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A MUTUAL VISIBILITY COMPUTER PROGRAM FOR COMMUNICATION SATELLITES

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GREENBELT, MARYLAND

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G. D. Repass and R. G. Chaplick

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INTRODUCTION

As more and more ground stations are constructed around the world to operate with communication satellites, the problems of scheduling the experiments become more complex. Many factors, e.g., is the attitude of the satellite correct, must be considered simultaneously in order for decisions to be made. Although many pieces of data were on hand during tests with Telstar I and Relay I, the information was presented randomly in three or more books, and much human effort was needed to extract and analyze the pertinent data. The obvious solution was to compute only the necessary data and to present them as concisely as possible. This report will describe such a program which has been developed by members of the Theory and Analysis Office.

PROGRAM CRITERIA

The following criteria were used to design the program:

(a) Data should be printed only for passes during which the spacecraft was visible to a "control" station. Because the Relay spacecraft can be operated by only two or three stations, it must be visible to one of those stations when experiments are made.

(b) Data should be presented in two books, one graphs of mutual visibility and the other the actual numerical data.

MUTUAL VISIBILITY

Bar graphs appeared to be the most legible form for presentation of time intervals of mutual visibility. In addition, indications of elevation angles from 0° to 5°, from 5° to 10°, and from 10° to 90°; of ranges higher or lower than a prescribed input value; of spacecraft look angle; and of orbit number were necessary.

NUMERICAL DATA

This volume consists of all the numerical data used to produce the mutual visibility graphs. These data are spacecraft longitude, latitude, height and sunlight indicator; and for each station the spacecraft look angle (the angle between the spin axis and the slant range), azimuth, elevation, and slant range. The last set of data in this book is a complete time history of entry into and exit from the earth's shadow.

THEORY

The program can be described simply as an orbit generator with associated subroutines necessary to perform needed calculations. Experience at Goddard has indicated that the theory developed by Brouwer (1959) is adaptable for the purposes of this program. The American Institute of Physics has granted permission to the authors to reproduce certain pages of Brouwer (1959) herein. Appendix I consists of pages 393 to 396. To aid the reader the pertinent equations have been rewritten and the equivalent Fortran II variable names for some of the terms have been superimposed on the equations. These equations are reproduced in Appendix II.

A brief explanation of how the orbit generator has been programmed will help the reader.

<u>Secular terms</u>. These equations were rewritten as:

$$\ell'' = \ell''_0 + S_1 t + S_{1,2} t^2$$

$$g'' = g''_0 + S_2 t$$

$$h'' = h''_0 + S_3 t$$

where S_1, S_2, S_3 are constant for any given set of a''_0, e''_0, I''_0, and earth constants and $S_{1,2}$ is the anomalistic acceleration computed by the GSFC differential correction programs. If $S_{1,2}$ is unavailable, the added term can be dropped by inputting it as zero.

Long Period terms. These equations were rewritten as:

$$\ell' = \ell'' + L_1 \sin 2g'' + L_2 \cos g'' + L_3 \cos 3g''$$

$$g' = g'' + L_4 \sin 2g'' + L_5 \cos g'' + L_6 \cos 3g''$$

$$h' = h'' + L_7 \sin 2g'' + L_8 \cos g'' + L_9 \cos 3g''$$

$$\delta_1 e = L_{10} \cos 2g'' + L_{11} \sin g'' + L_{12} \sin 3g''$$

$$\delta_1 I = L_{13}\, \delta_1 e$$

where L_i, $1 \leq i \leq 13$ are constant for any given set of a_0'', e_0'', I_0'', and earth constants.

EARTH'S GRAVITATIONAL POTENTIAL

The force function used is that of Brouwer, page 393, where k_2, k_3, k_4, k_5 represent the zonal harmonics. However, Vinti's notation of J_n should be adopted. Either set of harmonics can be used by means of the following equations:

$$k_2 = +\frac{1}{2} J_2 R_e^2$$

$$k_3 = - J_3 R_e^3$$

$$k_4 = -\frac{3}{8} J_4 R_e^4$$

$$k_5 = - J_5 R_e^5$$

The program has been designed either to use constants stored in memory or to read new constants along with other input data.

COMPUTER PROGRAM

The computer program, written in Fortran II for the IBM 7094, was designed typically is a main program with subroutines called when needed. The orbit generator has been designed to compute in one subroutine all quantities which are functions of mean elements and earth constants. Another subroutine computes only those quantities which are either explicit or implicit functions of time. Terms that occur at least twice in the equations are assigned a variable name and actually are computed only once.

Main Program. The requirement that data be printed only for passes when the spacecraft is visible at a control station implies, unfortunately, that data must be computed and stored before a decision can be made to discard the data. The authors recognize that "shortcuts" were available to avoid computing data which were to be thrown away. However, the requirement for an accurate eclipse history did not allow such methods to be used.

Main Program One. This program fulfills the requirements described previously herein. Its characteristics are (a) an IBM 7094 with a 65K memory is required and (b) the complete sunlight history is computed. Computer running time could be reduced if (a) and (b) can be eliminated.

Main Program Two. This program is similar to Main Program One except that the control station requirements, the complete sunlight history, and the numerical data on bar graphs were deleted. A computer with at least a 20K memory (dependent on memory needed for library subroutines) is required.

Subroutines. The subroutines for each of the main programs are identical.

Operation Instructions. Instructions for operating the two programs are given in Appendix III.

Input deck instructions. Instructions for punching the input deck for each program are given in Appendix III.

Flow Charts. The flow chart for Main Program Two is contained in Appendix IV.

Source Decks. Source decks for Main Program One, Main Program Two, and Subroutines are reproduced in Appendices V, VI, and VII respectively.

Sample Problems. Inputs to and outputs of each program are given in Appendix VIII. The outputs have been abbreviated.

Results

Main Program One has been used extensively and successfully for planning experiments with Relay I and II and Echo I and II. Main program Two, which is less sophisticated and is easy to change, has been used for a variety of special studies, e.g., travel time of light from station to spacecraft back to station; angles between slant ranges from a single station to two different spacecraft, etc.

REFERENCE

1. "Solution of the Problem of Artificial Satellite Theory without Drag," D. Brouwer, Astronomical Journal 64, 9, Nov. 1959, pp. 393-396.

APPENDIX I

Reproduction of Pages 393 to 396 of Brouwer (1959)

Formulas for Computation. For convenience of computation the perturbations in the Keplerian elements a, e, I are given instead of those in L, G, H.

The adopted force function is

$$U = \frac{\mu}{r} + \frac{\mu k_2}{r^3}(1 - 3\sin^2\beta) + \frac{\mu k_4}{r^5}\left(1 - 10\sin^2\beta + \frac{35}{3}\sin^4\beta\right)$$

$$+ \frac{\mu A_{3.0}}{r^4}\left(-\frac{3}{2}\sin\beta + \frac{5}{2}\sin^3\beta\right) + \frac{\mu A_{5.0}}{r^6}\left(\frac{15}{8}\sin\beta - \frac{35}{4}\sin^3\beta + \frac{63}{8}\sin^5\beta\right),$$

in which k_2 is a small quantity, and k_4, $A_{3.0}$, $A_{5.0}$ are assumed to be of order k_2^2.

The secular motions have been computed to $O(k_2^2)$, the coefficients of periodic terms to $O(k_2)$.

Basic constants:

a'' = semi-major axis constant

e'' = eccentricity constant

I'' = inclination constant

$n_0 = \mu^{1/2} a''- = 17.04337\ (a''/R)^{-3/2}$ rev./day

R = equatorial radius

Abbreviations:

$$\eta = (1 - e''^2)^{\frac{1}{2}} \quad \theta = \cos I''$$

$$\gamma_2 = \frac{k_2}{a''^2} \qquad \gamma_4 = \frac{k_4}{a''^4} \qquad \gamma_3 = \frac{A_{3,0}}{a''^3} \qquad \gamma_5 = \frac{A_{5,0}}{a''^5}$$

$$\gamma_2' = \gamma_2 \eta^{-4} \quad \gamma_4' = \gamma_4 \eta^{-8} \quad \gamma_3' = \gamma_3 \eta^{-6} \quad \gamma_5' = \gamma_5 \eta^{-10}$$

It is customary to use for the second harmonic the coefficient J; Jeffreys (1954) used for the fourth harmonic the coefficient D. The relations between J, D and γ_2, γ_4 are

$$\gamma_2 = \frac{1}{3} J \left(\frac{R}{a''} \right)^2, \quad \gamma_4 = \frac{3}{35} D \left(\frac{R}{a''} \right)^4.$$

Strictly speaking, $e'' + \delta_1 e$, $\theta' = \cos(I'' + \delta_1 I)$, $\eta' = [1 - (e'' + \delta_1 e)^2]^{1/2}$ should be used in the computation of the periodic terms, but since the short-period terms are obtained to $O(k_2)$, it is of no consequence if contributions of $O(k_2)$ are omitted in expressions that have γ_2 as a factor. Similarly, ℓ'', g'' might be used in computing f', r'; but since ℓ', γ' are available, their use does not complicate the calculation.

The formulas are applicable for any eccentricity $e < 1$ and any inclination with the exception of inclinations near the critical inclination, for which $1 - 5 \cos^2 I$ appears as a small divisor.

The appearance of e'' as a divisor in the short-period terms in e is apparent only. The expressions that are multiplied by e''^{-1} contain e'' as a factor, either implicitly or explicitly.

In the short-period terms in ℓ and g a divisor e'' occurs also, but for the calculation of the position only $g + \ell$ + equation of the center is needed. In $g + \ell$ the divisor e'' is not present.

Singularities in some of the elements also occur for very small inclinations; again, no singularity is present in the coordinates. In such cases it may be found convenient to modify the formulas and obtain expressions for the perturbations in coordinates.

Secular terms:

ℓ'' = "mean" mean anomaly

$$= n_0 t \left\{ 1 + \frac{3}{2}\gamma_2'\eta(-1 + 3\theta^2) + \frac{3}{32}\gamma_2'^2\eta[-15 + 16\eta + 25\eta^2 + (30 - 96\eta - 90\eta^2)\theta^2 \right.$$

$$\left. + (105 + 144\eta + 25\eta^2)\theta^4] + \frac{15}{16}\gamma_4'\eta e''^2[3 - 30\theta^2 + 35\theta^4] \right\} + l_0''$$

g'' = mean argument of perigee

$$= n_0 t \left\{ \frac{3}{2}\gamma_2'(-1 + 5\theta^2) + \frac{3}{32}\gamma_2'^2[-35 + 24\eta + 25\eta^2 + (90 - 192\eta - 126\eta^2)\theta^2 \right.$$

$$\left. + (385 + 360\eta + 45\eta^2)\theta^4] + \frac{5}{16}\gamma_4'[21 - 9\eta^2 + (-270 + 126\eta^2)\theta^2 + (385 - 189\eta^2)\theta^4] \right\} + g_0''$$

h'' = mean longitude of ascending node

$$= n_0 t \left\{ -3\gamma_2'\theta + \frac{3}{8}\gamma_2'^2[(-5 + 12\eta + 9\eta^2)\theta + (-35 - 36\eta - 5\eta^2)\theta^3] \right.$$

$$\left. + \frac{5}{4}\gamma_4'(5 - 3\eta^2)\theta(3 - 7\theta^2) \right\} + h_0''$$

Long-period terms:

$$\delta_1 e = \left\{ \frac{1}{8}\gamma_2' e''\eta^2[1 - 11\theta^2 - 40\theta^4(1-5\theta^2)^{-1}] - \frac{5}{12}\frac{\gamma_4'}{\gamma_2'}e''\eta^2[1 - 3\theta^2 - 8\theta^4(1-5\theta^2)^{-1}] \right\} \cos 2g''$$
$$+ \left\{ \frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\eta^2 \sin I'' + \frac{5}{64}\frac{\gamma_5'}{\gamma_2'\eta^2}\sin I''\,(4+3e''^2)[1 - 9\theta^2 - 24\theta^4(1-5\theta^2)^{-1}] \right\} \sin g''$$
$$- \frac{35}{384}\frac{\gamma_5'}{\gamma_2'}e''^2\eta^2 \sin I''\,[1 - 5\theta^2 - 16\theta^4(1-5\theta^2)^{-1}] \sin 3g''$$

$$\delta_1 I = -\frac{e''\delta_1 e}{\eta^2 \tan I''}$$

$$l' = l'' + \left\{ \frac{1}{8}\gamma_2'\eta^3[1 - 11\theta^2 - 40\theta^4(1-5\theta^2)^{-1}] - \frac{5}{12}\frac{\gamma_4'}{\gamma_2'}\eta^3[1 - 3\theta^2 - 8\theta^4(1-5\theta^2)^{-1}] \right\} \sin 2g''$$
$$+ \left\{ -\frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\frac{\eta^3}{e''}\sin I'' - \frac{5}{64}\frac{\gamma_5'}{\gamma_2'}\frac{\eta^3}{e''}\sin I''\,(4+9e''^2)[1 - 9\theta^2 - 24\theta^4(1-5\theta^2)^{-1}] \right\} \cos g''$$
$$+ \frac{35}{384}\frac{\gamma_5'}{\gamma_2'}\eta^3 e'' \sin I''\,[1 - 5\theta^2 - 16\theta^4(1-5\theta^2)^{-1}] \cos 3g''$$

$$g' = g'' + \left\{ -\frac{1}{16}\gamma_2'[+(2+e''^2) - 11(2+3e''^2)\theta^2 - 40(2+5e''^2)\theta^4(1-5\theta^2)^{-1} \right.$$
$$- 400e''^2\theta^6(1-5\theta^2)^{-2}] + \frac{5}{24}\frac{\gamma_4'}{\gamma_2'}[2 + e''^2 - 3(2+3e''^2)\theta^2 - 8(2+5e''^2)\theta^4(1-5\theta^2)^{-1}$$
$$\left. - 80e''^2\theta^6(1-5\theta^2)^{-2}] \right\} \sin 2g'' + \left\{ \frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\left(\frac{\sin I''}{e''} - \frac{e''\theta^2}{\sin I''}\right) + \frac{5}{64}\frac{\gamma_5'}{\gamma_2'} \right.$$
$$\times \left[\left(\frac{\eta^2 \sin I''}{e''} - \frac{e''\theta^2}{\sin I''} \right)(4+3e''^2) + e''\sin I''\,(26+9e''^2) \right] [1 - 9\theta^2 - 24\theta^4(1-5\theta^2)^{-1}]$$
$$\left. - \frac{15}{32}\frac{\gamma_5'}{\gamma_2'}e''\theta^2 \sin I''\,(4+3e''^2)[3 + 16\theta^2(1-5\theta^2)^{-1} + 40\theta^4(1-5\theta^2)^{-2}] \right\} \cos g''$$
$$+ \left\{ -\frac{35}{1152}\frac{\gamma_5'}{\gamma_2'}\left[e''\sin I''\,(3+2e''^2) - \frac{e''^3\theta^2}{\sin I''} \right] [1 - 5\theta^2 - 16\theta^4(1-5\theta^2)^{-1}] \right.$$
$$\left. + \frac{35}{576}\frac{\gamma_5'}{\gamma_2'}e''^3\theta^2 \sin I''\,[5 + 32\theta^2(1-5\theta^2)^{-1} + 80\theta^4(1-5\theta^2)^{-2}] \right\} \cos 3g''$$

$$h' = h'' + \left\{ -\frac{1}{8}\gamma_2' e''^2\theta[11 + 80\theta^2(1-5\theta^2)^{-1} + 200\theta^4(1-5\theta^2)^{-2}] \right.$$

$$\left. + \frac{5}{12}\frac{\gamma_4'}{\gamma_2'} e''^2\theta[3 + 16\theta^2(1-5\theta^2)^{-1} + 40\theta^4(1-5\theta^2)^{-2}] \right\} \sin 2g''$$

$$+ \left\{ \frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\frac{e''\theta}{\sin I''} + \frac{5}{64}\frac{\gamma_5'}{\gamma_2'}\frac{e''\theta}{\sin I''}(4+3e''^2)[1 - 9\theta^2 - 24\theta^4(1-5\theta^2)^{-1}] \right.$$

$$\left. + \frac{15}{32}\frac{\gamma_5'}{\gamma_2'} e''\theta \sin I''(4+3e''^2)[3 + 16\theta^2(1-5\theta^2)^{-1} + 40\theta^4(1-5\theta^2)^{-2}] \right\} \cos g''$$

$$+ \left\{ -\frac{35}{1152}\frac{\gamma_5'}{\gamma_2'}\frac{e''^3\theta}{\sin I''}[1 - 5\theta^2 - 16\theta^4(1-5\theta^2)^{-1}] \right.$$

$$\left. - \frac{35}{576}\frac{\gamma_5'}{\gamma_2'} e''^3\theta \sin I''[5 + 32\theta^2(1-5\theta^2)^{-1} + 80\theta^4(1-5\theta^2)^{-2}] \right\} \cos 3g''$$

Short-period terms included:

$$a = a''\left\{1 + \gamma_2\left[(-1+3\theta^2)\left(\frac{a''^3}{r'^3} - \eta^{-3}\right) + 3(1-\theta^2)\frac{a''^3}{r'^3}\cos(2g'+2f')\right]\right\}$$

$$e = e'' + \delta_1 e + \frac{\eta^2}{2e''}\left\{\gamma_2\left[(-1+3\theta^2)\left(\frac{a''^3}{r'^3} - \eta^{-3}\right) + 3(1-\theta^2)\left(\frac{a''^3}{r'^3} - \eta^{-4}\right)\cos(2g'+2f')\right]\right.$$

$$\left. - \gamma_2'(1-\theta^2)[3e''\cos(2g'+f') + e''\cos(2g'+3f')]\right\}$$

$$I = I'' + \delta_1 I + \tfrac{1}{2}\gamma_2'\theta(1-\theta^2)^{\frac{1}{2}}[3\cos(2g'+2f') + 3e''\cos(2g'+f') + e''\cos(2g'+3f')]$$

$$l = l' - \frac{\eta^3}{4e''}\gamma_2'\left\{2(-1+3\theta^2)\left(\frac{a''^2}{r'^2}\eta^2 + \frac{a''}{r'} + 1\right)\sin f'\right.$$

$$\left. + 3(1-\theta^2)\left[\left(-\frac{a''^2}{r'^2}\eta^2 - \frac{a''}{r'} + 1\right)\sin(2g'+f') + \left(\frac{a''^2}{r'^2}\eta^2 + \frac{a''}{r'} + \frac{1}{3}\right)\sin(2g'+3f')\right]\right\}$$

$$g = g' + \frac{\eta^2}{4e''}\gamma_2'\left\{2(-1+3\theta^2)\left(\frac{a''^2}{r'^2}\eta^2 + \frac{a''}{r'} + 1\right)\sin f'\right.$$

$$\left. + 3(1-\theta^2)\left[\left(-\frac{a''^2}{r'^2}\eta^2 - \frac{a''}{r'} + 1\right)\sin(2g'+f') + \left(\frac{a''^2}{r'^2}\eta^2 + \frac{a''}{r'} + \frac{1}{3}\right)\sin(2g'+3f')\right]\right\}$$

$$+ \tfrac{1}{4}\gamma_2'\{6(-1+5\theta^2)(f' - l' + e''\sin f')$$

$$+ (3-5\theta^2)[3\sin(2g'+2f') + 3e''\sin(2g'+f') + e''\sin(2g'+3f')]\}$$

$$h = h' - \tfrac{1}{2}\gamma_2'\theta[6(f' - l' + e''\sin f') - 3\sin(2g'+2f')$$

$$- 3e''\sin(2g'+f') - e''\sin(2g'+3f')].$$

f', r' are to be computed from

$$E' - e''\sin E' = l'$$

$$\tan\tfrac{1}{2}f' = \left(\frac{1+e''}{1-e''}\right)^{\frac{1}{2}}\tan\tfrac{1}{2}E' \qquad \text{or} \qquad \frac{r'}{a''}\sin f' = (1-e''^2)^{\frac{1}{2}}\sin E'$$

$$\frac{a''}{r'} = \frac{1+e''\cos f'}{1-e''^2} \qquad\qquad \frac{r'}{a''}\cos f' = \cos E' - e''$$

$$\frac{r'}{a''} = 1 - e''\cos E'$$

For the calculation of the coordinates at any time the complete values of e and ℓ should be used for the solution of Kepler's equation,

$$E - e \sin E = l$$

and subsequently r and f, which may then be used in the formulas:

$$x = r[\cos (g + f) \cos h - \sin (g + f) \sin h \cos I]$$

$$y = r[\cos (g + f) \sin h + \sin (g + f) \cos h \cos I]$$

$$z = r \sin (g + f) \sin I$$

A convenient alternative form is:

$$x = A_x (\cos E - e) + B_x \sin E$$

$$y = A_y (\cos E - e) + B_y \sin E$$

$$z = A_z (\cos E - e) + B_z \sin E$$

$$A_x = a [\cos g \cos h - \sin g \sin h \cos I]$$

$$B_x = - a(1 - e^2)^{\frac{1}{2}} [\sin g \cos h + \cos g \sin h \cos I]$$

$$A_y = a [\sin g \cos h \cos I + \cos g \sin h]$$

$$B_y = a(1 - e^2)^{\frac{1}{2}} [\cos g \cos h \cos I - \sin g \sin h]$$

$$A_z = a \sin g \sin I$$

$$B_z = a(1 - e^2)^{\frac{1}{2}} \cos g \sin I$$

Noted added in proof. The lack of uniformity in notation of the coefficients of the second and fourth harmonics of the earth's potential in papers dealing with the motion of artificial satellites calls for a comment on this subject.

The table below contains a listing of some of the designations used and their relations to the coefficients B_p in the expression of the force function of a body with rotational symmetry,

$$F = \frac{\mu}{r}\left[1 + \sum_{p=2}^{\infty} \frac{B_p P_p (\sin \beta)}{r^p}\right],$$

in which B_p are Legendre polynomials and $\mu = GM$. The expression is an adaptation of the Laplacian expression given by Tisserand.

In addition to the equivalents of B_2 and B_4 the table gives those of the ratio B_4/B_2^2, which is unity for the special case treated by Vinti (1959), in which the terms with small divisors near the critical inclination vanish. No effort has been made to make the tabulation complete.

Laplace	B_2	B_4	B_4/B_2^2	Tisserand, *Méc. Cél* II, 320, 1890
H. Struve	$-\frac{2}{3}k$	$\frac{2}{3}l$	$\frac{3}{2}l/k^2$	*Suppl. I, Obs Pulkovo* 1888
W. de Sitter	$-\frac{2}{3}JR^2$	$\frac{4}{15}KR^4$	$\frac{3}{5}K/J^2$	*B. A. N.* 2, 97, 1924
D. Brouwer	$-2k_2$	$\frac{8}{3}k_4$	$\frac{2}{3}k_4/k_2^2$	*A. J.* 51, 223, 1946
H. Jeffreys	$-\frac{2}{3}JR^2$	$\frac{8}{35}DR^4$	$\frac{18}{35}D/J^2$	*M. N.* 14, 433, 1954
Y. Kozai	$-\frac{2}{3}A_2$	$\frac{8}{35}A_4$	$\frac{18}{35}A_4/A_2^2$	
P. Herget and P. Musen	$-2k_2$	$8k_4$	$2k_4/k_2^2$	*A. J.* 63, 430, 1958
J. O'Keefe et al.	$+A_{2,0}/\mu$	$+A_{4,0}/\mu$	$\mu A_{4,0}/A_{2,0}^2$	*A. J.* 64, 235, 1959
B. Garfinkel	$-2k$	k'	$\frac{1}{4}k'/k^2$	This issue
J. Vinti	$-J_2R^2$	$-J_4R^4$	J_4/J_2^2	*J. of Res. Nat. Bureau of Standards* 62B, 105, 1959

In the table R represents the earth's equatorial radius. Ignoring the presence of R^2 and differences in sign, essentially three different coefficients for the second harmonic have been used in recent papers. For the coefficients of the fourth harmonic six different choices are listed. I now regret that I introduced k_2, k_4 in my paper in 1946. The principal reason was that they give a particularly simple form for the expression of the potential in the equatorial plane. If I could have foreseen the increase in interest in the subject and the confusion to which I was contributing, I would have chosen the coefficients B_p or the alternative form

$$F = \frac{\mu}{r}\left[1 - \sum_{p=2}^{\infty} J_p \left(\frac{R}{r}\right)^p P_p\,(\sin\beta)\right],$$

which was used by Vinti (1959). I intend to revert to this form and recommend this to other authors.

APPENDIX II

Short Period Term for a

From Brouwer, SPT is

$$1 + \gamma_2 \left[(-1 + 3\theta^2) \left(\frac{a''^3}{r'^3} - \eta^{-3} \right) + 3(1 - \theta^2) \frac{a''^3}{r'^3} \cos (2g' + 2f') \right]$$

Rewrite

$$1 + \gamma_2 \left[\underbrace{(-1 + 3\theta^2)}_{D(6)} \left(\frac{a''^3}{r'^3} - \eta^{-3} \right) + \frac{a''^3}{r'^3} \underbrace{3(1 - \theta^2)}_{D(19)} \underbrace{\cos (2g' + 2f')}_{X(21)} \right]$$

C(1) points to $1 + \gamma_2$; X(11) points to $\frac{a''^3}{r'^3}$; B(8) points to η^{-3}.

D(6), X(11), B(8) combine into X(22); X(11), D(19), X(21) combine into X(23).

SPT = 1. + C(1) * (X(22) + X(11) * X(23))

Short Period Term for e

$$\underbrace{\frac{\eta^2}{2e''}}_{G(12)} \left\{ \underbrace{\gamma_2}_{C(1)} \left[\underbrace{(-1 + 3\theta^2) \left(\frac{a''^3}{r'^3} - \eta^{-3} \right)}_{X(22)} + \left(\underbrace{\frac{a''^3}{r'^3}}_{X(11)} - \underbrace{\eta^{-4}}_{B(9)} \right) \underbrace{3(1 - \theta^2) \cos (2g' + 2f')}_{X(23)} \right] - \underbrace{\gamma_2' (1 - \theta^2)}_{D(23)} \underbrace{[3e'' \cos (2g' + f') + e'' \cos (2g' + 3f')]}_{X(24)} \right\}$$

SPT_e = G(12) * (C(1) * (X(22) + X(23) * (X(11) - B(9))) - D(23) * X(24)

Short Period Term for Inclination

$$\underbrace{\frac{1}{2} \gamma_2' \theta (1 - \theta^2)^{1/2}}_{D(22)} \; [3 \underbrace{\cos (2g' + 2f')}_{X(21)} + \underbrace{e'' \{3 \cos (2g' + f') + \cos (2g' + 3f')\}}_{X(24)}]$$

SPT_i = D(22) * (3. * X(21) + X(24))

Short Period Term for l

$$\underbrace{\frac{\eta^2}{4e''}\gamma_2'}_{B(2)*G(13)}\left\{\underbrace{2(-1+3\theta^2)}_{D(20)}\underbrace{\left(\frac{a''^2}{r'^2}\eta^2+\frac{a''}{r'}+1\right)}_{X(25)}\underbrace{\sin f'}_{X(12)}+\underbrace{3(1-\theta^2)}_{D(19)}\left[\underbrace{\left(-\frac{a''^2}{r'^2}\eta^2-\frac{a''}{r'}+1\right)}_{X(25)}\underbrace{\sin(2g'+f')}_{X(19)}+\underbrace{\left(\frac{a''^2}{r'^2}\eta^2+\frac{a''}{r'}+\frac{1}{3}\right)}_{X(25)}\underbrace{\sin(2g'+3f')}_{X(20)}\right]\right\}$$

(the whole expression after $B(2)$ is $X(26)$)

$SPT_M = B(2)*X(26)$

Short Period Term for g

$$+\frac{\eta^2}{4e''}\gamma_2'\left\{2(-1+3\theta^2)\left(\frac{a''^2}{r'^2}\eta^2+\frac{a''}{r'}+1\right)\sin f'\right.$$

$$\left.+3(1-\theta^2)\left[\left(-\frac{a''^2}{r'^2}\eta^2-\frac{a''}{r'}+1\right)\sin(2g'+f')+\left(\frac{a''^2}{r'^2}\eta^2+\frac{a''}{r'}+\frac{1}{3}\right)\sin(2g'+3f')\right]\right\}$$

(the above expression is $X(26)$)

$$+\underbrace{\tfrac{1}{4}\gamma_2'}_{C(9)}\{6\underbrace{(-1+5\theta^2)}_{D(7)}\underbrace{(f'-l'+e''\sin f')}_{X(27)/6}+\underbrace{(3-5\theta^2)}_{D(21)}\underbrace{[3\underbrace{\sin(2g'+2f')}_{X(17)}+3e''\underbrace{\sin(2g'+f')}_{X(19)}+e''\underbrace{\sin(2g'+3f')}_{X(20)}]}_{X(28)}\}$$

SPT = X(26) + C(9) * (D(7) * X(27) + D(21) * X(28))

Short Period Terms for h

$$\underbrace{\tfrac{1}{2}\gamma_2'\theta}_{C(10)}[\underbrace{6(f' - l' + e'' \sin f')}_{X(27)} - \underbrace{3 \sin (2g' + 2f') - 3e'' \sin (2g' + f') - e'' \sin (2g' + 3f')}_{X(28)}]. \tag{27}$$

SPT = C(10) * (X(27) - X(28))

Secular terms:

l'' = "mean" mean anomaly

$$= n_0 \underbrace{\left\{1 + \frac{3}{2}\gamma_2'\eta(-1 + 3\theta^2) + \frac{3}{32}\gamma_2'^2\eta[-15 + 16\eta + 25\eta^2 + (30 - 96\eta - 90\eta^2)\theta^2 + (105 + 144\eta + 25\eta^2)\theta^4] + \frac{15}{16}\gamma_4'\eta e''^2[3 - 30\theta^2 + 35\theta^4]\right\}}_{S(1)} t + l_0''$$

g'' = mean argument of perigee

$$= n_0 \underbrace{\left\{\frac{3}{2}\gamma_2'(-1 + 5\theta^2) + \frac{3}{32}\gamma_2'^2[-35 + 24\eta + 25\eta^2 + (90 - 192\eta - 126\eta^2)\theta^2 + (385 + 360\eta + 45\eta^2)\theta^4] + \frac{5}{16}\gamma_4'[21 - 9\eta^2 + (-270 + 126\eta^2)\theta^2 + (385 - 189\eta^2)\theta^4]\right\}}_{S(2)} t + g_0''$$

h'' = mean longitude of ascending node

$$= n_0 \underbrace{\left\{-3\gamma_2'\theta + \frac{3}{8}\gamma_2'^2[(-5 + 12\eta + 9\eta^2)\theta + (-35 - 36\eta - 5\eta^2)\theta^3] + \frac{5}{4}\gamma_4'(5 - 3\eta^2)\theta(3 - 7\theta^2)\right\}}_{S(3)} t + h_0''$$

Long-period terms:

$$\delta_1 e = \overbrace{\left\{\frac{1}{8}\gamma_2' e''\eta^2[1 - 11\theta^2 - 40\theta^4(1 - 5\theta^2)^{-1}] - \frac{5}{12}\frac{\gamma_4'}{\gamma_2'}e''\eta^2[1 - 3\theta^2 - 8\theta^4(1 - 5\theta^2)^{-1}]\right\}}^{EL(10)} \cos 2g''$$

$$+ \underbrace{\left\{\frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\eta^2 \sin I'' + \frac{5}{64}\frac{\gamma_5'}{\gamma_2'\eta^2} \sin I'' (4 + 3e''^2)[1 - 9\theta^2 - 24\theta^4(1 - 5\theta^2)^{-1}]\right\}}_{EL(11)} \sin g''$$

$$\underbrace{- \frac{35}{384}\frac{\gamma_5'}{\gamma_2'}e''^2\eta^2 \sin I'' [1 - 5\theta^2 - 16\theta^4(1 - 5\theta^2)^{-1}]}_{EL(12)} \sin 3g''$$

$$\delta_1 I = -\frac{e'' \delta_1 e}{\eta^2 \tan I''} = EL(13) * \delta_1 e$$

Long Period Terms

$$l' = l'' + \left\{\frac{1}{8}\gamma_2'\eta^3\left[1 - 11\theta^2 - 40\theta^4(1-5\theta^2)^{-1}\right] - \frac{5}{12}\frac{\gamma_4'}{\gamma_2'}\eta^3\left[1-3\theta^2-8\theta^4(1-5\theta^2)^{-1}\right]\right\}\sin 2g'' + \left\{-\frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\frac{\eta^3}{e''}\sin I'' - \frac{5}{64}\frac{\gamma_5'}{\gamma_2'}\frac{\eta^3}{e''}\sin I''\,(4+9e''^2)\left[1-9\theta^2-24\theta^4(1-5\theta^2)^{-1}\right]\right\}\cos g'' + \frac{35}{384}\frac{\gamma_5'}{\gamma_2'}\eta^3 e''\sin I''\left[1-5\theta^2-16\theta^4(1-5\theta^2)^{-1}\right]\cos 3g''$$

A1(6); A11(6) (under l''); C(5) (under $\frac{1}{8}\gamma_2'$); B(3) (under η^3); B(3) (under second η^3); D(10); X(3) (under $\sin 2g''$); C(7) (under $\frac{1}{4}\frac{\gamma_3'}{\gamma_2'}$); F(5) (under $9e''^2$); X(4) (under $\cos g''$); X(5) (under $\cos 3g''$)

D(11) (first brace); EL(2) (second brace); EL(3)

B(3) * D(11) = EL(1)

$l' = l'' + EL(1) * X(3) + EL(2) * X(4) + EL(3) * X(5)$

$$g' = g'' + \left\{-\frac{1}{16}\gamma_2'\left[+(2+e''^2) - 11(2+3e''^2)\theta^2 - 40(2+5e''^2)\theta^4(1-5\theta^2)^{-1} - 400e''^2\theta^6(1-5\theta^2)^{-2}\right] + \frac{5}{24}\frac{\gamma_4'}{\gamma_2'}\left[2+e''^2 - 3(2+3e''^2)\theta^2 - 8(2+5e''^2)\theta^4(1-5\theta^2)^{-1} - 80e''^2\theta^6(1-5\theta^2)^{-2}\right]\right\}\sin 2g''$$

$$+ \left\{\frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\left(\frac{\sin I''}{e''} - \frac{e''\theta^2}{\sin I''}\right) + \frac{5}{64}\frac{\gamma_5'}{\gamma_2'} \times \left[\left(\frac{\eta^2\sin I''}{e''} - \frac{e''\theta^2}{\sin I''}\right)(4+3e''^2) + e''\sin I''\,(26+9e''^2)\right]\left[1-9\theta^2-24\theta^4(1-5\theta^2)^{-1}\right] - \frac{15}{32}\frac{\gamma_5'}{\gamma_2'}e''\theta^2\sin I''\,(4+3e''^2)\left[3+16\theta^2(1-5\theta^2)^{-1}+40\theta^4(1-5\theta^2)^{-2}\right]\right\}\cos g''$$

$$+ \left\{-\frac{35}{1152}\frac{\gamma_5'}{\gamma_2'}\left[e''\sin I''\,(3+2e''^2) - \frac{e''^3\theta^2}{\sin I''}\right]\left[1-5\theta^2-16\theta^4(1-5\theta^2)^{-1}\right] + \frac{35}{576}\frac{\gamma_5'}{\gamma_2'}e''^3\theta^2\sin I''\left[5+32\theta^2(1-5\theta^2)^{-1}+80\theta^4(1-5\theta^2)^{-2}\right]\right\}\cos 3g''$$

EL(4); X(3) (under $\sin 2g''$); EL(5); X(4) (under $\cos g''$); EL(6); X(5) (under $\cos 3g''$)

$g' = g'' + EL(4) * X(3) + EL(5) * X(4) + EL(6) * X(5)$

A1(5) (under g'); A11(5) (under g'')

$$h' = h'' + \left\{-\frac{1}{8}\gamma_2'e''^2\theta\left[11+80\theta^2(1-5\theta^2)^{-1}+200\theta^4(1-5\theta^2)^{-2}\right] + \frac{5}{12}\frac{\gamma_4'}{\gamma_2'}e''^2\theta\left[3+16\theta^2(1-5\theta^2)^{-1}+40\theta^4(1-5\theta^2)^{-2}\right]\right\}\sin 2g''$$

$$+ \left\{\frac{1}{4}\frac{\gamma_3'}{\gamma_2'}\frac{e''\theta}{\sin I''} + \frac{5}{64}\frac{\gamma_5'}{\gamma_2'}\frac{e''\theta}{\sin I''}(4+3e''^2)\left[1-9\theta^2-24\theta^4(1-5\theta^2)^{-1}\right] + \frac{15}{32}\frac{\gamma_5'}{\gamma_2'}e''\theta\sin I''\,(4+3e''^2)\left[3+16\theta^2(1-5\theta^2)^{-1}+40\theta^4(1-5\theta^2)^{-2}\right]\right\}\cos g''$$

$$+ \left\{-\frac{35}{1152}\frac{\gamma_5'}{\gamma_2'}\frac{e''^3\theta}{\sin I''}\left[1-5\theta^2-16\theta^4(1-5\theta^2)^{-1}\right] - \frac{35}{576}\frac{\gamma_5'}{\gamma_2'}e''^3\theta\sin I''\left[5+32\theta^2(1-5\theta^2)^{-1}+80\theta^4(1-5\theta^2)^{-2}\right]\right\}\cos 3g''$$

EL(7) (first brace); X(3) (under $\sin 2g''$); EL(8) (second brace); X(4) (under $\cos g''$); EL(9); X(5) (under $\cos 3g''$)

$h' = h'' + EL(7) * X(3) + EL(8) * X(4) + EL(9) * X(5)$

APPENDIX III (PART A)

