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AFCRL-64-55

SCIENTIFIC REPORT NO. 3
CONTRACT NO. AF19(628)-2379
PROJECT NO. 7600
TASK NO. 760003

Differential Orbit Correction And Station Locator Program

CATALOGED BY DDC

"DOC-II"

AS AD NO.

By

Richard M. Moroney

Isabel M. Hussey

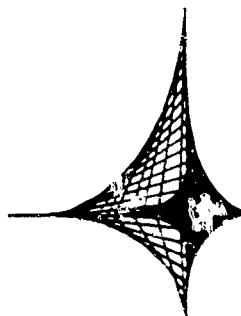
FEBRUARY 1964

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Prepared for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS



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ABSTRACT

The analysis and programming associated with performing a differential correction to orbital elements and/or station positions from weighted observations of range, range rate, azimuth-elevation and/or right ascension-declination on close earth satellites are described. The ephemeris computation considers perturbations due to the earth's gravitational potential as described by a spherical harmonic representation through $n = m = 5$, the lunar gravitational potential, air drag and radiation pressure. All observations may be simulated in punched card form for the purposes of conducting geometric studies.

This contract was administered under the direction of the project scientists, Mr. A. Mancini and Captain L.L. Sheldon, of the Geodesy and Gravity Branch, Terrestrial Sciences Laboratory.

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I INTRODUCTION

The multi-purpose program described herein, "DOC II," has been developed primarily to obtain geocentric positions of ground-based instrumentation sites from observations made on close earth satellites. The observations may be in the form of range, range rate, and/or directions (right ascension and declination, azimuth and elevation). Provision for weighting observations is included.

This program utilizes the analysis and much of the programming associated with the ephemeris computation and differential correction theory that is described in AFCRL 62-892, Research in Geodesy and Gravity, Computer Programs for Orbit Correction and Station Location. For ready reference this portion of 62-892 is contained in Appendix A. This original ephemeris computation has been modified to consider the following additional perturbations.

1. the sectorial and tesseral terms in the earth's gravitational potential (thru $n = m = 5$)
2. the lunar gravitational potential
3. solar radiation pressure

The station locator portion of 62-892 was completely reworked and is described in the body of this report. Further modifications made to the original program now allows one to:

1. Correct the orbital elements and station positions simultaneously.
2. Simulate observations in the form of punched card output. Using this as input allows one to observe the effect that varying amounts, distribution, accuracy, and types of data has on the end results.
3. Correct the six orbital elements only, applying from one to nine corrections.
4. Correct the station positions only for a number of stations contained in up to six different datums.
5. Generate orbital elements for each time step specified by a Δt from input.

II FORMULATION

A. General

1. Standard Keplerian elements are obtained by inverting:

$$\begin{aligned}L_o &= M_o + \omega + \Omega \\A_{xn} &= e \cos \omega \\A_{yn} &= e \sin \omega \\H_x &= \sqrt{a(1-e^2)} \sin \Omega \sin i \\H_y &= -\sqrt{a(1-e^2)} \cos \Omega \sin i \\H_z &= \sqrt{a(1-e^2)} \cos i\end{aligned}$$

2. Greenwich sidereal time in degrees for January 0.0 is selected internally from a table for the years 1958 to 1977. The present table for θ_g is:

$$\begin{aligned}(1960) &= 98.67401 \\(1961) &= 99.420937 \\(1962) &= 99.1822167 \\(1963) &= 98.943500314\end{aligned}$$

Greenwich sidereal time at the time of an observation is obtained by applying a mean rotation to GST of January 0.0 and then adding on the equation of equinoxes from a table. In the original ephemeris computation (Appendix A), the equation of equinoxes was not added.

3. The maximum size of the matrix is 24 x 24. This allows for correcting the 6 orbital elements and up to 6 different non-zero datums.
4. Observation sigmas are selected internally if none are given from input.

The program will use the following nominal values:

$$\begin{aligned}&10 \text{ meters for Range Observations} \\&10.0 \text{ cps for Range Rate Observations} \\&.00001 \text{ radians for Optical Observations}\end{aligned}$$

B. Observation Weighting and Calculation of Standard Deviation (σ)
in Satellite Position

1 Preliminaries

As noted in the writeup of the Station Corrector Portion (pg 6), each observation leads to a condition equation of the form

$$Q_{\text{obs}} - Q_{\text{comp}} = C_{\Delta i} \Delta i + \dots + C_{\Delta Z_j} \Delta Z_j \quad (1)$$

Here Q just denotes some quantity. The actual quantity used for Q varies with the type of observation as follows:

<u>Observation Type</u>	<u>Q</u>
Range rate	$(\underline{p} \cdot \dot{\underline{p}})$
Range	$\sqrt{\underline{p} \cdot \underline{p}}$
Azimuth or Right Ascension	$(\underline{p} \cdot \underline{A})$
Elevation or Declination	$(\underline{p} \cdot \underline{D})$

The basis of the entire differential correction method is the assumption that

$$Q_{\text{obs}} = Q_{\text{true}} + \epsilon \quad (2)$$

where ϵ is a sample from a distribution with zero mean and known standard deviation. Since some observations are more accurate than others, i. e., have smaller σ 's, the condition equations are weighted by dividing by a σ for the error in that observation.

An additional advantage of this weighting, aside from the obvious one of being able to take account of variable observational accuracy, is that the diagonal elements of the least-squares matrix can be interpreted as variances in the computed corrections $\Delta i, \Delta \Omega, \dots, \Delta X, \Delta Y, \Delta Z$. An additional assumption is necessary here, namely that the errors in different observations are independent.

The estimates of the variances in the elements at epoch can be converted into estimates of the variances in the computed x, y, z coordinates of the satellite.

2 Theory

a) Variances for x, y, z coordinates of satellite.

Formulas for converting $\Delta a_0, \Delta i_0, \dots, \Delta \Omega_0$ to $\Delta x(t_1), \Delta y(t_1), \Delta z(t_1)$ for each observation time t_1 are given in Reference 2. A standard technique then gives the variances for the conversion Matrix A.

$$\begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix} = \begin{bmatrix} & & \\ & A & \\ & & \end{bmatrix} \begin{bmatrix} \Delta a_0 \\ \Delta i_0 \\ \vdots \\ \Delta \Omega_0 \end{bmatrix}$$

A covariance Matrix C for $[\Delta x, \Delta y, \Delta z]$ is then related to the covariance Matrix for $[\Delta a_0, \Delta i_0, \dots, \Delta \Omega_0]$ by

$$C = ADA^T$$

b) Observational Sigmas

In order to get a σ for the ϵ in (2) one must take account of the nature of the observed quantities, Q. It is easy to see that

$$\begin{aligned} (\underline{p} \cdot \dot{\underline{p}}) &= r \dot{r} \\ \sqrt{\underline{p} \cdot \underline{p}} &= r, \\ \Delta(\underline{p} \cdot \underline{A}) &= \rho \cos \delta \Delta a, \\ \Delta(\underline{p} \cdot \underline{D}) &= \rho \Delta \delta, \end{aligned}$$

Thus appropriate sigmas are

$$\begin{aligned} (\underline{p} \cdot \dot{\underline{p}}) &: r \sigma_{\dot{r}}, \\ \sqrt{\underline{p} \cdot \underline{p}} &: \sigma_r, \\ \Delta(\underline{p} \cdot \underline{A}) &: \rho \cos \delta \sigma_a, \\ \Delta(\underline{p} \cdot \underline{D}) &: \rho \sigma_{\delta}. \end{aligned}$$

Additional Features

- a) Nominal values of the sigmas for each station's observations of range rate, range and angles are accepted from the station data cards. If the appropriate columns of a station's card are zero the program uses, for that station, a set of arbitrarily chosen values. When an observation card is read the program checks to see whether a sigma for the observation is on the card. If there is such a sigma it is the one used. If the appropriate columns are zero the nominal sigma for the observing station is used.
- b) The subroutine which forms the condition equations divides them by the appropriate σ as determined in the theory section.
- c) At each observation time the program saves on tape those values necessary for computing the matrix A mentioned in the theory section.
- d) At the conclusion of a run the tape record mentioned in (c) is read, and sigmas for x, y and z at each observation time computed.
- e) In order to be assured of getting sigmas in x, y, and z at epoch — even when this is not an observation time — a record, as in paragraph (c) is written at the start of the run, i. e., at epoch.
- f) Simulated data is available in punched card form. Format is that required for input to the simulated run with toggles set as noted in the section on input.

C. Station - Corrector Portion

1 Preliminaries

Let x, y, z be the inertial coordinates of the satellite at some sidereal time θ and X, Y, Z be the earth-fixed coordinates of an observing station. The inertial coordinates of this station, $\hat{X}, \hat{Y}, \hat{Z}$, are given by

$$\begin{aligned}\hat{X} &= X \cos \theta - Y \sin \theta \\ \hat{Y} &= X \sin \theta + Y \cos \theta \\ \hat{Z} &= Z\end{aligned}\tag{1}$$

The station-satellite vector, $\underline{\rho}$ is

$$\underline{\rho} = (x - \hat{X})\underline{i} + (y - \hat{Y})\underline{j} + (z - \hat{Z})\underline{k}\tag{2}$$

The time derivative of this vector, $\dot{\underline{\rho}}$, is

$$\dot{\underline{\rho}} = (\dot{x} - \dot{\hat{X}})\underline{i} + (\dot{y} - \dot{\hat{Y}})\underline{j} + (\dot{z} - \dot{\hat{Z}})\underline{k}\tag{3}$$

If we let the earth's rotation rate be ω and differentiate (1) we get

$$\begin{aligned}\dot{\hat{X}} &= (-X \sin \theta - Y \cos \theta)\omega \\ \dot{\hat{Y}} &= (X \cos \theta - Y \sin \theta)\omega \\ \dot{\hat{Z}} &= 0\end{aligned}\tag{4}$$

Using (1) and (4) to get rid of the hat variables in (2) and (3) gives

$$\underline{\rho} = (x - X \cos \theta + Y \sin \theta)\underline{i} + (y - X \sin \theta - Y \cos \theta)\underline{j} + (z - Z)\underline{k}\tag{5}$$

$$\begin{aligned}\dot{\underline{\rho}} &= (\dot{x} + [X \sin \theta + Y \cos \theta]\omega)\underline{i} \\ &+ (\dot{y} + [Y \sin \theta - X \cos \theta]\omega)\underline{j} \\ &+ \dot{z}\underline{k}\end{aligned}\tag{6}$$

Thus

$$\frac{\partial \underline{\rho}}{\partial X} = -\cos \theta \underline{i} - \sin \theta \underline{j}$$

$$\frac{\partial \underline{\rho}}{\partial Y} = \sin \theta \underline{i} - \cos \theta \underline{j}$$

$$\frac{\partial \underline{\rho}}{\partial Z} = -\underline{k}$$

Also

$$\begin{aligned} (\underline{\rho} \cdot \dot{\underline{\rho}}) &= (x - X \cos \theta + Y \sin \theta)(\dot{x} + [X \sin \theta + Y \cos \theta] \omega) \\ &\quad + (y - X \sin \theta - Y \cos \theta)(\dot{y} + [Y \sin \theta - X \cos \theta] \omega) \\ &\quad + (z - Z) \dot{z} \\ &= X (-\cos \theta \dot{x} + \omega \sin \theta x - \sin \theta \dot{y} - \omega \cos \theta y) \\ &\quad + Y (\sin \theta \dot{x} + \omega \cos \theta x - \cos \theta \dot{y} + \omega \sin \theta y) \\ &\quad + Z (-\dot{z}) \\ &\quad + \text{terms independent of } X, Y, Z. \end{aligned}$$

Notice that

$$(\underline{\rho} \cdot \dot{\underline{\rho}}) = \frac{1}{2} \frac{d}{dt} (\underline{\rho} \cdot \underline{\rho}) = \frac{1}{2} \frac{d}{dt} (\text{range})^2 = (\text{range})(\text{range rate}).$$

Here

$$\frac{\partial (\underline{\rho} \cdot \dot{\underline{\rho}})}{\partial X} = -\cos \theta (\dot{x} + \omega y) + \sin \theta (\omega x - \dot{y})$$

$$\frac{\partial (\underline{\rho} \cdot \dot{\underline{\rho}})}{\partial Y} = \cos \theta (\omega x - \dot{y}) + \sin \theta (\dot{x} + \omega y)$$

$$\frac{\partial (\underline{\rho} \cdot \dot{\underline{\rho}})}{\partial Z} = -\dot{z}$$

2

Theory

For each type of observation the original program (Appendix A) developed a condition equation. These were of the following forms:

Range Rate Observation

$$(\underline{p} \cdot \dot{\underline{p}})_{\text{obs}} - (\underline{p} \cdot \dot{\underline{p}})_{\text{comp}} = \frac{\partial(\underline{p} \cdot \dot{\underline{p}})}{\partial i} \Delta i + \dots + \frac{\partial(\underline{p} \cdot \dot{\underline{p}})}{\partial \Omega} \Delta \Omega$$

Azimuth or Right Ascension Observation

$$(\underline{p} \cdot \underline{A})_{\text{obs}} - (\underline{p} \cdot \underline{A})_{\text{comp}} = \frac{\partial(\underline{p} \cdot \underline{A})}{\partial i} \Delta i + \dots + \frac{\partial(\underline{p} \cdot \underline{A})}{\partial \Omega} \Delta \Omega$$

Elevation or Declination Observation

$$(\underline{p} \cdot \underline{D})_{\text{obs}} - (\underline{p} \cdot \underline{D})_{\text{comp}} = \frac{\partial(\underline{p} \cdot \underline{D})}{\partial i} \Delta i + \dots + \frac{\partial(\underline{p} \cdot \underline{D})}{\partial \Omega} \Delta \Omega$$

Range Observation

$$\sqrt{(\underline{p} \cdot \underline{p})}_{\text{obs}} - \sqrt{(\underline{p} \cdot \underline{p})}_{\text{comp}} = \frac{\partial \sqrt{(\underline{p} \cdot \underline{p})}}{\partial i} \Delta i + \dots + \frac{\partial \sqrt{(\underline{p} \cdot \underline{p})}}{\partial \Omega} \Delta \Omega$$

Here the subscripts "obs" and "comp" denote "observed" and "computed" respectively. $\underline{A}$ and $\underline{D}$ are unit vectors in a plane perpendicular to $\underline{p}_{\text{obs}}$ and perpendicular to each other (Appendix A).

To modify these condition equations when X, Y and Z are also unknown, we must add to the right side the partials of the relevant quantity with respect to X, Y, and Z. We have already computed $\partial(\underline{p} \cdot \dot{\underline{p}})$ with respect to X, Y and Z. In the case of $(\underline{p} \cdot \underline{D})$ or $(\underline{p} \cdot \underline{A})$

$$\frac{\partial(\underline{p} \cdot \underline{D})}{\partial X} = \left(\frac{\partial \underline{p}}{\partial X} \cdot \underline{D} \right)$$

$$\frac{\partial(\underline{p} \cdot \underline{A})}{\partial Y} = \left(\frac{\partial \underline{p}}{\partial Y} \cdot \underline{A} \right)$$

etc. and the partials of $\underline{p}$ are known. Finally,

$$\begin{aligned} \frac{\partial \sqrt{\underline{p} \cdot \underline{p}}}{\partial X} &= \frac{1}{2\sqrt{\underline{p} \cdot \underline{p}}} \frac{\partial(\underline{p} \cdot \underline{p})}{\partial X} \\ &= \frac{1}{2\sqrt{\underline{p} \cdot \underline{p}}} 2 \left(\frac{\partial \underline{p}}{\partial X} \cdot \underline{p} \right) \end{aligned}$$

$$= \left(\frac{\partial \underline{p}}{\partial X} \cdot \underline{L} \right)$$

where $\underline{L} = \underline{p} / \sqrt{\underline{p} \cdot \underline{p}}$ is a unit vector from station to satellite.

X → Y, Z.

3. Modifications To AFCRL 62-892

a) The first change in the program causes it to accept a datum number on each station card. Up to six different non-zero datum numbers may appear in the deck of station cards for any run. (These need not be numbered in order such as 1, 2, 3. The program reassigns internal datum numbers so that the input datum numbers could be 12, 24, 268 etc.) A zero datum number indicates that a station is to be held fixed. All stations in the same datum are moved together.

The program counts the number of non-zero datums present, say n, and sets the number of unknowns equal to 6 + 3n.

b) The second change is a revision of the routine which forms the condition equations. These are enlarged as described in the theory section. An essential part of this step is to determine the datum number of the observing station, so as to make the partials with respect to X, Y and Z refer to X, Y and Z of the relevant datum.

To make clear what is meant here, suppose that there are two non-zero datums numbered 1 and 2. There are twelve unknowns,

$$\frac{\Delta a}{a}, \Delta i, \dots, \Delta \Omega, \Delta X_1, \Delta Y_1, \Delta Z_1, \Delta X_2, \Delta Y_2, \Delta Z_2.$$

Each individual observation is made by a station in datum zero or one or two. If the station is in datum zero the coefficients of $\Delta X_1, \Delta Y_1, \dots, \Delta Z_2$ are all zero. If the station is in datum one the coefficients of $\Delta X_2, \Delta Y_2$ and ΔZ_2 are zero but the coefficients of $\Delta X_1, \Delta Y_1, \Delta Z_1$ are those we just derived.

c) A third change in the program consists of a bookkeeping chore. After a set of datum shifts is determined, the stations in non-zero datums must have their X, Y, Z coordinates updated. This involves rewriting the observation tape.

III PROCESSING

A. The general flow of the program during execution is:

1. Set up constants; read in the first five specification cards.
2. Compute, for epoch, the values of inclination, node, $\bar{W}$, mean motion, $\bar{A}$.
3. Set up to integrate ephemeris.
4. Write parameters used in computing standard deviations in satellite position at epoch on Tape 11.
5. Integrate ephemeris:
 - a. Compute time derivatives of $\bar{A}$, $\bar{H}$, and XL .
 - b. Compute perturbative accelerations and relate to orbital elements.
 - c. Compute required derivatives.
 - d. After each perigee passage, correct orbit parameters for atmospheric drag.
 - e. Transfer current values of $\bar{A}$, $\bar{H}$, and XL to ephemeris buffer.
 - f. Determine what to print for output.
 - g. Write ephemeris buffer on Tape 3 whenever it is filled.
6. Determine if Simulation Run or Differential Correction Run.

If Simulation Run

Compute and print simulated observations for each station - Range, Range Rate, Right Ascension/Declination, Azimuth/Elevation.

If Differential Correction Run

1. Read station cards.
2. Set up least squares routine for matrix size.
3. For each observation card perform the following:

- a. Read an observation card.
 - b. Match station number on observation card with station card.
 - c. Check if observation time is within ephemeris time, i. e., between T_0 and T_f .
 - d. Compute L Bar, etc.
 - e. Save observation data on Tape 9.
4. When all observation cards have been read in, continue processing each observation:
 - a. Find observation time in ephemeris.
 - b. Interpolate to get parameters from ephemeris.
 - c. Compute x , y , z , and related parameters.
 - d. Save x , y , z , $\dot{x}$, $\dot{y}$, $\dot{z}$ on Tape 6.
 - e. Write parameters for standard deviation for each observation time on Tape 11.
 - f. Compute correction equation coefficients and residuals.
 - g. Update sum of squares of residuals and normal equations.
 5. Save matrix A and B as determined by input code to correct both elements and station positions, elements only, or station positions only.
 6. Solve normal equations.
 7. Compute root mean square of residuals; reset limit for acceptance of residuals.
 8. Determine whether or not to do another pass.
 9. Apply correction to elements.
 10. Apply correction to station position.
 11. Determine whether or not to do another correction.

12. Compute the sigmas in x , y , and z (position of observer).
- 13 Output
14. Exit

B. Error Indicators

1. Subroutine Error

This is a general error exit from any subroutine and causes the execution of the program to stop. Location SUBER 1 contains the address within the subroutine from which the exit occurred.

2. Altitude Below 50000 Meters

Program exits. The internal table of altitudes has a lower limit of 50000 meters and an upper limit of 900000 meters.

3. Kepler's Equation Not Converging For "e"

Program exits. This error occurs as the value of eccentricity approaches 1.0.

4. Error in Range Kutta Routine

Program exits.

5. Number of Unknowns Exceeds Number of Observations

Program exits. This error exit is executed when the program does not have enough good observations, i. e., observations that pass the maximum residual test.

6. Error in Testing Time Points

Program exits. The count of the number of records on the ephemeris tape (Tape 3) is held in location NTAPE3. The value in NTAPE3 is tested before the program tries to find the observation time in the ephemeris. If $\text{NTAPE3} \leq 0$ at this time, this error exit occurs.

7. If the value for XNY in the XYZSB Subroutine is zero, the program will exit.

8. Observation Out of Time Range

This is printed when the observation time is not within T_0 to T_f . Program continues.

9. Station XXX Not Found

This is printed out when the program is unable to match the station number on the observation card with the station number on the station card.

IV INPUT

1. Specification Cards

For all runs the program requires 5 specification cards.

Cards 1 and 2 — used for headings of output pages.

Card 3 — tells program to start at time 0 minutes and in time steps of Δt , compute the ephemeris for t_f minutes. This card gives diameter (m.) and mass (kg.) of satellite.

Card 4 — This card inputs the elements. A minus sign in column 1 indicates that standard Keplerian elements are being used. Otherwise the elements are taken as those of Reference 1.

Card 5 — Information given on this card controls the type of execution. However, for all runs, the following columns are common:

Col. 1 has code for printed output — Code of 1 prints sub-satellite positions; Code of 2 prints $x, y, z, \dot{x}, \dot{y}, \dot{z}$; Code of 3 prints both; Code of 0 will suppress this printing.

Epoch day given must correspond to that of Keplerian elements. Restart day must be equal to or later than t_f from epoch.

Col. 21 must be 0.

Year of epoch is based on 1958 = 01.

Simulation — Code 0 in column 19.

Differential Correction

Card 5 Col. 20 tells program how many times to repeat correction.

Col. 38 is coded 1 when user wishes to correct both the elements and station positions. (Such stations must have non-zero datum.)

Col. 39 is coded 1 when user wishes to correct the station positions only.

Col. 40 is coded 1 when user wishes to correct the orbital elements only.

The maximum limits for the residuals are left to the descretion of the user, as are the sigmas.

2. Observation Cards

It is preferable that observations be ordered by time. This shortens the running time by eliminating rewind orders.

A card following the last observation card must have "END" punched in Cols. 1-3.

3. Station Cards

The station number must agree in Cols. 1-4 to the station number on the observation card in Cols. 11-14.

The sigmas that may be put in on the station cards are sigmas associated with the observations, not with station position.

Observational sigmas on the Observation Cards will take precedence over those on the Station Cards. Also if no sigmas are given on the Station Card, nominal values will be used (ASIG).

4. Options By Means Of Toggle Settings

The program user has options available to him by requesting certain toggles to be set manually by the computer operator at run time. The request is specified on the Request Card and on a card inserted in the data deck immediately following the Job Card, punched as shown below.

Col.	Col.
17	25
HLT	PLEASE PUT ON TOGGLES X, X, etc.

The HLT card causes the message to be printed on the flexo when the run starts.

Toggles 30, 31, 32 and 33 are on for generating simulated observations on punched cards in ANNA format. Any number of these may be specified during a run for the following:

- 30 for Azimuth and Elevation,
- 31 for Right Ascension and Declination,
- 32 for Range,
- 33 for Range Rate.

Toggle 35 on will cause program to print out Keplerian elements for each time step.

INPUT FORMAT FOR A SIMULATION RUN

May be run with or without station cards.
Without station cards output α , γ on print option.
With station cards output includes look angles.

CARD 1 LINE 1 - HEADING FOR OUTPUT PAGES

Col. 1-72

CARD 2 LINE 2 - HEADING FOR OUTPUT PAGES

Col. i-72

CARD 3

Col.	±								±		
1-12	+	0	0	0	0	0	0	0	+	0	0
13-24											
25-36											
37-48											
49-60											

ΔT (minutes)
Minutes from Epoch to Final Time
Diameter of Satellite (meters)
Mass of Satellite (kilograms)

CARD 4

	$\pm$	$\pm$
Col. 1-12	-	
13-24		
25-36		
37-48		
49-60		
61-72		

Axis (nautical miles)
Eccentricity
Inclination (degrees)
Mean Anomaly (degrees)
Arg. of Perigee (degrees)
Right ascension of node (degrees)

CARD 5

Col. 1		Print Option: 1 gives time, ϕ , λ , h; 2 gives x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$; 3 gives both											
7-10						Epoch Day							
11-18												Minutes from Epoch Day to Epoch	
19-21		0	0	0									
25-28						Restart Day							
29-37												Minutes from Restart Day to Restart Time	
41-42				Year (1963 = 06)									

STATION DATA

Col.

[illegible]

INPUT FORMAT FOR SPECIFICATION CARDS PROGRAM Differential Correction

CARD	Field	Description
1	9-72	Heading for Output Line 1
2	25-72	Heading (Line 2)
3*	1-12	+ 0 0 0 0 0 0 0 0 + 0 0
	13-24	T ₀
	25-36	ΔT (minutes)
	37-48	Time from Epoch to Final Time (minutes)
	49-60	Diameter of Vehicle (meters)
		Mass of Vehicle (kilograms)
OPTION - Use if only Keplerian elements are available; code with a Minus (-) in Col. 1.		
4a*	1-12	-
	13-24	Axis (nautical miles)
	25-36	Eccentricity
	37-48	Inclination (degrees)
	49-60	Mean Anomaly (degrees)
	61-72	Arg. of Perigee (degrees)
		Rt Asc of Node (degrees)
OPTION - Use if the following values are supplied as input; otherwise, see 4a.		
4b*	1-12	L ₀ (radians)
	13-24	A _{xn}
	25-36	A _{yn}
	37-48	H _x Earth radii
	49-60	H _y " "
	61-72	H _z " "
5	1-6	☐ Print Option (1 for Time, φ, λ, ht; 2 for Time, x, y, z, ẋ, ẏ, ż; 3 for both)
	7-10	Epoch (Day of Year; integer)
	11-18	Time; from beginning of Epoch Day to Epoch - minutes)
	19	☐ Blank for differential correction; 0 (zero) for simulation
	20	Number of times to repeat correction
	21	0
	22-24	Sigma 1
	25-28	Restart Time (day of year)
	29-37	Restart Time (minutes)
	38	☐ Code 1 to correct both elements and station positions. Use 1 of 3 only
	39	☐ Code 1 to correct station positions only
	40	☐ Code 1 to correct orbital elements only
	41-42	Year - 1958 = 01; 1959 = 02; 1960 = 03; 1961 = 04; 1962 = 05; 1963 = 06; etc
	43-48	Max. for angle and range residuals
	49-51	Sigma 2
	52-54	Sigma 3
	55-57	Sigma 4
	58-60	Sigma 5
	61-63	Sigma 6
	64-66	Sigma 7
	67-69	Sigma 8
	70-72	Sigma 9
	73-78	Max. for range rate residuals

*Format (xxxxxxx) (xxxxxxx) (xxxxxxx)

* Code 4 identifies data as a Base Frequency
Code 3 identifies data as a Received Frequency
** Sigma has decimal point assumed to be between Col. 50 and 51

21

* Code 1 identifies the type of observation as range
 ** The sigma for range is given in col 49-51 with decimal point assumed between col 50&51

YR	SAT I. D.	STATION I. D.	OBSERVATION TIME						Format + xxxxxxxxxx±yy RANGE (meters)		Sigma ±y
			yr	mo	day	hr	min	sec			
1	3	11	15	16	18	20	22	24	26	28	35 (rt. adjusted) 48 ±9

Input Format - STATION Cards

SAT I.D.	LATITUDE (degrees)	LONGITUDE (degrees)	HEIGHT (meters)	Datum no.	P _{obs}	P _{obs}	α or A	δ or h
1-4	5-12 (F8.5)	13-21 (F9.5)	22-27 (F6.0)	33-36	ASIG 1 38-45	ASIG 2 46-53	ASIG 3 54-61	ASIG 4 62-69

COL

V COMPILATION PROCEDURE

The program must be compiled on the Philco "2000" under the system called "Altac 2". This system requires that all tape units used be specified according to their use in an "Iounits" statement.

Decimal Input Tapes are LTO and LT10

Intermediate Binary Tapes are LT3, LT6, LT9, LT11,
LT13, LT14, and LT15

Decimal Output Tape is LT5, Data Select 0

Punched Card Output is LT13, Data Select 10

The program uses approximately 100 RPL block. Compilation time is about 20 minutes. The source deck consists of approximately 5000 cards (2 1/2 boxes).

VI EXECUTION OF DATA RUN

Col.	Col.
17	25
JOB	XXX (Identify run)
REWIND	0, 3, 6, 9, 10, 11, 13
RPL	1, DATA, GO
TAPE	0

For all runs, insert 5 specification or control cards here. For differential correction runs, the 5 specification cards are followed by the observation cards. The last observation card must be followed by a card with "END" in Cols. 1-3.

```
ENDDATA
REWIND    0
JMP       *
TAPE      10
```

Station cards are inserted here. The run must have a card with "END" in Cols. 1-3 before the following:

```
ENDDATA
REWIND    10
JPL       4, XXXX, GO (ID of program)
```

TAPE UNITS Requiring Write Rings

1. Input

TAPE 0 5 specification cards and observation cards.
TAPE 10 station cards

2. Output

TAPE 5 printed output
TAPE 13 punched cards using data select 10 when making
 a simulation run.

3. Binary

TAPE 3 saves time and sub-satellite positions
TAPE 6 saves time, x , y , z , $\dot{x}$, $\dot{y}$, $\dot{z}$.
TAPE 9 saves observations after processing
TAPE 11 saves data used in computing sigmas
TAPE 14 saves data used in computing the corrected latitude,
 longitude, and height of the observing station
 (spheroid specified).
TAPE 15 saves elements at every time step if Toggle switch
 35 is on.

VII OUTPUT

A. Printed Output:

1. Input data from the 5 specification cards.
2. L_0 , A_{xn} , A_{yn} , H_x , H_y , H_z if input is in form of Keplerian elements.
3. Time and satellite position in latitude, longitude, and altitude above a specified reference spheroid for each integration step. This is available with a print option of 1 or 3.
4. Time and inertial position and velocity ($x, y, z, \dot{x}, \dot{y}, \dot{z}$) of satellite for each integration step. This is available with a print option of 2 or 3.
5. Input data from station cards.
6. Input data from observation cards.
7. Station number, time, and residual for each observation.
8. Root-mean-square of the non-rejected residuals (SUM and SUM2) and the corrections to the orbital parameters (DELTA A/A, DELTA AXN, DELTA AYN, DELTA L_0 , DELTA NODE, DELTA I). The SUM2 column contains range rate residuals.
9. Suggested changes in coordinates of datum in earth-fixed coordinates (DELTA X, DELTA Y, and DELTA Z).
10. The differentially corrected Keplerian elements, differentially corrected L_0 , A_{xn} , A_{yn} , H_x , H_y , H_z , and the corrected $x, y, z, \dot{x}, \dot{y}, \dot{z}$ at epoch.
11. New positions for stations in non-zero datums, station number, latitude, longitude, elevation, and earth fixed rectangular coordinates (x, y, z) of station. Latitude, longitude and elevation are referenced to the spheroid whose parameters are specified in the Table of Program Constants.

12. The standard deviation (sigma) for DELTA A/A, DELTA AXN, DELTA AYN, DELTA L₀, DELTA NODE, DELTA I at epoch.
13. The standard deviation (sigma) in the observation station position (SIGMA X, SIGMA Y, and SIGMA Z).
14. Time and the satellite position (x, y, z) with the associated standard deviation are given at epoch and for each observation time.

B. Punched Card Output

An optional feature of DOC II will produce observation cards punched in correct format for use as input in the differential correction portion of the program.

These cards can be generated during a simulation run by toggle settings on the console. The settings are made manually by the computer operator as specified by the program user on the Computer Request Card, and by the insertion of a card in the run deck, immediately following the job card, as follows:

(Col. 17) HLT (Col. 25) PUT ON TOGGLES X,X, ETC.

This card will be printed out on the flexo-writer at run time for instruction to the operator.

Set Toggle 30 for azimuth and elevation observations

Set Toggle 31 for right ascension and declination observations

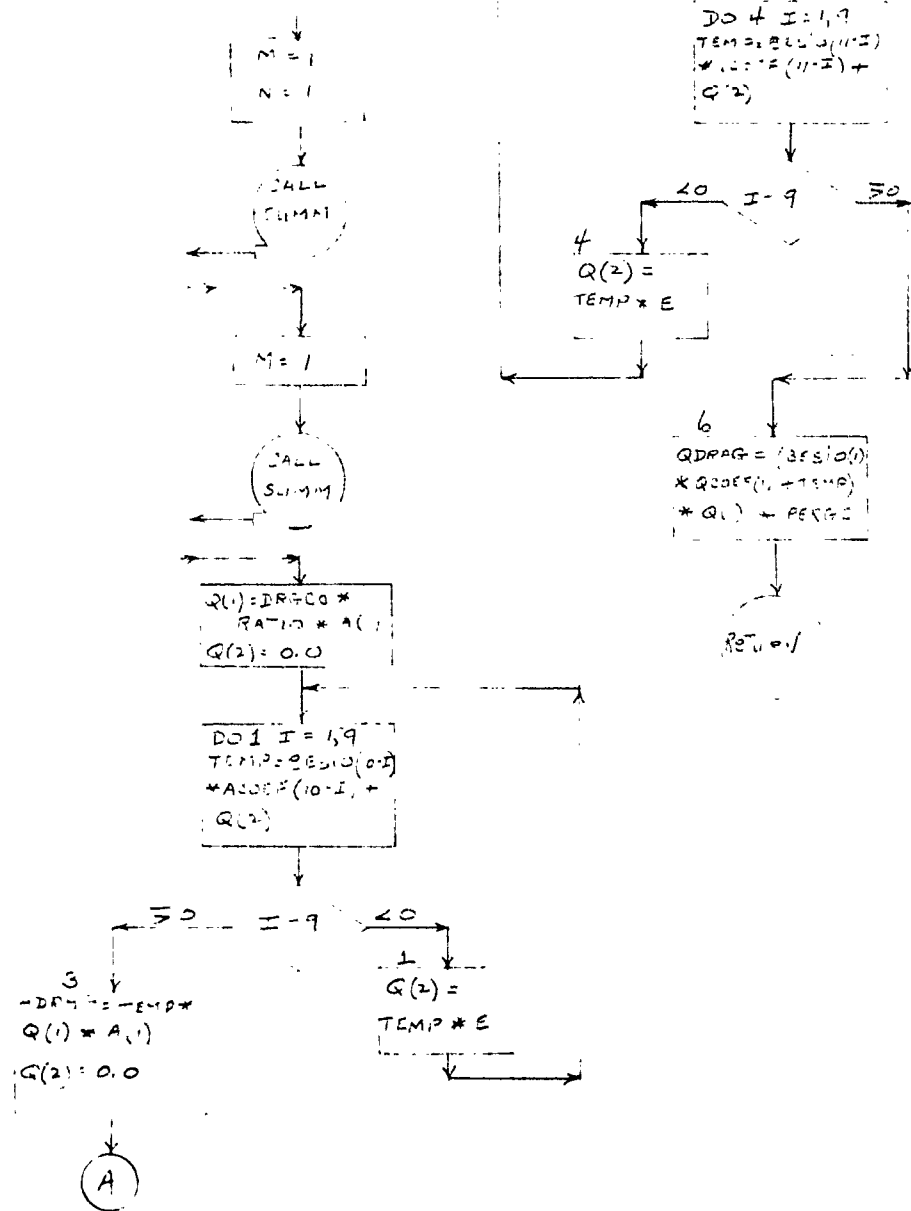
Set Toggle 32 for range observations

Set Toggle 33 for range rate observations

VIII

FLOW CHART OF SUBROUTINES

Subroutine A2DPA



Subroutine BELGE

INITIALIZE
ALFA(K,I) AND
BETA(X,I)
K=1,6
J=1,6

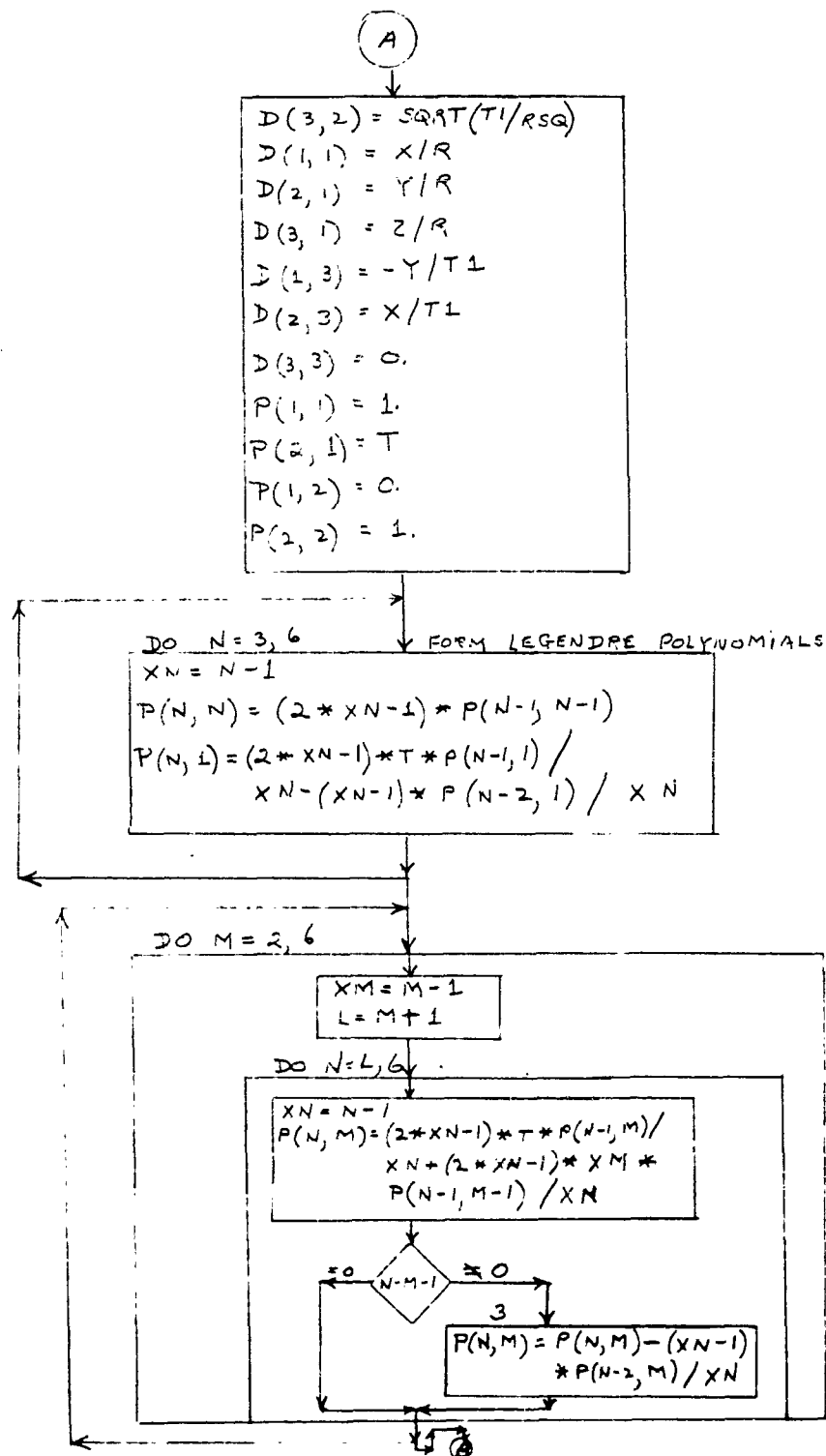
ALFA(3,3) = 1.056E-6; BETA(3,3) = 1.09E-6
ALFA(4,2) = 1.26E-6; BETA(4,2) = 1.5E-6
ALFA(4,3) = 1.210E-6; BETA(4,3) = 1.076E-6
ALFA(4,4) = 1.121E-6; BETA(4,4) = 1.165E-6
ALFA(5,2) = 1.405E-6; BETA(5,2) = 1.323E-6
ALFA(5,3) = 1.0793E-6; BETA(5,3) = 1.315E-6
ALFA(5,4) = 1.069E-6; BETA(5,4) = 1.0504E-6
ALFA(5,5) = 1.0098E-6; BETA(5,5) = 1.012E-6

20

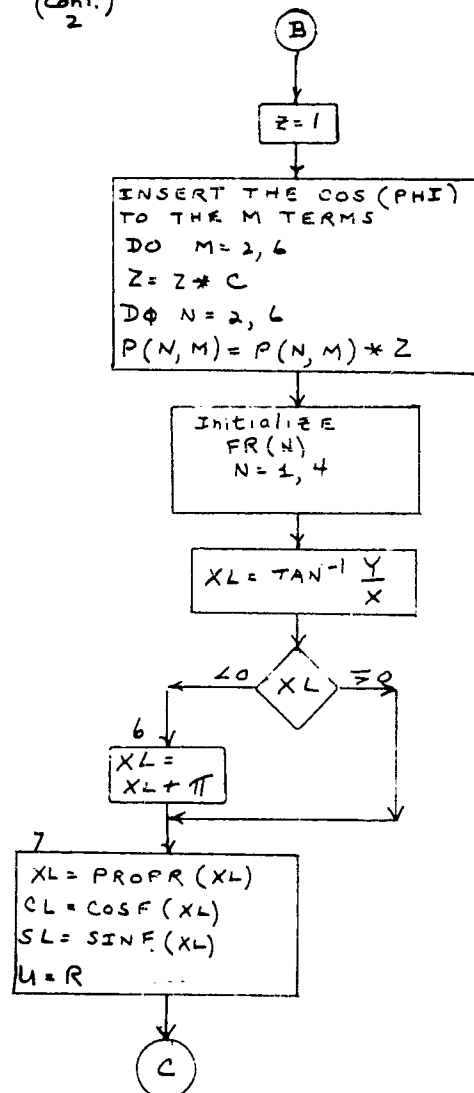
COMPUTE
CT = COSF(TH); ST = SINF(TH)
X = W(1)*CT + W(2)*ST
Y = -W(1)*ST + W(2)*CT
Z = W(3)
T1 = X² + Y²
QMU = 1.0
PSQ = T1 + Z²
T2 = Z/SQRTF(T1)
D(1,2) = -T2*X/PSQ
D(2,2) = -T2*Y/PSQ
R = 1/PSQ; E = ATANF(T2)
C = COS(E); S = SIN(E)

X
A

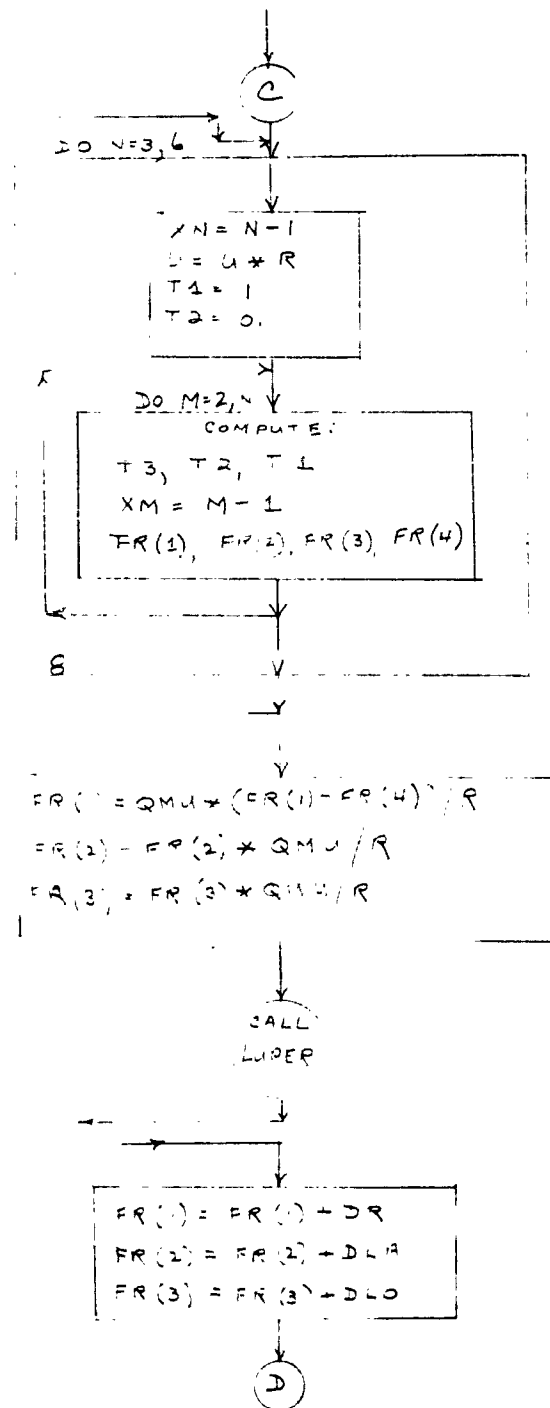
BELGE (CONT.)
(1)



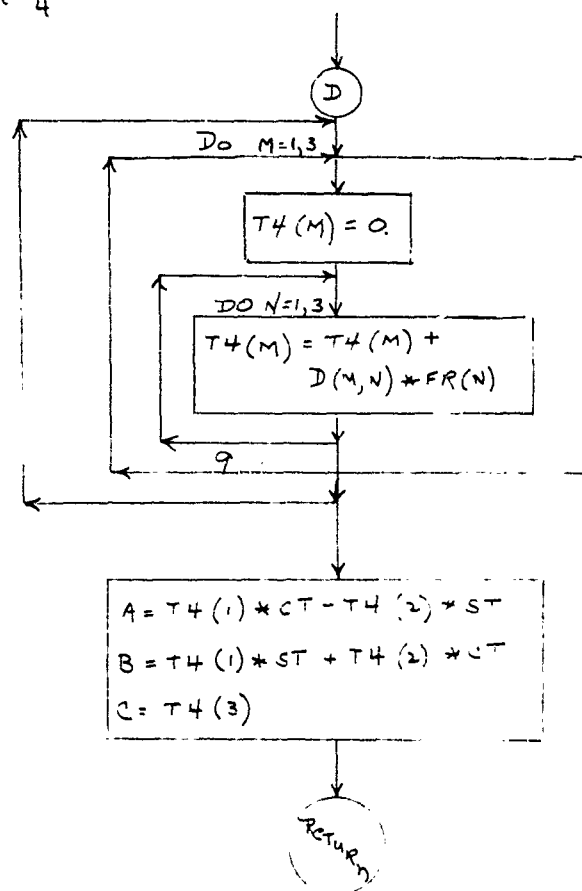
BELGE (cont.)
2



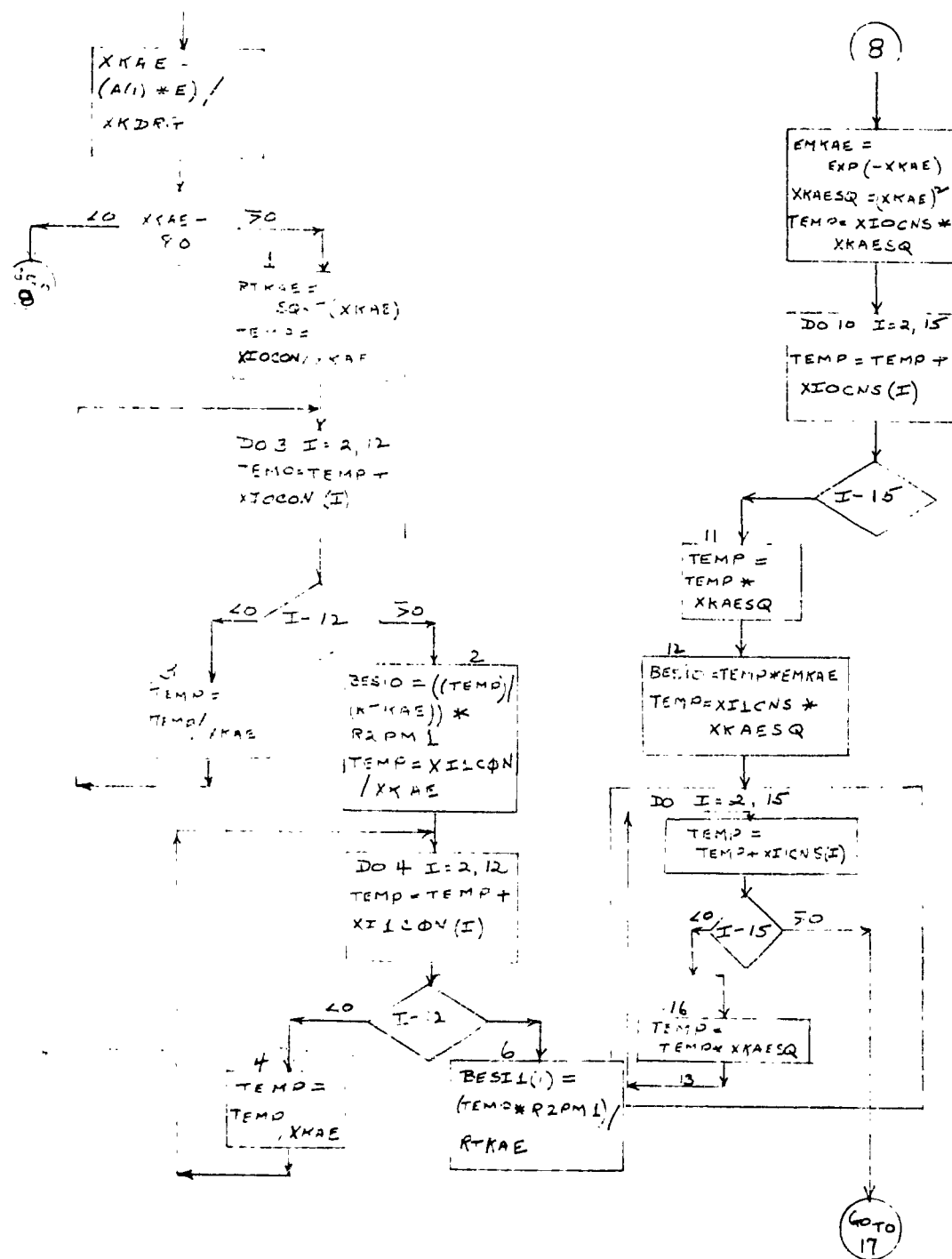
BELGE (cont)



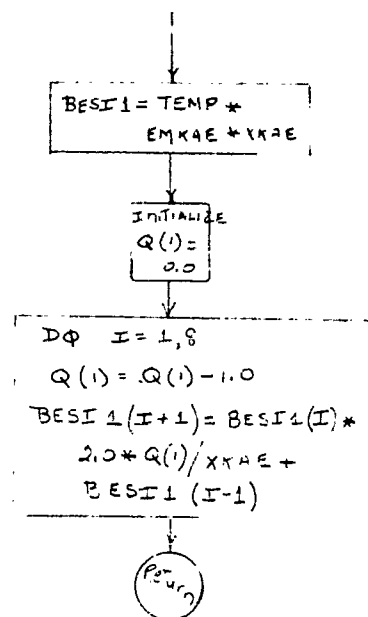
BELGE (cont.)
4



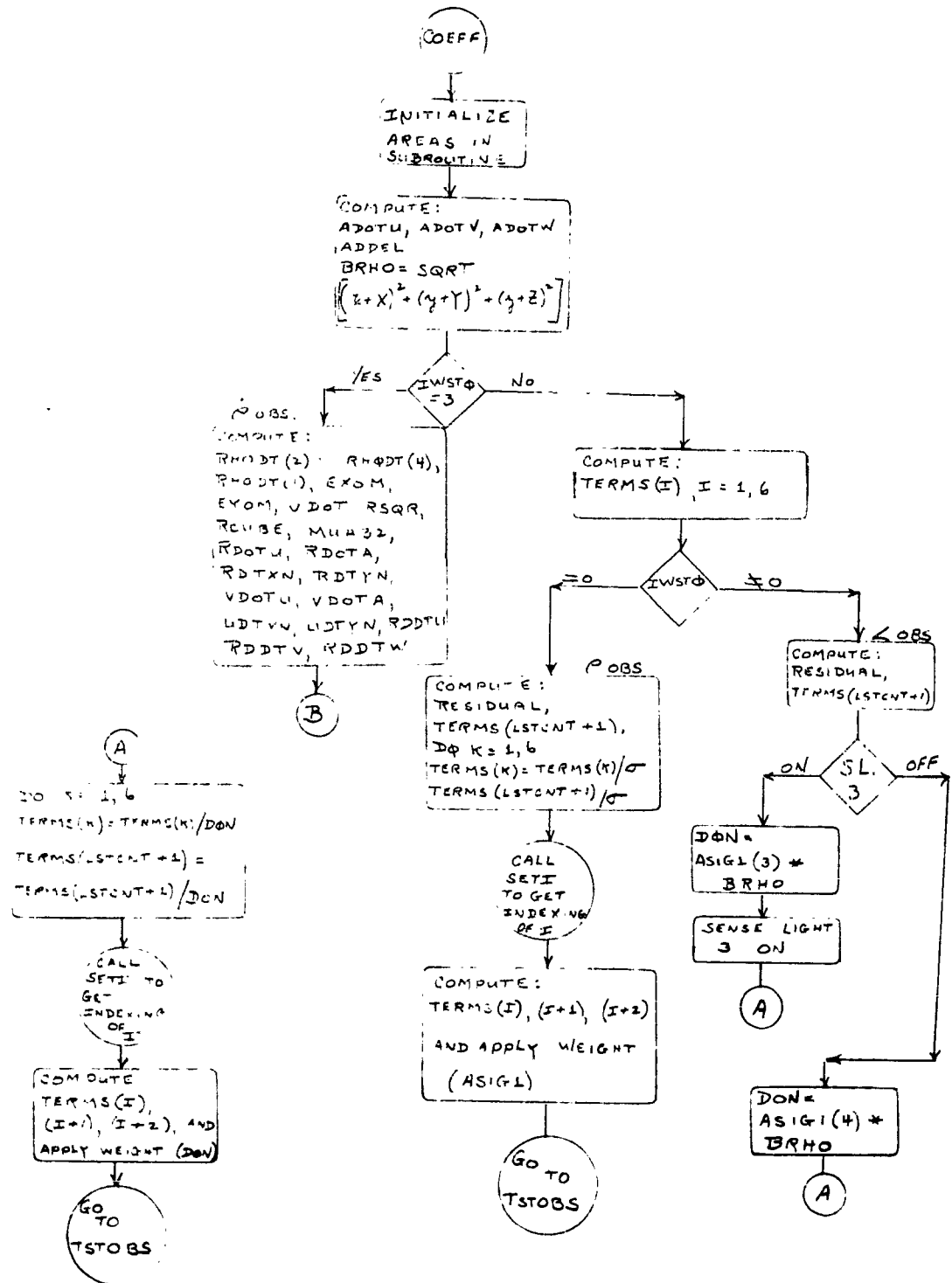
Subroutine BESSEL



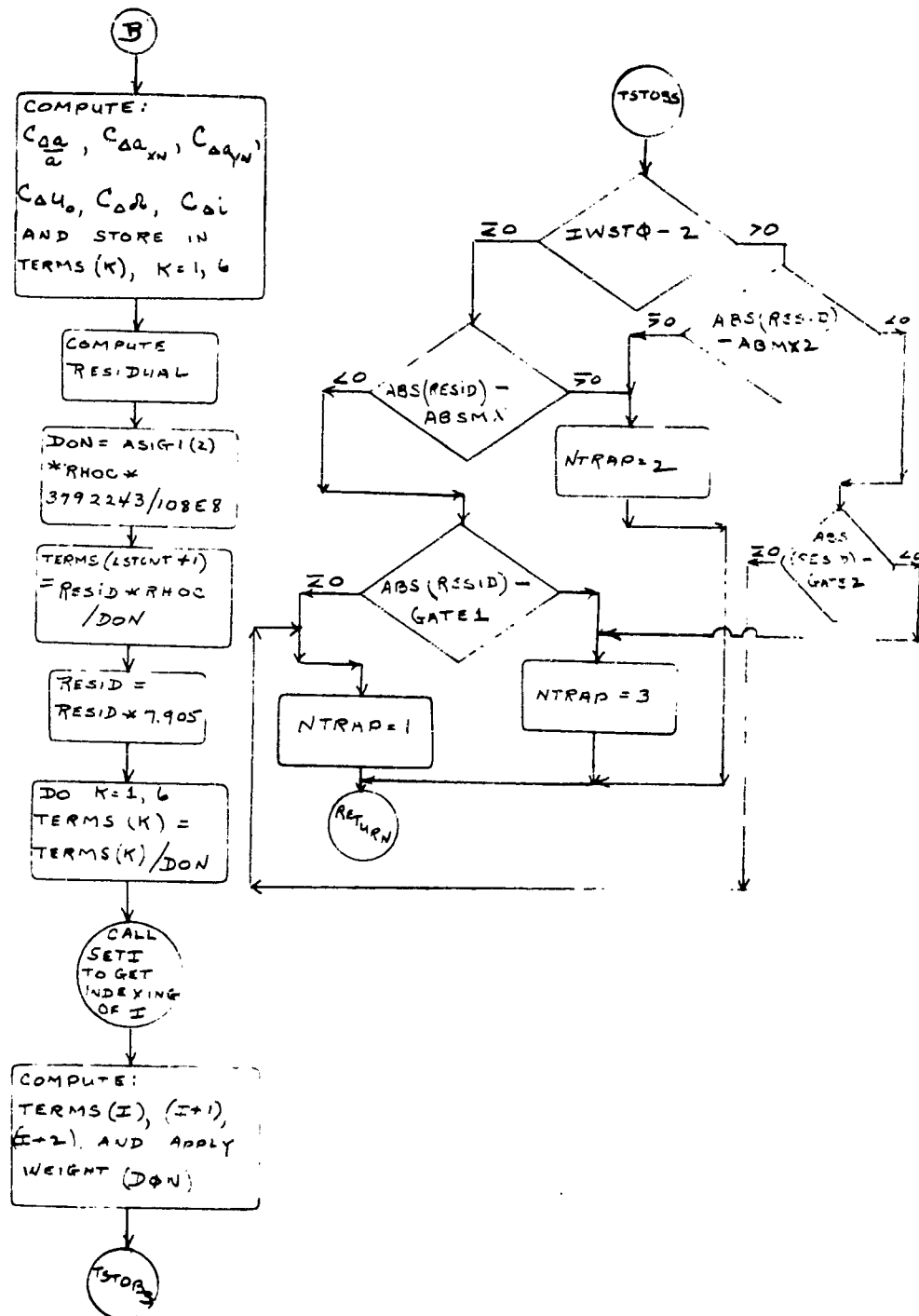
BESSEL (cont.)



