORTRAN CODE LISTINGS

```
      PROGRAM STEP (INPUT,OUTPUT,TAPE1,TAPE8,TAPE5=INPUT,TAPE6=OUTPUT)
C        SCOUT TRAJECTORY ERROR PROPAGATION PROGRAM
C  COV =        COVARIANCE MATRIX OF ALT,VEL,GAM,ZET,LAT,LONG.
C               INPUT IF IERROR=4.
C  DATAG    =  TABLE OF STANDARD DEVIATIONS OF PATH ANGLE FOR NORMALIZING.
C               (.428,.428,.428,.430,.434,.442,.453 BN)
C  DATAH    =  TABLE OF STANDARD DEVIATIONS OF ALTITUDE FOR NORMALIZING.
C               (3.35,4.85,5.80,6.45,6.90,7.20,7.30 BN)
C  DATAV    =  TABLE OF STANDARD DEVIATIONS OF VELOCITY FOR NORMALIZING.
C               (75.6,84.6,88.8,91.3,92.5,93.0,93.0 BN)
C  EMAG     =  VALUES FOR ERROR SOURCES USED TO CALCULATE COVARIANCE
C               MATRIX OF A SPIN STABILIZED STAGE.  ARRAY OF 4.  INPUT
C               WHEN PROPAGATION IS USED.  VALUES ARE THE RATIO OF
C               STANDARD DEVIATION DESIRED TO THE STANDARD DEVIATION
C               USED TO CALCULATE THE SEN1-SEN4 DATA.
C  HINJ     =  TABLE OF ALTITUDES FOR NORMALIZING.
C               (100.,200.,300.,400.,500.,600.,700. BN)
C  IERROR   =  OPTION FOR INPUTTING DATA ERRORS IN FLIGHT DATA BASE.
C               =1  INPUT FLIGHT RESULTS OF ALT,VEL,GAM.
C               =2  INPUT FLIGHT RESULTS OF ALT,VEL,GAM,ZET,LAT,LONG.
C               =3  INPUT STANDARD DEVIATIONS (SIG) AND CORRELATION
C                   COEFFICIENTS (RHO) OF ALT,VEL,GAM,ZET,LAT,LONG.
C               =4  INPUT COVARIANCE MATRIX (COV) OF ALT,VEL,GAM,ZET,
C                   LAT,LONG.
C  NERROR   =  NUMBER OF ERROR SOURCES OF THE SPIN STABLIZED STAGE.
C               MAXIMUM OF 4.  (3 BN)
C  NORM     =  NON-ZERO VALUE NORMALIZES ALT,VEL,GAM ERRORS OF THE
C               FLIGHT DATA BASE TO THE ALTITUDE OF S1. (1 BN)
C  NSAMP    =  NUMBER OF SAMPLES USED IN THE MONTE CARLO ANALYSES.
C               (5000 BN)
C  RHO      =  CORRELATION COEFFICIENTS IN ORDER OF ALT,VEL,GAM,ZET,
C               LAT,LONG.  ARRAY OF 15.  INPUT WHEN IERROR=3.
C  SEN1     =  SENSITIVITY OF SPIN STABLIZED STAGE BURNOUT STATE
C               PARAMETERS TO ONE SIGMA MOTOR PERFORMANCE ERROR SOURCE.
C               UNITS ARE STATE PARAMETER UNITS PER SIGMA.  ARRAY OF 6
C               ORDER IS ALT,VEL,GAM,ZET,LAT,LONG.
C  SEN2     =  SAME AS SEN1 EXCEPT ERROR SOURCE IS PITCH TIPOFF.
C               UNITS ARE STATE PARAMETER UNITS PER DEGREE.
C  SEN3     =  SAME AS SEN1 EXCEPT ERROR SOURCE IS YAW TIPOFF.
C               UNITS ARE STATE PARAMETER UNITS PER DEGREE.
C  SEN4     =  SAME AS SEN1 EXCEPT ERROR SOURCE IS TIME OF SPIN
C               STABLIZED STAGE IGNITION.  UNITS ARE STATE PARAMETER
C               UNITS PER SECOND.
C  SIG      =  STANDARD DEVIATION OF ALT,VEL,GAM,ZET,LAT,LONG.
C               INPUT WHEN IERROR=3.
C  S1       =  NOMINAL STATE PARAMETERS AT STAGE BURNOUT.  IF
C               PROPAGATION IS SELECTED, S1 IS STATE AT BURNOUT OF
C               NEXT TO LAST STAGE.  ARRAY OF 6.  ORDER IS ALT,VEL,
C               GAM,ZET,LAT,LONG.
C  S2       =  NOMINAL STATE PARAMETERS AT LAST STAGE BURNOUT.
C               INPUT IF TCOAST IS NON-ZERO.  ARRAY OF 6.  ORDER IS
C               ALT,VEL,GAM,ZET,LAT,LONG.
C  TCOAST   =  NOMINAL COAST TIME TO PROPAGATE COVARIANCE MATRIX.
C               INPUT ZERO IF PROPAGATION IS NOT DESIRED.  (0. BN)
C  TITLE1   =  TITLE INFORMATION PRINTED AT TOP OF EACH PAGE OF
C  TITLE2       OUTPUT.  72 CHARACTERS MAXIMUM.
C
```

```
C
      REAL MEANH,MEANV,MEANG,MEANZ,MEANL,MEANLG
      COMMON /BLK4/ XMU,SIGMA,GAUSS,GN(16),XK,ZRAN,ICNT
      COMMON /CONIC/ STATE(6), TCALL, KERR, DELT, T, TZERO
      COMMON /DIG/ ZERO,ONE,TWO,RAD,PI,TWOPI,GM,FT,RE,CON,ROTATE
      DIMENSION  SIG(6),X(6),DX(6),RHO(15), R(36), RR(6,6), W(6)
      DIMENSION  IWORD(100), WORD(11,100)
      DIMENSION  TITLE1(8), TITLE2(8), BEST(6,4)
      DIMENSION  SEN1(6), SEN2(6), SEN3(6), SEN4(6)
      DIMENSION  HINJ(7),DATAH(7),DATAG(7),DATAV(7)
      DIMENSION  EPAR(6), EXIC(6), S1(6), S2(6), SS(6), EMAG(4)
      DIMENSION  SUM1(6), SUM2(6), SUM3(6)
      DIMENSION  SUMSQ1(6), SUMSQ2(6), SUMSQ3(6)
      DIMENSION  CP1(15), CP2(15), CP3(15)
      DIMENSION  CMAT1(21), CMAT2(21)
      DIMENSION  DH1(100), DL1(100), DLG1(100), DV1(100), DG1(100)
      DIMENSION  DZ1(100), DH2(100), DV2(100). DG2(100), DZ2(100)
      DIMENSION  D(21), SC(6,6), COV(21)
      EQUIVALENCE (BEST(1,1),SEN1(1)),
     ^            (BEST(1,2),SEN2(1)),
     ^            (BEST(1,3),SEN3(1)),
     ^            (BEST(1,4),SEN4(1))
      EQUIVALENCE (R(1),RR(1,1))