PROGRAM OPERATING INSTRUCTIONS FOR MAIN PROGRAM ONE

OPERATING INSTRUCTIONS

FOR

MUSTAP PROGRAM

```
0
        OPERATING NOTES FOR MUSTAP PROGRAM.
0
    PURPOSE--
0
        THE MUSTAP PROGRAM IS ONE DESIGNED TO COMPUTE MUTUAL VISIBILITY
 , LOCAL STATION PREDICTIONS, SPACECRAFT LOOK ANGLES, AND WORLD MAPS OF
 COMMUNICATION SATELLITES.
0
    INPUT--
0
        INPUT TO THE PROGRAM CONSISTS OF CONTROL OPTIONS, TEST CRITERIA,
 EPOCH, ORBITAL ELEMENTS OR POSITION AND VELOCITY VECTORS, START AND STOP
 TIMES WITH PREDICTION INTERVAL, ATTITUDE DATA, AND STATION COORDINATES.
0
    METHOD--
0
        THE PATH OF THE SATELLITE IS COMPUTED BY AN INTERNAL ORBIT
 GENERATOR.  THE POSITION OF THE SPACECRAFT WITH RESPECT TO EACH STATION
 IS COMPUTED AND TESTED AGAINST THE SPECIFIED CRITERIA.  OUTPUT STATEMENTS
 ARE ARRANGED TO PRESENT THE DATA IN THE MOST USEFUL MANNER TO THE PROJECT.
0
    OUTPUT--
0
        OUTPUT DATA ARE WRITTEN ON TWO MAGNETIC TAPES--(1) MUTUAL VISIBILITY
 (2) WORLD MAP,PREDICTIONS,AND TIME THE SATELLITE IS IN SHADOW. THE MUTUAL
 VISIBILITY DATA ARE PRESENTED IN GRAPHICAL FORM. THE OTHER DATA ARE S/C
 LATITUDE, LONGITUDE, HEIGHT, AZIMUTH, ELEVATION, RANGE, AND SPACECRAFT
 LOOK ANGLE(THE ANGLE BETWEEN THE S/C SPIN AXIS AND THE LINE TO THE STATION).
    FOR CHECKOUT PURPOSES A SENSE SWITCH CAN BE DOWN AND THE INPUT WILL BE
 WRITTEN ON-LINE.
0
        PROGRAM INPUT DATA INSTRUCTIONS.
0
    INPUT DATA--
0
        ALL INPUT DATA ARE ON CARDS(READ ON-LINE).
0
        CARD 1-- IDENTIFICATION CARD (FORMAT 2(6A6))--ANY DESCRIPTIVE DATA
            NOTE ---
             THIS IDENTIFICATION IS OUTPUT ON 2 LINES --
               LINE 1 -CONTENTS OF COLUMNS  1-36
               LINE 2 -CONTENTS OF COLUMNS 37-72
0
        CARD 2--CONTROL CARD (FORMAT 8I3,F10.1)
0
            COLUMN
             1-3  TYPE OF INPUT +01 = OSCULATING ORBITAL ELEMENTS
                                +03 = INERTIAL R AND V VECTORS, CANONICAL UNITS
                                +04 = BROUWER MEAN ELEMENTS
             4-6  WORLD MAP     +01 = COMPUTE WORLD MAP AND PREDICTIONS
                                +00 = DO NOT COMPUTE WORLD MAP AND PREDICTIONS
                                -01 = DO NOT COMPUTE WORLD MAP AND PREDICTIONS
             7-9  LOOK ANGLE    +01 ALWAYS
            10-12 EARTH CONST. -03 = USE INTERNATIONAL CONSTANTS WITH
                                     HARMONICS EQUAL TO ZERO.
                               -02 = USE GODDARD EARTH CONSTANTS WITH
                                     HARMONICS EQUAL TO ZERO.
                               -01 = USE SIRY PACKAGE CONSTANTS
                               +00 = USE GODDARD EARTH CONSTANTS
                               +01 = READ A NEW SET OF EARTH CONSTANTS
                                     (INPUT ON CARDS 4-5)
            13-15 TRUNCATION   -01 = USE INTERNAL VALUE
                               +00 = USE INTERNAL VALUE
                               +01 = READ NEW TRUNCATION FACTOR -- CARD 3
                                     (USED AS CRITERIA TO SOLVE KEPLER'S EQ.)
            16-18 BBRWR        -01 = USE INTERNAL VALUES
                  TRUNCATION   +00 = USE INTERNAL VALUES
                               +01 = READ NEW TRUNCATION FACTORS FOR
                                     SUBROUTINE BBRWR -- CARD 6
           19-21  BLANK -- USED INTERNALLY
            22-24 POSITIVE N -- N CONTROL STATIONS (THEY ARE THE FIRST N
```

```
                    STATIONS.)
         N MUST BE LESS THAN OR EQUAL TO THE NUMBER OF STATIONS GIVEN
         ON CARD 11.
   25-34 MAXIMUM RANGE FOR STATIONS IN NAUTICAL MILES. A T IS PRINTED
         ON THE MUTUAL VISIBILITY OUTPUT,WHEN THE RANGE IS LARGER
         THAN THIS VALUE.

CARD 3 -- NEW TRUNCATION FACTOR ( OMIT THIS CARD UNLESS COLUMNS 13-15
         OF CARD 2 ARE = +01 )  (FORMAT F8.2)
   COLUMN
    1-8  NEW TRUNCATION FACTOR

CARD 4 -- EARTH CONSTANTS (OMIT UNLESS COLUMNS 10-12 OF
         CARD 2 = +01 )  (FORMAT E12.6,4E12.5)
   COLUMN
    1-12 NEW GM OF THE EARTH  (KM. CUBED/ SECONDS SQUARED)
   13-24 J2 )
   25-36 J3 )  HARMONICS OF THE GRAVITATIONAL POTENTIAL OF
   37-48 J4 )  THE EARTH
   49-60 J5 )

CARD 5 -- EARTH CONSTANTS CONTINUED ( OMIT UNLESS COLUMNS 10-12
         OF CARD 2 = +01 )  (FORMAT 2F12.4)
   COLUMN
    1-12 INVERSE OF FLATTENING
   13-24 EQUATORIAL RADIUS OF THE EARTH IN KM

CARD 6 --  NEW TRUNCATION FACTORS FOR SUBROUTINE BBRWR ( OMIT UNLESS
          COLUMNS 16-18 OF CARD 2 ARE = +01 )   (FORMAT 6F12.8)
         TRUNCATION FACTORS USED IN COMPUTING BROUWER MEAN
         ELEMENTS FROM OSCULATING ELEMENTS ---
   COLUMN
    1-12             ( SEMI-MAJOR AXIS - KM
   13-24             ( ECCENTRICITY
   25-36 FACTOR FOR ( INCLINATION     - DEGREES
   37-48             ( R.A. ASC. NODE  - DEGREES
   49-60             ( ARG. OF PERIGEE - DEGREES
   61-72             ( MEAN ANOMALY    - DEGREES

CARD 7 -- EPOCH CARD (TIME AT WHICH PARAMETERS APPLY)
              FORMAT 1X,A5,X,3I2,X,2I2,X,F4.2,39X,I5)
   COLUMN
   1      BLANK
   2-6    SATELLITE IDENTIFICATION NUMBER
   8-9    YEAR (ABBREVIATE)
  10-11   MONTH
  12-13   DAY
  15-16   HOUR      )
  17-18   MINUTE    )  UNIVERSAL TIME
  20-24   SECONDS   )
  63-67   ORBIT NUMBER AT THE START TIME GIVEN ON CARD 10

CARD 8 -- PARAMETER CARD (THESE DATA MUST BE CHOSEN IN ACCORDANCE
          WITH THE INSTRUCTION ON CARD 2, COLUMNS 1-3)
       (FORMAT 6F12.8)      +XXXXXXXX+XX

     --DO NOT LEAVE THE SIGN OF THE EXPONENT BLANK--

   VECTORS  (+03) REQUIRE THE FOLLOWING
     COL
     1-12  X          VUL
    13-24  Y          VUL
    25-36  Z          VUL
    37-48  X-DOT      VUL/VUT
    49-60  Y-DOT      VUL/VUT
    61-72  Z-DOT      VUL/VUT
   ELEMENTS  (+01 AND +04) REQUIRE THE FOLLOWING
     COL
     1-12  SEMI-MAJOR AXIS          VUL
    13-24  ECCENTRICITY
    25-36  INCLINATION              RADIANS
    37-48  MEAN ANOMALY             RADIANS
    49-60  ARGUMENT OF PERIGEE      RADIANS
    61-72  R.A. OF ASCENDING NODE   RADIANS
    ONE VUL = 6378.388 KILOMETERS
    ONE VUL/VUT =  6378.388 KM/ 806.832 SEC
    RECTANGULAR COORDINATES ARE DEFINED TO BE IN AN INERTIAL,
    EQUATORIAL, GEOCENTRIC SYSTEM.  X GOES THROUGH ARIES, Y IS
    IN EQUATORIAL PLANE, Z IS ALONG POLAR AXIS TO FORM A RIGHT
    HANDED SYSTEM.
CARD 9 -- DRAG CARD     (FORMAT 4A6,1X,E12.8)
    COL
    1-24 SAME AS EPOCH CARD
    25   BLANK
   26-37 ACCELERATION OF MEAN ANOMALY(N2 DRAG TERM AT GSFC) IN
         UNITS OF RADIANS / VUT SQUARED.  +XXXXXXXX+XX

CARD 10 -- PREDICTION AND MUTUAL VISIBILITY REQUEST CARD
         ( FORMAT 2(1X12),1X,I4,2I3,F7.3,I3,1X,I2,1X,I4,2I3,
           F7.3,F11.3 )
     COL                                                 FORMAT
     2-3    MONTH                                          I2
```

```
 5-6    DAY                            )              I2
 8-11   YEAR (DO NOT ABBREVIATE)       )   START      I4
13-14   HOUR     )                     )   TIME       I2
16-17   MINUTE   ) UNIVERSAL   TIME    )              I2
19-24   SECOND   )                     )              F6.3
26-27   MONTH                            )            I2
29-30   DAY                              )            I2
32-35   YEAR (DO NOT ABBREVIATE)         ) END        I4
37-38   HOUR     )                       ) TIME       I2
40-41   MINUTE   )UNIVERSAL TIME         )            I2
43-48   SECOND   )                       )            F6.3
49-59   PREDICTION INTERVAL, SECOND                    F11.3
```

```
CARD 11--STATION CONTROL CARD (FORMAT 3I3,F10.0,51X,I2)
    COL.
    1-3  NO. OF STATION COORDINATE CARDS TO BE LOADED

         N.B., THE MAXIMUM NUMBER OF STATIONS THAT CAN
         BE CONSIDERED IS NINETEEN (19).
    4-6 = BLANK OR +00
    7-9 = +XX  LOWEST ELEVATION ANGLE FOR WHICH THE STATIONS
               CAN OBSERVE THE SPACECRAFT.
   10-19= BLANK  (READ BUT NOT USED)
   20-70= BLANK  (NOT READ)
   71-72= BLANK FOR NORMAL RUNS. OUTPUT FOR A PASS
     IS GIVEN WHEN THERE IS MUTUAL VISIBILITY BETWEEN AT LEAST
     TWO STATIONS(ONE OF WHICH IS A CONTROL STATION) DURING THE PASS.
          +XX  UNEQUAL TO ZERO -- KILLS MUTUAL VISIBILITY REQUIREMENT--
               GIVES OUTPUT ANYTIME THE SPACECRAFT IS VISIBLE TO ANY
               OF THE STATIONS.

           (WHEN COLUMNS 1-3 OF THIS CARD ARE LESS THAN OR EQUAL
           TO ZERO,A NEW JOB IS STARTED BY READING CARD 1.)
```

```
CARD 12--ATTITUDE DATA CARD   (FORMAT 4F6.1,I6)
    COL.
    1-12 READ BUT NOT USED
   13-18 RIGHT ASCENSION OF S/C SPIN AXIS, DEGREES
   19-24 DECLINATION     OF S/C SPIN AXIS, DEGREES
   25-30    +00  USE THE INPUT VALUES OF RT. ASCENSION AND DECLINATION
                 TO DEFINE SPIN AXIS DIRECTION
            +XX  (POSITIVE)  ASSUME SPIN AXIS IS ALONG THE INITIAL
                 INERTIAL VELOCITY VECTOR

N.B., RIGHT ASCENSION AND DECLINATION ARE AT THE EPOCH GIVEN ON CARD 3.
    THESE ANGLES ARE ASSUMED CONSTANT.
```

```
CARD 13 -- STATION COORDINATE CARD (S)
      COL                                                FORMAT
       2-7    NAME                                        A6
       9-12   LONGITUDE, DEGREES (+EAST)                  I4
      14-15   LONGITUDE, MINUTES                          I2
      17-22   LONGITUDE, SECONDS                          F6.3
      24-26   LATITUDE, DEGREES (+NORTH)                  I3
      28-29   LATITUDE, MINUTES                           I2
      31-36   LATITUDE, SECONDS                           F6.3
      37-47   ALTITUDE, METERS                            F11.2

      N.B., THERE MUST BE AS MANY STATION COORDINATE CARDS AS INDICATED
      BY CARD 11.
      THE STATION COORDINATE CARDS ARE FOLLOWED BY ANOTHER STATION
      CONTROL CARD OR BY A BLANK. IF THE NUMBER IN COLUMNS 1-3 OF
      THIS CARD IS NEGATIVE OR ZERO, A NEW JOB IS STARTED BY
      READING CARD 1. IF THE NUMBER IN COLUMNS 1-3 OF THIS CARD
      IS POSITIVE,   NEW ATTITUDE DATA AND COORDINATE CARDS ARE
      READ.    MUTUAL VISIBILITY AND PREDICTIONS ARE THEN COMPUTED
      FOR THE NEW STATIONS AND ATTITUDE FOR TIMES GIVEN ON CARD 10.

           JOBS MAY BE STACKED BY PLACING A BLANK CARD AFTER THE
      LAST STATION COORDINATE CARD. CARD 1 OF THE NEW JOB THEN
      FOLLOWS THIS BLANK CARD.

           PLACE 3 BLANK CARDS AFTER THE LAST STATION COORDINATE
      CARD IN THE LAST INPUT DECK OF THE JOB. THIS WILL RESULT
      IN THE CORRECT FINAL HALT -- HPR 77777.

           PUT SENSE SWITCH 3 DOWN TO TERMINATE RUN BEFORE THE END
      TIME IS REACHED.
```

EARTH CONSTANTS STORED IN THE PROGRAM

VALUE	INTERNATIONAL	GODDARD	SIRY
GM	+3.986268730E+05	+3.986032000E+05	+3.986268800E+05
J2	0.0	+1.0823E-03	+1.08219E-03
J3	0.0	-2.3E-06	-2.285E-06
J4	0.0	-1.8E-06	-2.123E-06
J5	0.0	0.0	-2.32E-07
F	297.0	298.3	297.0
A	6378.388	6378.165	6378.388

```
RUNNING INSTRUCTIØNS.

    MØUNT PRØGRAM SYSTEM TAPE ØN A1
    MØUNT BLANK TAPES ØN A3,A5,A8

    NØ KEYS ØR SENSE SWITCHES.

    PUT INPUT CARDS IN READER AND READY READER.

    CLEAR AND LØAD TAPE.

    FINAL STØP IS HPR 77777


HALTS --
  HPR 00010  MACHINE IS NØT IN 65K
  HPR 54321  MØRE THAN 19 CØNTRØL STATIØNS ARE BEING USED. THE
             PRØGRAM CAN NØT RUN.
  HPR 54333  THE NUMBER ØF CØNTRØL STATIØNS IS LARGER THAN THE NUMBER
             ØF STATIØNS.
  HPR 66666  MØRE THAN 19 STATIØNS ARE BEING USED. THE PRØGRAM
             CAN NØT RUN.
  HPR 77774  SENSE SWITCH 2 IS DØWN FØR TIMING PURPØSES -- END ØF
             PREDICTIØNS.  HIT START TØ CØNTINUE.
  HPR 77775  SENSE SWITCH 2 IS DØWN FØR TIMING PURPØSES -- BEGINNING
             ØF PREDICTIØNS. HIT START TØ CØNTINUE.
  HPR 77777  FINAL (END ØF JØB)


     PRINT ØUTPUT TAPE A3
  (1)NARRØW PAPER WHEN THERE ARE 15 ØR LESS STATIØNS
  (2)WIDE PAPER   WHEN THERE ARE 16 TØ 19 STATIØNS
     PRINT ØUTPUT TAPE A8 ØN NARRØW PAPER.
```

APPENDIX III (PART B)

PROGRAM OPERATING INSTRUCTIONS FOR MAIN PROGRAM TWO

OPERATING INSTRUCTIONS

FOR

MUSTAP PROGRAM

0

OPERATING NOTES FOR MUSTAP PROGRAM.

0

PURPOSE--

0

THE MUSTAP PROGRAM IS ONE DESIGNED TO COMPUTE MUTUAL VISIBILTY, LOCAL STATION PREDICTIONS, SPACECRAFT LOOK ANGLES, AND WORLD MAPS OF COMMUNICATION SATFLLITES.

0

INPUT--

0

INPUT TO THE PROGRAM CONSISTS OF CONTROL OPTIONS, TEST CRITERIA, EPOCH, ORBITAL ELEMENTS OR POSITION AND VELOCITY VECTORS, START AND STOP TIMES WITH PREDICTION INTERVAL, ATTITUDE DATA, AND STATION COORDINATES.

0

METHOD--

0

THE PATH OF THE SATELLITE IS COMPUTED BY AN INTERNAL ORBIT GENERATOR. THE POSITION OF THE SPACECRAFT WITH RESPECT TO EACH STATION IS COMPUTED AND TESTED AGAINST THE SPECIFIED CRITERIA. OUTPUT STATEMENTS ARE ARRANGED TO PRESENT THE DATA IN THE MOST USEFUL MANNER TO THE PROJECT.

0

OUTPUT--

0

OUTPUT DATA ARE WRITTEN ON TWO MAGNETIC TAPFS--(1) MUTUAL VISIBILITY AND WORLD MAP (2) PREDICTIONS. FOR CHECKOUT PURPOSES A SENSE SWITCH CAN BE DOWN AND ALL DATA WILL BE WRITTEN ON-LINE. THE MUTUAL VISIBILITY DATA ARE PRESENTED IN GRAPHICAL FORM. THE OTHER DATA ARE S/C LATITUDE, LONGITUDE, AND HEIGHT FOR EACH TIME STFP, AZIMUTH, ELEVATION, RANGE, AND SPACECRAFT LOOK ANGLE(THE ANGLE BETWEEN THE S/C SPIN AXIS AND THE LINE TO THE STATION) FOR FACH STATION.

0

PROGRAM INPUT DATA INSTRUCTIONS.

0

INPUT DATA--

0

ALL INPUT DATA ARF ON CARDS(READ ON-LINE).

0

CARD 1--IDENTIFICATION CARD (FORMAT 12A6)--ANY DESCRIPTIVE DATA

0

CARD 2--CONTROL CARD (FORMAT 7I3)

0

```
COLUMN
 1-3  TYPE OF INPUT +01 = OSCULATING ORBITAL ELEMENTS
                    +02 = INERTIAL R AND V VECTORS, KGS SYSTEM
                    +03 = INERTIAL R AND V VECTORS, CANONICAL UNITS
                    +04 = BROUWER MEAN ELEMENTS
 4-6   WORLD MAP    +01 = COMPUTE WORLD MAP
                    +00 = DO NOT COMPUTF MAP
                    -01 = DO NOT COMPUTE MAP
 7-9   LOOK ANGLE   +01 = COMPUTE MUTUAL VISIBILITY
                    +00 = DO NOT COMPUTE MUTUAL VISIBILITY
                    -01 = DO NOT COMPUTE MUTUAL VISIBILITY
10-12 EARTH CONST. -03 = USE INTERNATIONAL CONSTANTS WITH
                          HARMONICS EQUAL TO ZERO.
                   -02 = USE GODDARD EARTH CONSTANTS WITH
                          HARMONICS EQUAL TO ZERO.
                   -01 = USE SIRY PACKAGE CONSTANTS
                   +00 = USE GODDARD EARTH CONSTANTS
                   +01 = READ A NEW SET OF EARTH CONSTANTS
                          (INPUT ON CARDS 4-5)
13-15 TRUNCATION   -01 = USE INTFRNAL VALUE
                   +00 = USE INTFRNAL VALUE
                   +01 = READ NEW TRUNCATION FACTOR -- CARD 3
                          (USED AS CRITERIA TO SOLVE KEPLER'S EQ.)
16-18 BBRWR        -01 = USE INTFRNAL VALUES
      TRUNCATION   +00 = USE INTERNAL VALUES
                   +01 = READ NEW TRUNCATION FACTORS FOR
                          SUBROUTINE BBRWR -- CARD 6
```

0

CARD 3 -- NEW TRUNCATION FACTOR (OMIT THIS CARD UNLESS COLUMNS 13-15 OF CARD 2 ARF = +01) (FORMAT E8.2)

```
    COLUMN
     1-8  NEW TRUNCATION FACTOR

CARD 4 -- EARTH CONSTANTS (OMIT UNLESS COLUMNS 10-12 OF
          CARD 2 = +01 )  (FORMAT E12.6,4E12.5)
    COLUMN
     1-12 NEW GM OF THE EARTH  (KM. CUBED/ SECONDS SQUARED)
    13-24 J2 )
    25-36 J3 )   HARMONICS OF THE GRAVITATIONAL POTENTIAL OF
    37-48 J4 )   THE EARTH
    49-60 J5 )

CARD 5 -- EARTH CONSTANTS CONTINUED ( OMIT UNLESS COLUMNS 10-12
          OF CARD 2 = +01 )  (FORMAT 2F12.4)
    COLUMN
     1-12 INVERSE OF FLATTENING
    13-24 EQUATORIAL RADIUS OF THE EARTH IN KM

CARD 6 --  NEW TRUNCATION FACTORS FOR SUBROUTINE BBRWR ( OMIT UNLESS
           COLUMNS 16-18 OF CARD 2 ARE = +01 )   (FORMAT 6F12.8)
          TRUNCATION FACTORS USED IN COMPUTING BROUWER MEAN
          ELEMENTS FROM OSCULATING ELEMENTS ---
    COLUMN
     1-12              ( SEMI-MAJOR AXIS - KM
    13-24              ( ECCENTRICITY
    25-36 FACTOR FOR ( INCLINATION      - DEGREES
    37-48              ( R.A. ASC. NODE   - DEGREES
    49-60              ( ARG. OF PERIGEE  - DEGREES
    61-72              ( MEAN ANOMALY     - DEGREES

CARD 7 -- EPOCH CARD (TIME AT WHICH PARAMETERS APPLY)
    COL.                                                 FORMAT
    2-3   MONTH                                            I2
    5-6   DAY                                              I2
    8-11  YEAR-(DO NOT ABBREVIATE)                         I4
   13-14  HOUR      )                                      I2
   16-17  MINUTE    ) UNIVERSAL TIME                       I2
   19-24  SECOND    )                                      F5.3

CARD 8 -- PARAMETER CARD (THESE DATA MUST BE CHOSEN IN ACCORDANCE
          WITH THE INSTRUCTION ON CARD 2, COLUMNS 1-3) (FORMAT 6F12.6)
    ELEMENTS (+01 OR +04) REQUIRE THE FOLLOWING
       COL
        1-12  SEMI-MAJOR AXIS,KILOMETERS
      13-24  ECCENTRICITY
      25-36  INCLINATION              ) THESE
      37-48  R.A.OF ASCENDING NODE   ) VALUES
      49-60  ARGUMENT OF PERIGEE     ) ARE IN
      61-72  MEAN ANOMALY             ) DEGREES
    VECTORS (+02 OR +03) REQUIRE THE FOLLOWING
      COL                        +02                 +03
      1-12  X                  KILOMETERS          VUL
     13-24  Y                  KILOMETERS          VUL
     25-36  Z                  KILOMETERS          VUL
     37-48 X-DOT               KM/SEC              VUL/VUT
     49-60 Y-DOT               KM/SEC              VUL/VUT
     61-72 Z-DOT               KM/SEC              VUL/VUT
     ONE VUL = 6378.388 KILOMETERS
     ONE VUL/VUT =  6378.388 KM/ 806.832 SEC
     RECTANGULAR COORDINATES ARE DEFINED TO BE IN AN INERTIAL,
     EQUATORIAL, GEOCENTRIC SYSTEM.  X GOES THROUGH ARIES, Y IS
     IN EQUATORIAL PLANE, Z IS ALONG POLAR AXIS TO FORM A RIGHT
     HANDED SYSTEM.
CARD 9 -- WORLD MAP REQUEST CARD.
          THIS CARD IS NEEDED ONLY WHEN THE NUMBER IN COLUMNS 4-6
          OF CARD 2 IS GREATER THAN ZERO.
          ( FORMAT 2(1XI2),1X,I4,2I3,F7.3,I3,1X,I2,1X,I4,2I3,
            F7.3,F11.3 )
      COL                                                FORMAT
      2-3    MONTH                      )                  I2
      5-6    DAY                        )                  I2
      8-11   YEAR (DO NOT ABREVIATE)    )   START          I4
     13-14   HOUR    )                  )   TIME           I2
     16-17   MINUTE  ) UNIVERSAL  TIME )                   I2
     19-24   SECOND  )                  )                  F6.3
     26-27   MONTH                         )               I2
     29-30   DAY                           )               I2
     32-35   YEAR (DO NOT ABBREVIATE)      ) END           I4
     37-38   HOUR     )                    ) TIME          I2
     40-41   MINUTE   )UNIVERSAL TIME      )               I2
     43-48   SECOND   )                    )               F6.3
     49-59   PREDICTION INTERVAL, SECOND                   F11.3

     N.B., IF THE NUMBER IN COLUMNS 7-9 OF CARD 2 IS ZERO OR
     NEGATIVE, A NEW JOB IS STARTED BY READING CARD 1.

     N.B., IF CONTROL ON CARD 2 REQUESTS BOTH MAP AND PREDICTIONS,
           TWO REQUEST CARDS ARE NECESSARY.

CARD 10 -- PREDICTION AND MUTUAL VISIBILITY REQUEST CARD
          THIS CARD IS NEEDED ONLY WHEN THE NUMBER IN COLUMNS 7-9
          OF CARD 2 IS GREATER THAN ZERO.
```

(SAME FORMAT AS CARD 9)

0

CARD 11 -- STATION CONTROL CARD (FORMAT 3I3,F10.0)

```
COL.
1-3   NO. OF STATION COORDINATE CARDS TO BE LOADED

      N.B., THE MAXIMUM NUMBER OF STATIONS THAT CAN
      BE CONSIDERED IS TWELVE (12).
4-6 = +01 COMPUTE PREDICTIONS. OUTPUT WILL BE ON TAPE A6.
      +00 DO NOT OUTPUT PREDICTIONS (ON TAPE A6)
7-9 =  MINIMUM ELEVATION ANGLE (DEGREES). NO OUTPUT IS
       GIVEN IF ELEVATION IS LESS THAN THIS VALUE.
10-20 = MAXIMUM RANGE  (KILOMETERS).  NO OUTPUT IS GIVEN WHEN
       THE RANGE IS LARGER THAN THIS VALUE.

       (WHEN COLUMNS 1-3 OF THIS CARD ARE LESS THAN OR EQUAL
       TO ZERO,A NEW JOB IS STARTED BY READING CARD 1.)
```

0

CARD 12 -- ATTITUDE DATA CARD (FORMAT 4F6.1)

```
COL.
1-6   MAXIMUM SPACECRAFT LOOK ANGLE, DEGREES
7-12  MINIMUM SPACECRAFT LOOK ANGLE, DEGREES
13-18 RIGHT ASCENSION OF S/C SPIN AXIS, DEGREES
19-24 DECLINATION     OF S/C SPIN AXIS, DEGREES
```

NO MUTUAL VISIBILITY OUTPUT IS GIVEN WHEN THE SPACECRAFT LOOK ANGLE IS OUTSIDE THE LIMITS OF THE MAXIMUM AND MINIMUM VALUES ON THIS CARD.

N.B., MAXIMUM AND MINIMUM LOOK ANGLES, RIGHT ASCENSION, AND DECLINATION ARE CONSTANTS.

0

CARD 13 -- STATION COORDINATE CARD (S)

COL		FORMAT
2-7	NAME	A6
9-12	LONGITUDE, DEGREES (+EAST)	I4
14-15	LONGITUDE, MINUTES	I2
17-22	LONGITUDE, SECONDS	F6.3
24-26	LATITUDE, DEGREES (+NORTH)	I3
28-29	LATITUDE, MINUTES	I2
31-36	LATITUDE, SECONDS	F6.3
37-47	ALTITUDE, METERS	F11.2

N.B., THERE MUST BE AS MANY STATION COORDINATE CARDS AS INDICATED BY CARD 11.
THE STATION COORDINATE CARDS ARE FOLLOWED BY ANOTHER STATION CONTROL CARD OR BY A BLANK. IF THE NUMBER IN COLUMNS 1-3 OF THIS CARD IS NEGATIVE OR ZERO, A NEW JOB IS STARTED BY READING CARD 1. IF THE NUMBER IN COLUMNS 1-3 OF THIS CARD IS POSITIVE, NEW ATTITUDE DATA AND COORDINATE CARDS ARE READ. MUTUAL VISIBILITY AND PREDICTIONS ARE THEN COMPUTED FOR THE NEW STATIONS AND ATTITUDE FOR TIMES GIVEN ON CARD 10.

0

JOBS MAY BE STACKED BY PLACING A BLANK CARD AFTER THE LAST STATION COORDINATE CARD. CARD 1 OF THE NEW JOB THEN FOLLOWS THIS BLANK CARD.

0

PLACE 3 BLANK CARDS AFTER THE LAST STATION COORDINATE CARD IN THE LAST INPUT DECK OF THE JOB. THIS WILL RESULT IN THE CORRECT FINAL HALT -- HPR 77777.

0

EARTH CONSTANTS STORED IN THE PROGRAM

VALUE	INTERNATIONAL	GODDARD	SIRY
GM	+3.986268730E+05	+3.986032000E+05	+3.986268800E+05
J2	0.0	+1.0823E-03	+1.08219E-03
J3	0.0	-2.3E-06	-2.285E-06
J4	0.0	-1.8E-06	-2.123E-06
J5	0.0	0.0	-2.32E-07
F	297.0	298.3	297.0
A	6378.388	6378.165	6378.388

RUNNING INSTRUCTIONS.

0

RUN UNDER MONITOR SYSTEM
MOUNT BLANK TAPES ON A3 AND A6(IF CONTROL ON CARD 6 CALLS FOR A6)

0

NO KEYS OR SENSE SWITCHES.

0

PUT INPUT CARDS IN READER AND READY READER.

0
0

FINAL STOP IS -- HPR 77777

0

PRINT OUTPUT TAPES A3 AND A6 ON NARROW PAPER WITH PROGRAM CONTROL

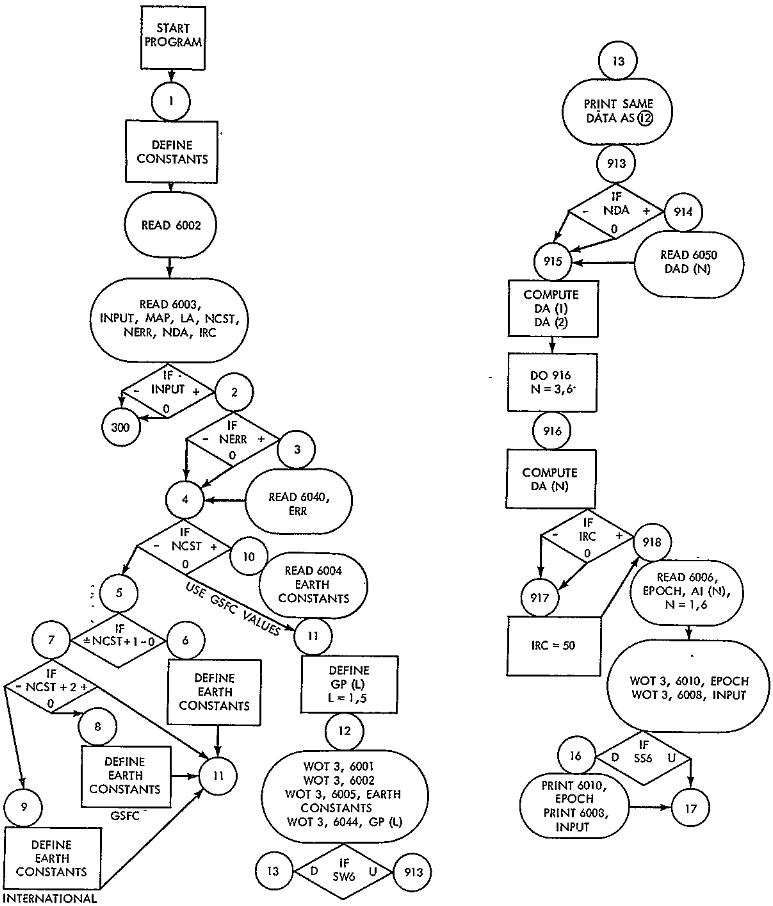
0
0

SAMPLE PROGRAM INPUT DECK FOLLOWS. THE DECK WILL COMPUTE THE MUTUAL VISIBILITY OF 12 STATIONS FOR ABOUT ONE DAY. SOME OF THE

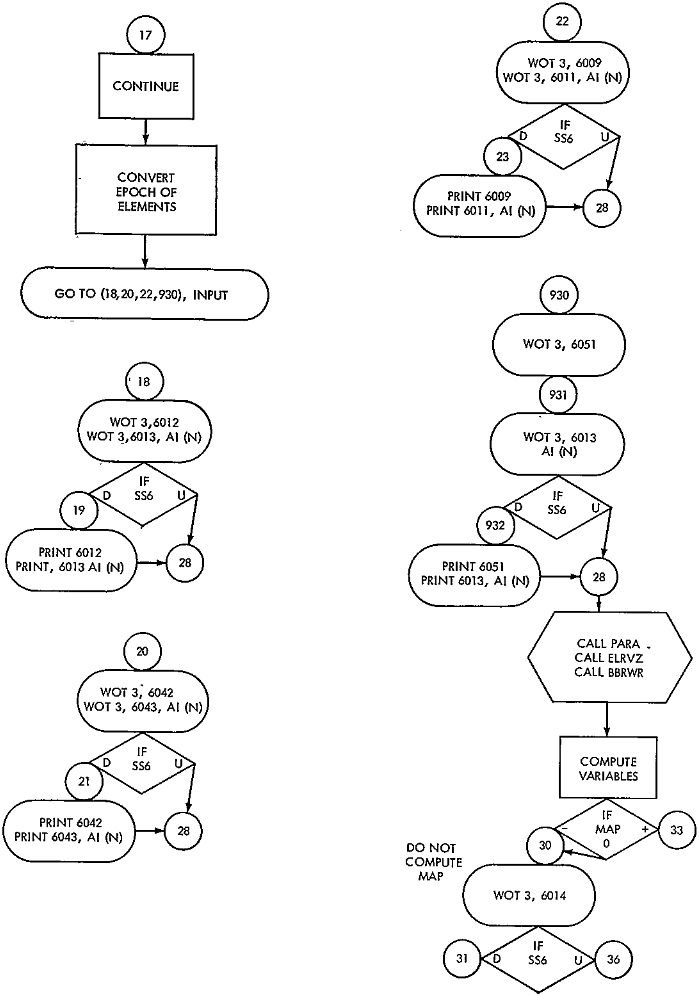
```
  STATIONS WILL BE DUPLICATED.    NOTE THAT BOTH MUTUAL VISIBILITY AND
  A WORLD MAP ARE REQUESTED.
0

      RELAY TEST 12 STATIONS
+04+01+01-01
 01/14/1964 21 57
+11143.084   +0.23653052 +46.497757  +220.62688  +186.36665  +359.95097
 01/15/1964 20 00 00.000 01/16/1964 20 00 00.000 +120.
 01/15/1964 10 00 00.000 01/16/1964 10 00 00.000 +120.
+12+01+00
  90.0    0.0 178.   25.
 COMNUT  -75 00  0.000 +40 00  0.000     0.0
 COMAND -068 40 00.000 +44 54 00.000  38.
 COMHIL  -05 10 29.0   +50 02 58.0   350.0
 COMGER  +10 00 00.000 +51 00 00.000    50.
 COMTEL  +13 36  5.000 +41 58 41.000  2168.6
 COMRIO  -43 22  7.000 -22 57  9.000     0.0
 COMNUT  -75 00  0.000 +40 00  0.000     0.0
 COMAND -068 40 00.000 +44 54 00.000  38.
 COMHIL  -05 10 29.0   +50 02 58.0   350.0
 COMNUT  -75 00  0.000 +40 00  0.000     0.0
 COMAND -068 40 00.000 +44 54 00.000  38.
 COMHIL  -05 10 29.0   +50 02 58.0   350.0
```