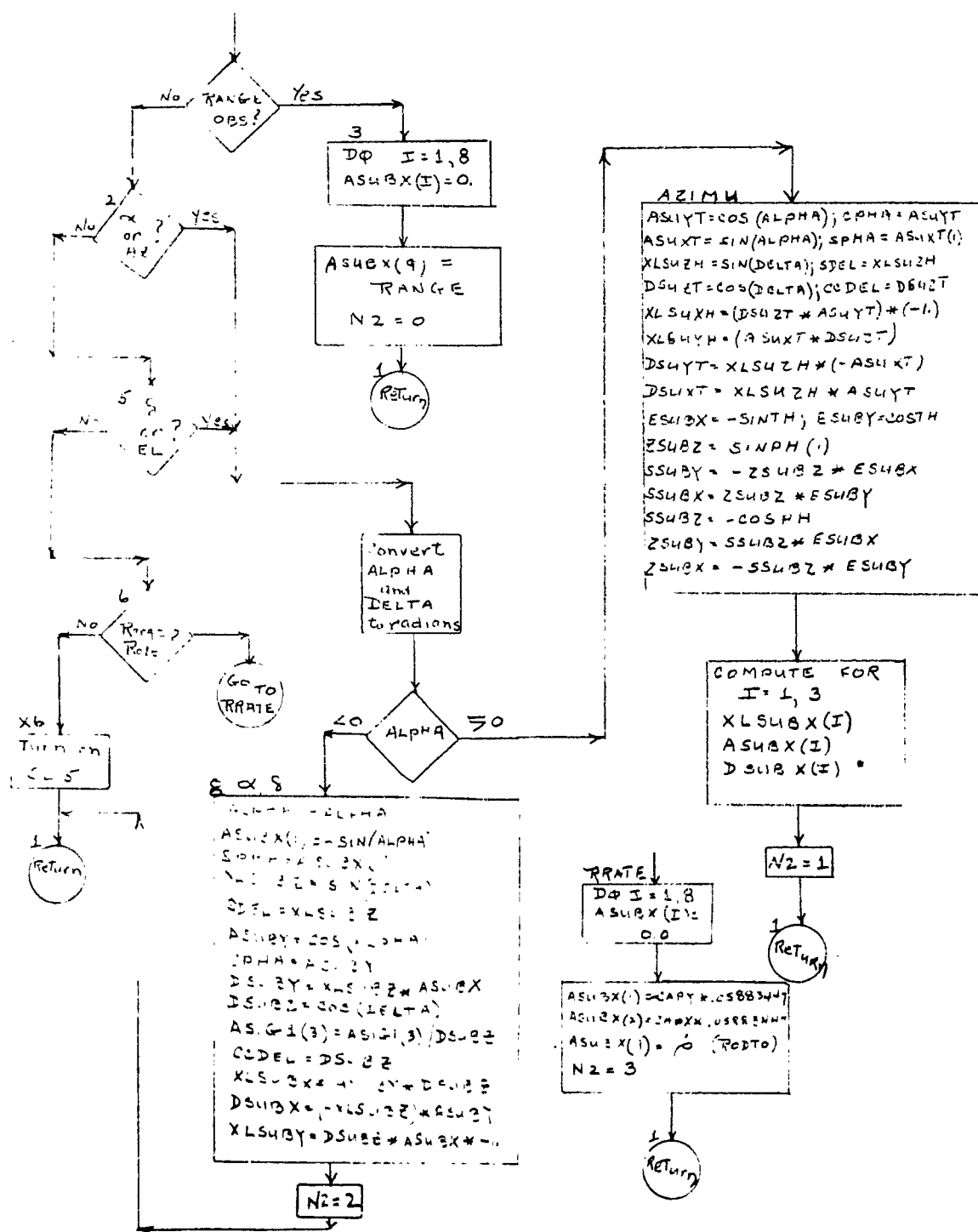
SUBROUTINE COEFF



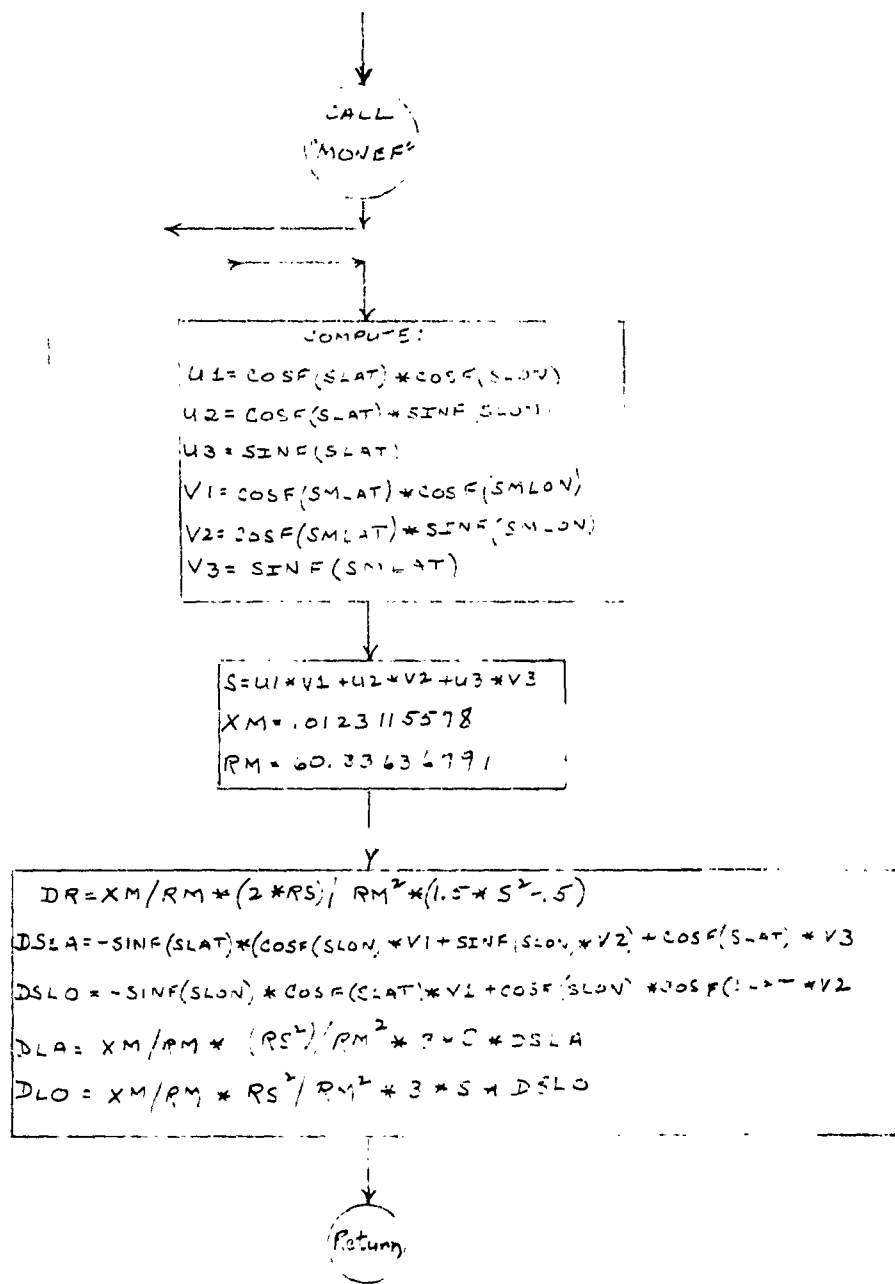
COEFF (CONT)



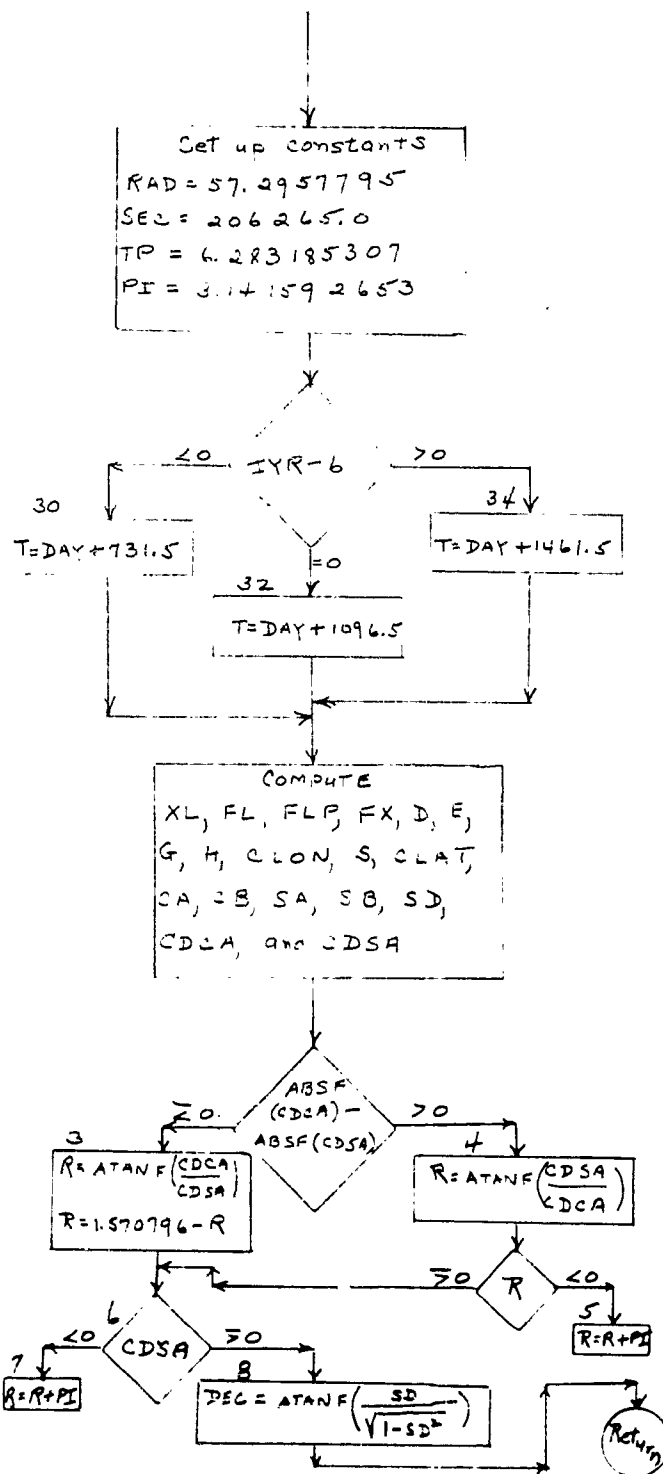
Subroutine GTOBS



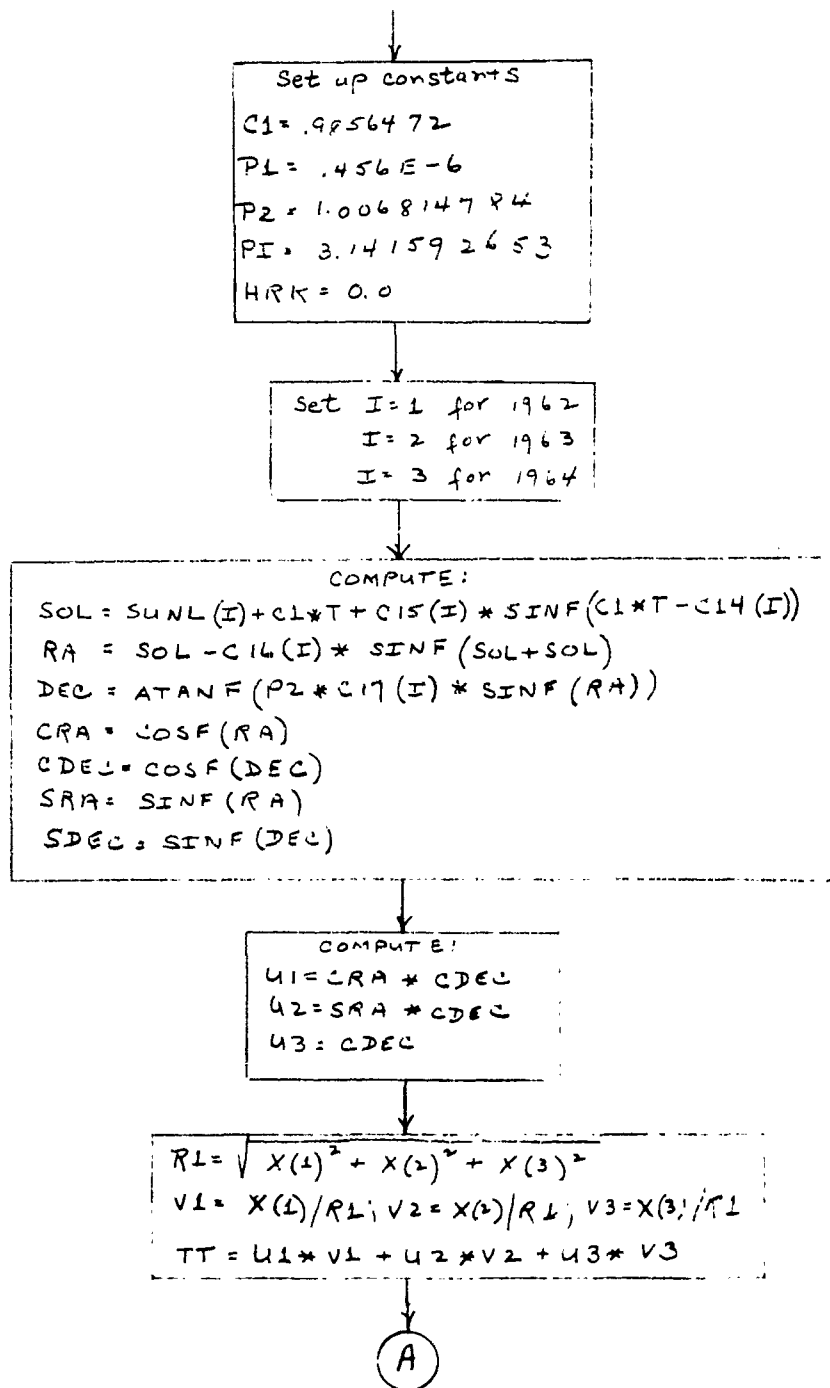
Subroutine L3DEF



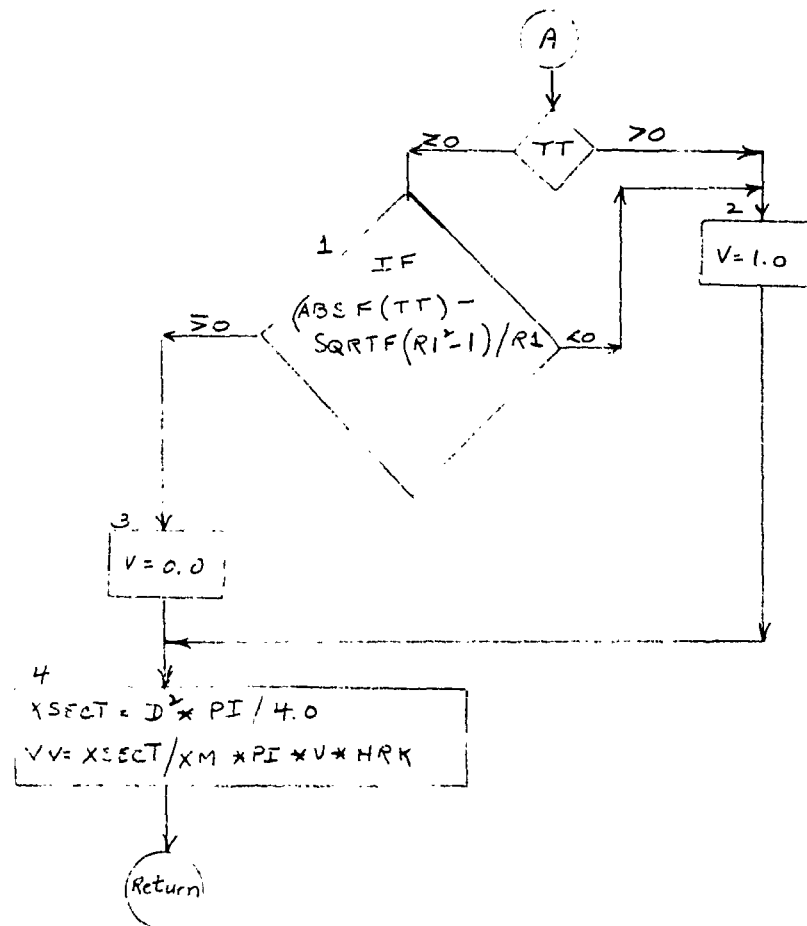
Subroutine MONEF



Subroutine PRESS

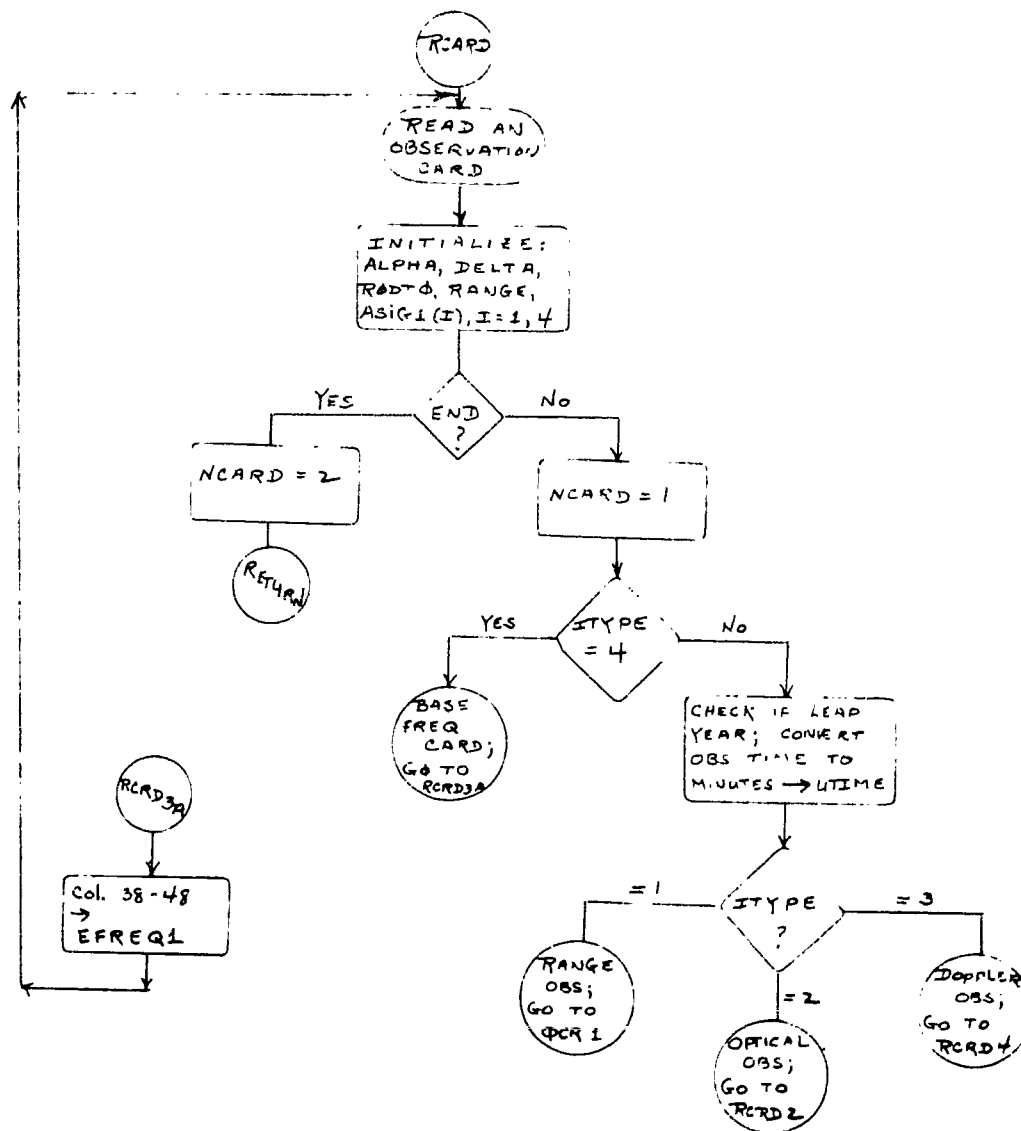


PRESS (cont)

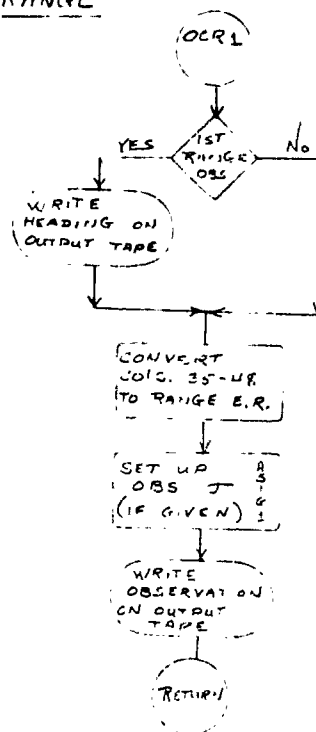


SUBROUTINE: RCARD

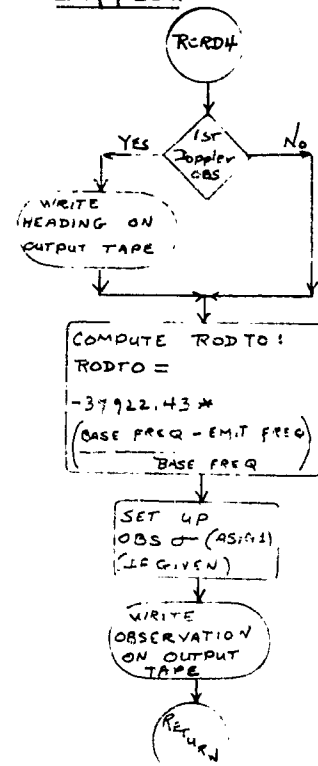
Read and convert an observation card



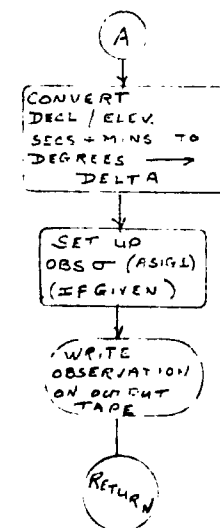
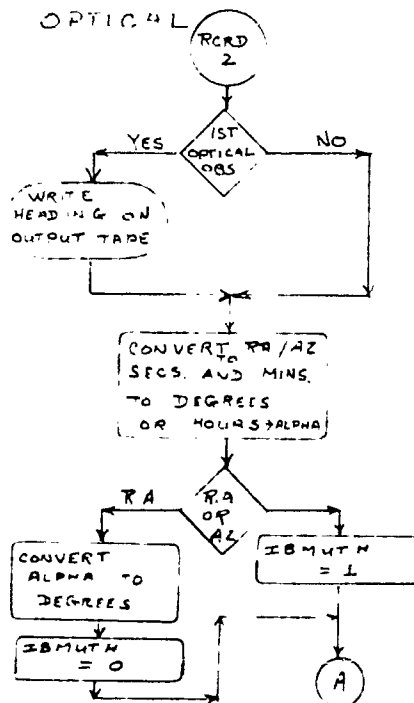
RANGE



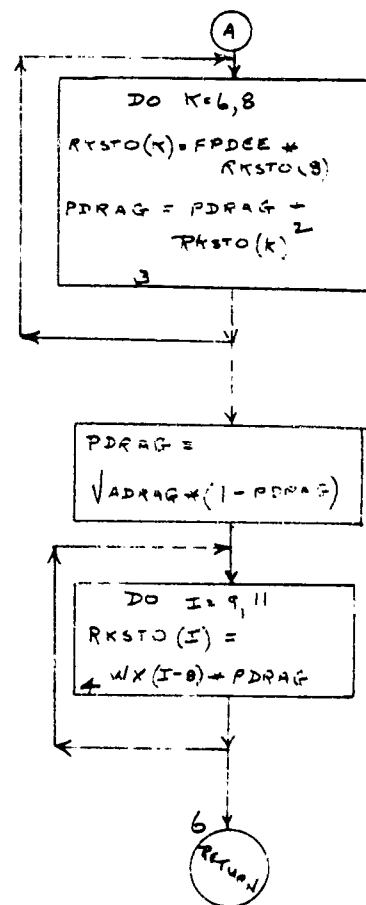
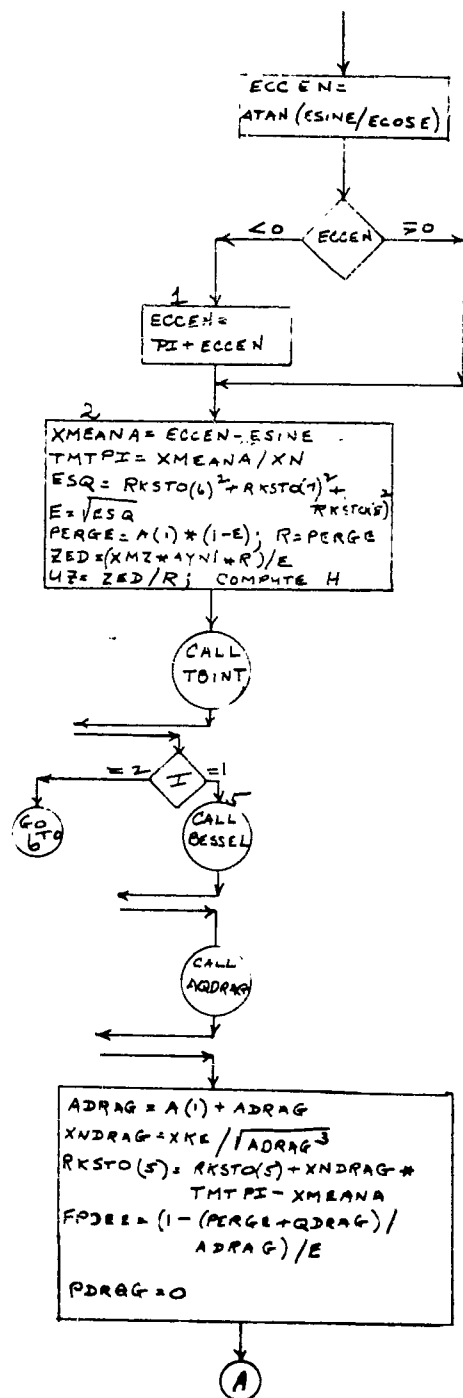
DOPPLER



OPTICAL

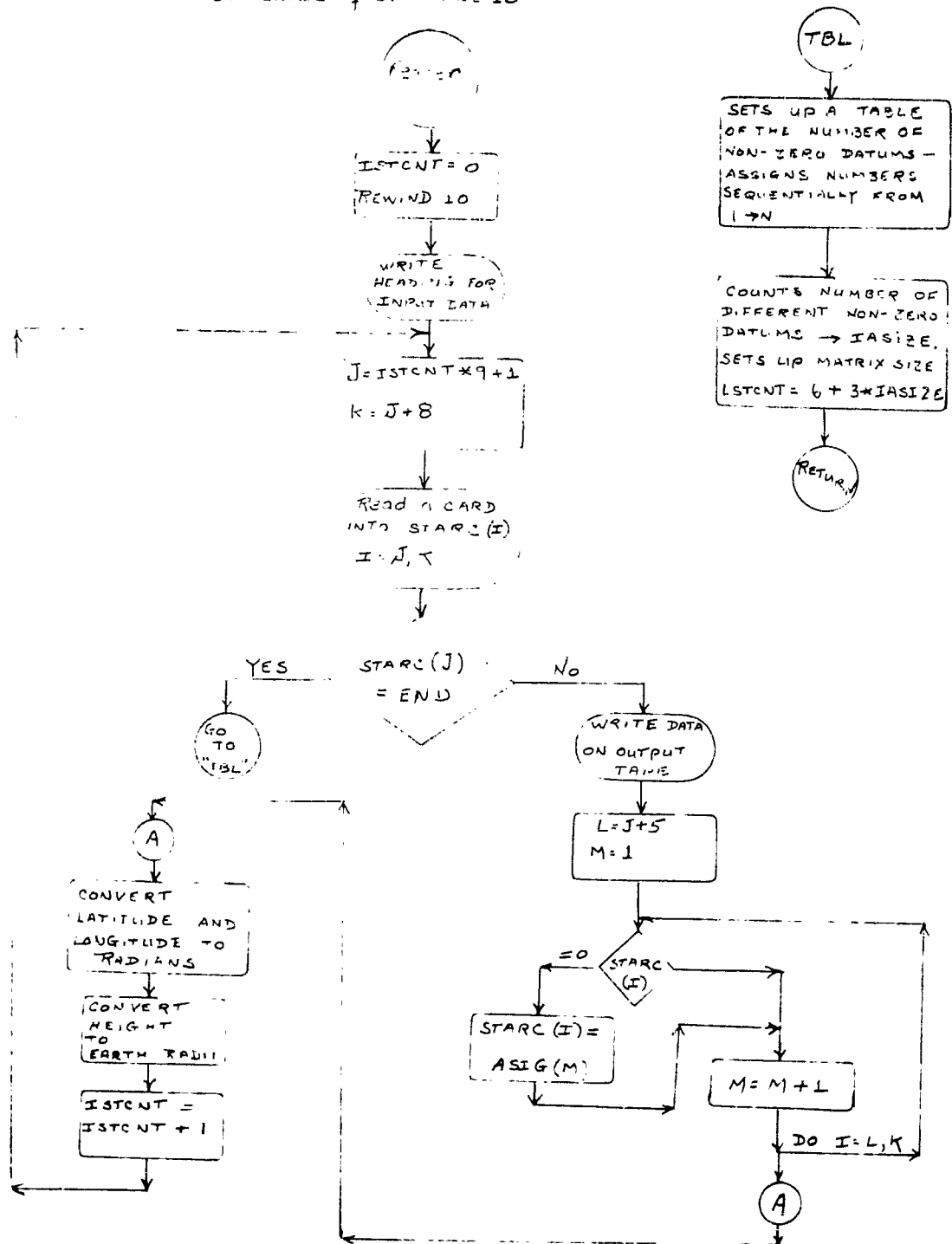


Subroutine RECTFY

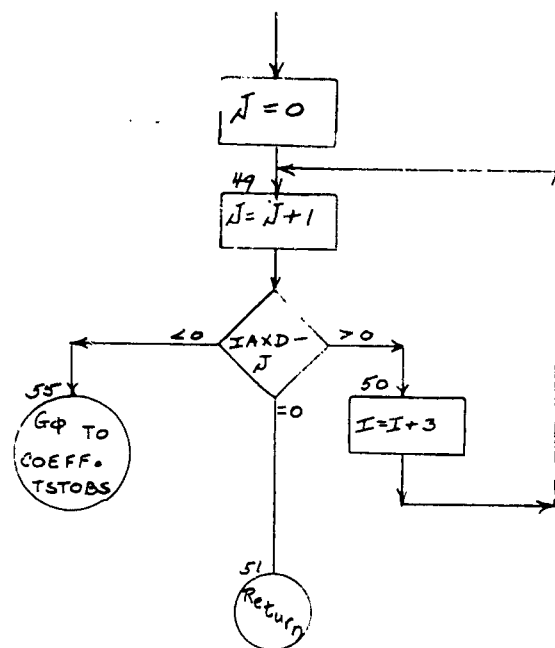


SUBROUTINE: REALTM

Read Station Cards from TAPE 10

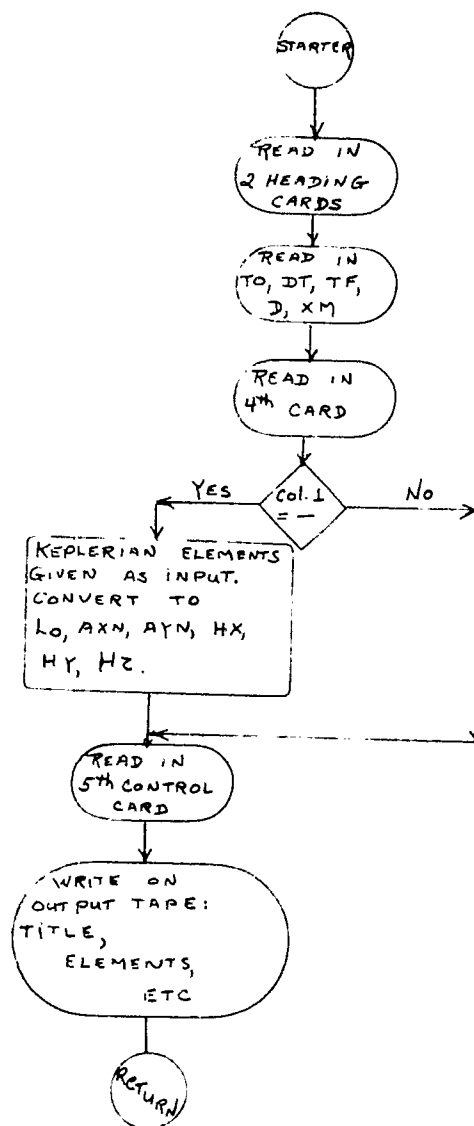


Subroutine SETI

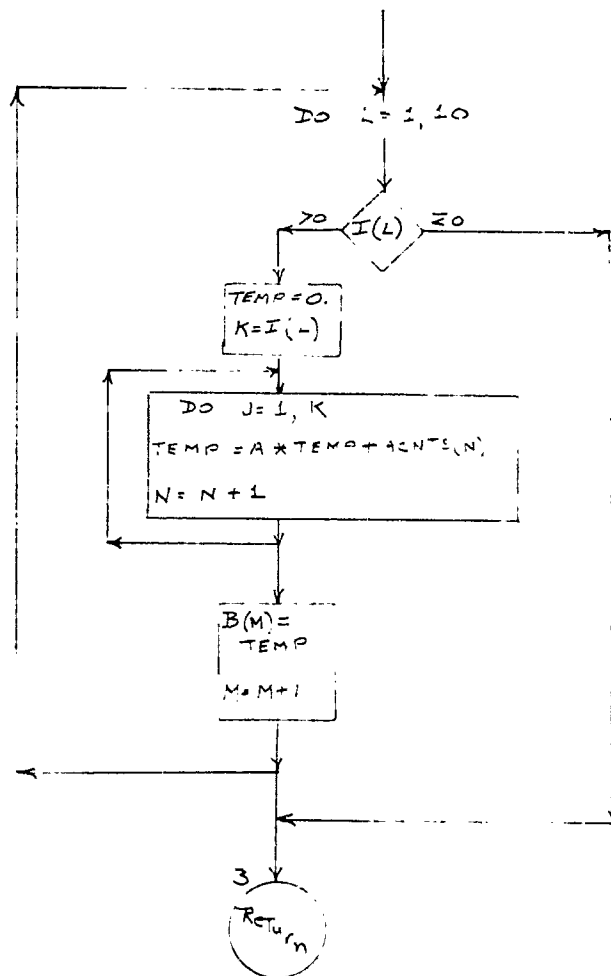


SUBROUTINE . STARTER

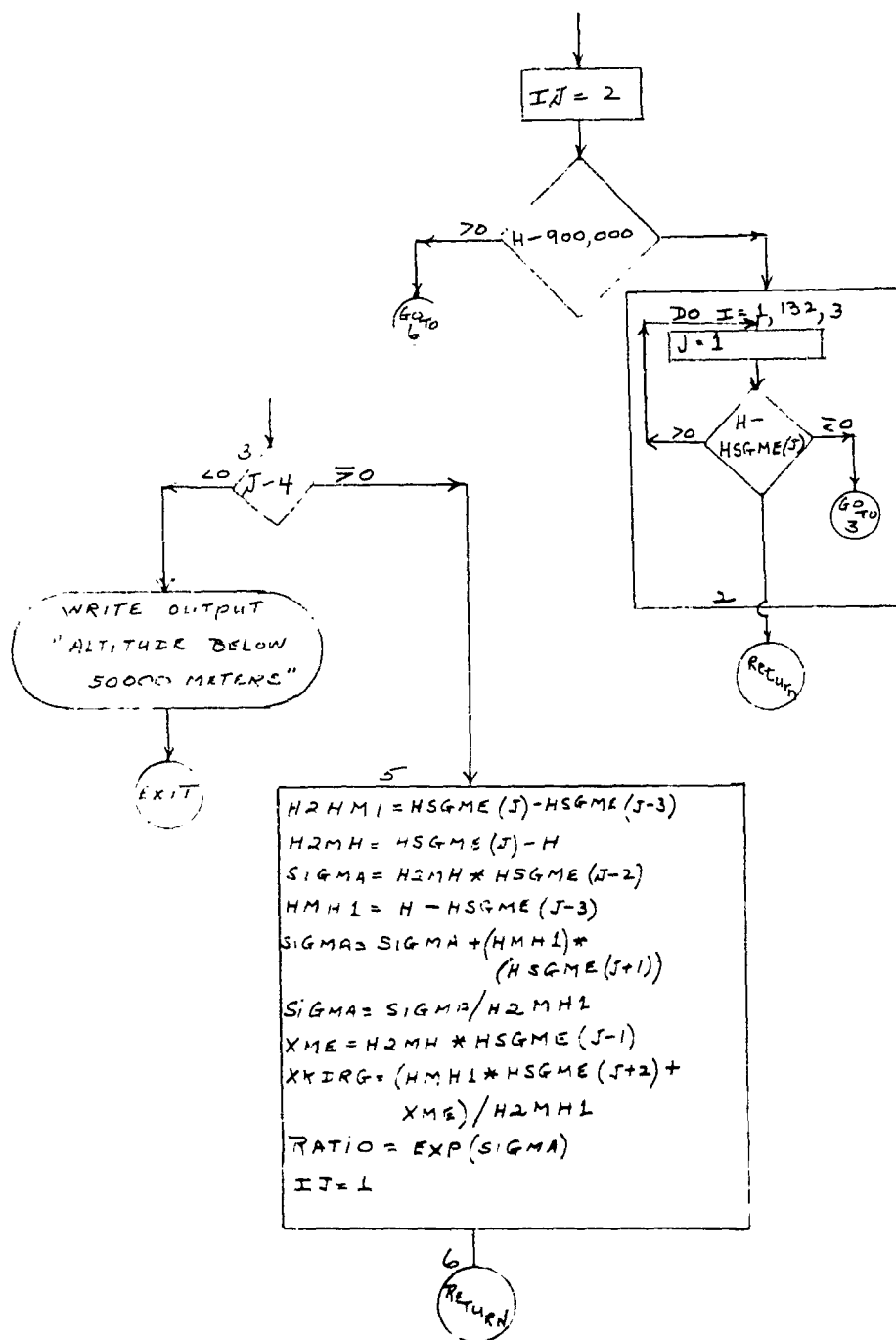
READ 1ST FIVE CONTROL CARDS



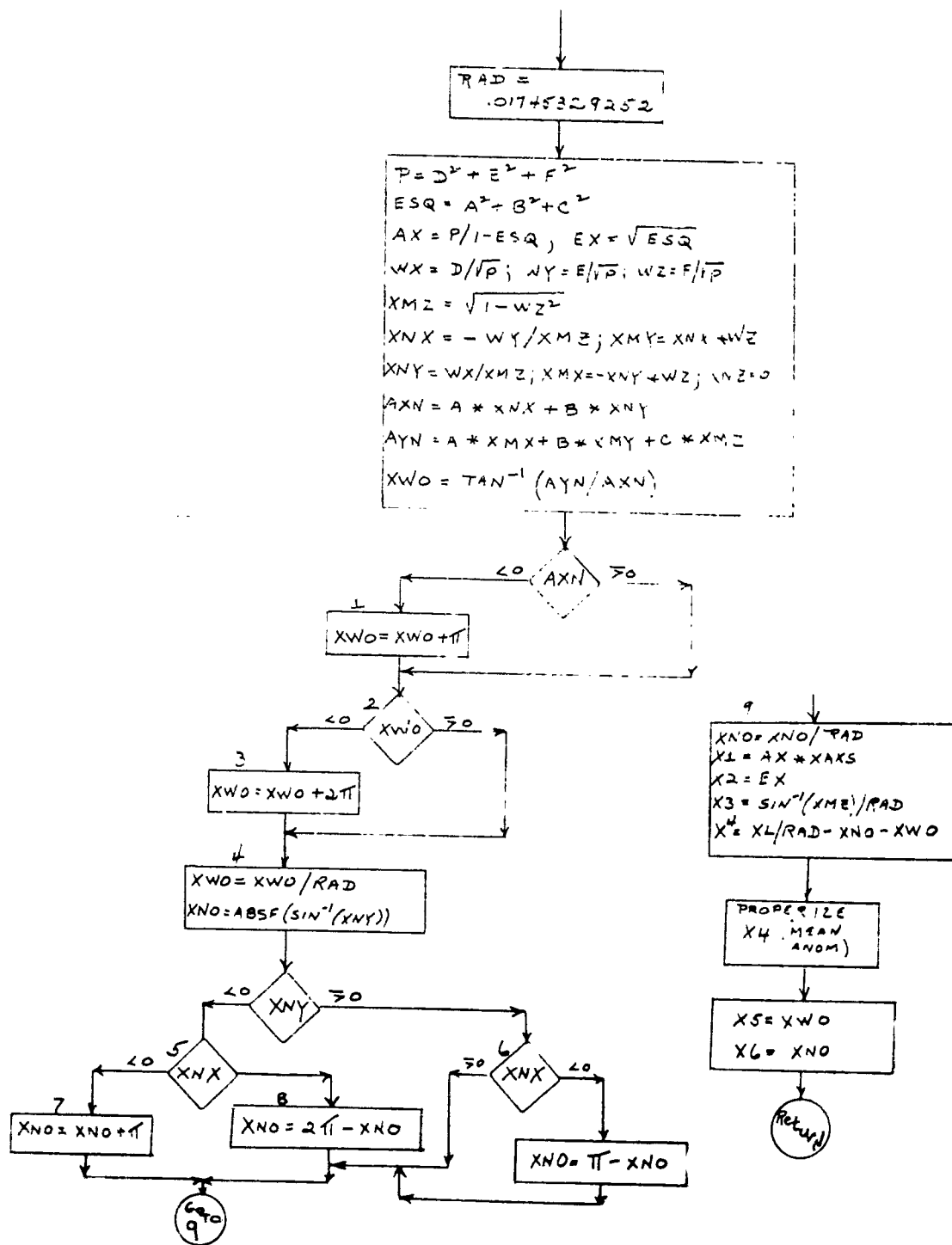
Subroutine SUMM



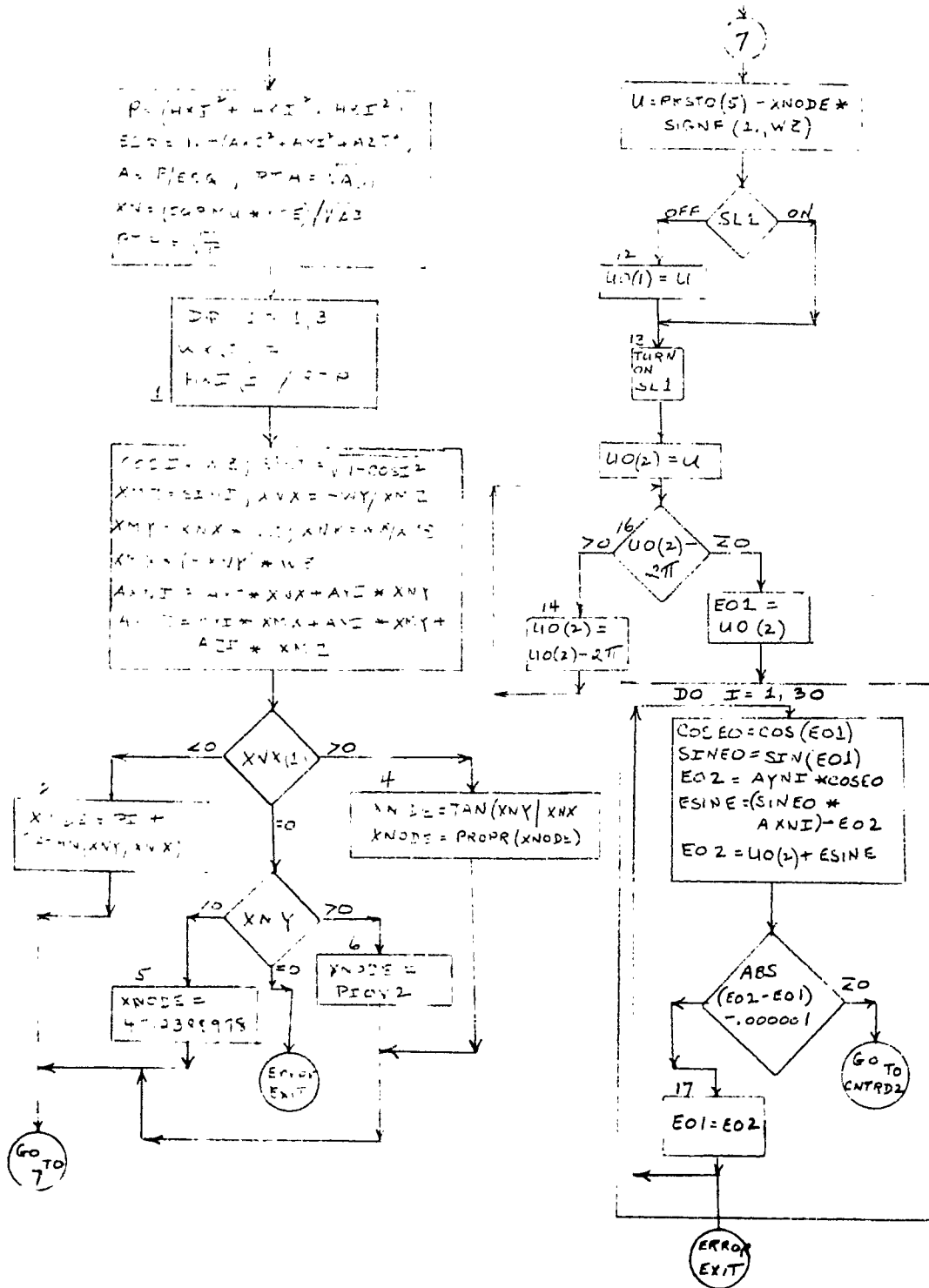
Subroutine TBINT



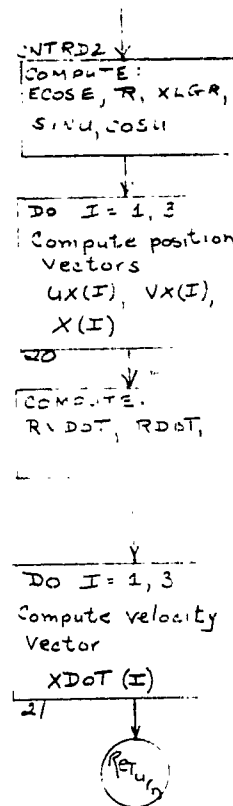
Subroutine XEL



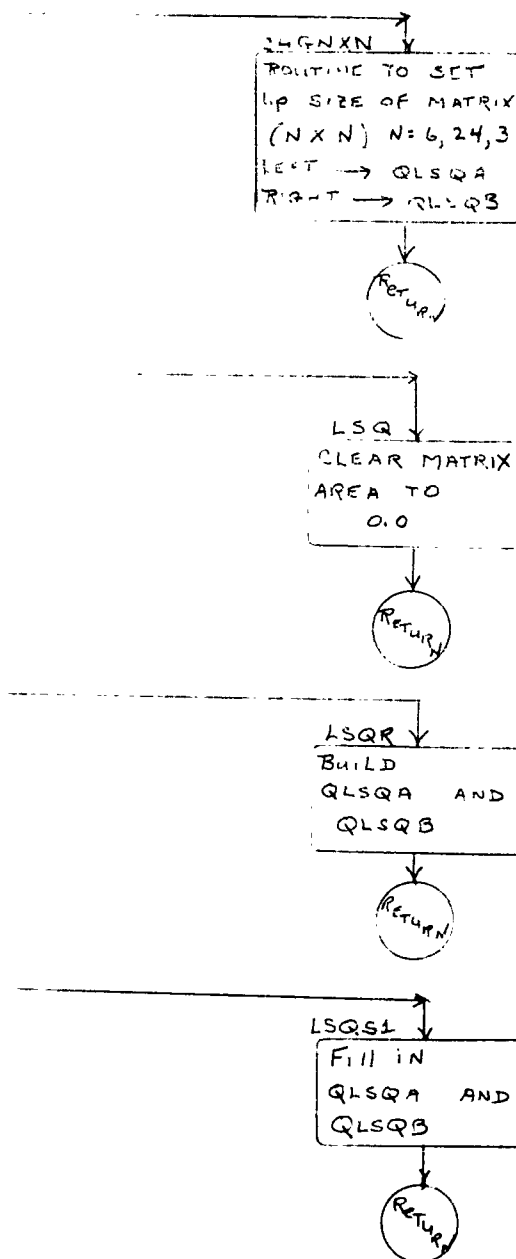
Subroutine A'2.0E

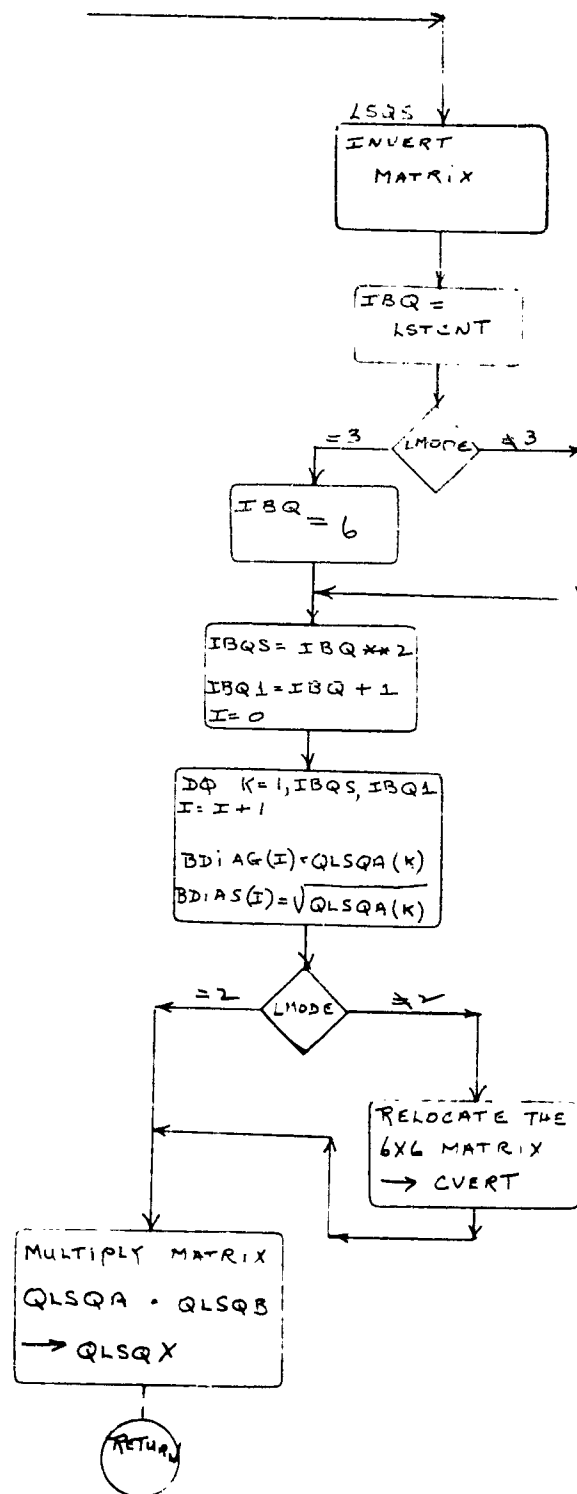


XYZS B (cont)