      EQUIVALENCE (SIGH  ,SIG( 1)),(SIGV  ,SIG( 2)),(SIGG  ,SIG( 3))
     ^           ,(SIGZ  ,SIG( 4)),(SIGL  ,SIG( 5)),(SIGLG ,SIG( 6))
     ^           ,(RHOHV ,RHO( 1)),(RHOHG ,RHO( 2)),(RHOHZ ,RHO( 3))
     ^           ,(RHOHL ,RHO( 4)),(RHOHLG,RHO( 5)),(RHOVG ,RHO( 6))
     ^           ,(RHOVZ ,RHO( 7)),(RHOVL ,RHO( 8)),(RHOVLG,RHO( 9))
     ^           ,(RHOGZ ,RHO(10)),(RHOGL ,RHO(11)),(RHOGLG,RHO(12))
     ^           ,(RHOZL ,RHO(13)),(RHOZLG,RHO(14)),(RHOLLG,RHO(15))
      DATA TITLE1,TITLE2/16*10H          /
      DATA HINJ/100.,200.,300.,400.,500.,600.,700./,
     ^     DATAH/3.35,4.85,5.80,6.45,6.90,7.20,7.30/,
     ^     DATAV/75.6,84.6,88.8,91.3,92.5,93.0,93.0/,
     ^     DATAG/.428,.428,.428,.430,.434,.442,.453/
      NAMELIST /INPUTO/ NSAMP,NERROR,SIG,RHO,COV,TCOAST,IERROR,S1,S2,
     ^                  SEN1,SEN2,SEN3,SEN4,EMAG,HINJ,DATAH,DATAG,
     ^                  DATAV,NORM
C
C
      REWIND 1
      REWIND 8
      CALL INIT
      NDATA=7
      NFLAG=0
      NSAMP=5000
      IERROR=2
      NORM=1
      TCOAST=0.
      MEAN=1
      NERROR=3
      NPROB=0
      WRITE(6,330)
C                  READ FIXED FIELD INPUT DATA
      CALL CARDS(N,100)
      READ(8,320) (IWORD(J),(WORD(I,J),I=2,11),J=1,N)
   10 CONTINUE
```

```
C                    READ NAMELIST DATA
      CALL INPUT(TITLE1,TITLE2)
      READ(8,INPUTD)
      NPROB=NPROB+1
      WRITE(6,340) NPROB,TITLE1,TITLE2
C                    INITIALIZE
      CALL INIT1
      DO 20 I=1,6
      SUM1(I)=0.
      SUM2(I)=0.
      SUM3(I)=0.
      SUMSQ1(I)=0.
      SUMSQ2(I)=0.
      SUMSQ3(I)=0.
   20 CONTINUE
      DO 30 I=1,15
      CP1(I)=0.
      CP2(I)=0.
      CP3(I)=0.
   30 CONTINUE
C
      DO 40 I=1,6
      STATE(I)=S1(I)
   40 CONTINUE
      CALL CONIC
      DELT=AMAX1(TCOAST,1.E-3)
      CALL TSTEP
      DO 50 I=1,6
      SS(I)=STATE(I)
   50 CONTINUE
C
      ALT=S1(1)/FT
      ZET=S1(4)
      XLAT=S1(5)
C
C                    SET-UP OF INPUT DATA ACCORDING TO IERROR
      GOTO (60,60,160,170), IERROR
C
   60 CONTINUE
      SZET=SIN(ZET/RAD)
      CZET=COS(ZET/RAD)
      CLAT=COS(XLAT/RAD)
      WRITE(6,350)
      WRITE(6,360) (J,IWORD(J),(WORD(I,J),I=3,9),J=1,N)
      WRITE(6,340) NPROB,TITLE1,TITLE2
      WRITE(6,370) ALT,ZET,XLAT
      WRITE(6,380)
      CALL INTER (ALT,DEVH1,NDATA,DATAH,HINJ)
      CALL INTER (ALT,DEVV1,NDATA,DATAV,HINJ)
      CALL INTER (ALT,DEVG1,NDATA,DATAG,HINJ)
      N1=0
      N2=0
      N3=0
C
      DO 120 I=1,N
      XH=WORD(4,I)*FT
      XV=WORD(5,I)
```

```
      XG=WORD(6,I)
      XZ=WORD(7,I)
      XL=WORD(8,I)
      XLG=WORD(9,I)
      IF (NORM.EQ.0) GOTO 70
C                 NORMALIZE FLIGHT ERRORS
      XALT=WORD(3,I)
      CALL INTER (XALT,DEVH2,NDATA,DATAH,HINJ)
      CALL INTER (XALT,DEVV2,NDATA,DATAV,HINJ)
      CALL INTER (XALT,DEVG2,NDATA,DATAG,HINJ)
      XH=DEVH1/DEVH2*XH
      XV=DEVV1/DEVV2*XV
      XG=DEVG1/DEVG2*XG
   70 ICODE=WORD(2,I)
      GOTO (80,80,90,120), ICODE
C
C                 CONVERT LAT,LONG DEVIATIONS TO RANGE,CROSSRANGE DEVIATIONS
   80 SZ=SIN(WORD(11,I)/RAD)
      CZ=COS(WORD(11,I)/RAD)
      CN=RE*XL/RAD
      CE=RE*XLG*COS(WORD(10,I)/RAD)/RAD
      DR=(CN*CZ+CE*SZ)/FT
      DCR=(CN*SZ-CE*CZ)/FT
C
C                 CONVERT RANGE,CROSSRANGE DEV TO LAT,LONG DEV FOR INPUT
C                 AZIMUTH AND LATITUDE
      CN=DR*CZET+DCR*SZET
      CE=DR*SZET-DCR*CZET
      XL=CN/RE*FT*RAD
      XLG=CE/RE*FT/CLAT*RAD
   90 CONTINUE
      N3=N3+1
      WRITE(6,390) N3,XH,XV,XG,XZ,XL,XLG,ICODE
      GOTO (100,100,110,120), ICODE
  100 N1=N1+1
      DH1(N1)=XH
      DV1(N1)=XV
      DG1(N1)=XG
      DZ1(N1)=XZ
      DL1(N1)=XL
      DLG1(N1)=XLG
      GOTO (120,110,110,120), ICODE
  110 N2=N2+1
      DH2(N2)=XH
      DV2(N2)=XV
      DG2(N2)=XG
      DZ2(N2)=XZ
  120 CONTINUE
C
      WRITE(6,340) NPROB,TITLE1,TITLE2
      IF (IERROR.EQ.1) GOTO 140
      IF (IERROR.GT.1) GOTO 150
  130 CALL CORCO (DH2,DZ2,N2,SIGH,SIGZ,RHOHZ,MEANH,MEANZ,MEAN)
      CALL CORCO (DV2,DZ2,N2,SIGV,SIGZ,RHOVZ,MEANV,MEANZ,MEAN)
      CALL CORCO (DG2,DZ2,N2,SIGG,SIGZ,RHOGZ,MEANG,MEANZ,MEAN)
      NFLAG=0
      WRITE(6,340) NPROB,TITLE1,TITLE2
```

```
140 WRITE(6,400)
    CALL CORCO (DH2,DV2,N2,SIGH,SIGV,RHOHV,MEANH,MEANV,MEAN)
    CALL CORCO (DH2,DG2,N2,SIGH,SIGG,RHOHG,MEANH,MEANG,MEAN)
    CALL CORCO (DV2,DG2,N2,SIGV,SIGG,RHOVG,MEANV,MEANG,MEAN)
    GOTO 160
150 CALL CORCO (DH1,DV1,N1,SIGH,SIGV,RHOHV,MEANH,MEANV,MEAN)
    CALL CORCO (DH1,DG1,N1,SIGH,SIGG,RHOHG,MEANH,MEANG,MEAN)