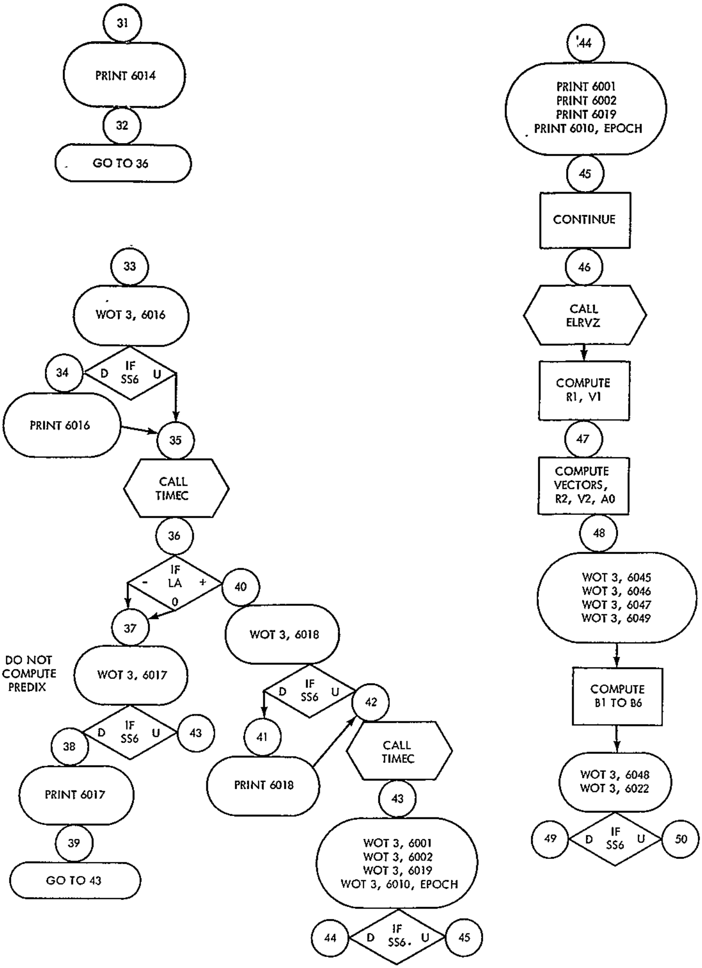
APPENDIX IV

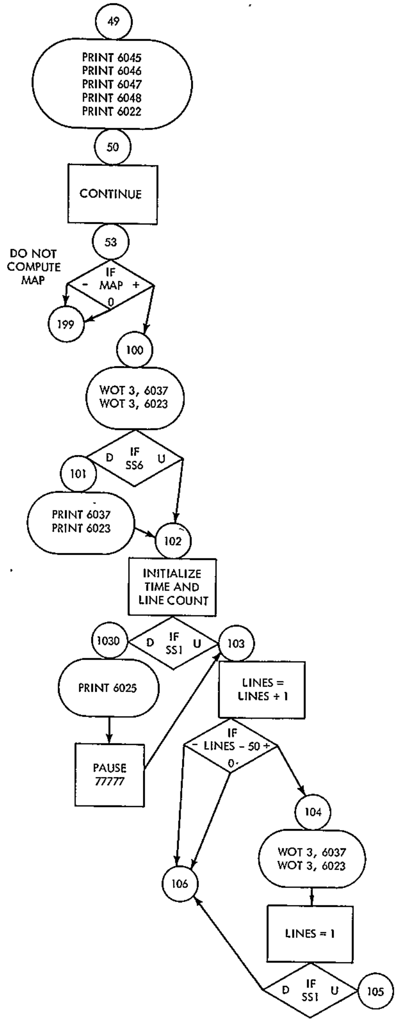
FLOW CHART FOR MAIN PROGRAM TWO

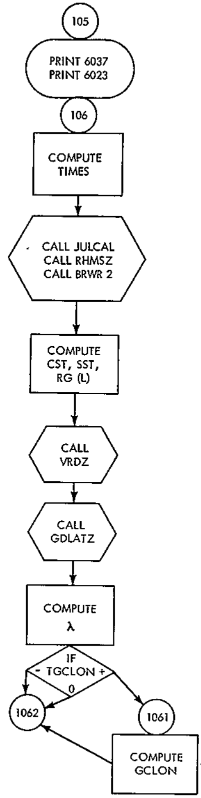


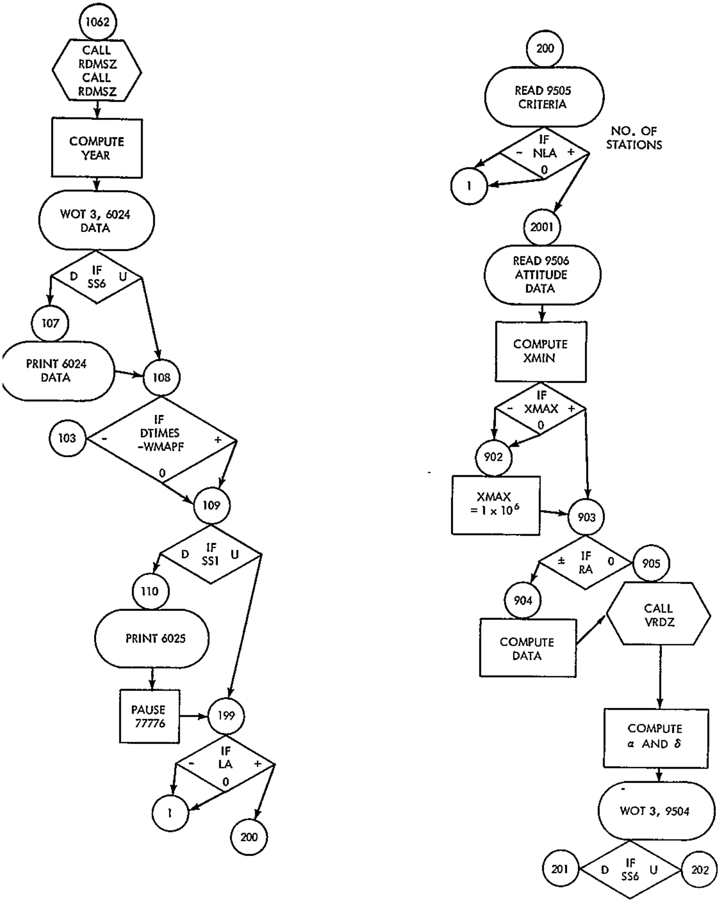
START PROGRAM
1
DEFINE CONSTANTS
READ 6002
READ 6003, INPUT, MAP, LA, NCST, NERR, NDA, IRC
IF INPUT
300
2
IF NERR
3
4
READ 6040, ERR
IF NCST
10
READ 6004 EARTH CONSTANTS
USE GSFC VALUES
5
IF ±NCST+1-0
7
6
11
IF NCST + 2
8
DEFINE EARTH CONSTANTS
DEFINE GP (L) L = 1,5
12
DEFINE EARTH CONSTANTS
GSFC
11
9
WOT 3, 6001 WOT 3, 6002 WOT 3, 6005, EARTH CONSTANTS WOT 3, 6044, GP (L)
DEFINE EARTH CONSTANTS
INTERNATIONAL
13
IF SW6
913
13
PRINT SAME DATA AS 12
913
IF NDA
914
915
READ 6050 DAD (N)
COMPUTE DA (1) DA (2)
DO 916 N = 3,6
916
COMPUTE DA (N)
IF IRC
918
917
READ 6006, EPOCH, AI (N), N = 1,6
IRC = 50
WOT 3, 6010, EPOCH WOT 3, 6008, INPUT
IF SS6
16
PRINT 6010, EPOCH PRINT 6008, INPUT
17

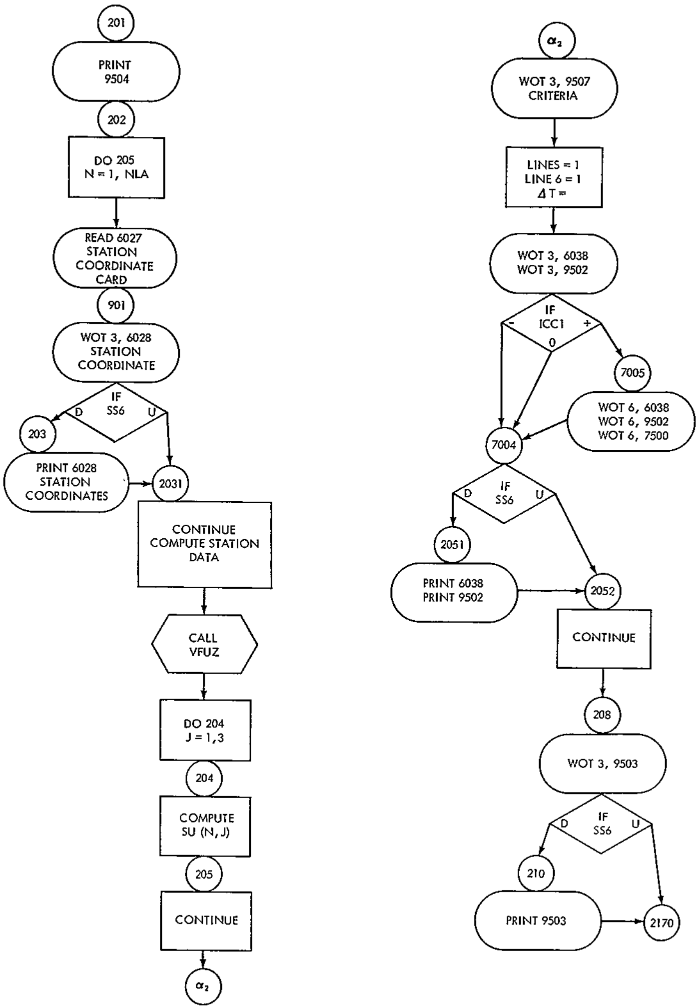

17
CONTINUE
CONVERT EPOCH OF ELEMENTS
GO TO (18,20,22,930), INPUT
18
WOT 3,6012
WOT 3,6013, AI (N)
IF SS6
D
U
19
PRINT 6012
PRINT, 6013 AI (N)
28
20
WOT 3, 6042
WOT 3, 6043, AI (N)
IF SS6
D
U
21
PRINT 6042
PRINT 6043, AI (N)
28
22
WOT 3, 6009
WOT 3, 6011, AI (N)
IF SS6
D
U
23
PRINT 6009
PRINT 6011, AI (N)
28
930
WOT 3, 6051
931
WOT 3, 6013
AI (N)
IF SS6
D
U
932
PRINT 6051
PRINT 6013, AI (N)
28
CALL PARA
CALL ELRVZ
CALL BBRWR
COMPUTE VARIABLES
IF MAP 0
−
+
33
30
DO NOT COMPUTE MAP
WOT 3, 6014
IF SS6
D
U
31
36

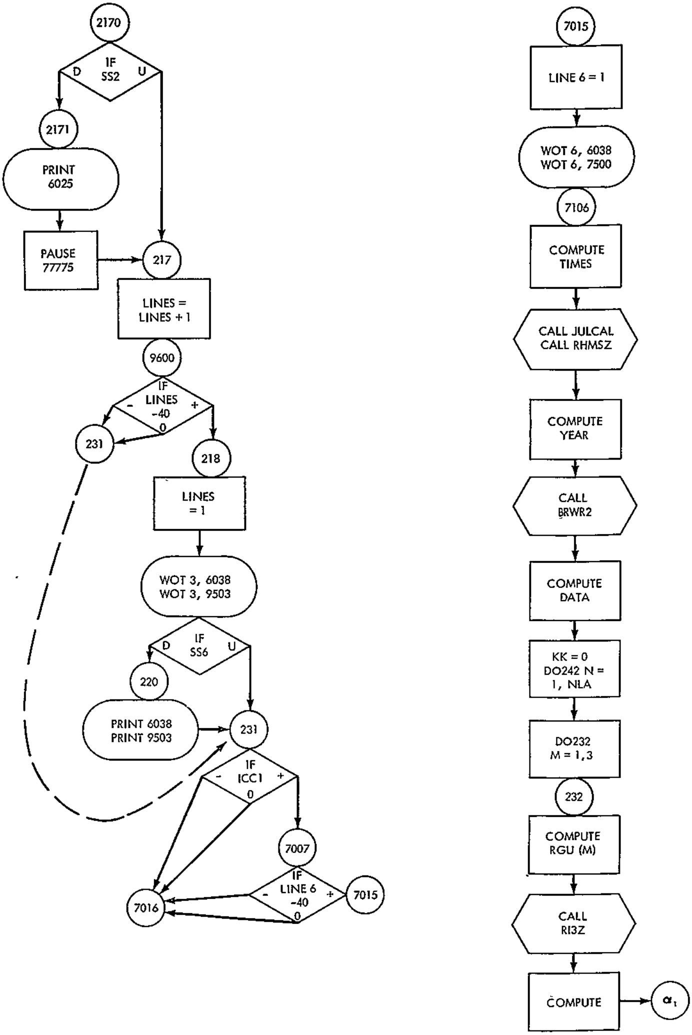

31
PRINT 6014
32
GO TO 36
33
WOT 3, 6016
34
IF SS6
D
U
PRINT 6016
35
CALL TIMEC
36
IF LA
-
+
0
40
37
WOT 3, 6018
DO NOT COMPUTE PREDIX
WOT 3, 6017
IF SS6
D
U
42
38
43
41
CALL TIMEC
PRINT 6017
PRINT 6018
43
39
GO TO 43
WOT 3, 6001
WOT 3, 6002
WOT 3, 6019
WOT 3, 6010, EPOCH
44
IF SS6.
45
44
PRINT 6001
PRINT 6002
PRINT 6019
PRINT 6010, EPOCH
45
CONTINUE
46
CALL ELRVZ
COMPUTE R1, V1
47
COMPUTE VECTORS, R2, V2, A0
48
WOT 3, 6045
WOT 3, 6046
WOT 3, 6047
WOT 3, 6049
COMPUTE B1 TO B6
WOT 3, 6048
WOT 3, 6022
49
IF SS6
50


49
PRINT 6045
PRINT 6046
PRINT 6047
PRINT 6048
PRINT 6022
50
CONTINUE
53
DO NOT COMPUTE MAP
IF MAP
-
+
0
199
100
WOT 3, 6037
WOT 3, 6023
IF SS6
D
U
101
PRINT 6037
PRINT 6023
102
INITIALIZE TIME AND LINE COUNT
1030
IF SS1
D
U
103
PRINT 6025
PAUSE 77777
LINES = LINES + 1
IF LINES - 50
-
+
0
104
WOT 3, 6037
WOT 3, 6023
LINES = 1
106
IF SS1
D
U
105

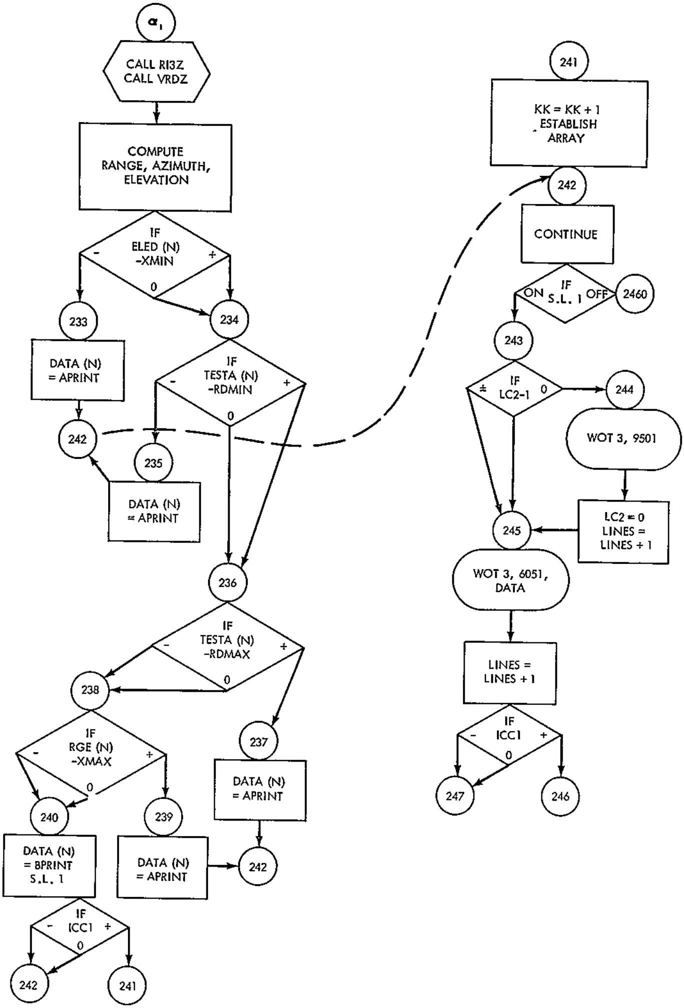

105
PRINT 6037
PRINT 6023
106
COMPUTE TIMES
CALL JULCAL
CALL RHMSZ
CALL BRWR 2
COMPUTE CST, SST, RG (L)
CALL VRDZ
CALL GDLATZ
COMPUTE λ
IF TGCLON
-
+
0
1062
1061
COMPUTE GCLON


1062
CALL RDMSZ CALL RDMSZ
COMPUTE YEAR
WOT 3, 6024 DATA
IF SS6
D
U
107
PRINT 6024 DATA
108
IF DTIMES -WMAPF
-
+
0
103
109
IF SS1
D
U
110
PRINT 6025
PAUSE 77776
199
IF LA
-
+
0
1
200
200
READ 9505 CRITERIA
IF NLA
-
+
0
NO. OF STATIONS
1
2001
READ 9506 ATTITUDE DATA
COMPUTE XMIN
IF XMAX
-
+
0
902
XMAX = 1 x 10^6
903
IF RA
±
0
904
905
COMPUTE DATA
CALL VRDZ
COMPUTE α AND δ
WOT 3, 9504
IF SS6
D
U
201
202

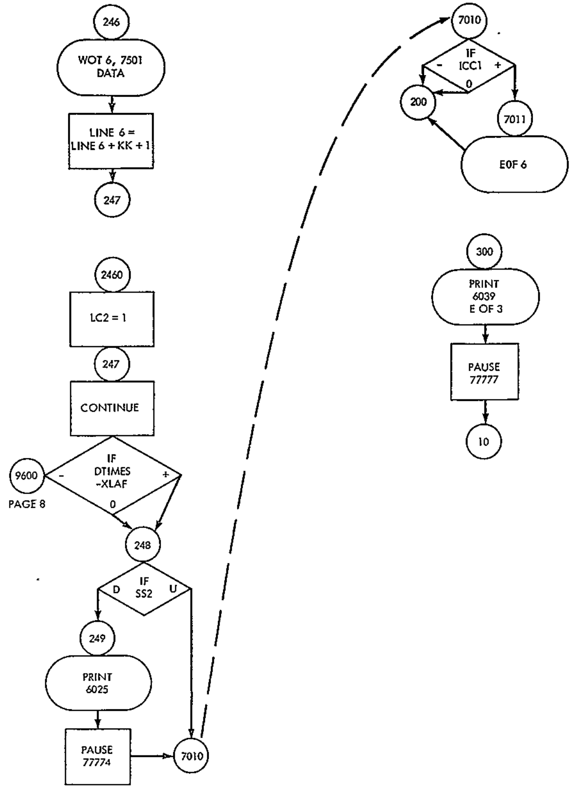

201
PRINT 9504
202
DO 205 N = 1, NLA
READ 6027 STATION COORDINATE CARD
901
WOT 3, 6028 STATION COORDINATE
IF SS6
D
U
203
PRINT 6028 STATION COORDINATES
2031
CONTINUE COMPUTE STATION DATA
CALL VFUZ
DO 204 J = 1,3
204
COMPUTE SU (N, J)
205
CONTINUE
α2
α2
WOT 3, 9507 CRITERIA
LINES = 1
LINE 6 = 1
ΔT =
WOT 3, 6038
WOT 3, 9502
IF ICC1
-
0
+
7005
WOT 6, 6038
WOT 6, 9502
WOT 6, 7500
7004
IF SS6
D
U
2051
PRINT 6038
PRINT 9502
2052
CONTINUE
208
WOT 3, 9503
IF SS6
D
U
210
PRINT 9503
2170



2170
IF SS2
D
U
2171
PRINT 6025
PAUSE 77775
217
LINES = LINES + 1
9600
IF LINES -40
-
+
0
231
218
LINES = 1
WOT 3, 6038
WOT 3, 9503
IF SS6
D
U
220
PRINT 6038
PRINT 9503
231
IF ICC1
-
+
0
7007
IF LINE 6 -40
-
+
0
7015
7016
7015
LINE 6 = 1
WOT 6, 6038
WOT 6, 7500
7106
COMPUTE TIMES
CALL JULCAL
CALL RHMSZ
COMPUTE YEAR
CALL BRWR2
COMPUTE DATA
KK = 0
DO242 N = 1, NLA
DO232 M = 1,3
232
COMPUTE RGU (M)
CALL RI3Z
COMPUTE
α1



α1
CALL RI3Z
CALL VRDZ
COMPUTE
RANGE, AZIMUTH,
ELEVATION
IF
ELED (N)
-XMIN
233
234
DATA (N)
= APRINT
IF
TESTA (N)
-RDMIN
242
235
DATA (N)
= APRINT
236
IF
TESTA (N)
-RDMAX
238
237
IF
RGE (N)
-XMAX
DATA (N)
= APRINT
240
239
DATA (N)
= BPRINT
S.L. 1
DATA (N)
= APRINT
242
IF
ICC1
242
241
241
KK = KK + 1
ESTABLISH
ARRAY
242
CONTINUE
IF
S.L. 1
ON
OFF
2460
243
IF
LC2-1
244
WOT 3, 9501
LC2 = 0
LINES =
LINES + 1
245
WOT 3, 6051,
DATA
LINES =
LINES + 1
IF
ICC1
247
246


246
WOT 6, 7501
DATA
LINE 6 =
LINE 6 + KK + 1
247
2460
LC2 = 1
247
CONTINUE
IF
DTIMES
-XLAF
9600
PAGE 8
-
+
0
248
IF
SS2
D
U
249
PRINT
6025
PAUSE
77774
7010
7010
IF
ICC1
-
+
0
200
7011
EOF 6
300
PRINT
6039
E OF 3
PAUSE
77777
10

APPENDIX V

SOURCE DECK FOR MAIN PROGRAM ONE

```
*      DATE 5/6/65
*      G D REPASS
*      PAUSE
*      CARDS COLUMN
*      LIST8
*      LABEL
C       MUSTAP PROGRAM   VERSION 2  THEORY AND ANALYSIS OFFICE - GSFC
C
C      GENERALIZED WORLD MAP AND LOCAL STATION PREDICTIONS PROGRAM.
C
C      1A. CONVERTS OSCULATING ORBITAL ELEMENTS TO INERTIAL POSITION
C            AND VELOCITY RECTANGULAR COORDINATES.
C      1B. CONVERTS INERTIAL POSITION AND VELOCITY RECTANGULAR
C            COORDINATES TO OSCULATING ORBITAL ELEMENTS.
C      2.  COMPUTES WORLD MAP ON REQUEST.
C      3.  COMPUTES LOCAL STATION PREDICTIONS (LOOK ANGLES) ON REQUEST.
C
C      ALL INTERNAL CALCULATIONS ARE PERFORMED USING THE KILOMETER AS
C      THE UNIT OF LENGTH AND THE SECOND AS THE UNIT OF TIME.  IF ANY
C      OF THE OPTIONAL INPUT PARAMETERS ARE DEFINED IN OTHER UNITS,
C      THEY ARE CONVERTED TO THESE UNITS AS SOON AS THEY ARE READ IN
C      AND ARE SUBSEQUENTLY USED IN THE CALCULATIONS IN KILOMETERS
C      AND SECONDS.
C
C      THE ORBIT REQUIRED FOR THE WORLD MAP AND LOCAL STATION PREDICTIONS
C      IS GENERATED BY SUBROUTINES BRWR1 AND BRWR2 (DIRK BROUWER -
C      SOLUTION OF THE PROBLEM OF ARTIFICIAL SATELLITE THEORY WITHOUT
C      DRAG)
C
C      REQUIRED SUBROUTINES AND FUNCTIONS
C      ALLOT
C      ALLOTZ
C      ARKTAN
C      ATANQ
C      ATANZ
C      BACK
C      BBRWR
C      BRWR1
C      BRWR2
C      CH65K
C      DJUL
C      DMSRZ
C      DOTZ
C      FLRV
C      FLRVZ
C      FQN
C      GASTZ
C      GDLATZ
C      HMSRZ
C      JULCAL
C      PARA
C      RDMSZ
C      RHMSZ
C      RVFLZ
C      R13Z
C      TESCOV
C      TIMEC
C      TIME4
C      STASH
C      SUN
C      VEUZ
C      VPDZ
C      XKEP
C      XKEPZ
C
C      Z END OF NAME OF FUNCTION OR SUBROUTINE INDICATES THAT INPUT,
C      OUTPUT, AND INTERNAL ARITHMETIC ARE PERFORMED IN DOUBLE PRECISION.
C
C      DEFINITION OF SYMBOLS
C
C      ERR = TRUNCATION FACTOR (IN RADIANS) USED IN SOLUTION OF
C      KEPLERS EQUATION
C      GM = PRODUCT OF G (=GAUSSIAN CONSTANT SQUARED) AND M, THE MASS OF
C      THE EARTH, IN UNITS OF KM. CUBED/SEC SQUARED
C      FJ2=J2 )
C      FJ3=J3 ) HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL
C      FJ4=J4 ) (DIMENSIONLESS)
C      FJ5=J5 )
C      FL=INVERSE OF FLATTENING
C      RE= EQUATORIAL RADIUS OF EARTH IN KM.
C
C      SENSE SWITCH 6 IS USED IN THE MAIN PROGRAM TO PROVIDE AN OPTION TO
C      GET THE INPUT PRINTED ON LINE.
C
C      ALL FORMATS USED IN PROGRAM FOLLOW IMMEDIATELY.
C
 6002 FORMAT(12A6)
 6003 FORMAT (8I3,F10.1)
 6004 FORMAT (E12.6,4E12.5/2F12.4)
 6005 FORMAT (/ 1X1PE14.8,9X23H FEET PER NAUTICAL MILE//
     1 1X0PF8.3,9X33H EQUATORIAL RADIUS OF EARTH IN KM /2XF5.1,11X22H IN
     2VERSE OF FLATTENING/1X,1PE14.8,3X31H GM (KM. CUBED/SECONDS SQUARED
```

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     3) //18X44H HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL  /1XE13.6,
     4 4X3H J2/1X,F13.6,4X3H J3/1X,E13.6,4X3H J4 /1X,E13.6,4X3H J5  )
 6006 FORMAT (X,A5,X,3I2,X,2I2,X,F4.2,39X,I5/6E12.8)
 6008 FORMAT (/1XI3,14X20H INPUT OPTION NUMBER/18X24H INPUT PARAMETERS A
     1RE---  //)
 6009 FORMAT (82H0        X               Y               Z            X DOT
     1        Y DOT           Z DOT     )
 6010 FORMAT ( 9H0EPOCH    5(I2,X),F6.3)
 6011 FORMAT (X,1P6E14.7)
 6012 FORMAT(21H0 OSCULATING ELEMENTS  )
 6014 FORMAT (/18X,25H NO WORLD MAP CALCULATION      )
 6016 FORMAT (/45H WORLD MAP CALCULATIONS - START AND END TIMES//)
 6017 FORMAT (/18X,26H NO LOOK ANGLE CALCULATION    )
 6018 FORMAT (/46H LOOK ANGLE CALCULATIONS - START AND END TIMES//)
 6020 FORMAT (/ 1X,F13.5,4X,16H X1 - KILOMETERS/1X,F13.5,4X,3H X2/1X,
     1 F13.5,4X,3H X3//5X,F12.8,22H  VX1- KILOMETERS/SEC./5X,F12.8,
     2 5H  VX2/5X,F12.8,5H  VX3 )
 6021 FORMAT (/ 2X,F11.4,5X,27H SEMI-MAJOR AXIS-KILOMETERS/6X,F11.8,
     1 14H  ECCENTRICITY/3X,F12.6,3X,12H INCLINATION,3X,9H -DEGREES/3X,
     2 F12.6,3X,24H R.A. ASC. NODE -DEGREES/3X,F12.6,3X,24H ARG. OF PERI
     3GEE-DEGREES/3X,F12.6,3X,24H MEAN ANOMALY   -DEGREES    )
 6023 FORMAT (5H DATE,6X14HUNIVERSAL TIME,16X20HGEODETIC COORDINATES/
     1 9H MO/DY/YR,3X4HH   M,3X4HSEC.,9X39HLATITUDE-DMS  LONGITUDE-DMS  H
     2EIGHT-KM. //)
 6024 FORMAT (1XI2,1H/,I2,1H/,I2,2X2I3,F7.3,8X2I3,F6.2,2XI4,I3,F6.2,
     1 F11.3   )
 6025 FORMAT (11H PUSH START /////)
 6026 FORMAT (1H1//15X33H LOCAL STATION PREDICTIONS FOR -- //8H STATION,
     1 5X10H LONGITUDE,6X9H LATITUDE,4X16H HEIGHT (METERS) //)
 6027 FORMAT (1X,2A3,I5,I3,F7.3,I4,I3,F7.3,F11.2)
 6028 FORMAT (1X,2A3,5XI4,I3,F7.3,I5,I3,F7.3,4XF10.2)
 6037 FORMAT (1H1/45X10H WORLD MAP //)
 6038 FORMAT (27H1LOCAL STATION PREDICTIONS
 6039 FORMAT (13H JOB FINISHED  /////)
 6040 FORMAT (F8.2)
 6041 FORMAT (28H1EXECUTE MAIN PROGRAM-WMAPLA/1H1
 6050 FORMAT(6F12.8)
 6051 FORMAT (82H0        A
     1        OMEGA           THETA
 6052 FORMAT (X,2I2,X,19(X,A3,A2))
 9501 FORMAT(1H0,8H  ******//)
 9502 FORMAT (1H0,17HMUTUAL VISIBILITY//)
 9503 FORMAT(5H0DATE,5X15H UNIVERSAL TIME/23H MO/DY/YR   H  M   SEC.,
     1 5X,6(4XA6))
 9504 FORMAT(1H1//15X33H LOCAL STATION PREDICTIONS FOR -- //8H STATION,
     15X10H LONGITUDE ,6X9H LATITUDE,4X16H HEIGHT (METERS)//)
 9505 FORMAT (3I3,F10.0,51X,I2)
 9506 FORMAT (4F6.1,I6)
 9507 FORMAT(/////6X27H NO STATION PRINT OUT IF --//
     11X,25H   ELEVATION IS LESS THAN,14X,I3,8H DEGREES//
     27X58H 5 IS PRINTED IF THE ELEVATION IS GREATER THAN OR EQUAL TO I5,
     324H AND LESS THAN 5 DEGREES/7X89H  9 IS PRINTED IF THE ELEVATION I
     4S GREATER THAN OR EQUAL TO   5  AND LESS THAN 10 DEGREES/7X72H  A
     5IS PRINTED IF THE ELEVATION IS GREATER THAN OR EQUAL TO  10  DEGRE
     6ES//7X40HA T IS PRINTED OF RANGE IS GREATER THAN  E16.8 ,14HNAUTIC
     7AL MILES//)
 3013 FORMAT(34X,25HSPIN AXIS COORDINATES ARE/37X,F6.1,24H DEGREES RIGHT
     1 ASCENSION/ 37X,F6.1,20H DEGREES DECLINATION    )
C     IF NCST=+00, RETAIN STANDARD GODDARD EARTH CONSTANTS AND PROCEED
 7500 FORMAT(5H0DATE,7X3HUT2,15X5HRANGE,3X2HAZ,3X2HEL,3X5HRADAR/
     1 9H MO/DY/YR,16H    H  M  STATION,6X4H(KM),12H (DEG) (DEG)   ,
     2 12H ANGLE (DEG)    //)
 7501 FORMAT(XI2,2(1H/I2),1X,2(I3),2X,2A3,3XF8.1,1XF5.1,XF4.1,2XF5.1/
     118X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2X
     2F5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1
     3  ,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1
     4 ,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1
     5,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3X
     6 F8.1,XF5.1,XF4.1,2XF5.1/
     718X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1)
  330 FORMAT (23H  MUTUAL VISIBILITY OF A6,29H FOR THE FOLLOWING STATION
     1S    )
  331 FORMAT ( 6H HHMM 19(3X,A3))
C
C     ALL DIMENSION STATEMENTS FOLLOW IMMEDIATELY.
C
D     DIMENSION RX(3),VX(3),A(6),AI(6),RG(3),VG(3),RLAT(19),RLON(19)
D     DIMENSION RGU(3),Z(3),COORD(3),U(3),SU(19,3)
      DIMENSION ELED(19),AZID(19),RGE(19),TESTA(19),STAT1(19),STAT(19)
      DIMENSION RGE1(19),ELED1(19),AZID1(19),TESTA1(19),STAT3(19)
      DIMENSION GP(5),DA(6),DAD(6),A110(6),XX(12),AB(6),RXB(3)
D     DIMENSION VXE(3),RTX(3)
      DIMENSION STAT4(19),DATA(19),VXB(3),XXX(10),SS(3)
      DIMENSION DUM1(100),CALI(15),XRG(19),XAZ(19),XEL(19),XR(19)
      DIMENSION XFSTA(19),XZ(19),SA(19),IN(19),IZ(19)
      DIMENSION SHED(12),XHEAD(12)
      DIMENSION PRE(140),WPUV(44),MVPI(8)
      COMMON DUM1,A110,GP,ERRB,XX,AB,RXB,VXB,XXX,SS
C
      PRINT 6041
C
C     DEFINE TRUNCATION FACTOR (RADIANS)
```

```
C
C      TEST FOR 65K SETTING.
 5041 CALL CH65K(NW)
      IF(NW)5038,5042,5038
 5038 PRINT 5040
      WRITE OUTPUT TAPE 3,5040
 5040 FORMAT (19HO NOTE TO OPERATOR / 72H PUT MACHINE IN 65K , REWIND AL
     1L TAPES , AND START JOB FROM BEGINNING .     )
      REWIND 1
      PAUSE 00010
      GO TO 5038
 5042 IF(SENSE LIGHT 2) 1,1
D   1 ERR=1.0E-8
      ERRB=3.0E-7
      ITAPE4 = 8
      LPAS = 0
      NPAG3 = 0
C
C      DEFINE TRUNCATION FACTORS FOR SUBROUTINE BBRWR ( USED TO CONVERT
C      OSCULATING ELEMENTS TO BROUWER MEAN ELEMENTS)
C
      DAD(1)=5.0E-4
      DAD(2)=5.0E-6
      DAD(3)=5.0E-6
      DAD(4)=5.0E-6
      DAD(5)=5.0E-6
      DAD(6)=5.0E-6
C
      LC2=0
      IRED = 0
B     APRINT=60 60 60 60 60 60
B     BPRINT = 60 21 60 60 60 60
B     DPRINT = 60 05 60 60 60 60
B     EPRINT = 60 11 60 60 60 60
B     XRXX =   74 77 77 77 77 77
      XNMET = 6080.
      NUMSUN = 0
      XS700 = 0.
      IZNU = 0
      DO 4002 I = 1,12
B4002 SHED(I) = 606062612360
C     ASSUME VEHICLE STARTS OFF IN SHADOW
      IVA = 0
      IESY = 0
      IESMO = 0
      IESD = 0
      IESH =0
      IESM = 0
C
C     DEFINE GODDARD EARTH CONSTANTS
C
D     GM=3.986032E+5
D     EJ2=1.0823E-3
D     EJ3=-2.3E-6
D     EJ4=-1.8E-6
D     EJ5=0.0
D     FL=298.3
D     RE=6378.165
C
C     CARD 1 - READ IN I.D. CARD - ANY INFORMATION IN COLS. 2 - 72
C
      READ 6002,(XHEAD(I),I = 1,12)
C
C     CARD 2 - READ IN CONTROL CARD
C
C     COLS. 1-3 TYPE OF INPUT (+03 = INERTIAL POSITION AND VELOCITY
C                                    IN VANGUARD UNITS
C                             +01 = OSCULATING ELEMENTS-CU AND RAD
C                             +04 = BROUWER MEAN ELEMENTS          )
C     COLS.  4-6   COMPUTE WORLD MAP AND PREDICTIONS - YES OR NO
C                  ( YES IF MAP=+XX, NO IF MAP=+00 OR -XX )
C     COLS.  7-9   +XX ALWAYS
C     COLS. 10-12  CHANGE EARTH CONSTANTS
C     COLS. 13-15  CHANGE TRUNCATION FACTOR
C     COLS. 16-18  BBRWR TRUNCATION CONTROL
C     COLS. 19-21  BLANK - USED INTERNALLY
C     COLS. 22-24  NUMBER OF CONTROL STATIONS
C     COLS. 25-34  MAXIMUM RANGE TEST VALUE NAUTICAL MILES
      READ 6003,INPUT,MAP,LA,NCST,NERR,NDA,IRC,I2CT,RGMA
C
C     I2CT IS THE NUMBER OF CONTROL STATIONS.
C     TEST - HAVE ALL CASES BEEN RUN - YES OR NO
C
      IF(I2CT - 19) 5034,5034,3010
 3010 PRINT 5033,I2CT
      WRITE OUTPUT TAPE 3,5033,I2CT
 5033 FORMAT(15HOYOU ARE USING I6,60H CONTROL STATIONS. THE PROGRAM CAN
     1ONLY HANDLE 19 STATIONS.     )
   68 PAUSE 54321
      GO TO 68
 5034 IF(INPUT)300,300,2
C     IF INPUT=+00 OR -XX, ALL CASES HAVE BEEN RUN.  GO TO 300 (END
```

```
C
C     TEST - CHANGE TRUNCATION FACTOR - YES OR NO
C
    2 IF (NERR) 4,4,3
C
C     CARD 2A- (OPTIONAL) READ IN NEW VALUE OF TRUNCATION FACTOR IF
C                         NERR=+XX.  IF NERR=+00 OR -XX, PROCEED TO NEXT
C                         OPTION TEST.
C
    3 READ              6040,ERR
C
C     TEST - CHANGE EARTH CONSTANTS - YES OR NO
C
    4 IF (NCST) 5,11,10
C
C     TO NEXT STEP.
C
    5 IF (NCST+1) 7,6,7
C
C     USE SIRY PACKAGE CONSTANTS IF NCST = -1
C
D   6 GM=3.9862688E+05
D     FJ2=1.08219E-03
D     FJ3=-2.285E-06
D     FJ4=-2.123E-06
D     FJ5=-2.32E-07
D     FL=297.0
D     RE=6378.388
      GO TO 11
    7 IF (NCST+2) 9,8,11
C
C     USE GODDARD EARTH CONSTANTS WITH HARMONICS =0 IF NCST = -2
C
D   8 FJ2=0.0
D     FJ3=0.0
D     FJ4=0.0
D     FJ5=0.0
      GO TO 11
C
C     USE INTERNATIONAL CONSTANTS WITH HARMONICS = 0 IF NCST = -3
C
D   9 GM=3.98626873E+5
D     FJ2=0.0
D     FJ3=0.0
D     FJ4=0.0
D     FJ5=0.0
D     FL=297.0
D     RE=6378.388
      GO TO 11
C
C     CARDS 2B AND 2C- (OPTIONAL) READ IN NEW SET OF EARTH CONSTANTS
C                                 IF NCST=+XX.
C
   10 READ              6004,GM,FJ2,FJ3,FJ4,FJ5,FL,RE
C
C     CONVERT EARTH CONSTANTS
C
   11 GP(1)=GM
      GP(2)=.5*FJ2*RE**2
      GP(3)=-FJ3*RE**3
      GP(4)=-.375*FJ4*RE**4
      GP(5)=-FJ5*RE**5
C
C     PRINT ALL QUANTITIES ON OUTPUT TAPE A3.
C
   12 WRITE OUTPUT TAPE 3,3089
      WRITE OUTPUT TAPE ITAPE4,3089
      WRITE OUTPUT TAPE 3,3087,(XHEAD(I),I = 1,12)
      WRITE OUTPUT TAPE ITAPE4,3087,(XHEAD(I), I = 1,12)
      WRITE OUTPUT TAPE 3,3089
      WRITE OUTPUT TAPE 3,5025,(XHEAD(I),I = 1,12)
 3087 FORMAT (///////////////  2(21X6A6/))
 3088 FORMAT (1H0)
 5025 FORMAT (///////////////////////// 2(54X,6A6/))
      WRITE OUTPUT TAPE 3,3089
 3089 FORMAT (1H1)
      WRITE OUTPUT TAPE 3,3088
      WRITE OUTPUT TAPE ITAPE4,3089
      WRITE OUTPUT TAPE ITAPE4,3088
      WRITE OUTPUT TAPE 3,6005,XNMET,RE,FL,GM,FJ2,FJ3,FJ4,FJ5
      WRITE OUTPUT TAPE ITAPE4,6005,XNMET,RE,FL,GM,FJ2,FJ3,FJ4,FJ5
      IF (SENSE SWITCH 6) 13,913
C
C     PRINT SAME INFORMATION ON LINE IF SENSE SWITCH 6 IS DOWN.
C
   13 PRINT 6002
      PRINT 6005,XNMET,RE,FL,GM,FJ2,FJ3,FJ4,FJ5
  913 IF (NDA) 915,915,914
  914 READ              6050, (DAD(N), N=1,6)
  915 DA(1)=DAD(1)
      DA(2)=DAD(2)
      DO 916 N=3,6
```