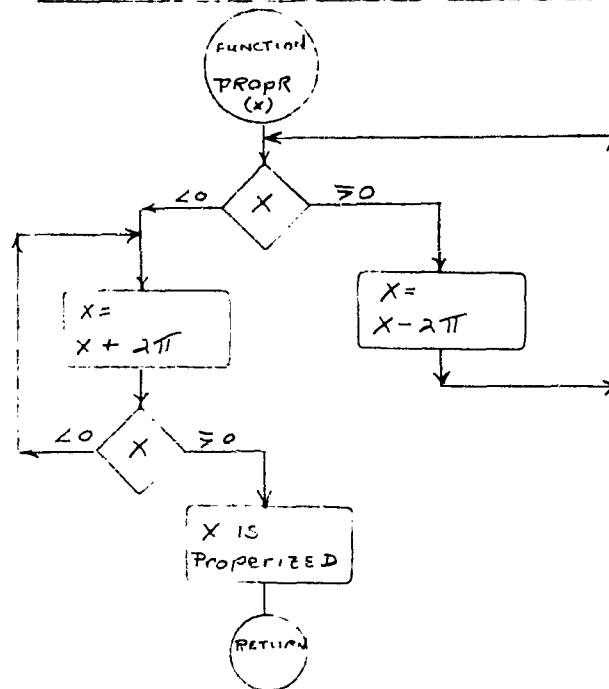
LEAST SQUARES SUBROUTINE



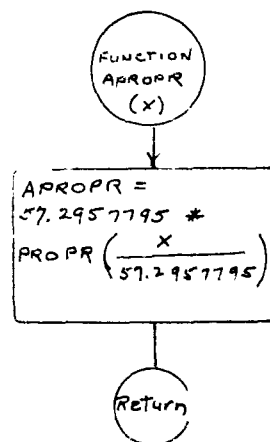


PROPERIZES ANGLE GIVEN IN RADIAN

SUBROUTINES

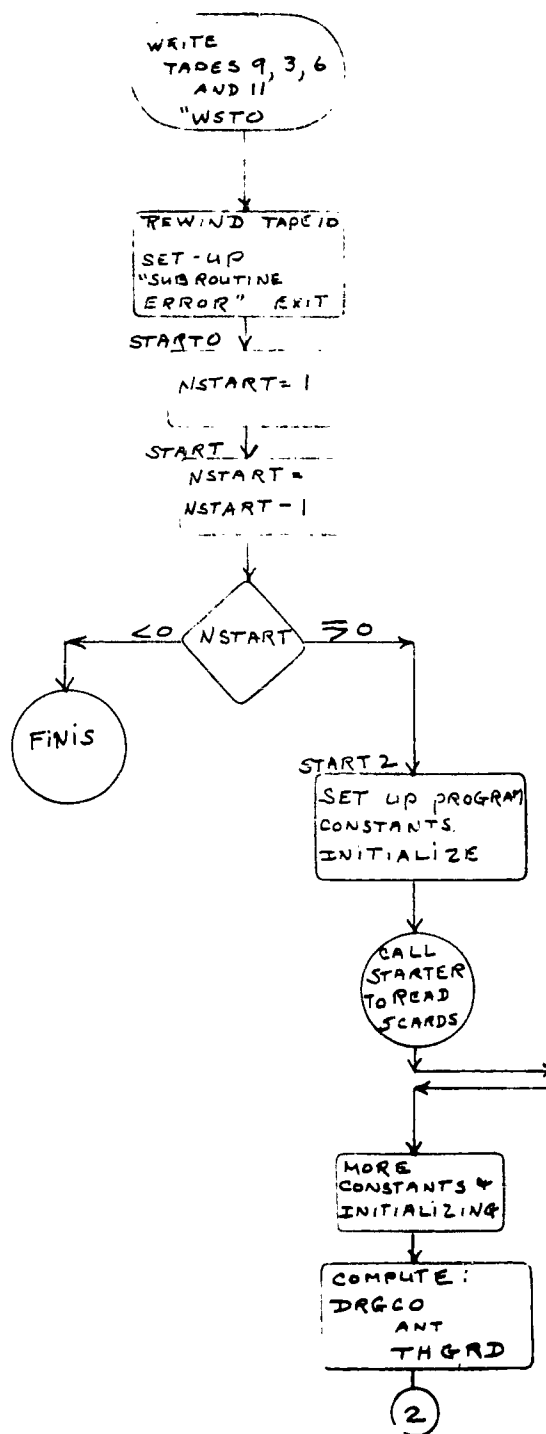


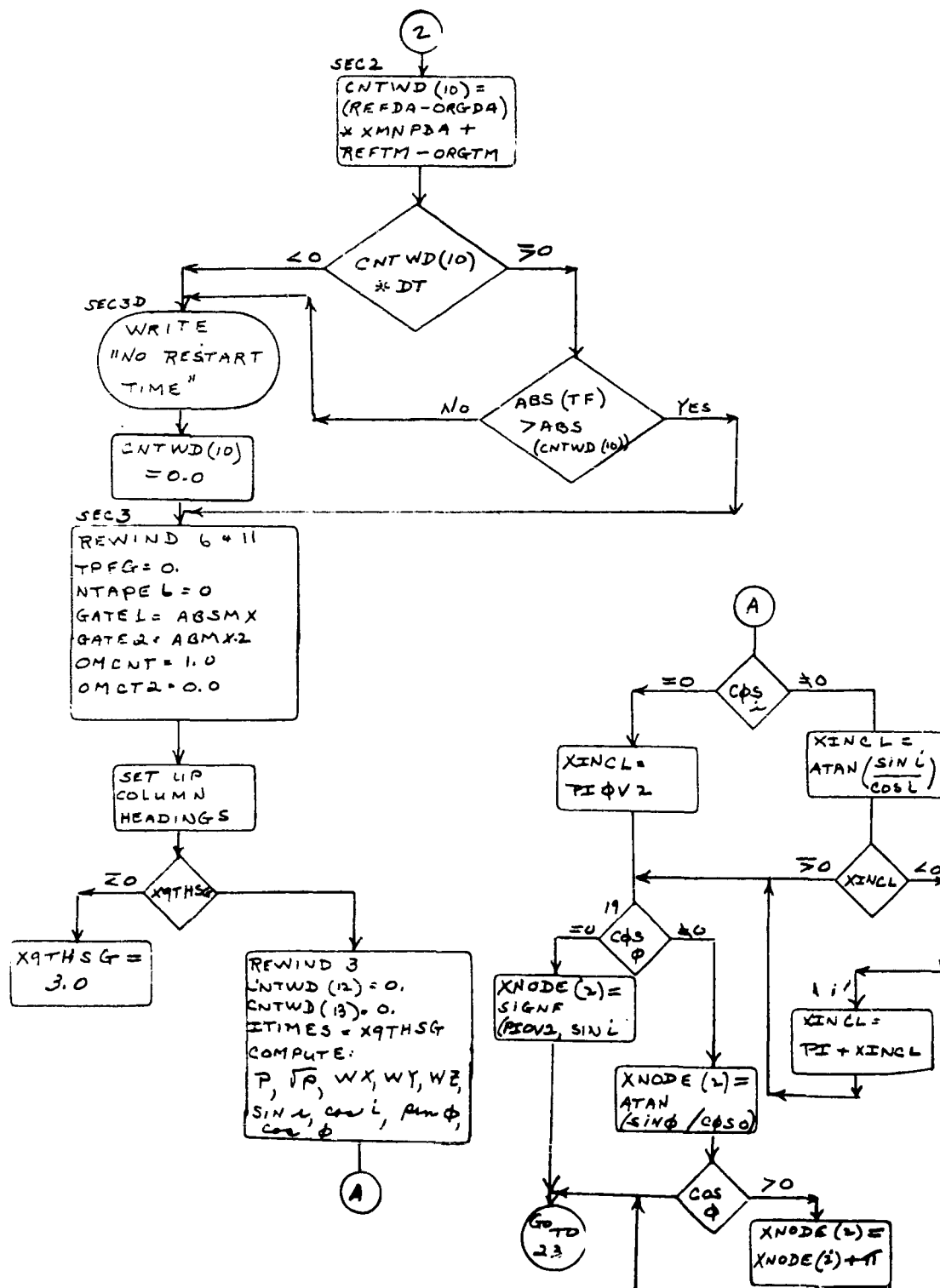
PROPERIZES ANGLE GIVEN IN DEGREES

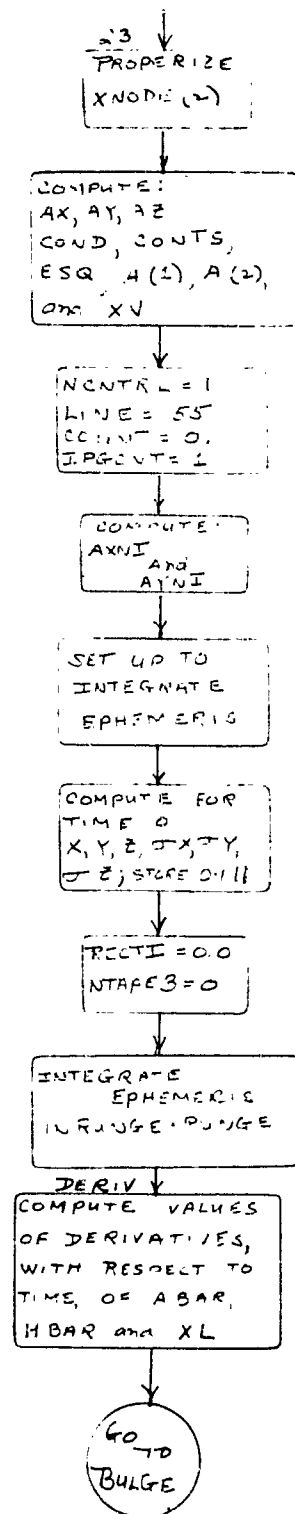


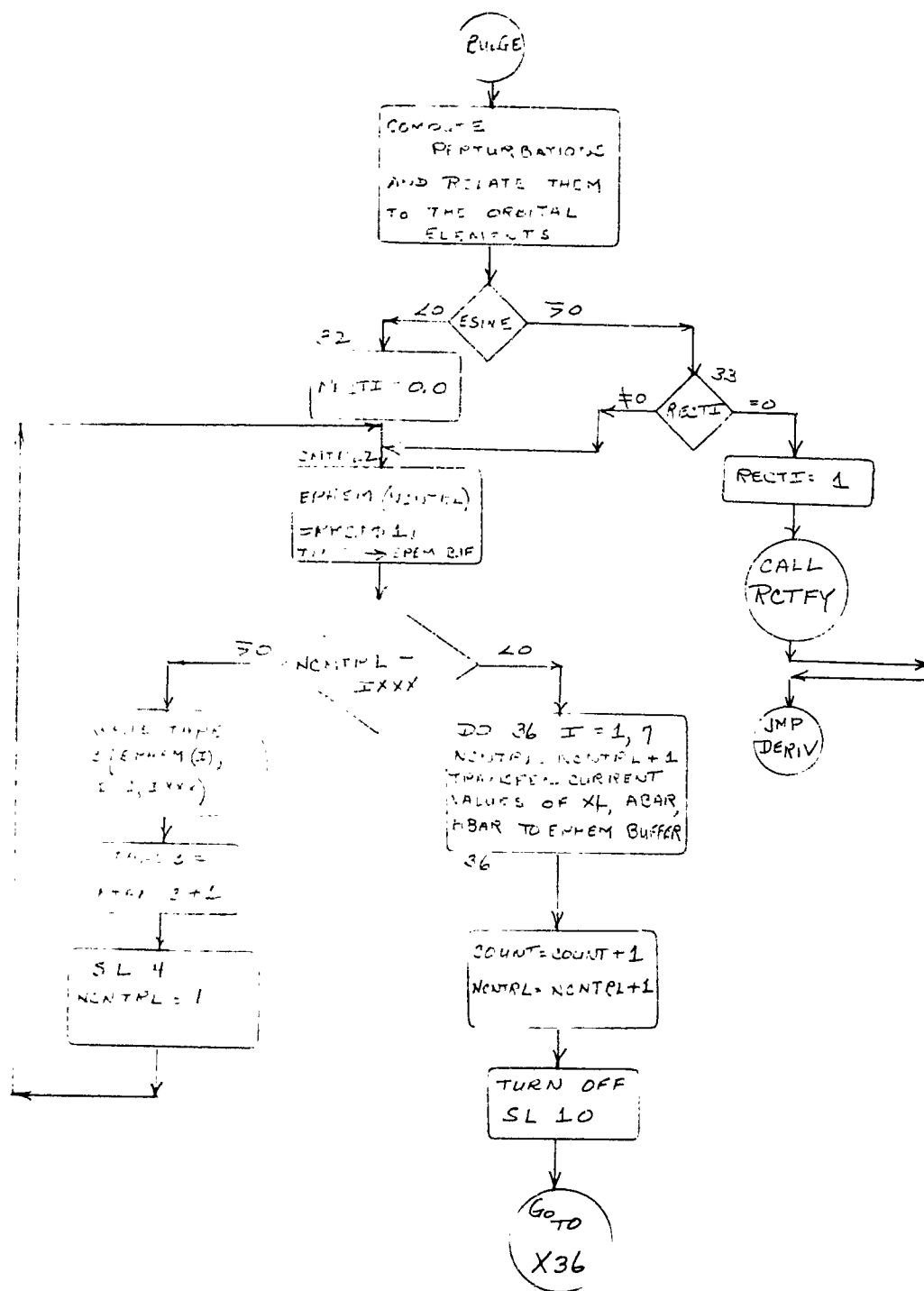
IX

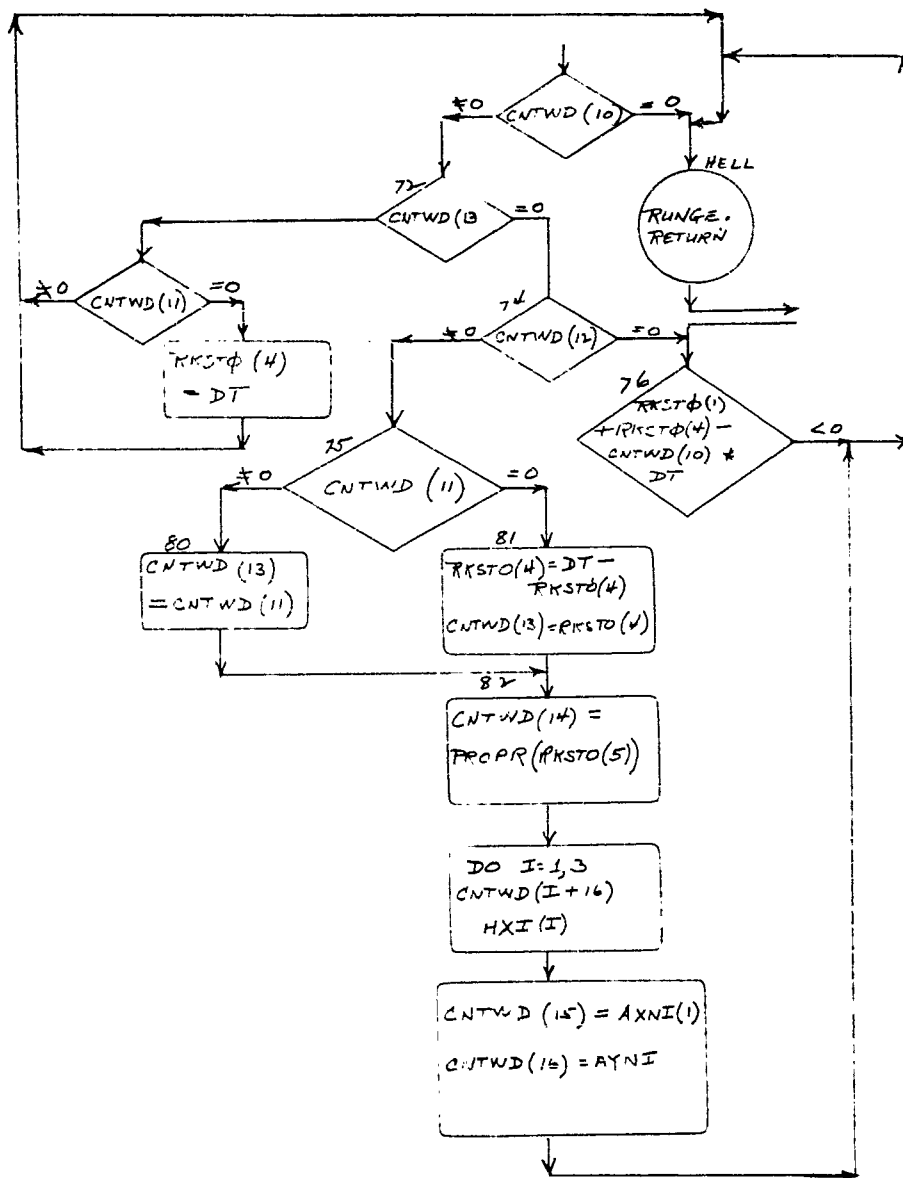
FLOW CHART OF MAIN PROGRAM

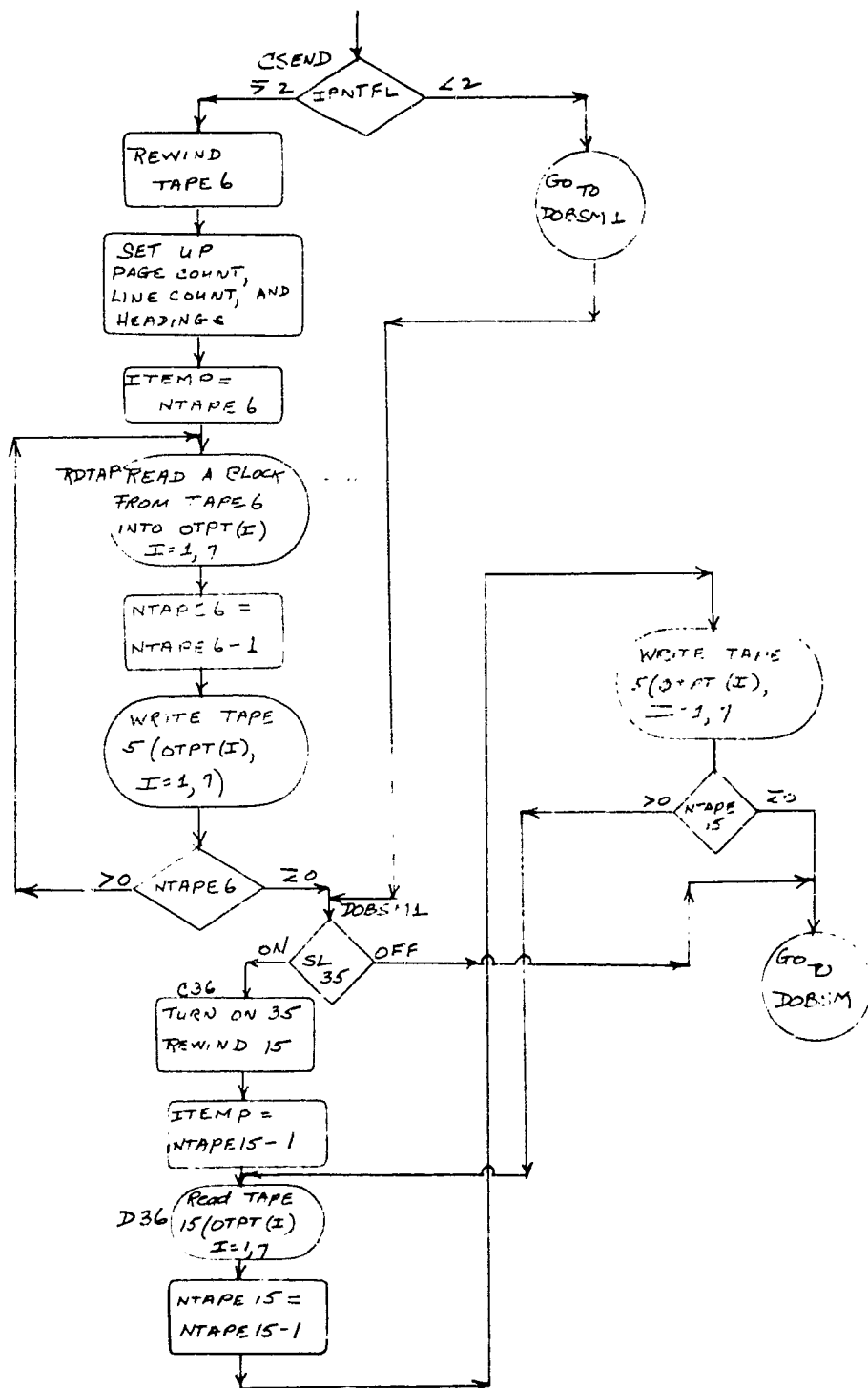


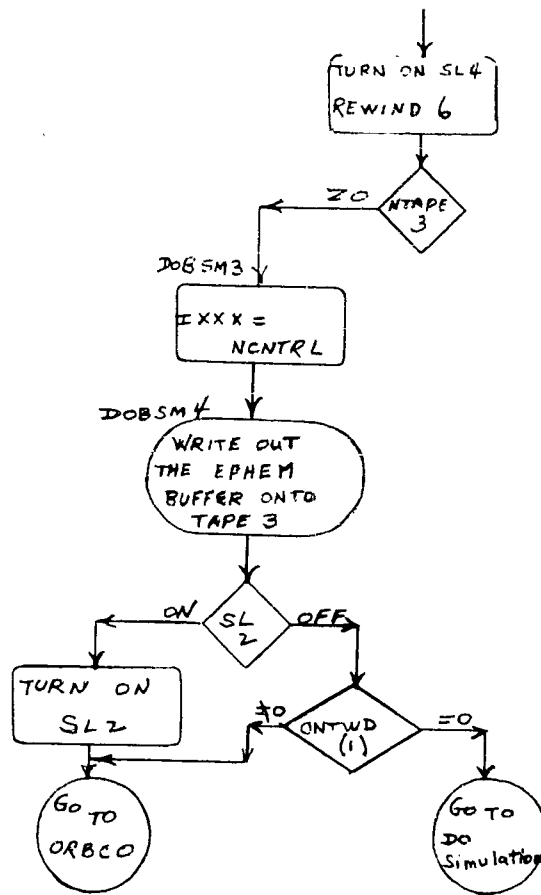


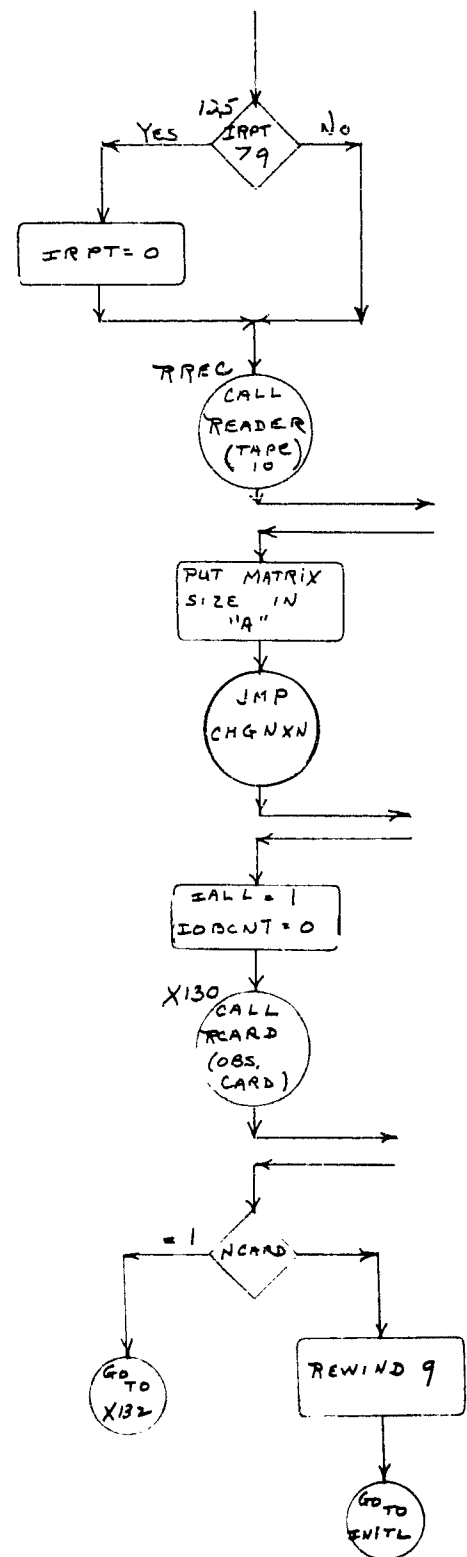
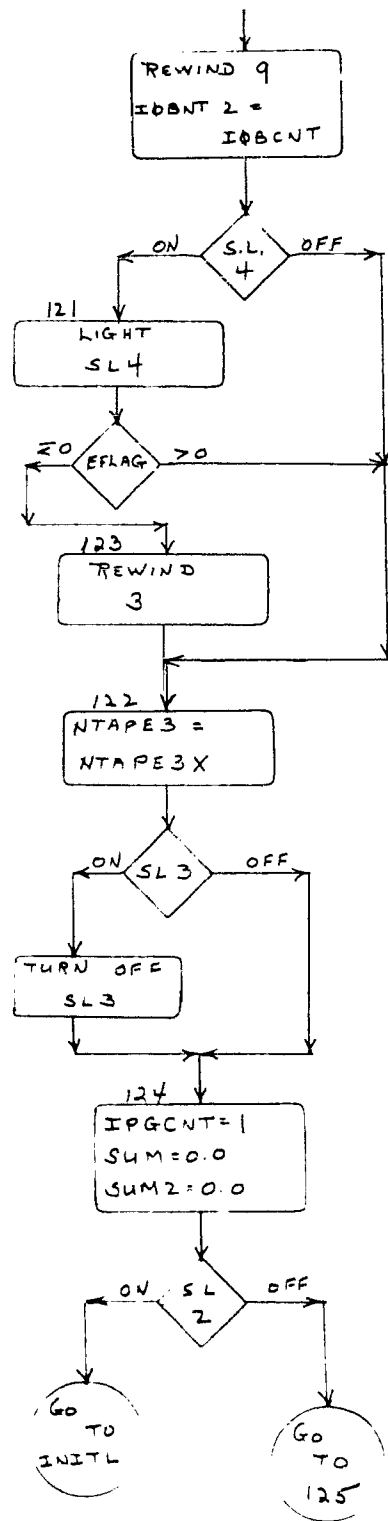


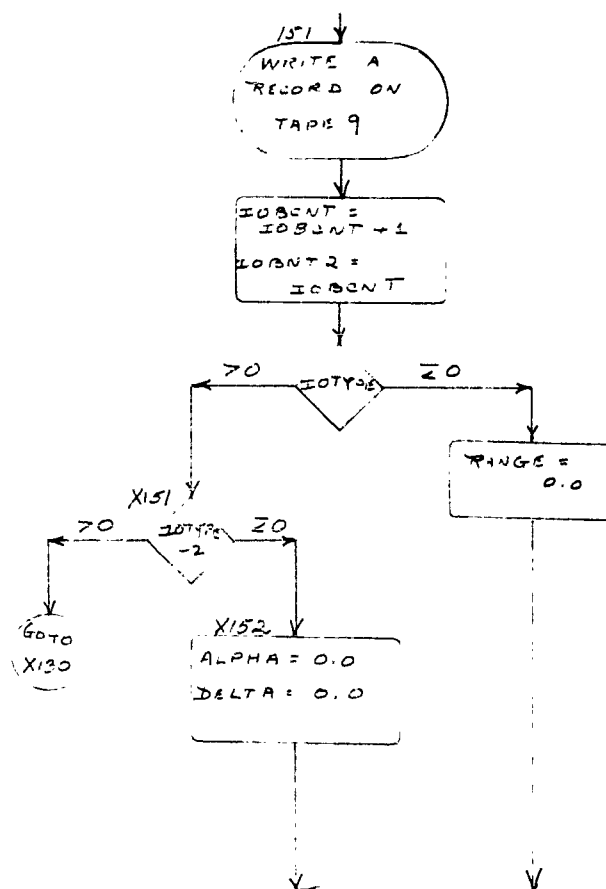
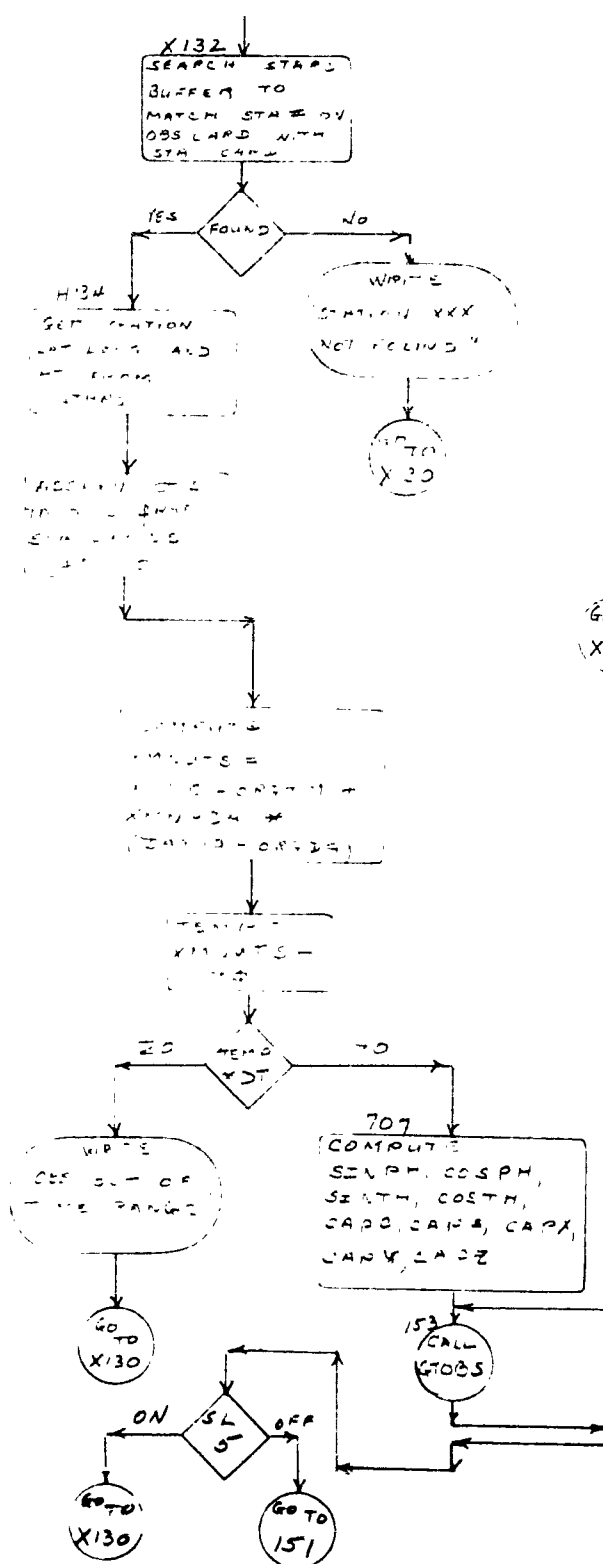


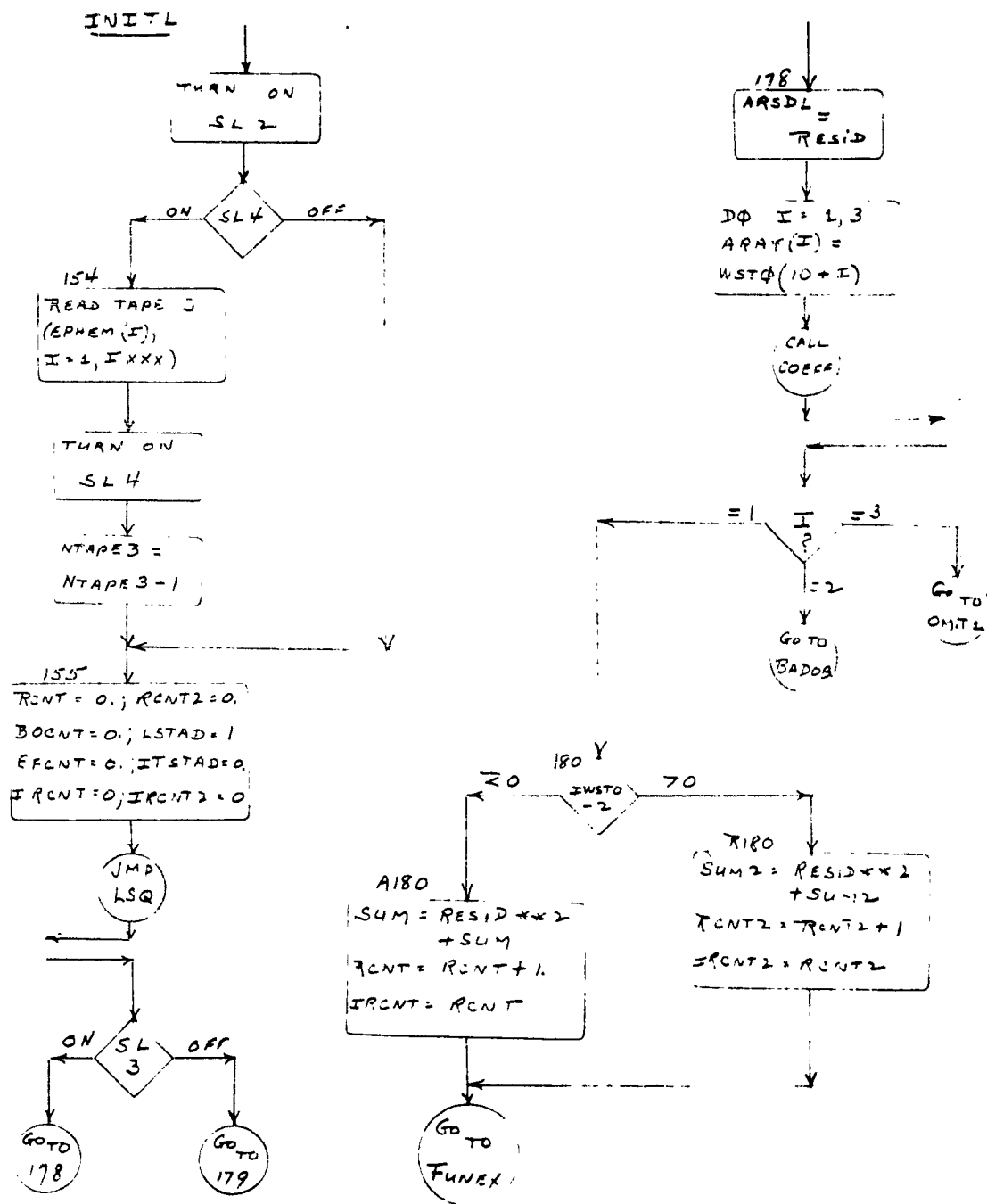


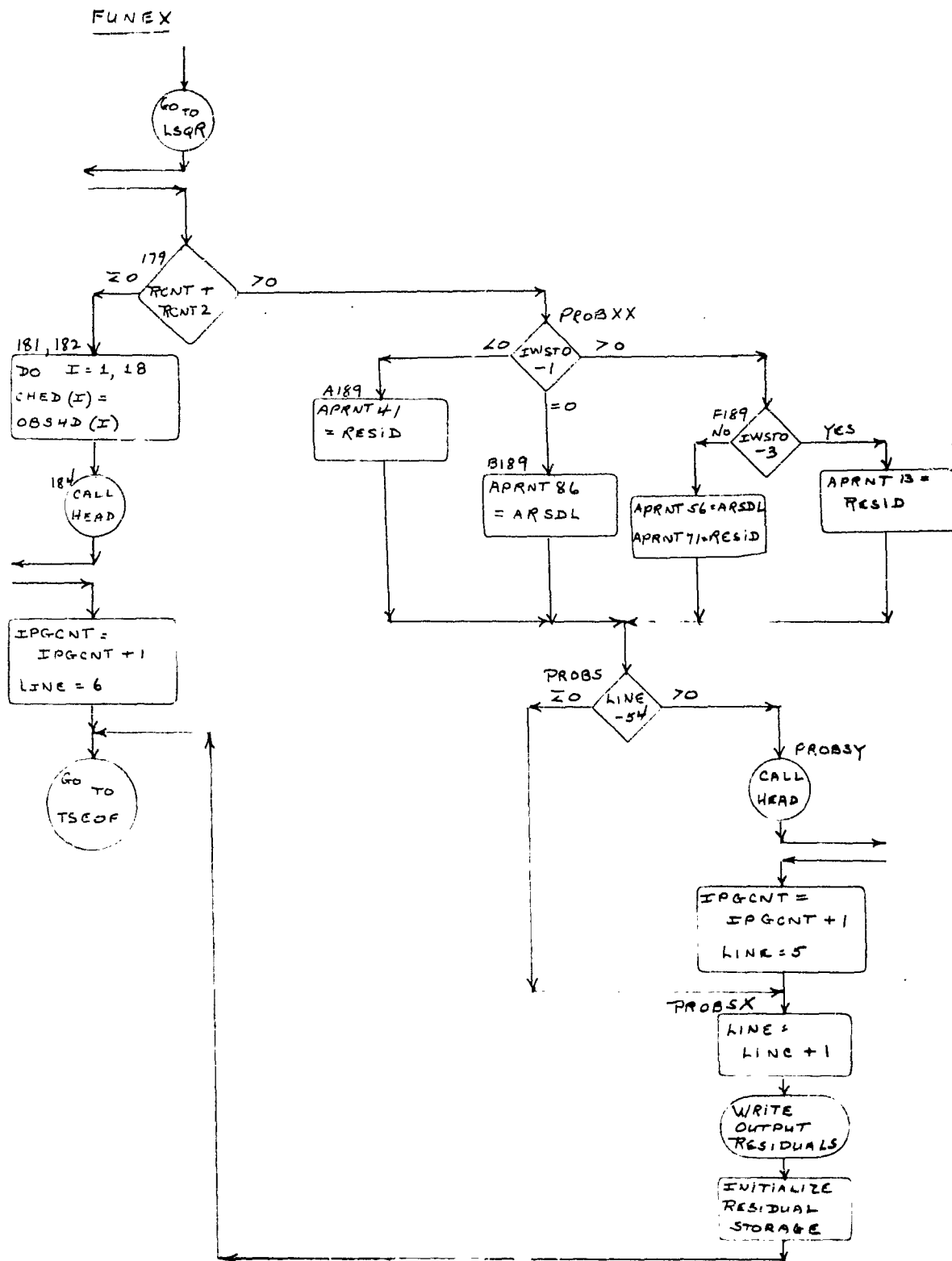


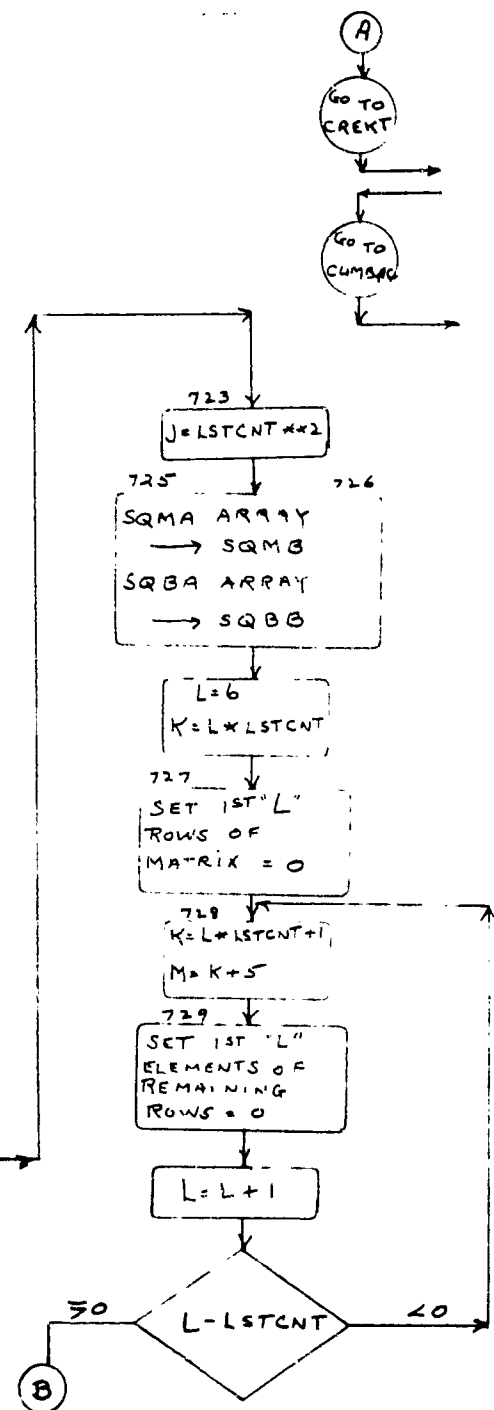
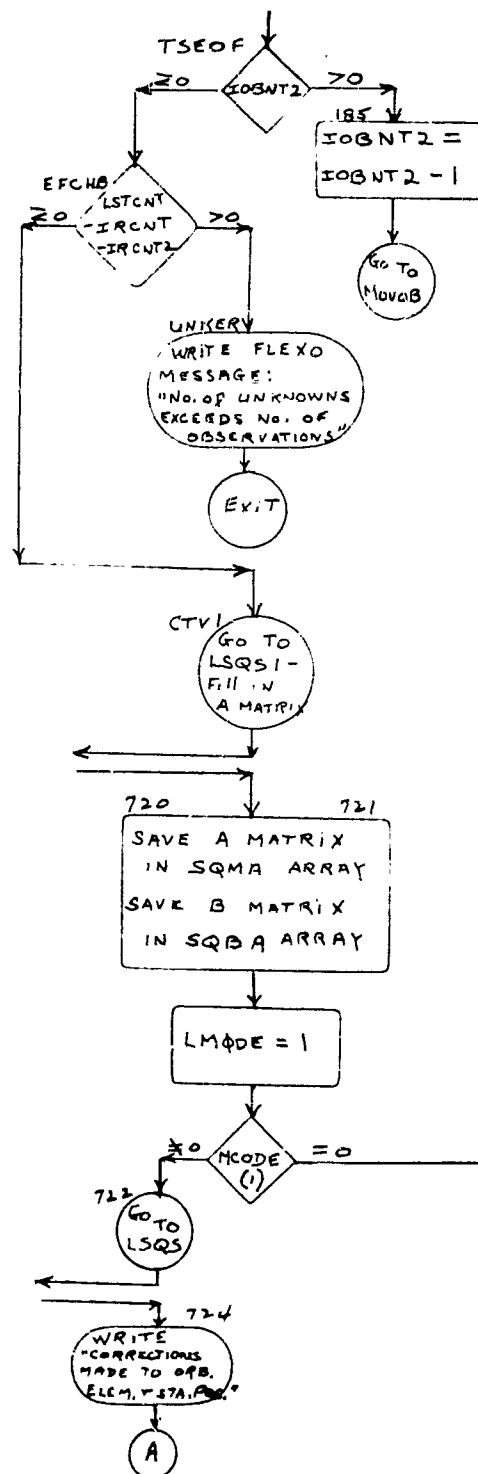


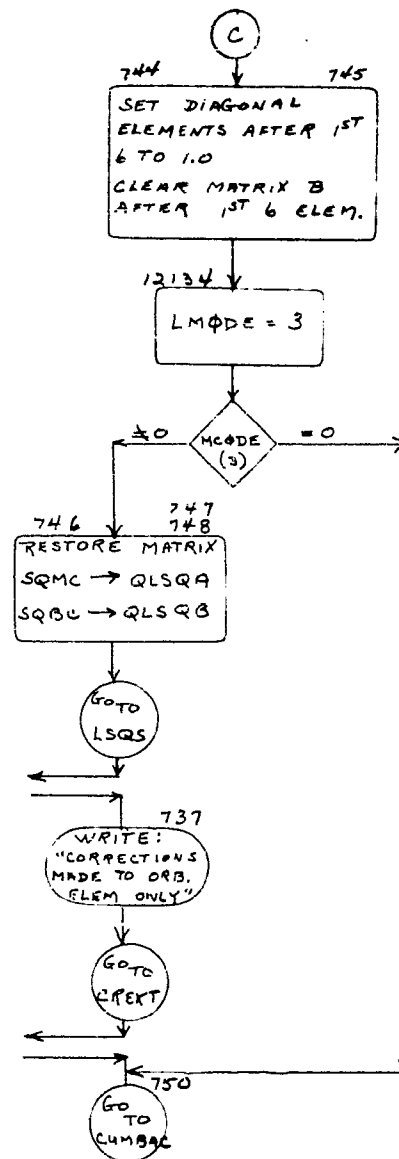


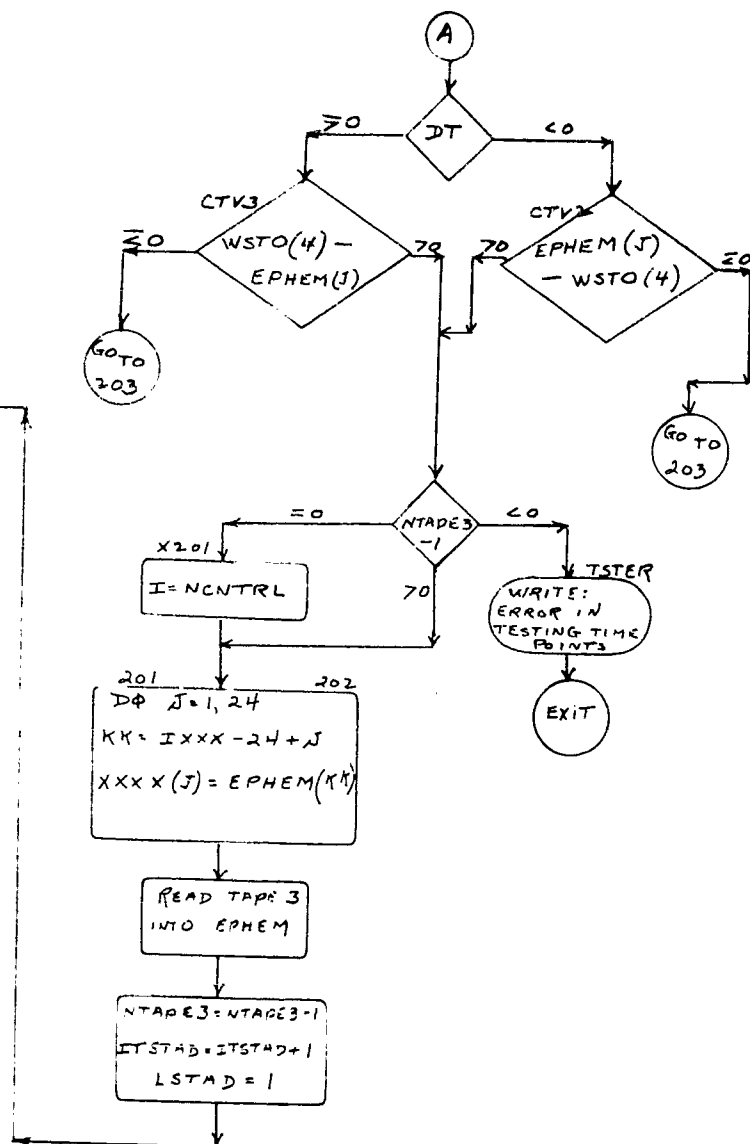
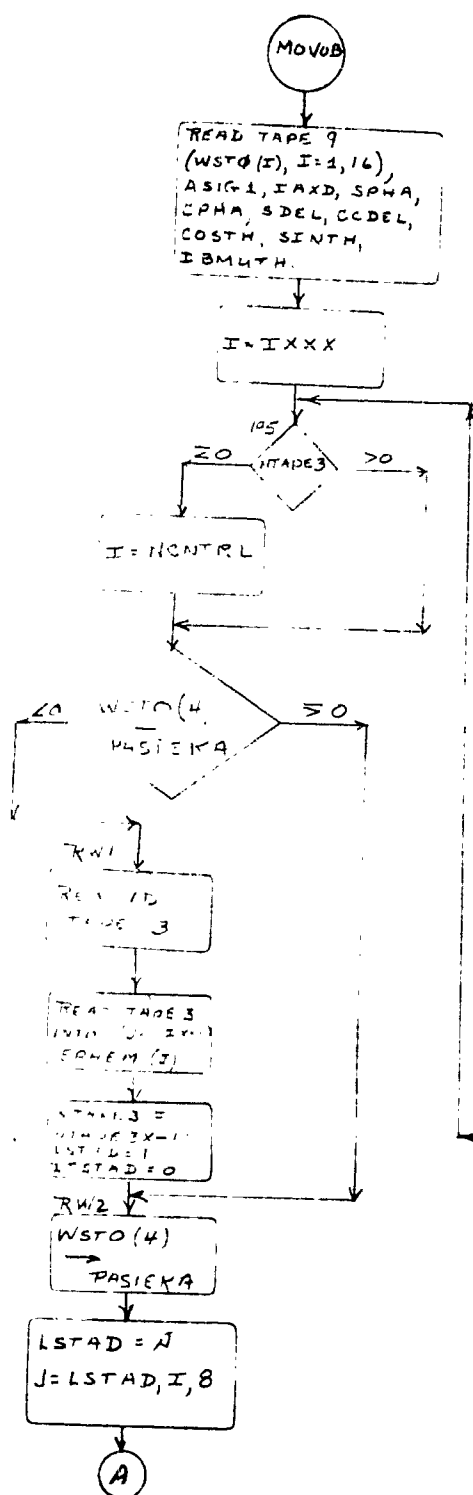




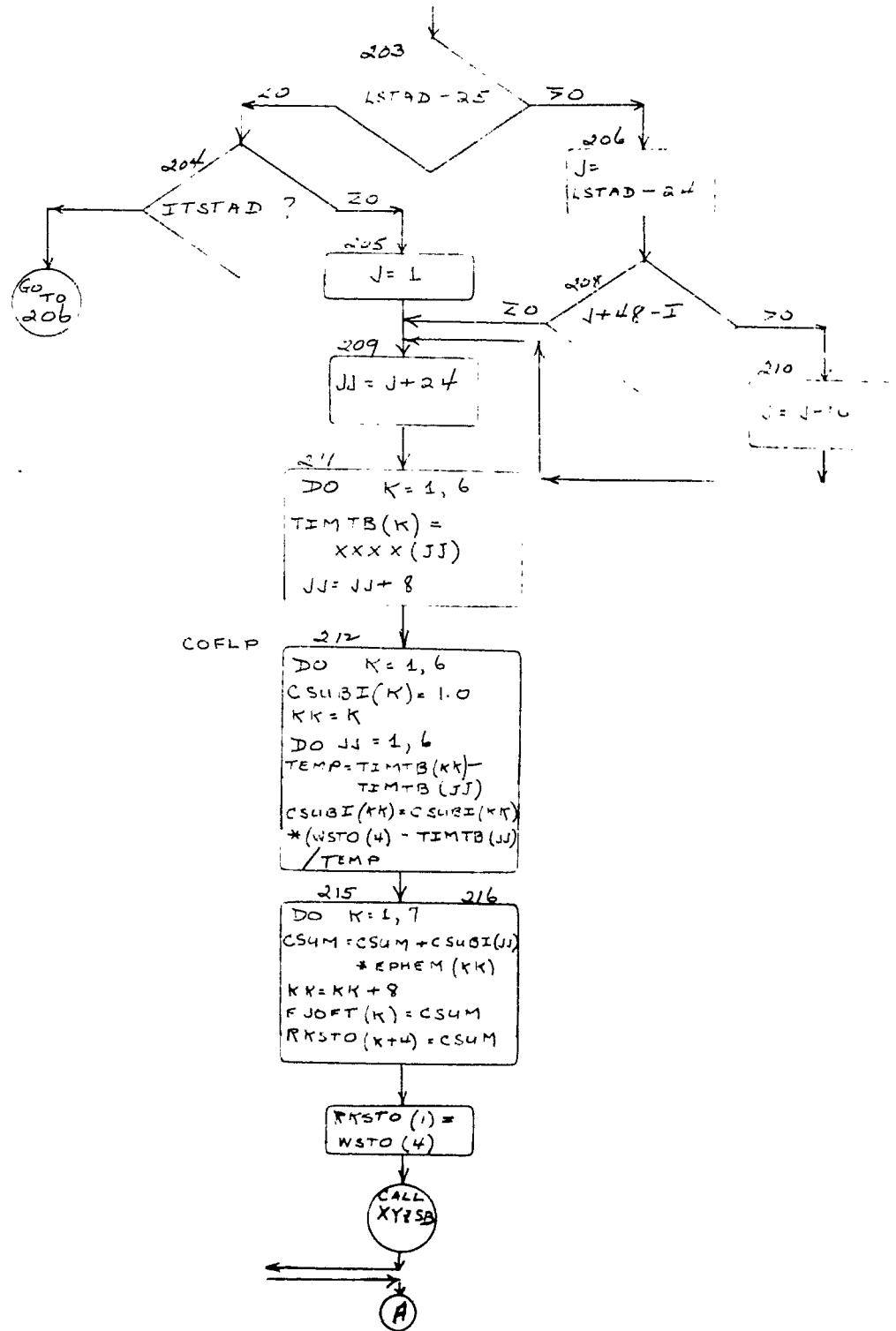


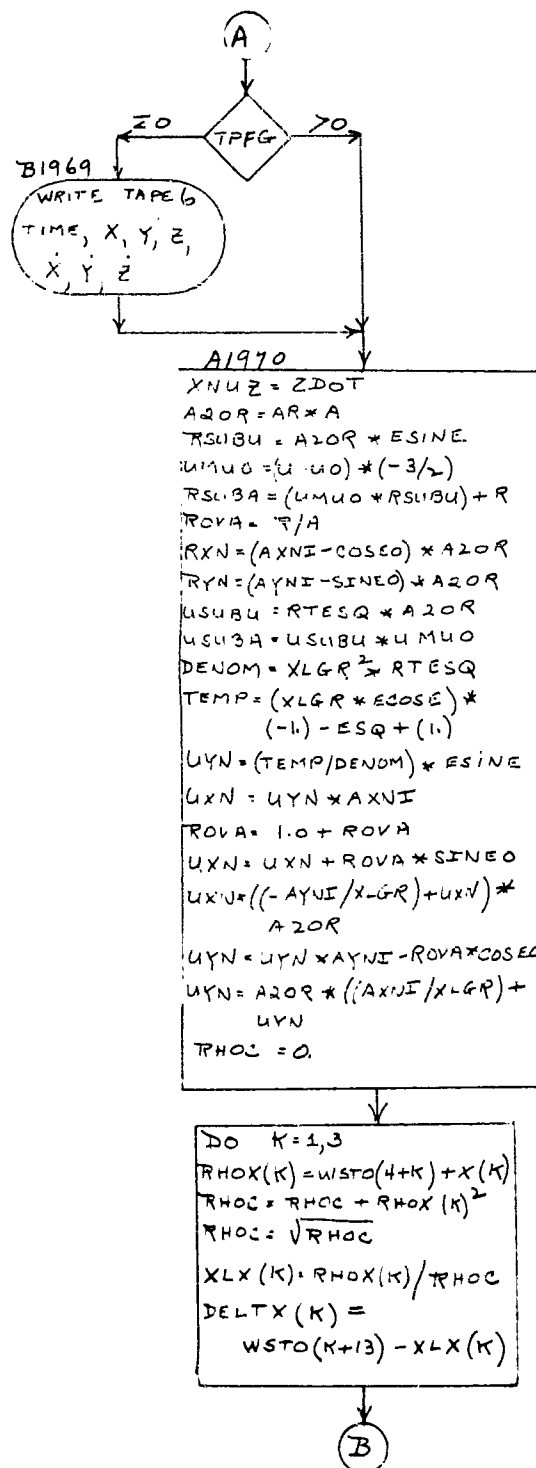


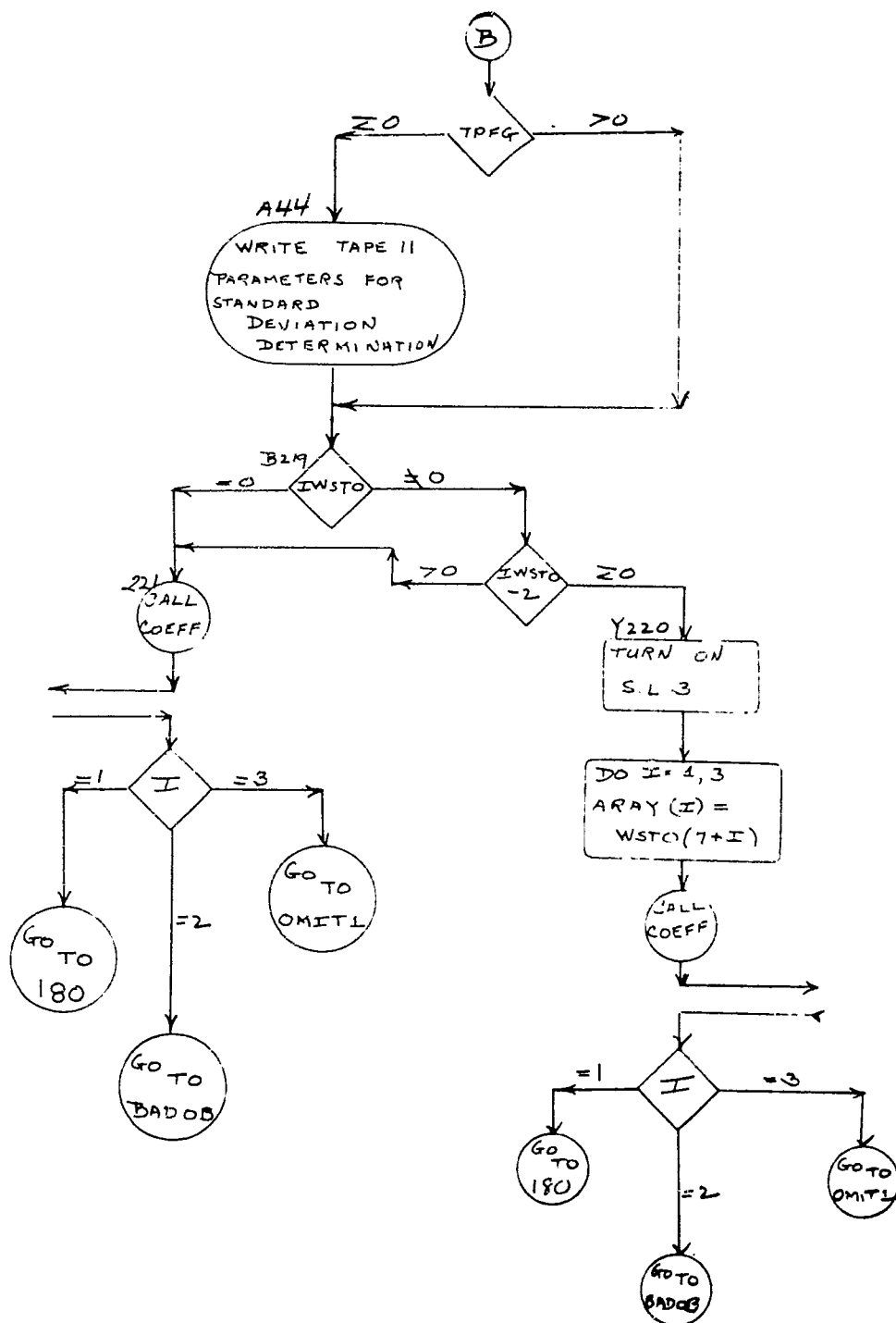


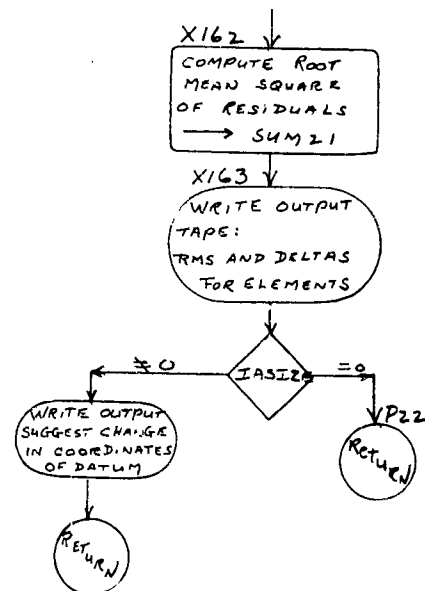
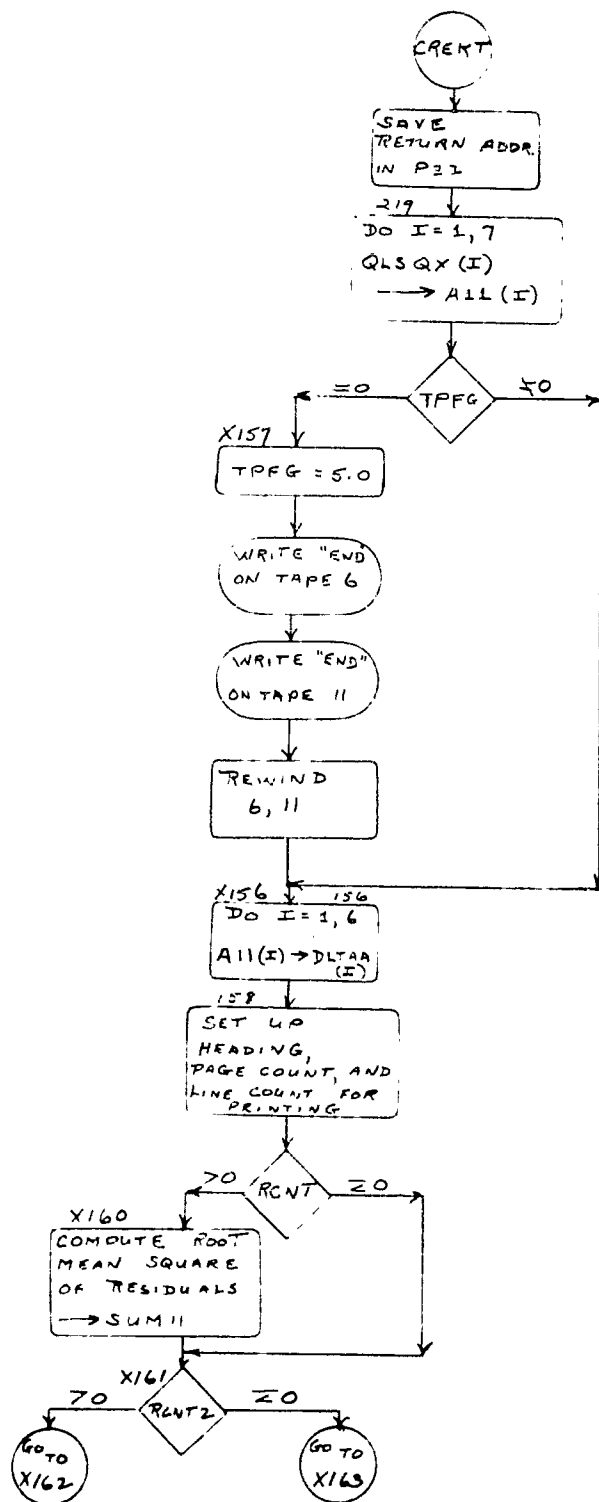