    CALL CORCO (DH1,DZ1,N1,SIGH,SIGZ,RHOHZ,MEANH,MEANZ,MEAN)
    CALL CORCO (DH1,DL1,N1,SIGH,SIGL,RHOHL,MEANH,MEANL,MEAN)
    CALL CORCO (DH1,DLG1,N1,SIGH,SIGLG,RHOHLG,MEANH,MEANLG,MEAN)
    CALL CORCO (DV1,DG1,N1,SIGV,SIGG,RHOVG,MEANV,MEANG,MEAN)
    CALL CORCO (DV1,DZ1,N1,SIGV,SIGZ,RHOVZ,MEANV,MEANZ,MEAN)
    CALL CORCO (DV1,DL1,N1,SIGV,SIGL,RHOVL,MEANV,MEANL,MEAN)
    CALL CORCO (DV1,DLG1,N1,SIGV,SIGLG,RHOVLG,MEANV,MEANLG,MEAN)
    CALL CORCO (DG1,DZ1,N1,SIGG,SIGZ,RHOGZ,MEANG,MEANZ,MEAN)
    CALL CORCO (DG1,DL1,N1,SIGG,SIGL,RHOGL,MEANG,MEANL,MEAN)
    CALL CORCO (DG1,DLG1,N1,SIGG,SIGLG,RHOGLG,MEANG,MEANLG,MEAN)
    CALL CORCO (DZ1,DL1,N1,SIGZ,SIGL,RHOZL,MEANZ,MEANL,MEAN)
    CALL CORCO (DZ1,DLG1,N1,SIGZ,SIGLG,RHOZLG,MEANZ,MEANLG,MEAN)
    CALL CORCO (DL1,DLG1,N1,SIGL,SIGLG,RHOLLG,MEANL,MEANLG,MEAN)
    NFLAG=1
    WRITE(6,410)
    WRITE(6,420) N1
160 D(1)=SIGH*SIGH
    D(2)=RHOHV*SIGH*SIGV
    D(3)=SIGV*SIGV
    D(4)=RHOHG*SIGH*SIGG
    D(5)=RHOVG*SIGV*SIGG
    D(6)=SIGG*SIGG
    D(7)=RHOHZ*SIGH*SIGZ
    D(8)=RHOVZ*SIGV*SIGZ
    D(9)=RHOGZ*SIGG*SIGZ
    D(10)=SIGZ*SIGZ
    D(11)=RHOHL*SIGH*SIGL
    D(12)=RHOVL*SIGV*SIGL
    D(13)=RHOGL*SIGG*SIGL
    D(14)=RHOZL*SIGZ*SIGL
    D(15)=SIGL*SIGL
    D(16)=RHOHLG*SIGH*SIGLG
    D(17)=RHOVLG*SIGV*SIGLG
    D(18)=RHOGLG*SIGG*SIGLG
    D(19)=RHOZLG*SIGZ*SIGLG
    D(20)=RHOLLG*SIGL*SIGLG
    D(21)=SIGLG*SIGLG
    WRITE(6,430) SIGH,SIGV,SIGG,SIGZ,SIGL,SIGLG
    SIGALT=SIGH/6076.11549
    WRITE(6,440) SIGALT
    WRITE(6,450) MEANH,MEANV,MEANG,MEANZ,MEANL,MEANLG
    WRITE(6,460) RHOHV, RHOHG, RHOHZ, RHOHL, RHOHLG,
   ^                RHOVG, RHOVZ, RHOVL, RHOVLG,
   ^                RHOGZ, RHOGL, RHOGLG,
   ^                RHOZL, RHOZLG,
   ^                RHOLLG
    GOTO 190
170 DO 180 I=1,21
180 D(I)=COV(I)
190 WRITE(6,470)
```

```
      WRITE(6,480) D
      IF (NFLAG.EQ.1) GOTO 130
      CALL EIGEN (D,R,6,0)
      WRITE(6,490)
C                     D ARRAY IS NOW THE EIGENVALUES
C                     RR ARRAY IS THE EIGENVECTORS
      WRITE(6,500) D(1),D(3),D(6),D(10),D(15),D(21)
      WRITE(6,510)
      WRITE(6,500) ((RR(I,J),J=1,6),I=1,6)
      W(1)=SQRT(D(1))
      W(2)=SQRT(D(3))
      W(3)=SQRT(D(6))
      W(4)=SQRT(D(10))
      W(5)=SQRT(D(15))
      W(6)=SQRT(D(21))
      DO 200 J=1,6
      DO 200 K=1,6
      SC(J,K)=W(K)*RR(J,K)
  200 CONTINUE
      WRITE(6,520)
      WRITE(6,500) ((SC(I,J),J=1,6),I=1,6)
C
      IF (TCOAST.EQ.0.) GOTO 310
C
      WRITE(6,340) NPROB,TITLE1,TITLE2
C                     COMPUTE LAST STAGE BOOST COVARIANCE MATRIX CMAT1
      DO 230 NTIMES=1,NSAMP
      CALL NORRAN
      X(1)=GAUSS
      CALL NORRAN
      TOMAG=ABS(GAUSS)
      CALL UNIRAN
      THET=ZRAN*TWOPI
      X(2)=TOMAG*COS(THET)
      X(3)=TOMAG*SIN(THET)
      IF (NERROR.LT.4) GOTO 210
      CALL NORRAN
      X(4)=GAUSS
  210 CONTINUE
C                     DX IS LAST STAGE BOOST STATE ERRORS
      DO 220 I=1,6
      DX(I)=0.
      DO 220 J=1,NERROR
  220 DX(I)=BEST(I,J)*X(J)*EMAG(J)+DX(I)
      CALL COVR (CMAT1,DX,NTIMES,SUM1,SUMSQ1,CP1)
  230 CONTINUE
C
      CALL COVR1 (CMAT1,DX,NSAMP,SUM1,SUMSQ1,CP1)
      WRITE(6,560)
      WRITE(6,530)
      WRITE(6,480) CMAT1
C
C
C
C                     COMPUTE COVARIANCE MATRIX AFTER PROPAGATION
      DO 280 NTIMES=1,NSAMP
C                     SAMPLE INPUT EPOCH  ERRORS
```

```
      DO 240 I=1,6
      CALL NORRAN
  240 EPAR(I)=GAUSS
      DO 250 J=1,6
      EXIC(J)=ZERO
      DO 250 I=1,6
  250 EXIC(J)=EXIC(J)+SC(J,I)*EPAR(I)
      DO 260 I=1,6
C                   STATE IS AT INPUT EPOCH
  260 STATE(I)=S1(I)+EXIC(I)
      CALL COVR (D,EXIC,NTIMES,SUM2,SUMSQ2,CP2)
C                   INITALIZE ORBIT PARAMETERS FOR STATE
      CALL CONIC
      DELT=TCOAST
C                   ADVANCE STATE
      CALL TSTEP
C                   DX IS STATE ERRORS AFTER PROPAGATION
      DO 270 I=1,6
  270 DX(I)=STATE(I)-SS(I)
      CALL COVR (CMAT2,DX,NTIMES,SUM3,SUMSQ3,CP3)
  280 CONTINUE
C
      WRITE(6,540)
      WRITE(6,530)
      CALL COVR1 (D ,DX,NSAMP,SUM2,SUMSQ2,CP2)
      WRITE(6,480) D
      WRITE(6,550)
      WRITE(6,530)
      CALL COVR1 (CMAT2,DX,NSAMP,SUM3,SUMSQ3,CP3)
      WRITE(6,480) CMAT2
C
C
C
C                   COMPUTE COVARIANCE MATRIX AT LAST STAGE BURNOUT
      DO 290 I=1,21
  290 D(I)=CMAT1(I)+CMAT2(I)
      WRITE(6,340) NPROB,TITLE1,TITLE2
      WRITE(6,570)
      WRITE(6,530)
      WRITE(6,480) D
C
C
C
C                   COMPUTE SENSITIVITIES
      CALL EIGEN (D,R,6,0)
      WRITE(6,490)
      WRITE(6,500) D(1),D(3),D(6),D(10),D(15),D(21)