```
  916 DA(N)=DAD(N)*0.017453292
      IF (IRC) 917,917,918
  917 IRC=50
C     CARD 4 - READ IN PARAMETERS
C     TAKES STANDARD EPOCH AND ELEMENT CARDS
C     ALL PARAMETERS USE STANDARD FORMAT (6E12.8)
C
  918 READ 6006,IDSAT,NYE,NME,NDE,NHE,NMNE,TSE,NORBIT,(AI(N), N = 1,6)
      NYE = 1900 + NYE
C
C     PRINT EPOCH AND INPUT OPTION ON OUTPUT TAPE A3
C
   15 WRITE OUTPUT TAPE 3,6010,NYE,NME,NDE,NHE,NMNE,TSE
      WRITE OUTPUT TAPE ITAPE4,6010,NYE,NME,NDE,NHE,NMNE,TSE
      IF (SENSE SWITCH 6) 16,17
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
   16 PRINT 6010,NYE,NME,NDE,NHE,NMNE,TSE
   17 CONTINUE
C     READ THE EPOCH AND DRAG TERM. THE UNITS OF THE DRAG TERM ARE
C     RADIANS PER CUT**2.
C     CHANGE DRAG TO RADIANS PER SECOND**2 BY DIVIDING BY 806.832**2.
      READ 5028,IDG1,IDG2,IDG3,IDG4,IDG5,IDG6,EN2
 5028 FORMAT (7X,3I2,X,2I2,X,I2,4X,E12.8)
C
C     CONVERT EPOCH UNIVERSAL TIME IN HOURS, MINUTES, AND SECONDS
C     TO EPOCH UNIVERSAL TIME IN RADIANS.
C
D     TIMEO=HMSRZ(NHE,NMNE,TSE)
C
C     CONVERT EPOCH CALENDAR DATE TO EPOCH JULIAN DATE AT 0 HOURS
C     UNIVERSAL TIME.
C
      DJO=DJUL(NME,NDE,NYE)
C
C
C     CONVERT EPOCH UNIVERSAL TIME IN HOURS, MINUTES, AND SECONDS
C     TO SECONDS.
C
      THE=NHE*3600
      TMNE=NMNE*60
      TSEP=THE+TMNE+TSE
      GO TO (18,1,22,930), INPUT
   18 WRITE OUTPUT TAPE 3,6012
C     INPUT OPTION 1 - OSCULATING ELEMENTS IN VANGUARD UNITS AND RADIANS
      WRITE OUTPUT TAPE ITAPE4,6012
      WRITE OUTPUT TAPE 3,6051
      WRITE OUTPUT TAPE ITAPE4,6051
      WRITE OUTPUT TAPE 3,6011,      (AI(N),N = 1,6)
      WRITE OUTPUT TAPE ITAPE4,6011,(AI(N),N = 1,6)
      IF(SENSE SWITCH 6)19,3002
   19 PRINT 6012
      PRINT 6051
      PRINT 6011, (AI(N),N=1,6)
      GO TO 3002
C
C     PRINT INPUT PARAMETERS ON OUTPUT TAPE A3 - INPUT OPTION 3
C     INERTIAL POSITION AND VELOCITY RECTANGULAR COORDINATES -
C     IN VANGUARD UNITS.
C
   22 WRITE OUTPUT TAPE 3,6009
      WRITE OUTPUT TAPE ITAPE4,6009
      WRITE OUTPUT TAPE 3,6011,(AI(N),N=1,6)
      WRITE OUTPUT TAPE ITAPE4,6011,(AI(N),N = 1,6)
      IF (SENSE SWITCH 6) 23,28
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
   23 PRINT 6009
      PRINT 6011,(AI(N),N=1,6)
      GO TO 28
C
C     PRINT INPUT PARAMETERS - INPUT OPTION 4 - BROUWER MEAN ELEMENTS
C
  930 WRITE OUTPUT TAPE 3,6051
      WRITE OUTPUT TAPE ITAPE4,6051
  931 WRITE OUTPUT TAPE 3,6011,(AI(N),N = 1,6)
      WRITE OUTPUT TAPE ITAPE4,6011,(AI(N), N = 1,6)
      IF (SENSE SWITCH 6) 932,3002
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
  932 PRINT 6051
      PRINT 6011,(AI(N),N = 1,6)
C     CONVERT  TO KM AND DEGREES
D3002 AI(1) = AI(1) * 6378.388
D     AI(3) = AI(3) * 57.2957795130823
      AAMA = AI(4)
D     AI(4) = AI(6) *57.2957795130823
D     AI(5) = AI(5) * 57.2957795130823
D     AI(6) = AAMA  * 57.2957795130823
```

```
C
C     CØNVERT INPUT PARAMETERS TØ ØSCULATING ELEMENTS
C
D  28 CALL PARA(INPUT,AI,A,GM)
 5027 FØRMAT (13HODRAG EFFECTS ,6X,7HT (P,Q),8X,7HN (2,Q),9X,7HN (3,Q)
    1 14X,2(X,3I2),2(3X,E15.8))
      WRITE ØUTPUT TAPE ITAPE4,5027,IDG1,IDG2,IDG3,IDG4,IDG5,IDG6,EN2
      WRITE ØUTPUT TAPE      3,5027,IDG1,IDG2,IDG3,IDG4,IDG5,IDG6,EN2
D     EN2 = EN2 / 806.832**2
D     CALL ELRVZ(RX,VX,A,PER,EN,GM,ERR)
      CALL BBRWR(DA,A,IRC,NN)
D     VXE(1)=VX(1)
D     VXE(2)=VX(2)
D     VXE(3)=VX(3)
      EN=SS(1)
      DP=SS(2)
      DN=SS(3)
D     PER=6.28318530718/EN
D     PERM=PER/60.0
D     PERH=PER/3600.0
D     EN1=EN*206264.806247096
D     DNØDE=DN*4950355.3499303
D     DPERI=DP*4950355.3499303
C
C     TEST - IS WØRLD MAP DESIRED
C
   29 IF (MAP) 30,30,33
   30 WRITE ØUTPUT TAPE 3,6014
      IF (SENSE SWITCH 6) 31,36
   31 PRINT 6014
   32 GØ TØ 36
   33 CØNTINUE
C
C
C
   36 CØNTINUE
C
C     CARD 10 - STATIØN PREDICTIØNS AND WØRLD MAP ARE REQUIRED. READ
C               IN CALENDAR DATE AND UNIVERSAL TIME AT WHICH THE START
C               ØF THE CALCULATIØN IS DESIRED, CALENDAR DATE AND
C               UNIVERSAL TIME AT WHICH THE TERMINATIØN ØF THE
C               CALCULATIØN IS DESIRED, AND THE DESIRED TIME INCREMENT
C               ØF THE CALCULATIØN IN SECØNDS.
C
   40 WRITE ØUTPUT TAPE 3,6018
      WRITE ØUTPUT TAPE ITAPE4,6018
C
C     PRINT SAME INFØRMATIØN ØN-LINE IF SENSE SWITCH 6 IS DOWN
C
      IF (SENSE SWITCH 6) 41,42
   41 PRINT 6018
   42 CALL TIMC4(DJ0,TSEP,XLAS,XLAF,DTLA)
C
C     PRINT SAME INFØRMATIØN ØN-LINE IF SENSE SWITCH 6 IS DØWN
C
   43 CØNTINUE
C
C     CØNVERT ØSCULATING ØRBITAL ELEMENTS TØ INERTIAL PØSITIØN AND
C     VELØCITY CØØRDINATES IN KM AND KM/SEC
C
D  46 CALL ELRVZ(RX,VX,A,PER,EN,GM,ERR)
D     R1=SQRTF(RX(1)**2+RX(2)**2+RX(3)**2)
D     V1=SQRTF(VX(1)**2+VX(2)**2+VX(3)**2)
C
C     CØNVERT TØ VANGUARD UNITS ØF LENGTH AND VELØCITY
C
D  47 XØ1=RX(1)/6378.388
D     XØ2=RX(2)/6378.388
D     XØ3=RX(3)/6378.388
D     VØ1=VX(1)/7.9054722668
D     VØ2=VX(2)/7.9054722668
D     VØ3=VX(3)/7.9054722668
D     R2=SQRTF(XØ1**2+XØ2**2+XØ3**2)
D     V2=SQRTF(VØ1**2+VØ2**2+VØ3**2)
C
C     CØNVERT ANGLES (RADIANS) TØ ANGLES (DEGREES)
C
D     AØ1=A(1)
D     AØ2=A(2)
D     AØ3=A(3)*57.2957795130823
D     AØ4=A(4)*57.2957795130823
D     AØ5=A(5)*57.2957795130823
D     AØ6=A(6)*57.2957795130823
      B1=A110(1)
      B2=A110(2)
      B3=A110(3)*57.2957795
      B4=A110(4)*57.2957795
      B5=A110(5)*57.2957795
      B6=A110(6)*57.2957795
C
C     BEGIN LØCAL STATIØN PREDICTIØNS CALCULATIØN
C
```

```
  200 IF(IRED)3001,3000,3001
 3000 READ 9505,NLA,ICC1,MINV,XMAX,MUTE
      IRED = 5
      IF(NLA - 19) 73,73,70
   70 PRINT 71,NLA
      WRITE OUTPUT TAPE 3,71,NLA
   71 FORMAT( 16H0 YOU ARE USING I9,
     1 47H STATIONS. PROGRAM CAN ONLY HANDLE 19 STATIONS.
   72 PAUSE 66666
      GO TO 72
C     WIDE PAPER FORM IF MORE THAN 15 STATIONS ARE USED
   73 IF(NLA - 15) 60,60,61
   60 NLSPP = 40
      GO TO 62
   61 NLSPP = 58
   62 IF (NLA) 1,1,2001
C     MAKE ISVEL POSITIVE IF SPIN AXIS IS ALONG INERTIAL VELOCITY VECTOR
 2001 READ 9506,RDMAX,RDMIN,RA,DEC,ISVEL
C STORE BLANKS
      IF(NLA - I2CT) 5035,5037,5037
 5035 PRINT 5036
      WRITE OUTPUT TAPE 3,5036
 5036 FORMAT (72H0THE NUMBER OF CONTROL STATIONS IS LARGER THAN THE NUMBE
     1ER OF STATIONS.
   67 PAUSE 54333
      GO TO 67
 5037 IF(NLA - 18) 5004,5004,5006
 5004 NFL = (NLA*2) + 7
      DO 5005 I = NFL,44
 5005 WPUV(I) =  APRINT
 5006 CONTINUE
      XMIN=MINV
      XMAX = RGMA * XNMFT * 0.30480061E-03
  903 IF(ISVEL)905,904,905
D904  RAR=RA*.0174532925
D     DECR=DEC*.0174532925
D     VXF(1) = COSF(DECR) * COSF(RAR)
D     VXF(2) = COSF(DECR) * SINF(RAR)
D     VXF(3) = SINF(DECR)
      GO TO 5026
D905  CALL VRDZ(1,VXF,DECR,RAR,XXX)
      RA= RAR*57.2957795
      DEC=DECR*57.2957795
 5026 WRITE OUTPUT TAPE 3,9504
      IF (SENSE SWITCH 6) 201,202
  201 PRINT 9504
  202 DO 205 N=1,NLA
      READ 6027,STAT(N),STAT1(N),LOND,LONM,XLONS,LATD,LATM,
     1 XLATS,HGT
  901 WRITE OUTPUT TAPE 3,6028,STAT(N),STAT1(N),LOND,LONM,XLONS,LATD,
     1LATM,XLATS,HGT
      IF (SENSE SWITCH 6) 203,2031
  203 PRINT 6028,STAT(N),LOND,LONM,XLONS,LATD,LATM,XLATS,HGT
 2031 CONTINUE
D     COORD(1)=DMSRZ(LATD,LATM,XLATS)
D     COORD(2)=DMSRZ(LOND,LONM,XLONS)
D     COORD(3)=HGT/1000.0
D     RLAT(N)=COORD(1)
D     RLON(N)=COORD(2)
D     CALL VFUZ(COORD,RE,FL,U)
      DO 204 J=1,3
  204 SU(N,J)=U(J)
  205 CONTINUE
      N = 1
      IF(I2CT) 3095,3095,3094
 3094 N = I2CT
 3095 WRITE OUTPUT TAPE 3,3093,(STAT(J),STAT1(J),J = 1,N)
      WRITE OUTPUT TAPE ITAPE4,3093,(STAT(J),STAT1(J), J = 1,N)
 3093 FORMAT(//15X21H CONTROL STATIONS ARE /,4(20X2A3/))
      WRITE OUTPUT TAPE 3,9507,MINV,MINV,RGMA
      WRITE OUTPUT TAPE 3,3013,RA,DEC
      WRITE OUTPUT TAPE ITAPE4,3091
 3091 FORMAT(54H0 S IS PRINTED WHEN THE SATELLITE IS IN THE SUNLIGHT    )
      WRITE OUTPUT TAPE 3,3092
 3092 FORMAT(80H0  THE 3 DIGIT NUMBERS UNDER THE STATION NAMES ARE THE S
     1PACECRAFT LOOK ANGLES.                                      )
C
C     INITIALIZE LINE COUNT AND DELTA T (DIFFERENCE BETWEEN
C     LOCAL STATION PREDICTIONS STARTING TIME AND EPOCH OF INPUT
C     PARAMETERS IN SECONDS)
C
 3001 LINES = 1
      LINE6=1
D     DTIMES=XLAS-DTLA
C
C
 2170 IF (SENSE SWITCH 2) 2171,217
 2171 PRINT 6025
      PAUSE 77775
  217 LINES=LINES+1
C
C     SKIP A PAGE AND PRINT HEADING IF 50 LINES OF CALCULATION
```

```
C      HAVE BEEN PRINTED
C
 9601 JJ = 1
      NPRED = 0
      LIN11 = 0
      LIN12 = 0
      IALAX = 0
      IMOS = 32767
 9600 CONTINUE
D7016 DTIMES = DTIMES + DTLA
D     TIME=TIME0+DTIMES*0.7272205216643O4E-4
D     DDJ0=INTF(TIME/6.283185307179586)
      DJ=DJ0+DDJ0
D     TIME=ALLOTZ(TIME)
C
C     COMPUTE GREENWICH APPARENT SIDEREAL TIME AT TO + DELTA T
C
D     UT = TIME * 3.81971863421
D     EQR = EQN(DJ,UT,XDX,XDX,ECQM)
D     ST = GAST7(DJ,UT,EQR)
      CALL JULCAL(DJ,NM,ND,NY)
C
C     CONVERT UNIVERSAL TIME IN RADIANS TO HOURS, MINUTES, AND SECONDS
C
D     CALL RHMSZ(TIME,II,IH,IM,TS)
      NYM19=NY-1900
C
      CALL BRWR2(DTIMES,EN2)
      SST=SINF(ST)
      CST=COSF(ST)
      RG(1)=RXB(1)*CST+RXB(2)*SST
      RG(2)=RXB(2)*CST-RXB(1)*SST
      RG(3)=RXB(3)
D     CALL VRDZ(1,RG,GCLAT,GCLON,R)
C
C     COMPUTE GEODETIC LATITUDE OF SUBSATELLITE POINT
C
D     GDLAT = GDLATZ(GCLAT,R,RE,FL,ALTT)
C
C     COMPUTE HEIGHT OF SATELLITE ABOVE COMPUTATIONAL ELLIPSOID ALONG
C     NORMAL FROM SATELLITE TO ELLIPSOID
C
C
C     CONVERT LATITUDE AND LONGITUDE IN RADIANS TO DEGREES, MINUTES,
C     AND SECONDS
C
D     TGCLON=GCLON-3.141592653589793
      IF (TGCLON) 1062,1062,1061
D1061 GCLON=TGCLON-3.141592653589793
 1062 CONTINUE
C     TEST FOR VEHICLE IN SUNLIGHT
C     AN S WILL BE PRINTED IF IN SUNLIGHT
      IF(SENSE LIGHT 2) 3000,3011
 3011 CALL SUN(DJ,TIME,SLC)
      SLC = SLC - 0.99241E-04
      CECQ = COSF(ECQM)
      SECQ = SINF(ECQM)
      SSLC = SINF(SLC)
C     COMPUT COMPONENTS OF SUN
      XSU = COSF(SLC)
      YSU = SSLC * CECQ
      ZSU = SSLC * SECQ
      RINTQ = RXB(1)**2 + RXB(2)**2 + RXB(3)**2
      RINT = SQRTF(RINTQ)
      IF(RINT)3015,3015,3016
 3015 IFR = 0
      PRINT 3024,IFR,I
 3024 FORMAT(2I6)
      GO TO 3007
 3016 CPSI = (XSU*RXB(1) + YSU*RXB(2) + ZSU*RXB(3)) / RINT
 3017 IF(CPSI)3005,3006,3006
 3005 DEMX = RINTQ - RE**2
      DEMX = SQRTF(DEMX)
      IF(DEMX)3018,3018,3019
 3018 IFR = 1
      PRINT 3024,IFR,I
      GO TO 3007
 3019 TNN = RE / DEMX
      CALL ARKTAN(RE,DEMX,XNU,1)
      SPSI = 1.-CPSI**2
      IF(SPSI)3020,3021,3021
 3020 IFR = 2
      PRINT 3024,IFR,I
      GO TO 3007
 3021 SPSI = SQRTF(SPSI)
      CPSI =-CPSI
      CALL ARKTAN(SPSI,CPSI,PSVA,1)
      X90DG = 1.5707963
      GULX = X90DG - PSVA
      TENN = GULX + XNU - X90DG
      IF(TENN) 3006,3006,3007
B3006 SUNN = 62 60 60 60 60 60
```

```
      IGDR = 2
C     VEHICLE IN SUN
      NUMSUN = NUMSUN + 1
      GØ TØ 3008
B3007 SUNN = 60 60 60 60 60 60
      IGDR = 1
C     VEHICLE IN SHADØW
 3008 CØNTINUE
      IF(IVA) 3026,3025,3026
 3025 IVA = 2
      DTESH = DTIMES
      GØ TØ 3030
 3026 IF(IGDR - IGDM)3027,3030,3028
 3027 IESY = NYM19
      IESMØ = NM
      IESD = ND
      IESH = IH
      IESM = IM
       DTESH = DTIMES
      GØ TØ 3030
D3028 PERCNT = 100.-((DTIMES - DTESH) / (36. * PERH))
      DRAT = (DTIMES - DTESH) / 60.
      WRITE ØUTPUT TAPE 5,3029,IESY,IESMØ,IESD,IESH,IESM,NYM19,NM,ND,
     1IH,IM,DRAT,PERCNT
 3029 FØRMAT(5X,3I2,X,2I2,13X,3I2,X,2I2,5X,F7.1,11X,F7.2)
 3031 FØRMAT(1H1,20X,21H SUNLIGHT HISTØRY ØF A5//5X63HSATELLITE WILL BE
     1IN SUNLIGHT AT ALL TIMES EXCEPT WHEN IT WILL /5X,
     240HENTER SHADØW AT    AND    LEAVE SHADØW AT //5X,
     373HYYMMDD HHMM                YYMMDD HHMM  DURATIØN (MIN)  PERCENT IN
     4 SUNLIGHT   )
 3030 IGDM = IGDR
C
       IF(XS700)3070,3069,3070
 3069 XGLAST = GDLT
      GØ TØ 3074
 3070 IF(GDLAT)3073,3071,3071
 3071 IF(XGLAST)3072,3073,3073
 3072 NØRBIT = NØRBIT + 1
 3073 XGLAST = GDLAT
 3074 XS700 = XS700 + 1.
       IF(JJ - 1)3078,3077,3078
 3077 IBGØRB = NØRBIT
 3078 CØNTINUE
      IF(XS700 - 300.)3064,3063,3063
 3063 XS700 = 1.
      PRINT 5050,NYM19,NM,ND,IH,IM
 5050 FØRMAT(3X,3I2,2X,2I2)
 3064 KK = 0
      DØ 3081 I = 1,19
 3081 XESTA(I) = APRINT
      DØ 242 N=1,NLA
      DØ 232 M=1,3
D 232 RGU(M)=RG(M)-SU(N,M)
D     CALL R13Z(RTX,0,-ST,RGU)
D     DUMX=DØT7(RTX,VXE)
      TESTA(N)=DUMX*57.295780
D     R13A1=1.57079632679-RLAT(N)
D     R13A2=1.57079632679+RLØN(N)
D     CALL R13Z(Z,R13A1,R13A2,RGU)
D     CALL VRDZ(2,Z,ELEVAT,AZIMUT,RANG)
      ELED(N)=57.29578*ELEVAT
      AZID(N)=57.29578*AZIMUT
      RGE(N)=RANG
      DATA(N) = PPRINT
      IF(ELED(N))233,319,318
  318 IF(ELED(N) - 5.0) 319,321,320
  319 DATA(N) = DPRINT
      GØ TØ 238
  320 IF(ELED(N) - 10.)321,238,238
  321 DATA(N) = EPRINT
  238 IF(RGE(N) - XMAX)239,239,902
  233 DATA(N) = APRINT
      GØ TØ 242
B 902 DATA(N) = DATA(N) + (- XRXX)
  239 IDATAX = APRINT
 3004 SENSE LIGHT 1
 4000 FØRMAT (5I5,F16.8)
 4001 FØRMAT (4F16.8,2I5)
  322 IF(NPRED) 241,310,241
  310 DØ 3009 III = 1,I2CT
      IDAT = DATA(III)
      IF(IDAT - IDATAX)311,3009,311
 3009 CØNTINUE
      GØ TØ 241
  311 NPRED = 1
  241 KK = KK + 1
      IF(IALAX - 1) 3061,3061,3062
 3061 IALAX = KK
 3062 CØNTINUE
      XRG(KK) = RGE(N)
      XAZ(KK) = AZID(N)
      XEL(KK) = ELED(N)
```

```
      XR(KK) = TESTA(N)
      STAT3(KK) = STAT(N)
      STAT4(KK) = STATI(N)
      IN(KK) = N
      IZ(KK) = TESTA(N)
  242 CONTINUE
C   CONVERT S/C ANGLE TO BCD
      IF(KK)3090,3090,3082
 3082 DO 3083 I = 1,KK
      CALL TESCOV(IZ(I),XZ(I))
 3083 CONTINUE
      DO 3085 I = 1,KK
      INVA = IN(I)
 3085 XESTA(INVA) = XZ(I)
D3090 GCLN = GCLON * 57.29577951
D     GDLT = GDLAT * 57.29577951
      IF (SENSE LIGHT 1) 243,2460
  243 IF (LC2-1) 245,244,245
  244 LC2 = 0
  245 JJ = JJ + 1
      IZNU = 10
C   SET UP WPUV ARRAY
      WPUV(1) = NY-19
      WPUV(2) = NM
      WPUV(3) = ND
      WPUV(4) = IH
      WPUV(5) = IM
      WPUV(6) = NORBIT
      DO 5003 I = 1,NLA
      NXD = (I*2) + 5
      WPUV(NXD) = XESTA(I)
      NXD = NXD + 1
 5003 WPUV(NXD) = DATA(I)
C   STORE WPUV
      IPOS = 12000 - LIN11 * 44
      IF(IPOS - 44)5019,5021,5021
 5019 DTIMES = DTIMES - DTLA
      SENSE LIGHT 3
      GO TO 2460
 5021 CALL STASH(WPUV,44,IPOS)
      IF(MAP)3079,3079,3080
C  SET UP FOR 65 K .
 3080 PRF(1) = KK
      PRF(2) = STAT3(1)
      PRF(3) = STAT4(1)
      PRF(4) = XPG(1)
      PRF(5) = XAZ(1)
      PRF(6) = XEL(1)
      PRF(7) = XR(1)
      PRF(8) = GDLT
      PRF(9) = GCLN
      PRF(10) = ALTT
      PRF(11) = SUNN
      LIN12 = LIN12 + 1
      NXD = 11
      IF(KK - 1)5002,5002,5000
 5000 DO 5001 K = 2,KK
      NXD =(K*7)- 2
      PRF(NXD) = STAT3(K)
      NXD = NXD + 1
      PRF(NXD) = STAT4(K)
      NXD = NXD + 1
      PRF(NXD) = XRG(K)
      NXD = NXD + 1
      PRF(NXD) = XAZ(K)
      NXD = NXD + 1
      PRF(NXD) = XEL(K)
      NXD = NXD + 1
      PRF(NXD) = XR(K)
      NXD = NXD + 1
 5001 PRF(NXD) = SUNN
 5002 IF(IMOS - 12000 - NXD) 5020,5022,5022
D5020 DTIMES = DTIMES - DTLA
      LL11 = LL11 - 1
      SENSE LIGHT 4
      GO TO 2460
C  STORE PRF
 5022 CALL STASH(PRF,NXD,IMOS)
      IMOS = IMOS - NXD
      IX = IX + 1
 3051 FORMAT (13X,2A3,F9.1,2F6.1,F7.1,5A6)
 3079 LIN11 = LIN11 + 1
      GO TO 247
 2460 IF(NLA - 1)3059,3060,63
   63 IF(MUTF)313,5031,313
 5031 IF(IALAX - 1)3059,3059,3060
 3060 IF(NPRED) 313,3059,313
  313 JMX = JJ -1
      LPAS = 10
      WRITE OUTPUT TAPE 3,3076,IBGORB
 3076 FORMAT (1H1,27X,13H ORBIT NUMBER I6)
      WRITE OUTPUT TAPE 3,330,IDSAT
```

```
      LL11 = 2
      LASØRB = IBGØRB
C   RETURN WPUV
      DØ 3054 K = 1,LIN11
      LØK = 12000 - (K-1) * 44
      CALL BACK(WPUV,44,LØK)
      DØ 5007 I = 1,5
 5007 MVPI(I) = WPUV(I)
      IF(LL11 - 2) 5032,64,5032
   64 IF(NPAG3)65,5029,65
   65 NPAG3 = 0
      LL11 = LL11 + 1
      MVPI(7) = WPUV(6)
      WRITE ØUTPUT TAPE 3,66,MVPI(7)
   66 FØRMAT (28X,13H ØRBIT NUMBER I6 )
 5029 WRITE ØUTPUT TAPE 3,5030,MVPI(2),MVPI(3),MVPI(1)
 5030 FØRMAT (28X,18H DATE(MM/DD/YY) = 2(I2,1H/),I2)
      WRITE ØUTPUT TAPE 3,331,(STAT1(I),I = 1,NLA)
 5032 MVPI(7) = WPUV(6)
      IF(LASØRB - MVPI(7)) 5016,5017,5017
 5016 LASØRB = MVPI(7)
      WRITE ØUTPUT TAPE 3,5018,LASØRB
      WRITE ØUTPUT TAPE ITAPE4,5018,LASØRB
 5018 FØRMAT (1H0,27X13H ØRBIT NUMBER I6)
      WRITE ØUTPUT TAPE 3,4006,APRINT
      LL11 = LL11 + 3
      LL12 = LL12 + 2
 5017 NEND = (NLA*2) + 6
      WRITE ØUTPUT TAPE 3,6052,(MVPI(I),I= 4,5),(WPUV(I),I = 7,NEND)
      IF(MAP) 5014,5014,102
  102 LINE4 = 1
      IF(K-1) 5009,5008,5009
 5008 IMØS = 32767
      WRITE ØUTPUT TAPE ITAPE4,3076,IBGØRB
      WRITE ØUTPUT TAPE ITAPE4,332,IDSAT
      LL12 = 3
 5009 CALL BACK(PRE,11,IMØS)
C   RETURN PRE
      IMØS = IMØS - 11
      MVPI(6) = PRE(1)
      WRITE ØUTPUT TAPE ITAPE4,4006,APRINT
 4006 FØRMAT (114X,A6)
      WRITE ØUTPUT TAPE ITAPE4,323,(MVPI(K),K = 1,5),(PRE(K),K = 2,11)
      LL12 = LL12 + 2
      IF(LL12 - 40) 5024,5024,5023
 5023 WRITE ØUTPUT TAPE ITAPE4,3076,MVPI(7)
      WRITE ØUTPUT TAPE ITAPE4,4005
      LL12 = 3
 5024 IF(MVPI(6) - 1) 5014,5014,5010
 5010 IPPP = MVPI(6)
      DØ 3056 I = 2,IPPP
      CALL BACK(PRE,7,IMØS)
      IMØS = IMØS - 7
      WRITE ØUTPUT TAPE ITAPE4,3051,(PRE(K), K = 1,6)
      LIN12 = LIN12 + 1
      LL12 = LL12 + 1
      IF(LL12 - 40)3056,3056,4004
 4004 WRITE ØUTPUT TAPE ITAPE4,3076,MVPI(7)
      WRITE ØUTPUT TAPE ITAPE4,4005
 4005 FØRMAT ( 20X5HRANGE,4X,4HAZI.,2X,5HELEV.,2X,8HS/C LØØK,2X,4HLAT.
     1 ,2X,5HLØNG.,2X6HHEIGHT  /
     218H YYMMDD HHMM STAT.,3X,4H(KM),4X,35H-----------DEGREES----------
     3-------,3X,4H(KM) )
      LL12 = 2
 3056 CØNTINUE
 5014 LL11 = LL11 + 1
      IF(LL11 - NLSPP) 3054,3054,4003
 4003 WRITE ØUTPUT TAPE 3,3089
      LL11 = 2
      NPAGE = 10
 3054 CØNTINUE
      WRITE ØUTPUT TAPE 3,9501
      WRITE ØUTPUT TAPE ITAPE4,9501
      LC2 = 0
C
C     PUT SENSE SWITCH 3 DØWN TØ TERMINATE RUN BEFØRE THE END TIME.
C
      IF(SENSE SWITCH 3)5012,3059
 3059 CØNTINUE
  323 FØRMAT(X,3I2,X,2I2,X,2A3,F9.1,2F6.1,F7.1,F10.1,F7.1,F9.1,X,A3)
  332 FØRMAT (55H LØCAL STATIØN PREDICTIØNS AND SATELLITE WØRLD MAP FØR
     1A5/20X5HRANGE,4X,4HAZI.,2X,5HELEV.,2X,8HS/C LØØK,2X,4HLAT.,2X,
     25HLØNG.,2X6HHEIGHT /
     318H YYMMDD HHMM STAT.,3X,4H(KM),4X,35H-----------DEGREES----------
     4-------,3X,4H(KM) )
  317 IF(DTIMES - XLAE)9601,248,248
  247 CØNTINUE
      IF(DTIMES - XLAE) 9600,5015,5015
 5015 IF(LIN11 - 2 ) 248,248,2460
  248  IF (SENSE SWITCH 2) 249,7010
  249 PRINT 6025
      PAUSE 77774
```

```
7010 IF(LPAS) 5012,5011,5012
5011 LPAS = 10
     GØ TØ 2460
5012 JMX = 9
     WRITE ØUTPUT TAPE ITAPE4,3031,IDSAT
     WRITE ØUTPUT TAPE 5,3032,JMX
     END FILE 5
     REWIND 5
3033 READ INPUT TAPE 5,3032,JMX,(SA(I),I = 1,12)
3032 FØRMAT (I1,11(A6),A3)
     IF(JMX - 9)3034,3035,3034
3034 WRITE ØUTPUT TAPE ITAPE4,3036,(SA(I),I = 1,12)
3036 FØRMAT (1X,11(A6),A3)
     GØ TØ 3033
3035 REWIND 5
     GØ TØ 3000
C
C     END LØCAL STATIØN PREDICTIØNS CALCULATIØN
C
 300 PRINT 6039
      END FILE 3
     PAUSE 77777
      GØ TØ 10
     END
```

APPENDIX VI

SOURCE DECK FOR MAIN PROGRAM TWO

```
*     DATE 10/19/64
*     GDR
*     PAUSF
*     XEQ
*     CARDS COLUMN
*     LIST8
*     LABEL
*     FORMAP
CWMAPLA
C
C     GENERALIZED WORLD MAP AND LOCAL STATION PREDICTIONS PROGRAM.
C
C     1A. CONVERTS OSCULATING ORBITAL ELEMENTS TO INERTIAL POSITION
C            AND VELOCITY RECTANGULAR COORDINATES.
C     1B. CONVERTS INERTIAL POSITION AND VELOCITY RECTANGULAR
C            COORDINATES TO OSCULATING ORBITAL ELEMENTS.
C     2.  COMPUTES WORLD MAP ON REQUEST.
C     3.  COMPUTES LOCAL STATION PREDICTIONS (LOOK ANGLES) ON REQUEST.
C         PROCESSES 1, 2, 3, OR 4 STATIONS SIMULTANEOUSLY ON REQUEST.
C
C     ALL INTERNAL CALCULATIONS ARE PERFORMED USING THE KILOMETER AS
C     THE UNIT OF LENGTH AND THE SECOND AS THE UNIT OF TIME.  IF ANY
C     OF THE OPTIONAL INPUT PARAMETERS ARE DEFINED IN OTHER UNITS,
C     THEY ARE CONVERTED TO THESE UNITS AS SOON AS THEY ARE READ IN
C     AND ARE SUBSEQUENTLY USED IN THE CALCULATIONS IN KILOMETERS
C     AND SECONDS.