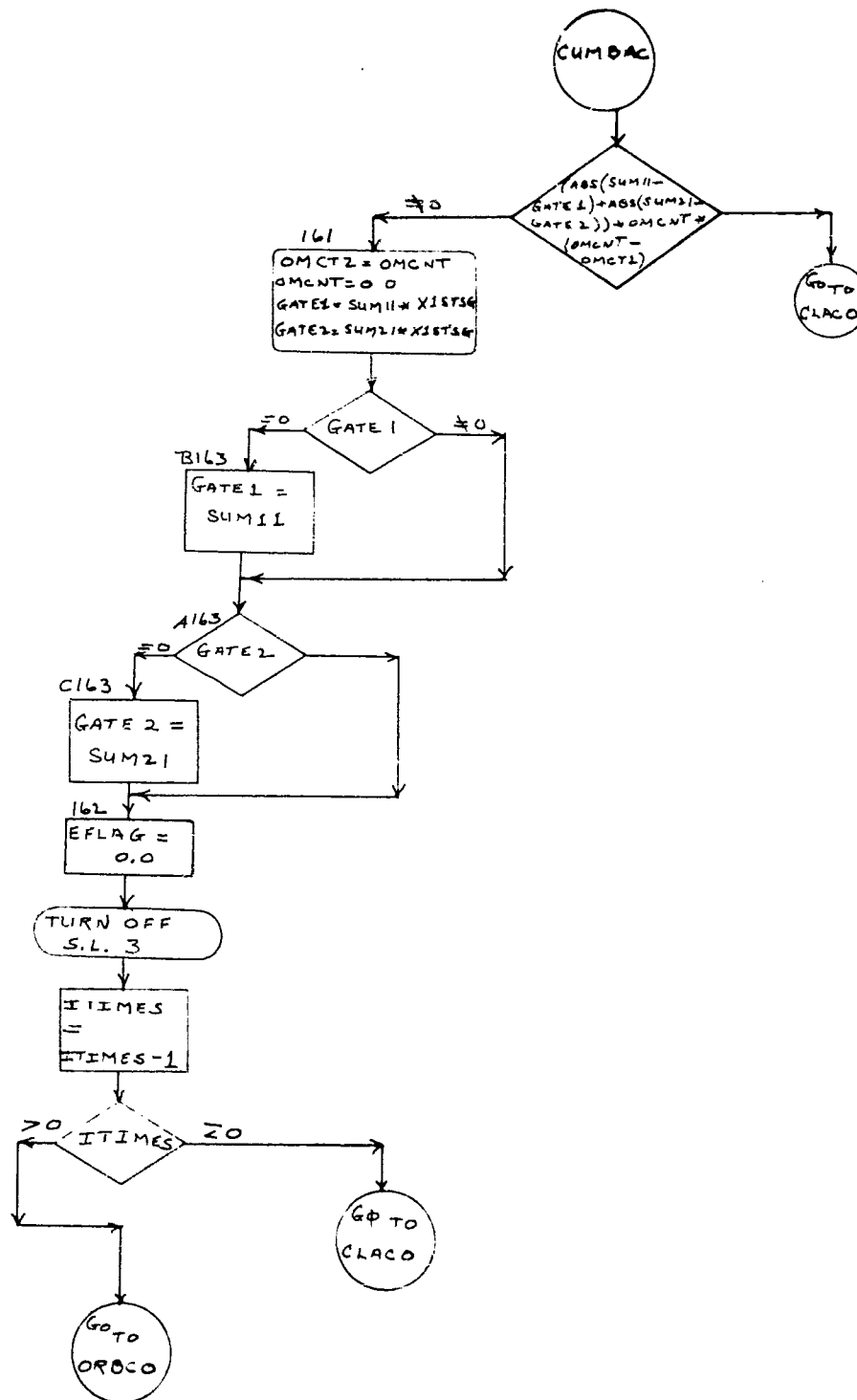
OBSERVATION TIME FOUND

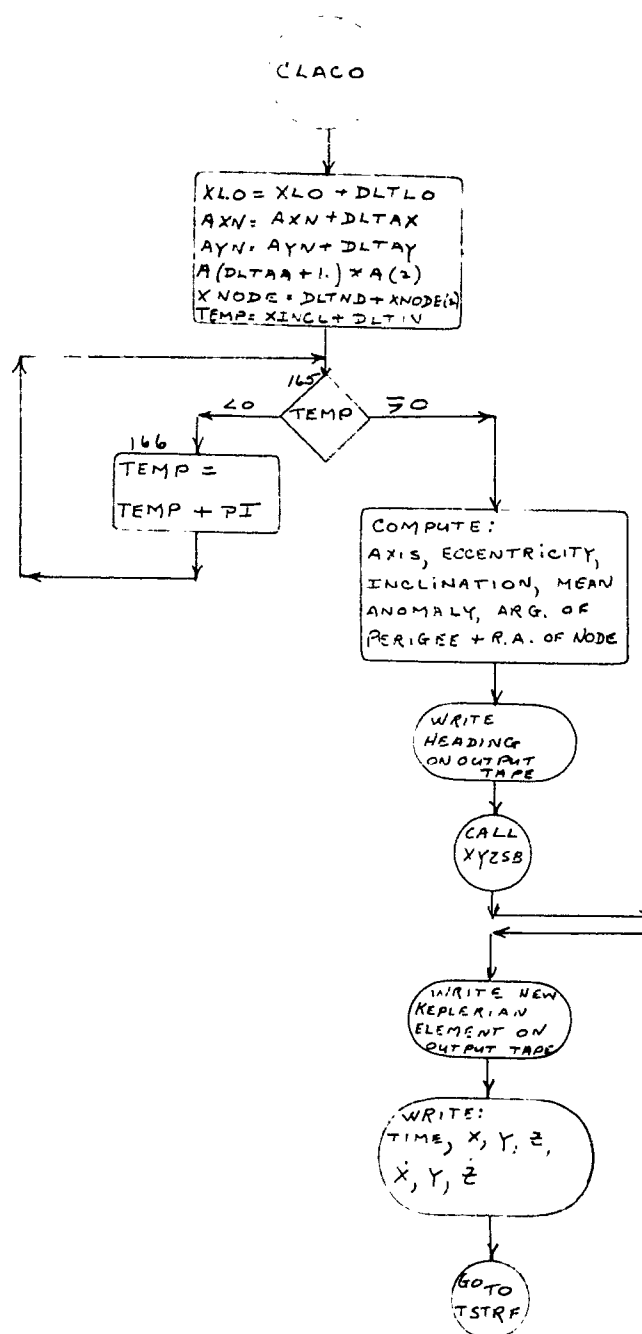


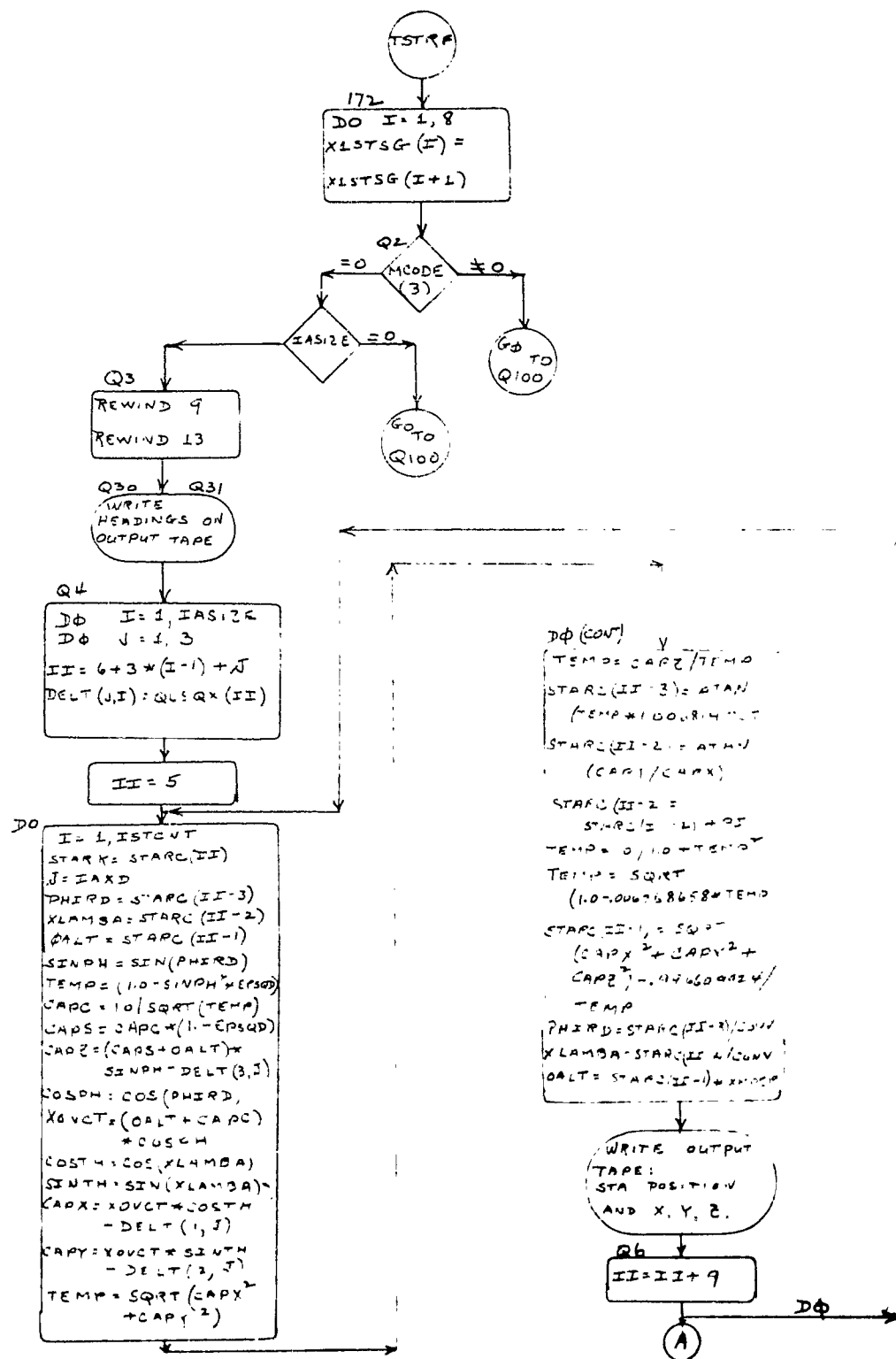


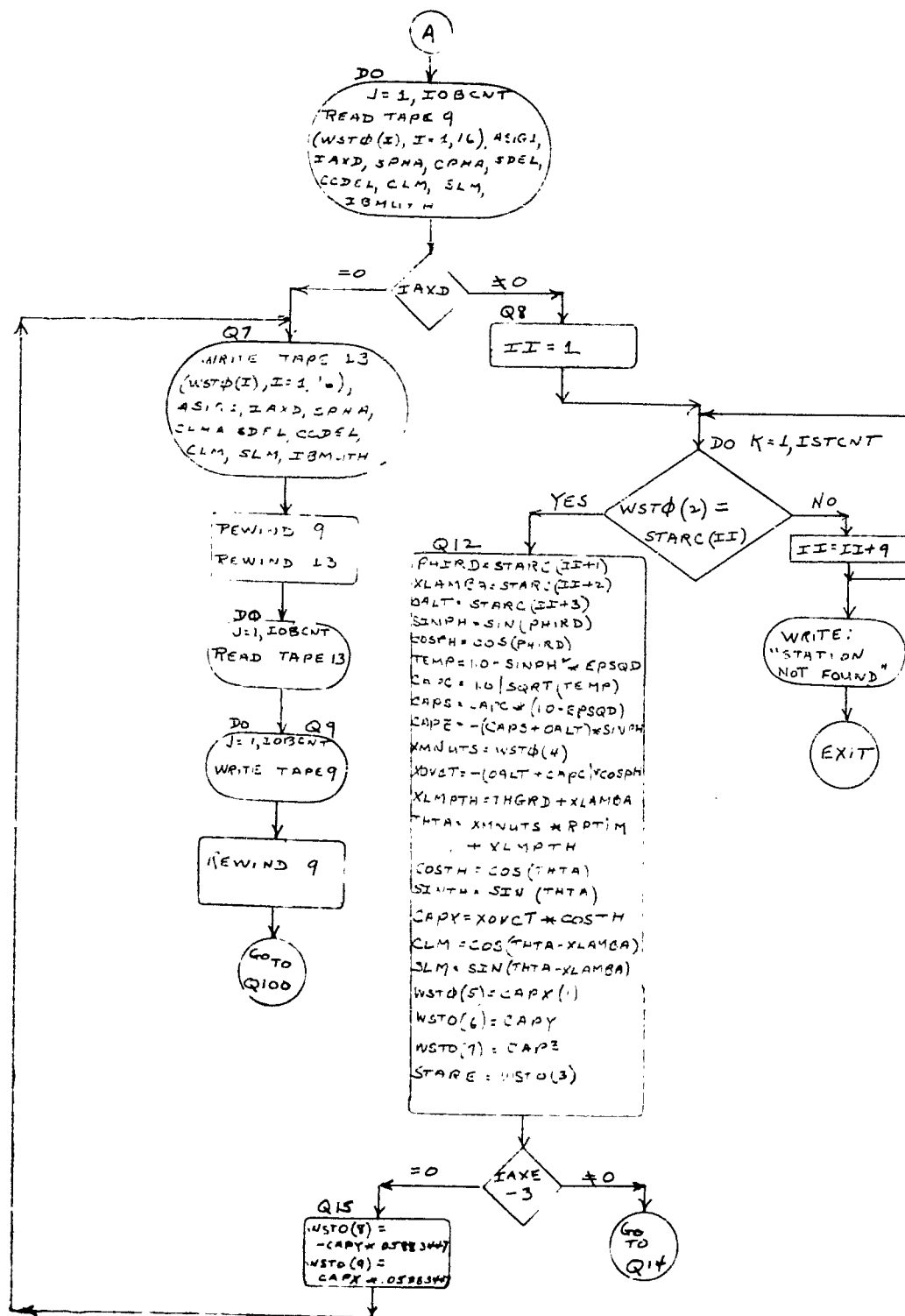


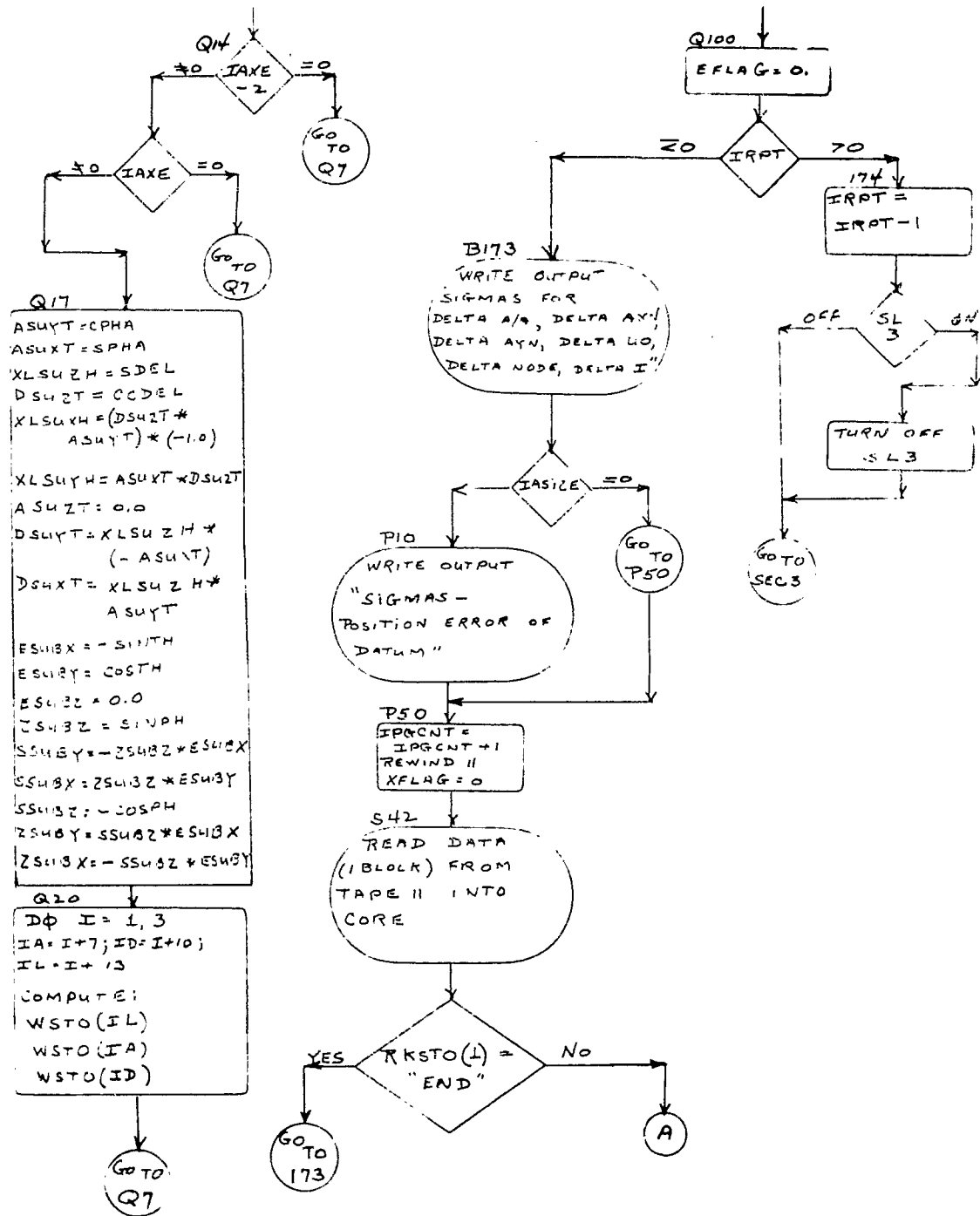


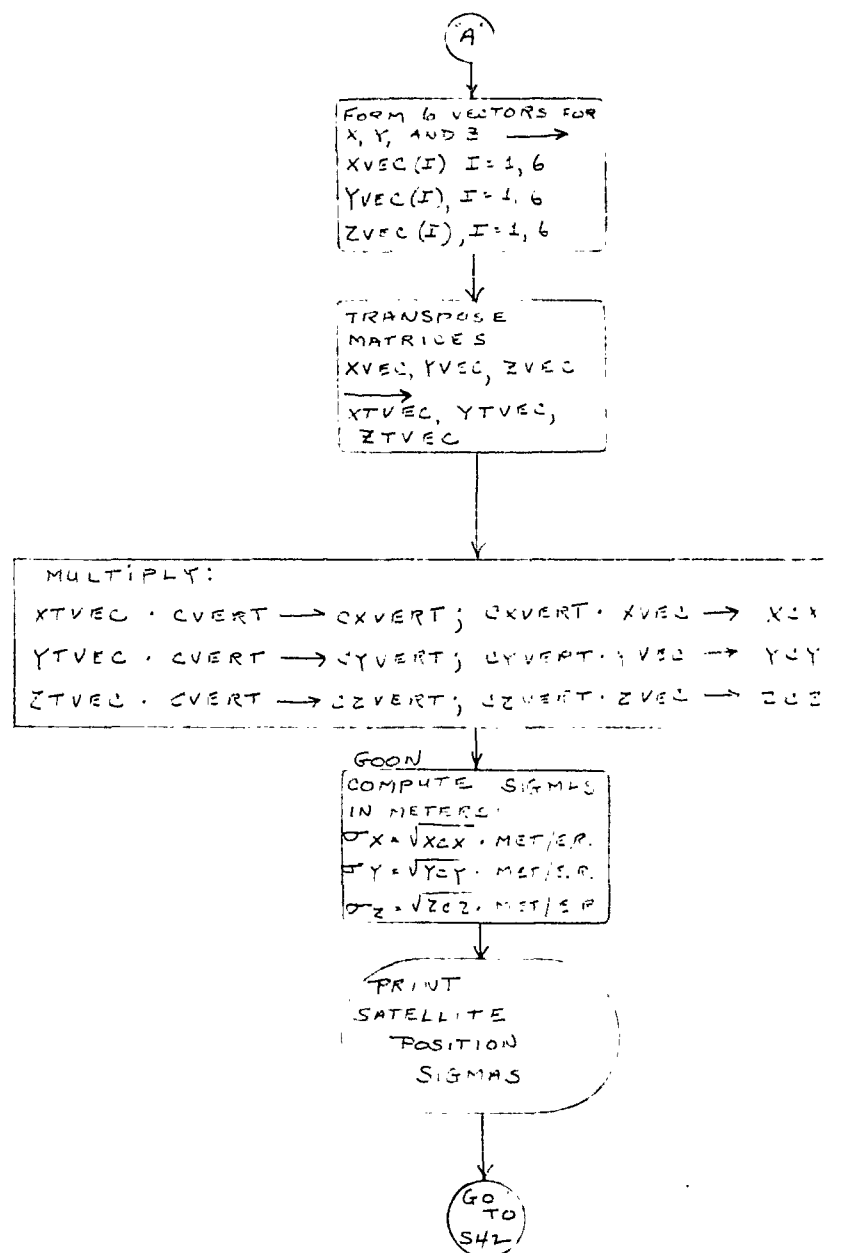


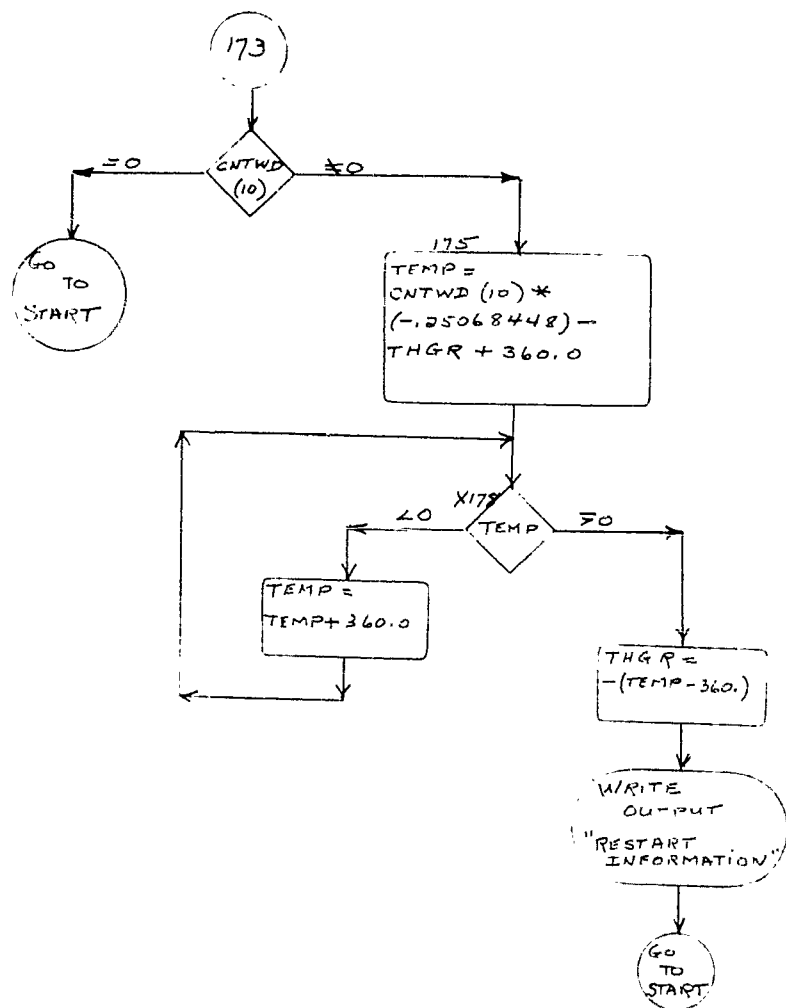












X
GLOSSARY

- A. Subroutines Used in Computation
- B. Important Mneumonic Codes
- C. Table of Program Constants

A. Subroutines Used In Computations

ALTAC Language

AQDRAG	Computes drag term
CALH	Computes height in meters above oblate earth
COEF	Computes the coefficients of the current correction equation and stores them in an array called Terms
GTOBS	Processes an observation card
RCTFY	Applies corrections for atmospheric drag during the intergration of the ephemeris
SETI	Used during COEF routine to store coefficients in proper locations in array
TBINT	Interpolates in a table
XYZSB	Computes intermediate orbit parameters and satellite positions and velocity vectors
BESSEL	Computes Bessel functions used in drag computation

TAC Language

CHGNXN	Establishes size of matrix as NXN. N can be any size from 6 x 6, 9x9, 12x12, ... , 24x24
LSQ	Initialices matrix area to zero
LSQR, LSQS1	Builds and fills in Matrix A and Matrix B
LSQS	Inverts matrix, saves diagonals, relocates 6x6 matrix, and then multiplies the inverted Matrix A by Matrix B

ALTAC Input-Output Subroutines

HEAD	Output routine to print headings on output pages
PRINT	Output routine to print ephemeris
PRINTO	Output routine to print x, y, z, SDOT, YDOT, ZDOT
RCARD	Input-output routine to read in observation cards from Tape 0, and print out this input

READER Input-output routine to read in station cards from
 Tape 10 and print out this input

STARTER Input-output routine to read in 5 specification cards
 from Tape 0, compute LSUBO, AXN, AYN, HX,
 HY, HZ, and print out the input and computed
 elements

ALTAC FUNCTIONS

PROPR(X) Properizes an angle given in radians

APROPR(X) Properizes an angle given in degrees

B. Glossary of Important Symbols

A	Semi-major axis
A+1	Semi-major axis
ABSMX	Absolute maximum for angle and range residuals
ABMX2	Absolute maximum for range rate residual reject criteria
ALPHA	Minus RA or azimuth in degrees
ASIG1	Std deviation of observed range
ASIG2	Std deviation of observed range rate
ASIG3	Std deviation of observed right ascension or azimuth
ASIG4	Std deviation of observed declination or elevation
AX	X component of a bar
AY	Y component of a bar
AZ	Z component of a bar
AXNI	X comp in orbit plane (on N bar) of a bar
AYNI	Y comp in orbit plane of a bar
AXI	Same as RKSTO+5
AZI	Same as RKSTO+7
CASE	Case number in BCD, T35
CASE2	Case number in BCD, T23
CD	Initial approximation to the drag coefficient
CDO	Empirically-determined constant to evaluate drag coefficient
CHEDI	Constant heading array; Time lat; long; altitude
CNTWD	Col 19 of control card 5 in BCD, T47
CNTWD+1	Epoch, day of year, in BCD W 4 trailing blanks
CNTWD	XL, at new epoch (or restart time)
CNTWD+2	Epoch time of day in minutes --- BCD, T47
CNTWD+3	Number of times to repeat correction - T15 - Same as IRPT
CNTWD+4	REFDA in BCD; 4 trailing blanks
CNTWD+5	REFTM in BCD, T47
CNTWD+9	Minutes difference new epoch minus old epoch (0 if no new ep
CNTWD+10	1st character of 2nd card, T15
CNTWD+14	AXN at new epoch (or restart time)
CNTWD+15	AYN at new epoch (or restart time)

CNTWD+16	HX, at new epoch (or restart time)
CNTWD+21-26	Position + vel vectors for sat. for transfer to tape 6
COND	Intermediate drag term; constant for object
CONTS	Intermediate drag term, Constant = $(VCO)**3/(4*EPS*SI$
COSI	Cosine (Inclination)
COSO	Cosine of right ascension of node
COUNT	Number of iteration steps in ephemeris
D	Reference diameter of vehicle in meters
DELTA	Elevation or declination of observation in degrees
DD	Day of observation --- Floating point
DT	Time interval used in Runge Kutta integration
ECOSE	$ECC * \cos (ECC \text{ ANOM})$
EFLAG	Column 21 of 5th control card (flo pt integer)
EMIS	Emissivity of the satellite
EO1	Eccentric anomaly + argument of perigee
EPHEM	Core buffer for ephemeris
EPSQD	Square of eccentricity of the terrestrial ellipsoid
ESINE	$ECC * \sin (ECC \text{ ANOM})$
ESQ	$1 - \text{Eccentricity} ** 2$
F	Flattening of the earth
FLP25	Neg of rot. rate of earth in degrees per minute
HDNG	Array contains output page heading for entire run
HH	Hour of observation (Floating point)
HMPRM	3rd harmonic of the earths gravitational potential
HXI	Same as RKSTO+8
HYI	Same as RKSTO+9
HZI	Same as RKSTO+10
IBMUTH	Obs code/ = 0 if RA-DEC / = 1 if AZ-ALT
IPGCNT	Current page number
IPNTFL	Print option as ALTAC integer
IRPT	Same as CNTWD+3 (Number of times to repeat correction
ISTCNT	Number of stations in starc buffer --- ALTAC integer
INXX	Size of ephemeris buffer
IY1	Year of observation since 1960, T15
LINE	Line count on page
LO	Mean longitude at epoch

MCODE	Col 38 of CN CRD 5 - If NE 0, correct elems + sta position
MICODE	Col 39 of CN CRD 5 - If NE 0, corr. sta position only
M2CODE	Col 40 of CN CRD 5 - If NE 0, corr. orbital elements only
MONTH	Month of observation ----- ALTAC integer
NCARD	Switch set by RCARD = 2 if no more obs; 1 if obs ready
NCNTRL	Index for next storage of ephemeris data into ephem buffer
NTAPE3	Number of records on tape 3
NTAPE6	Number of records on tape 6
OALT	Station height in earth radii
ONEPI	Empirically determined constant to evaluate drag coefficient
ORGDA	Epoch, Day of year
ORGTM	Epoch time of day in minutes
P	Semi-latus rectum
PHIRD	Station latitude in radians
QTR	Constant = .25
R	Magnitude of radius vector to satellite
R5	R^{*5} ; Fifth power of radius vector of satellite
RADYN	Degrees per radian
RDRDG	Dot product of RDOT and perturbations vector
RECTI	Switch = 1 if recification for drag has occurred; = 0 if not
REFDA	Restart, day of year (new epoch for new elements)
REFTM	Restart time of day
RHOO	Atmos. density at surface of the earth in grams per cubic cm.
RKCNT	Control array for Runge-Kutta integration
RKSTO	Current time (since epoch) of this integration step
RKSTO+3	Time interval for Runge-Kutta integration
RKSTO+4	L, Mean longitude at this integration step
RKSTO+5	X comp. of A bar at this integration step
RKSTO+6	Y comp. of A bar at this integration step
RKSTO+7	Z comp. of A bar at this integration step
RKSTO+8	X comp. of H bar, at this integration step
RKSTO+9	Y comp. of H bar, at this integration step
RKSTO+10	Z comp. of H bar, at this integration step

RRDGR	Dot product of R bar and total perturbation vector
RRDOT	Dot product of R bar and R bar dot
RSQR	R^{**2} Square of radius vector of satellite
RTA	Square root of semi-major axis
RTESQ	$\text{SQRT}(1 - \text{Eccentricity}^{**2})$
RTP	Square root of semi-latus rectum; magnitude of H bar
SATEL	Satellite ID on obs card ---- BCD, trailing blanks
SENSE LIGHT 1	Used by XYZSB to indicate when 1st time thru
SENSE LIGHT 2	On if obs on tape 9 in binary format; Off if not
SENSE LIGHT 3	On, we are processing RA-AZ portion of angle obs.
SENSE LIGHT 4	On if ephemeris is on tape 3; Off if not
SENSE LIGHT 5	Used by GTOBS to signal when obs card are all on tape 9
SENSE LIGHT 10	Used internally in CNTRL
SI	Second of observation (Floating point)
SIDRT	(Rot. rate of earth in deg/mean solar day) minus 360 degrees
SIGS	The Stefan-Boltzmann constant
SINI	Sine of inclination
SINO	Sine of right ascension of node
SIXP9	Empirically determined constant to evaluate drag coefficient
STAID	Station ID from obs card ---- BCD, leading zeroes
STARC	Start of station info buffer - Station ID, BCD, T47
STARC+1	Station latitude in radians
STARC+2	Station east longitude in radians
STARC+3	Station height in earth radii
STARC+4	Station datum number
STARC+5-7	Std. dev. of range, R-Rate, RA-AZ, Decl-Elev
SUM	Sum of squares of residuals of range or angle observations
SUM2	Sum of squares of residuals of range-rate observations
TF	Time after epoch to stop ephemeris calculation
THDOT	Rotation of earth in radians per kemin
TO	Time after epoch to begin ephemeris calculation
U	Mean argument of latitude at time, t.
UO	Mean argument of latitude at epoch
UO+1	$U, \text{ mod } 2\pi$
UTIME	Time of observation in minutes
UZSQR	UZ^{**2} ; the square of Z component of U bar

VCO3	Cube of speed of satellite in circular orbit with $r = 1$ earth radii in cent. cubed per sec cubed
WX	X component of W bar
WZ	Z component of W bar --- $WX+2$
X1STSG	1st reject factor for residuals
X2NDSG	2nd reject factor for residuals
X3RDSG	3rd reject factor for residuals
X4THSG	4th reject factor for residuals
X5THSG	5th reject factor for residuals
X6THSG	6th reject factor for residuals
X7THSG	7th reject factor for residuals
X8THSG	8th reject factor for residuals
X9THSG	Max no. of times to pass thru obs. before correcting
XBDGR	Partial derivative with respect to bulge of XDOT
XDGR	X component of total perturbations vector (excluding drag)
XINCL	Inclination
XJAY5	5th harmonic of the earth's gravitational potential
XJMPRM	2nd harmonic of the earth's gravitational potential
XK	Drag conversion constant
XK2ER	Meters per earth radii
XKMPRM	4th harmonic of the earth's gravitational potential
XLAMBA	Station east longitude
XLAT	Latitude of sub-satellite point
XLGR	$1 + \text{SQRT}(1 - \text{eccentricity}^2)$
XLO	Same as LO; mean longitude at epoch
XLONG	East longitude of sub-satellite point
XM	Mass of vehicle in kilograms
XMM	Minute of observation (floating point)
XMNPDA	Constant (minutes per day)
XMPER	Meters per earth radii
MX	X component of M bar
MY	Y component of M bar
MZ	Z component of M bar
NN	Mean motion
XNODE+ 1	Right ascension of node

XNX	X component of N bar
XNY	Y component of N bar
XOVR5	$(X/R)^5$
YBDGR	Partial derivative of Y dot with respect to bulge; same as XBDGR+1
YDGR	Y component of total perturbations vector; same as XDGR+1
ZBDGR	Partial derivative of Z dot with respect to bulge; same as XBDGR+2
ZDGR	Z component of total perturbations vector; same as XDGR+2
ZOVR5	$(Z/R)^5$

C. Program Constants

2.0	Initial approx to drag coefficient
.2504742E10	Constant used in drag calculation
.92	Emperical constant used in drag calculation
6.972E9	Emperical constnat used in drag calculation
1.173913	Emperical constant used in drag calculation
.0033523299	Flattening
.1685717364E-4	Flattening constant $(3/2F)^2$
.33691870736E-2	Flattening constant $(F + (3/2F)^2)$
1.62341E-3	2nd harmonic of earth's gravitational potential
-6.E-6	3rd harmonic of earth's gravitational potential
9.09E-6	4th harmonic of earth's gravitational potential
-0.2E-6	5th harmonic of earth's gravitational potential
.001225	Atmospheric density at surface of earth in gms/cm ³
3.141592653	PI
6.283185306	2 PI
57.2957795	Degrees per radian
.01745329251	Radians per degree
1.570796326	π
4.712388978	$3/2 \pi$
6378273.	Meters per earth radius
3441.605067	Nautical miles per earth radius
.15678527E-6	Earth radii per meter
.15678527	Earth radii per megameter
7.9048	km/sec per earth radius/kemin
.05883447	Rotation rate of earth in radians/kemin
.9856472	Rotation rate of earth in degrees per day minus 360
-.25068448	Negative rotation rate
.9	Emissivity of satellite
.49397574E18	Speed (cubed) of circ satellite at 1 E. R. in meters/second
.5672E-4	Stefan-Boltzmann constant
.07436574	kemins per minute
6.7686580E-3	Square of eccentricity of terrestrial ellipsoid

98.67401	Theta Greenwich for 1960
99.420937	Theta Greenwich for 1961
99.1822167	Theta Greenwich for 1962
98.943500314	Theta Greenwich for 1963
1×10^{-6} E. R.	Sigma for range observations
10.0 cps	Sigma for doppler observations
.00001 radians	Sigma for optical observations
-37922.43	Speed of light

XI
APPENDICES

APPENDIX A
EPHEMERIS COMPUTATION
and
DIFFERENTIAL CORRECTION THEORY*

*From AFCRL 62-892

THEORY

The Orbit Correction Program employs two computational techniques which speed the computation without loss of accuracy:

- (1) The satellite motion is numerically integrated by the variation of parameters formulation, thereby eliminating from the integrands the large central acceleration term.
- (2) The differential correction uses analytical differential expressions, thereby eliminating the need for more than one numerical integration over the observation period.

By developing the differential equations of motion in terms of parameters which remain invariant in the absence of perturbations to the two-body motion, the dominant two-body term is suppressed. The parameters employed in this formulation are:

$\underline{a} = e\underline{P}$	a vector defining eccentricity and perigee location
$\underline{h} = \sqrt{\mu} \underline{W}$	the orbital angular momentum
$L_o = M_o + \omega + \Omega$	the mean longitude of the object at some epoch

These parameters are valid, in the formulation employed here, for all satellite eccentricities and for all inclinations, including zero in either case.

The differential characteristics of a slightly-perturbed satellite orbit are, to a first order, identical to those of the osculating orbit. Thus the cause-and-effect linear relationships needed for differential correction may be developed analytically, rather than by the alternate "variant calculation" procedure where neighboring ephemerides are integrated, in each case with one of the parameters modified by a small amount. The parameters employed in the development of the differential expressions resemble those used in the variation-of-parameters ephemeris program, i.e.:

$\underline{a} = e\underline{P}$	a vector defining eccentricity and perigee location
a	semi-major axis
$U_o = M_o + \omega$	the mean argument of the latitude at some epoch
Ω	nodal longitude
i	inclination

The adoption of Ω and i to describe the orbit plane orientation and of U_0 to denote initial position, restricts the development to non-equatorial orbits. In addition, the vector $\underline{a}$ is described in terms of two components in the orbit plane to avoid redundancy; these components are designated a_{xN} and a_{yN} , with the former in the direction of the ascending node.

Any observation O_i by an earth-fixed observer may be expressed in terms of these six parameters or elements describing the orbit and the time. First order differential expressions relating observation and parameter follow from the leading term in a Taylor expansion, i.e.,

$$\Delta O_i = \sum_j \frac{\partial O_i}{\partial X_j} \Delta X_j \quad (1)$$

where the X_j are the six orbit parameters. Where there are m observations available to define the six parameters, a set of m differential expressions may be written; in matrix form, this set is

$$(\Delta O_i) = (C_{ij}) (\Delta X_j) \quad (2)$$

where (C_{ij}) is the $m \times 6$ matrix with typical element,

$$C_{ij} = \frac{\partial O_i}{\partial X_j} \quad (3)$$

The (ΔX_j) is a six component vector, and (ΔO_i) is an m component vector.

The elements of the (C_{ij}) matrix are the partial derivatives of the observed quantities with respect to the orbit parameters and may be determined analytically or by variant trajectory calculations, wherein the parameters are varied, one by one, and the resulting changes in the observations are noted.

If there are more observed quantities O_i than parameters X_j , that is, when $m > 6$, the system is overdetermined and the number of equations may be reduced by the method of least squares. The solution takes the form

$$(\Delta X_j) = \left[(C_{ij})^T (C_{ij}) \right]^{-1} (C_{ij})^T (\Delta O_i) \quad (4)$$

where the -1 and T superscripts denote inverse matrix and transpose matrix, respectively. The bracketed quantity in (4) is the so-called least square matrix, N :

$$N = (C_{ij})^T (C_{ij}) \quad (5)$$

In the interest of achieving efficiency, the C_{ij} are evaluated from analytical expressions, which are detailed in the following section presenting the formulation of the program.

FORMULATION

The Orbit Correction Program can be conveniently divided into three parts, one concerned with the correction process, another concerned with the generation of different types of ephemerides, and, most important, that portion necessary for both, (mainly concerned with the integration of the equations of motion). These parts will be documented below in the inverse order.

VARIATIONS OF THE PARAMETERS

The major portion of the Orbit Correction Program is spent in generating position and velocity of the satellite at successive times by numerically integrating the equations of motion. This integration process is started by generating the initial values of the integrands and other quantities:

Given a_{xN_0} , a_{yN_0} , $\underline{h}_0$, L_0 (subscript 0 indicates epoch), the fol-

lowing procedure is common to both the simulation and differential correction portions of the program:

- (a) Compute Greenwich sidereal time at epoch, Θ_{gr} :

$$\Theta_{gr} \text{ (in degrees)} = D (\dot{\Theta} - 360^\circ) + \dot{\Theta} f + \Theta'_{gr}$$

where D is epoch day number, f is the fraction of a day elapsed from start of epoch day to epoch, Θ'_{gr} is Greenwich sidereal time at the beginning of epoch year, and $\dot{\Theta} = 360^\circ.9856472$, the rotation rate of the earth in degrees per mean solar day.

- (b) Compute the semi-latus rectum:

$$p_o = \frac{h_o}{\mu} \cdot \frac{h_o}{r_o}$$

- (c) Compute the orientation vector, $\underline{W}_o$:

$$\underline{W}_o = \frac{\underline{h}_o}{\sqrt{p_o}}$$

- (d) Compute the orientation angles, i_o , Ω_o , and U_o :

$$\sin i_o = \sqrt{1 - W_{z_o}^2}$$

$$\cos i_o = W_{z_o}$$

$$i_o = \tan^{-1} \left(\frac{\sin i_o}{\cos i_o} \right) \quad 0 \leq i_o < \pi$$

$$\sin \Omega_o = W_{x_o} / \sin i_o$$

$$\cos \Omega_o = -W_{y_o} / \sin i_o$$

$$\Omega_o = \tan^{-1} \left(\frac{\sin \Omega_o}{\cos \Omega_o} \right) \quad 0 \leq \Omega_o < 2\pi$$

$$U_o = L_o + a_o \text{ if } W_{z_o} < 0 \quad (\text{retrograde motion})$$

$$U_o = L_o - a_o \text{ if } W_{z_o} > 0 \quad (\text{direct motion})$$

(e) Compute the equatorial coordinates of $\underline{a}_o$:

$$\underline{a}_o \begin{cases} a_{x_o} = a_{xN_o} \cos \delta_o - \cos i_o a_{yN_o} \sin \delta_o \\ a_{y_o} = a_{xN_o} \sin \delta_o + \cos i_o a_{yN_o} \cos \delta_o \\ a_{z_o} = a_{yN_o} \sin i_o \end{cases}$$

(f) Compute the eccentricity, e_o , and the semi-major axis, a_o :

$$e_o^2 = a_{x_o}^2 + a_{y_o}^2 + a_{z_o}^2$$

$$a_o = p_o / (1 - e_o^2)$$

Also common to both simulation and differential correction is the numerical integration. The equations to be integrated are of the form:

$$\frac{dy_i}{dt} = f_i(t, y_1, y_2, \dots, y_6, y_7) \quad i = 1, 2, \dots, 7$$

where the y_i equal $a_x, a_y, a_z, h_x, h_y, h_z$, and L .

The numerical integration scheme used is based on the following fourth order Runge-Kutta method:

$$y_i^{n+1} = y_i^n + \frac{\Delta t}{6} (K_{1_i} + 2K_{2_i} + 2K_{3_i} + K_{4_i})$$

where $K_{1_i} = f_i(t^n, y_1^n, \dots, y_7^n)$

$$K_{2_i} = f_i(t^n + \frac{\Delta t}{2}, y_1^n + \frac{K_{11}}{2}, \dots, y_7^n + \frac{K_{17}}{2})$$

$$K_{3_i} = f_i(t^n + \frac{\Delta t}{2}, y_1^n + \frac{K_{21}}{2}, \dots, y_7^n + \frac{K_{27}}{2})$$

$$K_{4_i} = f_i(t^n + \Delta t, y_1^n + K_{31}, \dots, y_7^n + K_{37})$$

As can be seen, it is necessary to compute $\frac{da}{dt}$, $\frac{dh}{dt}$, and $\frac{dL}{dt}$ from $\underline{a}$, $\underline{h}$, and L , several times at each integration step. The first step is to compute position and velocity, $\underline{r}$, $\dot{\underline{r}}$ from $\underline{a}$, $\underline{h}$, and L .

Given $\underline{a}$, $\underline{h}$, and L at some time t , the following procedure is used to derive position, $\underline{r}$, and velocity, $\dot{\underline{r}}$. Note that whenever the anomalies v , E , and M are used, they appear either in a sum with ω or in products with the coefficient e . Thus, no indeterminacy exists for zero eccentricity. In its present form, precisely equatorial orbits cannot be integrated, since the ascending node is employed as a reference direction.

(a) Compute p , e , a , n :

$$p = \underline{h} \cdot \underline{h} = h_x^2 + h_y^2 + h_z^2$$

$$e^2 = \underline{a} \cdot \underline{a} = a_x^2 + a_y^2 + a_z^2$$

$$a = p / (1 - e^2)$$

$$n = K_e \sqrt{\mu} / a^{3/2} \quad \text{where } K_e \sqrt{\mu} = .07436574$$

(b) Compute the orientation vectors $\underline{W}$, $\underline{M}$, and $\underline{N}$:

$$\underline{W} = \frac{\underline{h}}{\sqrt{p}} \quad (\text{note } W_z = \cos i)$$

$$M_z = \sqrt{1 - W_z^2} = \sin i$$

$$N_x = -W_y / M_z = \cos \delta$$

$$M_y = N_x W_z = \cos \Omega \cos i$$

$$N_y = \frac{W_x}{M_z} = \sin \Omega$$

$$M_x = -N_y W_z = -\sin \Omega \cos i$$

$$N_z = 0$$

- (c) Compute the components of $\underline{a}$ in the orbit plane, a_{xN} and a_{yN} :

$$a_{xN} = \underline{a} \cdot \underline{N}$$

$$a_{yN} = \underline{a} \cdot \underline{M}$$

- (d) Compute the orientation angles, Ω and U :

$$\Omega = \tan^{-1} \left(\frac{N_y}{N_x} \right) \quad 0 \leq \Omega < 2\pi$$

$$U = L + \Omega \quad \text{if } W_z < 0 \quad (\text{retrograde motion})$$

$$U = L - \Omega \quad \text{if } W_z > 0 \quad (\text{direct motion})$$

- (e) Solve Kepler's equation for $E + \omega$ by iteration, using a first guess of $U \pmod{2\pi}$:

$$E + \omega = U + a_{xN} \sin (E + \omega) - a_{yN} \cos (E + \omega)$$

- (f) Compute $\underline{r}$ and $\dot{\underline{r}}$:

$$e \cos E = a_{xN} \cos (E + \omega) + a_{yN} \sin (E + \omega)$$

$$e \sin E = a_{xN} \sin (E + \omega) - a_{yN} \cos (E + \omega)$$

$$r = a (1 - e \cos E)$$

$$\dot{r} = \frac{\sqrt{\mu a}}{r} e \sin E$$

$$r\dot{v} = \frac{\sqrt{\mu a}}{r} \sqrt{1 - e^2}$$

$$\cos u = \frac{a}{r} \left[\cos (E + \omega) - a_{xN} + a_{yN} \left(\frac{e \sin E}{1 + \sqrt{1 - e^2}} \right) \right]$$

$$\sin u = \frac{a}{r} \left[\sin (E + \omega) - a_{yN} - a_{xN} \left(\frac{e \sin E}{1 + \sqrt{1 - e^2}} \right) \right]$$

$$\underline{U} = \cos u \underline{N} + \sin u \underline{M}$$

$$\underline{V} = -\sin u \underline{N} + \cos u \underline{M}$$

$$\underline{r} = r \underline{U}$$

$$\dot{\underline{r}} = \dot{r} \underline{U} + r \dot{v} \underline{V}$$

From the position and velocity, it is possible to compute the perturbative accelerations, specifically the bulge perturbation, $\dot{\underline{r}}_B$:

$$\begin{aligned} \dot{x}_B = & \frac{x}{r^5} J' (5U_z^2 - 1) + \frac{xz}{r^7} H' (7U_z^2 - 3) \\ & + \frac{x}{6r^7} K' (42U_z^2 - 63U_z^4 - 3) + \frac{21xU_z}{8r^8} J_5 a_e^5 \mu (5 - 30 U_z^2 + 33U_z^4) \end{aligned}$$

$$\dot{y}_B' = y/x \quad \dot{x}_B'$$

$$\dot{z}_B = \frac{z}{r^5} J' (5U_z^2 - 3) + \frac{3}{5r^5} H' \left(\frac{35}{3} U_z^4 - 10U_z^2 + 1 \right)$$

$$+ \frac{z}{6r^7} K' (-63U_z^4 + 70U_z^2 - 15) + \frac{3}{8r^7} J_5 a_e^5 \mu (-5 + 105U_z^2$$

$$- 315 U_z^4 + 231 U_z^6)$$

where $U_z = \frac{z}{r}$ and $J' = .001\ 623\ 41$

$$H' = -.000\ 006$$

$$K' = .000\ 009\ 09$$

$$J_5 a_e^5 \mu = -.000\ 000\ 2$$

At each point during the integration at which the derivatives dL/dt , dh/dt , da/dt , are evaluated, the perturbative accelerations due to drag $\ddot{x}_D$, $\ddot{y}_D$, $\ddot{z}_D$, must be evaluated and added to the bulge accelerations, $\ddot{x}_B$, $\ddot{y}_B$, $\ddot{z}_B$, to obtain the total perturbative accelerations, $\ddot{x}$, $\ddot{y}$ and $\ddot{z}$.

Given $\underline{r}$ and $\dot{\underline{r}}$, and tabulated values of the density ratio and atmospheric molecular weight versus altitude:

- (1) Compute the relative air speed vector,:

$$v_x = \dot{x} + y \dot{\theta}$$

$$v_y = \dot{y} - x \dot{\theta}$$

$$v_z = \dot{z}$$

Also compute the magnitude of the relative air speed vector

$$V = \sqrt{V_x^2 + V_y^2 + V_z^2}.$$

$\dot{\theta}$ in the above equations, is the angular rotation rate of the Earth.

- (2) Compute the altitude above the oblate spheroid in Earth radii:

$$H = r - 1 - \frac{3}{2} f^2 \left(\frac{z}{r}\right)^4 + \left(f + \frac{3}{2} f^2\right) \left(\frac{z}{r}\right)^2,$$

where f is the flattening of the Earth = $1/298.3$.

- (3) Look up the density ratio $\sigma = \sigma(H)$ and the molecular weight $M^e = M(H)$ from the tabulated data (see Appendix C for the programmed tables), and calculate the atmospheric density :

$$\sigma = \rho / \rho_0$$

where ρ_0 is the sea level value of the atmospheric density = 0.001225 gm/cm^3 .

- (4) Compute the skin temperature of the vehicle:

$$T_s = \left[\frac{\rho C_D (v_{co})^3 \gamma^3}{4 \epsilon \sigma_s} + (300)^4 \right]^{1/4}$$

where

$$\sigma_s = \text{Stefan-Boltzmann constant} = 5.672 \times 10^{-5},$$

and

$$\epsilon = \text{emissivity of the satellite} = .9.$$

- (5) Compute the drag coefficient, C_D , by first computing the auxiliary quantity

$$C = \frac{6.972 \times 10^9 \gamma d}{C_{D0} \sqrt{(M_e T_s)}},$$

and then

$$C_D = C_{D0} (1 + 1.1739130 e^{-C}) ,$$

C_{D0} being a reference value of the drag coefficient = 0.92.

(6) Compute the drag terms:

$$\dot{\underline{x}}_D = \underline{v}_x \left[c_D \rho \underline{v} \left(- \frac{K \pi d^2}{8m} \right) \right] \quad x \rightarrow y, z,$$

where d is the diameter of the satellite, m is its mass, and K is a constant relating the units. The program value of $K = 2.504742 \times 10^9$.

Finally we are ready to calculate the integrands $d\underline{a}/dt$, $d\underline{h}/dt$, and dL/dt :

(a) Determine the total perturbations $\dot{\underline{r}}$

$$\dot{\underline{r}} = \dot{\underline{r}}_B + \dot{\underline{r}}_D$$

(b) Compute:

$$\underline{r} \dot{\underline{r}} = \underline{r} \cdot \dot{\underline{r}}$$

$$\dot{\underline{s}} \dot{\underline{s}} = \dot{\underline{r}} \cdot \dot{\underline{r}}$$

$$\underline{r} \dot{\underline{r}} = \underline{r} \cdot \dot{\underline{r}}$$

and the auxiliary quantities:

$$D = \frac{r \dot{r}}{\sqrt{\alpha}}$$

$$D' = \frac{r \dot{r}'}{\sqrt{\alpha}}$$

$$\dot{D}' = \frac{2 \dot{s} \dot{s}'}{\sqrt{\alpha}}$$

(c) Compute n' , rb' , ℓ' , $\underline{a}'$, ev' , and L' :

$$n' = -\frac{3}{2} na \frac{\dot{D}'}{\sqrt{\alpha}}$$

$$rb' = \underline{W} \cdot \underline{\dot{r}}'$$

$$\ell' = \frac{z (rb')}{(1 + W_z) \sqrt{\alpha p}}$$

$$\underline{a}' = \underline{\dot{D}_r} - D_r' - \underline{\dot{D}_r'}$$

$$eQ = \underline{W} \times \underline{a}$$

$$-e^2 v' = eQ \cdot \underline{a}'$$

$$\dot{L} = -\frac{2D}{\sqrt{a}} - \frac{e^2 \dot{v}}{1 + \sqrt{1 - e^2}}$$

(d) Compute $\dot{h}$:

$$\dot{h} = \frac{\underline{r} \times \underline{\dot{r}}}{\sqrt{\mu}}$$

(e) Compute the derivatives:

$$\frac{dL}{dt} = k_e \dot{L} + n$$

$$\frac{da}{dt} = k_e \dot{a}$$

$$\frac{dh}{dt} = k_e \dot{h}$$

EPHEMERIDES

The word ephemeris is defined as a table of the positions of celestial bodies at regular intervals of time. As used here in reference to the Earth satellite ephemerides, the intervals of time are integration steps. The ephemerides are of three kinds.

The first type of ephemeris shows geocentric position and velocity vectors. No additional formulation is needed to produce this.

The second type of ephemeris shows the position of the satellite as latitude, longitude, and height above the geoid. This is the subsatellite track.

The third type of ephemeris shows acquisition coordinates for a number of designated sensors. These "look angles" show the coordinates at which the satellite would appear to the station if it had started with the given boundary conditions at the epoch. These acquisition coordinates are produced for every integration step at which the satellite is above the horizon of the designated station.

a. Computation of Sub-Satellite Track:

If the option to compute a sub-satellite track consisting of latitude, ϕ , East longitude, λ_E , and height above the earth, H , is chosen, then these quantities are computed at each point of the ephemeris as follows:

$$\phi = \tan^{-1} \left[\frac{U_z}{(1-f)^2 \sqrt{1-U_z^2}} \right] - 90^\circ \leq \phi \leq 90^\circ$$

where $f = \frac{1}{298.3}$ is the flattening of the Earth

$$\lambda_E \text{ (in degrees)} = \theta - \dot{\theta} (t-t_0) - \theta_{gr}, \quad \lambda_E \geq 0^\circ$$

where $\theta = \tan^{-1} \left(\frac{y}{x} \right)$ $0^\circ \leq \theta < 360^\circ$

and $\dot{\theta} = .250\ 684\ 48$ is the rotation rate of the Earth in degrees per solar minute.

$$H \text{ (in Earth radii)} = r - 1 + \left(\frac{3}{2} f^2 + f \right) U_z^2 - \frac{3}{2} f^2 U_z^4$$

b. Simulation of Acquisition Coordinates:

This part of the program simulates "observations" of the satellite in the orbit specified by the input parameters. Given ϕ , the latitude of a station in degrees, λ_E , the East longitude of the station in degrees, H , the height of the station above sea level in meters, and θ_{gr} , Greenwich Sidereal Time at the initial time, t_o , in degrees, the following procedure computes α , δ , A , h , ρ , and $\dot{\rho}$ for time t :

- (1) Convert ϕ , λ_E , and θ_{gr} to radians and H to Earth radii

- (2) Compute:

$$C = (1 - \epsilon^2 \sin^2 \phi)^{-1/2}$$

where $\epsilon^2 = 2f - f^2$, $f = \frac{1}{298.3}$ = the flattening of the Earth.

$$S = C (1 - \epsilon^2)$$

- (3) Compute:

$$\theta = .004\ 375\ 269\ 1 (t - t_o) + \theta_{gr} + \lambda_E$$

- (4) Compute the station vector, $\underline{R}$:

$$X = - (C + H) \cos \phi \cos \Theta$$

$$Y = - (C + H) \cos \phi \sin \Theta$$

$$Z = - (S + H) \sin \phi$$

- (5) Compute the slant range ρ :

$$\rho = \underline{r} + \underline{R}$$

$$\rho = \sqrt{\underline{r} \cdot \underline{r}} = \sqrt{(x + X)^2 + (y + Y)^2 + (z + Z)^2}$$

- (6) Compute azimuth, A , and elevation angle, h , of object as "seen" from the observation station:

$$L_{xh} = \frac{(x+X) \cos \Theta \sin \phi + (y+Y) \sin \Theta \sin \phi - (z+Z) \cos \phi}{\rho}$$

$$L_{yh} = \frac{-(x+X) \sin \Theta + (y+Y) \cos \Theta}{\rho}$$

$$L_{zh} = \frac{(x+X) \cos \Theta \cos \phi + (y+Y) \sin \Theta \cos \phi + (z+Z) \sin \phi}{\rho}$$

$$h = \tan^{-1} \left(\frac{L_{zh}}{\sqrt{1 - L_{zh}^2}} \right), \quad -\pi/2 \leq h \leq \pi/2$$

If $h < 0$ (i.e., the object is below the local horizon) the output for this time is omitted.

$$A = \tan^{-1} \left(\frac{L_{yh}}{-L_{xh}} \right) \quad 0 \leq A < 2\pi$$

The quadrant is determined from an examination of the sign of the numerator and denominator.

- (7) Compute topocentric right ascension, α , and declination, δ :

$$\underline{L} = (L_x, L_y, L_z) = \frac{\underline{C}}{\rho}$$

$$\delta = \tan^{-1} \left(\frac{L_z}{\sqrt{1-L_z^2}} \right) \quad -\pi/2 \leq \delta \leq \pi/2$$

$$\alpha = \tan^{-1} \left(\frac{L_y}{L_z} \right) \quad 0 \leq \alpha < 2\pi$$

The quadrant is determined from sign of numerator and denominator.

(8) Compute the slant range rate, $\dot{\rho}$:

$$\left. \begin{aligned} \dot{X} &= -Y \dot{\theta} \\ \dot{Y} &= X \dot{\theta} \\ \dot{Z} &= 0 \end{aligned} \right\} \dot{\theta} = 0.058 \ 834 \ 47$$

$$\dot{\rho} = \dot{\underline{x}} + \dot{\underline{R}} \ (\dot{X}, \dot{Y}, \dot{Z})$$

$$\dot{\rho} = \underline{L} \cdot \dot{\underline{\rho}} = L_x (\dot{x} + \dot{X}) + L_y (\dot{y} + \dot{Y}) + L_z (\dot{z} + \dot{Z})$$

DIFFERENTIAL CORRECTION OF ORBITAL ELEMENTS:

This part of the program relates residuals in the observations at time, t , to corrections to be applied to the initial orbital parameters at time t_0 .

The procedure calculates the orbital parameters and quantities associated with the station coordinates at the observation time. It combines these quantities to obtain the coefficients of the linear relationships relating residuals to any combination of $\Delta a_o / a_o$, Δa_{xN} , Δa_{yN} , ΔU , $\Delta \Omega_o$, Δi_o and represents the observations to determine the residuals. Finally, the corrections to be applied to the parameters are determined by solving the (usually overdetermined) system of linear correction equations.

a. Forming the Linear Correction Equations

Given:

- | | |
|---|----------------------------|
| (1) ϕ , the latitude in degrees | } of the observing station |
| (2) λ_E , the longitude in degrees | |
| (3) H, meters above sea level | |
| (4) Θ_{gr_0} Greenwich Sidereal time at epoch in degrees | |
| (5) t, the time of the observation in minutes, and | |
| (6) one or more observed quantities at this time, | |

the following will compute one line of the above-mentioned system for each observed quantity.

- (1) Repeat steps 1 through 4 under simulation to obtain Θ and ϕ in radians and the station vector $\underline{R}$.