      WRITE(6,510)
      WRITE(6,500) ((RR(I,J),J=1,6),I=1,6)
      W(1)=SQRT(D(1))
      W(2)=SQRT(D(3))
      W(3)=SQRT(D(6))
      W(4)=SQRT(D(10))
      W(5)=SQRT(D(15))
      W(6)=SQRT(D(21))
      DO 300 J=1,6
      DO 300 K=1,6
```

```
  300 SC(J,K)=W(K)*RR(J,K)
      WRITE(6,520)
      WRITE(6,500) ((SC(I,J),J=1,6),I=1,6)
C
  310 CONTINUE
C                     WRITE SENSITIVITIES ON UNIT 1 FOR READING BY SOAR
      WRITE (1) ((SC(I,J),J=1,6),I=1,6)
      GOTO 10
C
  320 FORMAT (1X,A4,F4.0,5F7.0,2F8.0,2F10.0)
  330 FORMAT (*1*)
  340 FORMAT (*1*,T72,*ROUTINE STEP*/T72,*DTD MAR 1981*/
     ^ T72,*PROB. NO.*I3/ 10X,8A10/ 10X,8A10//)
  350 FORMAT (28X,*FLIGHT RESULTS AT INPUT TIME*//6X,*SAMPLE  VEHICLE  P
     ^REDALT*,5X,*DELTA   DELTA   DELTA   DELTA   DELTA   DELTA*/6X,*NUM
     ^BER   NUMBER*,15X,*ALT      VEL      GAM      AZ      LAT    LONG*/,2
     ^4X,*N.MI.*,6X,*N.MI.    FPS*,5X,*DEG*,5X,*DEG*,5X,*DEG*,5X,*DEG*/)
  360 FORMAT (6X,I3,6X,*S*,A4,F9.1,F11.3,F8.1,2F8.3,2F8.4)
  370 FORMAT (12X*NORMALIZED DEVIATIONS AND ADJUSTED LATITUDE, LONGITUDE
     ^ DEVIATIONS*/28X,*ALTITUDE=*,T38,F9.1,* N MI*/28X,*AZIMUTH=*,T38,F
     ^9.3,* DEG*/28X,*LATITUDE=*,T38,F9.4,* DEG*//)
  380 FORMAT (7X,*SAMPLE        ALT         VEL      GAMMA       ZETA      LAT
     ^      LONG    CODE*/7X,*NUMBER         FT         FPS       DEG         D
     ^EG        DEG         DEG*/)
  390 FORMAT(I11,F12.0,F10.1,2F10.3,2F9.4,I8)
  400 FORMAT (20X,*FLIGHTS FOR SCOUT FLIGHT EXPERIENCE ACCURACY*/)
  410 FORMAT (20X,*FLIGHTS WITH LATITIUDE/LONGITUDE DEVIATIONS*)
  420 FORMAT (30X,I2,* FLIGHT SAMPLES*)
  430 FORMAT (10X,*STANDARD DEVIATIONS*/10X*ALT-VEL-GAM-ZET-LAT-LONG (FT
     ^,FPS,DEG)*//10X,F10.0,F10.1,2F10.3,2F10.4)
  440 FORMAT (10X,F10.3,* NM*/)
  450 FORMAT (10X,*MEAN VALUES*/10X,*ALT-VEL-GAM-ZET-LAT-LONG*/
     ^  10X,F10.0,F10.1,2F10.3,2F10.4//)
  460 FORMAT (10X*CORRELATION COEFFICIENTS*/10X*ALT-VEL-GAM-ZET-LAT-LONG
     ^*//10X,5F10.5/20X,4F10.5/30X,3F10.5/40X,2F10.5/50X,F10.5/)
  470 FORMAT (/25X*COVARIANCE MATRIX (A MATRIX)*/12X*ALT*,9X*VEL*,9X,*GA
     ^M*,9X*ZET*,9X*LAT*,9X*LONG*/)
  480 FORMAT (6X,E13.5/6X,2E13.5/6X,3E13.5/6X,4E13.5/6X,5E13.5/,6X,6E13.
     ^5//)
  490 FORMAT (31X,*EIGENVALUES*)
  500 FORMAT (6X,6E13.5)
  510 FORMAT (/31X,*EIGENVECTORS*/)
  520 FORMAT (/25X*SENSITIVITY COEFFICIENTS*/25X*ALT-VEL-GAM-ZET-LAT-LON
     ^G (TOP TO BOTTOM)*/)
  530 FORMAT (13X*ALT*10X*VEL*10X*GAM*10X*ZET*10X*LAT*9X*LONG*)
  540 FORMAT (//10X,*SAMPLED COVARIANCE MATRIX AT INPUT EPOCH*/)
  550 FORMAT (//10X,*COVARIANCE MATRIX AFTER PROPAGATION*/)
  560 FORMAT (//10X,*COVARIANCE MATRIX OF LAST STAGE BOOST*/)
  570 FORMAT (//10X,*COVARIANCE MATRIX AT LAST STAGE BURNOUT*/)
      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 CONIC
C        INITIALIZES A CONIC FROM A SPHERICAL STATE VECTOR (STATE)
C        FOR SUBSEQUENT PROPAGATION OF THE STATE VECTOR ALONG THE
C        CONIC, WHICH IS ACCOMPLISHED BY SUB. TSTEP.
C
      COMMON /CENT/ CETA,SETA,CG,SG,R,V,SEA
      COMMON /CONIC/ STATE(6), TCALL, KERR, STEP, T, TZERO
      COMMON /CORD/ Q(3,3)
      COMMON /DIG/ ZERO,ONE,TWO,RAD,PI,TWOPI,GM,FT,RE,CON,ROTATE
      COMMON /MAN/ A,A1EE,AVG,E,DOG,EAREF,ETA,ICIRCL,LOUSY,P,
     ^              PGME,RREF,TANOM,TRUE,TREF,XNA,PERIOD,EP
      DATA SMALL/1.E-6/
C
      T=TZERO
      ICIRCL = 0
      LOUSY =  0
C
      SG =  SIN( STATE(3)    * CON )
      CG =  COS( STATE(3)    * CON )
      SZ =  SIN( STATE(4)    * CON )
      CZ =  COS( STATE(4)    * CON )
      SL =  SIN( STATE(5)    * CON )
      CL =  COS( STATE(5)    * CON )
      TEMP = STATE(6)    * CON
      SO =  SIN( TEMP )
      CO =  COS( TEMP )
      R = STATE(1) +RE
      V = STATE(2)
C
      Q(1,1) =    CO * CL
      Q(1,2) =  - SO * SZ - CO * SL * CZ
      Q(1,3) =    SO * CZ - CO * SL * SZ
      Q(2,1) =    SO * CL
      Q(2,2) =    CO * SZ - SO * SL * CZ
      Q(2,3) =  - CO * CZ - SO * SL * SZ
      Q(3,1) =    SL
      Q(3,2) =    CL * CZ
      Q(3,3) =    CL * SZ
C
      TP = ZERO
      TA = ZERO
C
      A = R * GM / ( TWO * GM - R * V * V )
      IF (A.GT.0.) GOTO 30
   10 LOUSY = 1
C                 COMPUTED A NON-ELLIPTIC, OR LOUSY, CONIC.
C                 IT WILL BE IGNORED.
      WRITE (6,20)
   20 FORMAT ( /, 6X 20HLOUSY CONIC FOR BODY )
      RETURN
   30 DOG = R * V * CG
      P = DOG ** 2  / GM
      E =  SQRT( ONE - P / A )
      IF (E-SMALL.GT.0.) GOTO 40
      E = ZERO
C                 CIRCULAR ORBIT ENCOUNTERED. SET ICIRCL TO UNITY.