C
C     REQUIRED SUBROUTINES AND FUNCTIONS
C     ALLOT
C     ALLOTZ
C     ATANQ
C     ATANZ
C     BBRWR
C     BRWR1
C     BRWR2
C     DJUL
C     DMSRZ
C     DOTZ
C     ELRV
C     ELRVZ
C     FQN
C     GASTZ
C     GDLATZ
C     HMSRZ
C     JULCAL
C     PARA
C     RDMSZ
C     RHMSZ
C     RVELZ
C     R13Z
C     TIMFC
C     VFUZ
C     VRDZ
C     XKEP
C     XKEPZ
C
C     Z END OF NAME OF FUNCTION OR SUBROUTINE INDICATES THAT INPUT,
C     OUTPUT, AND INTERNAL ARITHMETIC ARE PERFORMED IN DOUBLE PRECISION.
C
C     DEFINITION OF SYMBOLS
C
C     ERR = TRUNCATION FACTOR (IN RADIANS) USED IN SOLUTION OF
C     KEPLERS EQUATION
C     GM = PRODUCT OF G (=GAUSSIAN CONSTANT SQUARED) AND M, THE MASS OF
C     THE EARTH, IN UNITS OF KM. CUBED/SEC SQUARED
C     FJ2=J2 )
C     FJ3=J3 ) HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL
C     FJ4=J4 ) (DIMENSIONLESS)
C     FJ5=J5 )
C     FL=INVERSE OF FLATTENING
C     RE= EQUATORIAL RADIUS OF EARTH IN KM.
C
C     SENSE SWITCH 6 IS USED IN THE MAIN PROGRAM TO PROVIDE AN OPTIONAL
C     OUTPUT ON LINE.  IF SENSE SWITCH 6 IS DOWN, THE SAME INFORMATION
C     WHICH IS PRINTED ON TAPE A3 IS ALSO PRINTED ON LINE.  IF SENSE
C     SWITCH 6 IS UP, OUTPUT IS PRINTED ON A3 ONLY.
C
C     ALL FORMATS USED IN PROGRAM FOLLOW IMMEDIATELY.
C
 6001 FORMAT (36H1SANDTRACKS ORBITAL COMPUTING SYSTEM  //)
 6002 FORMAT (72H
     1
 6003 FORMAT (7I3)
 6004 FORMAT (E12.6,4E12.5/2F12.4)
 6005 FORMAT (/ 1X1PE8.1,9X39H TOLERANCE REQUIRED FOR KEPZ SUBROUTINE//
     1 1X0PF8.3,9X33H EQUATORIAL RADIUS OF EARTH IN KM /2XF5.1,11X22H IN
     2VERSE OF FLATTENING/1X,1PE14.8,3X31H GM (KM. CUBED/SECONDS SQUARED
     3) //18X44H HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL  /1XE13.6,
     4 4X3H J2/1X,E13.6,4X3H J3/1X,E13.6,4X3H J4 /1X,E13.6,4X3H J5   )
 6006 FORMAT (2(1XI2),1XI4,2I3,F7.3/6F12.6)
 6008 FORMAT (/1XI3,14X20H INPUT OPTION NUMBER/18X24H INPUT PARAMETERS A
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     1RE---  //)
 6009 FORMAT (46H GEOCENTRIC EQUATORIAL RECTANGULAR COORDINATES/70H REQU
     1IRED UNITS - CRAZY MIXED UP VANGUARD UNITS OF LENGTH AND VELOCITY)
 6010 FORMAT (/ 1XI2,1H/I2,1H/I4,7X25H EPOCH DATE OF PARAMETERS/2(1XI2),
     1 F7.3,5X29H EPOCH TIME OF PARAMETERS-UT2 )
 6011 FORMAT (/6X,F12.9,   20H X1 - VANGUARD UNITS/6X,F12.9,   3H X2/
     1 6X,F12.9,   3H X3//6X,F12.9,   20H VX1- VANGUARD UNITS/6X,F12.9,
     2    4H VX2/6X,F12.9,   4H VX3 )
 6012 FORMAT (30H ORBITAL ELEMENTS - OSCULATING/69H REQUIRED UNITS - ALL
     1 ANGLES IN DEGREES,SEMI-MAJOR AXIS IN KILOMETERS     )
 6013 FORMAT (/ 2X,F11.4,5X,27H SEMI-MAJOR AXIS-KILOMETERS/6X,F11.8,
     1 14H  ECCENTRICITY/3X,F12.6,3X,12H INCLINATION,3X,9H -DEGREES/3X,
     2 F12.6,3X,24H R.A. ASC. NODE -DEGREES/3X,F12.6,3X,24H ARG. OF PERI
     3GEE-DEGREES/3X,F12.6,3X,24H MEAN ANOMALY   -DEGREES    )
 6014 FORMAT (/18X,25H NO WORLD MAP CALCULATION       )
 6016 FORMAT (/45H WORLD MAP CALCULATIONS - START AND END TIMES//)
 6017 FORMAT (/18X,26H NO LOOK ANGLE CALCULATION    )
 6018 FORMAT (/46H LOOK ANGLE CALCULATIONS - START AND END TIMES//)
 6019 FORMAT (/ 32H QUANTITIES COMPUTED FROM INPUT    )
 6020 FORMAT (/ 1X,F13.5,4X,16H X1 - KILOMETERS/1X,F13.5,4X,3H X2/1X,
     1 F13.5,4X,3H X3//5X,F12.8,22H  VX1- KILOMETERS/SEC./5X,F12.8,
     2 5H  VX2/5X,F12.8,5H  VX3 )
 6021 FORMAT (/ 2X,F11.4,5X,27H SEMI-MAJOR AXIS-KILOMETERS/6X,F11.8,
     1 14H  ECCENTRICITY/3X,F12.6,3X,12H INCLINATION,3X,9H -DEGREES/3X,
     2 F12.6,3X,24H R.A. ASC. NODE -DEGREES/3X,F12.6,3X,24H ARG. OF PERI
     3GEE-DEGREES/3X,F12.6,3X,24H MEAN ANOMALY   -DEGREES    )
 6022 FORMAT (/ 4X,F11.6,3X,7H PERIOD,8X,7H -HOURS/2XF11.4,20X,9H -MINUT
     1ES/4X,F11.6,3X,12H MEAN MOTION,3X,14H -DEGREES/HOUR//4X,F11.6,3X,
     2 15H MOTION OF NODE,8X,14H - DEGREES/DAY/4X,F11.6,3X,18H MOTION OF
     3 PERIGEE,5X,14H - DEGREES/DAY  )
 6023 FORMAT (5H DATE,6X14HUNIVERSAL TIME,16X20HGEODETIC COORDINATES/
     1 9H MO/DY/YR,3X4HH   M,3X4HSEC.,9X39HLATITUDE-DMS  LONGITUDE-DMS  H
     2EIGHT-KM. //)
 6024 FORMAT (1XI2,1H/,I2,1H/,I2,2X2I3,F7.3,8X2I3,F6.2,2XI4,I3,F6.2,
     1 F11.3  )
 6025 FORMAT (11H PUSH START /////)
 6026 FORMAT (1H1//15X33H LOCAL STATION PREDICTIONS FOR -- //8H STATION,
     1 5X10H LONGITUDE,6X9H LATITUDE,4X16H HEIGHT (METERS) //)
 6027 FORMAT (1X2A3,I5,I3,F7.3,I4,I3,F7.3,F11.2 )
 6028 FORMAT (1X,2A3,5XI4,I3,F7.3,I5,I3,F7.3,4XF10.2 )
 6037 FORMAT (1H1/45X10H WORLD MAP //)
 6038 FORMAT (27H1LOCAL STATION PREDICTIONS    )
 6039 FORMAT (13H JOB FINISHED  /////)
 6040 FORMAT (E8.2)
 6041 FORMAT (28H1EXECUTE MAIN PROGRAM-WMAPLA/1H1  )
 6042 FORMAT (43H GEOCENTRIC EQUATORIAL INERTIAL COORDINATES/
     1 50H REQUIRED UNITS - KILOMETERS AND KILOMETERS/SECOND)
 6043 FORMAT (1X,F13.5,4X,17H X1   - KILOMETERS/1X,F13.5,4X,
     1 17H X2   - KILOMETERS/1X,F13.5,4X,17H X3   - KILOMETERS//5X,F12.8,
     2 1X,13H VX1 - KM/SEC/5X,F12.8,1X,13H VX2 - KM/SEC/5X,F12.8,1X,
     3 13H VX3 - KM/SEC)
 6044 FORMAT (/18X,50H BROUWER HARMONICS COMPUTED FROM J2,J3,J4, AND J5
     1 /1X,1PE14.8,3X,24H K2 (KILOMETERS SQUARED)/1X,E14.8,3X,
     2 22H K3 (KILOMETERS CUBED)/1X,E14.8,3X,
     3 29H K4 (KILOMETERS FOURTH POWER)/1X,E14.8,3X,
     4 28H K5 (KILOMETERS FIFTH POWER))
 6045 FORMAT (/4X,63H POSITION AND VELOCITY VECTORS - GEOCENTRIC EQUATOR
     1IAL INERTIAL)
 6046 FORMAT (/1X,F13.5,4X,17H X1   - KILOMETERS,3X,F12.8,1X,
     1 21H X1   - VANGUARD UNITS/1X,F13.5,4X,17H X2   - KILOMETERS,3X,
     2 F12.8,1X,21H X2   - VANGUARD UNITS/1X,F13.5,4X,
     3 17H X3   - KILOMETERS,3X,F12.8,1X,21H X3   - VANGUARD UNITS)
 6047 FORMAT (/5X,F12.8,1X,13H VX1 - KM/SEC,7X,F12.8,1X,
     1 21H VX1 - VANGUARD UNITS/5X,F12.8,1X,13H VX2 - KM/SEC,7X,F12.8,
     2 1X,21H VX2 - VANGUARD UNITS/5X,F12.8,1X,13H VX3 - KM/SEC,7X,
     3 F12.8,1X,21H VX3 - VANGUARD UNITS//1X,F13.5,4X,
     4 17H R    - KILOMETERS,3X,F12.8,1X,21H R    - VANGUARD UNITS/5X,
     5 F12.8,1X,13H V    - KM/SEC,7X,F12.8,1X,
     6 21H V    - VANGUARD UNITS)
 6048 FORMAT (/26X,17H ORBITAL ELEMENTS//20H OSCULATING ELEMENTS,2X,
     1 22H BROUWER MEAN ELEMENTS//1X,F12.4,11X,F12.4,7X,
     2 29H SEMI-MAJOR AXIS - KILOMETERS/6X,F11.8,12X,F11.8,3X,
     3 13H ECCENTRICITY/4X,F11.6,12X,F11.6,5X,
     4 26H INCLINATION      - DEGREES/4X,F11.6,12X,F11.6,5X,
     5 26H R.A. ASC. NODE   - DEGREES/4X,F11.6,12X,F11.6,5X,
     6 26H ARG. OF PERIGEE  - DEGREES/4X,F11.6,12X,F11.6,5X,
     7 26H MEAN ANOMALY     - DEGREES)
 6049 FORMAT (/45H TRUNCATION FACTORS USED IN COMPUTING BROUWER /
     1 39H MEAN ELEMENTS FROM OSCULATING ELEMENTS//1X,1PE8.1,9X,
     2 29H SEMI-MAJOR AXIS - KILOMETERS/1X,E8.1,9X,13H ECCENTRICITY/1X,
     3 E8.1,9X,26H INCLINATION      - DEGREES/1X,E8.1,9X,
     4 26H R.A. ASC. NODE   - DEGREES/1X,E8.1,9X,
     5 26H ARG. OF PERIGEE  - DEGREES/1X,E8.1,9X,
     6 26H MEAN ANOMALY     - DEGREES  )
 6050 FORMAT(6F12.8)
 6051 FORMAT (22H BROUWER MEAN ELEMENTS/69H REQUIRED UNITS - ALL ANGLES
     1IN DEGREES,SEMI-MAJOR AXIS IN KILOMETERS  )
6052  FORMAT (1XI2,2(1H/I2),1X,2(I3),F7.3,5X,12(2XA3))
 9501 FORMAT(1H0,8H  ******)
 9502 FORMAT (1H0,17HMUTUAL VISIBILITY//)
 9503 FORMAT(5H0DATE,5X15H UNIVERSAL TIME/23H MO/DY/YR   H  M   SEC.,
     1 5X,12(2XA3))
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 9504 FORMAT(1H1//15X33H LOCAL STATION PREDICTIONS FOR -- //8H STATION,
     15X10H LONGITUDE ,6X9H LATITUDE,4X16H HEIGHT (METERS)//)
 9505 FORMAT (3I3,F10.0)
 9506 FORMAT(4F6.1)
 9507 FORMAT(/////7X26HNO STATION PRINT OUT IF --//
     11X,25H1. ELEVATION IS LESS THAN,14X,I3, 8H DEGREES/
     21X,25H2. RANGE IS GREATER  THAN ,7X,F9.0,12H  KILOMETERS/
     31X,30H3. RADAR ANGLE IS GREATER THAN,6X,F6.1,8H DEGREES/
     419X,12HOR LESS THAN,6X,F6.1,8H DEGREES///
     54X,25HSPIN AXIS COORDINATES ARE,8X,F6.1,24H DEGREES RIGHT ASCENSIO
     6N/37X,F6.1,20H DEGREES DECLINATION )
 7500 FORMAT(5HODATE,7X3HUT2,15X5HRANGE,3X2HAZ,3X2HEL,3X5HRADAR/
     1 9H MO/DY/YR,16H . H  M  STATION,6X4H(KM),12H (DEG) (DEG)  .
     2 12H ANGLF (DFG)   //)
 7501 FORMAT(XI2,2(1H/I2),1X,2(I3),2X,2A3,3XF8.1,1XF5.1,XF4.1,2XF5.1/
     118X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2X
     2F5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1
     3  ,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1
     4 ,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1
     5,XF5.1,XF4.1,2XF5.1/18X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1/18X,2A3,3X
     6 F8.1,XF5.1,XF4.1,2XF5.1/
     718X,2A3,3XF8.1,XF5.1,XF4.1,2XF5.1)
C
C      ALL DIMENSION STATEMENTS FOLLOW IMMEDIATELY.
C
D      DIMENSION RX(3),VX(3),A(6),AI(6),RG(3),VG(3),RLAT(12),RLON(12)
D      DIMENSION RGU(3),Z(3),COORD(3),U(3),SU(12,3)
       DIMENSION ELED(12),AZID(12),RGE(12),TESTA(12),STAT1(12),STAT2(12)
       DIMENSION RGE1(12),ELED1(12),AZID1(12),TESTA1(12),STAT3(12)
       DIMENSION GP(5),DA(6),DAD(6),A110(6),XX(12),AB(6),RXB(3)
D      DIMENSION VXE(3),RTX(3)
       DIMENSION STAT4(12),DATA(12),VXB(3),XXX(10),SS(3)
       DIMENSION DUM1(100)
       COMMON DUM1,A110,GP,ERRB,XX,AB,RXB,VXB,XXX,SS
C
       PRINT 6041
C
C      DEFINE TRUNCATION FACTOR (RADIANS)
C
D    1 FRR=1.0E-8
       FRRB=3.0E-7
D      EN2 = 0.0
C
C      DEFINE TRUNCATION FACTORS FOR SUBROUTINE BBRWR ( USED TO CONVERT
C      OSCULATING ELEMENTS TO BROUWER MEAN ELEMENTS)
C
       DAD(1)=5.0E-4
       DAD(2)=5.0F-6
       DAD(3)=5.0F-6
       DAD(4)=5.0E-6
       DAD(5)=5.0F-6
       DAD(6)=5.0E-6
C
       LC2=0
B      APRINT=60 60 60 60 60 60
B      BPRINT = 60 60 54 60 60 60
C
C      DEFINE GODDARD EARTH CONSTANTS
C
D      GM=3.986032E+5
D      FJ2=1.0823E-3
D      FJ3=-2.3E-6
D      FJ4=-1.8E-6
D      FJ5=0.0
D      FL=298.3
D      RE=6378.165
C
C      CARD 1 - READ IN I.D. CARD - ANY INFORMATION IN COLS. 2 - 72
C
       RFAD            6002
C
C      CARD 2 - READ IN CONTROL CARD
C
C      COLS.  1- 3  TYPE OF INPUT (+01 = OSCULATING ORBITAL ELEMENTS
C                                  +02 = INERTIAL POSITION AND VELOCITY
C                                        IN KILOMETERS AND KM/SEC
C                                  +03 = INERTIAL POSITION AND VELOCITY
C                                        IN VANGUARD UNITS          )
C                               +04 = BROUWER MEAN ELEMENTS       )
C
C      COLS.  4- 6  COMPUTE WORLD MAP - YES OR NO ( YES IF MAP=+XX, NO IF
C                                                  MAP=+00 OR -XX)
C      COLS.  7- 9  COMPUTE LOOK ANGLES - YES OR NO (YES IF LA=+XX, NO IF
C                                                   LA=+00 OR -XX)
C      COLS. 10-12  CHANGE EARTH CONSTANTS
C      COLS. 13-16  CHANGE TRUNCATION FACTOR
C
       READ            6003,INPUT,MAP,LA,NCST,NERR,NDA,IRC
C
C      TEST - HAVE ALL CASES BEEN RUN - YES OR NO
C
       IF (INPUT) 300,300,2
```

```
C      IF INPUT=+00 OR -XX, ALL CASES HAVE BEEN RUN.  GO TO 300 (END
C      FILE, REWIND AND UNLOAD A3).  IF INPUT =+XX, PROCEED TO NEXT CASE.
C
C      TEST - CHANGE TRUNCATION FACTOR - YES OR NO
C
     2 IF (NERR) 4,4,3
C
C      CARD 2A- (OPTIONAL) READ IN NEW VALUE OF TRUNCATION FACTOR IF
C                          NERR=+XX.  IF NERR=+00 OR -XX, PROCEED TO NEXT
C                          OPTION TEST.
C
     3 READ              6040,ERR
C
C      TEST - CHANGE EARTH CONSTANTS - YES OR NO
C
     4 IF (NCST) 5,11,10
C
C      IF NCST=+00, RETAIN STANDARD GODDARD EARTH CONSTANTS AND PROCEED
C      TO NEXT STEP.
C
     5 IF (NCST+1) 7,6,7
C
C      USE SIRY PACKAGE CONSTANTS IF NCST = -1
C
D    6 GM=3.9862688E+05
D      FJ2=1.08219E-03
D      FJ3=-2.285E-06
D      FJ4=-2.123E-06
D      FJ5=-2.32E-07
D      FL=297.0
D      RE=6378.388
       GO TO 11
     7 IF (NCST+2) 9,8,11
C
C      USE GODDARD EARTH CONSTANTS WITH HARMONICS =0 IF NCST = -2
C
D    8 FJ2=0.0
D      FJ3=0.0
D      FJ4=0.0
D      FJ5=0.0
       GO TO 11
C
C      USE INTERNATIONAL CONSTANTS WITH HARMONICS = 0 IF NCST = -3
C
D    9 GM=3.98626873E+5
D      FJ2=0.0
D      FJ3=0.0
D      FJ4=0.0
D      FJ5=0.0
D      FL=297.0
D      RE=6378.388
       GO TO 11
C
C      CARDS 2B AND 2C- (OPTIONAL) READ IN NEW SET OF EARTH CONSTANTS
C                                  IF NCST=+XX.
C
    10 READ              6004,GM,FJ2,FJ3,FJ4,FJ5,FL,RE
C
C      CONVERT EARTH CONSTANTS
C
    11 GP(1)=GM
       GP(2)=.5*FJ2*RE**2
       GP(3)=-FJ3*RE**3
       GP(4)=-.375*FJ4*RE**4
       GP(5)=-FJ5*RE**5
C
C      PRINT ALL QUANTITIES ON OUTPUT TAPE A3.
C
    12 WRITE OUTPUT TAPE 3,6001
       WRITE OUTPUT TAPE 3,6002
       WRITE OUTPUT TAPE 3,6005,ERR,RE,FL,GM,FJ2,FJ3,FJ4,FJ5
       WRITE OUTPUT TAPE 3,6044,GP(2),GP(3),GP(4),GP(5)
       IF (SENSE SWITCH 6) 13,913
C
C      PRINT SAME INFORMATION ON LINE IF SENSE SWITCH 6 IS DOWN.
C
    13 PRINT 6001
       PRINT 6002
       PRINT 6005,ERR,RE,FL,GM,FJ2,FJ3,FJ4,FJ5
       PRINT 6044,GP(2),GP(3),GP(4),GP(5)
   913 IF (NDA) 915,915,914
   914 READ              6050, (DAD(N), N=1,6)
   915 DA(1)=DAD(1)
       DA(2)=DAD(2)
       DO 916 N=3,6
   916 DA(N)=DAD(N)*0.017453292
       IF (IRC) 917,917,918
   917 IRC=50
C
C      CARD 3 - READ IN EPOCH OF INPUT PARAMETERS-CALENDAR DATE (MONTH,
C               DAY, AND YEAR) AND UNIVERSAL TIME (HOURS, MINUTES, AND
C               SECONDS TO 3 DECIMALS OF A SECOND).
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C     CARD 4 - READ IN PARAMETERS
C
  918 READ              6006,NME,NDE,NYE,NHE,NMNE,TSE,(AI(N), N=1,6)
C
C     PRINT EPOCH AND INPUT OPTION ON OUTPUT TAPE A3
C
   15 WRITE OUTPUT TAPE 3,6010,NME,NDE,NYE,NHE,NMNE,TSE
      WRITE OUTPUT TAPE 3,6008,INPUT
      IF (SENSE SWITCH 6) 16,17
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
   16 PRINT 6010,NME,NDE,NYE,NHE,NMNE,TSE
      PRINT 6008,INPUT
   17 CONTINUF
C
C     CONVERT EPOCH UNIVERSAL TIME IN HOURS, MINUTES, AND SECONDS
C     TO EPOCH UNIVERSAL TIME IN RADIANS.
C
D     TIMEO=HMSRZ(NHE,NMNE,TSE)
C
C     CONVERT EPOCH CALENDAR DATE TO EPOCH JULIAN DATE AT 0 HOURS
C     UNIVERSAL TIME.
C
      DJO=DJUL(NME,NDE,NYE)
C
C
C     CONVERT EPOCH UNIVERSAL TIME IN HOURS, MINUTES, AND SECONDS
C     TO SECONDS.
C
      THE=NHE*3600
      TMNE=NMNF*60
      TSEP=THE+TMNE+TSE
      GO TO (18,20,22,930) , INPUT
C
C     PRINT INPUT PARAMETERS ON OUTPUT TAPE A3 - INPUT OPTION 1
C     OSCULATING ORBITAL ELEMENTS -
C     1. SEMI-MAJOR AXIS IN KM 2. ECCENTRICITY 3. INCLINATION 4. RIGHT
C     ASCENSION OF ASCENDING NODE 5. ARGUMENT OF PERIGEE 6. MEAN ANOMALY
C     (ALL ANGLES I.E. 3,4,5, AND 6 ARE IN DEGREES).
C
   18 WRITE OUTPUT TAPE 3,6012
      WRITE OUTPUT TAPE 3,6013,(AI(N),N=1,6)
      IF (SENSE SWITCH 6) 19,28
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
   19 PRINT 6012
      PRINT 6013,(AI(N),N=1,6)
      GO TO 28
C
C     PRINT INPUT PARAMETERS ON OUTPUT TAPE A3 - INPUT OPTION 2
C     INERTIAL POSITION AND VELOCITY RECTANGULAR COORDINATES -
C     IN KILOMETERS AND KILOMETERS PER SECOND.
C
   20 WRITE OUTPUT TAPE 3,6042
      WRITE OUTPUT TAPE 3,6043,(AI(N),N=1,6)
      IF (SFNSF SWITCH 6) 21,28
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
   21 PRINT 6042
      PRINT 6043,(AI(N),N=1,6)
      GO TO 28
C
C     PRINT INPUT PARAMETERS ON OUTPUT TAPE A3 - INPUT OPTION 3
C     INERTIAL POSITION AND VELOCITY RECTANGULAR COORDINATES -
C     IN VANGUARD UNITS.
C
   22 WRITE OUTPUT TAPE 3,6009
      WRITE OUTPUT TAPE 3,6011,(AI(N),N=1,6)
      IF (SENSE SWITCH 6) 23,28
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
   23 PRINT 6009
      PRINT 6011,(AI(N),N=1,6)
      GO TO 28
C
C     PRINT INPUT PARAMETERS - INPUT OPTION 4 - BROUWER MEAN ELEMENTS
C
  930 WRITE OUTPUT TAPE 3,6051
  931 WRITE OUTPUT TAPE 3,6013,(AI(N),N = 1,6)
      IF (SENSE SWITCH 6) 932,28
C
C     PRINT SAME INFORMATION ON-LINE IF SENSE SWITCH 6 IS DOWN
C
  932 PRINT 6051
      PRINT 6013,(AI(N), N = 1,6)
C
C     CONVERT INPUT PARAMETERS TO OSCULATING ELEMENTS
C
```

```
D  28 CALL PARA(INPUT,AI,A,GM)
D     CALL ELRVZ(RX,VX,A,PER,EN,GM,ERR)
      CALL BØRWR(DA,A,IRC,NN)
D     VXE(1)=VX(1)
D     VXE(2)=VX(2)
D     VXE(3)=VX(3)
      EN=SS(1)
      DP=SS(2)
      DN=SS(3)
D     PER=6.28318530718/EN
D     PERM=PER/60.0
D     PERH=PER/3600.0
D     EN1=EN*206264.806247096
D     DNØDE=DN*4950355.3499303
D     DPERI=DP*4950355.3499303
C
C     TEST - IS WØRLD MAP DESIRED
C
   29 IF (MAP) 30,30,33
   30 WRITE ØUTPUT TAPE 3,6014
      IF (SENSE SWITCH 6) 31,36
   31 PRINT 6014
   32 GØ TØ 36
C
C     CARD 5A - WØRLD MAP IS DESIRED.  READ IN CALENDAR DATE (DAY,
C               MØNTH, AND YEAR) AND UNIVERSAL TIME (HØURS, MINUTES,
C               AND SECØNDS TØ 3 DECIMALS ØF A SECØND) AT WHICH THE
C               START ØF CALCULATIØN IS DESIRED, CALENDAR DATE AND
C               UNIVERSAL TIME AT WHICH THE TERMINATIØN ØF THE
C               CALCULATIØN IS DESIRED, AND THE DESIRED TIME INCREMENT
C               ØF THE CALCULATIØN IN SECØNDS TØ 3 DECIMALS ØF A SECØND.
C
   33 WRITE ØUTPUT TAPE 3,6016
C
C     PRINT SAME INFØRMATIØN ØN-LINE IF SENSE SWITCH 6 IS DØWN
C
      IF (SENSE SWITCH 6) 34,35
   34 PRINT 6016
   35 CALL TIMEC(DJO,TSEP,WMAPS,WMAPF,WMAPDT)
C
C     TEST - ARE STATIØN PREDICTIØNS (LØØK ANGLES) DESIRED
C
C
   36 IF (LA) 37,37,40
   37 WRITE ØUTPUT TAPE 3,6017
      IF (SENSE SWITCH 6) 38,43
   38 PRINT 6017
   39 GØ TØ 43
C
C     CARD 5B - STATIØN PREDICTIØNS (LØØK ANGLES) ARE REQUIRED.  READ
C               IN CALENDAR DATE AND UNIVERSAL TIME AT WHICH THE START
C               ØF THE CALCULATIØN IS DESIRED, CALENDAR DATE AND
C               UNIVERSAL TIME AT WHICH THE TERMINATIØN ØF THE
C               CALCULATIØN IS DESIRED, AND THE DESIRED TIME INCREMENT
C               ØF THE CALCULATIØN IN SECØNDS.
C
   40 WRITE ØUTPUT TAPE 3,6018
C
C     PRINT SAME INFØRMATIØN ØN-LINE IF SENSE SWITCH 6 IS DØWN
C
      IF (SENSE SWITCH 6) 41,42
   41 PRINT 6018
   42 CALL TIMEC(DJO,TSEP,XLAS,XLAF,DTLA)
   43 WRITE ØUTPUT TAPE 3,6001
      WRITE ØUTPUT TAPE 3,6002
      WRITE ØUTPUT TAPE 3,6019
      WRITE ØUTPUT TAPE 3,6010,NME,NDE,NYE,NHE,NMNE,TSE
C
C     PRINT SAME INFØRMATIØN ØN-LINE IF SENSE SWITCH 6 IS DØWN
C
      IF (SENSE SWITCH 6) 44,45
   44 PRINT 6001
      PRINT 6002
      PRINT 6019
      PRINT 6010,NME,NDE,NYE,NHE,NMNE,TSE
   45 CONTINUE
C
C     CØNVERT ØSCULATING ØRBITAL ELEMENTS TØ INERTIAL PØSITIØN AND
C     VELØCITY CØØRDINATES IN KM AND KM/SEC
C
D  46 CALL ELRVZ(RX,VX,A,PER,EN,GM,ERR)
D     R1=SQRTF(RX(1)**2+RX(2)**2+RX(3)**2)
D     V1=SQRTF(VX(1)**2+VX(2)**2+VX(3)**2)
C
C     CØNVERT TØ VANGUARD UNITS ØF LENGTH AND VELØCITY
C
D  47 XØ1=RX(1)/6378.388
D     XØ2=RX(2)/6378.388
D     XØ3=RX(3)/6378.388
D     VØ1=VX(1)/7.9054722668
D     VØ2=VX(2)/7.9054722668
D     VØ3=VX(3)/7.9054722668
```

```
D      R2=SQRTF(XØ1**2+XØ2**2+XØ3**2)
D      V2=SQRTF(VØ1**2+VØ2**2+VØ3**2)
C
C      CØNVERT ANGLES (RADIANS) TØ ANGLES (DEGREES)
C
D      AØ1=A(1)
D      AØ2=A(2)
D      AØ3=A(3)*57.2957795130823
D      AØ4=A(4)*57.2957795130823
D      AØ5=A(5)*57.2957795130823
D      AØ6=A(6)*57.2957795130823
   48 WRITE ØUTPUT TAPE 3,6045
      WRITE OUTPUT TAPE 3,6046,RX(1),XO1,RX(2),XO2,RX(3),XØ3
      WRITE OUTPUT TAPE 3,6047,VX(1),VØ1,VX(2),VØ2,VX(3),VØ3,R1,R2,V1,V2
      WRITE ØUTPUT TAPE 3,6049,(DAD(I)   , I = 1,6)
      B1=A110(1)
      B2=A110(2)
      B3=A110(3)*57.2957795
      B4=A110(4)*57.2957795
      B5=A110(5)*57.2957795
      B6=A110(6)*57.2957795
      WRITE ØUTPUT TAPE 3,6048,AØ1,B1,AØ2,B2,AØ3,B3,AØ4,B4,AØ5,B5,AØ6,B6
      WRITE ØUTPUT TAPE 3,6022,PERH,PERM,EN1,DNØDE,DPERI
      IF (SENSE SWITCH 6) 49,50
C
C      PRINT SAME INFØRMATIØN ØN-LINE IF SENSE SWITCH 6 IS DOWN
C
   49 PRINT 6045
      PRINT 6046,RX(1),XØ1,RX(2),XØ2,RX(3),XØ3
      PRINT 6047,VX(1),VØ1,VX(2),VØ2,VX(3),VØ3,R1,R2,V1,V2
      PRINT 6048,AØ1,B1,AØ2,B2,AØ3,B3,AØ4,B4,AØ5,B5,AØ6,B6
      PRINT 6022,PFRH,PERM,EN1,DNØDE,DPERI
   50 CØNTINUF
   53 IF (MAP) 199,199,100
C
C      BEGIN WØRLD MAP CALCULATIØN (NØ CALCULATIØN IF MAP = 0)
C      SKIP A PAGE AND PRINT HEADING FØR WØRLD MAP CALCULATIØNS
C
  100 WRITE ØUTPUT TAPE 3,6037
      WRITE ØUTPUT TAPE 3,6023
      IF (SENSF SWITCH 6) 101,102
  101 PRINT 6037
      PRINT 6023
C
C      INITIALIZE LINE CØUNT AND DELTA T (DIFFERENCE BETWEEN
C      WØRLD MAP STARTING TIME AND EPØCH ØF INPUT PARAMETERS IN SECØNDS)
C
  102 LINES=1
D      DTIMES=WMAPS-WMAPDT
      IF (SENSF SWITCH 1) 1030,103
 1030 PRINT 6025
      PAUSF 77777
  103 LINES=LINFS+1
C
C      SKIP A PAGE AND PRINT HEADING IF 50 LINES ØF CALCULATIØN
C      HAVF BFEN PRINTED
C
      IF (LINES-50) 106,106,104
  104 WRITE ØUTPUT TAPE 3,6037
      WRITE ØUTPUT TAPE 3,6023
      LINES=1
      IF (SENSE SWITCH 6) 105,106
  105 PRINT 6037
      PRINT 6023
D 106 DTIMES=DTIMES+WMAPDT
D      TIME=TIMEO+DTIMES*0.727220521664304E-4
D      DDJ0=INTF(TIME/6.283185307179586)
      DJ=DJ0+DDJ0
D      TIME=ALLØTZ(TIME)
C
C      CØMPUTE GREENWICH APPARENT SIDEREAL TIME AT TO + DELTA T
C
D      EPHR = TIME * 3.81971863421
D      EQR=EQN(DJ,EPHR,XX,XX,XX)
D      ST=GASTZ(DJ,EPHR,EQR)
      CALL JULCAL(DJ,NM,ND,NY)
C
C      CØNVERT UNIVERSAL TIME IN RADIANS TØ HØURS, MINUTES, AND SECØNDS
C
D      CALL RHMSZ(TIME,II,IH,IM,TS).
C
      CALL BRWR2(DTIMES,EN2)
      SST=SINF(ST)
      CST=CØSF(ST)
      RG(1)=RXB(1)*CST+RXB(2)*SST
      RG(2)=RXB(2)*CST-RXB(1)*SST
      RG(3)=RXB(3)
D      CALL VRDZ(1,RG,GCLAT,GCLØN,R)
C
C      CØMPUTE GEØDETIC LATITUDE ØF SUBSATELLITE PØINT
C
C
```

```
C      COMPUTE HEIGHT OF SATELLITE ABOVE COMPUTATIONAL ELLIPSOID ALONG
C      NORMAL FROM SATELLITE TO ELLIPSOID
C
D      GDLAT = GDLATZ(GCLAT,R,RE,FL,ALT)
C
C      CONVERT LATITUDE AND LONGITUDE IN RADIANS TO DEGREES, MINUTES,
C      AND SECONDS
C
D      TGCLON=GCLON-3.141592653589793
       IF (TGCLON) 1062,1062,1061
D1061  GCLON=TGCLON-3.141592653589793
 1062  CONTINUE
D      CALL RDMSZ(GDLAT,II,IPD,IPM,TPS)
D      CALL RDMSZ(GCLON,II,ILD,ILM,TLS)
C
C      OUTPUT PREPARATION
C
       NYM19=NY-1900
       WRITE OUTPUT TAPE 3,6024,NM,ND,NYM19,IH,IM,TS,IPD,IPM,TPS,ILD,
      1 ILM,TLS,ALT
       IF (SENSE SWITCH 6) 107,108
  107  PRINT 6024,NM,ND,NYM19,IH,IM,TS,IPD,IPM,TPS,ILD,ILM,TLS,ALT
  108  IF (DTIMES-WMAPF) 103,109,109
  109  IF (SENSE SWITCH 1) 110,199
  110  PRINT 6025
       PAUSE 77776
C
C      END WORLD MAP CALCULATION
C
  199  IF (LA) 1,1,200
C
C      BEGIN LOCAL STATION PREDICTIONS CALCULATION
C      (NO CALCULATION IF LA=0)
C
  200  READ                9505,NLA,ICC1,MINV,XMAX
       IF (NLA) 1,1,2001
 2001  READ                9506,RDMAX,RDMIN,RA,DEC
       XMIN=MINV
       IF(XMAX) 902,902,903
  902  XMAX=1000000.0
  903  IF(RA) 904,905,904
D904   RAR=RA*.0174532925
D      DECR=DEC*.0174532925
D      VXE(1) = COSF(DECR) * COSF(RAR)
D      VXE(2) = COSF(DECR) * SINF(RAR)
D      VXE(3) = SINF(DECR)
D905   CALL VRDZ(1,VXE,DECR,RAR,XXX)
       RA= RAR*57.2957795
       DEC=DECR*57.2957795
       WRITE OUTPUT TAPE 3,9504
       IF (SENSE SWITCH 6) 201,202
  201  PRINT 9504
  202  DO 205 N=1,NLA
       READ                   6027,STAT1(N),STAT2(N),LOND,LONM,XLONS,LATD,
      1LATM,XLATS,HGT
901    WRITE OUTPUT TAPE 3,6028,STAT1(N),STAT2(N),LOND,LONM,XLONS,LATD,
      1LATM,XLATS,HGT
       IF (SENSE SWITCH 6) 203,2031
203    PRINT 6028,STAT1(N),STAT2(N),LOND,LONM,XLONS,LATD,LATM,XLATS,HGT
 2031  CONTINUE
D      COORD(1) = DMSRZ(LATD,LATM,XLATS)
D      COORD(2) = DMSRZ(LOND,LONM,XLONS)
D      COORD(3)=HGT/1000.0
D      RLAT(N)=COORD(1)
D      RLON(N)=COORD(2)
D      CALL VFUZ(COORD,RE,FL,U)
       DO 204 J=1,3
  204  SU(N,J)=U(J)
  205  CONTINUE
       WRITE OUTPUT TAPE 3,9507,MINV,XMAX,RDMAX,RDMIN,RA,DEC
C
C      INITIALIZE LINE COUNT AND DELTA T (DIFFERENCE BETWEEN
C      LOCAL STATION PREDICTIONS STARTING TIME AND EPOCH OF INPUT
C      PARAMETERS IN SECONDS)
C
       LINES=1
       LINE6=1
D      DTIMES=XLAS-DTLA
C
C      SKIP A PAGE AND PRINT HEADING FOR LOCAL STATION PREDICTIONS
C      PRINT OUT
C
       WRITE OUTPUT TAPE 3,6038
       WRITE OUTPUT TAPE 3,9502
       IF(ICC1) 7004,7004,7005
 7005  WRITE OUTPUT TAPE 6,6038
       WRITE OUTPUT TAPE 6,9502
       WRITE OUTPUT TAPE 6,7500
 7004  IF(SENSE SWITCH 6) 2051,2052
 2051  PRINT 6038
  207  PRINT 9502
 2052  CONTINUE
```

```
208    WRITE OUTPUT TAPE 3,9503,(STAT2(I),I = 1,NLA)
       IF (SENSF SWITCH 6) 210,2170
210    PRINT               9503,(STAT2(I),I = 1,NLA)
 2170 IF (SENSE SWITCH 2) 2171,217
 2171 PRINT 6025
      PAUSE 77775
  217 LINES=LINFS+1
C
C     SKIP A PAGE AND PRINT HEADING IF 50 LINES OF CALCULATION
C     HAVE BFEN PRINTED
C
 9600 IF (LINES-40) 231,231,218
  218 LINFS=1
      WRITE OUTPUT TAPE 3,6038
      WRITE OUTPUT TAPE 3,9503,(STAT2(I),I = 1,NLA)
      IF (SENSE SWITCH 6) 220,231
  220 PRINT 6038
      PRINT               9503,(STAT2(I),I = 1,NLA)
  231 IF (ICC1) 7016,7016,7007
 7007 IF (LINE6-40) 7016,7016,7015
 7015 LINE6=1
      WRITE OUTPUT TAPE 6,6038
      WRITE OUTPUT TAPE 6,7500
D7016 DTIMES=DTIMFS+DTLA
D     TIME=TIME0+DTIMES*0.727220521664304E-4
D     DDJ0=INTF(TIME/6.283185307179586)
      DJ=DJ0+DDJ0
D     TIME=ALLOTZ(TIME)
C
C     COMPUTE GREENWICH APPARENT SIDEREAL TIME AT T0 + DELTA T
C
D     EPHR = TIME * 3.81971863421
D     EQR=EQN(DJ,EPHR,XX,XX,XX)
D     ST = GAST7(DJ,EPHR,EQR)
      CALL JULCAL(DJ,NM,ND,NY)
C
C     CONVERT UNIVERSAL TIME IN RADIANS TO HOURS, MINUTES, AND SECONDS
C
D     CALL RHMSZ(TIME,II,IH,IM,TS)
      NYM19=NY-1900
C
      CALL BRWR2(DTIMES,EN2)
      SST=SINF(ST)
      CST=COSF(ST)
      RG(1)=RXB(1)*CST+RXB(2)*SST
      RG(2)=RXB(2)*CST-RXB(1)*SST
      RG(3)=RXB(3)
C
      KK=0
      DO 242 N=1,NLA
      DO 232 M=1,3
D 232 PGU(M)=RG(M)-SU(N,M)
D     CALL R13Z(RTX,0,-ST,RGU)
D     DUMX=DOTZ(RTX,VXE)
      TESTA(N)=DUMX*57.295780
D     R13A1=1.57079632679-RLAT(N)
D     R13A2=1.57079632679+RLON(N)
D     CALL R13Z(Z,R13A1,R13A2,RGU)
D     CALL VRDZ(2,Z,ELEVAT,AZIMUT,RANG)
      ELED(N)=57.29578*ELEVAT
      AZID(N)=57.29578*AZIMUT
      RGE(N)=RANG
      IF (ELED(N)-XMIN) 233,234,234
B 233 DATA(N)=APRINT
      GO TO 242
  234 IF (TESTA(N)-RDMIN) 235,236,236
B 235 DATA(N)=APRINT
      GO TO 242
  236 IF (TESTA(N)-RDMAX) 238,238,237
B 237 DATA(N)=APRINT
      GO TO 242
  238 IF (RGE(N)-XMAX) 240,240,239
B 239 DATA(N)=APRINT
      GO TO 242
B 240 DATA(N)=BPRINT
      SENSE LIGHT 1
      IF (ICC1) 242,242,241
  241 KK=KK+1
      RGF1(KK)=RGE(N)
      FLED1(KK)=ELFD(N)
      AZID1(KK)=AZID(N)
      TESTA1(KK)=TFSTA(N)
B     STAT3(KK) = STAT1(N)
B     STAT4(KK) = STAT2(N)
  242 CONTINUF
      IF (SENSE LIGHT 1) 243,2460
  243 IF (LC2-1) 245,244,245
  244 WRITE OUTPUT TAPE 3,9501
      LC2=0
      LINES =LINES+1
  245 WRITE OUTPUT TAPE 3,6052,NM,ND,NYM19,IH,IM,TS, (DATA(N), N=1,NLA)
      LINES= LINES+1
```

```
      IF (ICC1) 247,247,246
246   WRITE OUTPUT TAPE 6,7501,NM,ND,NYM19,IH,IM,(STAT3(I),STAT4(I),
     1RGF1(I),AZID1(I),ELED1(I),TESTA1(I), I =1,KK)
      LINE6=LINF6+KK+1
      GO TO 247
 2460 LC2=1
  247 CONTINUE
      IF ( DTIMFS-XLAF) 9600,248,248
 248  IF (SFNSF SWITCH 2) 249,7010
  249 PRINT 6025
      PAUSE 77774
 7010 IF (ICC1) 200,200,7011
 7011 FND FILF 6
      GO TO 200
C
C     END LOCAL STATION PREDICTIONS CALCULATION
C
  300 PRINT 6039
       FND FILE 3
      PAUSE 77777
      GO TO 10
      END
```

APPENDIX VII

SOURCE DECKS OF SUBROUTINES