- (2) Compute the coefficients R and U where:

$$R_u = (a^2/r) e \sin E$$

$$R_a = r - \frac{3}{2} (U - U_o) R_u$$

$$R_{xN} = (a^2/r) [a_{xN} - \cos (E + \omega)]$$

$$R_{yN} = (a^2/r) [a_{yN} - \sin (E + \omega)]$$

$$U_u = (a^2/r) \sqrt{1 - e^2}$$

$$U_a = - \frac{3}{2} (U - U_o) U_u$$

$$U_{xN} = \frac{a^2}{r} \left\{ \left(1 + \frac{r}{a}\right) \sin(E + \omega) + a_{xN} e \sin E \right.$$

$$\left. \left[\frac{e^2 - (1 + \sqrt{1 - e^2}) e \cos E}{\sqrt{1 - e^2} (1 + \sqrt{1 - e^2})^2} \right] - \frac{a_{yN}}{1 + \sqrt{1 - e^2}} \right\}$$

$$U_{yN} = \frac{a^2}{r} \left\{ - \left(1 + \frac{r}{a}\right) \cos(E + \omega) + a_{yN} e \sin E \right.$$

$$\left. \left[\frac{e^2 - (1 + \sqrt{1 - e^2}) e \cos E}{\sqrt{1 - e^2} (1 + \sqrt{1 - e^2})^2} \right] + \frac{a_{xN}}{1 + \sqrt{1 - e^2}} \right\}$$

(3) Compute:

$$\rho_c = r + R$$

$$\rho_c = \sqrt{\rho_c \cdot \rho_c}$$

$$\underline{L}_c = \frac{\rho_c}{\rho_c}$$

(4) If ρ , the slant range is observed, compute

$$\Delta \rho = \rho - \rho_c$$

Form the coefficients:

$$C_{\frac{\Delta a}{a}} = (\underline{L}_c \cdot \underline{U}) R_a + (\underline{L}_c \cdot \underline{V}) U_a$$

$$C_{\Delta a_{xN}} = (\underline{L}_c \cdot \underline{U}) R_{xN} + (\underline{L}_c \cdot \underline{V}) U_{xN}$$

$$C_{\Delta a_{yN}} = (\underline{L}_c \cdot \underline{U}) R_{yN} + (\underline{L}_c \cdot \underline{V}) U_{yN}$$

$$C_{\Delta U_o} = (\underline{L}_c \cdot \underline{U}) R_u + (\underline{L}_c \cdot \underline{V}) U_u$$

$$C_{\Delta \Omega} = (\underline{L}_c \cdot \underline{V}) r \cos i - (\underline{L}_c \cdot \underline{W}) r \sin i \cos u$$

$$C_{\Delta i} = (\underline{L}_c \cdot \underline{W}) r \sin u$$

Enter the following linear correction equation into the system of such equations:

$$\begin{aligned} \Delta \rho = C_{\frac{\Delta a}{a}} \frac{\Delta a_o}{a_o} + C_{\Delta a_{xN}} \Delta a_{xN_o} + C_{\Delta a_{yN}} \Delta a_{yN_o} \\ + C_{\Delta U_o} \Delta U_o + C_{\Delta \Omega_o} \Delta \Omega_o + C_{\Delta i_o} \Delta i_o \end{aligned}$$

- (5) If A, azimuth, and h, elevation angle are observed, compute:

$$\left. \begin{aligned} S_x &= \sin \phi \cos \Theta \\ S_y &= \sin \phi \sin \Theta \\ S_z &= -\cos \phi \end{aligned} \right\} \underline{S}$$

$$\left. \begin{aligned} E_x &= -\sin \Theta \\ E_y &= \cos \Theta \\ E_z &= 0 \end{aligned} \right\} \underline{E}$$

$$\left. \begin{aligned} Z_x &= \cos \phi \cos \Theta \\ Z_y &= \cos \phi \sin \Theta \\ Z_z &= \sin \phi \end{aligned} \right\} \underline{Z}$$

$$\left. \begin{aligned} L_{xh} &= -\cos A \cos h \\ L_{yh} &= \sin A \cos h \\ L_{zh} &= \sin h \end{aligned} \right\} \underline{L}_h$$

$$\left. \begin{aligned} A_{xh} &= \sin A \\ A_{yh} &= \cos A \\ A_{zh} &= 0 \end{aligned} \right\} \tilde{\underline{A}}_h$$

$$\left. \begin{aligned} D_{xh} &= \cos A \sin h \\ D_{yh} &= -\sin A \sin h \\ D_{zh} &= \cos h \end{aligned} \right\} \tilde{\underline{D}}_h$$

$$\underline{L}_{obs} = L_{xh} \underline{S} + L_{yh} \underline{E} + L_{zh} \underline{Z}$$

$$\tilde{\underline{A}}_{obs} = A_{xh} \underline{S} + A_{yh} \underline{E} + A_{zh} \underline{Z}$$

$$\tilde{\underline{D}}_{obs} = D_{xh} \underline{S} + D_{yh} \underline{E} + D_{zh} \underline{Z}$$

$$\text{Compute } \underline{\Delta L} = \underline{L}_{obs} - \underline{L}_c$$

Form the coefficients as in (4) with $\tilde{\underline{A}}_{obs}$ replacing $\underline{L}_c$ and enter the following linear correction equation into the system of such equations:

$$\rho_{c-\text{obs}}^{\tilde{A}} \cdot \frac{\Delta L}{a} = C \frac{\Delta a}{a} \frac{\Delta a_c}{a_c} + C \Delta a_{xN} \Delta a_{xN_o} \\ + C \Delta a_{yN} \Delta a_{yN_o} + C \Delta U_o \Delta U_o + C \Delta \Omega_o \Delta \Omega_o + C \Delta i_o \Delta i_o$$

Again form the coefficients as in (4), this time with $\tilde{D}_{\text{obs}}$ replacing $\tilde{L}_c$, and enter the following linear correction equation into the system of such equations:

$$\rho_{c-\text{obs}}^{\tilde{D}} \cdot \frac{\Delta L}{a} = C \frac{\Delta a}{a} \frac{\Delta a_o}{a_o} + C \Delta a_{xN} \Delta a_{xN_o} \\ + C \Delta a_{yN} \Delta a_{yN_o} + C \Delta U_o \Delta U_o + C \Delta \Omega_o \Delta \Omega_o + C \Delta i_o \Delta i_o$$

- (6) If α , topocentric right ascension, and δ , topocentric declination are observed, compute:

$$\left. \begin{aligned} L_x &= \cos \delta \cos \alpha \\ L_y &= \cos \delta \sin \alpha \\ L_z &= \sin \delta \end{aligned} \right\} \underline{L}_{\text{obs}}$$

$$\left. \begin{aligned} A_x &= -\sin \alpha \\ A_y &= \cos \alpha \\ A_z &= 0 \end{aligned} \right\} \underline{A}_{\text{obs}}$$

$$\left. \begin{aligned} D_x &= -\sin \delta \cos \alpha \\ D_y &= -\sin \delta \sin \alpha \\ D_z &= \cos \delta \end{aligned} \right\} \underline{D}_{\text{obs}}$$

$$\text{Compute } \underline{\Delta L} = \underline{L}_{\text{obs}} - \underline{L}_c$$

Form the coefficients and compute the linear correction equations as in (5), substituting $\underline{A}_{\text{obs}}$ for $\underline{\hat{A}}_{\text{obs}}$ and $\underline{D}_{\text{obs}}$ for $\underline{\hat{D}}_{\text{obs}}$

- (7) If $\dot{\rho}$, the slant range rate, is observed, compute:

$$\left. \begin{aligned} \dot{X} &= -Y \dot{\Theta} \\ \dot{Y} &= X \dot{\Theta} \\ \dot{Z} &= 0 \end{aligned} \right\} \underline{\dot{R}} \text{ where } \dot{\Theta} = 0.058 \ 834 \ 47$$

$$\dot{\rho}_c = \dot{r} + \dot{R}$$

$$\dot{\rho}_c = \underline{L}_c \cdot \dot{\rho}_c$$

$$ex_{\omega} = a (e \cos E - e^2)$$

$$ey_{\omega} = a \sqrt{1 - e^2} e \sin E$$

$$\dot{v} = \frac{r \dot{v}}{r}$$

Compute the coefficients $\dot{R}$ and $\dot{U}$ where:

$$\dot{R}_u = \sqrt{\mu} a^{3/2} ex_{\omega} / r^3$$

$$\dot{R}_a = -\dot{r}/2 - 3/2 (U - U_0) \dot{R}_u$$

$$\begin{aligned}
\dot{R}_{xN} &= (\sqrt{\mu} a^{5/2}/r^3) \left\{ \sin(E + \omega) - a_{xN} e \sin E - a_{yN} \right\} \\
\dot{R}_{yN} &= (\sqrt{\mu} a^{5/2}/r^3) \left\{ -\cos(E + \omega) - a_{yN} e \sin E + a_{xN} \right\} \\
\dot{U}_u &= -\sqrt{\mu} a^{3/2} e y \omega / r^3 \\
\dot{U}_a &= -\frac{r\dot{v}}{2} - \frac{3}{2} (U - U_o) \dot{U}_u \\
\dot{U}_{xN} &= (\sqrt{\mu} a^{5/2}/r^3) \sqrt{1 - e^2} \left\{ \cos(E + \omega) - a_{xN} \left(1 + \frac{r^2}{ap}\right) \right\} \\
\dot{U}_{yN} &= (\sqrt{\mu} a^{5/2}/r^3) \sqrt{1 - e^2} \left\{ \sin(E + \omega) - a_{yN} \left(1 + \frac{r^2}{ap}\right) \right\}
\end{aligned}$$

(8) Form the coefficients:

$$\begin{aligned}
C_{\frac{\Delta a}{a}} &= (\underline{L}_c \cdot \underline{U}) [\rho_c (\dot{R}_a - \dot{v} U_a) - \dot{\rho}_c R_a] + (\dot{\rho}_c \cdot \underline{U}) R_a \\
&\quad + (\underline{L}_c \cdot \underline{V}) [\rho_c (\dot{U}_a + \frac{\dot{r}}{r} U_a) - \dot{\rho}_c U_a] + (\dot{\rho}_c \cdot \underline{V}) U_a \\
C_{\Delta a_{xN}} &= (\underline{L}_c \cdot \underline{U}) [\rho_c (\dot{R}_{xN} - \dot{v} U_{xN}) - \dot{\rho}_c R_{xN}] + (\dot{\rho}_c \cdot \underline{U}) R_{xN} \\
&\quad + (\underline{L}_c \cdot \underline{V}) [\rho_c (\dot{U}_{xN} + \frac{\dot{r}}{r} U_{xN}) - \dot{\rho}_c U_{xN}] + (\dot{\rho}_c \cdot \underline{V}) U_{xN} \\
C_{\Delta a_{yN}} &= (\underline{L}_c \cdot \underline{U}) [\rho_c (\dot{R}_{yN} - \dot{v} U_{yN}) - \dot{\rho}_c R_{yN}] + (\dot{\rho}_c \cdot \underline{U}) R_{yN} \\
&\quad + (\underline{L}_c \cdot \underline{V}) [\rho_c (\dot{U}_{yN} + \frac{\dot{r}}{r} U_{yN}) - \dot{\rho}_c U_{yN}] + (\dot{\rho}_c \cdot \underline{V}) U_{yN} \\
C_{U_o} &= (\underline{L}_c \cdot \underline{U}) [\rho_c (\dot{R}_u - \dot{v} U_u) - \dot{\rho}_c R_u] + (\dot{\rho}_c \cdot \underline{U}) R_u \\
&\quad + (\underline{L}_c \cdot \underline{V}) [\rho_c (\dot{U}_u + \frac{\dot{r}}{r} U_u) - \dot{\rho}_c U_u] + (\dot{\rho}_c \cdot \underline{V}) U_u
\end{aligned}$$

$$C_{\Delta\Omega} = - (\underline{L}_c \cdot \underline{U}) \rho_c r \dot{v} \cos i + (\underline{L}_c \cdot \underline{V}) \cos i [\rho_c \dot{r} - \dot{\rho}_c r] \\ + (\dot{\rho}_c \cdot \underline{V}) r \cos i + (\underline{L}_c \cdot \underline{W}) \sin i [\rho_c (r \dot{v} \sin u - \dot{v} \cos u) \\ + \dot{\rho}_c r \cos u] - (\dot{\rho}_c \cdot \underline{W}) r \sin i \cos u$$

$$C_{\Delta i} = (\underline{L}_c \cdot \underline{W}) [\rho_c (r \dot{v} \cos u + \dot{r} \sin u) - \dot{\rho}_c r \sin u] \\ + (\dot{\rho}_c \cdot \underline{W}) r \sin u$$

Compute $\Delta \dot{\rho} = \dot{\rho}_{\text{obs}} - \dot{\rho}_c$

Enter the following linear correction equation into the system of such equations:

$$\rho_c \Delta \dot{\rho} = C_{\frac{\Delta a}{a}} \frac{\Delta a_o}{a_o} + C_{\Delta a_{xN}} \Delta a_{xN_o} + C_{\Delta a_{yN}} \Delta a_{yN_o} + C_{\Delta U_o} \Delta U_o \\ + C_{\Delta \Omega} \Delta \Omega_o + C_{\Delta i} \Delta i$$

b. Computing the Corrected $L_c, a_{xN_o}, a_{yN_o}, h_{x_o}, h_{y_o}, h_{z_o}$

Let $\sum_{j=1}^N C_{ij} \Delta X_j = \Delta 0_i, i = 1, 2, 3, \dots$ represent all of the linear correction equations (i.e., the C_{ij} 's are the coefficients, the ΔX_j 's are the corrections to the orbital parameters at time t_o , the $\Delta 0_i$ being corrected). The following matrix equation is solved to give the corrections, in a least squares sense, to the orbital parameters at time t_o .

$$\begin{bmatrix} \sum c_{i1}^2 & \sum c_{i1} c_{i2} & \dots & \sum c_{i1} c_{iN} \\ \sum c_{i1} c_{i2} & \sum c_{i2}^2 & \dots & \sum c_{i2} c_{iN} \\ \vdots & \vdots & \ddots & \vdots \\ \sum c_{i1} c_{iN} & \sum c_{i2} c_{iN} & \dots & \sum c_{iN}^2 \end{bmatrix} \begin{bmatrix} \Delta x_1 \\ \Delta x_2 \\ \vdots \\ \Delta x_N \end{bmatrix} = \begin{bmatrix} \sum c_{i1} \Delta o_i \\ \sum c_{i2} \Delta o_i \\ \vdots \\ \sum c_{iN} \Delta o_i \end{bmatrix}$$

These corrections are applied as follows (a prime means that the element is a corrected element):

$$a'_{xN_o} = a_{xN_o} + \Delta a_{xN_o}$$

$$a'_{yN_o} = a_{yN_o} + \Delta a_{yN_o}$$

$$a'_o = a_o \left(1 + \frac{\Delta a_o}{a_o} \right)$$

$$\rho'_o = \rho_o + \Delta \rho_o$$

$$i'_o = i_o + \Delta i_o \quad 0 \leq i_o < \pi$$

$$L'_o = L_o + \Delta U_o - \Delta \rho_o \text{ if } \cos i'_o < 0$$

$$L'_o = L_o + \Delta U_o + \Delta \rho_o \text{ if } \cos i'_o > 0$$

$$W'_o \begin{cases} W'_{x_o} = \sin i'_o \sin \rho'_o \\ W'_{y_o} = -\sin i'_o \cos \rho'_o \\ W'_{z_o} = \cos i'_o \end{cases}$$

$$e_o'^2 = a_{xN_o}'^2 + a_{yN_o}'^2$$

$$p_o' = a_o (1 - e_o'^2)$$

$$\underline{h}_o' = \sqrt{p_o'} \underline{w}_o'$$

$$\underline{a}_o' \begin{cases} a_{x_o}' = -a_{yN_o}' \cos i_o' \sin \Omega_o' - a_{xN_o}' \cos \Omega_o' \\ a_{y_o}' = a_{yN_o}' \cos i_o' \cos \Omega_o' + a_{xN_o}' \sin \Omega_o' \\ a_{z_o}' = a_{yN_o}' \sin i_o' \end{cases}$$

Changes made to preceeding ephemeris computation (See Appendix B, C, D).

1. Two subroutines, LUPER and MONEF, have been incorporated into the program to account for lunar perturbations.
2. A subroutine, BELGE, has been added to account for the perturbations due to higher order harmonics in the earth's gravitational potential.
3. A subroutine PRESS accounts for perturbations due to radiation pressure.

APPENDIX B

ANALYSIS FOR INCLUSION OF HIGHER ORDER GRAVITY HARMONICS

The earth's gravitational potential is

$$\phi = \frac{\mu}{r} \left\{ \sum_{n=0}^{\infty} \sum_{m=0}^n \frac{(a_n^m \cos m\lambda + b_n^m \sin m\lambda)}{r^n} P_n^m(\sin \phi) \right\}$$

Here

ϕ = geocentric latitude

λ = east longitude

$$P_n^m(x) = (1-x^2)^{m/2} \frac{d^m}{dx^m} P_n(x)$$

$P_n(x)$ = Legendre polynomial of degree n ; $P_n(1) = 1$

r = geocentric radius in earth radii

Symmetry considerations give

$$a_1^0 = a_1^1 = b_1^0 = b_1^1 = 0$$

$$a_0^0 = 1$$

The potential accounted for by the original program is

$$\frac{\mu}{r} \left\{ \sum_{n=0}^5 \frac{a_n^0}{r^n} P_n^0(\sin \phi) \right\}$$

The remaining potential is

$$\begin{aligned} & \frac{\mu}{r} \sum_{n=2}^5 \sum_{m=1}^n \frac{(a_n^m \cos m\lambda + b_n^m \sin m\lambda)}{r^n} P_n^m(\sin \phi) \\ & + \frac{\mu}{r} \sum_{n=6}^{\infty} \sum_{m=0}^n \frac{(a_n^m \cos m\lambda + b_n^m \sin m\lambda)}{r^n} P_n^m(\sin \phi) \end{aligned}$$

The first line of this expression was added to the original potential.

APPENDIX C

ANALYSIS FOR INCLUSION OF LUNAR PERTURBATIONS

The perturbing function of the moon is

$$R = \frac{m}{r} \left[1 + \left(\frac{r}{r_0} \right)^2 \left(\frac{3}{2} S^2 - \frac{1}{2} \right) \right]$$

where

r = distance of satellite from center of earth, in earth radii

r_0 = distance of moon from center of earth in earth radii

$$= 384,403/6,371$$

m = ratio of moon mass to earth mass = $7.35/5.97 \times 10^{-2}$

$$S = u_1 v_1 + u_2 v_2 + u_3 v_3$$

and

$$\begin{aligned} u_1 &= \cos \phi \cos \lambda \\ u_2 &= \cos \phi \sin \lambda \\ u_3 &= \sin \phi \end{aligned} \quad (\text{Satellite})$$

$$\begin{aligned} v_1 &= \cos \phi_c \cos \lambda_c \\ v_2 &= \cos \phi_c \sin \lambda_c \\ v_3 &= \sin \phi_c \end{aligned} \quad (\text{Moon})$$

The moon ephemeris is computed as described in (5). These equations have been truncated to save computer time. The effect of this truncation is minor as far as computing the perturbing acceleration. The values from the truncated version and the full — terms vary around 20 seconds of arc.

$$\dot{x} = \frac{\partial R}{\partial x}$$

$$\dot{y} = \frac{\partial R}{\partial y}$$

$$\dot{z} = \frac{\partial R}{\partial z}$$

APPENDIX D

ANALYSIS FOR INCLUSION OF RADIATION PRESSURE

Form $\underline{U}_{\odot}$, a unit vector from satellite to sun.

$$\underline{U}_{\odot} = \cos a_{\odot} \cos \delta_{\odot} \underline{i} + \sin a_{\odot} \cos \delta_{\odot} \underline{j} + \sin \delta_{\odot} \underline{k}$$

where

- a) right ascension of sun, $a_{\odot} = \ell_{\odot} - C_{16} \sin 2\ell_{\odot}$
- b) declination of sun, $\delta_{\odot} = C_{17} \sin a_{\odot}$
- c) $\ell_{\odot} = L_{\odot} + C_2(t - t_0) + C_{15} \sin [C_2(t - t_0) - C_{14}]$
- d) $L_{\odot}$ = longitude of sun at Jan 0.0 of year of interest
- e) $C_2 = 360.^{\circ}98564724$
- f) C_{14} = (longitude of perigee of sun minus longitude of sun at Jan 0.0 for year of interest)
- g) $C_{15} = 2(\text{eccentricity of earth's orbit})$
- h) $C_{16} = \tan^2 (\text{mean obliq of ecliptic} \div 2)$
- i) $C_{17} = \tan (\text{mean obliquity of ecliptic})$

Form

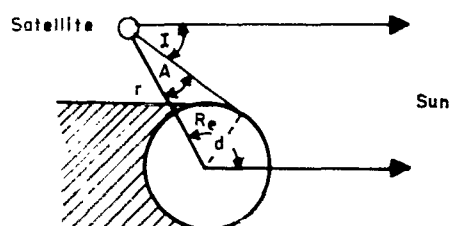
$$V = - \frac{A}{m} P \gamma v$$

where

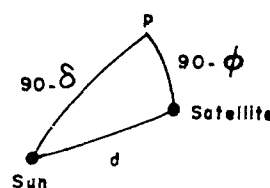
- A = area of satellite
- m = mass of satellite
- $P = 4.355 \times 10^{-7}$ earth radii/kemin²
- γ = emissivity factor of satellite
- v = eclipse factor

If the satellite is illuminated by the Sun, the angle I must be positive.

v is 1 if I positive, 0 if I negative.



$$I = 180 - d - A$$



$$A = \sin^{-1} \left(\frac{R_e}{r} \right)$$

$$d = \cos^{-1} (\sin \phi_{\odot} \sin \phi_{\bullet} + \cos \phi_{\odot} \cos \phi_{\bullet} \cos H)$$

where: $\bullet$ denotes satellite

$$H = |RA_{\bullet} - RA_{\odot}|$$

Form

$$\dot{z}' = VU_1$$

$$\dot{y}' = VU_2$$

$$\dot{z}' = VU_3$$

and add to the other perturbative accelerations.

APPENDIX E
PROGRAM LISTING


```

P(1,1)=1.
P(2,1)=T
P(1,2)=.
P(2,2)=1.
DO 1 N=1,6
  XN=N-1
  P(N,N)=(2.*XN-1.)*P(N-1,N-1)
  FOR: LEGENDRE POLYNOMIALS
  P(N,1)=(2.*N-1.)*T*P(N-1,1)/XN-(XN-1.)*P(N-2,1)/XN
  DO 2 M=2,6
    XM=N-1
    L=M+1
    DO 3 N=1,6
      XN=N-1
      P(N,M)=(2.*XN-1.)*T*P(N-1,M)/XN+(2.*XN-1.)*XM*P(N-1,M-1)/XN
      IF(N-M-1)3,2,3
      P(N,M)=P(N,M)-(XN-1.)*P(N-2,M)/XN
      CONTINUE
      INSERT THE COS(PHI) TO THE M TERMS
      Z=1.
      DO 4 M=2,6
        Z=Z*C
      DO 4 N=1,6
        P(N,M)=P(N,M)*Z
      FOR: PARTIALS
      DO 5 N=1,4
        FR(N)=0.
        XL=ATANF(Y/X)
        IF(XL)6,7,7
        XL=XL + 3.141596543
        XL=PROPR(XL)
        CL=COSE(XL)
        SL=SINF(XL)
        U=R
        DO 6 N=1,6
          XN=N-1
          U=U*R
          T1=1.
          T2=0.
          DO 9 M=2,N
            T3=T1*CL-T2*SL
            T2=T1*SL+T2*CL
            T1=T3
            XM=N-1
            FR(4)=FR(4)+(ALFA(N,M)*T1+BETA(N,M)*T2)/(U*R)*P(N,M)
            FR(1)=FR(1)-XN/(U*R)*(ALFA(N,M)*T1+BETA(N,M)*T2)*P(N,M)
            FR(3)=FR(3)-(XN*ALFA(N,M)*T2-XM*BETA(N,M)*T1)*P(N,M)/U
            FR(2)=FR(2)-(XN*P(N,M)*T/C-P(N,M+1))*(ALFA(N,M)*T1+BETA(N,M)*
              T2)/U
          CONTINUE
          FR(1)=U*(FR(1)-FR(4))/R
          FR(2)=FR(2)*GM/R
          FR(3)=FR(3)*GM/R
          CALL LUER(I,TT,F,XL,R,DR,DLA,DLO)
          FR(1)=FR(1)+FR
          FR(2)=FR(2)+DL
          FR(3)=FR(3)+LL
          DO 8 M=1,3
            T4(M)=.
          DO 9 N=1,3
            T4(N)=T(N)+I(N,N)*FR(N)

```

```

A=T4(1)*CT-T4(2)*ST $
B=T4(1)*ST+T4(2)*CT $
C=T4(3) $
RETURN
END ( ) $
SUB-ROUTINE FESSEL (XKDRG,A,E,XKAE,RTKAE,BESTO,BESI1,EMKAE,XKAESQ
, ) $
EQUIVALENCE (BESI1, RESIO(2)) $
DIMENSION Q(2), A(2), RESIO(10), RESI1(1) $
TABLEDEF XIOCON(12),XI1CON(12),XIOCNS(15),XI1CNS( 15) $
XKAE=(A(1)*E)/XKDRG $
IF(XKAE-8.0)8,1,1$
1RTKAE=SQRT (XKAE)$
TEMP=XIOCON/XKAE$
DO 3 I=2,12$
TEMP=TEMP+XIOCON(I)$
IF(I-12)3,2,2$
3TEMP=TEMP/XKAE$
RESIO(1)=((TEMP)/(RTKAE))*R2PM1 $
TEMP=XI1CON/XKAE$
DO 4 I=2,12$
TEMP=TEMP+XI1CON(I)$
IF(I-12)5,6,6$
5TEMP=TEMP/XKAE$
4CONTINUE$
RESI1(1)=(TEMP*R2PM1)/RTKAE$
GO TO 5
5EMKAE=EXP (-XKAE)$
XKAESQ=XKAE**2$
TEMP=XIOCNS*XKAESQ$
DO 10 I=2,15$
TEMP=TEMP+XIOCNS(I)$
IF(I-15)11,12,12$
11TEMP=TEMP*XKAESQ$
10CONTINUE$
12BESTO(1)=TEMP*EMKAE $
*NOTE THAT RESIO=RESI1(-1)$
TEMP=XI1CNS*XKAESQ$
DO 13 I=2,15$
TEMP=TEMP+XI1CNS(I)$
IF(I-15)16,17,17$
16TEMP=TEMP*XKAESQ$
13CONTINUE$
17BESI1(1)=TEMP*EMKAE*XKAE $
9Q(1)=0.0$
DO 18 I=1,8$
Q(1)=Q(1)-1.0 $
18 BESI1(I+1)=RESI1(I)*2.0*Q(1)/XKAE+BESI1(I-1)$
RETURN$
START TAC $
XIOCON F/551.335894$
F/110.01714$
F/24.385294$
F/6.07404200$
F/1.7277275$
F/.57251421$
F/.227108002$
F/.1121521$
F/.0732421875$
F/.0703125$
F/.125$

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```

      F/1.0$
XI1CON F/-603.244077$
      F/-121.597892$
      F/-27.2488274$
      F/-6.84391429$
      F/-1.99353174$
      F/-6.7659259E-1$
      F/-0.277576447$
      F/-0.144195557$
      F/-0.102539063$
      F/-0.1171875$
      F/-0.375$
      F/1.0$
XI0CNS F/.490166265E-30$
      F/.384290352E-27$
      F/.259780278E-24$
      F/.14963344E-21$
      F/.0724225848E-18$
      F/.0289690339E-15$
      F/9.38596699E-15$
      F/2.40230755E-12$
      F/.47095028E-9$
      F/.0678168403E-6$
      F/6.78168403E-6$
      F/.434027778E-3$
      F/.015625$
      F/.25$
      F/1.0$
XI1CNS F/.0163388755E-30$
      F/.0137246554E-27$
      F/9.99154915E-27$
      F/6.23472667E-24$
      F/3.29193568E-21$
      F/1.44845170E-18$
      F/.521442611E-15$
      F/.150175472E-12$
      F/.0336393058E-9$
      F/5.65140337E-9$
      F/.678168403E-6$
      F/.0542534723E-3$
      F/2.60416667E-3$
      F/.0625$
      F/.5$
P R2PM1 F/.398942281 $
      END TAC $
      END$
      SUBROUTINE COEFF(ARRAY,INTRAP,XMPER)$
*
* SUBROUTINE COEFF COMPUTES THE COEFFICIENTS OF THE CURRENT
* CORRECTION EQUATION, AND STORES THEM IN TERMS ARRAY
*
* ENTER COMMON, DIMENSION, AND EQUIV STATEMENTS HERE$
EQUIVALENCE(RKST0,RKCNT(2)),(HYI,RKCNT(11)),(HZI,RKCNT(12)),
      (HXI,RKCNT(10)),(AXI,RKCNT(7)),(AYI,RKCNT(8)),
      (AZI,RKCNT(9)),(AYN,AXN(2)),(HY,HX(2)),(HZ,PX(3)),
      (WY,WX(1)),(WZ,WX(3)),(AY,AX(2)),(AZ,AX(3)),
      (XVY,XVY(2)),(XMZ,XVX(3)),(XNY,XNX(2)),(XNZ,XNX(3)),
      (AYNI,AYNI(2)),(UY,UX(2)),(UZ,UX(3)),(VY,VX(2)),(VZ,VX(3)),
      (Y,X(2)),(Z,X(3)),(YDOT,XDOT(2)),(ZDOT,XDOT(3)),
      (XUY,XUY(2)),(XUZ,XUZ(3)),(EY ,EOX(2)),
      (EZ ,EOX(3)),(COSPH,SINPH(2)),(CAPY,CAPX(2)),

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(CAPZ,CAPX(3)),(RHOY,RHOX(2)),(RHOZ,RHOX(3)),
(X2THSG,X1STSG(2)),(X3THSG,X1STSG(3)),(X4THSG,X1STSG(4)),
(X5THSG,X1STSG(5)),(X6THSG,X1STSG(6)),(X7THSG,X1STSG(7)),
(X8THSG,X1STSG(8)),(X9THSG,X1STSG(9)),(ASUBY,ASUBX(2)),
(ASURZ,ASURX(3)),(DSURY,DSURX(2)),(DSURZ,DSUBX(3)),
(XLSUBY,XLSURX(2)),(XLSURZ,XLSUBX(3)),(ESUBY,ESUBX(2)),
(ESURZ,ESUBX(3)),(SSUBY,SSURX(2)),(SSURZ,SSUBX(3)),
(ZSURY,ZSURX(2)),(ZSURZ,ZSURX(3)),(XLSUYH,XLSUXH(2)),
(XLSUZH,XLSUXH(3)),(ADOTV,ADOTU(2)),(ADOTW,ADOTU(3)),
(ASUYT,ASUXT(2)),(ASUZH,ASUXT(3)),(DSUYT,DSUXT(2)),
(DSUZH,DSUXT(3)),(XLY,XLX(2)),(XLZ,XLX(3)),(DELTZ,DELT(2)),
(DELTZ,DELT(3)),(IRPT,CNTWD(4)),(IWSTO,WSTO(3)),
(DLYV,DLXV(2)),(DLZV,DLXV(3)),
(RXN,RSUBA(2)),(RYN,RSUBA(3)),(RSUBU,RSUBA(4)),(UXN,USUBA(2)),
(UYN,USUBA(3)),(USUBU,USUBA(4)),(RDOTV,RDOTU(2)),(RDOTW,
RDOTU(3)),(RDTXN,RDOTA(2)),(RDTYN,RDOTA(3)),(RDOTV,
RDOTA(4)),(UDTXN,UDOTA(2)),(UDTYN,UDOTA(3)),(UDOTU,UDOTA(4)),
(RDOTU,RDOTA(4)),(IAXD,STARK),
(DGR,CAPD(2)),(DDGR,CAPD(3)) $
EQUIVALENCE(DLTAA(2),DLTAX),(DLTAA(3),DLTAY),(DLTAA(4),DLTLO),
(DLTAA(5),DLTND),(DLTAA(6),DLTIN) $
COMMON TO,DT,TF,D,XM,THGR,XLO,AXN,
HX,XN,IPGCNT,COUNT,FRAC,P,RTP,WX,SINI,COSI,SINO,
COSQ,AX,COND,CONTS,ESQ,E,A,XX,XNX,AXNI,
XNODE,U,UO,E01,E02,SINE0,COSE0,ESINE,ECOSE,R,
SINU,COSU,AR,RTESQ,UX,VX,X,XDOT,RDOT,RTA,RVDOT,
XNUX,X-U,UZETH,RHO,XNUSQR,TS,C,DC,XOVR5,ZOVR5,
RSGR,RDOT,EQX,XLAT,XLONG,RKCNT,
OTPT,CNTWD,STACD,OBSCD,SINPH,CAPD,CAPC,CAPS,
CAPX,OALT,PHIRD,XOVCT,SINTH,COSTH,THTA,TXYZ,
RHOX,RHO1,SMLH,TERMS,WSTO,TIMTR,CSUBI,XLMPTH,XINCL,DLTAA,
RHOX,SUR,ARSDI,XLGR,
RCNT,BSCNT,RESID,EFCNT,LSTAD,GATE2,EFLAG,
BCNT,OMCNT,X1STSG,ABSX,OMCT2,ETPF6,TIMJ,
CSUM,FUJFT,ASURX,DSUBX,XLSURX,ESUBX,SSURX,
ZSURX,XLSUXH,ADOTU,ADDEL,ASUXT,DSUXT,FACTR,CTYPE,
XMNUTS,XLX,DELT, A2OR,UMUO,RSUBA,ROVA,
USUBA,DENOM,SS,OPRA1,CBRAN,TMM,SATEL,STAID,
XLAMRA,ALPHA,DELTA,ITIMES,RANGE,
Q,DRGCO,XKAE,R2PM1,XK,EMIS,
SIDRT,THGR0,FLP25,VC03,SIGS,SQRMU,XMU,
THDOT,F,XKE,RHCO,CDO,XJMPRM,XKMPRM,
SIXP9,EMPRM,ONEPI,RADYN,XMPER,LINE,
DEN7,FLAG4,VFLAG,XM,SS,TS,DC,VDATA,ISTORV,
RDOTU,RDOTA,UDOTA,RDOTO,RHODT,EXOM,EYOM,RCUPE,
XMUA32,ABMX2,GATE1,GATE2,XJAY5,SUM2,RCNT2,
LSTCNT,SPHA,CPHA,SDEL,CODEL,
ADEL,BDEL,CDEL,ABDEL,FDEL,HDELA,HDELB,HDELC,HDELX,CAPXX,
ARAY,XTEC,YTEC,ZTEC,BXSS,BYSS,BZSS,RCOF,PAB,BIG,BBUF,CVERT,
AVEC,XVEC,YVEC,ZVEC,ASIG1,IAXD,IBOUTH,
ISTORC,DLXV,RHUV,ADDELV,C,DC,INOVBS
DIMENSION Q(2),AXN(2),HX(3),FRAC(2),WX(3),AX(3),A(2),X'X(3),
XNX(3),AXNI(2),XNODE(2),UO(2),UX(3),VX(3),X(3),XDOT(3),
XJX(3),EQX(3),
CNTWD(27),STACD(6),OBSCD(6),SINPH(2),CAPX(3),RHOX(3),TXYZ(4),
TERMS(25),WSTO(25),TIMTR(6),CSUBI(6),X1STSG(9),ASURX(3),
DSURX(3),XLSURX(3),OTPT(9),DLTAA(6),
ESURX(3),SSURX(3),ZSURX(3),XLSUXH(3),ADOTU(3),ASUXT(3),
DSUXT(3),XLX(3),DELT(3),RSUBA(4),USUBA(4),
RSTO(79),HXI(3),
RKCNT(90),VDATA(1000),DLXV(3),

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FJOFT(7), ARAY(3), XTVEC(6), YTVEC(6), ZTVEC(6),
RDOTU(3), RDOTA(4), UDOTA(4), RHODT(4),
BXSS(6), BYSS(6), BZSS(4), BCOF(20), BAR(3),
BIG(6), BRUF(26), CVERT(36), AVEC(3), XVEC(6),
YVFC(6), ZVEC(6), ASIG1(4), CAPXX(3), CAPD(3),
ADEL(3), BDEL(3), CDEL(3), ABDEL(3), FDEL(3),
HDELA(2), HDELB(2), HDELC(2), HDELX(3)
DIMENSION QLX(3) $

*
ADOTU=0.0RADOTV=0.0RADOTW=0.0RADDEL=0.0$
DO (R1) I = 1, 25 $
B1  TERMS(I)=0.0$
DO 1 I=1, 3$
ADOTU=ADOTU+UX(I)*ARAY(I)$
ADOTV=ADOTV+VX(I)*ARAY(I)$
ADOTW=ADOTW+WX(I)*ARAY(I)$
1  ADEL = ADEL + DELTX(I) * ARAY(I)$
BX=X(1)+CAPX(1)BY=X(2)+CAPX(2)BZ=X(3)+CAPX(3)$
BXX=RX**2BYY=RY**2BZZ=BZ**2 $
BRHO=SQRT(BXX+BYY+BZZ) $
IF(IWSTO=3)A1,CORRO,A1$
A1  I = 1 $ RANGE OR ANGLE OBSERVATION
CDLTA TERMS(I)=ADOTU*RSUBA+ADOTV*USUBA$
I=I+1$
DLTAA=TERMS(I-1)$
3TERMS(I)=ADOTV*UXN+ADOTU*RXN$
DLTAX=TERMS(I)I=I+1$
5TERMS(I)=ADOTU*RYN+ADOTV*UYN$
DLTAY=TERMS(I)I=I+1$
7TERMS(I)=ADOTV*USUBU+ADOTU*RSURU$
DLTLO=TERMS(I)I=I+1$
9TERMS(I)=ADOTV*WZ*R+ADOTW*R*(-XMZ)*COSU$
DLTID=TERMS(I)I=I+1$
11TERMS(I)=R*SINU*ADOTW$
DLTIN=TERMS(I)I=I+1$
12 IF (IWSTO) 14, 13, 14$ FIND OBSERVATION TYPE
* RANGE OBSERVATION
13 TERMS (LSTCNT+1) = WSTO(16) - RHOCGRESID = TERMS(LSTCNT+1)*
XMPER $
DO 60 K = 1, 6 $
60 TERMS(K)=TERMS(K)/ASIG1 $ APPLY WEIGHT TO EQUATION
TERMS(LSTCNT+1)=TERMS(LSTCNT+1)/ASIG1(1) $
CALL SETI(IAXD, I)$
BAX=RX/BRHOBAY=BY/BRHOBZ=BZ/BRHO $
BAXX=COSTH*PAX+SINTH*PAY $
BAYY=-SINTH*BAX+COSTH*BAY $
BAX=BAXX $
BAY=BAYY $
TERMS(I)=PAX/ASIG1 $
I=I+1 $
TERMS(I)=BAY/ASIG1 $
I=I+1 $
TERMS(I)=BAZ/ASIG1 $
GO TO TSTOR$
* ANGLE OBSERVATION
14 TERMS(LSTCNT+1)=ADEL*RHOCGRESID=TERMS(LSTCNT+1)*XMPER $
IF(SENSE LIGHT3)90, 90$
* DECL OR ELEV PASS
90 DON=ASIG1(3)*BRHO $
SENSE LIGHT 3 $
GO TO 22 $

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CALL SETI(IXD,I)$
BAX=XDOT(1)+0.05883447*X(2)$
BAY=XDOT(2)-0.05883447*X(1)$
BAZ=XDOT(3)$
BAXX=COSTH*BAX+SINTH*BAY$
BAYY=-SINTH*BAX+COSTH*BAY$
BAX=BAXX$
BAY=BAYY$
TER S(1)=BAX/DON$
I=I+1
TER S(1)=BAY/DON$
I=I+1
TER S(1)=BAZ/DON$
TSTORS IF (IWSTO = 2) AGATE, AGATE, BGATE$
AGATE IF (ABS(RESID)-ABSMX)16,BADOB,BADOB$
16IF (ABS(RESID)-GATE1)17,17,OMIT1$
17NTRAP=1$
18RETURN$
BGATE IF (ABS(RESID)-ABMX2)16,BADOB,BADOB$
16IF (ABS(RESID)-GATE2)17,17,OMIT1$
BADOB NTRAP=2$
GO TO 1$
OMIT1 NTRAP=3$
GO TO 1$
START TAC$
P PT F/3.141592653$
P PIOV2 F/1.570796326$
P CONV F/.01745329251$ DEGREES TO RADIANS
P TEOP F/6.283185306$
SYMPROT COEFF.TSTORS$
PAGE$
END TAC$
END$
SURROUTINE GTOFS (N2)$
* ENTER DIMENSION, COMMON, AND EQUIV. HERE$
EQUIVALENCE(RKSTO,RKCNT(2)),(HYI,RKCNT(11)),(HZ I,RKCNT(12)),
(HXI,RKCNT(10)),(AXI,RKCNT(7)),(AYI,RKCNT(8)),
(AZI,RKCNT(9)),(AYN,AXN(2)),(HY,HX(2)),(HZ,HX(3)),
(WY,WX(2)),(WZ,WX(3)),(AY,AX(2)),(AZ,AX(3)),
(XMY,XMX(2)),(XNZ,XNX(3)),(XNY,XNX(2)),(XNZ,XNX(3)),
(AYNI,AXNI(2)),(UY,UX(2)),(UZ,UX(3)),(VY,VX(2)),(VZ,VX(3)),
(Y,X(2)),(Z,X(3)),(YDOT,XDOT(2)),(ZDOT,XDOT(3)),
(XNUY,XNUX(2)),(XNUZ,XNUX(3)),(EQY ,EQX(2)),
(EQZ ,EQX(3)),(COSPH,SINPH(2)),(CAPY,CAPX(2)),
(CAPZ,CAPX(3)),(RHOY,RHOX(2)),(RHOZ,RHOX(3)),
(X2RDSG,X1STSG(2)),(X3RDSG,X1STSG(3)),(X4THSG,X1STSG(4)),
(X5THSG,X1STSG(5)),(X6THSG,X1STSG(6)),(X7THSG,X1STSG(7)),
(X8THSG,X1STSG(8)),(X9THSG,X1STSG(9)),(ASUBY,ASUBX(2)),
(ASURZ,ASURX(3)),(DSUBY,DSUBX(2)),(DSUFZ,DSUBX(3)),
(XLSUBY,XLSURX(2)),(XLSUBZ,XLSURX(3)),(ESUBY,ESUBX(2)),
(ESURZ,ESURX(3)),(SSUBY,SSUBX(2)),(SSUFZ,SSUBX(3)),
(ZSUBY,ZSUBX(2)),(ZSUBZ,ZSUBX(3)),(XLSUYH,XLSUXH(2)),
(XLSUZH,XLSUXH(3)),(ADOTV,ADOTU(2)),(ADOTW,ADOTU(3)),
(ASUYT,ASUYT(2)),(ASUZY,ASUYT(3)),(DSUYT,DSUYT(2)),
(DSUYZ,DSUYT(3)),(XLY,XLY(2)),(XLZ,XLY(3)),(DELTZ,DELTZ(2)),
(DELTZ,DELTZ(3)),(IRPT,CNTWD(4)),(IWSTO,WSTO(3)),
(DLYV,DLXV(2)),(DLZV,DLXV(3)),
(RXN,RSUBA(2)),(RYN,RSUBA(3)),(RSURU,RSUBA(4)),(UXN,USUBA(2)),
(UYN,USUBA(3)),(USURU,USUBA(4)),(RDOTV,RDOTU(2)),(RDOTW,
RDOTU(3)),(RDOTM,RDOTA(2)),(RDOTN,RDOTA(3)),(RDOTV,
RDOTA(4)),(UDOTM,UDOTA(2)),(UDOTN,UDOTA(3)),(UDOTU,UDOTA(4)),

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(DTOT, DOTA(4)), (IAXD, STARK), (IAXE, STARE),
(DDT, CD(2)), (DDGE, CAPD(3)) $
EQUIVALENCE (DLTAA(2), DLTAX), (DLTAA(3), DLTAY), (DLTAA(4), DLTLO),
(DLTA(5), LL(1)), (DLTAA(6), DLTIN) $
COMMON TO, T, TF, , AV, THGR, XLO, AXN,
HX, XK, IRGCT, COUNT, FRAC, P, RTP, WX, SINI, COSI, SINO,
COSQ, AX, COI, COUNTS, ESQ, E, A, XMX, XNX, AXNI,
XNOIE, UO, E01, E02, SINE0, COSE0, ESINE, ECOSE, R,
SINI, COSU, AT, RIESQ, UX, VX, X, XDOT, RDOT, RTA, RVDOT,
XNUX, XU, UZPTH, RHO, XNUSQR, TS, C, DC, XOVR5, ZOVR5,
RSDR, RRDOT, RQX, YLAT, XLONG, RKCNT,
OTPT, CTWD, STACD, OBSCD, SINPH, CAPD, CAPC, CAPS,
CAPX, OALT, PHIRD, XOVRT, SINTH, COSTH, THTA, TXYZ,
RHOX, REQ1, SWLH, TERMS, WSTO, TIMTR, CSURI, XLMPTH, XINCL, DLTAA,
RHOC, SUR, ARSDL, XLGR,
RCNT, BSCNT, RESID, EFCNT, LSTAD, GATE2, EFLAG,
RRCNT, G CNT, X1STSG, ABSAX, OMCT2, ETPFG, TIMJ,
CSUM, FJFT, ASUBX, DSUBX, XLSUBX, ESUBX, SSURX,
ZSUBX, XLSUXH, ADOTU, ADDEL, ASUXT, DSUXT, FACTR, OTYPE,
XMI TS, LX, DELTX, A2OR, UMUO, RSUR, ROVA,
USUR, TENO, SS, ORRA1, OBPA, TMM, SATL, STAD,
XLANRA, ALPHA, DELTA, ITIMES, RANGE,
Q, IRGCT, XKA, R2PM1, XK, EMIS,
SI, FT, THGR, FLP25, VC03, SIGS, SQRMU, XMU,
THUCT, F, XKE, RHOC, CDO, XUMPRM, XKMPRM,
SIXP9, PR, ONEPI, RADYN, XMPER, LINE,
DEW7, FLAG4, VFLAG, XMASS, TS, DC, VDATA, ISTORV,
RDOTU, RDOTA, UDOTA, RDOT, RHODT, EXOM, EYOM, RCUE,
XMA32, ABMX2, GATE1, GATE2, XJAY5, SUM2, RCNT2,
LSTCNT, SPHA, CPHA, SDEL, CCDEL,
ADEL, BDEL, CDEL, ABDEL, FDEL, HDELA, HDELB, HDELC, HDELX, CAPXX,
ARAY, XTVEC, YTVEC, ZTVEC, BXSS, BYSS, BZSS, BCOF, BAB, BIG, BBUF, CVERT,
AVEC, XVEC, YVEC, ZVEC, ASIG1, IAXD, IBMUTH,
ISTORC, DLXV, RHOV, ADDLV, C, DC, IMOVBS
DIMENSION Q(2), AXN(2), HX(3), FRAC(2), WX(3), AX(3), A(2), XMX(3),
XNX(3), AXNI(2), XNOIE(2), UO(2), UX(3), VX(3), X(3), XDOT(3),
XNUX(3), EQX(3),
CNTD(27), STACD(6), OBSCD(6), SINPH(2), CAPX(3), RHOX(3), TXYZ(4),
TERMS(25), WSTO(25), TIMTR(6), CSURI(6), X1STSG(9), ASUBX(3),
DSUBX(3), XLSUBX(3), CTPT(8), DLTAA(6),
ESUBX(3), SSUBX(3), ZSUBX(3), XLSUXH(3), ADOTU(3), ASUXT(3),
DSUXT(3), LX(3), DELTX(3), RSUBA(4), USUBA(4),
RKSTO(79), HXI(3),
RKCNT(90), VDATA(1000), DLXV(3),
FJFT(7), ARAY(3), XTVEC(6), YTVEC(6), ZTVEC(6),
RDOTU(3), RDOTA(4), UDOTA(4), RHODT(4),
BXSS(6), BYSS(6), BZSS(4), BCOF(20), BAB(3),
BIG(6), BBUF(26), CVERT(36), AVEC(3), XVEC(6),
YVEC(6), ZVEC(6), ASIG1(4), CAPXX(3), CAPD(3),
ADEL(3), RDEL(3), CDEL(3), ABDEL(3), FDEL(3),
HDELA(2), HDELB(2), HDELC(2), HDELX(3) $
IF(RANGE) 3, 3 $
IF(ALPHA) 4, 5, 4 $
IF(DELTA) 4, 6, 4 $
IF(RDOT) RRATE, X6, RRATE $
IF(ISTORV) LIGHT $
GO TO 1
300 7 IF, P5
7ASUBX(1)=0, P5
ASUBX(9)=RANGE $
N2=0 $

```



```

CALL MONEF(T,TT,SYN,T,SYLON,FA,DEC)*
U1=COSF(SLAT)*COSF(SLON)
U2=COSF(SLAT)*SINF(SLON)
U3=SINF(SLAT)
V1=COSF(SML*T)*COSF(SMLON)
V2=COSF(SML*T)*SINF(SMLON)
V3=SINF(SML*T)
S=U1*V1+U2*V2+U3*V3
XM=.0123115E78
RM=60.33636791
DR=YM/R*(2.*RS)/(R.*R)*(1.5*S*-F)
DSLX=-SINF(SLAT)*(COSF(SLON)*V1+SINF(SLON)*V2)+COSF(SLAT)*V3
DSLX=-SINF(SLAT)*COSF(SLAT)*V1+COSF(SLON)*COSF(SLAT)*V2
DLA=XM/RM*(RS*RS)/(R.*RM)*3.*S*DSLX
DLO=XM/RM*(RS*RS)/(R.*RM)*3.*S*DLO
RETURN
END (
SUBROUTINE MONEF(IYR,DAY,CLAT,CLON,R,DEC)
RAD=57.2957795
SEC=206265.
TP=6.243185307
PI=3.141592653
IF(IYR-4)30,32,34
30 T=DAY+731.5
GO TO 115
32 T=DAY+1096.5
GO TO 115
34 T=DAY+1061.5
115 XL=MODF(5.200850+0.22997150*T,TP)
FL=MODF(0.739177+0.22802713*T,TP)
FLP=MODF(6.229427+0.01720197*T,TP)
FX=MODF(2.031039+0.23089572*T,TP)
D=MODF(0.328366+0.21276872*T,TP)
E=MODF(D+D,TP)
G=MODF(FL+FL,TP)
H=MODF(FX+FX,TP)
CLO=SEC*XL+22640.*SINF(FL)-4586.*SINF(FL-E)+2370.*SINF(E)
+749.*SINF(G)-468.*SINF(FLP)-412.*SINF(H)-212.*SINF(G-E)
-205.*SINF(FL+FLP-E)+192.*SINF(FL+E)-165.*SINF(FLP-E)
+148.*SINF(FL+FLP)-125.*SINF(D)-109.*SINF(FL+FLP)-55.*SINF(H-E)
-45.*SINF(FL+H)+40.*SINF(FL-H)-38.*SINF(FL-E-E)+36.*SINF(FL+G)
-31.*SINF(G-E-E)+28.*SINF(FL-FLP-E)-24.*SINF(FLP+E)
+19.*SINF(FL-D)+18.*SINF(FLP+D)
CLO=MODF(CLO,1296000.)/SEC
S=FX+.1096*SINF(FL)-.0222*SINF(FL-E)+.0115*SINF(E)
+.0037*SINF(G)
CLAT=14520.*SINF(S)*(1.-.00293*SINF(1.403808-.0009242203*T))
-31.*SINF(FX-FL-E)-25.*SINF(FX-G)-23.*SINF(FLP+FX-E)
+21.*SINF(FX-FL)-526.*SINF(FX-F)+44.*SINF(FL+FX-E)
CLAT=CLAT/SEC
CA=COSF(CLO)
CR=COSF(CLAT)
SA=SINF(CLO)
SR=SINF(CLAT)
SD=.91745*SB+.30784*CR*SA
CDCA=C.*CA
CDSA=-.79784*S+.91745*CR*S/
IF(ARF(CDCA)-ARF(CDSA))3,3,4
3 R=ATANF(CDCA/CDSA)
R=1.571796-R
GO TO 6

```

```

4      R=ATANF(CDSA/CDCA)
      IF(R)5,6,6
5      R=R+PI
6      IF(CDS-7)7,8,8
7      R=R+PI
8      DEC=ATA F(SF/SRTF(1.-SD*SD))
9      RETURN
      END (
      SUBROUTINE PRESS(IXYR,X,T,D,XM,VV,U1,U2,U3)$
      DIMENSION X(3)$
      TABLEDEF SUNL(4),C14(4),C15(4),C16(4),C17(4) $
      C1=.9856472 $
      P1=.456E-6 $
      P2=1.006814784 $
      PI=3.141592653 $
      HRK=0.0 $
      IF(IXYR-6)10,11,12 $
10     I=1 $
      GO TO 13$
11     I=2 $
      GO TO 13 $
12     IF(IXYR-7)100,101,100 $
101    I=3$
13     SOL=SUNL(I)+C1*T+C15(I)*SINF(C1*T-C14(I)) $
      RA=SOL-C16(I)*SINF(SOL+SOL) $
      DEC=ATANF(P2*C17(I)*SINF(RA))$
      CRA=COSF(RA)@CDEC=COSF(DEC)$
      SRA=SINF(RA)@SDEC=SINF(DEC)$
      U1=CRA*CDEC@U2=SRA*CDEC@U3=CDEC $
      R1=SRTF(X(1)*X(1)+X(2)*X(2)+X(3)*X(3))$
      V1=X(1)/R1@V2=X(2)/R1@V3=X(3)/R1$
      TT=U1*V1+U2*V2+U3*V3 $
      IF(TT)1,1,2 $
1     IF(ABSF(TT)-SRTF(R1*R1-1.)/R1)2,3,3 $
2     V=1.0 $
      GO TO 4$
3     V=0.0 $
4     XSECT=D*PI/4.0$
      VV=-XSECT/X*PI*V*HRK$
100   RETURN $
      START TAC $
SUNL  F/4.870848558 $
      F/4.866842762 $
      F/4.8621843 $ SUNL FOR 1964
      F/0.0 $
      F/0.0 $
C14   F/.055997282 $
      F/.054833352 $
      F/.0652514 $ C14 FOR 1964
      F/0.0 $
      F/0.0 $
C15   F/.0334502 $
      F/.0334514 $
      F/.0334484 $ C15 FOR 1964
      F/0.0 $
      F/0.0 $
C16   F/.043053055 $
      F/.043052682 $
      F/.04305219 $ C16 FOR 1964
      F/0.0 $
      F/0.0 $

```

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\$

```

4      R=ATANF(CDSA/CDCA)
      IF(R)5,6,6
5      R=R+PI
6      IF(CDS-)7,8,8
7      R=R+PI
8      DEC=ATA F(SF/SRTF(1.-SD*SD))
9      RETURN
      END (
      SUBROUTINE PRESS(IXYR,X,T,D,XM,VV,U1,U2,U3)$
      DIMENSION X(3)*
      TABLEDEF SUNL(4),C14(4),C15(4),C16(4),C17(4) $
      C1=.9856472 $
      P1=.456E-6 $
      P2=1.006814784 $
      PI=3.141592653 $
      HRK=0.0 $
      IF(IXYR-6)10,11,12 $
10     I=1 $
      GO TO 13$
11     I=2 $
      GO TO 13 $
12     IF(IXYR-7)100,101,100 $
101    I=3$
13     SOL=SUNL(I)+C1*T+C15(I)*SINF(C1*T-C14(I)) $
      RA=SOL-C16(I)*SINF(SOL+SOL) $
      DEC=ATANF(P2*C17(I)*SINF(RA))$
      CRA=COSF(RA)@CDEC=COSF(DEC)$
      SRA=SINF(RA)@SDEC=SINF(DEC)$
      U1=CRA*CDEC@U2=SRA*CDEC@U3=CDEC $
      R1=SQRTF(X(1)*X(1)+X(2)*X(2)+X(3)*X(3))$
      V1=X(1)/R1@V2=X(2)/R1@V3=X(3)/R1$
      TT=U1*V1+U2*V2+U3*V3 $
      IF(TT)1,1,2 $
1     IF(4RSE(TT)-SQRTF(R1*R1-1.)/R1)2,3,3 $
2     V=1.0 $
      GO TO 4$
3     V=0.0 $
4     XSECT=D*D*PI/4.0$
      VV=-XSECT/X*P1*V*HRK$
100   RETURN $
      START TAC $
      SUNL F/4.870848558 $
      F/4.866542762 $
      F/4.8621843 $ SUNL FOR 1964
      F/0.0 $
      F/0.0 $
      C14 F/.055997282 $
      F/.0548733582 $
      F/.0652514 $ C14 FOR 1964
      F/0.0 $
      F/0.0 $
      C15 F/.0334502 $
      F/.0334514 $
      F/.0334484 $ C15 FOR 1964
      F/0.0 $
      F/0.0 $
      C16 F/.043053055 $
      F/.043152682 $
      F/.0431219 $ C16 FOR 1964
      F/0.0 $
      F/0.0 $

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C17  F/.43385539  $
      F/.43385269  $
      F/.43385999  $ C17 FOR 1964
      F/0.0  $
      F/0.0  $
      END TAC $
      END  $
      SUBROUTINE SUMA(I,N,M,A,B)$
      DIMENSION I(18),R(10)$
      TABLEDEF ACNTS(23),QCNIS(53)  $
      DO 1 L=1,10$
      IF(I(L))3,3,2$
2      TEMP=0.0$
      K=I(L)$
      DO 4 J=1,K$
      TEMP=A*TEMP+ACNTS(N)$
4      N = N + 1  $
      B(K)=TEMP$
      1  I = I + 1  $
      3  RETUR  $
      START TAC  $
ACNTS F/.160217285$
      F/.21454375$
      F/.328125$
      F/.75$
      F/1.0$
      F/.341796875$
      F/.46875$
      F/.75$
      F/2.0$
      F/.256347656$
      F/.322265625$
      F/.4375$
      F/.75$
      F/.205078125$
      F/.234375$
      F/.25$
      F/.128173828$
      F/.12891625$
      F/.109375$
      F/.068359375$
      F/.046875$
      F/.0366210938$
      F/.021474375$
QCNIS F/.0747680664$
      F/-.854492186E-1$
      F/.09765625$
      F/-.1171875$
      F/.140625$
      F/-.1875$
      F/.25$
      F/-.5$
      F/1.0$
      F/-.1345825$
      F/.170898438$
      F/-.170898438$
      F/.234375$
      F/-.234375$
      F/.375$
      F/-.375$
      F/1.0$

```

```

F/-1.0$
F/.119328906$
F/-.13671875$
F/.1464437-$
F/-.1738125$
F/.1875$
F/-.25$
F/.25$
F/-.5$
F/-.0897216797$
F/.102539063$
F/-.102539063$
F/.1171875$
F/-.1171875$
F/.125$
F/-.125$
F/.0598144531$
F/-.068359375$
F/.05859375$
F/-.0703125$
F/.046875$
F/-.0625$
F/-.0384521484$
F/.0341796875$
F/-.0341796875$
F/.0234375$
F/-.0234375$
F/.0170898438$
F/-.01953125$
F/.009735625$
F/-.01171875$
F/-.00951303711$
F/.0048828125$
F/-.0048828125$
F/.00213623047$
F/-.00244140625$
ENDTAC $
END$
SUBROUTINE RCARD (SATEL,STAIID,ASIG1,IBMUTH,DAYNO,ALPHA,DELTA,
RANGE,ROD TO,UTIME,NCARD,XMPER)$

```

```

*
*   RCARD READS AND CONVERTS AN OBSERVATION CARD
*
      DIMENSION HARAY(7), D1(3), ASIG1(4) $
      TABLEF TMOTO (12) $
      READ READ INPUT TAPE N,OCR,ENDER,SATEL,ITYPE,STAIID,IY1,MONTH,DD,HH,
      XMP,SI,HARAY $
      OCR FOR AT (A2,A3,I1,4X,W4,I1,I2,3F2.0,F6.4,A3,6A8) $
      ALPHA = 0.0 DELTA = 0.0 ROD TO = 0.0 RANGE = 0.0 $
      DO 10 I = 1,4$
      10 ASIG1(I) = 0.0 $
      IF (ENDER) E (HEND) , NCARD = 20 RETURN $
      NCARD = 1 $
      IF (ITYPE-4) RCARD2A,RCARD3A,RCARD2A $ JMP IF PASE FREQ
      RCARD2A DAYNO = TMOTO(MONTH) + DD $
      START ICS CHECK FOR LEAP YEAR
      TMA HARAYS
      SRA 30 $
      TAY HARAY
      INCDL IY1 $
      TML IY1$

```

```

SR      32%
JCR      SMC      JCR IF NOT LEAP YEAR
JCR      SMC      JCR IF NOT LEAP YEAR
END TAC
IF (CUTHT)T( ), CRYNC=DAY*0+1.$ LEAP YEAR
S2      UT1 F = 20. * H + MM + SI/60. $ GET OPS TIME IN MINUTES
IF (IT. F - 2) CR1, RCRD2, RCRD4 $
START TAC
AFR10 40%
P FREQ w/21 $
* RCRD3A READS IN EMITTED FREQUENCY, JUMPS TO READ NEXT CARD
RCRD3A TM 6/1747 $
ETA HARAY+1 $
TM HARAY+2 $
JMP FLTFLT.FXFLT
TAR EFREQ1
JMP READ $
END TAC $
* OCX1 READS IN RANGE AND STD. DEV OF RANGE FOR RADAR OBSERVATION
OCX1 IF(IRH)HD2,HD1,HD2 $
H11 WRITE OUTPUT TAPE 5,HD2 $
H112 FORMAT(2H20,3HSTA,6X,4HTIME,5X,10HRANGE-E.R.,3X,5HSIGMA)$
IRH=10 $
IOH=0
IDH=0
H11 CONTINUE $
START TAC $
TM 36/1747 $
ETA HARAY + 1$
TA HARAY+1 $
TM HARAY+2 $
JMP FLTFLT.FLTFLT
FDA XMPER$
TAR RANGE$ RANGE IN EARTH RADII
JMP INDFX$ GET L(ASIG1) TO IP4
CA $
TM HARAY+3$
SLAP 6 $
SLA 6 $
AM 0/33747$
SRAP 36$
JMP FLTFLT.FXFLT $
FDA XMPER
TA 4 $
END TAC $
WRITE OUTPUT TAPE 5,ROB1,STAD,UTIME,RANGE,ASIG1(1)$
ROB1 FORMAT(2H20,4X,F2.2,3X,E12.8,3X,F4.2)$
START TAC$
JMP RT1 $
INDEX TJ (P)+6H4
CD$
TXDLC 0,4$
TD SAV1$
TM ASI-1$
TDxLC 0,4$
JMP 2$
END TAC $
ROB2 IF(IOH)HD5,HD6,HD5 $
H16 WRITE OUTPUT TAPE 5,HD4 $
H164 FORMAT(2H20,3HSTA,6X,4HTIME,6X,9HALPHA-DEG,4X,9HDELTA-DEG,4X,
9HSIG-ALPHA,3X,9HSIG-DELTA,3X,9H0=RA 1=A2) $