      ICIRCL = 1
```

```
   GOTO 50
40 IF (ABS(E-ONE)-SMALL .LE. 0.) GOTO 10
   PGME =  SQRT( P / GM ) / E
50 AVG =  SQRT( GM /   A**3 )
   PERIOD = TWOPI / AVG
   XNA = AVG * A
   A1EE = A *  SQRT( ONE - E**2 )
   IF (ICIRCL.GT.0) GOTO 60
   STA = PGME * V  * SG
   CTA = ( P - R  ) / ( R  * E )
   TA =  ATAN2( STA, CTA )
   SEA = R  * STA / A1EE
   CEA = E + R  * CTA / A
   EA =  ATAN2( SEA, CEA )
   IF (EA.LT.ZERO) EA=EA+TWOPI
   TP = ( EA - E * SEA ) / AVG
60 TANOM = TA
   TRUE = TA
   RREF = R
   EAREF = EA
   TREF = TP
   ETA = ZERO
   RETURN
   END
```

```
      SUBROUTINE CORCO(X,Y,NSAMP,SIGX,SIGY,RHOXY,XMEAN,YMEAN,MEAN)
C         CALCULATES STANDARD DEVIATIONS, MEAN VALUES AND THE
C         CORRELATION COEFFICIENT OF TWO VARIABLES OF (NSAMP)
C         RANDOM SAMPLES EACH.
      DIMENSION X(1),Y(1)
C
      XSUM=0.
      YSUM=0.
      XSQSUM=0.
      YSQSUM=0.
      XYSUM=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)
   10 XYSUM=XYSUM+X(I)*Y(I)
      XMEAN=XSUM/SAMPN
      YMEAN=YSUM/SAMPN
      IF (MEAN.EQ.0) XMEAN=0.
      IF (MEAN.EQ.0) YMEAN=0.
      SIGX=SQRT (XSQSUM/(SAMPN-1.)-XMEAN*XMEAN)
      SIGY=SQRT (YSQSUM/(SAMPN-1.)-YMEAN*YMEAN)
      RHOXY=(XYSUM-SAMPN*XMEAN*YMEAN)/SAMPN/SIGX/SIGY
      RETURN
      END
```

```
      SUBROUTINE COVR(COV,DX,NTIMES,SUMX,SUMSQX,CP)
C        GENERATES A SYMMETRIC COVARIANCE MATRIX OF SIX PARAMETERS.
C        COVR  IS CALLED EACH SAMPLE.
C        COVR1 IS CALLED AFTER ALL SAMPLES ARE CALCULATED.
C             COVARIANCE MATRIX IS GENERATED.
      DIMENSION DX(6),SUMX(6),SUMSQX(6),CP(15),XMOM2(6),
     ^ RHO(15),SIG(6),SVAR(6),COV(21)
C
C                    CALL WHEN EACH SAMPLE SET IS GENERATED.
      XN =  FLOAT(NTIMES)
      XNP = (XN - 1.)/XN
      DO  10 I=1,6
      D2X = DX(I)*DX(I)
      SUMX(I) = XNP*SUMX(I) + DX(I)/XN
      SUMSQX(I) = XNP*SUMSQX(I) + D2X/XN
   10 CONTINUE
      DO  20 I=1,5
      LB = I+1
      DO  20 J=LB,6
      PROD = DX(I)*DX(J)
      IND = I + (J*J -3*J +2)/2
      CP(IND) = XNP*CP(IND) + PROD/XN
   20 CONTINUE
      RETURN
C
C
C                    CALL WHEN ALL SAMPLE SETS ARE GENERATED AND
C                    COVARIANCE MATRIX IS DESIRED.
      ENTRY COVR1
      XN=FLOAT(NTIMES)
      XNPR = XN/(XN-1.)
      DO  30 I=1,6
      XM2 = SUMX(I)*SUMX(I)
      XMOM2(I) = SUMSQX(I) - XM2
      SVAR(I) =  XNPR*XMOM2(I)
   30 CONTINUE
      DO 40 I=1,5
      LB = I+1
      DO 40 J=LB,6
      IND = I + (J*J-3*J+2)/2
      DENOM =  SQRT(XMOM2(I)*XMOM2(J))
      RHO(IND) = (CP(IND)-SUMX(I)*SUMX(J))/DENOM
      IF (DENOM.EQ.0.) RHO(IND)=0.
   40 CONTINUE
      DO 50 I=1,6
   50 SIG(I) =  SQRT(SVAR(I))
      COV(1) = SVAR(1)
      COV(2) = RHO(1)*SIG(1)*SIG(2)
      COV(3) = SVAR(2)
      COV(4) = RHO(2)*SIG(1)*SIG(3)
      COV(5) = RHO(3)*SIG(2)*SIG(3)
      COV(6) = SVAR(3)
      COV(7) = RHO(4)*SIG(1)*SIG(4)
      COV(8) = RHO(5)*SIG(2)*SIG(4)
      COV(9)= RHO(6)*SIG(3)*SIG(4)
      COV(10) = SVAR(4)
      COV(11) = RHO(7)*SIG(1)*SIG(5)
```

```
COV(12) = RHO(8)*SIG(2)*SIG(5)
COV(13) = RHO(9)*SIG(3)*SIG(5)
COV(14) = RHO(10)*SIG(4)*SIG(5)
COV(15) = SVAR(5)
COV(16) = RHO(11)*SIG(1)*SIG(6)
COV(17) = RHO(12)*SIG(2)*SIG(6)
COV(18) = RHO(13)*SIG(3)*SIG(6)
COV(19) = RHO(14)*SIG(4)*SIG(6)
COV(20) = RHO(15)*SIG(5)*SIG(6)
COV(21) = SVAR(6)
RETURN
END
```

```
      SUBROUTINE  EIGEN(A,R,N,MV)
      DIMENSION A(1),R(1)
C
C       DESCRIPTION OF PARAMETERS
C         A  - ORIGINAL SYMMETRIC MATRIX, DESTROYED IN COMPUTATION.
C              RESULTANT EIGENVALUES ARE DEVELOPED IN DIAGONAL OF MATRIX
C              A IN DESCENDING ORDER.
C         R  - RESULTANT MATRIX OF EIGENVECTORS STORED COLUMNWISE IN
C              SAME SEQUENCE AS EIGENVALUES.
C         N  - ORDER OF MATRICES A AND R
C         MV - INPUT CODE
C              0   COMPUTE EIGENVALUES AND EIGENVECTORS
C              1   COMPUTE ONLY EIGENVALUES
C       METHOD - DIAGONALIZATION METHOD ORIGINATED BY JACOBI AND ADAPTED
C          BY VON NEUMANN FOR LARGE COMPUTERS AS FOUND IN MATHEMATICAL
C          METHODS FOR DIGITAL COMPUTERS, EDITED BY A. RALSTON AND H. S.
C          WILF, JOHN WILEY AND SONS, NEW YORK, 1962, CHAPTER 7.
C
C                   GENERATE IDENTITY MATRIX
C
    5 RANGE=1.0E-12
      IF (MV-1) 10,25,10
   10 IQ=-N
      DO 20 J=1,N
      IQ=IQ+N
      DO 20 I=1,N
      IJ=IQ+I
      R(IJ) = 0.0
      IF (I-J) 20,15,20
   15 R(IJ) = 1.0
   20 CONTINUE
C
C                   COMPUTE INITIAL AND FINAL NORMS ( ANORM AND ANORMX)
C
   25 ANORM=0.0
      DO 35 I=1,N