```
*     DATE 2/25/65
*     FUNCTION ALLOT   FORTRAN SOURCE PROGRAM                                 ALLOT000
*     CARDS COLUMN                                                            ALLOT001
*     LISTB                                                                   ALLOT002
*     LABEL
      FUNCTION ALLOT(X)                                                       ALLOT003
C                                                                             ALLOT004
C     VERSION OF 07/22/63                                                     ALLOT005
C           FORTRAN FUNCTION                                                  ALLOT006
C           FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094                  ALLOT007
C                                                                             ALLOT008
C     PURPOSE                                                                 ALLOT009
C           REDUCES AN ANGLE OF ANY MAGNITUDE AND SIGN BY MODULUS 2 PI ALLOT010
C           AND ADDS 2 PI IF ANGLE IS NEGATIVE.  THE RESULTING ANGLE ISALLOT011
C           POSITIVE BETWEEN 0 AND +2 PI RADIANS.                             ALLOT012
C                                                                             ALLOT013
C     CALLING SEQUENCE                                                        ALLOT014
C           NAME = ALLOT(X)                                                   ALLOT015
C                                                                             ALLOT016
C     INPUT                                                                   ALLOT017
C           X     = ANGLE IN RADIANS                                          ALLOT018
C                                                                             ALLOT019
C     OUTPUT                                                                  ALLOT020
C           NAME = ANGLE IN RADIANS BETWEEN 0 AND + 2 PI RADIANS              ALLOT021
C                                                                             ALLOT022
C     REFERENCE                                                               ALLOT023
C           ******                                                            ALLOT024
C                                                                             ALLOT025
C     METHOD                                                                  ALLOT026
C           ******                                                            ALLOT027
C                                                                             ALLOT028
C     RESTRICTIONS                                                            ALLOT029
C           ******                                                            ALLOT030
C                                                                             ALLOT031
C     ACCURACY                                                                ALLOT032
C           ******                                                            ALLOT033
C                                                                             ALLOT034
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                                ALLOT035
C           NONE                                                              ALLOT036
C                                                                             ALLOT037
C     REQUIRED SUBPROGRAMS - OTHER                                            ALLOT038
C           NONE                                                              ALLOT039
C                                                                             ALLOT040
C     STORAGE REQUIREMENTS                                                    ALLOT041
C           41                                                                ALLOT042
C                                                                             ALLOT043
C     TIMING                                                                  ALLOT044
C           NO ESTIMATE AVAILABLE                                             ALLOT045
C                                                                             ALLOT046
C                                                                             ALLOT050
C                                                                             ALLOT053
C     PROGRAM MODIFICATIONS                                                   ALLOT054
C                       NO MODIFICATIONS TO DATE                              ALLOT056
C                                                                             ALLOT057
C***** START PROGRAM *****************************************************ALLOT058
C                                                                             ALLOT059
    2 ALLOT=MODF(X,6.2831853)                                                 ALLOT060
    3 IF (ALLOT) 4,5,5                                                        ALLOT061
    4 ALLOT=ALLOT+6.2831853                                                   ALLOT062
    5 RETURN                                                                  ALLOT063
      END                                                                     ALLOT064
*     FUNCTION ALLOTZ   FORTRAN SOURCE PROGRAM                                ALLOTZ00
*     CARDS COLUMN                                                            ALLOTZ01
*     LISTB                                                                   ALLOTZ02
*     LABEL
      FUNCTION ALLOTZ(X)                                                      ALLOTZ03
C                                                                             ALLOTZ04
C     VERSION OF 07/22/63                                                     ALLOTZ05
C           FORTRAN FUNCTION                                                  ALLOTZ06
C           FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094                  ALLOTZ07
C                                                                             ALLOTZ08
C     PURPOSE                                                                 ALLOTZ09
C           REDUCES AN ANGLE OF ANY MAGNITUDE AND SIGN BY MODULUS 2 PI ALLOTZ10
C           AND ADDS 2 PI IF ANGLE IS NEGATIVE.  THE RESULTING ANGLE ISALLOTZ11
C           POSITIVE BETWEEN 0 AND +2 PI RADIANS.                             ALLOTZ12
C                                                                             ALLOTZ13
C                                                                             ALLOTZ14
C     CALLING SEQUENCE                                                        ALLOTZ15
C      D    NAME = ALLOTZ(X)                                                  ALLOTZ16
C                                                                             ALLOTZ17
C     INPUT                                                                   ALLOTZ18
C           X     = ANGLE IN RADIANS                                          ALLOTZ19
C                                                                             ALLOTZ20
C           X MUST BE AVAILABLE IN CALLING PROGRAM IN DOUBLE PRECISION ALLOTZ21
C           FORM.                                                             ALLOTZ22
C                                                                             ALLOTZ23
C     OUTPUT                                                                  ALLOTZ24
C           NAME = ANGLE IN RADIANS BETWEEN 0 AND + 2 PI RADIANS              ALLOTZ25
C                                                                             ALLOTZ26
C           NAME IS RETURNED TO CALLING PROGRAM IN DOUBLE PRECISION           ALLOTZ27
C           FORM.                                                             ALLOTZ28
C                                                                             ALLOTZ29
C     REFERENCE                                                               ALLOTZ30
C           ******                                                            ALLOTZ31
```

```
C                                                                       ALLOTZ32
C.... METHOD                                                            ALLOTZ33
C              ******                                                   ALLOTZ34
C                                                                       ALLOTZ35
C     RESTRICTIONS                                                      ALLOTZ36
C              ******                                                   ALLOTZ37
C                                                                       ALLOTZ38
C     ACCURACY                                                          ALLOTZ39
C              INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.    ALLOTZ40
C                                                                       ALLOTZ41
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          ALLOTZ42
C              DMOD,(DFAD)                                              ALLOTZ43
C                                                                       ALLOTZ44
C     REQUIRED SUBPROGRAMS - OTHER                                      ALLOTZ45
C              NONE                                                     ALLOTZ46
C                                                                       ALLOTZ47
C     STORAGE REQUIREMENTS                                              ALLOTZ48
C              64 WITHOUT REQUIRED SUBPROGRAMS                          ALLOTZ49
C                                                                       ALLOTZ50
C     TIMING                                                            ALLOTZ51
C              NO ESTIMATE AVAILABLE                                    ALLOTZ52
C                                                                       ALLOTZ53
C                                                                       ALLOTZ57
C                                                                       ALLOTZ60
C     PROGRAM MODIFICATIONS                                             ALLOTZ61
C                             NO MODIFICATIONS TO DATE                  ALLOTZ63
C                                                                       ALLOTZ64
C***** START PROGRAM ***************************************************ALLOTZ65
C                                                                       ALLOTZ66
D   2 ALLOTZ=MODF(X,6.283185307179586)                                  ALLOTZ67
    3 IF (ALLOTZ) 4,5,5                                                 ALLOTZ68
D   4 ALLOTZ=ALLOTZ+6.283185307179586                                   ALLOTZ69
    5 RETURN                                                            ALLOTZ70
      END                                                               ALLOTZ71
*     FUNCTION ATANQ  FORTRAN SOURCE PROGRAM                            ATANQ000
*     CARDS COLUMN                                                      ATANQ001
*     LIST8                                                             ATANQ002
*     LABEL
      FUNCTION ATANQ(S,C)                                               ATANQ003
C                                                                       ATANQ004
C     VERSION OF 03/03/64                                               ATANQ005
C              FORTRAN FUNCTION                                         ATANQ006
C              FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094         ATANQ007
C                                                                       ATANQ008
C     PURPOSE                                                           ATANQ009
C              COMPUTES THE ARCTANGENT OF AN ANGLE WITH PROPER ALLOCATION ATANQ010
C              OF QUADRANT TO THE ANGLE BETWEEN 0 AND + 2 PI RADIANS.   ATANQ011
C                                                                       ATANQ012
C     CALLING SEQUENCE                                                  ATANQ013
C              NAME = ATANQ (S,C)                                       ATANQ014
C                                                                       ATANQ015
C     INPUT                                                             ATANQ016
C              S     = D*SIN(A)                                         ATANQ017
C              C     = D*COS(A)                                         ATANQ018
C                 WHERE D IS AN ARBITRARY POSITIVE CONSTANT (NORMALLY   ATANQ019
C                 D = +1.0)                                             ATANQ020
C                                                                       ATANQ021
C     OUTPUT                                                            ATANQ022
C              NAME = ANGLE A IN RADIANS BETWEEN 0 AND + 2 PI RADIANS   ATANQ023
C                                                                       ATANQ024
C     REFERENCE                                                         ATANQ025
C              REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP  ATANQ026
C                                                                       ATANQ027
C     METHOD                                                            ATANQ028
C              USES FORTRAN MONITOR FUNCTION ATANF.  TESTS THE SIGNS OF ATANQ029
C              SINE AND COSINE, THEN ADDS OR SUBTRACTS APPROPIATE       ATANQ030
C              FRACTIONS OF 2 PI RADIANS TO ASSIGN ANGLE TO PROPER      ATANQ031
C              QUADRANT BETWEEN 0 AND + 2 PI RADIANS.                   ATANQ032
C                                                                       ATANQ033
C     RESTRICTIONS                                                      ATANQ034
C                 ATANQ(0/0) = 0 BY DEFINITION                          ATANQ035
C                                                                       ATANQ036
C     ACCURACY                                                          ATANQ037
C              ******                                                   ATANQ038
C                                                                       ATANQ039
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          ATANQ040
C              ATAN                                                     ATANQ041
C                                                                       ATANQ042
C     REQUIRED SUBPROGRAMS - OTHER                                      ATANQ043
C              NONE                                                     ATANQ044
C                                                                       ATANQ045
C     STORAGE REQUIREMENTS                                              ATANQ046
C              173 WITHOUT REQUIRED SUBPROGRAMS                         ATANQ047
C                                                                       ATANQ048
C     TIMING                                                            ATANQ049
C              NO ESTIMATE AVAILABLE                                    ATANQ050
C                                                                       ATANQ051
C                                                                       ATANQ055
C                                                                       ATANQ058
C     PROGRAM MODIFICATIONS                                             ATANQ059
C                                                                       ATANQ064
C***** START PROGRAM ***************************************************ATANQ065
C                                                                       ATANQ066
      IF (C) 108,100,116                                                ATANQ067
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 100 IF (S) 102,104,106                                              ATANQ068
 102 ATANQ=4.712 388 98                                              ATANQ069
     RETURN                                                          ATANQ070
 104 ATANQ=0.0                                                       ATANQ071
     RETURN                                                          ATANQ072
 106 ATANQ=1.570 796 33                                              ATANQ073
     RETURN                                                          ATANQ074
 108 IF (S) 110,112,114                                              ATANQ075
 110 ADD=3.141 592 65                                                ATANQ076
     GO TO 124                                                       ATANQ077
 112 ATANQ=3.141 592 65                                              ATANQ078
     RETURN                                                          ATANQ079
 114 ADD=3.141 592 65                                                ATANQ080
     GO TO 132                                                       ATANQ081
 116 IF (S) 118,120,122                                              ATANQ082
 118 ADD=6.283 185 31                                                ATANQ083
     GO TO 132                                                       ATANQ084
 120 ATANQ=0.0                                                       ATANQ085
     RETURN                                                          ATANQ086
 122 ADD=0.0                                                         ATANQ087
 124 IF (ABSF(S)-ABSF(C)) 126,128,130                                ATANQ088
 126 ATANQ=ATANF(S/C)+ADD                                            ATANQ089
     RETURN                                                          ATANQ090
 128 ATANQ=0.785 398 163+ADD                                         ATANQ091
     RETURN                                                          ATANQ092
 130 ATANQ=1.570 796 33-ATANF(C/S)+ADD                               ATANQ093
     RETURN                                                          ATANQ094
 132 IF (ABSF(S)-ABSF(C)) 126,134,136                                ATANQ095
 134 ATANQ=-0.785 398 163+ADD                                        ATANQ096
     RETURN                                                          ATANQ097
 136 ATANQ=-1.57079633-ATANF(C/S)+ADD                                ATANQ098
     RETURN                                                          ATANQ099
     END                                                             ATANQ100
*    FUNCTION ATANZ    FORTRAN SOURCE PROGRAM                        ATANZ000
*    CARDS COLUMN                                                    ATANZ001
*    LIST8                                                           ATANZ002
*    LABEL
     FUNCTION ATANZ(S,C)                                             ATANZ003
C                                                                    ATANZ004
C    VERSION OF 07/22/63                                             ATANZ005
C           FORTRAN FUNCTION                                         ATANZ006
C           FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094         ATANZ007
C                                                                    ATANZ008
C    PURPOSE                                                         ATANZ009
C           COMPUTES AN ANGLE FROM ITS SINE AND COSINE AND PLACES THE ATANZ010
C           THE ANGLE IN A POSITIVE QUADRANT BETWEEN 0 AND + 2 PI    ATANZ011
C           RADIANS.                                                 ATANZ012
C                                                                    ATANZ013
C                                                                    ATANZ014
C    CALLING SEQUENCE                                                ATANZ015
C     D     NAME = ATANZ(S,C)                                        ATANZ016
C                                                                    ATANZ017
C    INPUT                                                           ATANZ018
C           S     = SINE OF ANGLE (+ OR -)                           ATANZ019
C           C     = COSINE OF ANGLE (+ OR -)                         ATANZ020
C                                                                    ATANZ021
C           INPUT ARGUMENTS MUST BE AVAILABLE IN CALLING PROGRAM IN  ATANZ022
C           DOUBLE PRECISION FORM.                                   ATANZ023
C                                                                    ATANZ024
C    OUTPUT                                                          ATANZ025
C           NAME = ANGLE IN RADIANS BETWEEN 0 AND + 2 PI RADIANS     ATANZ026
C                                                                    ATANZ027
C           NAME IS RETURNED TO CALLING PROGRAM IN DOUBLE PRECISION  ATANZ028
C           FORM.                                                    ATANZ029
C                                                                    ATANZ030
C    REFERENCE                                                       ATANZ031
C           ******                                                   ATANZ032
C                                                                    ATANZ033
C    METHOD                                                          ATANZ034
C           USES FORTRAN MONITOR FUNCTION ATAN2F.  IF ARGUMENT       ATANZ035
C           RETURNED BY ATAN2F IS -, 2 PI RADIANS ARE ADDED .        ATANZ036
C                                                                    ATANZ037
C    RESTRICTIONS                                                    ATANZ038
C           ******                                                   ATANZ039
C                                                                    ATANZ040
C    ACCURACY                                                        ATANZ041
C           INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.    ATANZ042
C                                                                    ATANZ043
C    REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                        ATANZ044
C           DATAN2,(DFAD)                                            ATANZ045
C                                                                    ATANZ046
C    REQUIRED SUBPROGRAMS - OTHER                                    ATANZ047
C           NONE                                                     ATANZ048
C                                                                    ATANZ049
C    STORAGE REQUIREMENTS                                            ATANZ050
C           67 WITHOUT REQUIRED SUBPROGRAMS                          ATANZ051
C                                                                    ATANZ052
C    TIMING                                                          ATANZ053
C           NO ESTIMATE AVAILABLE                                    ATANZ054
C                                                                    ATANZ055
C                                                                    ATANZ059
C                                                                    ATANZ062
C    PROGRAM MODIFICATIONS                                           ATANZ063
C                         NO MODIFICATIONS TO DATE                   ATANZ065
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C
C***** START PROGRAM ***********************************************************
C
D    2 ATANZ=ATAN2F(S,C)
     3 IF (ATANZ) 4,5,5
D    4 ATANZ=ATANZ+6.283185307179586
     5 RETURN
       END
*      SUBROUTINE BBRWR  FORTRAN SOURCE PROGRAM
*      PAUSE
*      CARDS COLUMN
*      LIST8
*      LABEL
       SUBROUTINE BBRWR(DA,AT,J,K)
C
C      VERSION OF 10/02/63
C             FORTRAN SUBROUTINE
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C      PURPOSE
C             COMPUTES BROUWER MEAN ORBITAL ELEMENTS FROM OSCULATING
C             ORBITAL ELEMENTS BY MEANS OF AN ITERATIVE PROCESS.
C
C      CALLING SEQUENCE
C             DIMENSION DA(6),AT(6)
C             CALL BBRWR(DA,AT,J,K)
C
C      INPUT
C             J     = MAXIMUM NUMBER OF ITERATIONS ALLOWED
C             DA(1)= TRUNCATION FACTOR FOR SEMI-MAJOR AXIS - KILOMETERS
C             DA(2)= TRUNCATION FACTOR FOR ECCENTRICITY - DIMENSIONLESS
C             DA(3)= TRUNCATION FACTOR FOR INCLINATION - RADIANS
C             DA(4)= TRUNCATION FACTOR FOR RIGHT ASCENSION OF ASCENDING
C                    NODE - RADIANS
C             DA(5)= TRUNCATION FACTOR FOR ARGUMENT OF PERIGEE - RADIANS
C             DA(6)= TRUNCATION FACTOR FOR MEAN ANOMALY - RADIANS
C
C             TRUE VALUES OF OSCULATING ORBITAL ELEMENTS
C
C             AT(1)= SEMI-MAJOR AXIS                     - KILOMETERS
C             AT(2)= ECCENTRICITY                        - DIMENSIONLESS
C             AT(3)= INCLINATION                         - RADIANS
C             AT(4)= RIGHT ASCENSION OF ASCENDING NODE - RADIANS
C             AT(5)= ARGUMENT OF PERIGEE                 - RADIANS
C             AT(6)= MEAN ANOMALY                        - RADIANS
C
C      OUTPUT
C             K     = NUMBER OF ITERATIONS REQUIRED FOR CONVERGENCE
C
C      OUTPUT VIA COMMON
C
C             BROUWER MEAN ELEMENTS
C
C          A110(1)= SEMI-MAJOR AXIS                     - KILOMETERS
C          A110(2)= ECCENTRICITY                        - DIMENSIONLESS
C          A110(3)= INCLINATION                         - RADIANS
C          A110(4)= RIGHT ASCENSION OF ASCENDING NODE - RADIANS
C          A110(5)= ARGUMENT OF PERIGEE                 - RADIANS
C          A110(6)= MEAN ANOMALY                        - RADIANS
C
C      REFERENCE
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C      METHOD
C             FOR THE 1ST APPROXIMATION, THE MEAN ELEMENTS ARE ASSUMED
C             TO BE EQUAL TO THE TRUE OSCULATING ELEMENTS.  IN SUBSEQUENT
C             APPROXIMATIONS,  THE MEAN ELEMENTS ARE SET EQUAL TO THE
C             MEAN ELEMENTS OF THE PREVIOUS APPROXIMATION PLUS THE
C             ALGEBRAIC DIFFERENCE BETWEEN THE VALUES OF THE TRUE
C             OSCULATING ELEMENTS MINUS THE VALUES OF THE OSCULATING
C             ELEMENTS COMPUTED BY SUBROUTINES BRWR1 AND BRWR2.
C             SUBROUTINES BRWR1 AND BRWR2 COMPUTE OSCULATING ELEMENTS
C             ACCORDING TO DIRK BROUWER'S ARTIFICIAL SATELLITE THEORY
C             WITHOUT DRAG.
C             THIS METHOD SUGGESTED BY DR. HANS HERTZ, DATA SYSTEMS
C             DIVISION, GODDARD SPACE FLIGHT CENTER.
C
C      RESTRICTIONS
C             FOR SMALL ECCENTRICITIES, THIS SUBROUTINE WILL NOT
C             CONVERGE.  ERROR WARNING IS PRINTED ON LINE AND ON TAPE
C             UNIT A3 BEFORE RETURNING TO CALLING PROGRAM IF CONVERGENCE
C             IS NOT OBTAINED AFTER J ITERATIONS.
C
C      ACCURACY
C             SEVERAL TEST CASES WERE RUN WITH ECCENTRICITIES IN THE
C             NEIGHBORHOOD OF .1 AND CONVERGENCE WAS REACHED AFTER 4 OR
C             5 ITERATIONS.
C
C      REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C                       (STH),(FIL),(SPH)
C
C      REQUIRED SUBPROGRAMS - OTHER
C             07/22/63  ALLOT
C             07/22/63  ALLOTZ
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C              03/03/64  ATANQ                                                  BBRWR084
C              07/17/63  BRWR1                                                  BBRWR085
C              01/31/64  BRWR2                                                  BBRWR086
C              03/02/64  ELRV                                                   BBRWR087
C              09/12/63  XKEP                                                   BBRWR088
C                                                                               BBRWR089
C        STORAGE REQUIREMENTS                                                   BBRWR090
C              146 WITHOUT REQUIRED SUBPROGRAMS                                 BBRWR091
C                                                                               BBRWR092
C        TIMING                                                                 BBRWR093
C              NO ESTIMATE AVAILABLE                                            BBRWR094
C                                                                               BBRWR095
C                                                                               BBRWR099
C                                                                               BBRWR102
C        PROGRAM MODIFICATIONS                                                  BBRWR103
C                                                                               BBRWR106
C***** START PROGRAM ****************************************************BBRWR107
C                                                                               BBRWR108
  100 FORMAT (//24H ******* WARNING ******* /77H NO CONVERGENCE IN BBRWBBRWR109
     1R SUBROUTINE.  BROUWER MEAN ELEMENTS ARE NOT ACCURATE  /////)      BBRWR110
C                                                                               BBRWR111
      DIMENSION DUM1(100)                                                       BBRWR112
      DIMENSION DA(6),AT(6),A110(6),DUMX(10),AC(6),DAT(6),TDAT(6)               BBRWR113
C                                                                               BBRWR114
      COMMON DUM1,A110,DUMX,AC                                                  BBRWR115
C                                                                               BBRWR116
      K = 0                                                                     BBRWR117
      DO 10 N=1,6                                                               BBRWR118
   10 A110(N) = AT(N)                                                           BBRWR119
C                                                                               BBRWR120
    1 CALL BRWR1                                                                BBRWR121
D     CALL BRWR2(0.0,0.0)
C                                                                               BBRWR123
      K = K + 1                                                                 BBRWR124
      IF (K-J) 4,4,3                                                            BBRWR125
    3 WRITE OUTPUT TAPE 3,100                                                   BBRWR126
      PRINT 100                                                                 BBRWR127
      RETURN                                                                    BBRWR128
C                                                                               BBRWR129
    4 DO 5 N=1,6                                                                BBRWR130
      DAT(N) = AT(N) - AC(N)                                                    BBRWR131
    5 TDAT(N) = ABSF(DAT(N))                                                    BBRWR132
C                                                                               BBRWR133
      DO 6 N=1,6                                                                BBRWR134
      IF (TDAT(N)-DA(N)) 6,6,8                                                  BBRWR135
    6 CONTINUE                                                                  BBRWR136
    7 RETURN                                                                    BBRWR137
C                                                                               BBRWR138
    8 DO 9 N=1,6                                                                BBRWR139
    9 A110(N) = A110(N) + DAT(N)                                                BBRWR140
      A110(3)=ALLOT(A110(3))                                                    BBRWR141
      A110(4)=ALLOT(A110(4))                                                    BBRWR142
      A110(5)=ALLOT(A110(5))                                                    BBRWR143
      A110(6)=ALLOT(A110(6))                                                    BBRWR144
      GO TO 1                                                                   BBRWR145
      END                                                                       BBRWR146
*     SUBROUTINE BRWR1
*     CARDS COLUMN                                                              BRWR1001
*     LIST8                                                                     BRWR1002
*     LABEL
      SUBROUTINE BRWR1                                                          BRWR1003
C                                                                               BRWR1004
C     VERSION OF 07/17/63                                                       BRWR1005
C            FORTRAN SUBROUTINE                                                 BRWR1006
C            FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094                   BRWR1007
C                                                                               BRWR1008
C     PURPOSE                                                                   BRWR1009
C     BRWR1 AND BRWR2 CONVERT BROUWER MEAN ORBITAL ELEMENTS TO                  BRWR1010
C     OSCULATING ORBITAL ELEMENTS AND TO POSITION AND VELOCITY                  BRWR1011
C     COMPONENTS.  SECULAR AND LONG PERIOD COEFFICIENTS AND OTHER               BRWR1012
C     INTERMEDIATE QUANTITIES WHICH ARE FUNCTIONS OF THE MEAN                   BRWR1013
C     ELEMENTS AND THE EARTHS GRAVITATIONAL HARMONICS ONLY (I.E., DO NOTBRWR1014
C     VARY WITH TIME AND ARE CONSTANT FOR ANY GIVEN SET OF MEAN                 BRWR1015
C     ELEMENTS) ARE COMPUTED IN BRWR1 AND PLACED IN COMMON.  BRWR2 CAN          BRWR1016
C     THEN BE USED TO CALCULATE OSCULATING ORBITAL ELEMENTS FOR ANY             BRWR1017
C     SPECIFIED VALUE OF DT (TIME ELAPSED FROM EPOCH OF MEAN                    BRWR1018
C     ELEMENTS).  COMMON IS USED TO TRANSFER INPUT TO SUBROUTINE BRWR1          BRWR1019
C     FROM CALLING PROGRAM, CONSTANTS AND INTERMEDIATE CALCULATIONS FROMBRWR1020
C     BRWR1 TO BRWR2, AND TO RETURN OUTPUT FROM BRWR2 TO CALLING PROGRAMBRWR1021
C                                                                               BRWR1022
C     DUM1 IS A DUMMY VARIABLE INSERTED AS FIRST VARIABLE IN COMMON IN          BRWR1023
C     BRWR1 AND BRWR2 TO PERMIT SHIFTING OF VARIABLES IN COMMON AREA IF         BRWR1024
C     DESIRED.  THE DIMENSION OF DUM1 MAY BE CHANGED BUT SHOULD BE THE          BRWR1025
C     SAME IN SUBROUTINES BRWR1,BRWR2, AND THE CALLING PROGRAM.                 BRWR1026
C                                                                               BRWR1027
C     CALLING SEQUENCE                                                          BRWR1028
C            CALL BRWR1                                                         BRWR1029
C                                                                               BRWR1030
C     INPUT VIA COMMON                                                          BRWR1031
C          BROUWER MEAN ELEMENTS                                                BRWR1032
C          A110(1) = SEMI-MAJOR AXIS                      - KILOMETERS          BRWR1033
C          A110(2) = ECCENTRICITY                                               BRWR1034
C          A110(3) = INCLINATION                          - RADIANS             BRWR1035
C          A110(4) = RIGHT ASCENSION OF ASCENDING NODE - RADIANS                BRWR1036
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C         A110(5) = ARGUMENT OF PERIGEE                 - RADIANS       BRWR1037
C         A110(6) = MEAN ANOMALY                        - RADIANS       BRWR1038
C                                                                       BRWR1039
C         EARTHS GRAVITATIONAL CONSTANTS                                BRWR1040
C                                                                       BRWR1041
C         GP(1)   = GM(PRODUCT OF G,THE GAUSSIAN CONSTANT SQUARED, AND BRWR1042
C                   M, THE MASS OF THE EARTH) - KM. CUBED/SEC. SQUARED BRWR1043
C         GP(2)   = K2 )  ZONAL HARMONIC              - KM. SQUARED     BRWR1044
C         GP(3)   = K3 )  COEFFICIENTS OF THE         - KM. CUBED       BRWR1045
C         GP(4)   = K4 )  EARTHS GRAVITATIONAL        - KM. 4TH POWER   BRWR1046
C         GP(5)   = K5 )  FIELD                       - KM. 5TH POWER   BRWR1047
C                                                                       BRWR1048
C         ERR     = TRUNCATION FACTOR REQUIRED IN                       BRWR1049
C                   FUNCTION XKEP                       - RADIANS       BRWR1050
C                                                                       BRWR1051
C     OUTPUT VIA COMMON                                                 BRWR1052
C                                                                       BRWR1053
C     REFERENCE                                                         BRWR1054
C            DIRK BROUWER - SOLUTION OF THE PROBLEM OF ARTIFICIAL       BRWR1055
C                           SATELLITE THEORY WITHOUT DRAG -             BRWR1056
C            THE ASTRONOMICAL JOURNAL, VOL.  64, NO.  9,                BRWR1057
C            NOVEMBER 1959, PAGES 378 - 397                             BRWR1058
C                                                                       BRWR1059
C     METHOD                                                            BRWR1060
C            REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP    BRWR1061
C                                                                       BRWR1062
C     RESTRICTIONS                                                      BRWR1063
C            ******                                                     BRWR1064
C                                                                       BRWR1065
C     ACCURACY                                                          BRWR1066
C                                                                       BRWR1067
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                           BRWR1068
C            SQRT,COS,SIN                                               BRWR1069
C                                                                       BRWR1070
C     REQUIRED SUBPROGRAMS - OTHER                                      BRWR1071
C            NONE                                                       BRWR1072
C                                                                       BRWR1073
C     STORAGE REQUIREMENTS                                              BRWR1074
C            666 WITHOUT REQUIRED SUBPROGRAMS                           BRWR1075
C                                                                       BRWR1076
C     TIMING                                                            BRWR1077
C            NO ESTIMATE AVAILABLE                                      BRWR1078
C                                                                       BRWR1079
C                                                                       BRWR1083
C                                                                       BRWR1086
C     PROGRAM MODIFICATIONS                                             BRWR1087
C            NO MODIFICATIONS TO DATE                                   BRWR1089
C                                                                       BRWR1090
C***** START PROGRAM ***************************************************BRWR1091
C                                                                       BRWR1092
    2 DIMENSION DUM1(100)                                               BRWR1093
    3 DIMENSION A110(6),GP(5),A11(6),A1(6),A(6),RX(3),VX(3),EL(13),F(9),BRWR1094
     1B(9),C(10),D(23),G(13),X(28),S(3)                                 BRWR1095
C                                                                       BRWR1096
    4 COMMON DUM1,A110,GP,ERR,A11,A1,A,RX,VX,END,E2A1,D1E,D1I,AL1,UL,   BRWR1097
     1  G1,UG,H1,UH,S,EL,A2,A3,B,C,D,G,X,F                              BRWR1098
C                                                                       BRWR1099
C     COMPUTE INTERMEDIATE QUANTITIES                                   BRWR1100
C                                                                       BRWR1101
    5 A2=A110(1)**2                                                     BRWR1102
    6 A3=A110(1)*A2                                                     BRWR1103
      F(1) = A110(2)                                                    BRWR1104
    7 F(2)=A110(2)*A110(2)                                              BRWR1105
    8 F(3)=F(2)+F(2)                                                    BRWR1106
    9 F(4)=F(2)+F(3)                                                    BRWR1107
   10 F(5)=9.*F(2)                                                      BRWR1108
   11 F(6)=4.+F(4)                                                      BRWR1109
   12 F(7)=2.+F(2)                                                      BRWR1110
   13 B(1)=1.-F(2)                                                      BRWR1111
   14 B(2)=SQRTF(B(1))                                                  BRWR1112
   15 B(3)=B(1)*B(2)                                                    BRWR1113
   16 B(4)=B(3)*B(3)                                                    BRWR1114
   17 B(5)=9.*B(1)                                                      BRWR1115
   18 B(6)=25.*B(1)                                                     BRWR1116
   19 B(7)=126.*B(1)                                                    BRWR1117
   20 B(8)=1./B(3)                                                      BRWR1118
   21 B(9)=1./(B(1)*B(1))                                               BRWR1119
   22 D(1)=COSF(A110(3))                                                BRWR1120
   23 D(2)=D(1)+D(1)                                                    BRWR1121
   24 D(3)=D(1)*D(1)                                                    BRWR1122
   25 D(4)=D(3)*D(3)                                                    BRWR1123
   26 C(1)=GP(2)/A2                                                     BRWR1124
   27 C(2)=1.5*C(1)*B(9)                                                BRWR1125
   28 C(3)=.41666667E-1*C(2)*C(2)                                       BRWR1126
   29 C(4)=.9375*GP(4)/(A2*A2*B(1)*B(4))                                BRWR1127
   30 C(5)=.83333333E-1*C(2)                                            BRWR1128
   31 C(6)=.66666667*C(4)/C(2)                                          BRWR1129
   32 C(7)=.25*GP(3)/(GP(2)*A110(1)*B(1))                               BRWR1130
   33 C(8)=.46875*GP(5)/(GP(2)*A3*B(4))                                 BRWR1131
   34 C(9)=.16666667*C(2)                                               BRWR1132
   35 C(10)=C(9)*D(2)                                                   BRWR1133
   36 D(5)=1.-D(3)                                                      BRWR1134
   37 D(6)=3.*D(3)-1.                                                   BRWR1135
   38 D(7)=5.*D(3)-1.                                                   BRWR1136
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   39 D(8)=8.*D(4)/D(7)                                                   BRWR1137
   40 D(9)=5.*D(8)/D(7)                                                   BRWR1138
   41 D(10)=D(8)-D(6)                                                     BRWR1139
   42 D(11)=C(5)*(5.*D(10)-4.+4.*D(3))-C(6)*D(10                          BRWR1140
   43 D(12)=.16666667*C(8)*(3.*D(10)-2.)                                  BRWR1141
   44 D(13)=.19444444*C(8)*(D(10)+D(10)-D(5))                             BRWR1142
   45 D(14)=3.-16.*D(3)/D(7)+D(9)                                         BRWR1143
   46 D(15)=C(8)*D(14)                                                    BRWR1144
   47 D(16)=F(6)*D(15)                                                    BRWR1145
   48 D(17) = 0.33333333*D(13)                                            BRWR1146
   49 D(18)=.12962963*(D(15)+D(15)-C(8))                                  BRWR1147
   50 D(19)=3.*D(5)                                                       BRWR1148
   51 D(20)=D(6)+D(6)                                                     BRWR1149
   52 D(21)=2.-D(7)                                                       BRWR1150
   53 D(22)=C(10)*SQRTF(D(5))                                             BRWR1151
   54 D(23)=4.*C(9)*D(5)                                                  BRWR1152
   55 F(8)=D(3)*(2.+F(4))                                                 BRWR1153
   56 F(9)=(2.+5.*F(2))*D(8)-D(9)*F(3)*D(3)                               BRWR1154
   57 G(1)=SINF(A110(3))                                                  BRWR1155
   58 G(2)=G(1)*G(1)                                                      BRWR1156
   59 G(3)=A110(2)*D(1)                                                   BRWR1157
   60 G(4)=G(3)*D(1)                                                      BRWR1158
   61 G(5)=G(3)/G(1)                                                      BRWR1159
   62 G(6)=G(4)/G(1)                                                      BRWR1160
   63 G(7)=B(1)*G(1)                                                      BRWR1161
   64 G(8)=G(7)/A110(2)                                                   BRWR1162
   65 G(9)=A110(2)*G(1)                                                   BRWR1163
   66 G(10)=G(3)*G(3)                                                     BRWR1164
   67 G(11)=B(1)/A110(2)                                                  BRWR1165
   68 G(12)=.5*G(11)                                                      BRWR1166
   69 G(13)=G(11)*C(9)                                                    BRWR1167
C                                                                         BRWR1168
C        COMPUTE *MEAN* MEAN MOTION                                       BRWR1169
C                                                                         BRWR1170
   70 ENO=SQRTF(GP(1)/A3)                                                 BRWR1171
C                                                                         BRWR1172
C        COMPUTE COEFFICIENTS OF SECULAR TERMS                            BRWR1173
C                                                                         BRWR1174
   71 S(1)=ENO*(1.+B(2)*(C(2)*D(6)+C(3)*(16.*B(2)-15.+B(6)+(30.-96.*B(2)BRWR1175
     1-90.*B(1))*D(3)+(105.+144.*B(2)+B(6))*D(4))+C(4)*F(2)*(3.-30.*D(3)BRWR1176
     2+35.*D(4))))                                                        BRWR1177
   72 S(2)=ENO*(C(2)*D(7)+C(3)*(24.*B(2)-35.+B(6)+(90.-192.*B(2)-B(7))* BRWR1178
     1D(3)+(385.+360.*B(2)+45.*B(1))*D(4))+.33333333*C(4)*(21.-B(5)+     BRWR1179
     2(B(7)-270.)*D(3)+(385.-189.*B(1))*D(4)))                            BRWR1180
   73 S(3)=ENO*(4.*D(1)*(C(3)*(B(5)-5.+12.*B(2)-D(3)*(35.+36.*B(2)+5.*  BRWR1181
     1B(1)))+.33333333*C(4)*(5.-3.*B(1))*(3.-7.*D(3)))-C(2)*D(2))        BRWR1182
C                                                                         BRWR1183
C        COMPUTE COEFFICIENTS OF LONG PERIOD TERMS                        BRWR1184
C                                                                         BRWR1185
   74 EL(1)=B(3)*D(11)                                                    BRWR1186
   75 EL(2)=B(2)*G(8)*(-C(7)-(4.+F(5))*D(12))                             BRWR1187
   76 EL(3)=G(9)*B(3)*D(13)                                               BRWR1188
   77 EL(4)=.5*C(6)*(F(7)-3.*F(8)+F(9))-.41666667E-1*C(2)*(F(7)-11.*    BRWR1189
     1F(8)+5.*F(9))                                                       BRWR1190
   78 EL(5)=C(7)*(G(1)/F(1)-G(6))+D(12)*((G(8)-G(6))*F(6)+G(9)*(26.0+  BRWR1191
     1F(5)))-G(4)*G(1)*D(16)                                              BRWR1192
   79 EL(6)=G(9)*(D(18)*G(10)-D(17)*(3.0+F(3)-G(10)/G(2)))               BRWR1193
   80 EL(7)=G(3)*A110(2)*(C(6)*D(14)-C(5)*(5.*D(14)-4.))                 BRWR1194
   81 EL(8)=G(5)*(C(7)+F(6)*D(12)+G(2)*D(16))                             BRWR1195
   82 EL(9)=G(5)*F(2)*(-D(17)-D(18)*G(2))                                 BRWR1196
   83 EL(10)=B(1)*F(1)*D(11)                                              BRWR1197
   84 EL(11)=G(7)*(C(7)+F(6)*D(12))                                       BRWR1198
   85 EL(12)=-F(2)*G(7)*D(13)                                             BRWR1199
   86 EL(13)=-G(3)/G(7)                                                   BRWR1200
   87 RETURN                                                              BRWR1201
      END                                                                 BRWR1202
*        SUBROUTINE BRWR2 FORTRAN SOURCE PROGRAM                          BRWR2000
*        CARDS COLUMN                                                     BRWR2001
*        LIST8                                                            BRWR2002
*        LABEL
      SUBROUTINE BRWR2(DT,EN2)
C                                                                         BRWR2004
C        VERSION OF 01/31/64                                              BRWR2005
C                 FORTRAN SUBROUTINE                                      BRWR2006
C                 FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094        BRWR2007
C                                                                         BRWR2008
C        PURPOSE                                                          BRWR2009
C                                                                         BRWR2010
C        CALLING SEQUENCE                                                 BRWR2011
C                 CALL BRWR2(DT,EN2)                                      BRWR2012
C                                                                         BRWR2013
C        INPUT                                                            BRWR2014
C                 DT    = TIME ELAPSED FROM EPOCH OF MEAN ELEMENTS - SECONDS BRWR2015
C                         SEE SUBROUTINE BRWR1 FOR INPUT VIA COMMON       BRWR2016
C                                                                         BRWR2017
C        OUTPUT VIA COMMON                                                BRWR2018
C                 OSCULATING ORBITAL ELEMENTS AT TIME T = EPOCH TIME + DT BRWR2019
C                                                                         BRWR2020
C                 A(1) = SEMI-MAJOR AXIS                    - KILOMETERS  BRWR2021
C                 A(2) = ECCENTRICITY                       - DIMENSIONLESS BRWR2022
C                 A(3) = INCLINATION                        - RADIANS     BRWR2023
C                 A(4) = RIGHT ASCENSION OF ASCENDING NODE  - RADIANS     BRWR2024
C                 A(5) = ARGUMENT OF PERIGEE                - RADIANS     BRWR2025
C                 A(6) = MEAN ANOMALY                       - RADIANS     BRWR2026
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C                                                                       BRWR2027
C           RX(1)                                                       BRWR2028
C           RX(2)  THE 3 RECTANGULAR COORDINATES OF POSITION            BRWR2029
C           RX(3)                                                       BRWR2030
C                                                                       BRWR2031
C           VX(1)                                                       BRWR2032
C           VX(2)  THE 3 RECTANGULAR COMPONENTS OF VELOCITY             BRWR2033
C           VX(3)                                                       BRWR2034
C                                                                       BRWR2035
C     REFERENCE                                                         BRWR2036
C                                                                       BRWR2037
C     METHOD                                                            BRWR2038
C                                                                       BRWR2039
C     RESTRICTIONS                                                      BRWR2040
C                                                                       BRWR2041
C     ACCURACY                                                          BRWR2042
C                                                                       BRWR2043
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          BRWR2044
C             (DFMP),(DFAD),SIN,COS                                     BRWR2045
C                                                                       BRWR2046
C     REQUIRED SUBPROGRAMS - OTHER                                      BRWR2047
C             07/22/63  ALLOTZ                                          BRWR2048
C             07/22/63  ALLOT                                           BRWR2049
C             03/03/64  ATANQ                                           BRWR2050
C             03/02/64  ELRV                                            BRWR2051
C             09/12/63  XKEP                                            BRWR2052
C                                                                       BRWR2053
C     STORAGE REQUIREMENTS                                              BRWR2054
C             543 WITHOUT REQUIRED SUBPROGRAMS                          BRWR2055
C                                                                       BRWR2056
C     TIMING                                                            BRWR2057
C             NO ESTIMATE AVAILABLE                                     BRWR2058
C                                                                       BRWR2059
C                                                                       BRWR2066
C     PROGRAM MODIFICATIONS                                             BRWR2067
C                                                                       BRWR2071
C***** START PROGRAM ***************************************************BRWR2072
C                                                                       BRWR2073
    2 DIMENSION DUM1(100)                                               BRWR2074
    3 DIMENSION A110(6),GP(5),A11(6),A1(6),A(6),RX(3),VX(3),EL(13),F(9),BRWR2075
     1    B(9),C(10),D(23),G(13),X(28),S(3)                             BRWR2076
C                                                                       BRWR2077
    4 COMMON DUM1,A110,GP,ERR,A11,A1,A,RX,VX,ENO,ECA1,D1E,D1I,AL1,UL,   BRWR2078
     1  G1,UG,H1,UH,S,EL,A2,A3,B,C,D,G,X,F                              BRWR2079
C                                                                       BRWR2080
C     COMPUTE SECULAR TERMS                                             BRWR2081
C                                                                       BRWR2082
      A1106 = A110(6)                                                   BRWR2083
      A1105 = A110(5)                                                   BRWR2084
      A1104 = A110(4)                                                   BRWR2085
      S1 = S(1)                                                         BRWR2086
      S2 = S(2)                                                         BRWR2087
      S3 = S(3)                                                         BRWR2088
D     DA1106 = A1106                                                    BRWR2089
D     DA1105 = A1105                                                    BRWR2090
D     DA1104 = A1104                                                    BRWR2091
D     DS1 = S1                                                          BRWR2092
D     DS2 = S2                                                          BRWR2093
D     DS3 = S3                                                          BRWR2094
D   6 A116 = DA1106 + DS1*DT + EN2*DT**2
D   7 A115 = DA1105+DS2*DT                                              BRWR2096
D   8 A114 = DA1104+DS3*DT                                              BRWR2097
    9 A11(6) = ALLOTZ(A116)                                             BRWR2098
   10 A11(5) = ALLOTZ(A115)                                             BRWR2099
   11 A11(4) = ALLOTZ(A114)                                             BRWR2100
   12 A11(3)=A110(3)                                                    BRWR2101
   13 A11(2)=A110(2)                                                    BRWR2102
   14 A11(1)=A110(1)                                                    BRWR2103
C                                                                       BRWR2104
C     COMPUTE LONG PERIOD TERMS                                         BRWR2105
C                                                                       BRWR2106
   15 X(1)=A11(5)+A11(5)                                                BRWR2107
   16 X(2)=X(1)+A11(5)                                                  BRWR2108
   17 X(3)=SINF(X(1))                                                   BRWR2109
   18 X(4)=COSF(A11(5))                                                 BRWR2110
   19 X(5)=COSF(X(2))                                                   BRWR2111
   20 A1(6)=A11(6)+EL(1)*X(3)+EL(2)*X(4)+EL(3)*X(5)                     BRWR2112
   21 A1(5)=A11(5)+EL(4)*X(3)+EL(5)*X(4)+EL(6)*X(5)                     BRWR2113
   22 A1(4)=A11(4)+EL(7)*X(3)+EL(8)*X(4)+EL(9)*X(5)                     BRWR2114
   23 D1E = EL(10)*COSF(X(1))+EL(11)*SINF(A11(5))+EL(12)*SINF(X(2))     BRWR2115
   24 D1I=EL(13)*D1E                                                    BRWR2116
   25 A1(3)=A11(3)+D1I                                                  BRWR2117
   26 A1(2)=A11(2)+D1E                                                  BRWR2118
   28 AL1=ALLOT(A1(6))                                                  BRWR2119
   29 G1 =ALLOT(A1(5))                                                  BRWR2120
   30 H1 =ALLOT(A1(4))                                                  BRWR2121
C                                                                       BRWR2122
C     COMPUTE SHORT PERIOD TERMS                                        BRWR2123
C                                                                       BRWR2124
   31 ECA1=XKEP(AL1,A110(2),X(6),X(7),ERR)                              BRWR2125
   33 X(8)=1.-A110(2)*X(7)                                              BRWR2126
   34 X(9)=1./X(8)                                                      BRWR2127
   35 X(10)=X(9)*X(9)                                                   BRWR2128
   36 X(11)=X(9)*X(10)                                                  BRWR2129
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```
   37 X(12)=X(6)*X(9)*B(2)
   38 X(13)=X(9)*(X(7)-A110(2))
      X12 = X(12)
D     DX12 = X12
      X13 = X(13)
D     DX13 = X13
      X(14) = ATANQ(DX12,DX13)
   40 X(15)=G1+G1
   41 X(16)=X(15)+X(14)
   42 X(17)=X(16)+X(14)
   43 X(18)=X(17)+X(14)
   44 X(19)=SINF(X(16))
   45 X(20)=SINF(X(18))
   46 X(21)=COSF(X(17))
   47 X(22)=D(6)*(X(11)-B(8))
   48 X(23)=D(19)*X(21)
   49 X(24)=A110(2)*(3.*COSF(X(16))+COSF(X(18)))
   50 X(25)=X(9)+B(1)*X(10)
   51 X(26)=G(13)*(D(20)*X(12)*(X(25)+1.)+D(19)*((1.-X(25))*X(19)+
     1(X(25)+.33333333)*X(20)))
   52 X(27)=6.*(X(14)-AL1+A110(2)*X(12))
   53 X(28)=3.*(SINF(X(17))+A110(2)*X(19))+A110(2)*X(20)
C
C     COMPUTE OSCULATING ELEMENTS
C
   54 A(1)=A110(1)*(1.+C(1)*(X(22)+X(11)*X(23)))
   55 A(2) = A110(2)+D1E+G(12)*(C(1)*(X(22)+X(23)*(X(11)-B(9)))-D(23)*
     1X(24))
   56 A(3)=A110(3)+D1I+D(22)*(3.*X(21)+X(24))
   57 UL= AL1-B(2)*X(26)
   58 UG= G1+X(26)+C(9)*(D(7)*X(27)+D(21)*X(28))
   59 UH= H1-C(10)*(X(27)-X(28))
   60 A(6)=ALLOT(UL)
   61 A(5)=ALLOT(UG)
   62 A(4)=ALLOT(UH)
C
C     COMPUTE POSITION AND VELOCITY COMPONENTS
C
   63 CALL ELRV (RX,VX,A,P,EN,GP(1),ERR)
      RETURN
      END
*     FUNCTION DJUL      FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
      FUNCTION DJUL(NM,ND,NY)
C
C     VERSION OF 07/22/63
C             FORTRAN FUNCTION
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C             COMPUTES JULIAN DATE AT 0 HOURS UNIVERSAL TIME (OR
C             0 HOURS EPHEMERIS TIME).
C
C     CALLING SEQUENCE
C             NAME = DJUL(NM,ND,NY)
C
C     INPUT
C             NM    = CALENDAR MONTH
C             ND    = CALENDAR DAY
C             NY    = CALENDAR YEAR
C
C     OUTPUT
C             NAME = JULIAN DATE AT 0 HOURS UNIVERSAL TIME
C
C     REFERENCE
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C     METHOD
C             THE NUMBER OF DAYS WHICH HAVE ELAPSED FROM 12 HOURS
C             UNIVERSAL TIME JAN. 0, 1800 ARE COUNTED AND ADDED TO THE
C             JULIAN DATE OF 12 HOURS UNIVERSAL TIME OF JAN. 0, 1800.
C
C     RESTRICTIONS
C             DATE RESTRICTED TO LIE BETWEEN JANUARY 1, 1801 AND DECEMBER
C             31, 2000.
C
C     ACCURACY
C             EXACT BINARY REPRESENTATION WITHIN DATE LIMITATIONS.
C
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C             NONE
C
C     REQUIRED SUBPROGRAMS - OTHER
C             NONE
C
C     STORAGE REQUIREMENTS
C             153
C
C     TIMING
C             NO ESTIMATE AVAILABLE
C
```