```

IOHD=100\$
 IRHD=0 \$
 IDHD=0
 CO 1 INU\$
 STA-T MAC \$
 TMW HARAY+1\$
 CA
 SLAQ 12 0000003334
 TAA D1+1 MINS
 CA
 SLAQ 12 0000003536
 SLA 6
 AM 0/33T47 000003536.
 SRAG 36 0003536.3738 TO Q
 JMP FLTFLT.FXFLT
 FDA F/3600 CONVERT SECS TO DEGS OR HRS
 TQM ALPHA
 TMQ D1+1
 CA
 JMP FLTFLT.FXFLT
 FDA F/60 CONVERT MINS TO DEGS OR HRS
 TQA
 FAMS ALPHA
 TMQ HARAY\$ 30 - 32
 CA
 JMP FLTFLT.FXFLT
 TAM D2
 TMA HARAY\$ FIND WHETHER RA-DEC OR AZ-ALT
 SRA 12
 SM 0/40T47
 JAZ (P)+6H
 TMA D/1R15\$
 TAN IRMUTH
 TMA D2
 FAM ALPHA
 JMP (P)+6H\$
 CM IRMUTH\$ RA-DEC
 TMA D2
 FSR ALPHA
 TAG
 FMWR F/15 CONVERT AZIM FROM HRS TO DEGS
 TAM ALPHA -RT ASCEN IN DEGS TO ALPHA
 TMQ 0/7777T47
 ETA HARAY+1\$ 0000003940 TO A
 TMQ HARAY+2\$ 41-48 TO Q
 SLAQ 12 000039-42 TO A,43-4800 TO Q
 TAA D1 DEGS
 CA
 SLAQ 12 0000004344
 TAA D1+1\$ MINS
 CA
 SLAQ 12 0000004546
 SLA 6
 AM 0/33T47
 SLAQ 6 00004546.47 TO A
 TA
 CA
 JMP FLTFLT.FXFLT
 FDA F/3600 CONVERT SECS TO DEGS
 TQ ELTA
 TA D1+1

```

CA
JMP FLTFLT.FXFLT
FPA F/6
TCA
FAMS DELTA
TMA D1
CA
JMP FLTFLT.FXFLT
TMA D1 $
TMA FLTFLT.MSIGN $
JA2 (P)+4H $
TMA D1 $
FSMS DELTA $
JMP (P)+3H $
TMA D1 $
FAMS DELTA $
TMA HARAY+4$
SLA 12$ GET 0059-62
SRAG 24
SRAG 12
SLA 6
AM 0/33T47
SRAG 36
JMP FLTFLT.FXFLT
CM HARAY+6
TMA HARAY+6
TMA HARAY+6
JMP INDEX $
TAM 2,4$
TMR 12/1T47$
ETA HARAY+4$
TMR HARAY+5$
SLA 6
AM 0/33T47
SRAG 36
JMP FLTFLT.FXFLT
TAM 3,4$
END TAC $
WRITE OUTPUT TAPE 5,0081,STAIID,UTIME,ALPHA,DELTA,ASIG1(3),
ASIG1(4),IBNUTH $
0011 FOR AT(2H2D,W4,3X,F8.2,3X,F10.6,3X,F11.6,5X,F5.2,8X,F5.2,
8X,I1) $
DO(CV) I=3,4 $
CV ASIG1(I)=ASIG1(I)*.000005 $ CONVERT SIGMA TO RADIAN
START TAC $
JMP RTN $
TKOTO F/0.0$
F/31.0$
F/59.0$
F/90.0$
F/120.0$
F/151.0$
F/181.0$
F/212.0$
F/243.0$
F/273.0$
F/304.0$
F/334.0$
F/365.0$
* OCR3 READS IN DOPPLER OBSERVATION (RANGE RATE)
END TAC $

```

```

RCPD4 IF(IDH0)HD3,HD4,HD3 $
HD4 WRITE OUTPUT TAPE 5,HD03 $
HD03 FOR AT(2H20,3HSTA,6Y,4HTIME,6X,10HFREQ - CPS,4X,5HSIGMA) $
      IDH0=100 $
      IOH=0 $
      IRH0=0 $
HI 7 CONTINUE $
      START TAC $
      TMO 6/1T47 $
      ETA HARAY+1 $
      TMO HARAY+2 $
      JMP FLTFLT.FXFLT
      TAO 01
      FAL F/100.EP $
      TAM 01+1 $
      FDA F/100. $
      TGM 02 $
      TMA 01 $
      FSM EFREQ1 $
      FDA 01+1 $
      FMAR F/-37922.43
      TAM RODTO
      JMP INDEX $
      AIX0 1,4$
OCF12 CA $
      TMO HARAY+3 $
      SLAQ 6
      SLA 6
      AM 0/33T47
      SRAQ 36
      JMP FLTFLT.FXFLT
      TAM ,4$
      END TAC $
      WRITE OUTPUT TAPE 5,DOB1,STAID,UTIME,D2,ASIG1(2)$
DOF1 FORMAT(2H20,W4,3X,FA.2,3X,F12.2,3X,F4.2)$
      START TAC$
RTN TMO SAV1 $ RESTORE INDEX REGISTER 4
      TDXLC 0,4 $
E AFEND
      END TAC $
      RETURN $
      END $
      SUBROUTINE RCTFY(XMPER,ESINE,ECOSF,A,WX,DRGCO,RKSTO,XN,XMZ,AYNI,
      UZ,R) $
*
* SUBROUTINE RCTFY APPLIES THE CORRECTIONS FOR ATMOSPHERIC DRAG
* DURING THE INTEGRATION OF THE EPHEMERIS
* IT IS CALLED ONCE PER REVOLUTION BY CNTRL, INTEGRATION CONTROL
*
      EQUIVALENCE (BESI1, BESI0(2)) $
      DIMENSION RKSTO(79),RESIO(10),RESI1(1),WX(3),A(2),Q(2)$
      START TAC $
P PI F/3.141592653 $
P XKE F/.074365284$
      END TAC $
      ECCEN=ATAN (ESINE/ECOSF)$
      IF(ECOSF)1,2,2$
1 ECCEN=PI+ECCEN
2 XMEANA=ECCEN-ESINE/VTPI=XMEANA/XM $
      ES=RKSTO(6)**2+RKSTO(7)**2+RKSTO(8)**2
      E=SQRT (ES)$

```

```

PERGE = (1) * (1. - F) - F * RGE$
ZE = (X * AY * 1 * ) / E * Z = ZE / $
F = 1.0 / (A * X * F) $
CALL TINT(I, H, SIGMA, X - F, XKFRG, RATIO) $
GO TO (1, 6), I $
CALL RESSEL(XKFRG, A, E, XKA, PTKAE, PESIO, PESI1, EMKAE, XKAESQ, Q) $
CALL ADPRAG(ES, E, DP6C, RATIO, A, Q, RESI, PERGE, ADPRAG, QDRAG)$
ADPRAG = (1) + ADPRAG $
XNPRAG = RE / SQRT(ADPRAG ** 3) $
RKSTO(I) = RKSTO(5) + XNPRAG * TWTPI - XMEANA $
FPRGE = (1.0 - (PERGE + QDRAG) / ADPRAG) / ES
PDRAG = 1.05
DO K = 6, 5 $
RKSTO(K) = FPRGE * RKSTO(K) $
3 PDRAG = PDRAG + RKSTO(K) ** 2 $
PDRAG = SQRT(ADPRAG * (1.0 - PDRAG)) $
DO I = 1, 11 $
4 RKSTO(I) = IX(I - 8) * PDRAG $
RETURN
END $
SUBROUTINE HEADER (STARC, ISENT, LSTCNT, IASIZE, IDBUF, XMPER) $
DIMENSION STARC(1000), IDBUF(10) $
TABLEDEF ASIG(4) $
*
* READ STATION CARDS FROM TAPE 10
* STORE STATION INFO IN 9 WORD GROUPS IN STARC BUFFER
* ASSIGN INTERNAL DATUM NUMBERS AND STORE EXTERNAL DATUM NUMBERS
* IN IDBUF TABLE
ISTC T = 00 REMIND 10 $
WRITE OUTPUT TAPE 5, SC1 $
SC1 FORMAT(10H70 INPUT DATA = STATION CARDS/) $
WRITE OUTPUT TAPE 5, SC2 $
SC2 FORMAT(2H20, 3HSTA, 3X, 8PLATITUDE, 4X, 9HLONGITUDE, 4X, 9HELEVATION,
4X, 9HDATUM, 12X, 19H OBSERVATION SIGMAS) $
WRITE OUTPUT TAPE 5, SC5 $
SC5 FORMAT(2H10, 53X, 30HPANGE RRATE RA-AZ DEC-EL) $
KN1 J = ISENT * 9 + 1 $ READ NEXT STATION CARD
K = J + 8 $
READ INPUT TAPE 10, KN3, (STARC(I), I = J, K) $
KN3 FORMAT(4, F8.5, F9.5, F6.0, 5X, I4, 1X, F8.8, 3F8.5) $
IF (STARC(J)) = (HEND), GO TO TRL $
WRITE OUTPUT TAPE 5, SC3, (STARC(I), I = J, K) $
SC3 FORMAT(2H10, 4, 1X, F8.5, 3X, F10.5, 4X, F7.0, 5X, I4, 4X, 4F8.5) $
L = J + 5 $
M = 1 $ REPLACE SIGMAS THAT
DO 20 I = L, K $ WERE NOT GIVEN
IF (STARC(I)) 20, 10, 20 $ WITH STANDARD VALUES
10 STARC(I) = ASIG(M) $
20 M = M + 1 $
STARC(J+1) = STARC(J+1) * .01745329251 $ CONVERT LAT AND LONG TO
STARC(J+2) = PRPR(-STARC(J+2) * .01745329251) $ RADIANS
STARC(J+3) = STARC(J+3) / XMPER $
STARC(J+5) = STARC(J+5) / XMPER $
ISENT = ISENT + 1 $ FORM STATION COUNT IN ISENT
GO TO M1 $ GO GET NEXT STATION CARD
START TACS
P HEND W/0000E B $
FOUND TXOLC , INCUR$ THIS EXTERNAL DATUM NO. ALREADY IN TABLE
TDA $ REPLACE STARC ENTRY W. INTERNAL DATUM NO.
SM IDBUF $
AFEND 72 $

```

```

TAM      ,INSTARC
JMP      NEXT
ASIG     F/10.0 $ METERS - RANGE SIGMA
        F/10.0 $ CYCLES PER SECOND
        F/0.00001 $ RADIANS
        F/0.00001 $ FA. TANS
        SAME INSTARC,3 $
        SAME INCR,1 $
TFL      CD$
        TXDLC ,2
        TXDRC ,3
        TDI   SAVE
        TMA   ISENT
        SLA   3
        AM    ISENT
        TMD   STARC$
        TDXLC ,INSTARC
        AIXO  4,INSTARC$
        CD$
        TXDLC 0,INSTARC $
        AD$
        AM    C/HLT,ORC/JMP,TEST$
        TAM   DONEKEY$ C/HLT,STARC+4+9*ISENT@C/JMP,TEST$
        TMD   28/1T27@8/1T47
        ETD   SEARCH
        TDI   SEARCH
TEST     TMA   ,INSTARC
        JAZ   NEXT$ IGNORE STARC ENTRY IF DATUM NO. ZERO
        TMD   IDBUF$
RSEARCH  RPTAN 0,INCR$ IR = ADDR OF DATUM NO. TABLE
        TMD   0$ IS THIS DATUM NO. ALREADY IN TABLE<
        JAED  1,INCR
        NTFND INCR SEARCH$ NO - FORM NEW INTERNAL DATUM NO.
        TMD   0/7777739
        ETD   SEARCH
        SCD   24$ REPLACE DATUM NO. IN STARC TABLE
        TDI   ,INSTARC$ W. INTERNAL DATUM NO.
        TAM   ,INCR$ EXT. DATUM NO. TO DATUM NO. TABLE
NFTY     TMD   DONEKEY
        AIXO  9,1 STARC$
*        GO TO **TEST** IF MORE DATA IN STARC ARRAY
FINI     TMD   12/1T3$ END OF STARC TABLE
        ETD   SEARCH$ STORE SIZE OF DATUM NO. TABLE
        SCU   24$ IN IASIZE
        TDA   IASIZE
        TDA
        SLA   1
        AD
        AM    0/6-15
        TAM   LSTCNT $ 3 * IASIZE + 6
        TMD   SAVE
        TDXLC ,2
        TDARC ,3
E        AFED $
        END TAC $
ATN      RETURN $
        EN $
SUB OUTLINE REAL (C,TAD,STARC,INFD,CARD)$
DE ENSTON STA C (1700) , C TAD (27) $
RE. INUT TAPE 10,10,C TAD (8) , STARC(3),STARC(4),STARC(5) $

```

```

10  FORMAT(4,F5.5,F9.5,F6.0)$
    NCARD=1-
    IF(NT(2))F(500)GO TO 3001
    IF(PE=50,51,1)
50  WRITE(OUTPUT)T SE 5,SC1$
SUB1  FORMAT(1H71)PUT DATA = STATION CARDS/$
    WRITE(OUTPUT)T SE 5,SC2$
SUB2  FORMAT(1H20,3H-1A,3,8,LATITUDE,4X,9HLONGITUDE,4X,9HELEVATION/)$
    IMP=1-
51  WRITE(OUTPUT)T SE 5,SC3, CNTWD(8),STARC(3),STARC(4),STARC(5)$
SUB3  FORMAT(1H10,4,2X,F5.5,4X,F9.5,5X,F6.0)$
    GO TO 31$
30  NCARD=2-
31  RETURN$
    START TAC $
P-END  w/END
END TAC $
END $
SUBROUTINE STARTER (HDNG,CNTWD,X1STSG,TO,DT,TF,D,XM,XLO,AXN,HX,
IPNTFL,IRSMX,MCODE,CRGLA,ORGTM,REFCA,REFTM,ABMX2,EFLAG,IXYR,
XAXS)$
    DIMENSION X1STSG(9),HDNG(24),CNTWD(27),AXN(2),HX(3),MCODE(3)$
    DIMENSION OUT1(7),OUT2(6),OUT3(4)$
*
*   STARTER READS THE FIVE CONTROL CARDS
*   INPUTS ORBITAL ELEMENTS AND CONTROL PARAMETERS FOR THE RUN
*
    N=0-
    READ INPUT TAPE N,CCR,(HDNG(I),I=1,10),(HDNG(I),I=11,20)$
CCR  FORMAT(10A8)$
    READ INPUT TAPE N,CCR1,TO,DT,TF,D,XM$      CARD 3
CCR1  FORMAT(6E12,F)$
    OUT3(1)=OUT3(2)=TF$
    OUT3(3)=OUT3(4)=XM$
    READ INPUT TAPE N,CCR1,XLO,AXN,HX$      CARD 4
CCR5  IF(XLO)CCR5,CCR4,CCR4$
    XLO=-XLO$
    OUT1(2)=XLO,OUT1(3)=AXN(1),OUT1(4)=AXN(2)$
    OUT1(5)=HX(1),OUT1(6)=HX(2),OUT1(7)=HX(3)$
    TEM1=SQRT(XLO/XAXS*(1.0-AXN(1)**2))$
    TEM2=(H(1)+HX(2)+HX(3))*0.01745329$
    TEM3=6.283185306$
CL3  IF(TEM2)GT(TEM3),GO TO CL1$
    XLO=TEM2$
    GO TO CL21$
CL3  TEM2=TEM2-TEM3$
    GO TO CL3$
CL21  HX(2)=H(2)*0.01745329$
    HX(3)=H(3)*0.01745329$
    AXN(2)=XN(2)*0.01745329$
CL2  TEM4=XN(1)*COS(HX(2))$
    TEM5=XN(1)*SIN(HX(2))$
    TEM6=TEM1*SIN(HX(3))*SIN(AXN(2))$
    TEM7=COS(HX(3))$
    TEM8=-TEM6$
    TEM9=TEM1*TEM7*SIN(AXN(2))$
    TEM10=TEM1*COS(AXN(2))$
    AXN(1)=TEM4,AXN(2)=TEM5$
    HX(1)=TEM6,HX(2)=TEM7,HX(3)=TEM8$
CCR4  OUT2(1)=XLO,OUT2(2)=AXN(1),OUT2(3)=AXN(2)$
    OUT2(4)=HX(1),OUT2(5)=HX(2),OUT2(6)=HX(3)$

```

```

      REF 1, OUT TAP: N,CCR2,IPNTFL,ORGDA,ORGTN,C,TW2(1),CNT-D(4),
      EFLTG,X1STS6(1),REFTA,LEFTA,RCODE,IVYR,ABSMY,(X1STS6(I),I=2,9),
      AP 2
CUT2  FOR AT(1,5,5,F1.0,F2.0,1,11,F1.0,F3.0,F4.0,F9.0,311,I2,F6.0,
      BE1.0,F1.0) $
      OUT1(1)=ORG A+RGD /14.0.0 $
      WRITE OUTPUT TAPE 5, TPAGE1 $
TPAGE1 FOR AT(2H70,28,144H BRIT PREDICTION AND STATION LOCATOR PROGRAM/
      /) $
      IF(CNT (1))E(-LNK),GO TO TPAGE2 $
      WRITE OUTPUT TAPE 5, TPAGE2 $
TPAGE2 FOR AT(2H10,44,144H SIMULATION RUN//) $
      GO TO TPAGE3 $
TPAGE3 WRITE OUTPUT TAPE 5, TPAGE4 $
TPAGE4 FOR AT(2H10,36,27H DIFFERENTIAL CORRECTION RUN//) $
TPAGE5 WRITE OUTPUT TAPE 5, TPAGE6 $
TPAGE6 FOR AT(2H10,11H INPUT DATA//) $
      WRITE OUTPUT TAPE 5, TPAGE7, OUT1(1), OUT2(1), OUT3(1) $
TPAGE7 FOR AT(2H10,9X,9HEPOCH DAY,F15.8,7X,3HL/0,F15.8,7X,7HDELTA T,
      F15.8//) $
      WRITE OUTPUT TAPE 5, TPAGE8, OUT1(2), OUT2(2), OUT3(2) $
TPAGE8 FOR AT(2H10,9X,9HAXIS-M,M,F15.8,7X,3HAXN,F15.8,7X,7HT/0-T/F,
      F15.8//) $
      WRITE OUTPUT TAPE 5, TPAGE9, OUT1(3), OUT2(3) $
TPAGE9 FOR AT(2H10,9X,9HECCEN-TY,F15.8,7X,3HAYN,F15.8//) $
      WRITE OUTPUT TAPE 5, TPAGE10, OUT1(4), OUT2(4) $
TPAGE10 FOR AT(2H10,9X,9HINCLIN,F15.8,7X,3HHX,F15.8//) $
      WRITE OUTPUT TAPE 5, TPAGE11, OUT1(5), OUT2(5), OUT3(3) $
TPAGE11 FOR AT(2H10,9X,9HMEAN ANOM,F15.8,7X,3HBY,F15.8,7X,7HDIAM,
      F15.8//) $
      WRITE OUTPUT TAPE 5, TPAGE12, OUT1(6), OUT2(6), OUT3(4) $
TPAGE12 FOR AT(2H10,9X,9HARG PERG,F15.8,7X,3HHZ,F15.8,7X,7HWEIGHT,
      F15.8//) $
      WRITE OUTPUT TAPE 5, TPAGE13, OUT1(7) $
TPAGE13 FOR AT(2H10,9X,9HRA NODE,F15.8) $
      RETURN $
      START TAC $
PBL K W/0000000 $
      END TAC $
      END $
      FUNCTION CALH (UZ,R,XMPER)$
*      COMPUTES HEIGHT IN METERS ABOVE OBLITE EARTH
      UZSR=UZ**2$
      CALH = XMPER * (F2*UZSR-UZSR**2*F1 - 1. + P ) $
      RETURNS
      START TAC$
*      EARTH FLATTENING CONSTANTS
P F1 F/.1685717364E-4 $ (3/2) * F**2
P F2 F/.33693870736E-2 $ F + (3/2) * F**2
      PAGE $
      END TAC $
      EN $
      SUBROUTINE TRI T(IJ,P,SIGMA,XMF,XKPRG,ATIO)$
      TABLEDEF HSCME(132) $
      IJ=0$
      IF(H-HSCME(130))1,1,6 $
      100 2 I=,132,3$
      J=1$
      IF(H-HSCME(J)) 3,3,7$
      100 3 I=,132,3$
      R=TRT $

```

```

      IF (J- ) LTAL, 5, 5$
LALTL WRITE UTPIT LPE F, 10, 0 $
      1  F/ NAT (14 10ALITUDE OF ,E12.4) $
      START 1 C$
      TMR C/-LT, ABCD C/-LT, 4$
      JMR 6$
      RU OUT $
      JMR 3$
LAPCD A/ALTITUDE FELC 5000 METERS $
      ENDTAC $
      H2MH1=HSGME(J)-HSGME(J-3)$
      H2MH=HSGME(J)-H$
      SIGMA=H2MH*HSGME(J-2)$
      HMH1=H-HSGME(J-3)$
      SIGMA=SIGMA+(H-H1)*(HSGME(J+1)) $
      SIGMA=SIGMA/H2MH1$
      XME=H2MH*HSGME(J-1)$
      XMRG=(HMH1*HSGME(J+2)+XME)/H2MH1$
      RATIO=EXP (SIGMA)$
      IJ=1 $
      RETURN $
      START TACS
HSGME F/50.0E7$
      F/-7.0310587$
      F/.131751E-02$
      F/55.0E7$
      F/-7.6032281$
      F/.128756E-2$
      F/60.0E7$
      F/-8.1538223$
      F/.118625E-02$
      F/65.0E7$
      F/-8.7576457$
      F/.108476E-02$
      F/70.0E7$
      F/-9.4124843$
      F/.98311899E-3$
      F/75.0E7$
      F/-10.173371$
      F/.88135E-3$
      F/80.0E7$
      F/-10.934450$
      F/.77957E-3$
      F/85.0E7$
      F/-11.939229$
      F/.78060E-3$
      F/90.0E7$
      F/-12.972557$
      F/.78187E-3$
      F/95.0E7$
      F/-14.007187$
      F/.65117E-3$
      F/100.0E7$
      F/-15.03575$
      F/.64417E-3$
      F/105.0E7$
      F/-15.911001$
      F/.10847E-2$
      F/110.0E7$
      F/-16.803617$
      F/.13689E-2$

```

F/115.0F3\$
 F/-17.625944\$
 F/.1829E-2\$
 F/120.0F3\$
 F/-18.241597\$
 F/.22922E-2\$
 F/125.0F3\$
 F/-18.705451\$
 F/.27547E-2\$
 F/130.0F3\$
 F/-19.172311\$
 F/.32187E-2\$
 F/135.0F3\$
 F/-19.503103\$
 F/.36827E-2\$
 F/140.0F3\$
 F/-19.220952\$
 F/.41485E-2\$
 F/145.0F3\$
 F/-20.125377\$
 F/.46141E-2\$
 F/150.0F3\$
 F/-20.361461\$
 F/.50797E-2\$
 F/155.0F3\$
 F/-20.595472\$
 F/.5547E-2\$
 F/160.0F3\$
 F/-20.802337\$
 F/.60742E-2\$
 F/165.0F3\$
 F/-21.003537\$
 F/.64124E-2\$
 F/170.0F3\$
 F/-21.147902\$
 F/.66821E-2\$
 F/175.0F3\$
 F/-21.345866\$
 F/.69157E-2\$
 F/180.0F3\$
 F/-21.434534\$
 F/.70411E-2\$
 F/185.0F3\$
 F/-21.561085\$
 F/.71660999E-2\$
 F/190.0F3\$
 F/-21.685493\$
 F/.72910E-2\$
 F/195.0F3\$
 F/-21.87622\$
 F/.74174E-2\$
 F/200.0F3\$
 F/-21.907794\$
 F/.75444E-2\$
 F/210.0F3\$
 F/-22.179273\$
 F/.77737E-2\$
 F/220.0F3\$
 F/-22.37907\$
 F/.79567E-2\$
 F/225.0F3\$

```

F/-22.40934-5
F/.023- E-2
F/40. 3$
F/-13. 88-5
F/.457- E-2
F/250. 3$
F/-23.4 614-5
F/.888- E-2$
F/300.
F/-23.07177$
F/.452- E-2$
F/330. 3$
F/-14.5 4617$
F/.10022E-1$
F/350. 3$
F/-25.007847$
F/.1054- E-1$
F/400. 3$
F/-25.63742-5
F/.1137-1$
F/450. 3$
F/-26.386557$
F/.12347E-1$
F/500. 3$
F/-27.00063$
F/.1333- E-1$
F/500. 3$
F/-28.246917$
F/.1536-1$
F/900. 3$
F/-31.84747$
F/.2213- E-1$
PAGE $
END TAC $
END $
SUBROUTINE XEL(XEL1,XAX5,X1,X2,X3,X4,X5,X6)$
DIMENSION XFL1(7)$
XL=XFL1(1)$
A=XFL1(2) $
B=XFL1(3) $
C=XFL1(4) $
D=XFL1(5) $
E=XFL1(6) $
F=XFL1(7) $
RAD=.01745329252 $
P=1/D + E/E + F/F $
ESQ=A*A + B*B + C*C $
AX=D/(1.-ESQ) $
EX=SQRT(ESQ) $
WX=E/SQRT(F) $
WZ=F/SQRT(F) $
XWZ=SQRT(1.-WZ*WZ) $
XNX=-WY/XWZ $
XNY=XNX * .7 $
XNY=XNY/XWZ $
XAX=-XNX * .7
XWZ=0.
AX=AX * XNX + . * . Y
AY=AX * XNX + . * . Y + C * XWZ $
XND=ATA F(WY/XL)

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```

      IF (X1) 2, 3, 4
      1XNO=XNO + 3.141592654
      IF (X1) 4, 5, 6
      2XNO=XNO + 2.*3.141592654
      3XNO=XNO/RA
      XNO=43.7(ASIN(F(XY)))
      IF (XY) 6, 7, 8
      4IF (XNX) 7, 8, 9
      5XNO=XNO + 3.141592654
      GO TO 4
      6XNO = 2.*3.141592654 - XNO
      GO TO 4
      7IF (XNX) 10, 9, 9
      8XNO=3.141592654 - XNO
      9XNO=XNO/RAD
      X1=AX*AX$
      X2=EX $ = ECCN
      X3=ASIN(F(XN7)/RAD $ = INC
      X4=XL/RAD - XNO - XNC $ = MEAN ANOMALY
      20IF (X4) 21, 21, 21 $
      20X4=X4-360. $
      GO TO 20 $
      21IF (X4-360.) 38, 38, 25 $
      25X4=X4-360. $
      GO TO 21 $
      38X5=XNO $ = PERIGEE
      X6=XNO $ = NODE
      RETURN
      END
      SUBROUTINE XYZSB
      XYZSB, GIVEN A BAR, H BAR, AND XL AT SOME TIME T -----
      COMPUTES INTERMEDIATE ORBIT PARAMETERS AND SATELLITE POSITIONS AND
      VELOCITY VECTORS
      EQUIVALENCE (RKSTO,RKCNT(2)), (HYI,RKCNT(11)), (HZI,RKCNT(12)),
      (HXI,RKCNT(10)), (AXI,RKCNT(7)), (AYI,RKCNT(8)),
      (AZI,RKCNT(9)), (AYN,AXN(2)), (HY,HX(2)), (HZ,HX(3)),
      (WY,WX(1)), (WZ,WX(3)), (AY,AX(2)), (AZ,AX(3)),
      (XNY,XNX(2)), (XNZ,XNX(3)), (XNY,XNX(2)), (XNZ,XNX(3)),
      (AYNI,AYNI(2)), (UY,UX(2)), (UZ,UX(3)), (VY,VX(2)), (VZ,VX(3)),
      (Y,X(2)), (Z,X(3)), (YDOT,XDOT(2)), (ZDOT,XDOT(3)),
      (XNY,XNX(2)), (XNZ,XNX(3)), (EQY, EQX(2)),
      (EQY, EQX(3)), (COSPH, SINPH(2)), (CAPY, CAPX(2)),
      (CAPZ, CAPX(3)), (RHOY,RHOX(2)), (RHOZ,RHOX(3)),
      (X2THSG,X1STSG(2)), (X3THSG,X1STSG(3)), (X4THSG,X1STSG(4)),
      (X5THSG,X1STSG(5)), (X6THSG,X1STSG(6)), (X7THSG,X1STSG(7)),
      (X8THSG,X1STSG(8)), (X9THSG,X1STSG(9)), (ASUBY,ASUBX(2)),
      (ASURZ,ASURX(3)), (DSURY,DSURX(2)), (DSURZ,DSURX(3)),
      (XLSUBY,XLSURX(2)), (XLSURZ,XLSURX(3)), (ESUBY,ESUBX(2)),
      (ESURZ,ESURX(3)), (SSURY,SSURX(2)), (SSURZ,SSURX(3)),
      (ZSURY,ZSURX(2)), (ZSURZ,ZSURX(3)), (XLSUYH,XLSUXH(2)),
      (XLSURZ,XLSUXH(3)), (ADOTV,ADOTU(2)), (ADOTW,ADOTU(3)),
      (ASUYT,ASUXT(2)), (ASUZY,ASUXT(3)), (DSUYT,DSUXT(2)),
      (DSUZY,DSUXT(3)), (ALY,ALX(2)), (XLZ,XLX(3)), (DELT,DELT(2)),
      (DELTZ,DELT(3)), (IRPT,CITWE(4)), (CWSTO,WSTO(3)),
      (DLV,DLX(2)), (DLZ,DLX(3)),
      (RXY,RSUBA(1)), (RY,RSUBA(3)), (RSURU,RSUBA(4)), (UX,USUBA(2)),
      (UY,USUBA(3)), (USURU,USUBA(4)), (RDOTV,RDOTU(2)), (RDOTW,
      RDOTU(3)), (RDOTX,RDOTA(2)), (RDOTY,RDOTA(3)), (RDOTZ,
      RDOTA(4)), (UDTX,UDOTA(2)), (UDTY,UDOTA(3)), (UDOTU,UDOTA(4)),
      (RDOTU,RDOTA(4)), (IAXD,STARK), (IAXE,STAPE),
      (DGR,CAPD(2)), (DDGR,CAPD(3)) $

```

1. Name of the person: _____

```

      AY = AYT * X + ATY * Y + AZI * Z
      IF (X(1)) 2,3,4 $
      XNODE = RT + ATN (YNY/XNX)
      GO TO 7
      IF (YNY) 5, FERROR, 6$
      XNODE = 4.712388978 $      XNODE = (3/2) * PI
      GO TO 7
      XNODE = P OV2
      GO TO 7
      XNODE = ATAN (XNY/XNX)
      XNODE(1) = PROPR(XNODE(1))$
7      U = RKSTO (5) - XNODE * SIGNF (1., 7) $      XL += XNODE
      IF (SENSE LIGHT 1) 13,12 $
      12 UO(1) = U
      13 SENSE LIGHT 1 $
      UO(2) = U $      SOLVE KEPLERS EQUATION FOR E + OMEGA
      IF (UO(2) - TWOPI) 15,15,14$
      UO(2) = UO(2) - TWOPI$
      GO TO 16$
      EO1 = UO(2)$
      DO 18 I=1,30$
      COSEO = COS (EO1)$
      SINEO = SIN (EO1)$
      EO2 = AYN1 * COSEO$
      ESINE = (SINEO * AXNI) - EO2$
      EO2 = UO(2) + ESINE$
      IF (ABS (EO2 - EO1) - .000001) CNTRD2, CNTRD2, 17 $ TEST CNVRGNC
      17 EO1 = EO2
      CONTINUE$
      START TAC $
      TMA C/HLT, CWRD C/HLT, 5$
      JMPL 6$
      ENDTAC $
      TRD2 ECOSE = SINEO * AYN1 + COSEO * AXNI $
      R = (1.0 - ECOSE) * AR$ AR = A/R$ RTESQ = SQRT (ESQ)$
      XLGR = 1.0 + RTESQ - COSU = ESINE/XLGR$
      SINU = ((SINEO - AYN1) - (AXNI * COSU)) * AR$
      COSU = (COSEO - AXNI + AYN1 * COSU) * AR$
      DO 20 I=1,3$
      UX(I) = SINU * XM(X(I)) + COSU * XNX(I)$
      VX(I) = COSU * XM(X(I)) - SINU * XNX(I)$
      20 X(I) = UX(I) * R$      COMPUTE POSITION VECTOR
      RVDOT = (RTA * SQRT(U)) / R$
      RDOT = (RVDOT * ESINE)$
      RVDOT = RVDOT * RTESQ$
      DO 21 I=1,3$
      21 XDOT(I) = VX(I) * RVDOT + UX(I) * RDOT$      COMPUTE VELOCITY VECTOR
      RETUR $
      START TAC $
      ERROR RUNOUT $
      JMPL 3 $
      I F/3.141592653 $
      OPI F/6.283185306 $
      IOV2 F/1.570796326 $
      4RD A/KEPLERS EQUATION NOT CONVERGING FOR F $
      END TAC $
      ENDT
      SUBROUTINE SETI(IXC,I)$
      J=0
      49 J=J+1
      IF (IXC-J) 55,51,50$

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```

50 I=I+3 $
GO TO 40 $
51 START TAC $
JMP COEFF.TST055 $
REF OUT COEFF.TST055 $
PAGE $
END TAC $
51 RETURN $
END $
SUBROUTINE HEAL (IPAGE) $
START TAC $
SAVE HDNG,0.01PRO.HDNG $
SAVE CHED,0.01PRO.CHED $
END TAC $
TABLEDEF HDNG(24),CHED(15) $
WRITE OUTPUT TAPE 5, 6,(HDNG(I),I=1,10)$ WRITE 1ST LINE HEDING
6 FORMAT (2H70,3X,10A8)$
WRITE OUTPUT TAPE 5,7,(HDNG(I),I=11,20),IPAGE,(CHED(I),I=1,15)$
7 FORMAT (2H10,10A8,6H PAGE,I8/2H10/2H10,15A8) $
RETURNS
END $
SUBROUTINE PRINT(RKSTO,XLAT,XLONG,H) $
AH = H / 1000. $
WRITE OUTPUT TAPE 5,6,RKSTO,XLAT, XLONG, AH $
6 FORMAT (2H10,4(F15.7,5X))$
RETURNS
END $
SUBROUTINE PRINTO(STARC,TXYZ ,RH01,CAPA,SMLH)$
WRITE OUTPUT TAPE 5,6,STARC,TXYZ,RH01,CAPA,SMLH$
6 FORMAT(2H10,A8,4E15.8)$
RETURNS
END $
FUNCTION APROPR(X)$
* PROPRIZES ANGLE GIVEN IN DEGREES
APROPR = 57.2957795 * PROPR(X/57.2957795) @ RETURN $
END $
FUNCTION PROPR(X)$
* PROPRIZES ANGLE GIVEN IN RADIAN$
START TAC$
TMA X$
JAN (P)+3H$
FSM TWOPI$
JMP (P)-1$
FAA TWOPI$
JAN (P)-1H$
TAA Y$
P THOP F/6.283185306 $
END TAC $
PROPR = Y @ RETURN $
END $
EQUIVALENCE(RKSTO,RKCNT(2)),(HYI,RKCNT(11)),(HZ I,RKCNT(12)),
(HXI,RKCNT(10)),(AXI,RKCNT(7)),(AYI,RKCNT(8)),
(AZI,RKCNT(9)),(AYN,AX(2)),(HY,HX(2)),(HZ,HX(3)),
(WY,AX(1)),(HZ,HX(3)),(AY,AX(2)),(AZ,AX(3)),
(XY,X(2)),(XZ,X(3)),(XNY,XN(2)),(XNZ,XN(3)),
(AYI,AX(1)),(UY,UX(2)),(UZ,UX(3)),(VY,VX(2)),(VZ,VX(3)),
(Y,UX(2)),(Z,UX(3)),(YDOT,XDOT(2)),(ZDOT,XDOT(3)),
(XUY,UX(2)),(XNUZ,UX(3)),(YDTGR,XDTGR(2)),
(ZDTGR,XDTGR(3)),(YDGR,XDGR(2)),(ZDGR,XDGR(3)),
(YGR,XGR(1)),(ZDGR,XGR(3)),(AYGR,AXGR(2)),
(AZGR,AXGR(1)),(EQY,EQX(2)),(EQZ,EQX(3)),(HYGR,HXGR(2)),

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(H2GR, HGR(2)), (COSTH, SINPH(2)), (CAPY, CAPY(2)),
 (C4Z, C4PX(2)), (RPH, R4CX(2)), (PHCZ, RPHY(2)),
 (X2THSG, X1STSG(2)), (X3THSG, X1STSG(3)), (X4THSG, X1STSG(4)),
 (X5THSG, X1STSG(5)), (X6THSG, X1STSG(6)), (X7THSG, X1STSG(7)),
 (X8THSG, X1STSG(8)), (X9THSG, X1STSG(9)), (ASUBY, ASUBX(2)),
 (ASURZ, ASURX(3)), (DSUBY, DSURX(2)), (DSURZ, DSUBX(3)),
 (XLSUBY, XLSURX(2)), (XLSURZ, YLSURX(3)), (ESUBY, ESUBX(2)),
 (ESURZ, SUBX(3)), (SSUBY, SSURX(2)), (SSURZ, SSUBX(3)),
 (ZSUBY, ZSUBX(2)), (ZSURZ, ZSURX(3)), (XLSUYH, XLSUXH(2)),
 (XLSUZH, XLSUXH(3)), (ADOTV, ADOTU(2)), (ADOTW, ADOTU(3)),
 (ASUYT, ASUXT(2)), (ASUZH, ASUXT(3)), (DSUYT, DSUXT(2)),
 (DSUZH, SUXT(3)), (XLY, XLX(2)), (XLZ, XLX(3)), (DELT, DELTX(2)),
 (DELTZ, DELTX(3)),
 (IRPT, C4TW(4)), (EPHEN, XXXX(25)), (IWSTO, WSTO(3)),
 (DLV, DLXV(2)), (DLZV, DLXV(3)),
 (RXN, RSUBA(2)), (RYN, RSUBA(3)), (RSURU, RSUBA(4)), (UXN, USUBA(2)),
 (UYN, USUBA(3)), (USURU, USUBA(4)), (RDOTV, RDOTU(2)), (RDOTW,
 RDOTU(3)), (PDTXN, RDOTA(2)), (RDTYN, RDOTA(3)), (RDOTV,
 RDOTA(4)), (UDTXN, UDOTA(2)), (UDTYN, UDOTA(3)), (UDOTU, UDOTA(4)),
 (RDOTU, RDOTA(4)), (IAXD, STARK), (IAXE, STARE),
 (DGR, CAPD(2)), (DDGR, CAPD(3)) \$
 EQUIVALENCE(DLTAA(2), DLTAX), (DLTAA(3), DLTAY), (DLTAA(4), DLTLO),
 (DLTAA(5), DLTND), (DLTAA(6), DLTIN) \$
 COMMON TO, DT, TF, D, XM, THGR, XLO, AXN,
 HX, XN, IPGCNT, COUNT, FRAC, P, RTP, WX, SINI, COSI, SINO,
 COSO, AX, COND, CONTS, FSQ, E, A, XMX, XNX, AXNI,
 XNOE, U, UO, E01, E02, SINE0, COSE0, ESINE, ECOSE, R,
 SINI, COSU, AR, RTESQ, UX, VX, X, XDOT, RDOT, RTA, RVDOT,
 XNIX, XU, UZETH, RHO, XNUSQR, TS, C, DC, XOVRS, ZOVRS,
 RSR, RRDOT, EOX, XLAT, XLONG, RKCNT,
 OTPT, CNTWD, STACD, OBSCD, SINPH, CAPD, CAPC, CAPS,
 CAPX, OALT, PHIRD, XOVCT, SINTH, COSTH, THTA, TXYZ,
 RHOX, RHO1, SMLH, TERMS, WSTO, TIMTB, CSUBI, XLMPH, XINCL, DLTAA,
 RHOC, SUN, ARSDL, XLGR,
 RCNT, BSCNT, RESID, EFCNT, LSTAD, GATE2, EFLAG,
 BOCNT, O, CNT, X1STSG, APSX, OMCT2, FTPFG, TIMJ,
 CSUB, F, FT, ASURX, DSURX, XLSURX, ESURX, SSURX,
 ZSURX, XLSUXH, ADOTU, ADDEL, ASUXT, DSUXT, FACTR, OTYPE,
 XNITS, XLX, DELTX, A2OR, UMUO, RSUBA, ROVA,
 USUBA, ENO, SS, ORRA1, ORPAN, TMN, SATEL, STAD,
 XLAMRA, ALPHA, DELTA, ITIMES, PANGF,
 Q, IRGC, XAE, R2P1, XK, EMIS,
 SIGHT, THGR, FLP25, VCO3, SIGS, SARMU, XMU,
 THCT, F, XKE, RHO, CDC, XJPRM, XKPRM,
 SIXPO, F, PRM, ONEPI, RACYN, XMPER, LINE,
 DENT, FLAG4, VFLAG, XMSS, TS, DC, VDATA, ISTORV,
 RDOTU, RDOTA, UDOTA, RDOT, RHOCT, EXOM, EYON, RCUPE,
 XMA32, ABMX2, GATE1, GATE2, XJAY5, SUN2, RCNT2,
 LSTCNT, SPHA, CP, A, SDFL, CCDEL,
 ADFL, BFL, CDEL, ABDEL, FLDEL, HDEL4, HDELB, HDELC, HDELX, CAPXX,
 ARAY, XTVEC, YTVEC, ZTVEC, PXSS, PYSS, BZSS, RCOF, PAB, BIG, BBUF, CVERT,
 AVFC, XVEC, YVEC, ZVEC, ASI61, IAXD, IBUTH,
 ISTORC, LXY, RHOV, ADLV, C, DC, INOVORS
 DIMENSION W(2), AXN(2), X(3), FRAC(2), WX(3), AX(3), A(2), XMX(3),
 XNX(3), XNI(2), XNOE(2), UO(2), UX(3), VX(3), X(3), YDOT(3),
 XNIX(3), XDOT(2), XEGR(3), XEGR(3), XEGR(3), EOX(3), HXGR(3),
 CNTD(2), STACD(6), OBSCD(6), SINPH(2), C4PX(3), RHOX(3), TXYZ(4),
 TERMS(25), A11(36), R11(12), OUF(28), WSTO(25), TIMTB(6), CSUBI(6),
 KNTFL(2), X1STSG(9), ASURX(2), DSURX(3), XLSURX(3), OTPT(2),
 DLTAA(6), CXVERT(6), CYVERT(6), CZVERT(6),
 ESURX(3), SSURX(3), ZSUBX(3), XLSUXH(3), ADOTU(3), ASUXT(3),

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DSUBT(3),XLP(3),DELT(3),RSUBA(4),USUBA(4),
XXX(1000),PH(1004),RKSTO(79),FXI(3),
HF(24),HIG1(4),
RKT(4),C-ED(15),MFAA(1000),QLXV(3),
FJFT(7),AFY(4),XTVEC(6),YTVEC(6),ZTVEC(6),
RDITU(4),RDTA(4),UDCT(4),RHOFT(4),
BXSS(6),BYSS(6),RZSS(4),BCOF(20),RAB(3),
BIG(6),RUF(26),CVCCT(36),AVEC(3),XVEC(6),
YVEC(6),ZVEC(6),RDIAG(25),BDIAS(25),
WLN(25),
SQRA(25),SQRB(25),SQRC(25),
SQRA(625),SQRB(625),SQRC(625),
QLSQA(576),QLSR(24),QLSQX(24),
ADEL(3),BDEL(3),CDEL(3),ABDEL(3),FDEL(3),
HDELA(2),HDELB(2),HDELC(2),HDELX(3),
CAPXX(3),QLX(3),DELT(3,6),
STARC(1000),CAPD(3) $
DIMENSION IDBUF(10) $
DIMENSION MCODE(3) $
TABLE DEF TNOTC(12),CHED1(15),CHED2(15),CHED3(15),
CHED4(15),OCHED(15),OBSHD(15),CHED5(15),THGROC(20) $
TABLEDEF EQEQ(100) $
READ ALL TAPES AHEAD
WRITETAPE9,WSTO $
WRITETAPE3,WSTO $
WRITETAPE6,WSTO $
WRITETAPE11,WSTO $
START TAC $
PI F/3.141592653 $
PIQV2 F/1.570796326 $
CONV F/0.1745329251 $ DEGREES TO RADIANS
TROP F/6.283185306 $
TMD N/10T23GH/8AT47$REWIND TAPE 10
TIC $
JMP (P)-1HF
TMA 3 $
TAM SKIPSAVE
TMA C/TLM,SUBER16 C/JMP, SUBER $
TAM 3 $
JMP STARTO $
AFRNT W/ $
XNPIA F/144.1 $
CTR F/.25 $
OPTI F/.437536912-25
FASQD F/6.7685580E-3 $
THGROC F/0.0 $ 1958
F/0.0 $ 1959
F/98.67001 $ 1960
F/99.421937 $ 1961
F/99.1822167 $ 1962
F/98.943500314 $ 1963
F/98.7007917 $ 1964
F/0.0 $ 1965
F/0.0 $ 1966
F/0.0 $ 1967
F/0.0 $ 1968
F/0.0 $ 1969
F/0.0 $ 1970

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	F/0.0	\$ 1971
	F/0.0	\$ 1972
	F/0.0	\$ 1973
	F/0.0	\$ 1974
	F/0.0	\$ 1975
	F/0.0	\$ 1976
	F/0.0	\$ 1977
QEQ	F/-0.91	\$ NOV 1 1962
	F/-0.97	\$
	F/-0.97	\$
	F/-0.97	\$
	F/-0.96	\$
	F/-0.967	\$
	F/-0.969	\$
	F/-0.973	\$
	F/-0.979	\$
	F/-0.98	\$
	F/-0.98	\$
	F/-0.98	\$
	F/-0.98	\$
	F/-0.981	\$
	F/-0.981	\$
	F/-0.97	\$
	F/-0.97	\$
	F/-0.98	\$
	F/-0.98	\$
	F/-0.981	\$
	F/-0.981	\$
	F/-0.982	\$
	F/-0.986	\$
	F/-0.97	\$
	F/-0.973	\$
	F/-0.981	\$
	F/-0.981	\$
	F/-0.98	\$ NOV27 1962
	F/-0.973	\$ NOV28 1962
	F/-0.976	\$
	F/-0.96	\$
	F/-0.957	\$
	F/-0.957	\$
	F/-0.947	\$
	F/-0.947	\$
	F/-0.949	\$
	F/-0.952	\$
	F/-0.953	\$
	F/-0.95	\$
	F/-0.957	\$
	F/-0.95	\$
	F/-0.94	\$
	F/-0.94	\$
	F/-0.931	\$
	F/-0.92	\$
	F/-0.913	\$
	F/-0.913	\$
	F/-0.91	\$
	F/-0.91	\$
	F/-0.91	\$
	F/-0.91	\$
	F/-0.921	\$
	F/-0.927	\$
	F/-0.925	\$
	F/-0.925	\$
	F/-0.923	\$ DEC24 1962

F/-0.917	\$	EC25 1962
F/-0.913	\$	
F/-0.9	\$	
F/-0.897	\$	
F/-0.894	\$	
F/-0.89	\$	
F/-0.887	\$	
F/-0.884	\$	EC31 1962
F/-0.881	\$	JAN 1 1963
F/-0.878	\$	
F/-0.875	\$	
F/-0.872	\$	
F/-0.869	\$	
F/-0.866	\$	
F/-0.863	\$	
F/-0.86	\$	
F/-0.857	\$	
F/-0.854	\$	
F/-0.851	\$	JAN13 1963
F/-0.848	\$	JAN14 1963
F/-0.845	\$	
F/-0.842	\$	
F/-0.839	\$	
F/-0.836	\$	
F/-0.833	\$	
F/-0.83	\$	
F/-0.827	\$	
F/-0.824	\$	
F/-0.821	\$	
F/-0.818	\$	
F/-0.815	\$	
F/-0.812	\$	
F/-0.809	\$	
F/-0.806	\$	
F/-0.803	\$	
F/-0.8	\$	
F/-0.797	\$	
F/-0.794	\$	
F/-0.791	\$	
F/-0.788	\$	
F/-0.785	\$	
F/-0.782	\$	
F/-0.779	\$	
F/-0.776	\$	
F/-0.773	\$	
F/-0.77	\$	
F/-0.767	\$	
F/-0.764	\$	
F/-0.761	\$	
F/-0.758	\$	
F/-0.755	\$	
F/-0.752	\$	
F/-0.749	\$	
F/-0.746	\$	
F/-0.743	\$	
F/-0.74	\$	
F/-0.737	\$	
F/-0.734	\$	
F/-0.731	\$	
F/-0.728	\$	
F/-0.725	\$	
F/-0.722	\$	
F/-0.719	\$	
F/-0.716	\$	
F/-0.713	\$	
F/-0.71	\$	
F/-0.707	\$	
F/-0.704	\$	
F/-0.701	\$	
F/-0.698	\$	
F/-0.695	\$	
F/-0.692	\$	
F/-0.689	\$	
F/-0.686	\$	
F/-0.683	\$	
F/-0.68	\$	
F/-0.677	\$	
F/-0.674	\$	
F/-0.671	\$	
F/-0.668	\$	
F/-0.665	\$	
F/-0.662	\$	
F/-0.659	\$	
F/-0.656	\$	
F/-0.653	\$	
F/-0.65	\$	
F/-0.647	\$	
F/-0.644	\$	
F/-0.641	\$	
F/-0.638	\$	
F/-0.635	\$	
F/-0.632	\$	
F/-0.629	\$	
F/-0.626	\$	
F/-0.623	\$	
F/-0.62	\$	
F/-0.617	\$	
F/-0.614	\$	
F/-0.611	\$	
F/-0.608	\$	
F/-0.605	\$	
F/-0.602	\$	
F/-0.599	\$	
F/-0.596	\$	
F/-0.593	\$	
F/-0.59	\$	
F/-0.587	\$	
F/-0.584	\$	
F/-0.581	\$	
F/-0.578	\$	
F/-0.575	\$	
F/-0.572	\$	
F/-0.569	\$	
F/-0.566	\$	
F/-0.563	\$	
F/-0.56	\$	
F/-0.557	\$	
F/-0.554	\$	
F/-0.551	\$	
F/-0.548	\$	
F/-0.545	\$	
F/-0.542	\$	
F/-0.539	\$	
F/-0.536	\$	
F/-0.533	\$	
F/-0.53	\$	
F/-0.527	\$	
F/-0.524	\$	
F/-0.521	\$	
F/-0.518	\$	
F/-0.515	\$	
F/-0.512	\$	
F/-0.509	\$	
F/-0.506	\$	
F/-0.503	\$	
F/-0.5	\$	
F/-0.497	\$	
F/-0.494	\$	
F/-0.491	\$	
F/-0.488	\$	
F/-0.485	\$	
F/-0.482	\$	
F/-0.479	\$	
F/-0.476	\$	
F/-0.473	\$	
F/-0.47	\$	
F/-0.467	\$	
F/-0.464	\$	
F/-0.461	\$	
F/-0.458	\$	
F/-0.455	\$	
F/-0.452	\$	
F/-0.449	\$	
F/-0.446	\$	
F/-0.443	\$	
F/-0.44	\$	
F/-0.437	\$	
F/-0.434	\$	
F/-0.431	\$	
F/-0.428	\$	
F/-0.425	\$	
F/-0.422	\$	
F/-0.419	\$	
F/-0.416	\$	
F/-0.413	\$	
F/-0.41	\$	
F/-0.407	\$	
F/-0.404	\$	
F/-0.401	\$	
F/-0.398	\$	
F/-0.395	\$	
F/-0.392	\$	
F/-0.389	\$	
F/-0.386	\$	
F/-0.383	\$	
F/-0.38	\$	
F/-0.377	\$	
F/-0.374	\$	
F/-0.371	\$	
F/-0.368	\$	
F/-0.365	\$	
F/-0.362	\$	
F/-0.359	\$	
F/-0.356	\$	
F/-0.353	\$	
F/-0.35	\$	
F/-0.347	\$	
F/-0.344	\$	
F/-0.341	\$	
F/-0.338	\$	
F/-0.335	\$	
F/-0.332	\$	
F/-0.329	\$	
F/-0.326	\$	
F/-0.323	\$	
F/-0.32	\$	
F/-0.317	\$	
F/-0.314	\$	
F/-0.311	\$	
F/-0.308	\$	
F/-0.305	\$	
F/-0.302	\$	
F/-0.299	\$	
F/-0.296	\$	
F/-0.293	\$	
F/-0.29	\$	
F/-0.287	\$	
F/-0.284	\$	
F/-0.281	\$	
F/-0.278	\$	
F/-0.275	\$	
F/-0.272	\$	
F/-0.269	\$	
F/-0.266	\$	
F/-0.263	\$	
F/-0.26	\$	
F/-0.257	\$	
F/-0.254	\$	
F/-0.251	\$	
F/-0.248	\$	
F/-0.245	\$	
F/-0.242	\$	
F/-0.239	\$	
F/-0.236	\$	
F/-0.233	\$	
F/-0.23	\$	
F/-0.227	\$	
F/-0.224	\$	
F/-0.221	\$	
F/-0.218	\$	
F/-0.215	\$	
F/-0.212	\$	
F/-0.209	\$	
F/-0.206	\$	
F/-0.203	\$	
F/-0.2	\$	
F/-0.197	\$	
F/-0.194	\$	
F/-0.191	\$	
F/-0.188	\$	
F/-0.185	\$	
F/-0.182	\$	
F/-0.179	\$	
F/-0.176	\$	
F/-0.173	\$	
F/-0.17	\$	
F/-0.167	\$	
F/-0.164	\$	
F/-0.161	\$	
F/-0.158	\$	
F/-0.155	\$	
F/-0.152	\$	
F/-0.149	\$	
F/-0.146	\$	
F/-0.143	\$	
F/-0.14	\$	
F/-0.137	\$	
F/-0.134	\$	
F/-0.131	\$	
F/-0.128	\$	
F/-0.125	\$	
F/-0.122	\$	
F/-0.119	\$	
F/-0.116	\$	
F/-0.113	\$	
F/-0.11	\$	
F/-0.107	\$	
F/-0.104	\$	
F/-0.101	\$	
F/-0.098	\$	
F/-0.095	\$	
F/-0.092	\$	
F/-0.089	\$	
F/-0.086	\$	
F/-0.083	\$	
F/-0.08	\$	
F/-0.077	\$	
F/-0.074	\$	
F/-0.071	\$	
F/-0.068	\$	
F/-0.065	\$	
F/-0.062	\$	
F/-0.059	\$	
F/-0.056	\$	
F/-0.053	\$	
F/-0.05	\$	
F/-0.047	\$	
F/-0.044	\$	
F/-0.041	\$	
F/-0.038	\$	
F/-0.035	\$	
F/-0.032	\$	
F/-0.029	\$	
F/-0.026	\$	
F/-0.023	\$	
F/-0.02	\$	
F/-0.017	\$	
F/-0.014	\$	
F/-0.011	\$	
F/-0.008	\$	
F/-0.005	\$	
F/-0.002	\$	
F/-0	\$	

F/-0.867	\$
F/-0.873	\$
F/-0.881	\$
F/-0.888	\$
F/-0.891	\$
F/-0.893	\$
F/-0.899	\$
F/-0.899	\$
F/-0.895	\$ MAR 4 1963
F/-0.892	\$ MAR 5 1963
F/-0.890	\$
F/-0.890	\$
F/-0.892	\$
F/-0.897	\$
F/-0.903	\$
F/-0.911	\$
F/-0.919	\$
F/-0.928	\$
F/-0.935	\$
F/-0.940	\$
F/-0.944	\$
F/-0.946	\$
F/-0.946	\$
F/-0.944	\$
F/-0.942	\$
F/-0.941	\$
F/-0.941	\$
F/-0.944	\$
F/-0.940	\$
F/-0.957	\$
F/-0.965	\$
F/-0.973	\$
F/-0.978	\$
F/-0.980	\$ MAR29 1963
F/-0.980	\$ MAR30 1963
F/-0.977	\$
F/-0.974	\$
F/-0.971	\$
F/-0.971	\$
F/-0.973	\$
F/-0.976	\$
F/-0.982	\$
F/-0.990	\$
F/-0.990	\$
F/-1.006	\$
F/-1.013	\$
F/-1.018	\$
F/-1.022	\$
F/-1.023	\$
F/-1.023	\$
F/-1.021	\$
F/-1.019	\$
F/-1.016	\$
F/-1.015	\$
F/-1.016	\$
F/-1.019	\$
F/-1.024	\$
F/-1.031	\$
F/-1.038	\$ APR23 1963
F/-1.043	\$ APR24 1963
F/-1.045	\$

F/-1.042	\$
F/-1.037	\$
F/-1.043	\$
F/-1.027	\$
F/-1.025	\$
F/-1.024	\$
F/-1.025	\$
F/-1.025	\$
F/-1.030	\$
F/-1.040	\$
F/-1.046	\$
F/-1.051	\$
F/-1.055	\$
F/-1.054	\$
F/-1.056	\$
F/-1.054	\$
F/-1.050	\$
F/-1.045	\$
F/-1.041	\$
F/-1.037	\$
F/-1.036	\$
F/-1.036	\$
F/-1.039	\$ MAY18 1963
F/-1.047	\$ MAY19 1963
F/-1.047	\$
F/-1.051	\$
F/-1.052	\$
F/-1.051	\$
F/-1.044	\$
F/-1.037	\$
F/-1.029	\$
F/-1.022	\$
F/-1.017	\$
F/-1.015	\$
F/-1.016	\$
F/-1.013	\$
F/-1.022	\$
F/-1.026	\$
F/-1.030	\$
F/-1.032	\$
F/-1.032	\$
F/-1.031	\$
F/-1.027	\$
F/-1.022	\$
F/-1.016	\$
F/-1.009	\$
F/-1.004	\$
F/-1.000	\$ JUN12 1963
F/-0.993	\$ JUN13 1963
F/-0.991	\$
F/-1.001	\$
F/-1.000	\$
F/-1.007	\$
F/-1.000	\$
F/-1.007	\$
F/-1.001	\$
F/-0.993	\$
F/-0.980	\$
F/-0.974	\$
F/-0.969	\$
F/-0.965	\$

F/-0.966	\$
F/-0.965	\$
F/-0.963	\$
F/-0.971	\$
F/-0.975	\$
F/-0.977	\$
F/-0.977	\$
F/-0.977	\$
F/-0.974	\$
F/-0.969	\$
F/-0.963	\$
F/-0.956	\$ JUL 7 1963
F/-0.950	\$ JUL 8 1963
F/-0.946	\$
F/-0.943	\$
F/-0.944	\$
F/-0.946	\$
F/-0.950	\$
F/-0.953	\$
F/-0.957	\$
F/-0.954	\$
F/-0.953	\$
F/-0.947	\$
F/-0.94	\$
F/-0.932	\$
F/-0.928	\$
F/-0.922	\$
F/-0.921	\$
F/-0.922	\$
F/-0.926	\$
F/-0.931	\$
F/-0.936	\$
F/-0.940	\$
F/-0.947	\$
F/-0.944	\$
F/-0.943	\$
F/-0.940	\$ AUG 1 1963
F/-0.936	\$ AUG 2 1963
F/-0.931	\$
F/-0.927	\$
F/-0.927	\$
F/-0.922	\$
F/-0.923	\$
F/-0.927	\$
F/-0.933	\$
F/-0.930	\$
F/-0.940	\$
F/-0.947	\$
F/-0.945	\$
F/-0.943	\$
F/-0.939	\$
F/-0.933	\$
F/-0.929	\$
F/-0.923	\$
F/-0.927	\$
F/-0.930	\$
F/-0.937	\$
F/-0.94	\$
F/-0.940	\$
F/-0.956	\$
F/-0.961	\$

F/-0.965	\$ AUG26 1963
F/-0.967	\$ AUG27 1963
F/-0.967	\$
F/-0.966	\$
F/-0.963	\$
F/-0.961	\$
F/-0.959	\$
F/-0.959	\$
F/-0.961	\$
F/-0.966	\$
F/-0.971	\$
F/-0.971	\$
F/-0.980	\$
F/-0.990	\$
F/-0.996	\$
F/-0.998	\$
F/-0.993	\$
F/-0.980	\$
F/-0.986	\$
F/-0.985	\$
F/-0.986	\$
F/-0.990	\$
F/-0.996	\$ SEP17 1963
F/-1.004	\$ SEP18 1963
F/-1.013	\$
F/-1.021	\$
F/-1.029	\$
F/-1.034	\$
F/-1.037	\$
F/-1.039	\$
F/-1.039	\$
F/-1.032	\$
F/-1.036	\$
F/-1.038	\$
F/-1.038	\$
F/-1.037	\$
F/-1.042	\$
F/-1.040	\$
F/-1.057	\$
F/-1.066	\$
F/-1.071	\$
F/-1.070	\$
F/-1.074	\$
F/-1.071	\$
F/-1.067	\$
F/-1.063	\$
F/-1.061	\$
F/-1.061	\$
F/-1.060	\$
F/-1.060	\$ OCT14 1963
F/-1.070	\$ OCT15 1963
F/-1.080	\$
F/-1.090	\$
F/-1.090	\$
F/-1.100	\$
F/-1.100	\$
F/-1.100	\$
F/-1.107	\$
F/-1.100	\$
F/-1.100	\$
F/-1.100	\$

F/-1.097	\$
F/-1.095	\$
F/-1.100	\$
F/-1.100	\$
F/-1.111	\$
F/-1.111	\$
F/-1.123	\$
F/-1.123	\$
F/-1.123	\$
F/-1.11	\$
F/-1.113	\$
F/-1.108	\$
F/-1.100	\$
F/-1.097	\$
F/-1.097	\$
F/-1.099	\$ NOV10 1963
F/-1.103	\$ NOV11 1963
F/-1.100	\$
F/-1.110	\$
F/-1.119	\$
F/-1.122	\$
F/-1.123	\$
F/-1.122	\$
F/-1.123	\$
F/-1.115	\$
F/-1.110	\$
F/-1.105	\$
F/-1.101	\$
F/-1.090	\$
F/-1.096	\$
F/-1.090	\$
F/-1.101	\$
F/-1.105	\$
F/-1.100	\$
F/-1.110	\$
F/-1.100	\$
F/-1.100	\$
F/-1.093	\$
F/-1.083	\$
F/-1.070	\$
F/-1.067	\$
F/-1.067	\$
F/-1.062	\$ DEC 7 1963
F/-1.060	\$ DEC 8 1963
F/-1.067	\$
F/-1.070	\$
F/-1.073	\$
F/-1.070	\$
F/-1.070	\$
F/-1.070	\$
F/-1.060	\$
F/-1.060	\$
F/-1.050	\$
F/-1.040	\$
F/-1.040	\$
F/-1.037	\$
F/-1.030	\$
F/-1.030	\$
F/-1.030	\$
F/-1.030	\$
F/-1.040	\$

F/-1.042	\$
F/-1.041	\$
F/-1.036	\$
F/-1.029	\$
F/-1.017	\$
F/-1.017	\$ DEC 31 1963
F/-0.999	\$ JAN 1 1964
F/-0.997	\$
F/-0.994	\$
F/-0.990	\$
F/-0.987	\$
F/-0.984	\$
F/-0.981	\$
F/-1.001	\$
F/-1.002	\$
F/-1.001	\$
F/-0.997	\$
F/-0.993	\$
F/-0.987	\$
F/-0.987	\$
F/-0.981	\$
F/-0.975	\$
F/-0.970	\$
F/-0.969	\$
F/-0.967	\$
F/-0.970	\$
F/-0.973	\$
F/-0.970	\$
F/-0.981	\$
F/-0.983	\$
F/-0.981	\$
F/-0.978	\$
F/-0.969	\$
F/-0.960	\$
F/-0.957	\$
F/-0.949	\$
F/-0.946	\$
F/-0.947	\$
F/-0.951	\$ FEB 1 1964
F/-0.956	\$
F/-0.961	\$
F/-0.966	\$
F/-0.970	\$
F/-0.971	\$
F/-0.971	\$
F/-0.969	\$
F/-0.966	\$
F/-0.963	\$
F/-0.958	\$
F/-0.956	\$
F/-0.955	\$
F/-0.957	\$
F/-0.961	\$
F/-0.967	\$
F/-0.970	\$
F/-0.980	\$
F/-0.985	\$
F/-0.986	\$
F/-0.985	\$
F/-0.981	\$
F/-0.976	\$
F/-0.971	\$

F/-0.96	\$
F/-0.967	\$
F/-0.97	\$
F/-0.977	\$
F/-0.987	\$
F/-0.99	\$ APR 1 1964
F/-0.99	\$
F/-1.009	\$
F/-1.009	\$
F/-1.011	\$
F/-1.012	\$
F/-1.011	\$
F/-1.010	\$
F/-1.007	\$
F/-1.007	\$
F/-1.007	\$
F/-1.007	\$
F/-1.010	\$
F/-1.015	\$
F/-1.022	\$
F/-1.030	\$
F/-1.032	\$
F/-1.045	\$
F/-1.047	\$
F/-1.048	\$
F/-1.047	\$
F/-1.043	\$
F/-1.032	\$
F/-1.036	\$
F/-1.036	\$
F/-1.030	\$
F/-1.044	\$
F/-1.052	\$
F/-1.060	\$
F/-1.069	\$
F/-1.075	\$
F/-1.081	\$
F/-1.084	\$ APRIL 1 1964
F/-1.086	\$
F/-1.085	\$
F/-1.084	\$
F/-1.082	\$
F/-1.081	\$
F/-1.080	\$
F/-1.081	\$
F/-1.085	\$
F/-1.091	\$
F/-1.092	\$
F/-1.106	\$
F/-1.113	\$
F/-1.116	\$
F/-1.117	\$
F/-1.113	\$
F/-1.109	\$
F/-1.102	\$
F/-1.092	\$
F/-1.093	\$
F/-1.096	\$
F/-1.100	\$
F/-1.105	\$
F/-1.112	\$
F/-1.119	\$

F/-1.124	\$
F/-1.123	\$
F/-1.133	\$
F/-1.132	\$
F/-1.131	\$
F/-1.127	\$ MAY 1 1964
F/-1.123	\$
F/-1.12	\$
F/-1.117	\$
F/-1.115	\$
F/-1.113	\$
F/-1.112	\$
F/-1.120	\$
F/-1.131	\$
F/-1.135	\$
F/-1.138	\$
F/-1.137	\$
F/-1.133	\$
F/-1.125	\$
F/-1.117	\$
F/-1. 09	\$
F/-1. 07	\$
F/-1. 06	\$
F/-1. 11	\$
F/-1. 00	\$
F/-1. 05	\$
F/-1. 13	\$
F/-1. 17	\$
F/-1. 19	\$
F/-1. 20	\$
F/-1. 18	\$
F/-1. 15	\$
F/-1. 10	\$
F/-1. 00	\$
F/-1.099	\$
F/-1.090	\$
F/-1. 90	\$ JUNE 1 1964
F/-1. 89	\$
F/-1. 80	\$
F/-1. 91	\$
F/-1. 05	\$
F/-1. 91	\$
F/-1.101	\$
F/-1.100	\$
F/-1.093	\$
F/-1.088	\$
F/-1.077	\$
F/-1.067	\$
F/-1.053	\$
F/-1.050	\$
F/-1.05	\$
F/-1.051	\$
F/-1.053	\$
F/-1.057	\$
F/-1.051	\$
F/-1.05	\$
F/-1.050	\$
F/-1.05	\$
F/-1.057	\$
F/-1.051	\$
F/-1.05	\$

F/-1.037	\$	
F/-1.033	\$	
F/-1.029	\$	
F/-1.025	\$	
F/-1.021	\$	
F/-1.017	\$	JULY 1 1964
F/-1.013	\$	
F/-1.009	\$	
F/-1.005	\$	
F/-1.001	\$	
F/-0.997	\$	
F/-0.993	\$	
F/-0.989	\$	
F/-0.985	\$	
F/-0.981	\$	
F/-0.977	\$	
F/-0.973	\$	
F/-0.969	\$	
F/-0.965	\$	
F/-0.961	\$	
F/-0.957	\$	
F/-0.953	\$	
F/-0.949	\$	
F/-0.945	\$	
F/-0.941	\$	
F/-0.937	\$	
F/-0.933	\$	
F/-0.929	\$	
F/-0.925	\$	
F/-0.921	\$	
F/-0.917	\$	
F/-0.913	\$	
F/-0.909	\$	
F/-0.905	\$	
F/-0.901	\$	
F/-0.897	\$	
F/-0.893	\$	
F/-0.889	\$	
F/-0.885	\$	
F/-0.881	\$	
F/-0.877	\$	
F/-0.873	\$	
F/-0.869	\$	
F/-0.865	\$	
F/-0.861	\$	
F/-0.857	\$	
F/-0.853	\$	
F/-0.849	\$	
F/-0.845	\$	
F/-0.841	\$	
F/-0.837	\$	
F/-0.833	\$	
F/-0.829	\$	
F/-0.825	\$	
F/-0.821	\$	
F/-0.817	\$	
F/-0.813	\$	
F/-0.809	\$	
F/-0.805	\$	
F/-0.801	\$	
F/-0.797	\$	
F/-0.793	\$	
F/-0.789	\$	
F/-0.785	\$	
F/-0.781	\$	
F/-0.777	\$	
F/-0.773	\$	
F/-0.769	\$	
F/-0.765	\$	
F/-0.761	\$	
F/-0.757	\$	
F/-0.753	\$	
F/-0.749	\$	
F/-0.745	\$	
F/-0.741	\$	
F/-0.737	\$	
F/-0.733	\$	
F/-0.729	\$	
F/-0.725	\$	
F/-0.721	\$	
F/-0.717	\$	
F/-0.713	\$	
F/-0.709	\$	
F/-0.705	\$	
F/-0.701	\$	
F/-0.697	\$	
F/-0.693	\$	
F/-0.689	\$	
F/-0.685	\$	
F/-0.681	\$	
F/-0.677	\$	
F/-0.673	\$	
F/-0.669	\$	
F/-0.665	\$	
F/-0.661	\$	
F/-0.657	\$	
F/-0.653	\$	
F/-0.649	\$	
F/-0.645	\$	
F/-0.641	\$	
F/-0.637	\$	
F/-0.633	\$	
F/-0.629	\$	
F/-0.625	\$	
F/-0.621	\$	
F/-0.617	\$	
F/-0.613	\$	
F/-0.609	\$	
F/-0.605	\$	
F/-0.601	\$	
F/-0.597	\$	
F/-0.593	\$	
F/-0.589	\$	
F/-0.585	\$	
F/-0.581	\$	
F/-0.577	\$	
F/-0.573	\$	
F/-0.569	\$	
F/-0.565	\$	
F/-0.561	\$	
F/-0.557	\$	
F/-0.553	\$	
F/-0.549	\$	
F/-0.545	\$	
F/-0.541	\$	
F/-0.537	\$	
F/-0.533	\$	
F/-0.529	\$	
F/-0.525	\$	
F/-0.521	\$	
F/-0.517	\$	
F/-0.513	\$	
F/-0.509	\$	
F/-0.505	\$	
F/-0.501	\$	
F/-0.497	\$	
F/-0.493	\$	
F/-0.489	\$	
F/-0.485	\$	
F/-0.481	\$	
F/-0.477	\$	
F/-0.473	\$	
F/-0.469	\$	
F/-0.465	\$	
F/-0.461	\$	
F/-0.457	\$	
F/-0.453	\$	
F/-0.449	\$	
F/-0.445	\$	
F/-0.441	\$	
F/-0.437	\$	
F/-0.433	\$	
F/-0.429	\$	
F/-0.425	\$	
F/-0.421	\$	
F/-0.417	\$	
F/-0.413	\$	
F/-0.409	\$	
F/-0.405	\$	
F/-0.401	\$	
F/-0.397	\$	
F/-0.393	\$	
F/-0.389	\$	

AUG 1 1964

SEPT 1 1964

OCT 1 1954

F/-1.127	\$
F/-1.126	\$
F/-1.116	\$
F/-1.110	\$
F/-1.111	\$
F/-1.121	\$
F/-1.127	\$
F/-1.137	\$
F/-1.137	\$
F/-1.137	\$
F/-1.142	\$
F/-1.140	\$
F/-1.143	\$
F/-1.141	\$
F/-1.137	\$
F/-1.132	\$
F/-1.129	\$
F/-1.125	\$
F/-1.123	\$
F/-1.123	\$
F/-1.125	\$
F/-1.122	\$
F/-1.133	\$
F/-1.132	\$
F/-1.141	\$
F/-1.141	\$
F/-1.137	\$
F/-1.130	\$
F/-1.120	\$
F/-1.110	\$
F/-1.102	\$
F/-1.097	\$
F/-1.096	\$
F/-1.097	\$
F/-1.100	\$
F/-1.100	\$
F/-1.107	\$
F/-1.100	\$
F/-1.100	\$
F/-1.107	\$
F/-1.103	\$
F/-1.097	\$
F/-1.090	\$
F/-1.083	\$
F/-1.077	\$
F/-1.073	\$
F/-1.070	\$
F/-1.070	\$
F/-1.071	\$
F/-1.070	\$
F/-1.077	\$
F/-1.070	\$
F/-1.070	\$
F/-1.070	\$
F/-1.060	\$
F/-1.057	\$
F/-1.040	\$
F/-1.030	\$
F/-1.020	\$
F/-1.020	\$
F/-1.021	\$
F/-1.022	\$

CV 1 1963

DEC 1 1964