      DO 35 J=I,N
      IF (I-J) 30,35,30
   30 IA=I+(J*J-J)/2
      ANORM=ANORM+A(IA)*A(IA)
   35 CONTINUE
      IF (ANORM) 165,165,40
   40 ANORM=1.414*SQRT (ANORM)
      ANRMX = ANORM*RANGE/ FLOAT(N)
C
C                   INITIALIZE INDICATORS AND COMPUTE THRESHOLD, THR
C
      IND=0
      THR=ANORM
   45 THR = THR/FLOAT(N)
   50 L=1
   55 M=L+1
C
C                   COMPUTE SIN AND COS
C
   60 MQ=(M*M-M)/2
      LQ=(L*L-L)/2
```

```
      LM=L+MQ
   62 IF (ABS (A(LM))-THR)130,65,65
   65 IND=1
      LL=L+LQ
      MM=M+MQ
      X=0.5*(A(LL)-A(MM))
   69 Y=-A(LM)/SQRT (A(LM)*A(LM)+X*X)
      IF (X) 70,75,75
   70 Y=-Y
   75 SINX=Y/SQRT (2.0*(1.0+(SQRT (1.0-Y*Y))))
      SINX2=SINX*SINX
   78 COSX=SQRT (1.0-SINX2)
      COSX2=COSX*COSX
      SINCS=SINX*COSX
C
C                    ROTATE L AND M COLUMNS
C
      ILQ=N*(L-1)
      IMQ=N*(M-1)
      DO 125 I=1,N
      IQ=(I*I-I)/2
      IF (I-L) 80,115,80
   80 IF (I-M) 85,115,90
   85 IM=I+MQ
      GOTO 95
   90 IM=M+IQ
   95 IF (I-L) 100,105,105
  100 IL=I+LQ
      GOTO 110
  105 IL=L+IQ
  110 X=A(IL)*COSX-A(IM)*SINX
      A(IM)=A(IL)*SINX+A(IM)*COSX
      A(IL)=X
  115 IF (MV-1) 120,125,120
  120 ILR=ILQ+I
      IMR=IMQ+I
      X=R(ILR)*COSX-R(IMR)*SINX
      R(IMP)=R(ILR)*SINX+R(IMR)*COSX
      R(ILR)=X
  125 CONTINUE
      X=2.0*A(LM)*SINCS
      Y=A(LL)*COSX2+A(MM)*SINX2-X
      X=A(LL)*SINX2+A(MM)*COSX2+X
      A(LM)=(A(LL)-A(MM))*SINCS+A(LM)*(COSX2-SINX2)
      A(LL)=Y
      A(MM)=X
C
C                    TESTS FOR COMPLETION
C                    TEST FOR M = LAST COLUMN
C
  130 IF (M-N) 135,140,135
  135 M=M+1
      GOTO 60
  140 IF (L-(N-1)) 145,150,145
  145 L=L+1
      GOTO 55
  150 IF (IND-1) 160,155,160
```

```
  155 IND=0
      GOTO 50
C
C                    COMPARE THRESHOLD WITH FINAL NORM
C
  160 IF (THR-ANRMX) 165,165,45
C                    SORT EIGEN VALUES AND EIGENVECTORS
  165 IQ=-N
      DO 185 I=1,N
      IQ=IQ+N
      LL=I+(I*I-I)/2
      JQ=N*(I-2)
      DO 185 J=I,N
      JQ=JQ+N
      MM=J+(J*J-J)/2
      IF (A(LL)-A(MM)) 170,185,185
  170 X=A(LL)
      A(LL)=A(MM)
      A(MM)=X
      IF (MV-1) 175,185,175
  175 DO 180 K=1,N
      ILR=IQ+K
      IMR=JQ+K
      X=R(ILR)
      R(ILR)=R(IMR)
  180 R(IMR)=X
  185 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INIT
C   INITIALIZES CONSTANTS
      COMMON /DIG/ ZERO,ONE,TWO,RAD,PI,TWOPI,GM,FT,RE,CON,ROTATE
      COMMON /BLK4/ XMU,SIGMA,GAUSS,GN(16),XK,ZRAN,ICNT
      DATA GN/23.,71.,47.,43.,59.,19.,61.,37.,89.,97.,13.,29.,73.,83.,
     ^     31.,67.  /
C
      ZERO=0.0
      ONE=1.0
      TWO=2.0
      RAD=57.2957795
      CON=1./RAD
      PI=3.1415926536
      TWOPI=TWO*PI
      GM=1.4076576E16
      FT=6076.11549
      RE=20925741.
      ROTATE=7.29211E-5
C
      ENTRY INIT1
      ICNT=1
      SIGMA=1.
      XK=12345678.
      XMU=0.
      RETURN
      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 INTER (X,Y,NUM,B,A)
C        SECOND ORDER INTERPOLATOR
C        SELECT FOUR DATA POINTS CLOSEST TO X TO INTERPOLATE FOR Y.
C        X=INDEPENDENT VARIABLE VALUE
C        Y=RESULTING DEPENDENT VARIABLE VALUE
C        LMT=NO. OF ELEMENTS IN A AND B
C        B=ARRAY OF DEPENDENT VARIABLES
C        A=ARRAY OF INDEPENDENT VARIABLES
      DIMENSION A(15),B(15)
C
      I=1
      IF (NUM.EQ.4) GOTO 30
      IF (NUM.LT.4) WRITE (6,40) NUM
      IF (NUM.LT.4) STOP
C
      IF (X.LT.A(3)) I=1
      IF (X.GT.A(NUM-2)) I=NUM-3
      IF (X.LT.A(3) .OR. X.GT.A(NUM-2)) GOTO 30
C
      LMT=NUM-2
      DO 10 K=4,LMT
         IF (X.LT.A(K)) GOTO 20
   10 CONTINUE
   20 CONTINUE
      I=K-2
C
   30 CONTINUE
      X0=A(I)
      X1=A(I+1)
      X2=A(I+2)
      X3=A(I+3)
      Y11=((X1-X)*B(I)-(X0-X)*B(I+1))/(X1-X0)
      Y21=((X2-X)*B(I)-(X0-X)*B(I+2))/(X2-X0)
      Y31=((X3-X)*B(I)-(X0-X)*B(I+3))/(X3-X0)
      Y22=((X2-X)*Y11-(X1-X)*Y21)/(X2-X1)
      Y32=((X3-X)*Y11-(X1-X)*Y31)/(X3-X1)
      Y=((X3-X)*Y22-(X2-X)*Y32)/(X3-X2)
      RETURN
C
   40 FORMAT (//10X,*SUBROUTINE INTER - VALUES IN INTERPOLATION TABLE =*
     ^                 I3*   MUST BE .GE. 4*)
      END
```

```
      SUBROUTINE NEWTON
C    ITERATES ON ECCENTRIC ANOMALY GIVEN A TIME (TCALL)
C
      COMMON /CENT/ CETA,SETA,CG,SG,R,V,SEA
      COMMON /CONIC/ STATE(6), TCALL, KERR, STEP, T, TZERO
      COMMON /MAN/ A,A1EE,AVG,E,DOG,EAREF,ETA,ICIRCL,LOUSY,P,
     ^          PGME,RREF,TANOM,TRUE,TREF,XNA,PERIOD,EP
C
C
      KERR = 0
      K = -30
      DTM = TCALL - TREF
      EA = EAREF + XNA * DTM / RREF
      VALUE = AVG * TCALL