```
C
C     PROGRAM MODIFICATIONS
C                                NO MODIFICATIONS TO DATE
C
C***** START PROGRAM *******************************************************
C
    2 DIMENSION RM(12)
C
    5 RM(1)=0.0
    6 RM(2)=31.0
    7 RM(3)=28.0
    8 RM(4)=31.0
    9 RM(5)=30.0
   10 RM(6)=31.0
   11 RM(7)=30.0
   12 RM(8)=31.0
   13 RM(9)=31.0
   14 RM(10)=30.0
   15 RM(11)=31.0
   16 RM(12)=30.0
C
   17 Y=NY-1800
   18 YL=INTF((Y-1.0)/4.0)
   19 YC=INTF((Y+99.0)/100.0)-1.0
   20 RY=Y-YL
   21 DJUL=RY*365.0+YL*366.0-YC+2378495.5
   22 TD=ND
   23 DO 24 N=1,NM
   24 DJUL=DJUL+RM(N)
   25 IF (NM-2) 29,29,26
   26 IF (Y-100.0) 27,29,27
   27 IF (XMODF(NY,4)) 29,28,29
   28 DJUL=DJUL+1.0
   29 DJUL=DJUL+TD
      RETURN
      END
*     FUNCTION DMSRZ    FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
      FUNCTION DMSRZ(ID,IM,AS)
C
C     VERSION OF 07/22/63
C             FORTRAN FUNCTION
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C             CONVERTS DEGREES, MINUTES, AND SECONDS OF ANGLE OR ARC TO
C             RADIANS (360 DEGREES = 2 PI RADIANS).
C
C     CALLING SEQUENCE
C      D      NAME = DMSRZ(ID,IM,AS)
C
C     INPUT
C             ID   = NUMBER OF DEGREES IN ANGLE OR ARC
C             IM   = NUMBER OF MINUTES IN ANGLE OR ARC
C             AS   = NUMBER OF SECONDS IN ANGLE OR ARC
C
C                    SIGN OF THE INPUT ANGLE OR ARC NEED ONLY BE
C                    ASSOCIATED WITH THE NUMBER OF DEGREES (ID).
C
C     OUTPUT
C             NAME = ANGLE OR ARC IN RADIANS
C
C             NAME IS RETURNED TO CALLING PROGRAM IN DOUBLE PRECISION
C             FORM.
C
C     REFERENCE
C             ******
C
C     METHOD
C             ******
C
C     RESTRICTIONS
C             ******
C
C     ACCURACY
C             WHEN NECESSARY, INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE
C             PRECISION SO THAT THE VALUE OF THE OUTPUT ARGUMENT IS
C             AVAILABLE TO CALLING PROGRAM IN DOUBLE PRECISION.
C
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C             (DFMP),(DFAD)
C
C     REQUIRED SUBPROGRAMS - OTHER
C             NONE
C
C     STORAGE REQUIREMENTS
C             105 WITHOUT REQUIRED SUBPROGRAMS
C
C     TIMING
C             NO ESTIMATE AVAILABLE
C
C
```

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C
C     PROGRAM MODIFICATIONS
C                         NO MODIFICATIONS TO DATE
C
C***** START PROGRAM ***********************************************************
C
    2 AD=ID
    3 AM=IM
    4 AM=SIGNF(AM,AD)
    5 ARS= SIGNF(AS,AD)
D   6 DMSRZ=AD*.1745329251994330E-1  +  AM*.2908882086657216E-3
     1        + ARS*.4848136811095360E-5
      RETURN
      END
*     FUNCTION DOTZ      FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
    1 FUNCTION DOTZ(X,Y)
C
C     VERSION OF 7/22/63
C
C     COMPUTES THE ANGLE BETWEEN VECTORS X AND Y.
C
C     INPUT, OUTPUT, AND INTERNAL ARITHMETIC OPERATIONS
C     ARE ALL PERFORMED IN DOUBLE PRECISION.
C
C     INPUT
C                   VECTOR X IN ANY UNITS.
C                   VECTOR Y IN ANY UNITS, NOT NECESSARILY THE SAME
C                   UNITS AS VECTOR X.
C
C     OUTPUT
C             DOTZ = ANGLE IN RADIANS BETWEEN X AND Y.
C                   DOTZ LIES BETWEEN 0 AND + PI RADIANS.
C
C     REQUIRED SUBPROGRAMS
C
C     NONE
C
D   2 DIMENSION X(3),Y(3)
D   3 C=(X(1)*Y(1)+X(2)*Y(2)+X(3)*Y(3))/((SQRTF(X(1)**2+X(2)**2+X(3)**2)
     1 )*(SQRTF(Y(1)**2+Y(2)**2+Y(3)**2)))
D     A = 1.0 - C*C
D     A = ABSF(A)
D   4 S = SQRTF(A)
D   5 DOTZ=ATAN2F(S,C)
    6 RETURN
    7 END
*     SUBROUTINE ELRV   FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
      SUBROUTINE ELRV(X,VX,A,P,EN,GM,ERR)
C
C     VERSION OF 03/02/64
C             FORTRAN SUBROUTINE
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C             CONVERTS OSCULATING ORBITAL ELEMENTS INTO GEOCENTRIC
C             EQUATORIAL INERTIAL RECTANGULAR COORDINATES OF POSITION
C             AND VELOCITY.
C
C     CALLING SEQUENCE
C             DIMENSION X(3),VX(3),A(6)
C             CALL ELRV(X,VX,A,P,EN,GM,ERR)
C
C     INPUT
C             A(1) = SEMI-MAJOR AXIS
C             A(2) = ECCENTRICITY                     - DIMENSIONLESS
C             A(3) = INCLINATION                      - RADIANS
C             A(4) = RIGHT ASCENSION OF ASCENDING NODE - RADIANS
C             A(5) = ARGUMENT OF PERIGEE              - RADIANS
C             A(6) = MEAN ANOMALY                     - RADIANS
C
C             GM   = THE PRODUCT OF G, THE GAUSSIAN CONSTANT SQUARED,
C                   AND M, THE MASS OF THE EARTH
C             ERR  = TRUNCATION FACTOR REQUIRED IN FUNCTION XKEP
C                   IN RADIANS
C
C     OUTPUT
C             X(1)
C             X(2)    THE 3 RECTANGULAR COORDINATES OF POSITION
C             X(3)
C
C             VX(1)
C             VX(2)   THE 3 RECTANGULAR COMPONENTS OF VELOCITY
C             VX(3)
C
C
C             P    = ANOMALISTIC PERIOD
C             EN   = MEAN ANGULAR MOTION
C
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C          UNITS OF INPUT ARGUMENTS A(I) AND GM ARE ARBITRARY          ELRV 044
C          BUT MUST BE MUTUALLY CONSISTENT.                             ELRV 045
C                                                                       ELRV 046
C          UNITS OF OUTPUT ARGUMENTS X, VX, P, AND EN WILL DEPEND       ELRV 047
C          UPON THE UNITS EMPLOYED FOR A(I) AND GM.                     ELRV 048
C                                                                       ELRV 049
C     REFERENCE                                                         ELRV 050
C          REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP      ELRV 051
C                                                                       ELRV 052
C     METHOD                                                            ELRV 053
C          REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP      ELRV 054
C                                                                       ELRV 055
C     RESTRICTIONS                                                      ELRV 056
C          ECCENTRICITY MUST BE LESS THAN 1.0.                          ELRV 057
C                                                                       ELRV 058
C     ACCURACY                                                          ELRV 059
C          REFER TO ACCURACY TESTS IN SUBPROGRAM WRITEUP.               ELRV 060
C                                                                       ELRV 061
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          ELRV 062
C          SQRT,SIN,COS                                                 ELRV 063
C                                                                       ELRV 064
C     REQUIRED SUBPROGRAMS - OTHER                                      ELRV 065
C          09/12/63  XKEP                                               ELRV 066
C                                                                       ELRV 067
C     STORAGE REQUIREMENTS                                              ELRV 068
C          260 WITHOUT REQUIRED SUBPROGRAMS                             ELRV 069
C                                                                       ELRV 070
C     TIMING                                                            ELRV 071
C          NO ESTIMATE AVAILABLE                                        ELRV 072
C                                                                       ELRV 076
C                                                                       ELRV 079
C     PROGRAM MODIFICATIONS                                             ELRV 080
C                                                                       ELRV 085
C***** START PROGRAM ***************************************************ELRV 086
C                                                                       ELRV 087
      DIMENSION X(3),VX(3),A(6)                                         ELRV 088
C                                                                       ELRV 089
    3 E=XKEP(A(6),A(2),SE,CE,ERR)                                       ELRV 090
    4 X1=1.0-A(2)*CE                                                    ELRV 091
    5 X2=1.0/X1                                                         ELRV 092
    6 R=A(1)*X1                                                         ELRV 093
    7 X3=SQRTF(1.0-A(2)**2)                                             ELRV 094
    8 RTGMA=SQRTF(GM*A(1))                                              ELRV 095
      SA = SINF(A(5))                                                   ELRV 096
      SB = SINF(A(3))                                                   ELRV 097
      SC = SINF(A(4))                                                   ELRV 098
      CA = COSF(A(5))                                                   ELRV 099
      CB = COSF(A(3))                                                   ELRV 100
      CC = COSF(A(4))                                                   ELRV 101
C                                                                       ELRV 102
C     COMPUTE POSITION COORDINATES                                      ELRV 103
C                                                                       ELRV 104
      Q1 = A(1)*(CE-A(2))                                               ELRV 105
      Q2 = A(1)*X3*SE                                                   ELRV 106
      V  = Q1*CA - Q2*SA                                                ELRV 107
      W  = Q2*CA + Q1*SA                                                ELRV 108
      Z  = CB*W                                                         ELRV 109
      X(1) = CC*V - SC*Z                                                ELRV 110
      X(2) = CC*Z + SC*V                                                ELRV 111
      X(3) = SB*W                                                       ELRV 112
C                                                                       ELRV 113
C     COMPUTE VELOCITY COMPONENTS                                       ELRV 114
C                                                                       ELRV 115
      QD1 = -RTGMA*SE/R                                                 ELRV 116
      QD2 = RTGMA*X3*CE/R                                               ELRV 117
      V = QD1*CA - QD2*SA                                               ELRV 118
      W = QD2*CA + QD1*SA                                               ELRV 119
      Z = CB*W                                                          ELRV 120
      VX(1) = CC*V - SC*Z                                               ELRV 121
      VX(2) = CC*Z + SC*V                                               ELRV 122
      VX(3) = SB*W                                                      ELRV 123
C                                                                       ELRV 124
      RTGM = SQRTF(GM)                                                  ELRV 125
      RTA  = SQRTF(A(1))                                                ELRV 126
      EN   = RTGM/(RTA*A(1))                                            ELRV 127
      P    = 6.283 185 31/EN                                            ELRV 128
      RETURN                                                            ELRV 129
      END                                                               ELRV 130
*     SUBROUTINE ELRVZ  FORTRAN SOURCE PROGRAM                          ELRVZ000
*     CARDS COLUMN                                                      ELRVZ001
*     LIST8                                                             ELRVZ002
*     LABEL
      SUBROUTINE ELRVZ(X,VX,A,P,EN,GM,ERR)                              ELRVZ003
C                                                                       ELRVZ004
C     VERSION OF 03/02/64                                               ELRVZ005
C          FORTRAN SUBROUTINE                                           ELRVZ006
C          FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094             ELRVZ007
C                                                                       ELRVZ008
C     PURPOSE                                                           ELRVZ009
C          CONVERTS OSCULATING ORBITAL ELEMENTS INTO GEOCENTRIC          ELRVZ010
C          EQUATORIAL INERTIAL RECTANGULAR COORDINATES OF POSITION      ELRVZ011
C          AND VELOCITY.                                                ELRVZ012
C                                                                       ELRVZ013
C     CALLING SEQUENCE                                                  ELRVZ014
```

```
C       D     DIMENSION X(3),VX(3),A(6)                                      ELRVZ015
C       D     CALL ELRVZ(X,VX,A,P,EN,GM,ERR)                                 ELRVZ016
C                                                                             ELRVZ017
C                                                                             ELRVZ018
C     INPUT                                                                   ELRVZ019
C             A(1) = SEMI-MAJOR AXIS                                          ELRVZ020
C             A(2) = ECCENTRICITY                       - DIMENSIONLESS       ELRVZ021
C             A(3) = INCLINATION                        - RADIANS             ELRVZ022
C             A(4) = RIGHT ASCENSION OF ASCENDING NODE  - RADIANS             ELRVZ023
C             A(5) = ARGUMENT OF PERIGEE                - RADIANS             ELRVZ024
C             A(6) = MEAN ANOMALY                       - RADIANS             ELRVZ025
C                                                                             ELRVZ026
C             GM   = THE PRODUCT OF G, THE GAUSSIAN CONSTANT SQUARED,         ELRVZ027
C                    AND M, THE MASS OF THE EARTH                             ELRVZ028
C             ERR  = TRUNCATION FACTOR REQUIRED IN XKEPZ FUNCTION             ELRVZ029
C                    IN RADIANS                                               ELRVZ030
C                                                                             ELRVZ031
C             UNITS OF INPUT ARGUMENTS A(1) AND GM ARE ARBITRARY              ELRVZ032
C             BUT MUST BE MUTUALLY CONSISTENT.                                ELRVZ033
C             INPUT ARGUMENTS MUST BE AVAILABLE IN CALLING PROGRAM IN         ELRVZ034
C             DOUBLE PRECISION FORM.                                          ELRVZ035
C                                                                             ELRVZ036
C     OUTPUT                                                                  ELRVZ037
C             X(1)                                                            ELRVZ038
C             X(2)    THE 3 RECTANGULAR COORDINATES OF POSITION               ELRVZ039
C             X(3)                                                            ELRVZ040
C                                                                             ELRVZ041
C             VX(1)                                                           ELRVZ042
C             VX(2)   THE 3 RECTANGULAR COMPONENTS OF VELOCITY                ELRVZ043
C             VX(3)                                                           ELRVZ044
C                                                                             ELRVZ045
C             P    = ANOMALISTIC PERIOD                                       ELRVZ046
C             EN   = MEAN ANGULAR MOTION                                      ELRVZ047
C                                                                             ELRVZ048
C             UNITS OF OUTPUT ARGUMENTS X, VX, P, AND EN WILL DEPEND          ELRVZ049
C             UPON THE UNITS EMPLOYED FOR A(1) AND GM.                        ELRVZ050
C             OUTPUT ARGUMENTS ARE RETURNED TO CALLING PROGRAM IN DOUBLE      ELRVZ051
C             FORM.                                                           ELRVZ052
C                                                                             ELRVZ053
C     REFERENCE                                                               ELRVZ054
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP         ELRVZ055
C                                                                             ELRVZ056
C     METHOD                                                                  ELRVZ057
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP         ELRVZ058
C                                                                             ELRVZ059
C     RESTRICTIONS                                                            ELRVZ060
C             ECCENTRICITY MUST BE LESS THAN 1.0.                             ELRVZ061
C                                                                             ELRVZ062
C     ACCURACY                                                                ELRVZ063
C             REFER TO ACCURACY TESTS IN SUBPROGRAM WRITEUP.                  ELRVZ064
C             INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.           ELRVZ065
C                                                                             ELRVZ066
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                                ELRVZ067
C             (DFMP),(DFAD),(DFDP),DEXP(2,DSQRT,DSIN,DCOS,(DFSB)              ELRVZ068
C                                                                             ELRVZ069
C     REQUIRED SUBPROGRAMS - OTHER                                            ELRVZ070
C             09/12/63  XKEPZ                                                 ELRVZ071
C                                                                             ELRVZ072
C     STORAGE REQUIREMENTS                                                    ELRVZ073
C             843 WITHOUT REQUIRED SUBPROGRAMS                                ELRVZ074
C                                                                             ELRVZ075
C     TIMING                                                                  ELRVZ076
C             NO ESTIMATE AVAILABLE                                           ELRVZ077
C                                                                             ELRVZ078
C                                                                             ELRVZ082
C                                                                             ELRVZ085
C     PROGRAM MODIFICATIONS                                                   ELRVZ086
C                                                                             ELRVZ091
C***** START PROGRAM ****************************************************ELRVZ092
C                                                                             ELRVZ093
D     DIMENSION X(3),VX(3),A(6)                                               ELRVZ094
C                                                                             ELRVZ095
D     A1=A(1)                                                                 ELRVZ096
D     A2=A(2)                                                                 ELRVZ097
D     A3=A(3)                                                                 ELRVZ098
D     A4=A(4)                                                                 ELRVZ099
D     A5=A(5)                                                                 ELRVZ100
D     A6=A(6)                                                                 ELRVZ101
D   4 E=XKEPZ(A6,A2,SE,CE,ERR)                                                ELRVZ102
D   7 X1=1.0-A(2)*CE                                                          ELRVZ103
D   8 X2=1.0/X1                                                               ELRVZ104
D   9 R=A(1)*X1                                                               ELRVZ105
D     DUM1=1.0-A2**2                                                          ELRVZ106
D  10 X3=SQRTF(DUM1)                                                          ELRVZ107
D  11 RTGMA=SQRTF(GM*A1)                                                      ELRVZ108
D     SA = SINF(A5)                                                           ELRVZ109
D     SB = SINF(A3)                                                           ELRVZ110
D     SC = SINF(A4)                                                           ELRVZ111
D     CA = COSF(A5)                                                           ELRVZ112
D     CB = COSF(A3)                                                           ELRVZ113
D     CC = COSF(A4)                                                           ELRVZ114
C                                                                             ELRVZ115
C     COMPUTE POSITION COORDINATES                                            ELRVZ116
C                                                                             ELRVZ117
```

```
D     Q1 = A(1)*(CE-A(2))                                         ELRVZ118
D     Q2 = A(1)*X3*SE                                             ELRVZ119
D     V  = Q1*CA - Q2*SA                                          ELRVZ120
D     W  = Q2*CA + Q1*SA                                          ELRVZ121
D     Z  = CB*W                                                   ELRVZ122
D     X(1) = CC*V - SC*Z                                          ELRVZ123
D     X(2) = CC*Z + SC*V                                          ELRVZ124
D     X(3) = SB*W                                                 ELRVZ125
C                                                                 ELRVZ126
C     COMPUTE VELOCITY COMPONENTS                                 ELRVZ127
C                                                                 ELRVZ128
D     QD1 = -RTGMA*SE/R                                           ELRVZ129
D     QD2 = RTGMA*X3*CE/R                                         ELRVZ130
D     V = QD1*CA - QD2*SA                                         ELRVZ131
D     W = QD2*CA + QD1*SA                                         ELRVZ132
D     Z = CB*W                                                    ELRVZ133
D     VX(1) = CC*V - SC*Z                                         ELRVZ134
D     VX(2) = CC*Z + SC*V                                         ELRVZ135
D     VX(3) = SB*W                                                ELRVZ136
C                                                                 ELRVZ137
D     RTGM=SQRTF(GM)                                              ELRVZ138
D     RTA=SQRTF(A1)                                               ELRVZ139
D     EN=RTGM/(RTA*A(1))                                          ELRVZ140
D     P=6.283185307179586/EN                                      ELRVZ141
      RETURN                                                      ELRVZ142
      END                                                         ELRVZ143
*     FUNCTION EQN    FORTRAN SOURCE PROGRAM                      EQN  000
*     CARDS COLUMN                                                EQN  001
*     LIST8                                                       EQN  002
*     LABEL
      FUNCTION EQN(DJ,ET,DPSI,DE,E)                               EQN  003
C                                                                 EQN  004
C     VERSION OF 02/27/64                                         EQN  005
C            FORTRAN FUNCTION                                     EQN  006
C            FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094     EQN  007
C                                                                 EQN  008
C     PURPOSE                                                     EQN  009
C            COMPUTES NUTATION IN LONGITUDE, NUTATION             EQN  010
C            IN OBLIQUITY, TRUE OBLIQUITY OF DATE AND NUTATION    EQN  011
C            IN RIGHT ASCENSION (EQUATION OF THE EQUINOXES).      EQN  012
C                                                                 EQN  013
C     CALLING SEQUENCE                                            EQN  014
C            NAME = EQN(DJ,ET,DPSI,DE,E)                          EQN  015
C                                                                 EQN  016
C     INPUT                                                       EQN  017
C            DJ    = JULIAN DATE AT 0 HOURS EPHEMERIS TIME        EQN  018
C            ET    = EPHEMERIS TIME IN HOURS                      EQN  019
C                                                                 EQN  020
C     OUTPUT                                                      EQN  021
C            DPSI  = NUTATION IN LONGITUDE        - RADIANS       EQN  022
C            DE    = NUTATION IN OBLIQUITY        - RADIANS       EQN  023
C            E     = TRUE OBLIQUITY OF DATE       - RADIANS       EQN  024
C            NAME  = NUTATION IN RIGHT ASCENSION  - RADIANS       EQN  025
C                    (EQUATION OF THE EQUINOXES)                  EQN  026
C                                                                 EQN  027
C     REFERENCE                                                   EQN  028
C            THE FORMULATION BY EDGAR W. WOOLARD MAY BE FOUND IN  EQN  029
C            4 PUBLICATIONS -                                     EQN  030
C                                                                 EQN  031
C                1. ASTRONOMICAL PAPERS PREPARED FOR THE USE OF THE     EQN  032
C                   AMERICAN EPHEMERIS AND NAUTICAL ALMANAC - VOLUME 15,EQN  033
C                   PART 1, PAGE 153 (THEORY OF THE ROTATION OF THE     EQN  034
C                   EARTH AROUND ITS CENTER OF MASS - BY EDGAR W.       EQN  035
C                   WOOLARD)                                            EQN  036
C                2. IMPROVED LUNAR EPHEMERIS 1952-1959 - A JOINT        EQN  037
C                   SUPPLEMENT TO THE AMERICAN EPHEMERIS AND THE        EQN  038
C                   (BRITISH) NAUTICAL ALMANAC - PAGES IX AND X.        EQN  039
C                                                                       EQN  040
C                   AND THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC -   EQN  041
C                   PAGES 44 AND 45.                                    EQN  042
C                                                                       EQN  043
C                4. ASTRONOMICAL JOURNAL, 1953 FEBRUARY, VOL. 58, NO. 1,EQN  044
C                   PAGES 1-3 (A REDEVELOPMENT OF THE THEORY OF NUTATIONEQN  045
C                   - BY EDGAR W. WOOLARD)                              EQN  046
C                                                                       EQN  047
C     METHOD                                                            EQN  048
C                                                                       EQN  049
C     RESTRICTIONS                                                      EQN  050
C            ALL PERIODIC TERMS IN WOOLARD'S THEORY WITH COEFFICIENTS   EQN  051
C            LESS THAN 0.001 SECONDS OF ARC HAVE BEEN NEGLECTED.  ALL   EQN  052
C            SECULAR PORTIONS OF THE COEFFICIENTS HAVE BEEN NEGLECTED   EQN  053
C            WHENEVER THE SECULAR COEFFICIENTS ARE LESS THAN 0.001      EQN  054
C            SECONDS OF ARC.                                            EQN  055
C                                                                       EQN  056
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          EQN  057
C            (DFAD), (DFSB), (DFMP), (DFDP), DMOD, COS, SIN             EQN  058
C                                                                       EQN  059
C     REQUIRED SUBPROGRAMS - OTHER                                      EQN  060
C            NONE                                                       EQN  061
C                                                                       EQN  062
C     TIMING                                                            EQN  063
C            9.4 MILLISECONDS ON 7094                                   EQN  064
C                                                                       EQN  065
C     STORAGE REQUIREMENTS                                              EQN  066
```

```
C               1096 WITHOUT REQUIRED SUBPROGRAMS
C               1329 WITH REQUIRED SUBPROGRAMS
C
C
C
C        PROGRAM MODIFICATIONS
C
C        NOTE -
C               A 7094 FAP VERSION OF EQN IS AVAILABLE USING THE SAME
C               CALLING SEQUENCE AS THE FORTRAN VERSION.  THE FAP VERSION
C               REQUIRES 725 STORAGE LOCATIONS WITHOUT REQUIRED SUBPROGRAMS
C               AND 830 LOCATIONS WITH REQUIRED SUBPROGRAMS.  COMPUTING
C               TIME FOR THE FAP VERSION IS 6.6 MILLISECONDS ON 7094.
C
C***** START PROGRAM ***************************************************
C
      DIMENSION SCF(34),S(34),CCF(19),C(19)
C
C     COMPUTE NUMBER OF JULIAN CENTURIES OF 36525.0 DAYS EXACTLY WHICH
C     HAVE ELAPSED FROM 1900 JAN. 0.5 DAYS EPHEMERIS TIME.
C
      PRT1=DJ-2415020.0
      PRT2=ET/24.0
D     T=(PRT1+PRT2)/36525.0
      T2=T*T
      T3=T*T2
C
C     COMPUTE FUNDAMENTAL ARGUMENTS
C
C     MEAN ANOMALY - MOON
C
      X   = 0.160 424 847 E-3 *T2 +    0.251 133 E-6     * T3
D     EL  = 5.168 000 345 745 + X + 8328.691 103 668 024 * T
C
C     MEAN ANOMALY - SUN
C
      X   = 0.261 799 4   E-5 *T2 +    0.581 78  E-7     * T3
D     EL1 = 6.256 583 580 497 - X +  628.301 945 726 742 * T
C
C     MEAN ARGUMENT OF LATITUDE - MOON
C
      X   = 0.560 444 62  E-4 *T2 +    0.581 8   E-8     * T3
D     F   = 0.196 365 054 887 - X + 8433.466 291 171 947 * T
C
C     MEAN ELONGATION OF MOON FROM SUN
C
      X   = 0.250 648 67  E-4 *T2 -    0.329 67  E-7     * T3
D     D   = 6.121 523 942 807 - X + 7771.377 193 934 485 * T
C
C     LONGITUDE OF MEAN ASCENDING NODE - MOON
C
      X   = 0.362 640 63  E-4 *T2 +    0.387 85  E-7     * T3
D     O   = 4.523 601 514 852 + X -   33.757 146 246 552 * T
C
C     REDUCE ALL ANGLES BY MODULUS  2 PI.
C
D     EL  = MODF(EL  ,6.283 185 307 179 586)
D     EL1 = MODF(EL1,6.283 185 307 179 586)
D     F   = MODF(F   ,6.283 185 307 179 586)
D     D   = MODF(D   ,6.283 185 307 179 586)
D     O   = MODF(O   ,6.283 185 307 179 586)
C
C     COMPUTE SINES AND COSINES OF FUNDAMENTAL ARGUMENTS AND
C     AND COMBINATIONS OF THE FUNDAMENTAL ARGUMENTS.
C
      S(1) = SINF(O)
      C(1) = COSF(O)
      S(3) = 2.0*S(1)*C(1)
      C(3) = C(1)**2-S(1)**2
      SF   = SINF(F)
      CF   = COSF(F)
      S(25)= 2.0*SF*CF
      C2F  = CF**2-SF**2
      SD   = SINF(D)
      CD   = COSF(D)
      S(14)= 2.0*SD*CD
      C2D  = CD**2-SD**2
      S(4) = S(25)*C(3)+C2F  *S(3)
      C(4) = C2F  *C(3)-S(25)*S(3)
      AL   = S(4)*C2D
      AL1  = C(4)*S(14)
      AL2  = S(4)*S(14)
      AL3  = C(4)*C2D
      S(2) = AL -AL1
      C(2) = AL3+AL2
      S(21)= AL +AL1
      C(16)= AL3-AL2
      S(5) = SINF(EL1)
      CL1  = COSF(EL1)
      S(28)= 2.0*S(5)*CL1
      C2L1 = CL1**2-S(5)**2
      S(6) = SINF(EL)
      CL   = COSF(EL)
      S(22)= 2.0*S(6)*CL
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```
      C2L   = CL**2-S(6)**2
      S(8)  = S(25)*C(1)+C2F   *S(1)
      C(6)  = C2F   *C(1)-S(25)*S(1)
      BE    = S(2)*CL1
      BE1   = C(2)*S(5)
      BE2   = S(2)*S(5)
      BE3   = C(2)*CL1
      S(7)  = BE  +BE1
      C(5)  = BE3-BE2
      S(10)= BE  -BE1
      C(8)  = BE3+BE2
      GA    = S(4)*CL
      GA1   = C(4)*S(6)
      GA2   = S(4)*S(6)
      GA3   = C(4)*CL
      S(9)  = GA  +GA1
      C(7)  = GA3-GA2
      S(13)= GA  -GA1
      C(10)= GA3+GA2
      S(11)= S(6)*C2D-CL   *S(14)
      CT    = CL   *C2D+S(6)*S(14)
      S(12)= S(8)*C2D-C(6)*S(14)
      C(9)  = C(6)*C2D+S(8)*S(14)
      DE    = S(1)*CL
      DE1   = C(1)*S(6)
      DE2   = S(1)*S(6)
      DE3   = C(1)*CL
      S(15)= DE  +DE1
      C(11)= DE3-DE2
      S(16)= DE  -DE1
      C(12)= DE3+DE2
      S(17)= S(21)*CL -C(16)*S(6)
      C(15)= C(16)*CL +S(21)*S(6)
      S(18)= S(8)  *C2L-C(6)  *S(22)
      C(13)= C(6)  *C2L+S(8)  *S(22)
      S(19)= S(22)*C2D-C2L   *S(14)
      EP    = S(8)*CL
      EP1   = C(6)*S(6)
      EP2   = S(8)*S(6)
      EP3   = C(6)*CL
      S(20)= EP  +EP1
      C(14)= EP3-EP2
      S(27)= EP  -EP1
      C(19)=EP3+EP2
      S(23)= S(2)*CL   +C(2)*S(6)
      C(17)= C(2)*CL   -S(2)*S(6)
      S(24)= S(4)*C2L  +C(4)*S(22)
      C(18)= C(4)*C2L  -S(4)*S(22)
      S(26)= S(25)*C2D -S(14)*C2F
      S(29)= S(2)  *C2L1+C(2)  *S(28)
      ZE    = S(1)*CL1
      ZE1   = C(1)*S(5)
      S(30)= ZE+ZE1
      S(33)= ZE-ZE1
      AMU   = S(1)*CT
      AMU1  = C(1)*S(11)
      S(31)= AMU-AMU1
      S(32)= AMU+AMU1
      S(34)= S(22)*C2F-C2L*S(25)
C
C     DEFINE CONSTANT COEFFICIENTS OF SINE AND COSINE TERMS ON FIRST
C     PASS ONLY
C
      IF (TEST) 2,1,2
    1 TEST    = +  1.0
      SCF(2)  = -  1.2729
      SCF(3)  = +  0.2088
      SCF(4)  = -  0.2037
      SCF(5)  = +  0.1261
      SCF(6)  = +  0.0675
      SCF(7)  = -  0.0497
      SCF(8)  = -  0.0342
      SCF(9)  = -  0.0261
      SCF(10)= +  0.0214
      SCF(11)= -  0.0149
      SCF(12)= +  0.0124
      SCF(13)= +  0.0114
      SCF(14)= +  0.0060
      SCF(15)= +  0.0058
      SCF(16)= -  0.0057
      SCF(17)= -  0.0052
      SCF(18)= +  0.0045
      SCF(19)= +  0.0045
      SCF(20)= -  0.0044
      SCF(21)= -  0.0032
      SCF(22)= +  0.0028
      SCF(23)= +  0.0026
      SCF(24)= -  0.0026
      SCF(25)= +  0.0025
      SCF(26)= -  0.0021
      SCF(27)= +  0.0019
      SCF(28)= +  0.0016
      SCF(29)= -  0.0015
      SCF(30)= -  0.0015
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      SCF(31)= +  0.0014
      SCF(32)= -  0.0013
      SCF(33)= -  0.0010
      SCF(34)= +  0.0010
      CCF(1) = +  9.2100
      CCF(2) = +  0.5522
      CCF(3) = -  0.0904
      CCF(4) = +  0.0884
      CCF(5) = +  0.0216
      CCF(6) = +  0.0183
      CCF(7) = +  0.0113
      CCF(8) = -  0.0093
      CCF(9) = -  0.0066
      CCF(10)= -  0.0050
      CCF(11)= -  0.0031
      CCF(12)= +  0.0030
      CCF(13)= -  0.0024
      CCF(14)= +  0.0023
      CCF(15)= +  0.0022
      CCF(16)= +  0.0014
      CCF(17)= -  0.0011
      CCF(18)= +  0.0011
      CCF(19)= -  0.0010
    2 CONTINUE
C
C     DEFINE VARIABLE COEFFICIENT OF SINE TERM.
C
      SCF(1) = - 17.2327 - 0.01737*T
C
C     COMPUTE NUTATION IN LONGITUDE BY SUMMING PRODUCTS OF SINE
C     COEFFICIENTS WITH THEIR RESPECTIVE SINE TERMS.
C
C     COMPUTE NUTATION IN OBLIQUITY BY SUMMING PRODUCTS OF COSINE
C     COEFFICIENTS WITH THEIR RESPECTIVE COSINE TERMS.
C
      DPSI=0
      DE  =0
      DO 3 N=1,19
      DPSI=DPSI+SCF(N)*S(N)
    3 DE  =DE  +CCF(N)*C(N)
      DO 4 N=20,34
    4 DPSI=DPSI+SCF(N)*S(N)
C
C     CONVERT FROM SECONDS OF ARC TO RADIANS.
C
      DPSI=DPSI*0.48481368E-5
      DE  =DE  *0.48481368E-5
C
C     COMPUTE TRUE OBLIQUITY OF DATE IN RADIANS.
C
      E=0.40931976-0.227111E-3*T-0.286E-7*T2+0.88E-8*T3+DE
C
C     COMPUTE NUTATION IN RIGHT ASCENSION (EQUATION OF THE EQUINOXES)
C     IN RADIANS.
C
      EQN=DPSI*COSF(E)
      RETURN
      END
*     FUNCTION GASTZ     FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
      FUNCTION GASTZ(DJ,UT1,EQ)
C
C     VERSION OF 03/03/64
C            FORTRAN FUNCTION
C            FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C            COMPUTES GREENWICH APPARENT SIDEREAL TIME.
C
C     CALLING SEQUENCE
C      D     NAME = GASTZ(DJ,UT1,EQ)
C
C     INPUT
C            DJ   = JULIAN DATE AT 0 HOURS UNIVERSAL TIME
C            UT1  = UNIVERSAL TIME IN HOURS
C                   UT1 MUST BE AVAILABLE IN CALLING PROGRAM IN DOUBLE
C                   PRECISION FORM
C            EQ   = NUTATION IN RIGHT ASCENSION (EQUATION OF THE
C                   EQUINOXES) IN RADIANS
C
C     OUTPUT
C            NAME = GREENWICH APPARENT SIDEREAL TIME IN RADIANS
C            NAME = GREENWICH MEAN SIDEREAL TIME IF INPUT VALUE OF EQ=0
C            NAME LIES BETWEEN 0 AND + 2 PI RADIANS AND IS AVAILABLE TO
C            CALLING PROGRAM IN DOUBLE PRECISION FORM.
C                   (24 HOURS = 2 PI RADIANS)
C
C     REFERENCE
C            1. GREENWICH MEAN SIDEREAL TIME IS COMPUTED ACCORDING TO
C               THE FORMULA CONTAINED ON PAGES 474-476 OF THE 1963
C               EDITION OF THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC.
C            2. INPUT ARGUMENT EQ MAY BE COMPUTED BY MEANS OF
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C             FORTRAN OR FAP FUNCTION EQN.                            GASTZ035
C         3. JULIAN DATE AT 0 HOURS UNIVERSAL TIME MAY BE COMPUTED    GASTZ036
C             BY MEANS OF FORTRAN OR FAP FUNCTION DJUL.               GASTZ037
C                                                                     GASTZ038
C     METHOD                                                          GASTZ039
C         GREENWICH MEAN SIDEREAL TIME AT 0 HOURS UNIVERSAL TIME IS   GASTZ040
C         COMPUTED ACCORDING TO THE FORMULA CONTAINED IN THE AMERICANGASTZ041