```

F/-1.025 $
F/-1.025 $
F/-1.025 $
F/-1.025 $
F/-1.025 $
F/-1.025 $ REC 71 1064
END TAC $

*
*
START: NSTRT= 1
START NSTRT= START-1$
IF (ST4-T)FNIS, START2, START2 $
START2 IXXX=1.04 $
IHFD=0 $
XFTNM=6.280833333 $ FEET PER METER 328083333
XFTNM=6080.2 $ FEET PER NAUTICAL MILE 6080.2
XMPNM=XFTNM/XFTNM $ METERS PER NAUT MILE
XMPER=6378165.0 $ METERS PER EARTH RADIUS 6378165
XAXS=XMPER/XMPNM $ NAUT MILES PER EARTH RADIUS
PASTEKA = 0.0 $
NTAPE6=0 $
NTAPE3=0 $

*
*
GO TO FRANK BROWNS DATA READ$
DO (EDFA) I=1,7 $
E1FR CNT D(I)=0.0$ SET CNTWD ARRAY TO ZERO
CALL STARTER(HONG,CNTWD,X1STSG,TO,BT,TF,D,XM,XLO,AXN,HX,IPNTFL,
ABSIX,ICODE,ORGD,ORGT,REFDA,REFTM,ABWX2,EFLAG,IXYR,XAXS)$
RADYN = 57.2957795$ SET UP CONSTANTS
XR = .2504742E10 $
R2P 1=.3989422E15
PASIFKA = 0.0 $
IF (IXYR-5) IS1, IS2, IS1 $
IS1 IF (IXYR-6) IS3, IS4, IS3 $
IS7 IF (IXYR-7) IS5, IS8, IS5 $
IS4 WRITE OUTPUT TAPE 5, IS6, IXYR $
IS5 FOR AT(PH10,5HYEAR, I2,36H GIVEN AS INPUT NOT IN EQUINOX TABLE)$
START TAC $
RUBOUT $
JMPL 5 $
END TAC $
IS4 IT=ORGD+308 $
GO TO 157 $
IS4 IT=ORGD+619 $
GO TO 157 $
IS4 IT=ORGD+422 $
IS7 CONTINUE $
RKCUT=1.0 $
EMIS=.4 $
SINT=.856472$
THETA=GRD(I,YR)
FLH5=-.25038448$
VOR=4.40176294E16$
SINSE=.4721-4$
SOR=1.0$
XM=1.0$
THETA=.0588744$
FE=.034523200$
RH=1.225$
XKE=.07436522 $
CNO=.9 $

```

```

X.MPRM=1.62341E-3$
H.MPRM=-6.E-6$
X.MPRM=5.39E-6$
XJAY5=-0.2E-6$
SIXP9=6.972E-6$
ONEPI=1.17391$
CD=2.0 $
AE=1.0$
START2XAPRNT1 = 0.0 $
APRNT56 = 0.0 $
APRNT71 = 0.0 $
APRNT66 = 0.0 $
APRNT63 = 0.0 $
APRNT13=0.0$
APRNT5=APRNT5 $
NTAPE3X= 100 $
IPAG = $
DRGCO=XMFER*(D**2/XM)*(CD*RH00/2.0)*PI**2* (-1.0) $
FRAC(1)=DRGTM/XMNPDA;FRAC(2)=SIDRT*FRAC(1)$
FRAC(2)=360. *FRAC(1)+FRAC(2)$
THGR = APROPR (ORGDA * SIDRT + FRAC(2) + THGR0 ) $
THGRD = CONV * THGR $
START TAC $
TMA CNTWD
JAZ (P)+2H$
JMP SEC2 $
TMD /0 $
TUM CNTWD
RND TAC
SE CNTWD(10)=(REFDA-ORGDA)*XMNPDA+REFTM-ORGTMS NEW-OLD EPOCH, INS
IF(CNTWD(10)*DT)LT(0.),GO TO SEC3D$ =0 IF CANNOT BE REACHED
IF(ABS(CNTWD(10)))GT(ABS(CNTWD(10))),GO TO SEC3$ IN SPECIFIED
SEC3D PRINT OUTPUT TAPE 5,SEC2D$ INTEGRATION
SEC3D FORMAT(18H20NO , START TIME //)$
CNTWD(10) = 0.0 $
SE REWIND6 $
REWIND 11 $
TPFG =0.0 $
NTAPE6=0 $
GATE1=ASMX1$
GATE2=ASMX2$
OMCNT=1.080-CT2=0.0$
THE FOLLOWING TRANSFER OF COLUMN HEADINGS MAY BE CHANGED
DO 1, I=1,19$
HEAD(I) = CHEAD1(I) $ TIME-LATITUDE-LONGITUDE - ALTITUDE TO HEAD
COMPUTE FOR EPOCH, VALUES OF -
INCLINATION, NODE, BAR, MEAN MOTION, A BAR
BEGIN IF( 9THSG) TE(0.), X9THSG = 3.$
RADI Z$
CNTWD(12)=0.0;CNTWD(13)=0.0$
ITIP S=XTHSG$
R=F**2+HY**2+HZ**2$
RTP=RGRT(P)$
X=HX/RTP;Y=HY/RTP;Z=HZ/RTP$
SINI=SQRT(1.0-WZ**2)$
SINO=X/SINI;COS0=(-Y/SINI)$
COS1=YZ$
IF(COS1 E (0.)), XINCL = PIOV2; GO TO 19$
XINCL = ATAN( SINI/ COS1) $
IF(XINCL) LT (0.), XINCL = PI + XINCL$
19 IF (COS0) E (0.), XNODE(2) = SIGNF(PIOV2,SINI)* GO TO 23 $

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15

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      ENCTAL
      CALL XLSF
      XNMP=ZT#
*   COMPUTE PERTURB TIME ACCELERATIONS
*   I.F., LEAVE OUT DRAG UNTIL RECTIFY ROUTINE IS CALLED, AND
*   COMPUTE RULGE PERTURBATION
      RULGE
      RSQR=R*%R#RS R*RSQR*%$
      UZSQR=U*%UZ XOVRS=X/R5, ZOVRS=Z/R5$
      XRDR=X*VR5*(5.0*UZSQR-1.0)*XJNPRM$
      XRDR=X*DRGR+(X*VR5*7*H*PRM/RSQR)*(7.0*UZSQR-3.0)$
      XRDR=X*DRGR+((XOVRS*XK*PRM)/(6.0*RSQR))*(42.0*UZSQR
      -63.0*UZSQR*UZSQR-3.0)$
      XRDR=X*DRGR+((21.0*XJAY5*XOVRS*UZ)/(8.0*RSQR*R))*(5.0
      -30.0*UZSQR+33.0*UZSQR*UZSQR)$
      YRDR=X*DRGR*(Y/X)$
      ZRDR=X*VR5*(5.0*UZSQR-3.0)*XJNPRM$
      ZRDR=X*DRGR+(.6*HMPRM/R5)*(35.0*UZSQR*UZSQR/3.0
      -10.0*UZSQR+1.0)$
      ZRDR=X*DRGR+((ZOVRS*XK*PRM)/(6.0*RSQR))*(-63.0*UZSQR
      *UZSQR+70.0*UZSQR-15.0)$
      ZRDR=X*DRGR+((3.0*XJAY5)/(8.0*R5*RSQR))*(-5.0
      +UZSQR*(105.0+UZSQR*(-315.0+UZSQR*231.0)))$
      THGRM=CMV*(THGPO+SIDRT*ORGDA+(TWOPI+SIDRT)*RKSTO(4)/XNMPDA)$
      UXTIME=RGDA+RKSTO(4)/XNMPDA$
      CALL RELGE(IXYR, UXTIME, X, THGRM, AAA, BBB, CCC)$
      XRDR=X*DRGR+AAA$
      YRDR=Y*DRGR+BBB$
      ZRDR=Z*DRGR+CCC$
      CALL PRFSS(IXYR, X, UXTIME, D, XM, VV, U1, U2, U3)$
      XRDR=X*DRGR+VV*U1$
      YRDR=Y*DRGR+VV*U2$
      ZRDR=Z*DRGR+VV*U3$
      DETERMINE TOTAL PERTURBATIONS
      XDGR=X*DRGR(1)$
      YDGR=Y*DRGR$
      ZDGR=Z*DRGR$
      RRDOT=X*XDOT+Y*YDOT+Z*ZDOT$
      RRDGR=X*XDGR+Y*YDGR+Z*ZDGR$
      RDRDGR=XDGR*XDOT+YDGR*YDOT+ZDGR*ZDOT$
      CAPD=RRDOT/SQRMU$
      DGR=RRDGR/SQRMU$
      DRGR=RRDGR/SQRMU$
      DDGR=DRGR*2.0$
*   RELATE PERTURBATIONS TO CRITICAL PARAMETERS
      XNMP=(DDGR/SQRPMU)*A*XN*(-1.5)GRBDGR=0.0$
      DO 29 I=1,3$
20      RRDGR=XDGR(I)*WX(I)+RPDGR$
      SMLGR=SQRMU*(WZ+1.0)*RTP$
      SMLGR=(RRDGR/SMLGR)*7$
      EQX=X*AZI-Z*AYI$
      EQY=WZ*AXI-X*WZI$
      EQZ=WX*YI-Y*AXI$
      E2VGR=0.0$
      DO 3 I=1,3$
      AXGR(I)=X(I)*DGR-(XDGR(I)*CAPD+XDOT(I)*DGR)$
      E2VGR=E2VGR(I)*X(I)+E2VGR$
      XLGR=E2VGR/ALGR$
      XLGR=(-DGR/RTA)*2.0+XLGR+SMLGR$
      HXGR=(ZGR*Y-YGR*Z)/SQRMU$
      HYGR=(XGR*Z-ZGR*X)/SQRMU$
      HZGR=(YGR*X-XGR*Y)/SQRMU$

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* COMPUTE RECTIFIED DERIVATIVES
* VT RKSTO(1) = XGCR * XKE + 11$
  DO I = 1, 3$
    RKSTO(I+1) = AX - (I) * K$
    DOTG(I+1) = -XG - (I) * XKE$
  ST T T C$
  DO P = 1, 10$
    PA = (P)$
  END DO
* CONTROL ROUTINE FOR EPHEMERIS INTEGRATION
* CALLED AT COMPLETION OF EACH INTEGRATION STEP
  ENDTAC
* IMMEDIATELY AFTER EACH PERIGEE PASSAGE, CORRECT ORBIT PARAMETERS
* FOR ATMOSPHERIC DRAG (RECTIFY ORBIT)
  CNTRL = IF(PSI) 32, 33, 33$
  PRECTI = 1.0$
  GO TO CNTRL$
3  IF(RECT) CNTRL = 34, CNTRL$
  PRECTI = 1.0$
  CALL RECTIFY(NMPER, ESTNE, ECOSF, A, WX, URGCO, RKSTO, XN, XNZ, AYN1,
    U7, -)
  START TAC$
  DO P = 1, 10$
    PA = (P)$
  END DO
CNTRL = EPHEM(CNTRL) = RKSTO(1)$ CURRENT TIME (SINCE EPOCH) TO EPHEM BUFF
SUMP2 = IF(NCNTRL - IXX) 35, OFLO, OFLO$ IF EPHEM BUFFER IS FULL, GO WRITE
36  DO I = 1, 7$
    NCNTRL = CNTRL + 1$
* TRANSFER CURRENT VALUES OF XL, ABAR, F BAR TO EPHEMERIS BUFFER
  IF(EPHEM(CNTRL) = RKSTO(I+4))$
    COUNT = COUNT + 1$
    NCNTRL = NCNTRL + 1$
  IF(SENSE LIGHT 10) X36, X36$ TURN OFF SENSE LIGHT 10
  IF(CNTRL(1)) 38, SEC5E, 3-$
* DETERMINE WHAT TO OUTPUT FOR PRINTING
37  IF(IPNTFL-1) LI E7, 41, SEC5E$
  SENSE = IF(SENSE LIGHT 10) 43, X44$ PRINT R BAR, R BAR DOT
  IF 4 WRITE TPE 6, RKSTO(1), (X(I), I=1, 3), (XDOT(I), I=1, 3)$
  NTAPF6 = TAPF6 + 1$
  SENSE LIGHT 10$
  IF(SENSE SWITCH 35) 36, 38$
  CONTINUE$
  DO (XEL) I=1, 7$
  X12  XEL(I) = RKSTO(I+4)$
  CALL XEL(XEL1, XXS, EL1, EL2, EL3, EL4, EL5, EL6)$
  WRITE TPE 15, RKSTO(1), EL1, EL2, EL3, EL4, EL5, EL6$
  NTAPF15 = TAPF15 + 1$
  GO TO 3$
40  IF(IPNTFL-2) LI E7, 41, 41$
41  IF(1.0 - 0.7**2) 45, 46, 45$ PREPARE LAT-LONG, ALTITUDE, FOR PRINTOUT
  XLAT = SIGNF(0.0, 0.23)$ GO TO 40$
42  XLAT = 0.7 * (SIGN(1.0 - 0.7**2) * 0.99330658)$
  XLAT = ATAN(XLAT) * RADYNS$
  IF(1) 50(0.0), XLONG = SIGNF(0.0, Y) @ GO TO 56$
  XLONG = ATAN(Y/Z) * RADYNS$
  IF(X(1) LT 0.0), XLONG = XLONG + 180.0$
  XLONG = CNTRL - (RKSTO - TO) * FLP25 - THGR$
  XLONG = 360.0 - APPROX(XLONG)$
  F0 = LH(2, X, XBAR)$
  IF(1) 54(1.0, 1.0, 1.0)$
  CALL F0(I - COUNT)$
  LI 54 = 1.0 - COUNT + 1$

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      -1LI E=LE+1$
      CALL PRINT(EKST(1),AL T,XLONG,H)$
LINE7 IF((RKSTO-TE)*T)GT(0.),GO TO CSEND$      JUMP IF THRU INTEGRATING
*      IS THERE A RESTART TIME (NEW EPOCH)
71      IF(CNT D(10)) 72, HELL, 72$
*      LOGIC TO STORE VALUES OF PARAMETERS WHEN RESTART TIME REACHED
72IF(CNT D(13))IFNE,74,IRENE $
74IF(CNT D(12))75,76,75$
      START TAC $
      CALL JUMP RUNGE,RETURN$      RESUME INTEGRATION
      END TAC $
76      IF((RKSTO+RKSTO(4)-CNTWD(10))*DT)LT(0.), GO TO HELL$
      RKSTO(4)=CNTWD(10)-RKSTO(4)CNTWD(12)=RKSTO(4)$
      GO TO HELL$
77IF(CNTWD(11))80,81,80$
      RCNTWD(13)=CNTWD(11)$
      GO TO 82$
81RKSTO(4)=DT-RKSTO(4)RCNTWD(13)=RKSTO(4)$
82      CNT D(14) = PR(PR (RKSTO(5))) $
      ADDO87I=1,3$
87      CNT D (I+16) = HXI (I) $
      CNTWD(15) = AXNI(1), CNTWD(16) = AYN1 $
      GO TO HELL$
IFNE      IF(CNT D(11)) E (0.), RKSTO(4) = DT$
      GO TO HELL$
*      WRITE EPHEM BUFFER ON TAPE 3, TURN ON SENSE LIGHT 4
OFLU      WRITETAPE3,(EPHEM(1),I=1,IXXX) $
      NTAPE3=NTAPE3+1 $
      SENSE LIGHT 46 NCNTRL = 16 GO TO CNTRL2 $
      START TAC$
      PAGE $
*      CSEND RECEIVES CONTROL AFTER INTEGRATION OF EPHEMERIS
*      IF REQUESTED ,OUTPUT CODE 2 OR 3, PRINTS X,Y,Z EPHEMERIS
*      RUNS OUT EPHEM BUFFER ONTO TAPE 3
*      SENDS CONTROL TO DIFFERENTIAL CORRECTION OR SIMULATION
      END TAC $
CSEND      IF(IPNTFL)LT(2),GO TO CORSM1 $
      REWIND $ $ YES - PRINT X,Y,Z EPHEMERIS, FROM DATA ON TAPE 6
      IPGCNT = 1$
      DO 225 I=1,15$
225      CHFD(I) = CHFD2(I) $ TIME X Y Z XDOT YDOT ZDOT - TO HEADING
      LI C=60 $
      ITAP=NTAPE3 $
      RTAP      READ TAPE 6,(OTPT(I),I=1,7)$
      NTAPE6= NTAPE6-1 $
226      IF(LINC-54)227,227,228 $
228      CALL HEAD (IPGCNT)$
      LI C=5*IPGCNT=IPGCNT+1$
227      LINC=LI C+1$
      WRITE OUTPUT TAPE 5,227,(OTPT(I),I=1,7)$
227      FORMAT(2H1, 14X, 7F15.8)$
227      IF( NTAPE6) GT (0), GO TO RTAP$      LOOP TILL ALL PRINTED
      NTAPE6 = ITAP $
D35M1      IF(SENSE SWITCH 35)C36,DOPS $
      CONTINUE $
      REWIND 15 $
      IPGCNT=1 $
      LI C=60 $
      ITAP=NTAPE15 $
D36      READ TAPE 15,(OTPT(I),I=1,7)$
      NTAPE15=NTAPE15-1 $

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      IF(LINE=54)G36,F36,F36 $
      WRITE (TPUT TAPE 5,ELEM1 $
ELEM1 FOR AT( F70,37)REPLERISM ELEMENTS FOR EACH TIME STEP///)$
      WRITE (TPUT TAPE 5,ELEM2 $
ELEM2 FOR AT( F10,6X,4HTI E,10X,4HAXIS,11X,5HECCE, 9X,6HINCLIN,9X,
      6H AND ,8X,6HARG PERG,7X,8HRA NOIF//)$
      LINE=5 $
      IPGNT=IPGNT+1 $
      LINE=LINE+1 $
      WRITE (OUTPUT TAPE 5,G36,(CTPT(I),I=1,7)$
      FOR AT(FH10,7F1F,P)$
      IF( TAPF15)G1(),GO TO F36 $
      NTAPF1=CTPT P $
      REIND 15$
      DO SM SENSE LIGHT 40REWIND 6$
      IF( TAPF3)DUBS,3,DUBSM3,DOBSM4$
      DO SM3 IX4X= NCNTRL$
* RUN OUT EPHEM BUFFER ONTO TAPE 3
      DO SM4 WRITE TAPE 3,(EPHEM(I),I=1,IXXX ) $
      NTAPF3= TAPF3+1 $
      NTAPF3=NTAPF3 $
      CNTRD IF(SENSE LIGHT 2) NO, GO$ ARE OPS ON TAPE 9
      9 SENSE LIGHT 2 $ YES - GO DO CORRECTION
      GO TO ORBCO$
      10 IF (CNTD(1)) ORBCO, 92, ORBCO $ SIMULATION OR CORRECTION
      START 1-C$
      PAGE $
* SIMULATION RUN
      SAVE TMOTO, RCARD, TMOTO $
      END TAC $
      20 LINE = 100 IPGNT=1 $
      ISAVE6= TAPF6$
      DO 3 I=1,15$
      30 XCHET(I)=OCHET(1)$
      CASE=CASE2$
      40 SIM CALL READI(CNTRD,STARC,IHED,NCARD)$
      READI GO TO(9),NLISTA),NCARD$
      50 PHIRD=STARC(3)*CONV$
      XLAMPRA = APPROX (-STARC(4)) $
      60 SINPH(1)=SIN(PHIRD) $
      CAPC=(1.0-EPSON)*SINPH**2)$
      CAPC=1.0/SQRT (CAPC)$
      CAPS=CAPC*(1.0-EPSON)$
      QALT=STARC(5)/XAMPERS
      CAPL=(QALT+CAPS)*(-SINPH)$
      COSPH=COS(PHIRD)$
      XOMCT=(QALT+CAPC)*(-COSPH)$
      100 IF( TAPF6)100,100,101 $
      100 REIND 6 $
      NTAPF6=ISAVE6$
      GO TO 100 SIM
      101 REW TAPE 6,(TXYZ(I),I=1,4),(CFSCD(I),I=1,3)$
      NTAPF6= TAPF6-1 $
      CH HC XL = THET+(XLAMPRA)*CONV $
      ITF P=(RG1 +TXYZ)/XAMPRA$
      T=ITF P $
      ITF F=ITF P+IT $
      T=(RG1 +TXYZ)/XAMPRA-I $
      EQE=(1.-T)*EQE(ITF P)+T*EQE(JTEMP+1) $
      EQE=EQE-COOL/24 . $
      THET=(TXYZ-TC)*RPT1+XLAPTH+EQE $

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COSTH=1/SIN(THTA)$
CAPX=XC*CT*COSTH$
RHOX=CAPX+TXYZ(2)$
SINTH=SIN(THTA)$
CAPY=XC*CT*SINTH$
RHOY=CAPY+TXYZ(3)$
RHOZ=CAPZ+TXYZ(4)$
RHO1=SQRT(RHOX**2+RHOY**2+RHOZ**2)$
105 XLX=RHO1*COSPH$
XLZ=RHO1*SINTH+RHOX*COSTH$
XLX=(XLZ*SINTH-XLX)/RHO1$
XLY=(COSTH*RHOY-SINTH*RHOX)/RHO1$
XLZ=(XLZ*COSPH+SINTH*RHOZ)/RHO1$
IF(XLZ)104,106,106$
106 IF(XLX(1))COMPA,107,COMPA$
107 IF(XLY)108,ERROR,109$
108 TEMP=3.0*PI/2$
GO TO CVDG2$
109 TEMP=PI/2$
GO TO CVDG2$
COMPA CAPA=ATAN(XLY/(-1.0*XLX))$
IF(XLX(1))110,110,111$
110 IF(XLY)112,113,113$
111 TEMP=CAPA+PI$
GO TO CVDG2$
112 TEMP=CAPA+2.0*PI$
GO TO CVDG2$
113 TEMP=CAPA$
CVDG2 CAPA=TEMP/CONV$
TEMP=1.0-XLZ**2$
IF(TEMP)LTE(0.),SMLF=SIGNF(90.,XLZ)@ GO TO H2DEG $
SMLF=ATAN(XLZ/SQRT(TEMP))/CONV $
H2DEG TEMP=(ORGTW+TXYZ)/XVNPDA$
ITEMP=TEMP$
CNTWD(14)=ITEMP+ORGTW$
CNTWD(15)=TEMP-ITEMP$
CNTWD(16)=CNTWD(15)*XVNPDA$
*A FUNCTION ROUTINE MUST BE ENTERED HERE TO PURCH OUT$
*AN OBSVCART. USING CASE NO AS SATELITE NO.$
*
* STATION NO FROM CNTWD(6) IN BCD,CURRENT YRS
* DAY NO FROM CNTWD(14), TO BE CHANGED TO MONTHS
* AND DAY AND FROM CNTWD(15) TO HRS, MIN AND SEC.$
*
*
DO 300 I=2,13$
IF P1=i-1 $
IF(TWOT(I)-CNTWD(14))300,300,301$
300 CONTINUE$
301 IF P2=INTW(14)-TWOT(ITEMP1) $
IF P3=(CNTWD(15)/60.0)$
TEMP2=(CNTWD(15)-(ITEMP3*60.0))$
IF P4=TEMP2$
ITEMP4=TEMP2+.00001 $
TEMP2=(TEMP2-ITEMP4)*60. $ SECONDS AND FRACTIONS
IF(TEMP2)LT(0.0),TEMP2=0.0 $
INT P2=TEMP2 $ SECS
INT P3=((TEMP2-INT P2)*10000.+.00000001 $
STAT TBC $
TV4 INT P2 $
SRA 32 $
TA INT P2 $

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S      HI=FC INT P2 $
      TA= INT P2 $
      TM= INT P3 $
      SP= 72
      TA= INT P3 $
S      HI=FC INT P3 $
      TA= INT P3 $
      EL=TA $
      TEMP2=(TEMP1-TEMP4)*4/0000.0$
      TEMP3=SEH*1/000.0$
      TEMP3=COPA*10000.0$
      TEMP4=P*01*INPER$
      DO(X905)I=1,3$
X905  XLSUBX(1)=RHOX(I)/RHO1$
      TEMP5=1.0-XLSUBZ**2$
      IF(TEMP5)X914,X914,X915$
X914  IF(XLSUBZ)X916,X917,X917$
X916  TEMP5=-1.0*PIOV2$
      GO TO DELTA2$
X917  TEMP5=PIOV2$
      GO TO DELTA2$
X915  DELTA=SQRT(TEMP5)$
      TEMP5=ATAN(XLSUBZ/DELTA)$
      DELTA2=DELTA/CONV$
      IF(XLSUBX(1))CALFA,X907,CALFA$
X907  IF(XLSUBY)X908,ERROR,X909$
X908  TEMP5=3.0*PIOV2$
      GO TO ALF2H$
X909  TEMP5=PIOV2$
      GO TO ALF2H$
      CALFA=ATAN(XLSUBY/XLSUBX)$
      IF(XLSUBX(1))X911,X911,X910$
X910  IF(XLSUBY)X912,X913,X913$
X911  TEMP5=ALPHA+PI$
      GO TO ALF2H$
X912  TEMP5=ALPHA+2.0*PI$
      GO TO ALF2H$
X913  TEMP5=ALPHA$
      ALF2H=ALPHA/(CONV*15.0)$
      CPXDT=-1.0*CAPY*THOOT$
      CPYDT=CPX*THOOT$
      RRATE=XLSUBX*(OBSCD+CPXDT)+XLSUBY*(OBSCD(2)+CPYDT)$
      RRATE=RRATE+XLSUBZ*OBSCD(3)$
119  IF(LINE=54)119,119,120 $
12  CALL HEAD (IPGENT) $
      LINE=54 IPGENT=IPGENT+1 $
119  LINE=LINE+1 $
      ALFA=ALPHA*15.0$
      WRITE OUTPUT TAPE 5,P1,CNTWD(8),TXYZ(1),RHO1,RRATE,ALFA,
      DELTA,COPA,SMLH $
      P1=FORMAT(2H10,A4,7X,7F15.8) $
*      SENSE S ITCH 30 PUNCH AZ AND EL CARDS
*      SENSE S ITCH 31 PUNCH RA AND DEC CARDS
*      SENSE S ITCH 32 PUNCH RANGE CARDS
*      SENSE S ITCH 33 PUNCH RANGE RATE CARDS
      IF (SENSE S ITCH 31) 7300,7301 $
7300  INRAH=ALPHA $ RT. ASCENSION TO FIXED POINT
      RAERK=1 RAH $ HOURS TO FLOATING POINT
      RA=LINE(ALPHA-RAERK)*60. $ FRACTIONAL HOURS TO MINUTES
      INRAN=RAH $ TO FIXED POINT
      RAERK=1 RAH $ BACK TO FLOATING

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RASEC=(TAN1-R.FRK)*60.0. $ SECONDS/100
INRAH=ASEC $ CONVERT TO FIXED POINT
DELTA=DELTA $ ASSUME DECLINATION TO
DELSN=PLUS $ BE POSITIVE ==
IF(FLT) 7302,7303,7303 $ UNTIL PROVEN OTHERWISE --
7302 DELSN=MINUS $
DELTAE=-DELTA $ CHANGE SIGN OF DECLINATION
7303 INDCD=DELTA $ DECLINATION DEGREES TO FIXED POINT
DCF RK=1 INCD $ INTEGER TO FLOATING POINT
DCMIN=(DELTA-DCF RK)*60. $ FRACTIONAL DEGREES TO MINUTES
INDCM=DCMIN $ MINUTES TO FIXED POINT
DCF RK=1 INCD $ BACK TO FLOATING
DCSEC=(DCMIN-DCF RK)*600. $ SECONDS/10
INDCS=DCSEC $ TO FIXED POINT
START TAC $
TMA INRAH $
SRA 32 $
TAM INRAH $
S BIN2BCD INRAH $
TAM INRAH $
TMA INRAM $
SRA 32 $
TAM INRAM $
S BIN2BCD INRAM $
TAM INRAM $
TMA INRAS $
SRA 32 $
TAM INRAS $
S BIN2BCD INRAS $
TAM INRAS $
TMA INDCD $
SRA 32 $
TAM INDCD $
S BIN2BCD INDCD $
TAM INDCD $
TMA INDCM $
SRA 32 $
TAM INDCM $
S BIN2BCD INDCM $
TAM INDCM $
TMA INDCS $
SRA 32 $
TAM INDCS $
S BIN2BCD INDCS $
TAM INDCS $
END TAC $
PUNCH (CBSCR),JXYR,CNTWD(8),IXYR,ITEMP1,ITEMP2,
ITE P3,ITEMP4,INTMP2,INTMP3,INRAH,INRAM,INRAS,DELSN,INDCD,INDCM,
INDCS $
CBSCR FOR AT(I2,3X,1H2,4X,A4,I1,4I2,W2,W4,1H-,2W2,W4,W1,W3,W2,W3 ) $
7401 IF (SEISE SWITCH 30) 7400,7401 $
START TAC $
PLUS A/ $
XINS A/ - $
END TAC $
7400 INAZN=CAPA $
AZFRK=1 AZN $
AZMIN=(CAPA-AZFRK)*60. $
INAZN=AZMIN $
AZFRK=1 AZN $
AZSEC=(AZMIN-AZFRK)*6000. $

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      INAZS=ATSEC $
      INELDES LH $
      ELFRK=1 EL $
      ELMI=(SMLH-ELFRK)*60. $
      INELM=MI $
      ELFRK=1 EL $
      ELSFC=(ELMI-ELFRK)*600. $
      INELSEC $
      START TAC $
      TMA INAZD $
      SRA 32 $
      TAM INAZD $
S     BIRBCD INAZD $
      TAM INAZD $
      TMA INAZM $
      SRA 32 $
      TAM INAZM $
S     BIRBCD INAZM $
      TAM INAZM $
      TMA INAZS $
      SRA 32 $
      TAM INAZS $
S     BIRBCD INAZS $
      TAM INAZS $
      TMA INELD $
      SRA 32 $
      TAM INELD $
S     BIRBCD INELD $
      TAM INELD $
      TMA INELM $
      SRA 32 $
      TAM INELM $
S     BIRBCD INELM $
      TAM INELM $
      TMA INELS $
      SRA 32 $
      TAM INELS $
S     BIRBCD INELS $
      TAM INELS $
      END TAC $
      PUNCH(CSCAR),IXYR,CHTWO(8),IXYR,ITEMP1,ITEMP2,
      ITEMP3,ITEMP4,INTMP2,INTMP3,INAZD,INAZM,INAZS,INELD,INELM,INELS$
      FORMAT(I2,3X,1-2,4X,A4,I1,4I2,2,4,4,4,W3,W3,W2,2,4,W2,W3)$
7401 IF (SENSE SWITCH 32) 7500,7501 $
7500 EXPUT=1.0 $
      DO 7550 I=1,99 $
      EXPUT=1.0*F.PUI $
      IF (TEMP1) LT (EXPUT), GO TO 7560 $
7550 CONTINUE $
7560 IUTT=I $
      START TAC $
      SRA 32 $
      TAM IUTT $
S     BIRBCD IUTT $
      TAM IUTT $
      END TAC $
      TEMP4=TEMP4/EXPUT $
      PUNCH(CSCAR),IXYR,CHTWO(8),IXYR,ITEMP1,ITEMP2,ITEMP3,ITEMP4,
      INTMP2,INTMP3,TEMP4,IUTT $
      FORMAT(I2,3X,1-1,4X,A4,I1,4I2,2,4,4,4,5X,F11.11,1H+,2)$
7601 IF (SENSE SWITCH 33) 7600,7601 $

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```

7600 RRJTT= .1*((F,*37922.43-100,*RRATE)/(37922.43+RRATE))$
IS=10$
PUNCH (SSCR),IXYR,CNTND(8),IXYR,ITEMP1,ITEMP2,
ITEMP3,ITEMP4,INTMP2,INTMP3,IS,RRJTT $
05SCR FORAT(I2,3X,1H3,4X,A4,I1,4I2,W2,W4,8X,I2,F9.9) $
7601 GO TO 14$
START TACS
PAGE$
* DIFFERENTIAL CORRECTION RUN
END TAC $
0600 REWIND 9 $
IORNT2=IORCNT $
IF (SENSE LIGHT 4)121,122$
121 SENSE LIGHT4$
IF (EFLAG)123,123,122$
123 REWIND 3 $ IF EPHEMERIS ON TAPE 3, REWIND 3
122 NTAPE3= NTAPE3 $
IF (SENSE LIGHT 3) 124, 124 $ TURN OFF SENSE LIGHT 3
124 IPECNT = 10 SUM = 0.00 SUM2 = 0.0$
IF (SENSE LIGHT 2) INITL,125$ IF FIRST PASS THRU OBS, RD FM CRD
* READ STATION AND OBSERVATION CARDS
125 IF (IRPT)GT (9), IRPT=0$ SET NO. OF TIMES TO REPEAT CORR.
RREC CALL READER(STARC,ISTCNT,LSTCNT,IASIZE,IDBUF,XMPER)$
START TAC $
TMA LSTCNT $
JMP CHGNXN $ SET UP LEAST SQUARES ROUTINE FOR MATRIX SIZ
PAGE$
END TAC $
* READ OBSERVATION CARDS, STORE ON TAPE 9
IAL=1$ IORCNT=0$
*ENTER RCARD AND READ 1 OBSV CARD STORING$
*UTIME, ALPHA,DELTA,RANGE, AND STAID = STA NO IN BCD$
*WHEN LAST CARD IS READ SET IAL=2$
X130 CALL RCARD(SATEL,STAID,ASIG1,IBMUTH,DAYNO,ALPHA,
DELTA,RANGE,ROUTO,UTIME,NCARD,XMPER)$
GO TO (X132, 131), NCARD $ CHECK IF ALL OBS. CARDS READ
131 REWIND 9$ ALL OBS. CARDS READ - GO DO CORRECTION
GO TO INITL$
X132 I = 1 $ NO. OF STATION RECORD IN STARC
START TAC $
TMA ISTCNT$
SLA 3$
AD $
AM C/HLT,STARC$
TDXLC ,3$
TAM JXXY$ JXXY HAS ADDRESS OF END OF STARC TABLE
* FIND STATION IN STARC BUFFER
ZXXY TMA STAID$
TMD ,3$
JAED H134$ SEARCH FOR STAID IN STARC TABLE
TMA N/9T15$
AMS I $
TMD JXXY$
AIXOL 9,3 $
JNO ZXXY$
TMD STAID$ STATION NOT FOUND - NOTE ON FLEXO
TMD BLAB3+2$
TMA C/HLT,BLAB3$ C/HLT,5$
JMP 6$ AND ON OUTPUT TAPE 5
END TAC$
WRITE OUTPUT TAPE 5, 705, STAID$ GO TO X130$

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705  FORMAT(10H10STATION ,A8, 10H NOT FOUND )$
-134 PHIRD = STARC(I+1) $ GET LATITUDE, EAST LONGITUDE, HEIGHT
      XLAMB = STARC(I+2) $ CALT = STARC(I+3) $
      STARK = STARC(I+4) $ GET IAXD
      DO 708 J = 1,4 $
706  IF( SIG1(J)) E (0.), ASIG1(J) = STARC(I+J+4) $
      XMNUTS = UTIME - ORGTM + XMNPDA*(DAYNO-ORGDA) $ MINUTES SINCE EPC
      TEMP = XMNUTS - TO $
      IF(TEMP*DT) LT(0.), GO TO 706$ FIND IF THIS TIME IN EPHEMERS
      IF(TEMP*(TF-XMUTS)) GTE(0.), GO TO 707$
706  WRITE OUTPUT TAPE 5, 709, STAID, DAYNO$ GO TO X130 $
709  FOR AT (19H10OBSERVATION FROM ,A8,3H ON,F4.0,18H OUT OF TIME RANGE ) $
707  SINPH = SIN (PHIRD) $
      TEMP=(1.0-SINPH**2*EPSQD)$
      CAPC=(1.0/SPRT (TEMP))$
      CAPS=CAPC*(1.0-EPSQD) $
      CAPZ=(CAPS+OALT)*(-SINPH)$
      COSPH=COS (PHIRD)$
      XOVCT=(OALT+CAPC)*(-COSPH)$
      XLMPH = THGRU + XLAMBA $
      IDAY=DAYNO-ORGDA+IT $
      IITT=UTIME/1440. $
      T=UTIME/1440.-T $
      T=IITT$
      EQQ=(1.-T)*EQEQ(IDAY)+T*EQEQ(IDAY+1) $
      EQQ=EQQ*CONV/240.$
      THTA=XMUTS*RPTIM+XLMPH+EQQ $
      COSTH=COS (THTA)$
      CAPX=XOVCT*COSTH$
      SINTH=SIN (THTA)$
      CLW=COS(THTA-XLAMBA)$
      SLM=SIN(THTA-XLAMBA)$
      CAPY=XOVCT*SINTH$
103  CALL STORS(IOTYPE)$ COMPUTE L BAR, ETC.
      IF(SENSE LIGHT 5) X130, 151$ GTOBS TURNS THIS ON WHEN OBS DONE
101  WRTETAPE9,SATEL,STAID,IOTYPE,XMUTS,
      (CAPX(I),I=1,3),(ASUBX(I),I=1,9),ASIG1,IAXD,SPHA,CPHA,SDEL,
      CODEL,CLW,SLM,IRMUTH,EQQ $
      IOBCNT=IOBCNT+1$
      IOBCNT2=IOBCNT $
      IF(IOTYPE)152,152,X151$
      X151IF(IOTYPE-2)X152,X152,X130$
      X152ALPHA=0.0@DELTA=0.0$
      GO TO 153$
152  RANGE=0.0$
      GO TO 153$
      STAT IAC$
      PAGE$
*  OBSERVATIONS ARE ON TAPE 9 - MAKE PASS THRU THEM.
      END TAC $
      I ITL SENSE LIGHT 2$
      IF(SENSE LIGHT 4)154,155$
104  REA TAPE3,(EPHEM(I),I=1,IXXX) $
      SENSE LIGHT 4 $
      NTAPE3= TAPE3-1 $
105  RCNT=0.0@RCNT2=0.0$
      BOCNT=0.0$
      LSTAD=1EFC T=0.0$
      ITSTAD= $
      IPC T= IPC T2=0$

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```

*      ENTER LEAST SQUARES HE.F$
      STA TIME $
      J = 1 $
      LSK $
      E = 1 $
* PASS THRU OBSERVATIONS
      F = 1 $
      IF (SENSE LIGHT) 178,179$
*      JUST DIR RA OR AZIMUTH - DO DECL OR ELEVATION
178  ARS = RESID
      DO (X1) I = 1,3 $
X180  ARAY(I) = WST(10+I) $
      CALL COEFF(ARAY,I,X1PER)$
      GO TO (180,PADCR,OMIT1),I $
180  IF (IWST-2) A180,A180,R180 $
      A180 SUM = RESID**2 + SUM $ FORM SUM OF SQUARES OF RESIDUALS
      RCNT = RCNT + 1.0 $
      IRCNT = IRCNT $
      GO TO FINEX $
R180  SUM2 = RESID**2 + SUM2 $
      RCNT2 = RCNT2 + 1.0 $
      IRCNT2 = IRCNT2 $
FINEX GO TO LSQRS ADD THESE COEFFICIENTS TO LEAST SQUARES MATRIX
179  IF (RCNT+RCNT2) 181,181,PROBXX $
181  DO 182 I=1,18 $
182  CHED(I) = ORSD(I) $ SAT. STA. TIME RHO RESID/KM RA RESID/KM...ETC.
183  CALL HEAD(IPGCT) $
      IPGCT = IPGCT + 1 $
      LINE = 6 $
      GO TO TSECF $
PROBXX IF (IWST - 1) A189, B189, F189 $
F189  IF (IWST) E (3), APRNT13 = RESID GO TO PROBS$
      APRNT71 = RESID $
      APRNT56 = ARSCL $
*      PRINT ACCORDING TO PAGE 59$
PROBS IF (LINE-54) PROBSX,PROBSX,PROBSY$
PROBSY CALL HEAD (IPGCT)$
      IPGCT = IPGCT + 1$
      LINE = 5$
PROBSX LINE = LINE + 1$
      WRITE OUTPUT TAPE 5,CVTOBJ,WSTO(1),WSTO(2),WSTO(4),APRNT41,
      APRNT56,APRNT71,APRNT86,APRNT01,APRNT13,APRNTS $
C.TORL FOR AT(2H10,A3,3X,64,7E14.7,2X,A4)$
C.TOP  APRNT41 = 0.0 $
      APRNT56 = 0.0 $
      APRNT71 = 0.0 $
      APRNT86 = 0.0 $
      APRNT01 = 0.0 $
      APRNT13 = 0.0 $
      APRNTS = APRNTS $
TSECF IF (IOP.T2) EFCH ,EFCHP,185$
185  IOP.T2 = IOP.T2 - 1 $
      GO TO CVORS
C.T1  CMLT = CMLT + 1$
      APRNTS = STARS $
      IF (SENSE LIGHT) 178, PROBXX $
      APRNT41 = RESID $
      GO TO PROBS $
      APRNT56 = ARSCL $
      APRNT71 = RESID $
      GO TO PROBS $
      IF (IOP.T2 - IOP.T2) CTV1,CTV1,UNKERS$
      STA TIME $

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UIKER TMA C/FLT, HCBF C/FLT, 6$
JMP L 6$
RTHLT $
JMP L 6$
END TAC $
CTV1 GO TO L90S1$ GC FILL IN A MATRIX
J = LSTCNT**2 $
DO 720 K=1, J$
720 SQA(K) = QLS A(K)$ SAVE A MATRIX IN SQMA
DO 721 K = 1, LSTCNT $
721 SQA(K) = QLS B(K)$ SAVE B MATRIX IN SQBA
LMOVE = 1$
IF (MCORRE(1)) 722, 723, 722 $
722 GO TO L90S$
WRITE OUTPUT TAPE 5, 724$
724 FORMAT(4H2DCORRECTION MADE TO ORBITAL ELEMENTS AND STATION POSI
TIO .)$
GO TO CFEKT$
GO TO CWRAC $
*
723 J = LSTCNT**2$
DO 725 K = 1, J $
725 SQA(K) = SQMA(K)$ MATRIX A TO MATRIX A1
DO 726 K = 1, LSTCNT $
726 SQR(K) = SQBA(K)$ MATRIX B TO MATRIX B1
L=L+1$
K = L * LSTCNT $
DO 727 =1, K$
727 SQA(M)=0. SET 1ST L ROWS OF MATRIX A1 = 0
728 K = L * LSTCNT + 1 $
M = K + 5 $
DO 729 =K, $
729 SQA(N) = 0. SET 1ST L ELEMENTS OF REMAINING ROWS = 0.
L=L+1$
IF (L - LSTCNT ) 728, 730, 730 $
730 K=LSTCNT+1$
L=6*LSTCNT-3*IASIZES$
DO 731 =1, L, K$
731 SQA(M) = 1.0$ SET FIRST L DIAGONAL ELEMENTS = 1.
DO 732 =1, 6$
732 SQB(M) = 0.0$ SET FIRST L ELEMENTS OF MATRIX B1 = 0.
LMOVE = 2$
IF (MCORRE(2)) 733, 734, 733 $ SHALL WE CORRECT STATIONS ONLY
733 DO 735 =1, J$
735 QLSQA(M) = SQMH(M) $ YES-TRANFER A1 AND B1 MATRICES TO
IF(IASIZE) 5 (0), WRITE OUTPUT TAPE 5, 773$ GO TO CUMBAC $
773 FOR AT (2H10 / 38H10NO STATION POSITIONS TO BE CORRECTED ) $
DO 736 = 1, LSTCNT$ WORKING AREA USED BY LEAST SQUARES
736 QLSQB(M) = SQHB(M)$ SUBROUTINE
GO TO SOS$ AND GO SOLVE EQUATIONS
WRITE OUTPUT TAPE 5, 749$
749 FOR AT(43H2DCORRECTION MADE TO STATION POSITION ONLY.)$
GO TO CFEKT$
GO TO CWRAC $
*
734 J = LSTCNT **2 $
DO 738 K = 1, J $ MATRIX A TO MATRIX A2 (SQAC)
738 SQAC(K) = SQMA(K)$
DO 739 K = 1, LSTCNT $ MATRIX B TO MATRIX B2 (SQBC)
739 SQBC(K) = SQBA(K)$
IF (STC(1-6)) 12134, 12134, 12135$