   10 FCN = ( EA - E*SIN(EA) - VALUE )/(1. - E*COS(EA) )
      EA = EA - FCN
      K = K + 1
      IF (K.GE.0) GOTO 30
      IF (ABS(FCN)-1.E-9 .LE. 0.) GOTO 50
      GOTO 10
   30 WRITE (6,40)
   40 FORMAT( / 6X 22H30 ITERATIONS FOR BODY  // )
      KERR=1
      GOTO 60
C
   50 EAREF = EA
      SEA =  SIN( EA )
      CEA =  COS( EA )
      RREF = A * ( 1.   - E * CEA )
      TREF = TCALL
      STA = SEA * A1EE / RREF
      CTA = ( CEA - E ) * A / RREF
      ETA  =  ATAN2( STA, CTA )  - TANOM
      TRUE = STA
C                  TRUE STORES STA FOR SIGN ON GAMMA
   60 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE NORRAN
C    GENERATES A NORMALLY DISTRIBUTED RANDOM NUMBER.
      REAL NG,KX,MU
      COMMON /BLK4/  MU, SIGMA, GAUSS, NG(16), KX, ZRAN, ICNT
C
      TEMP = 0.
      DO 100 I=1,12
      KX = NG(ICNT)*KX
      KTEMP = INT(KX/100000000.00)
      KX = ABS(KX - FLOAT(KTEMP)*100000001.00)
      ZRAN = KX*0.0000000100
      ICNT = ICNT + 1
      IF (ICNT.GT.16) ICNT = 1
  100 TEMP = TEMP + ZRAN
      GAUSS = SIGMA*(TEMP - 6.0) + MU
      RETURN
      END
```

```
      SUBROUTINE TSTEP
C        PROPAGATES ALONG A CONIC BY TIME INCREMENT (STEP)
C        SUBROUTINE CONIC MUST BE CALLED TO INITIALIZE
C
C
      COMMON /CENT/ CETA,SETA,CG,SG,R,V,SEA
      COMMON /CONIC/ STATE(6), TCALL, KERR, STEP, T, TZERO
      COMMON /CORD/ Q(3,3)
      COMMON /DIG/ ZERO,ONE,TWO,RAD,PI,TWOPI,GM,FT,RE,CON,ROTATE
      COMMON /MAN/ A,A1EE,AVG,E,DOG,EAREF,ETA,ICIRCL,LOUSY,P,
     ^             PGME,RREF,TANOM,TRUE,TREF,XNA,PERIOD,EP
      DIMENSION        XU(3), XV(3), ZN(3), DN(3), DA(3)
      DATA ZN / 0., 0., 1. /
C
C
      IF (LOUSY.GT.0) GOTO 80
      IF (ICIRCL.LE.0) GOTO 10
C                   CIRCULAR ORBIT REQUIRES SPECIAL CARE.
      ETA  = AVG * STEP    +  ETA
      TRUE = ZERO
      EAREF=ETA
      GOTO 20
C
   10 TCALL = TREF + STEP
      CALL NEWTON
      IF (KERR.NE.0) GOTO 90
C
   20 T= T + STEP
C
C                   CALCULATE POSITION AND INERTIAL VELOCITY COMPONENTS.
C
      SETA =  SIN( ETA )
      CETA =  COS( ETA )
      R = RREF
      V =  SQRT( GM*(TWO/R - ONE/A) )
      CG = DOG / ( R * V )
      SG =  SQRT(  ABS( ONE - CG * CG ) )
      IF (TRUE.LT.0.) SG = -SG
      RCOMP = V * ( CETA * SG - SETA * CG )
      HCOMP = V * ( SETA * SG + CETA * CG )
C                   CONVERT INTO INERTIAL X-Y-Z AXES.
      X = R * ( CETA * Q(1,1)  +  SETA * Q(1,2) )
      Y = R * ( CETA * Q(2,1)  +  SETA * Q(2,2) )
      Z = R * ( CETA * Q(3,1)  +  SETA * Q(3,2) )
      DXDT = RCOMP * Q(1,1)  +  HCOMP * Q(1,2)
      DYDT = RCOMP * Q(2,1)  +  HCOMP * Q(2,2)
      DZDT = RCOMP * Q(3,1)  +  HCOMP * Q(3,2)
C
C
C
C
      XU(1) = X / R
      XU(2) = Y / R
      XU(3) = Z / R
      XV(1) = DXDT
      XV(2) = DYDT
      XV(3) = DZDT
```

```
      DA(1)=XU(2)*ZN(3)-XU(3)*ZN(2)
      DA(2)=XU(3)*ZN(1)-XU(1)*ZN(3)
      DA(3)=XU(1)*ZN(2)-XU(2)*ZN(1)
      AA=DA(1)*DA(1)+DA(2)*DA(2)+DA(3)*DA(3)
      IF (AA.GT.1.E-60) GOTO 40
      DA(1)=1.
      DA(2)=0.
      DA(3)=0.
      GOTO 50
   40 AA=SQRT(AA)
      DA(1)=DA(1)/AA
      DA(2)=DA(2)/AA
      DA(3)=DA(3)/AA
   50 CONTINUE
      DN(1)=DA(2)*XU(3)-DA(3)*XU(2)
      DN(2)=DA(3)*XU(1)-DA(1)*XU(3)
      DN(3)=DA(1)*XU(2)-DA(2)*XU(1)
      AA=DN(1)*DN(1)+DN(2)*DN(2)+DN(3)*DN(3)
      IF (AA.GT.1.E-60) GOTO 60
      DN(1)=1.
      DN(2)=0.
      DN(3)=0.
      GOTO 70
   60 AA=SQRT(AA)
      DN(1)=DN(1)/AA
      DN(2)=DN(2)/AA
      DN(3)=DN(3)/AA
   70 CONTINUE
      VNORTH= XV(1)*DN(1)+XV(2)*DN(2)+XV(3)*DN(3)
      VEAST=-(XV(1)*DA(1)+XV(2)*DA(2)+XV(3)*DA(3))
C                     UPDATE THE STATE TRAJECTORY VARIABLES
      H =   R- RE
      GAM=RAD*ASIN(SG)
      ZET = RAD * ATAN2( VEAST, VNORTH )
      IF (ZET.LT.0.) ZET=ZET+360.
      ALAT = RAD * ASIN( XU(3) )
      ALON = RAD * ATAN2( XU(2), XU(1) ) - ROTATE*(T-TZERO)*RAD
      STATE(1)=H
      STATE(2)=V
      STATE(3)=GAM
      STATE(4)=ZET
      STATE(5)=ALAT
      STATE(6)=ALON
C
   80 RETURN
C
   90 WRITE(6,100) STEP
  100 FORMAT( // 10X 16HTROUBLE IN TSTEP  4X 6HSTEP = 1PE15.5)
      RETURN
      END
```

```
      SUBROUTINE UNIRAN
C    GENERATES A UNIFORM RANDOM NUMBER
      REAL NG,KX,MU
      COMMON /BLK4/ MU,SIGMA,GAUSS,NG(16),KX,ZRAN,ICNT
C
      IF (ICNT.LE.0 .OR. ICNT.GT.16) ICNT=1
      KX = NG(ICNT)*KX
      KTEMP =  INT(KX/100000000.00)
      KX = ABS(KX - FLOAT(KTEMP)*100000001.00)
      ZRAN = KX*.000000010
      ICNT = ICNT + 1
      IF (ICNT.GT.16) ICNT = 1
      RETURN
      END
```

APPENDIX C

SCIENTIFIC DATA PROCESSING ROUTINE
SUMMARY DOCUMENTATION

IDENTIFICATION

Title Scout Trajectory Error Propagation

Routine No. 1801 Date Filed 1974 Security Class. U

Responsible Engineer T. R. Myler

Date Completed 1974 Source Language: FORTRAN IV

Key Words Covariance matrix, propagation, conic, Monte Carlo, statistics

RESOURCE REQUIREMENTS

Typical CPU 10 sec Machine(s) CDC CYBER 175 No. Source Cards 1125

Core 65k (octal) Tape none Plot no Graphics none

DESCRIPTION

Purpose: To calculate error statistics in the trajectory parameters, including an error covariance matrix, from flight experience. The covariance matrix is propagated on option.

Input: Flight experience errors in the trajectory parameters.

Output: Error statistics in the trajectory parameters, error covariance matrix, propagated covariance matrices, spin-stabilized stage boost covariance matrix, sensitivity matrix which represents the final covariance matrix after propagation.

Functional Description:

Flight samples are combined statistically to obtain an error covariance matrix. The covariance matrix is propagated using a Monte Carlo technique of sampling, propagating the deviated trajectory along the conic, and statistically combining the resulting errors into another covariance matrix. The sensitivity matrix is developed from the eigenvalues and eigenvectors of the covariance matrix.

DOCUMENTATION

Vought Report 2-53030/1R-52776, "Scout Trajectory Error Propagation Computer Program" dated 1 October 1981.

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15 Supplementary Notes

Langley Technical Monitor: Robert J. Keynton

16 Abstract

Since 1969, flight experience has been used as the basis for predicting Scout orbital accuracy. The data base used for calculating the accuracy consists of errors in the trajectory parameters (altitude, velocity, etc.) at stage burnout as observed on Scout flights. Approximately 50 sets of errors are used in Monte Carlo analysis to generate error statistics in the trajectory parameters. A covariance matrix is formed which may be propagated in time. The mechanization of this process resulted in computer program Scout Trajectory Error Propagation (acronym STEP) and is described herein.

Computer program STEP may be used in conjunction with the Statistical Orbital Analysis Routine (Reference 1) to generate accuracy in the orbit parameters (apogee, perigee, inclination, etc.) based upon flight experience.

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