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12135 M=7-
      N = LSTCNT
      K = N * LSTCNT
      DO 741 L=M, N
741  SQMC(L) = 0.0 $ CLEAR FIRST SIX ROWS MATRIX A2, EXCEPT 1ST 6 CL
      M=M+LSTCNT
      N=N+LSTCNT
      IF (N-K) 740, 740, 742$
742 M=K+1$
      DO 743 L=M, N
743  SQMC(L) = 0.0 $ CLEAR REMAINING ROWS OF MATRIX A2
      M = K + 7 $
      K = LSTCNT + 1 $
      DO 744 L=M, N, K$
744  SQMC(L) = 1.0 $ SET DIAGONAL ELEMENTS AFTER FIRST 6 TO 1.0
      DO 745 L = 7, LSTCNT $
745  SQMC(L) = 0.0 $ CLEAR MATRIX B AFTER FIRST 6 ELEMENTS
12134 LMODE= 3 $
      IF (MCOPE(3)) 746, 750, 746 $ ARE WE TO CORRECT ORB ELEMS ONLY
746 DO 747 J=1, J$
747  QLSQA(M) = SQMC(M)$
      DO 748 J = 1, LSTCNT $ YES - TRANSFER A2, B2 MATRICES TO
748  QLSQB(M) = SQBC(M) $ WORKING AREA USED BY LEAST SQUARES
      GO TO LSQS $ AND GO SOLVE EQUATIONS
      WRITE OUTPUT TAPE 5, 737$
737  FORMAT(43H20CORRECTION MADE TO ORBITAL ELEMENTS ONLY.)$
      GO TO CREKT$
750 GO TO CUMBAC$
MOV08 REAL TAPE 9, (WSTO(I), I = 1,16), ASIG1, IAXD,
      SPHA,CPHA,SOEL,CCDEL,COSTH,SINTH,IBMUTH,EQQ$
      I = IXXX$
195  IF (NTAPE3) LTE (0), I = NCNTRL $
* FIND OBSERVATION TIME IN EPHEMERIS
      IF (WSTO(4)-PASIEKA)RW1,RW2,RW2 $
R.1  RE:IND * $
      READ TAPE 3, (EPHEM(J), J=1, IXXX)$
      NTAPE3=NTAPE3X-1 $
      LSTAD=1 ITSTAD=0 $
R.2  PASIEKA=WSTO(4) $
      DO 197 J = LSTAD, T, 8$
      LSTAD = J $
      IF (OT) CTV2, CTV3, CTV3 $
CTV3 IF (WSTO(4)-EPHEM(J)) 203, 203, 198 $
CTV2 IF (EPHEM(J)-WSTO(4)) 203, 203, 198 $
198 CONTINUE $
      IF (NTAPE3-1) TSTER, X201, 201 $
X201 I=NCNTRL$
201  DO 202 J=1, 24$
      KK = IXXX - 24 + J $
      XXXX(J) = EPHEM(KK)$
202  READ TAPE 3, (EPHEM(J), J=1, I) $
      NTAPE3= NTAPE3-1 $
      ITSTAD=ITSTAD+1 $
      LSTAD=L$
      GO TO 195$
* OBSERVATION TIME FOUND
203 IF (LSTAD-25) 204, 206, 206$
204 IF (ITSTAD) 205, 205, 206 $
205 J=1 $
      GO TO 209$
206 J=LSTAD-24 $

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209 IF(J+4-I ) 209,209,210 $
210 J=J-16 $
211 JJ=J+24 $
DO 211 I=1,8$
TI=TR(K)=XXXX(JJ)$
211 JJ = JJ + 8$
* INTERPOLATE TO GET PARAMETERS FM EPHEMERIS
COFLP DO 212 I=1,6$
CSUBI(K)=1.0RKN=K$
DO 213 JJ=1,6$
TEMP=TI-TR(KK)-TIMTP(JJ)$
IF(TEMP)214,213,214$
214 CSUBI(KK)=CSUBI(KK)*(WSTO(4)-TIMTP(JJ))
/TEMP$
217 CONTINUE$
212 CONTINUE$
FC S DO 215 I=1,7$
C SUM=0.0RKN=K+J$
DO 216 JJ=1,6$
CSUM=CSUM+CSUBI(JJ)*EPHEM(KK)$
216 KK = KK + 8 $
FJGFT(K)=CSUM$
215 RKSTO (I+4) = CSUM $
RKSTO(1)=WSTO(4)$
CALL XYZSR $ GET X,Y,Z, RELATED PARAMETERS
IF(TPFG)B1969,B1969,A1970 $
B1969 WRITE TAPE 6, RKSTO(1), X(1), Y, Z, XDOT(1), YDOT, ZDOT$
A1970 XNUZ=ZDOT $
A2OR=AR*ARFSUBU=A2OR*ESINES$
UMUC=(1-UO)*(-3.0/2.0)$
RSUBA=(UMUC*RSUBU)+R$
ROVA=R/1$
RXN=(AXNI-COSEO)*A2OR$
RYN=(AYNI-SINEO)*A2OR$
USUBU=RTESQ*A2OR$
USUBA=USUBU*UMUC$
DENOM=XLGR**2*RTESQ$
TEMP=(XLGR*ECOSE)*(-1.0)-ESQ+(1.0)$
UYN=(TEMP/DENOM)*ESINES$
UXN=UYN*AXNIS$
ROVA=1.7+ROVA$
UXN=UXN+ROVA*SINEO$
UXN=(((-YNI/XLGR)+UXN)*A2OR$
UYN=UYN*AYNI-ROVA*COSEC$
UYN=A2OR*((AXNI/XLGR)+UYN)$
RHOC=0.7$
DO 217 K=1,3$
RHOC(K)=WSTO(4+K)+X(K) $
217 RHOC = RHOC + RHOC(K)**2$
RHOC=SQRT (RHOC)$
DO 218 I=1,3$
XLX(K)=RHOC(K)/RHOC$
218 DELTX(I) = WSTO(K+13) - XLX(K)$
IF(TPFG) A44, A44, F219 $
* WRITE PARAMETERS FOR STD DEVIATION DETERMINATION
A44WRITE TAPE 11,RKSTO(1),(RSUBA(I),I=1,4),(USUBA(I),I=1,4),
(UX(I),I=1,3),(VX(I),I=1,3),R,COSI,SINI,SINU,COSU,
(X(I),I=1,3),(YX(I),I=1,3) $
* INTERPRET OBSERVATION TYPE AND CALL COEFF TO COMPUTE
* CORRECTION EQUATION COEFFICIENTS.
P219 IF(I=SI ) 220,221,220 $

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221 CALL COEFF(NLX,I,XMPER)$
    GO TO (181,BADOB,OMIT1),I $
220 IF(1&ST1-2)Y220,Y220,221$
Y220 SENSE LIGHT 3$
    DO(220)I=1,3 $
X220 ARAY(I)=WSTG(7+I) $
    CALL COEFF(ARAY,I,XMPER)$
    GO TO(180,BADOB,OMIT1),I$
    START TAC $
CHKRT TUM P22$
    END TAC $
    DO 219 I = 1,7$
219 A11(I) = QLSQX(I)$
    IF(TPFG)X156,X157,X156$
X157 TPFG = 5.0$ FIRST TIME HERE - PUT END SENTINELS ON TAPE 6,11
    WRITE TAPE 6, HEND, X(1), Y, Z, XDOT(1), YDOT, ZDOT$
    REWIND 6 $
    WRITE TAPE 11,HEND,(STARC(I),I=1,25)$
    REWIND 11 $
X156 DO 156 I = 1,6 $
156 DLTA(I) = A11(I)$
    DO 158 I=1,18$
158 CHED(I) = CHED3(I) $
    CALL HEAD (IPGCNT) $
    IPGCNT=IPGCNT+1$
    LINE=6 $
    IF(RCNT) X161,X161,X160 $
X160 SUM11 = SQRT(SUM/RCNT)$ COMPUTE ROOT MEAN SQUARES OF RESIDUALS
X161 IF(RCNT2) X163,X163,X162 $
X162 SUM21=SQRT(SUM2/RCNT2) $
* OUTPUT CASE,SUM,DLTAA,OUTAP, SEE PAGE 61$
* $
X163 WRITE OUTPUT TAPE 5,1011,ITIME,IRPT,SUM11,SUM21,
    (DLTAA(I),I=1,6)$
1011 FORMAT(2H10,I1,2X,I1:F12.2,F12.8,6F15.8/2H70)$
    IF(IASIZE)XP1,P22,XP1$
XP1 WRITE OUTPUT TAPE 5, 1004$
1004 FORMAT(21H10SUGGESTED CHANGE IN )$
    WRITE OUTPUT TAPE 5, 1005$
1005 FORMAT(2H10,I1X,29HCOORDINATES OF DATUM - METERS)$
    L=LCNT $
    J=7$
    DO 809 K = 1,IASIZE $
    QLM(J)=QLSQX(J)*XMPER$
    QLM(J+1)=QLSQX(J+1)*XMPER$
    QLM(J+2)=QLSQX(J+2)*XMPER$
    WRITE OUTPUT TAPE 5,752,IDBUF(K),QLM(J),QLM(J+1),QLM(J+2)$
752 FORMAT(2H10,26X,I3,4X,10HDELTA X = ,F13.4,4X,10HDELTA Y = ,
    F13.4,4X,10HDELTA Z = ,F13.4)$
    J = J + 3 $
809 START TAC $
P22 JMP (P)$
    END TAC$
CUMBAC IF((ABS(SUM11-GATE1)+ABS(SUM21-GATE2))*OMCNT*(OMCNT-OMCT2))
    161, CLACO, 161 $
161 OMCT2=OMCNTGOMCNT=0.0$
    GATE1 = SUM11 * X1STS6 $ RESET GATES FOR ACCEPTANCE OF RESIDUALS
    GATE2 = SUM21 * X1STS6 $
    IF(GATE1)A163,B163,A163$
R163 GATE1 = SUM11 $
A163 IF(GATE2)162,C163,162$

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C163 GATE2 = SUM21 $
1-2 EFLG = 0.0 $
IF (SE SE LIGHT 3 ) 164, 164 $ TURN OFF SENSE LIGHT 3
1-3 ITI ES=ITI ES-1$
IF (ITI ES) CLACO, CLACO, ORBCO $ SHALL WE DO ANOTHER PASS
GO TO PRINT $
CLACO XLO=XLO+DLTLOG, XN=AXN+DLTAX $
AYN=AYN+DLTAY$
A=(DLTAA+1.0)*A(2)$
XNODE=DLTND+XNODE(2) $
TEMP=X1*CL+DLTINS
1-5 IF (TEMP) 166, 167, 167$
1-6 TEMP=TEMP+PI$
GO TO 165$
1-7 XINCL=TEMP$
COSI=COS (TEMP)$
WZ=COSI$
XLO = XLO + DLTND*SIGNF(1.0,WZ) $
170 RKSTO(5)=XLO$
SINI=SIN (XINCL)$
COSQ=COS(XNODE(1))$
SINO=SIN(XNODE(1))$
WX=SINI*SINQ$
WY=(-COSQ*SINI)$
ESQ=AXN**2+AYN**2$
P=(1.0-ESQ)*A$
RTP=SQRT (P)$ P
DO 171 I=1,3 $
171 HX(I) = WX(I) * RTP $ HXI(I) = HX(I)$
AXI=-COSI*AYN*SINO+COSQ*AXN $
AYI=(SINO*AXN+COSI*AYN*COSQ)$
AZI=AYN*SINI$
*
X1A=A*AXS $
X2A=SQRT(ESQ) $ ECCENTRICITY
X3A=XINCL*RADYN $ INCLINATION
X3B=XNODE(1)*RADYN$
X2H=ATAN (AYN/AXN(1)) $
IF (AXN(1))X1X,X2X,X2X $
X2H=X2H+PI$
X2X IF (X2B)X3X,X4X,X4X $
X3X X2H=X2H+TWOPI $
X4X X2H=X2H*RADYN $
X1B=(XLO*RADYN)-X2B-X3B $ MEAN ANOMALY
X1C IF (X1B)X2C,X3C,X3C $
X2C X1A=X1A+360. $
GO TO X1C $
X3C WRITE OUTPUT TAPE 5,X4C $
X4C FORMAT(2H70//,4X,4HAXIS,9X,5HECCEN,6X,5HINCLN,8X,9HMEAN ANOM,3X,
8HANG PERG,5X,7HRA MODE)$
WRITE OUTPUT TAPE 5,X5C,X1A,X2A,X3A,X1B,X2B,X3B $
X5C FOR AT(2H10,1X,F10.5,3X,F9.8,2X,4(F12.8,1X)//)$
CALL XY2SR$
*
*PRINT OUT CHECK, CASE,LO,X,THRU X(6)$
*
PRINT- WRITE OUTPUT TAPE 5,X6C $
X6C FORMAT(2H10,3X,7HL SUP 0,2X,3HAXN,9X,3HAYN,9X,2HHX,10X,2HHY,10X,
2HHZ) $
WRITE OUTPUT TAPE 5,X7C,XLO,AXN,HX $
X7C FOR AT(2H10,6F12.8) $

```

```

CAR10 OTPT=0.75
      WRITE (OUTPUT TAPE 5,X8) $
X4C   FORMAT(2H10,4X,4HTIME,11X,1HX,11X,1HY,11X,1HZ,9X,5HX DOT,7X,
      5HY DOT,7X,5HZ DOT)$
      WRITE OUTPUT TAPE 5,X9C,OTPT(1),(X(I),I=1,3),(XDOT(I),I=1,3)$
X4C   FORMAT(2H10,7F12.8) $
*
*
*
TSTRF DO 172 I=1,5$
172   X1STSG(I) = X1STSG(I+1) $
      IF(CCODE(3))G100,Q2,Q100$
Q2    IF(IASIZE)G3,Q100,Q3$
Q3    REWIND 9 $
      REWIND 14 $
      WRITE OUTPUT TAPE 5,Q30$
Q30   FORMAT(2H70,44HNEW POSITIONS FOR STATIONS IN NON=ZERO DATUM/)$
      WRITE OUTPUT TAPE 5,Q31$
Q31   FORMAT(2H10,4H STA,6X,8HLATITUDE,9X,9HLONGITUDE,6X,
      8HELEV=TS) $
      DO(Q4)I=1,IASIZE $
      DO(Q4)J=1,3 $
      II=6+3*(I-1)+J $
Q4    DELT(J,I)=GLSQX(II)$
      II=5 $
      DO(Q6)I=1,ISTCNT $
      STARK=STARC(II) $
      J=IAXD $
      IF(J)Q5,Q6,Q5 $
Q5    PHIRD=STARC(II-3) $
      XLAMBA=STARC(II-2)$
      OALT=STARC(II-1) $
      SINPH=SIN(PHIRD) $
      TEMP=(1.0-SINPH**2*EPSQD)$
      CAPC=1.0/SQRT(TEMP) $
      CAPS=CAPC*(1.0-EPSQD) $
      CAPZ=(CAPS+OALT)*SINPH-DELT(3,J)$
      COSPH=COS(PHIRD) $
      XOVC=(OALT+CAPC)*COSPH$
      COSTH=COS(XLAMBA) $
      SINTH=SIN(XLAMBA) $
      CAPX=XOVC*COSTH-DELT(1,J) $
      CAPY=XOVC*SINTH-DELT(2,J) $
      TEMP=SQRT(CAPX**2+CAPY**2)$
      TEMP=CAPZ/TEMP $
      STARC(II-3)=ATAN(TEMP*1.006814755)$
      STARC(II-2)=ATAN(CAPY/CAPX)$
      IF(CAPX(1))Q01,Q02,Q02 $
Q01   STARC(II-2)=STARC(II-2)+PI $
Q02   CONTINUE $
      TEMP=1.0/(1.0+TEMP**2) $
      TEMP=SQRT(1.0-.0067686580*TEMP)$
      STARC(II-1)=SQRT(CAPX**2+CAPY**2+CAPZ**2)-.996609924/TEMP$
      PHIRD=STARC(II-3)/CONV $
      XLAMBA=STARC(II-2)/CONV $
      XLAMBA=-XLAMBA $
      OALT=STARC(II-1)*XMPER $
      WRITE OUTPUT TAPE 5,Q32,STARC(II-4),PHIRD,XLAMBA,OALTS
Q32   FORMAT(2H10,4X,2(4X,F13.8),4X,F8.2///)$
      WRITE OUTPUT TAPE 5,Q32A,CAPX(1),CAPY,CAPZ$
Q32A  FORMAT(2H10,10X,3HX= ,F11.8,6X,3HY= ,F11.8,6X,3HZ= ,F11.8)$
Q6    II=II+9 $

```

```

DO(Q7) Q=1,I0BCNT $
READ TAPE 9,(WSTO(I),I=1,16),ASIG1,IAXD,SPHA,
CPHA,SDEL,CCDEL,CLM,SLM,IBMUTH,EQQ $
IF(IAXD)GQ,Q7,Q9 $
Q7 WRITE TAPE 14,(WSTO(I),I=1,16),ASIG1,IAXD,SPHA,
CPHA,SDEL,CCDEL,CLM,SLM,IBMUTH,EQQ $
REWIND 9 $
REWIND 14 $
DO(Q9) Q=1,I0BCNT $
READ TAPE 14,(WSTO(I),I=1,16),ASIG1,IAXD,SPHA,
CPHA,SDEL,CCDEL,COSTH,SINTH,IBMUTH,EQQ $
Q9 WRITE TAPE 9,(WSTO(I),I=1,16),ASIG1,IAXD,SPHA,CPHA,SDEL,CCDEL,
COSTH,SINTH,IBMUTH,EQQ $
REWIND 9 $
GO TO Q100 $
Q10 II=1 $
DO(Q10) Q=1,ISTCNT $
IF(WSTO(2))E(STARC(II)),GO TO Q12 $
Q11 II=II+9 $
WRITE OUTPUT TAPE 5,Q13 $
Q13 FOR AT(2H10,17HSTATION NOT FOUND)$
STAT TAC $
RUNOUT $
JMPLE 5 $
ENDTAC $
Q12 PHIRD=STARC(II+1) $
XLAMBA=STARC(II+2) $
OALT=STARC(II+3) $
SINPH=SIN(PHIRD) $
COSPH=COS(PHIRD) $
TEMP=1.0-SINPH**2*EPSQ $
CAPC=1.0/SQRT(TEMP) $
CAPS=CAPC*(1.0-EPSQ) $
CAPZ=-(CAPS+OALT)*SINPH $
XWUTS=WSTO(4) $
XOVCT=-(OALT+CAPC)*COSPH $
XLMPTH=THGRD+XLAMBA $
THTA=XWUTS*RPTIM+XLMPTH+EQQ $
COSTH=COS(THTA) $
SINTH=SIN(THTA) $
CAPX=XOVCT*COSTH $
CAPY=XOVCT*SINTH $
CLM=COS(THTA-XLAMBA) $
SLM=SIN(THTA-XLAMBA) $
WSTO(5)=CAPX(1) $
WSTO(6)=CAPY $
WSTO(7)=CAPZ $
STARE=WSTO(3) $
IF(IAXD-3)Q14,Q15,Q14 $
Q15 WSTO(8)=-CAPY*.05883447 $
WSTO(9)=CAPX*.05883447 $
GO TO Q7 $
Q16 IF(IAXD-2)Q16,Q7,Q16 $
Q16 IF(IAXD)Q17,Q7,Q17 $
Q17 ASUXT=CPHA*SUXT=SPHA $
XLSUZH=SDEL*DSUZT=CCDEL $
XLSUXH=(DSUZT*ASUXT)*(-1.0) $
XLSUYH=SUXT*DSUZT $
ASUXT=1.0 $
DSUXT=XLSUZH*(-ASUXT) $
DSUXT=XLSUZH*ASUXT $

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```

      ESUX=-RINT (ESURY=CCSTHRESURZ=0.$
      ZS=7=1-NP(1)
      SSUY=-SUZ*ESUX+
      SSUX=SUBZ*ESUY
      SSU7=-7USP
      ZSUBY=SUBZ*ESUX
      ZSUBX=-SSUZ*ESUY
      DO (20) I=1,3 $
      IA=I+7-ID=1+10,IL=I+13 $
      WSTC(IL)=XLSUY+*ESUX(I)+XLSUX+*SSUX(I)+XLSUZ+*ZSUBX(I)$
      WSTC(IA)=ASLXT*SSUX(I)+ASUYT*ESUX(I)+ASUZT*ZSUBX(I)$
021  WSTC(IL)=DSLXT*SSUBX(I)+DSUYT*ESUBX(I)+DSUZT*ZSUBX(I)$
      GO TO 173$
0100  EFLAG = 0.$
      IF(IRPT)8173,8173,174 $
0173  IRPT=IRPT-1$
      IF (SENSE LIGHT 1) SEC3, SEC3 $ GO DO ANOTHER CORRECTION
*START A NEW PAGE AND PRINT SIGMAS
0173  WRITE OUTPUT TAPE 5, 1006$
0106  FORMAT(2H10,21X,10HSIGMAS FOR,3X,9HDELTA A/4X,9HDELTA AXN,6X,
      9HDELTA AYN,6X,9HDELTA UO,7X,10HDELTA NODE,6X,7HDELTA I)$
      WRITE OUTPUT TAPE 5, 1007,(BDIAS(I),I=1,6)$
0107  FORMAT(2H10,29X,6F15.9)$
*PRINT OUT SIGMAS FOR POSITIONAL ERRORS
      IF(IASIZE)P10,P50,P10 $
P10  WRITE OUTPUT TAPE 5, 1008$
0108  FORMAT (34H10SIGMAS POSITION ERROR OF DATUM )$
      L=LSTCNT $
      J=7$
      DO 753 J = 1,IASIZE $
      BDIAS(J)=BDIAS(J)*XMPER $
      BDIAS(J+1)=BDIAS(J+1)*XMPER $
      BDIAS(J+2)=BDIAS(J+2)*XMPER $
0109  WRITE OUTPUT TAPE 5,1009,IDFUF(K),BDIAS(J),BDIAS(J+1),BDIAS(J+2)
      $
0109  FORMAT(2H10,26X,I3,4X,10HSIGMA X =,3X,F13.2,4X,10HSIGMA Y =,3X
      ,F13.2,4X,10HSIGMA Z =,3X,F13.2) $
0173  J = J + 3 $
      P50IPGCNT=IPGCNT+1 $
      RE=IND 11 $
      XFLAG=0 $
0102  REAL TATE 11,RKSTO(1),(RSUBA(I),I=1,4),(USUBA(I),I=1,4),(UX(I),I
      =1,3),(X(I),I=1,3),R,COSI,SINI,SINU,COSU,(X(I),I=1,3),
      (VX(I),I=1,3) $
      IF(RKSTO(1)) E (HEND), GO TO 173 $
*FORM THE 6 VECTORS FOR X,Y,Z
      DO 759 I=1,3$
0759  AVEC(1) = UX(I) * RSUBU+VX(I) * USUBU $
      XVEC(1)=AVEC(1)GYVEC(1)=AVEC(2)GZVEC(1)=AVEC(3) $
      DO 760 I=1,3$
0760  AVEC(I) = UX(I) * RSUBA + VX(I) * USUBA $
      XVEC(2)=AVEC(1)GYVEC(2)=AVEC(2)GZVEC(2)=AVEC(3) $
      DO 761 I=1,3$
0761  AVEC(I) = UX(I) * RX + VX(I) * UYN $
      XVEC(3)=AVEC(1)GYVEC(3)=AVEC(2)GZVEC(3)=AVEC(3) $
      DO 762 I=1,3$
0762  AVEC(I) = UX(I) * RYN + VX(I) * UYN$
      XVEC(4)=AVEC(1)GYVEC(4)=AVEC(2)GZVEC(4)=AVEC(3) $
      DO 763 I=1,3$
0763  AVEC(I) = VX(I) * X(I)*COSI - WX(I)*X(I) *COSU*SINI $
      XVEC(5)=AVEC(1)GYVEC(5)=AVEC(2)GZVEC(5)=AVEC(3) $

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DO 764 I=1,3$
764  AVEC(I) = X(I) * X(I) * SINU $
XVEC(6)=AVEC(1)CYVEC(6)=AVEC(2)ZVEC(6)=AVEC(3) $
*TRANSPOSE AT-RICES X,Y,Z
STAT TFC $
SA=1 FMAMU,FC,FMAMU,FMAMU+1 $
TMA ADR0 $
TMI ADR1 $
JMP TRP,TRP $
TMA ADR0 $
TMI ADRY $
JMP TRP,TRP $
TMA ADR0 $
TMI ADRZ $
JMP TRP,TRP $
*TO MULTIPLY 3 AT-RICES
A FMAMU ADRCCADR1XADR2X$
A FMAMU ADRCCADR3XADR4X$
A FMAMU ADRCCADR1YADR2Y$
A FMAMU ADRCCADR3YADR4Y$
A FMAMU ADRCCADR1ZADR2Z$
A FMAMU ADRCCADR3ZADR4Z$
JMP GOO1 $
ADR0 C/HLT,FC/HLT,1 $
ADR1 C/HLT,AVEC0C/HLT,XTVEC $
ADR2 C/HLT,YVEC0C/HLT,YTVEC $
ADR3 C/HLT,ZVEC0C/HLT,ZTVEC $
ADR0C C/HLTL,10C/HLTL,6 $
ADR1X C/HLTL,60C/HLTL,XTVEC $
ADR1Y C/HLTL,60C/HLTL,YTVEC $
ADR1Z C/HLTL,60C/HLTL,ZTVEC $
ADR2X C/HLTL,CVERT0C/HLTL,CXVERT $
ADR2Y C/HLTL,CVERT0C/HLTL,CYVERT $
ADR2Z C/HLTL,CVERT0C/HLTL,CZVERT $
ADR3X C/HLTL,10C/HLTL,CXVERT $
ADR3Y C/HLTL,10C/HLTL,CYVERT $
ADR3Z C/HLTL,10C/HLTL,CZVERT $
ADR4X C/HLTL,XVEC0C/HLTL,YCX $
ADR4Y C/HLTL,XVEC0C/HLTL,YCY $
ADR4Z C/HLTL,ZVEC0C/HLTL,ZCZ $
END TAC
*FOLLOWING THE FMAMU ROUTINES
GOO1 AXSIG=SR(XCX)*XMPER $
AYSIG=SR(YCY)*XMPER $
AZSIG=SR(ZCZ)*XMPER $
DO 765 I=1,18$
765 CHEN(I) = CHEN5(I)$
IF(NFLAP)766,767,766$
767XFLAG=1$
LINC=60 $
766IF(LINC=54)769,769,768$
769CALL HEAD(IPGCT)$
LINC=5+IPGCT=1PGCT+1 $
768LINC=LINC+1$
*PRINT SATELLITE POSITION SIGMAS
XX4M WRITE OUTPUTTAPE 5,2227,RKST0(1),(X(I),I=1,3),AXSIG,AYSIG,AZSIG$
1010 FOR AT(2H10,7F15,8)$
GO TO S-2$
173 IF(CNT(10))175,START,175$
175 TEMP=CN2WD(10)*(-.25068448)-THGP+360.0$
X176 IF(TEMP)176,177,177$

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```

176 TE =TP + 36.04
GO TO 178 $
177 TH = (TPF-36.0)$
WRITE OUTPUT TAPE 5,XPUNH1,0,XA $
XPUNH1 FOR AT(2H70/2H10,30Y,2HRESTART INFORMATION /2H10/2H10,25X,1HD,
14X,1HM/2H10,23X,2E15.8/2H10) $
WRITE OUTPUT TAPE 5,XPUNH2, XLO, AXN, AYN, FX, HY, HZ $
XPUNH2 FOR AT(2H10,24X,2HLO,11X,3HAXN,11X,3HAYN,11X,2HFX,12X,2HHY,12X,
2HHZ/2H10,15X,6E15.6) $
WRITE OUTPUT TAPE 5,XPUNH3,CNTWD(5) $
XPUNH3 FOR AT(2H10/2H10,50X,9HEPOCH DAY/2H10,51X,A4) $
GO TO START$
SUPER WRITE OUTPUT TAPE 5, SUPER2 $
SUPER2 FOR AT (2H10/18H10SUBROUTINE ERROR ) $
START TAC $
RUNOUT $
JMP 2 $
RKER TMA C/HLT,RKBCD2GC/HLT,4$
JMP 6$
RUNOUT $
JMP 3$
RKBCD2 A/ERROR IN RUNGE KUTTA ROUTINE$
NDSTA TMA C/HLT,NSBCD0 C/HLT,4$
JMP 6$
END TAC $
GOTO START $
STARTTAC $
NSBCD A/END OF STATION DATA CARDS $
ERROR TMA C/HLT,0BBCD0 C/HLT,4$
JMP 6$
JMP START $
OPBCD A/ERROR IN TAN A DIVIDING 0 BY 0$
EXERR TMA C/HLT,0XBCD0 C/HLT,3$
JMP 6$
RUNOUT $
JMP 3$
MXBCD A/CANNOT SOLVE MATRIX$
RLAB4 TMA C/HLT,RLAB3 C/HLT,5$
JMP 6$
JMP X130 $
RLAB3 A/STATION NUMBER NOT FOUND$
STARS A/***** $
LUNPCR A/NO.OF UNKNOWN EXCEEDS NO.OF OBSERVATIONS$
TSTER TMA C/HLT,TSTER3 C/HLT,4$
JMP 6$
FINIS RUNOUT $
JMP 2$
LTSTER3 A/ERROR IN TESTING TIME POINTS$
CHED1 A/ TIME LATITUDE LONGITUDE $
A/ ALTITUDE-K' $
CHED2 A/ TIME X Y Z-DOT $
X-DOT Y-DOT Z-DOT $
CHED3 A/CASE SUM-1 SUM2-KV/SEC DELTA A/A DELTA AXN
DELTA AYN DELTA UO DELTA NODE DELTA I
A/
CHED4 A/CASE L AXN HZ $
AYN FX HY
CHED5 A/SIGMA-POSITION TIME X Y
SIG X(M) SIG Y(M) SIG Z(M)$
OCHED A/STA TIME - MIN RANGE RANGE RATE R
T ASCEN DECLIN AZIMUTH ALTITUDE

```

```

OFSHD A/SAT $ STA TIME RHO RES-M P A RES-M DEC RES
          = M AZ RESID- M EL RESID- M ROOT RES-KM/S $
HFD A/F D $
*TABLE OF DAYS IN YEAR (NOTE THIS TABLE IS REVERSED)$
PAGE $
*LEAST SQUARES SUBROUTINE,
*
* CHGNXN SETS UP THE LEAST SQUARES ROUTINE FOR MATRIX SIZE N
* ENTER WITH N15 IN A
* SETS UP THE FOLLOWING PARAMETERS -----
* COUNTL NT15
* COUNTR NT39
* COUNTLR NT15@NT39
* LSQP1 C/HLTL,TERMS+N@C/JMP,LSQMULT
* LSQP2 C/HLTL,QLSQA+N*(N+1)@ C/JMP,LSQLOD2
* LSQP3 C/HLTL,QLSQB+N@ C/HLTL,QLSQA+N
* LSQSP1 NT15
* LSQP5 (N-1)T15
* LSQSP3 NT15@NT39
* LSQDN C/TM,0,2@C/AIXOL,N,2 ----- PROGRAM INSTRUCTION
* LSQP6 (N+1)T15@ (N+1)T39
CHGNXN TDM CHGNXNX$
TAM COUNTL$
SRD 24$
TDM COUNTR$
AD $
TAM COUNTLR$
TMA C/HLTL,TERMS@C/JMP,LSQMULT$
AM COUNTL$
TAM LSQP1$
TMD COUNTR$
SRQ 8$
MM COUNTL$
TQA $
AM COUNTL$
AM C/HLTL,QLSQA@C/JMP,LSQLOD2$
TAM LSQP2$
TMA C/HLTL,QLSQB@C/JMP,LSQLOC$
AM COUNTL$
TAM LSQP3$
TMA C/HLTL,QLSQA@C/HLTL,QLSQA$
AM COUNTR$
TAM LSQP4$
TMA COUNTL$
TDM LSQSP1$
SM C/HLTL,1$
TAM LSQP5$
TMD COUNTLR$
TDM LSQSP3$
TMA C/TM,0,2@C/AIXOL,0,2$
AM COUNTR$
TAM LSQDN$
TMA C/HLTL,1@C/HLTL,1$
AM COUNTLR$
TAM LSQP6$
CHGNXNXJMP 0$
LSQ TMD C/HLTL,0@C/HLTL,QLSQA$
TDXFC 1$
TMD F/0$
L RPT 600$

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```

      TD      0,1$
LSQEXECJMP  EXECUT$
LSQR      TMD  LSQKDE$
      TD      LSQP1$
      TIC      0$
      TJM      LSQADD$
      TMD      C/HLTR,QLSQAS
      TDXLC     ,1$
LSQLOP2TMD  LSQNP1$
      TDXLC     ,2$
      TMD      0,2$
LSQMULTEFMR 0,2$
      FMS      0,1$
      TMD      LSQP1$
      AIXJ     1,2$
      INCAL    LSQNP1$
      INCA     LSQADD$
LLSQTMD TMD  LSQP2$
LSQADD AIXJ  0,1$
      TMD      C/HLTR,TERMSGC/HLTL,QLSQBS
      TDXLC     ,1$
      TDXRC     ,3$
      TMD      0,2$
LSQLOC FMR  0,1$
      FMS      0,3$
      TMD      LSQP3$
      AIXJ     1,3$
      JMP      LSQEXEC$
LSQS1 TJM    LSQSX$
      TMD      LSQP4$
      TMD      LSQP4V$
      TMD      LSQP5$
      TMD      LSQP5V$
LSQRLOC TMD  LSQP4V$
      TDXLC     ,1$
      TDXRC     ,2$
      TMD      LSQP5V$
      TDXLC     ,3$
LSQTRA TMD  1,1$
LLSQDN TMD  0,2$
      AIXJ     2,2 $
      TMD      C/HLT,URC/JMP,LSQTRAS
      SIXJ     1,3$
      CAM      LSQP6$
      AMS      LSQP4V$
      CSW      C/HLTL,1$
      AMS      LSQP5V$
      JAZ      LSQSX$
      JMP      LSQRLOC$
LSQS TJM    LSQSX$
A      FMAIN  LSQSP1$ LSQSP2 $
      END TAC$
*DIAGONAL ELEMENTS AND ROOTS
      IR=ELSTENT $
      IF(LMODE)E(3), IBG = 6 $
      IR=S=IR**2 $
      IR=1=IR+1 $
      I=0$
      DO 774 K = 1, IBG5, IBG1 $
      I=I+1$
      IF(LMODE) NE(2), GO TO 770 $

```

BUILD A

BUILD B

FILL IN A MATRIX

```

      IF (I - 6) 774, 774, 770 $
770  BDIAG(I)=QLSQA(K)$
      BDIAS(I) = SORT(QLSQA(K))$ SORT(DIAG ELEM OF INVERSE MATRIX A)
774  CONTINUE $
      IF (LMODE) E (2), GO TO MATM $
*RF-LOCATE THE 6X6 MATRIX IN CVERT
      I = 1 $
      DO 772 = 1,6 $
      J = (M-1) * LSTCNT + 1 $ FORM CVERT,
      K = J + 5 $
      DO 771 L = J,K $
      CVERT(I) = QLSQA(L) $
771  I = I + 1 $
772  CONTINUE $
      START TAC$
A MATM FMANU LSQSP3,LSQSP4,LSQSP5 $
      LSQSPX JMP 0$
      LSQNP1 C/HLTL,TERMSQC/HLTL,0$
      LSQSP1 C/HLT,TERMSQC/HLTL,0$
      LSQSP1 C/HLT,TERMSQC/JMP,LSQMULT$
      LSQSP2 C/HLTL,QLSQAQC/HLTL,LSQBUF$
      LSQSP4 C/HLTL,1QC/HLTL,QLSQA$
      LSQSP5 C/HLTL,QLSQAQC/HLTL,QLSQA$
      LSQBUF SET (P)+50 $
      PAGE$
      AFEND 40 $
      AFEND 40$
      NAME BCD2BIN
EXIT JMP (P)
BCD2BIN TJM EXIT
      TMQ 0/77
      TAN BCDWORD
      ETA BCDWORD
      JOO EXIT
TAD1 TAD
      SRAQ 2
      AD
      SRAQ 3
      EA BCDWORD
      JOE TAD1
      JMP EXIT
      PAGE$
*COVERT EXP.DEC. TO FLT. BINARY$
      AFEND 40$
      NAME FLTFLT
FLTFLT TJM FLTFLTX
      JMP INDEX
      TJM DCNTR $
      CM MSIGN
      CM CSIGN
      CM DIGITS
      CM CNTDIG
      CM ADIG
      TMD K8
      TDM AF
      TMD K9
      TDM AD
      TGM SAV
      SRAQ 18
      TGM SAV1
      TAG

```

	TIXZ	0,5
	TIXZ	0,3
	TIXZ	0,4
AB	TIXZ	0,6
AA	CA	
	SLAG	6
	TMD	ENE
	JAED	AC
LAF	JAZ	AC
	TMD	BLANK
	JAED	AC
	TMD	PLUS
	JAED	AC
	TMD	MINUS
AZY	JAED	MIN
LAD	TMD	DEC
	JAED	DECA
	SM	DIC
	JAP	AC
	AM	DIC
	TMD	K7
	TDM	AF
	INCAR	CNTDIG
	TAM	DIG
	TMA	DIGITS
	SLA	2
	AM	DIGITS
	SLA	1
	AM	DIG
	TAM	DIGITS
AC	TMD	K1
	AIXJ	1,6
	TMQ	SAV1
	TMD	K2
	AIXJ	1,5
	TMA	DCNTR \$
	TMD	CNTDIG \$
	JAZ	(P)+2H \$
	TDM	ADIG \$
	TMA	CNTDIG
	SM	ADIG
	SMS	CNTDIG
	TMQ	DIGITS
	CA	
	SLAON	12
	SLAN	35
	AM	D/47
	TAN	DIGITS
	FCAMS	DIGITS
	TQA	
	AM	D/35
	FAMS	DIGITS
	TMQ	K4
	ETA	SAV
	SRO	6
	SRA	4
	AD	
	SLA	1
	TMQ	K5
	EA	SAV
	TMQ	SAV

EXP IN A

EXPT 39

	SLA	8
	TAM	SAV
	SRQ	16
	JQO	(P)+2H
	CSMS	SAV
	TMA	SAV
	AMS	CNTDIG
	JAZ	AM
	JAP	(P)+3H
	TJM	CSIGN
	CSMS	CNTDIG
	TMD	CNTDIG
	TDX ^{PC}	,4
	TMA	F/1.
	TMO	F/10.
AN	FMAR	
	TMD	K6
	SIXJ	1,4
	TAM	SAV
	TMA	CSIGN
	JAZ	(P)+5H
	TMA	DIGITS
	FDA	SAV
	TOM	DIGITS
	JMP	(P)+3H
	TMO	SAV
	FMMPS	DIGITS
AM	TMA	MSIGN
	JAZ	(P)+2H
	FCSMS	DIGITS
	TMA	DIGITS
	JMP	INDEXE
FLTFLTX	JMP	(P)
MIN	TJM	MSIGN
	JMP	AC
DECA	TMD	K3
	TDM	AD
	CM	DCNTR \$
	JMP	AC
INDEX	TJM	INDEXX
	TXDLC	,1
	TXDRC	,2
	TDM	X1X
	TXDLC	,3
	TXDRC	,4
	TDM	X2X
	TXDLC	,5
	TXDRC	,6
	TDM	X3X
INDEXX	JMP	(P)
X1X	\$	
X2X	\$	
X3X	\$	
INDEXE	TJM	INDEXEX
	TMD	X1X
	TDXLC	,1
	TDXRC	,2
	TMD	X2X
	TDXLC	,3
	TDXRC	,4
	TMD	X3X

	TDXLC	,5
	TDXPC	,6
	INFEEXJMP	(P)
	BLANK	0/60T47
	K1	C/HLT,80C/JMP,AA
	K2	C/HLT,20C/JMP,AB
	K3	C/INCAR,ADIG0C/NOP
	K4	0/7700T47
	K5	0/77T47
	K6	C/HLT,00C/JMP,AN
	PLUS	0/20T47
	MINUS	0/40T47
	K7	C/NOP,00C/TMD,BLANKS
	K8	C/JAZ,AC0C/TMD,BLANK
	K9	C/TMD,DEC0C/JAED,DECA
	DEC	0/33T47
	ENE	W/0000000E
	DIC	0/12T47
	* FIXED POINT DEC. TO FLOATING BINARY\$	
	AFEND	40\$
FXFLT	TJM	FXFLT
	JMP	INDEX
	CM	MSIGN
	CM	DIGITS
	CM	ADIG
	TMD	X1
	TDM	BD
	TQM	SAV
	TQA	
	TIXZ	0,1
BB	TIXZ	0,2
BA	CA	
	SLAQ	6
	TMD	BLANK
	JAED	BC
	TMD	PLUS
	JAED	BC
	TMD	MINUS
	JAED	BMIN
LBD	TMD	DEC
	JAED	BDEC
	TAM	DIG
	TMA	DIGITS
	SLA	2
	AM	DIGITS
	SLA	1
	AM	DIG
	TAM	DIGITS
BC	TMD	X3
	AIXU	1,2
	TMQ	SAV
	TMO	X4
	AIXU	1,1
	TMO	DIGITS
	CA	
	SLAQN	12
	SLAN	35
	AM	D/47
	TAM	SAV1
	FCAMS	SAV1
	TQA	

	AM	D/35
	FAMS	SAV1
	TMA	ADIG
	JAZ	BR
	TDXRC	,1
	TMA	F/1.
	TMG	F/10.
RN	FMAP	
	TMD	X5
	SIXU	1,1
	TAM	SAV
	TMA	SAV1
	FDAS	SAV
BR1	TMA	MSIGN
	JAZ	(P)+2H
	FCSMS	SAV
	TMA	SAV
	JMP	INDEXE
FXFLTX	JMP	(P)
*		
BR	TMD	SAV1
	TDM	SAV
	JMP	BR1
LX1	TMD	DEC
	JAED	BDEC
X2	C/NOP,0RC/INCAR,ADIG	
X3	C/HLT,8RC/JMP,BA	
X4	C/HLT,2RC/JMP,BB	
X5	C/HLT,0RC/JMP,BN	
BMIN	TJM	MSIGN
	JMP	BC
BDEC	TMD	X2
	TDM	BD
	JMP	BC
	PAGES	
	AFEND	80\$
	NAME	TRP\$
LRESET	HLT	\$
	HLT	\$
LTRP	TAD	\$
	NOP	TRANS\$
	TDXLC	,1X\$
	TDXRC	,2X\$
	TJM	EXIT\$
	TIJ	,1X\$
	TJM	TRANS\$
	TIJ	,2X\$
	TJM	TRANS+1H\$
	TQM	RESET\$
	ADXL	,2X\$
	TIJ	,2X\$
	TDXLC	,1X\$
	TDXRC	,2X\$
	TJM	TRP\$
RTRANS	RPTAA	\$
	TMD	0,1X\$
	TDM	1,2X\$
	INCA	RESET\$
	TDXL	,1X\$
	TMD	TRP\$
	AIXU	0,1X\$

EXIT	JMP	(P)\$	
	ENDSUB	\$	
*	RUNGE	KUTTA INTEGRATION ROUTINE	
	NAME	RUNGE\$	
LEXIT	JMP	(P)\$	
ERROR	JMP	(P)\$	
RUNGE	TJM	ERROR\$	SET ERROR EXIT
	TXDLC	,3X\$	SAVE 3X THRU 0X
	TXDRC	,4X\$	
	TDM	X3X4\$	
	TXDLC	,5X\$	
	TXDRC	,6X\$	
	TDM	X5X6\$	
	TXDLC	,7X\$	
	TXDRC	,0X\$	
	TDM	X7X0\$	
*	SET	UP INPUT PARAMETERS	
LXSET	TAD	\$	GET A PARAMETER
	TDXFC	,1X\$	
	TDXLC	,2X\$	
	TXDRC	,1X\$	
	TJM	CTL\$	SET CONTROL ENTRY
	TXDLC	,2X\$	
	TJM	DER1\$	SET DERIV ENTRIES
	TJM	DER2\$	
	TJM	DER3\$	
	TJM	DER4\$	
	TJM	DER5\$	
	TQD	\$	GET Q PARAMETER
	TDXLC	,1X\$	
	TXDLC	,1X\$	
	TJM	TESTM\$	SET MODE ADDRESS
	TCXSC	,1X\$	
	TXDL	,1X\$	
	TJM	CX\$	X FL
	TJM	EX\$	
	TCXZ	,1X\$	
	TXDL	,1X\$	
	TJM	BX\$	X FX
	TJM	IX\$	
	AIXCR	1,1X\$	
	TXDL	,1X\$	
	TJM	ADXP\$	PREV DELTA-X FX
	TJM	BDXP\$	
	AIXCR	1,1X\$	
	TXDL	,1X\$	
	TJM	AXZ\$	X-ZERO FX
	TJM	IXZ\$	
	TJM	BXZ\$	
	TCXSC	,1X\$	
	TXDL	,1X\$	
	TJM	HDX1\$	DELTA-X FL
	TJM	HDX2\$	
	TJM	HDX3\$	
	TCXZ	,1X\$	
	TXDL	,1X\$	
	TJM	ADX\$	DELTA-X FX
	TJM	BDX\$	
	AIXCR	1,1X\$	
	TXDL	,1X\$	
	TJM	XSET\$	Y FX

TQD	\$	
ADXR	,1X\$	
TXDL	,1X\$	Y+N TO JA
TMD	FILL\$	SET LOOP TESTERS
TDXRC	,1X\$	
RPTN	9\$	
TJM	,1X\$	
TQD	\$	
TDXR	,1X\$	GET N
TCXS	,1X\$	
TXDL	,1X\$	
TJM	DN\$	N FL
TJM	EN\$	
TJM	FN\$	
TCXZ	,1X\$	
TXDL	,1X\$	
TJM	ALOOP\$	N FX
TJM	CN\$	
TQD	\$	
ADXR	,1X\$	
TXDL	,1X\$	
TJM	A2N\$	2N FX
TJM	B2N\$	
TJM	I2N\$	
TQD	\$	
ADXR	,1X\$	
TXDL	,1X\$	
TJM	B3N\$	3N FX
TJM	D3N\$	
TJM	E3N\$	
TJM	GLOOP\$	
TJM	I3N\$	
TCXS	,1X\$	
TXDL	,1X\$	
TJM	CLLOOP\$	3N FL
TJM	DLLOOP\$	
TJM	ELLOOP\$	
TJM	F3N\$	
TJM	H3N\$	
TQD	\$	
ADXP	,1X\$	
TXDL	,1X\$	
TJM	H4N\$	4N FL
TCXZ	,1X\$	
TXDL	,1X\$	
TJM	A4N\$	4N FX
TJM	G4N\$	
TQD	\$	
ADXP	,1X\$	
TXDL	,1X\$	
TJM	A5N\$	5N FX
TJM	B5N\$	
TJM	ILLOOP\$	
TCXS	,1X\$	
TXDL	,1X\$	
TJM	H5N\$	5N FL
TQD	\$	
ADXR	,1X\$	
TXDL	,1X\$	
TJM	D6N\$	6N FL
TJM	E6N\$	

TJM	F6N\$	
TCXZ	,1X\$	
TXDL	,1X\$	
TJM	C6N\$	6N FX
TGD	\$	
ADXP	,1X\$	
TCXS	,1X\$	
TXDL	,1X\$	
TJM	H7N\$	7N FL
TGD	\$	
ADXR	,1X\$	
TCXZ	,1X\$	
TXDL	,1X\$	
TJM	HLOOP\$	8N FX
TGD	\$	
ADXR	,1X\$	
TXDL	,1X\$	
TJM	B9N\$	9N FX
TJM	I9N\$	
TCXS	,1X\$	
TXDL	,1X\$	
TJM	F9N\$	9N FL
TJM	H9N\$	
TMD	JUMP\$	SET NO DECREASE
JQE	(P)+1\$	TEST FOR DECREASE LOOP
TMD	RETURN\$	SET DECREASE
TDXRC	,1X\$	
TXDRC	,1X\$	
TJM	OPTJ\$	SET OPTIONAL JUMP
TMA	EXIT\$	
AM	FBIT\$	
TAD	\$	
TDXRC	,1X\$	
TXDRC	,1X\$	
TJM	EXIT\$	SET NORMAL EXIT
* ACTUAL RUNGE-KUTTA INTEGRATION STARTS HERE		
RESTARTTMD	DONE\$	SET SWITCH PLUS
TDM	SWITCH\$	
TMD	XSET\$	SET REGIONS TO ZERO
TDXLC	,1X\$	FOR INITIAL PRINT
TMD	F/0\$	GET F.P. ZERO
ALOOP	TQM	CLEAR Y-HALF
A2N	TDM	Y-ZERO
A4N	TDM	D-HALF
A5N	TDM	D-ZERO
TMD	TEST0\$	
AIXJ	1,1X\$	LOOP TIL DONE
AXZ	TQM	CLEAR X-ZERO
ADX	TMD	MOVE DELTA-X TO
ADXP	TDM	PREVIOUS DELTA-X
DER1	JMP	ENTER DERIV
LCTINU	TMD	SET INDEX FOR
TDXE	,7X\$	VARIABLE RETURN
CTL	JMP	ENTER CONTROL
JMP	RETURN\$	DUMMY ADDRESS
BX	TMD	MOVE X TO X-ZERO
BXZ	TDM	
TMD	XSET\$	SET LOOP
TDXLC	,1X\$	
TMD	F/0\$	GET F.P. ZERO
BLOOP	TMD	MOVE Y TO Y-ZERO

B2N	TDM	,1X\$	
B3N	TMD	,1X\$	D TO D-ZERO
B5N	TOM	,1X\$	
B9N	TQM	,1X\$	CLEAR DELTA-Y ACCUMULATOR
	TMD	TEST1\$	
	AIXJ	1,1X\$	LOOP TIL DONE
BDX	TMA	\$	IF DELTA-X = 0
	JAF	XERROR\$	MAKE ERROR EXIT
BDXP	TAM	\$	MOVE DELTA-X TO PREVIOUS DX
	FDA	F/2\$	FORM DX/2
	TQM	HDELTS	
	TDA	\$	
	FDA	F/2\$	FORM DX/4
	TQM	QDELTS	
STEP1	TMD	XSET\$	SET LOOP FOR STEP 1
	TDXLC	,1X\$	
	TMQ	QDELTS	GET DX/4
CLOOP	FMMR	,1X\$	D*DX/4
C6P	TAM	,1X\$	TO CUMULATIVE
	TMD	0,1X\$	MOVE Y TO Y-HALF
CN	TDM	,1X\$	
	FAMS	0,1X\$	Y+D*DX/4 TO Y
	TMD	TEST2\$	
	AIXJ	1,1X\$	LOOP TIL DONE
	TQA	\$	
Cx	FAMS	\$	X+DX/4 TO X
DER2	JMP	(P)\$	ENTER DERIV
	TMD	XSET\$	SET LOOP FOR STEP 2
	TDXLC	,1X\$	
	TMQ	QDELTS	GET DX/4
DLOOP	FMMRS	,1X\$	D*DX/4 TO D
DN	FAM	,1X\$	D*DX/4+Y-HALF TO Y
	TAM	0,1X\$	
D3N	TMA	,1X\$	
	FAD	\$	D*DX/2+CUMULATIVE
D6N	FAMS	,1X\$	TO CUMULATIVE
	TMD	TEST3\$	
	AIXJ	1,1X\$	LOOP TIL DONE
DER3	JMP	(P)\$	ENTER DERIV
	TMQ	HDELTS	GET DX/2
	TMD	XSET\$	SET LOOP FOR STEP 3
	TDXLC	,1X\$	
ELOOP	FMMRS	,1X\$	D*DX/2 TO D
EN	FAM	,1X\$	D*DX/2+Y-HALF TO Y
	TAM	0,1X\$	
E3N	TMA	,1X\$	D*DX/2+CUMULATIVE
E6N	FAMS	,1X\$	TO CUMULATIVE
	TMD	TEST4\$	
	AIXJ	1,1X\$	LOOP TIL DONE
	TMA	QDELTS	X + DX/4 TO X
EX	FAMS	\$	
DER4	JMP	(P)\$	ENTER DERIV
	TMD	XSET\$	SET LOOP FOR STEP 4
	TDXLC	,1X\$	
FLOOP	TMQ	QDELTS	GET DX/4
F3N	FMMR	,1X\$	(D*DX/4 + CUMUL.)/3
F6N	FAM	,1X\$	+ Y-HALF TO Y
	FDA	F/2\$	
	TQA	\$	
FN	FAM	,1X\$	
	TAM	0,1X\$	

F4N	TQA	\$	ADD HALF-STEP INCREMENT
	FAGE	,1X\$	TO DELTA-Y ACCUMULATOR
	TMD	TEST5\$	
	AIXU	1,1X\$	LOOP TIL DONE
DER5	JMP	(P)\$	ENTER DERIV
	CSMS	SWITCH\$	FLIP SWITCH
	JAP	TESTM\$	IF FULL STEP, TO MODE TEST
	TMD	XSET\$	SET LOOP FOR D MOVE
	TDXLC	,1X\$	
GL00P	TMD	,1X\$	MOVE D TO D-HALF
G4N	TDM	,1X\$	
	TMD	TEST6\$	
	AIXU	1,1X\$	LOOP TIL DONE
	JMP	STEP1\$	TO 2ND HALF-STEP
TESTM	TMA	\$	GET MODE
	JAZ	(P)+1\$	VARIABLE-TO FIND MAX
	JMP	CTINUS	FIXED-TO CONTROL ENTRY
	TMD	F/0\$	
	TDM	MAX\$	F.P. ZERO TO MAX
	TMD	XSET\$	SET MAX ERROR LOOP
	TDXLC	,1X\$	
HLOOP	TMQ	,1X\$	GET REL ERR CONTROL
	FMMA	0,1X\$	R*Y-ABS
H7N	FAM	,1X\$	ADD ABS ERR CONTROL
	TAM	QDELTS	SAVE ERR CONTROL TERM
	TMD	F/0\$	IF ZERO
	JAED	DERROR\$	MAKE ERROR EXIT
	TMQ	F/4\$	FORM SIMPSON'S RULE DY
H4N	FMM	,1X\$	(4*D-HALF
H3N	FAM	,1X\$	+D
H5N	FAM	,1X\$	+D-ZERO)/3
	FDA	F/3\$	
	FMM	HDELTS	*DX/2
H9N	FSM	,1X\$	SUBTRACT RK DELTA-Y
	FDA	QDELTS	FORM ERROR TERM
	FCAGA	\$	ABS VALUE TO A
	TMQ	MAX\$	TEST MAX
	JAGGF	(P)+1\$	TO SET NEW MAX
	JMP	(P)+1\$	TO LOOP TEST
	TAM	MAX\$	STORE NEW MAX
	TMD	TEST7\$	
	AIXU	1,1X\$	LOOP TIL DONE
	TMA	MAX\$	GET MAX ERROR TERM
	TMQ	F/1\$	TEST 1.0
	JAED	DC\$	TO DECREASE AND CONTINUE
	JAGGF	DB\$	TO DECR. AND BACKUP
	TMQ	F/.75\$	TEST 0.75
	JAED	CTINUS	TO CONT.
	JAGGF	DC\$	TO DECR. AND CONT.
	TMQ	F/.075\$	TEST 0.075
	JAGGF	CTINUS	TO CONT.
	TMQ	RT10\$	INCREASE AND CONT.
HUX1	FMMS	\$	
	JMP	CTINUS	
DR	TMQ	RRT10\$	DECREASE AND BACKUP
HUX2	FMMS	\$	
OPTU	JMP	(P)\$	OPTIONAL DECREASE LOOP
	TMQ	F/.1\$	
	FMMS	MAX\$	MAX/10 TO MAX
	TMQ	F/1\$	
	JAGGF	DB\$	TO DECREASE AGAIN

DC	JMP	BAKUP\$	OK
H-X3	TMD	RRT10\$	DECREASE AND CONT.
	FMS	\$	
	JMP	CTIAUS	
BAKUP	TMD	XSET\$	SET LOOP
	TDXLC	,1X\$	
	TMD	F/0\$	GET F.P. ZERO
ILOOP	TMD	,1X\$	MOVE D-ZERO TO D
I3N	TMD	,1X\$	
I2N	TMD	,1X\$	Y-ZERO TO Y
	TMD	0,1X\$	
I9N	TMD	,1X\$	CLEAR DELTA-Y
	TMD	TEST8\$	
	AIXJ	1,1X\$	LOOP TIL DONE
IxZ	TMD	\$	MOVE X-ZERO TO X
IX	TMD	\$	
	JMP	BDX\$	TO REPEAT STEP
RFILL	HLTR	TEST0\$	ADDRESS DUMMY
LRETURN	JMP	BXS	NORMAL CONTINUE
	JMP	OPTJ+1H\$	
LJUMP	JMP	BAKUP\$	
	JMP	BAKUP\$	
LFBIT	JMP	RESTART\$	
	HLTP	0\$	
LDONE	JMP	RESET\$	
	JMP	EXIT\$	
XERROR	CSM	DONE\$	SET A-SIGN MINUS
	JMP	RESET\$	FOR DELTA-X=0
	JMP	ERROR\$	TO ERROR EXIT
DERKOR	CAM	DONE\$	SET A-SIGN PLUS
	JMP	XERROR+1H\$	ERR CONTROL TERM=0
RESET	TJM	BACK\$	RESTORE X-REGS
	TMD	X3X4\$	
	TDXLC	,3X\$	
	TDXRC	,4X\$	
	TMD	X5X6\$	
	TDXLC	,5X\$	
	TDXRC	,6X\$	
	TMD	X7X0\$	
	TDXLC	,7X\$	
	TDXRC	,0X\$	
BACK	JMP	(P)\$	
_TEST0	HLT	0\$	LOOP CONTROLS
	JMP	AL00P\$	
TFST1	HLT	0\$	
	JMP	BL00P\$	
TEST2	HLT	0\$	
	JMP	CL00P\$	
TEST3	HLT	0\$	
	JMP	DL00P\$	
TEST4	HLT	0\$	
	JMP	EL00P\$	
TFST5	HLT	0\$	
	JMP	FL00P\$	
TEST6	HLT	0\$	
	JMP	GL00P\$	
TEST7	HLT	0\$	
	JMP	HL00P\$	
TEST8	HLT	0\$	
	JMP	IL00P\$	
RT10	F/1.584	93193\$	

RRT10 F/.6309573443\$
NAME 0001PRO \$
END TAC \$
END \$

XIII

REFERENCES

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2. Handbook of Astronautical Engineering; Koelle, H. H. (1961); McGraw-Hill.
3. Optical Generator Program; AFCRL-63-445, H. R. Kahler, R. M. Moroney, W. T. Nixon (1963)
4. An Introduction to Astrodynamics; Academic Press; Baker and Makemson (1960)
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AF Cambridge Research Laboratories, Bedford, Mass.
Report No. AFRL-64-55
DIFFERENTIAL ORBIT CORRECTION AND STATION
LOCATOR PROGRAM - "DOC II"
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230 p., incl., analysis, flow charts, program listing
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- I. AF Project
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