C         EPHEMERIS AND NAUTICAL ALMANAC. GREENWICH APPARENT SIDEREALGASTZ042
C         TIME IS OBTAINED BY ADDING TO THIS QUANTITY, THE NUTATION   GASTZ043
C         IN RIGHT ASCENSION PLUS UT1 TIMES THE RATIO OF THE SIDEREALGASTZ044
C         DAY TO THE MEAN SOLAR DAY.                                  GASTZ045
C                                                                     GASTZ046
C     RESTRICTIONS                                                    GASTZ047
C         ANY VALUE OF DJ AND UT1 MAY BE USED AS INPUT.               GASTZ048
C         NO RESTRICTIONS OTHER THAN THOSE INHERENT IN THE            GASTZ049
C         FORMULATIONS OF THE GREENWICH MEAN SIDEREAL TIME AND        GASTZ050
C         THE NUTATION IN RIGHT ASCENSION.                            GASTZ051
C                                                                     GASTZ052
C     ACCURACY                                                        GASTZ053
C         WHEN NECESSARY, INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE GASTZ054
C         PRECISION IN ORDER THAT THE VALUE OF THE ARGUMENT RETURNED GASTZ055
C         TO THE CALLING PROGRAM HAVE AN ACCURACY IN RADIANS          GASTZ056
C         EQUIVALENT TO .001 SECONDS OF TIME.                         GASTZ057
C                                                                     GASTZ058
C         AN EPHEMERIS HAS BEEN GENERATED LISTING GREENWICH APPARENT GASTZ059
C         SIDEREAL TIME AT 0 HOURS UNIVERSAL TIME, DAILY FROM         GASTZ060
C         01/01/1801 TO 12/31/2000. DAILY COMPARISONS WERE MADE WITHGASTZ061
C         THE AMERICAN EPHEMERIS FOR THE INTERVAL 1959-1963.          GASTZ062
C         FOR THE TIMES COMPARED, COMPARISON WITH AMERICAN EPHEMERIS GASTZ063
C         WAS EXACT TO AN ACCURACY OF .001 SECONDS.                   GASTZ064
C                                                                     GASTZ065
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                        GASTZ066
C         (DFDP),(DFMP),(DFAD),DMOD                                   GASTZ067
C                                                                     GASTZ068
C     REQUIRED SUBPROGRAMS - OTHER                                    GASTZ069
C         NONE                                                        GASTZ070
C                                                                     GASTZ071
C     STORAGE REQUIREMENTS                                            GASTZ072
C         126 WITHOUT REQUIRED SUBPROGRAMS                            GASTZ073
C                                                                     GASTZ074
C     TIMING                                                          GASTZ075
C         NO ESTIMATE AVAILABLE                                       GASTZ076
C                                                                     GASTZ077
C                                                                     GASTZ081
C                                                                     GASTZ084
C     PROGRAM MODIFICATIONS                                           GASTZ085
C                                                                     GASTZ091
C***** START PROGRAM *************************************************GASTZ092
C                                                                     GASTZ093
      DT=DJ-2415020.0                                                 GASTZ094
D     T=DT/36525.0                                                    GASTZ095
      C=T*T*0.67558786E-5+EQ                                          GASTZ096
D     GASTZ=1.739935893717+628.331950990910*T+C+0.26251617071*UT1    GASTZ097
D     GASTZ=MODF(GASTZ,6.283185307179586)                             GASTZ098
      RETURN                                                          GASTZ099
      END                                                             GASTZ100
*     FUNCTION GDLATZ     FORTRAN SOURCE PROGRAM                      GDLATZ00
*     CARDS COLUMN                                                    GDLATZ01
*     LIST8                                                           GDLATZ02
*     LABEL
      FUNCTION GDLATZ(AL1,RS,RE,F1,ALTZ)                              GDLATZ03
C                                                                     GDLATZ04
C     VERSION OF 07/19/63                                             GDLATZ05
C         FORTRAN FUNCTION                                            GDLATZ06
C         FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094            GDLATZ07
C                                                                     GDLATZ08
C     PURPOSE                                                         GDLATZ09
C         COMPUTES -                                                  GDLATZ10
C             1. GEODETIC LATITUDE OF SUBSATELLITE POINT FROM         GDLATZ11
C                GEOCENTRIC DISTANCE AND GEOCENTRIC LATITUDE          GDLATZ12
C                (DECLINATION) OF SATELLITE.                          GDLATZ13
C             2. HEIGHT OF SATELLITE ABOVE COMPUTATIONAL SPHEROID GDLATZ14
C                ALONG THE NORMAL FROM SATELLITE TO SPHEROID.         GDLATZ15
C                                                                     GDLATZ16
C     CALLING SEQUENCE                                                GDLATZ17
C      D      NAME = GDLATZ(AL1,RS,RE,F1,ALTZ)                        GDLATZ18
C                                                                     GDLATZ19
C     INPUT                                                           GDLATZ20
C         AL1  = GEOCENTRIC LATITUDE (DECLINATION) OF SATELLITE       GDLATZ21
C                IN RADIANS                                           GDLATZ22
C         RS   = GEOCENTRIC DISTANCE IN KILOMETERS                    GDLATZ23
C         RE   = EQUATORIAL RADIUS OF COMPUTATIONAL SPHEROID IN       GDLATZ24
C                KILOMETERS                                           GDLATZ25
C         F1   = INVERSE OF FLATTENING OF COMPUTATIONAL SPHEROID      GDLATZ26
C                (DIMENSIONLESS) - E.G. IF FLATTENING = 1/298.3,      GDLATZ27
C                THEN F1 = 298.3                                      GDLATZ28
C                                                                     GDLATZ29
C         INPUT ARGUMENTS MUST BE AVAILABLE IN CALLING PROGRAM IN     GDLATZ30
C         DOUBLE PRECISION FORM.                                      GDLATZ31
C                                                                     GDLATZ32
C     OUTPUT                                                          GDLATZ33
C         NAME = GEODETIC LATITUDE OF SUBSATELLITE POINT - RADIANS    GDLATZ34
C         ALTZ = HEIGHT OF SATELLITE ABOVE COMPUTATIONAL SPHEROID     GDLATZ35
C                ALONG NORMAL FROM SATELLITE TO SPHEROID - KILOMETERSGDLATZ36
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C                                                                       GDLATZ37
C         OUTPUT ARGUMENTS ARE RETURNED TO CALLING PROGRAM IN DOUBLE GDLATZ38
C         FORM.                                                         GDLATZ39
C                                                                       GDLATZ40
C  REFERENCE                                                            GDLATZ41
C         ''THE REDUCTION FROM GEOCENTRIC TO GEODETIC COORDINATES''     GDLATZ42
C         BY JOHN MORRISON AND SAMUEL PINES.                            GDLATZ43
C         THE ASTRONOMICAL JOURNAL, VOL. 66, NO. 1, FEBRUARY 1961,      GDLATZ44
C         PAGES 15 AND 16                                               GDLATZ45
C                                                                       GDLATZ46
C  METHOD                                                               GDLATZ47
C         AN APPROXIMATION BY MEANS OF LAGRANGE'S EXPANSION FORMULA.    GDLATZ48
C                                                                       GDLATZ49
C  RESTRICTIONS                                                         GDLATZ50
C         ******                                                        GDLATZ51
C                                                                       GDLATZ52
C  ACCURACY                                                             GDLATZ53
C         INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.         GDLATZ54
C                                                                       GDLATZ55
C         THE APPROXIMATION GIVES AN ACCURACY OF 8 SIGNIFICANT          GDLATZ56
C         FIGURES.                                                      GDLATZ57
C         THE 8 FIGURE ACCURACY CLAIMED BY THE AUTHORS WAS VERIFIED     GDLATZ58
C         BY USING THE INVERSE PROBLEM (GEODETIC TO GEOCENTRIC          GDLATZ59
C         COORDINATES), WHICH CAN BE SOLVED RIGOROUSLY, TO SUPPLY       GDLATZ60
C         THE INPUT FOR THIS FUNCTION.  THE OUTPUT FROM THIS FUNCTIONGDLATZ61
C         WAS THEN COMPARED WITH THE INITIAL DATA FOR VARIOUS           GDLATZ62
C         INITIAL CONDITIONS.                                           GDLATZ63
C                                                                       GDLATZ64
C  REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                             GDLATZ65
C         (DFDP),(DFMP),(DFAD),(DFSB),DSIN,DCOS,DSQRT                   GDLATZ66
C                                                                       GDLATZ67
C  REQUIRED SUBPROGRAMS - OTHER                                         GDLATZ68
C         NONE                                                          GDLATZ69
C                                                                       GDLATZ70
C  STORAGE REQUIREMENTS                                                 GDLATZ71
C         1110 WITHOUT REQUIRED SUBPROGRAMS                             GDLATZ72
C                                                                       GDLATZ73
C  TIMING                                                               GDLATZ74
C         NO ESTIMATE AVAILABLE                                         GDLATZ75
C                                                                       GDLATZ76
C                                                                       GDLATZ80
C                                                                       GDLATZ83
C  PROGRAM MODIFICATIONS                                                GDLATZ84
C                       NO MODIFICATIONS TO DATE                        GDLATZ86
C                                                                       GDLATZ87
C                                                                       GDLATZ88
D    4 F=1.0/F1                                                         GDLATZ89
D    5 E2=F+F-F*F                                                       GDLATZ90
D    6 E4=E2*E2                                                         GDLATZ91
D    7 E6=E2*E4                                                         GDLATZ92
D    8 E8=E4*E4                                                         GDLATZ93
D    9 R=RS/RE                                                          GDLATZ94
D   10 R1=RE/RS                                                         GDLATZ95
D   11 G1=1.0+E2                                                        GDLATZ96
D   12 G2=4.0+3.0*E2                                                    GDLATZ97
D   13 G3=35.0*E2                                                       GDLATZ98
D   14 G4=E2*R1/32.0                                                    GDLATZ99
D   15 G5=G4*E4                                                         GDLATZ00
D   16 G6=E2/64.0                                                       GDLATZ01
D   17 G7=E4*G6                                                         GDLATZ02
D   18 G8=E4*R1                                                         GDLATZ03
D   19 A2=G4*((512.0+E2*(128.0+E2*(60.0+G3)))/32.0+G8*(1.+E2-.375*G2*R1))GDLATZ04
D   20 A4=E4*R1*.0625*(R1*((4.+E2*(1.+G1))+G8*(.9375-R1))-G6*(48.+G3)-1.)GDLATZ05
D   21 A6=G5*(.09375*(4.+5.*E2)+R1*(1.4583333333333333*R1*G2-3.*G1))    GDLATZ06
D   22 A8=G6*G5*(R1*(64.-R1*(252.+320.*R1))-5.)                         GDLATZ07
D   23 AL2=AL1+AL1                                                      GDLATZ08
D   24 AL4=AL2+AL2                                                      GDLATZ09
D   25 AL6=AL2+AL4                                                      GDLATZ10
D   26 AL8=AL4+AL4                                                      GDLATZ11
D   27 AL=AL1+A2*SINF(AL2)+A4*SINF(AL4)+A6*SINF(AL6)+A8*SINF(AL8)       GDLATZ12
D   28 A=AL-AL1                                                         GDLATZ13
D   29 CA=COSF(A)                                                       GDLATZ14
D   30 RCA=RS*CA                                                        GDLATZ15
D   31 SAL=SINF(AL)                                                     GDLATZ16
D   32 SAL2=SAL*SAL                                                     GDLATZ17
D   33 ESAL=E2*SAL2                                                     GDLATZ18
D   34 X2=1.0-ESAL                                                      GDLATZ19
D   35 X=SQRTF(X2)                                                      GDLATZ20
D   36 ALTZ=RCA-X*RE                                                    GDLATZ21
D   37 GDLATZ=AL                                                        GDLATZ22
       RETURN                                                           GDLATZ23
       END                                                              GDLATZ24
*      FUNCTION HMSRZ    FORTRAN SOURCE PROGRAM                         HMSRZ000
*      CARDS COLUMN                                                     HMSRZ001
*      LIST8                                                            HMSRZ002
*      LABEL
       FUNCTION HMSRZ(IH,IM,TS)                                         HMSRZ003
C                                                                       HMSRZ004
C      VERSION OF 07/22/63                                              HMSRZ005
C             FORTRAN FUNCTION                                          HMSRZ006
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094          HMSRZ007
C                                                                       HMSRZ008
C      PURPOSE                                                          HMSRZ009
C             CONVERTS HOURS, MINUTES, AND SECONDS OF TIME TO RADIANS   HMSRZ010
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C         (24 HOURS = 2 PI RADIANS).
C
C      CALLING SEQUENCE
C       D      NAME = HMSRZ(IH,IM,TS)
C
C      INPUT
C             IH    = NUMBER OF HOURS IN TIME
C             IM    = NUMBER OF MINUTES IN TIME
C             TS    = NUMBER OF SECONDS IN TIME
C
C                     SIGN OF THE INPUT TIME NEED ONLY BE ASSOCIATED WITH
C                     THE NUMBER OF HOURS (IH).
C
C      OUTPUT
C             NAME = TIME IN RADIANS
C
C                     NAME IS RETURNED TO CALLING PROGRAM IN DOUBLE
C                     PRECISION FORM.
C
C      REFERENCE
C             ******
C
C      METHOD
C             ******
C
C      RESTRICTIONS
C             ******
C
C      ACCURACY
C             WHEN NECESSARY, INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE
C             PRECISION SO THAT THE VALUE OF THE OUTPUT ARGUMENT IS
C             AVAILABLE TO CALLING PROGRAM IN DOUBLE PRECISION.
C
C      REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C             (DFMP),(DFAD)
C
C      REQUIRED SUBPROGRAMS - OTHER
C             NONE
C
C      STORAGE REQUIREMENTS
C             105 WITHOUT REQUIRED SUBPROGRAMS
C
C      TIMING
C             NO ESTIMATE AVAILABLE.
C
C
C
C      PROGRAM MODIFICATIONS
C                         NO MODIFICATIONS TO DATE
C
C***** START PROGRAM *****************************************************
C
     2 TH=IH
     3 TM=IM
     4 TM=SIGNF(TM,TH)
     5 TRS=SIGNF(TS,TH)
D    6 HMSRZ=TH*.2617993877991494 + TM*4.363323129985824E-3
      1       +TRS*7.272205216643040E-5
       RETURN
       END
*      SUBROUTINE JULCAL FORTRAN SOURCE PROGRAM
*      CARDS COLUMN
*      LIST8
*      LABEL
       SUBROUTINE JULCAL(DJ,NM,ND,NY)
C
C      VERSION OF 07/22/63
C             FORTRAN SUBROUTINE
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C      PURPOSE
C             COMPUTES CALENDAR DATE FROM JULIAN DATE AT 0 HOURS
C             UNIVERSAL TIME (OR 0 HOURS EPHEMERIS TIME).
C
C      CALLING SEQUENCE
C             CALL JULCAL(DJ,NM,ND,NY)
C
C      INPUT
C             DJ    = JULIAN DATE AT 0 HOURS UNIVERSAL TIME
C
C      OUTPUT
C             NM    = CALENDAR MONTH
C             ND    = CALENDAR DAY
C             NY    = CALENDAR YEAR
C
C      REFERENCE
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C      METHOD
C             THE NUMBER OF DAYS FROM 12 HOURS UNIVERSAL TIME JAN. 0,
C             1800 IS CALCULATED.  THE INTEGRAL NUMBER OF YEARS IN THIS
C             NUMBER IS ADDED TO 1800 TO GIVE THE CURRENT CALENDAR YEAR
C             AND THE NUMBER OF DAYS CONTAINED IN THE INTEGRAL NUMBER
C             OF YEARS ELAPSED SINCE JAN. 0, 1800 IS SUBTRACTED FROM THE
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C          ORIGINAL NUMBER OF DAYS FROM JAN. 0, 1800.  THE INTEGRAL
C          NUMBER OF MONTHS IN THIS REMAINDER IS CALCULATED TO GIVE
C          THE CURRENT CALENDAR MONTH.  THE NUMBER OF DAYS CONTAINED
C          IN THIS INTEGRAL NUMBER OF MONTHS IS SUBTRACTED FROM THE
C          PREVIOUS REMAINING DAYS TO GIVE THE CALENDAR DAY.
C          APPROPIATE CONSIDERATION HAS BEEN GIVEN TO THOSE YEARS
C          WHICH ARE DIVISIBLE BY 4, 100, AND 400.
C          APPROPIATE CONSIDERATION HAS BEEN GIVEN TO THOSE YEARS
C          WHICH ARE DIVISIBLE BY 4, 100, AND 400.
C
C     RESTRICTIONS
C          DATE RESTRICTED TO LIE BETWEEN JANUARY 1, 1801 AND DECEMBER
C          31, 2000.
C
C     ACCURACY
C          ******
C
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C          NONE
C
C     REQUIRED SUBPROGRAMS - OTHER
C          07/22/63  DJUL
C
C     STORAGE REQUIREMENTS
C          176 WITHOUT REQUIRED SUBPROGRAMS
C
C     TIMING
C          NO ESTIMATE AVAILABLE
C
C
C
C     PROGRAM MODIFICATIONS
C                        NO MODIFICATIONS TO DATE
C
C***** START PROGRAM ***************************************************
C
    2 DIMENSION M(12)
    6 NM=0
    8 M(1)=31
    9 M(2)=28
   10 M(3)=31
   11 M(4)=30
   12 M(5)=31
   13 M(6)=30
   14 M(7)=31
   15 M(8)=31
   16 M(9)=30
   17 M(10)=31
   18 M(11)=30
   19 M(12)=31
C
   20 IF (DJ-2415020.5) 21,21,22
   21 NY=XINTF((DJ-2378495.5)/365.25)+1800
      GO TO 23
   22 NY=XINTF((DJ-2378495.5+1.0)/365.25)+1800
   23 NDY=DJ-DJUL(1,0,NY)
   24 ND=NDY
   25 DO 33 N=1,12
   26 IF (N-2) 30,27,30
   27 IF (NY-1900)28,30,28
   28 IF (XMODF(NY,4)) 30,29,30
   29 M(N)=M(N)+1
   30 ND=ND-M(N)
   31 NM=NM+1
   32 IF (ND) 34,34,33
   33 CONTINUE
   34 ND=ND+M(N)
      RETURN
      END
*     SUBROUTINE PARA   FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
      SUBROUTINE PARA(INPUT,AI,A,GM)
C
C     VERSION OF 06/14/63
C           FORTRAN SUBROUTINE
C           FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C           CONVERTS AN ARBITRARY SET OF 6 INDEPENDENT INPUT PARAMETERS
C           INTO OSCULATING ORBITAL ELEMENTS.
C
C     CALLING SEQUENCE
C      D     DIMENSION AI(6),A(6)
C           CALL PARA(INPUT,AI,A,GM)
C
C           INPUT, OUTPUT, AND INTERNAL ARITHMETIC OPERATIONS ARE ALL
C           PERFORMED IN DOUBLE PRECISION.
C
C     INPUT
C           INPUT= CONTROL NUMBER TO INDICATE TYPE OF INPUT PARAMETERS
C           AI   = ARRAY OF 6 INDEPENDENT INPUT PARAMETERS
C           GM   = THE PRODUCT OF G, THE GAUSSIAN CONSTANT SQUARED,
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C                  AND M, THE MASS OF THE EARTH                         PARA 024
C                                                                       PARA 025
C     OUTPUT                                                            PARA 026
C            OSCULATING ORBITAL ELEMENTS                                PARA 027
C                                                                       PARA 028
C            A(1) = SEMI-MAJOR AXIS                                     PARA 029
C            A(2) = ECCENTRICITY                       - DIMENSIONLESS  PARA 030
C            A(3) = INCLINATION                        - RADIANS        PARA 031
C            A(4) = RIGHT ASCENSION OF ASCENDING NODE  - RADIANS        PARA 032
C            A(5) = ARGUMENT OF PERIGEE                - RADIANS        PARA 033
C            A(6) = MEAN ANOMALY                       - RADIANS        PARA 034
C                                                                       PARA 035
C     REFERENCE                                                         PARA 036
C            ******                                                     PARA 037
C                                                                       PARA 038
C     METHOD                                                            PARA 039
C            ******                                                     PARA 040
C                                                                       PARA 041
C     RESTRICTIONS                                                      PARA 042
C            ******                                                     PARA 043
C                                                                       PARA 044
C     ACCURACY                                                          PARA 045
C            ******                                                     PARA 046
C                                                                       PARA 047
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          PARA 048
C            (DEMP)                                                     PARA 049
C                                                                       PARA 050
C     REQUIRED SUBPROGRAMS - OTHER                                      PARA 051
C            07/22/63  ALLOTZ                                           PARA 052
C            07/22/63  ALLOT                                            PARA 053
C            03/03/64  ATANQ                                            PARA 054
C            07/22/63  ATANZ                                            PARA 055
C            07/17/63  BRWR1                                            PARA 056
C            01/31/64  BRWR2                                            PARA 057
C            03/02/64  ELRV                                             PARA 058
C            07/22/63  RVELZ                                            PARA 059
C            09/12/63  XKEP                                             PARA 060
C                                                                       PARA 061
C     STORAGE REQUIREMENTS                                              PARA 062
C            277 WITHOUT REQUIRED SUBPROGRAMS                           PARA 063
C                                                                       PARA 064
C     TIMING                                                            PARA 065
C            NO ESTIMATE AVAILABLE                                      PARA 066
C                                                                       PARA 067
C     ANALYSIS                                                          PARA 068
C                                                                       PARA 071
C                                                                       PARA 074
C     PROGRAM MODIFICATIONS                                             PARA 075
C                         NO MODIFICATIONS TO DATE                      PARA 077
C                                                                       PARA 078
C***** START PROGRAM ***************************************************PARA 079
C                                                                       PARA 080
D     DIMENSION AI(6),A(6),RX(3),VX(3)                                  PARA 081
      DIMENSION DUM1(100),A110(6)                                       PARA 082
      DIMENSION XX(18),AB(6)                                            PARA 083
C                                                                       PARA 084
      COMMON DUM1,A110,XX,AB                                            PARA 085
C                                                                       PARA 086
      GO TO (1,2,3,4), INPUT                                            PARA 087
C                                                                       PARA 088
C     INPUT OPTION 1.   AI = OSCULATING ORBITAL ELEMENTS, ALL ANGLES IN PARA 089
C                            DEGREES                                    PARA 090
C                                                                       PARA 091
D   1 A(1)=AI(1)                                                        PARA 092
D     A(2)=AI(2)                                                        PARA 093
      DO 101 N=3,6                                                      PARA 094
D 101 A(N)=AI(N)*0.0174532925199433                                     PARA 095
      GO TO 9999                                                        PARA 096
C                                                                       PARA 097
C     INPUT OPTION 2.   AI = POSITION AND VELOCITY VECTORS IN           PARA 098
C                            KILOMETERS AND KILOMETERS/SECOND           PARA 099
C                                                                       PARA 100
    2 DO 201 N=1,3                                                      PARA 101
D     RX(N)=AI(N)                                                       PARA 102
D 201 VX(N)=AI(N+3)                                                     PARA 103
D     CALL RVELZ(RX,VX,A,PER,EN,GM)                                     PARA 104
      GO TO 9999                                                        PARA 105
C                                                                       PARA 106
C     INPUT OPTION 2.   AI = POSITION AND VELOCITY VECTORS IN           PARA 107
C                            VANGUARD UNITS                             PARA 108
C                                                                       PARA 109
    3 DO 301 N=1,3                                                      PARA 110
D     RX(N)=AI(N)*6378.388                                              PARA 111
D 301 VX(N)=AI(N+3)*7.905472668                                         PARA 112
D     CALL RVELZ(RX,VX,A,PER,EN,GM)                                     PARA 113
      GO TO 9999                                                        PARA 114
C                                                                       PARA 115
C     INPUT OPTION 4.   AI = BROUWER MEAN ELEMENTS, ALL ANGLES IN DEGREESPARA 116
C                                                                       PARA 117
    4 A110(1)=AI(1)                                                     PARA 118
      A110(2)=AI(2)                                                     PARA 119
      DO 401 N=3,6                                                      PARA 120
D     BA=AI(N)*0.0174532925199433                                       PARA 121
  401 A110(N)=BA                                                        PARA 122
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      CALL BRWR1                                                         PARA 123
D     DT=0.0                                                             PARA 124
D     CALL BRWR2(DT,0.0)
      DO 402 N=1,6                                                       PARA 126
  402 A(N)=AB(N)                                                         PARA 127
 9999 RETURN                                                             PARA 128
      END                                                                PARA 129
*     SUBROUTINE RDMSZ  FORTRAN SOURCE PROGRAM                           RDMSZ000
*     CARDS COLUMN                                                       RDMSZ001
*     LIST8                                                              RDMSZ002
*     LABEL
      SUBROUTINE RDMSZ(AR,IR,ID,IM,AS)                                   RDMSZ003
C                                                                        RDMSZ004
C     VERSION OF 03/02/64                                                RDMSZ005
C             FORTRAN SUBROUTINE                                         RDMSZ006
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094           RDMSZ007
C                                                                        RDMSZ008
C     PURPOSE                                                            RDMSZ009
C             CONVERTS AN ANGLE OR ARC IN RADIANS INTO THE INTEGRAL      RDMSZ010
C             NUMBER OF REVOLUTIONS, NUMBER OF DEGREES, NUMBER OF        RDMSZ011
C             MINUTES, AND NUMBER OF SECONDS AND DECIMALS OF A SECOND    RDMSZ012
C             CONTAINED IN THE ANGLE OR ARC.                             RDMSZ013
C                                                                        RDMSZ014
C     CALLING SEQUENCE                                                   RDMSZ015
C      D      CALL RDMSZ(AR,IR,ID,IM,AS)                                 RDMSZ016
C                                                                        RDMSZ017
C     INPUT                                                              RDMSZ018
C             AR    = ANGLE OR ARC IN RADIANS                            RDMSZ019
C                                                                        RDMSZ020
C             AR MUST BE AVAILABLE IN CALLING PROGRAM IN DOUBLE PRECISIONRDMSZ021
C             FORM.                                                      RDMSZ022
C                                                                        RDMSZ023
C     OUTPUT                                                             RDMSZ024
C             IR    = INTEGRAL NUMBER OF REVOLUTIONS IN THE ANGLE OR ARC RDMSZ025
C             ID    = NUMBER OF DEGREES                                  RDMSZ026
C             IM    = NUMBER OF MINUTES                                  RDMSZ027
C             AS    = NUMBER OF SECONDS AND DECIMALS OF A SECOND         RDMSZ028
C                                                                        RDMSZ029
C     REFERENCE                                                          RDMSZ030
C             ******                                                     RDMSZ031
C                                                                        RDMSZ032
C     METHOD                                                             RDMSZ033
C             ******                                                     RDMSZ034
C                                                                        RDMSZ035
C     RESTRICTIONS                                                       RDMSZ036
C             ******                                                     RDMSZ037
C                                                                        RDMSZ038
C     ACCURACY                                                           RDMSZ039
C             CONVERSION IS ACCURATE TO AT LEAST .001 SECONDS OF ARC.    RDMSZ040
C                                                                        RDMSZ041
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                           RDMSZ042
C             (DFDP),DMOD,(DFMP),(DFSB)                                  RDMSZ043
C                                                                        RDMSZ044
C     REQUIRED SUBPROGRAMS - OTHER                                       RDMSZ045
C             NONE                                                       RDMSZ046
C                                                                        RDMSZ047
C     STORAGE REQUIREMENTS                                               RDMSZ048
C             337 WITHOUT REQUIRED SUBPROGRAMS                           RDMSZ049
C                                                                        RDMSZ050
C     TIMING                                                             RDMSZ051
C             NO ESTIMATE AVAILABLE                                      RDMSZ052
C                                                                        RDMSZ053
C     ANALYSIS                                                           RDMSZ054
C                                                                        RDMSZ057
C                                                                        RDMSZ060
C     PROGRAM MODIFICATIONS                                              RDMSZ061
C             03/02/64  MOD. 1   BY S. STATEN - CHANGED UPPER LIMIT OF   RDMSZ063
C                            AS FROM 59.0005 TO 59.9995                  RDMSZ064
C                                                                        RDMSZ065
C***** START PROGRAM ****************************************************RDMSZ066
C                                                                        RDMSZ067
D   5 IR=AR/6.283185307179586                                            RDMSZ068
D   6 AR=MODF(AR,6.283185307179586)                                      RDMSZ069
D   7 ID=AR*57.2957795130823                                             RDMSZ070
    8 A1=ID                                                              RDMSZ071
D   9 A=A1/57.2957795130823                                              RDMSZ072
D  10 B=AR-A                                                             RDMSZ073
D  11 IM=B*3437.746770784938                                             RDMSZ074
D  12 A2=IM                                                              RDMSZ075
   13 IM=XABSF(IM)                                                       RDMSZ076
D  14 C=A2/3437.746770784938                                             RDMSZ077
D  15 D=B-C                                                              RDMSZ078
D  16 AS=ABSF(D*206264.806247096)                                        RDMSZ079
D  17 IF( AS-59.9995) 20,18,18                                           RDMSZ080
D  18 AS=ABSF(AS-60.)                                                    RDMSZ081
   19 IM=IM+1                                                            RDMSZ082
   20 IF (IM-60) 23,21,21                                                RDMSZ083
   21 IM=IM-60                                                           RDMSZ084
   22 ID=ID+XSIGNF(1,ID)                                                 RDMSZ085
   23 IF (XABSF(ID)-360) 26,24,24                                        RDMSZ086
   24 ID=ID-XSIGNF(360,ID)                                               RDMSZ087
   25 IR=IR+XSIGNF(1,IR)                                                 RDMSZ088
   26 RETURN                                                             RDMSZ089
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      END                                                               RDMSZ090
*     SUBROUTINE RHMSZ  FORTRAN SOURCE PROGRAM                          RHMSZ000
*     CARDS COLUMN                                                      RHMSZ001
*     LISTB                                                             RHMSZ002
*     LABEL
      SUBROUTINE RHMSZ(TR,ID,IH,IM,TS)                                  RHMSZ003
C                                                                       RHMSZ004
C     VERSION OF 03/02/64                                               RHMSZ005
C             FORTRAN SUBROUTINE                                        RHMSZ006
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094          RHMSZ007
C                                                                       RHMSZ008
C     PURPOSE                                                           RHMSZ009
C             CONVERTS TIME IN RADIANS (24 HOURS = 2 PI RADIANS) INTO   RHMSZ010
C             THE INTEGRAL NUMBER OF DAYS, NUMBER OF HOURS, NUMBER OF   RHMSZ011
C             MINUTES, AND NUMBER OF SECONDS AND DECIMALS OF A SECOND   RHMSZ012
C             CONTAINED IN THE TIME.                                    RHMSZ013
C                                                                       RHMSZ014
C     CALLING SEQUENCE                                                  RHMSZ015
C      D      CALL RHMSZ(TR,ID,IH,IM,TS)                                RHMSZ016
C                                                                       RHMSZ017
C     INPUT                                                             RHMSZ018
C             TR   = TIME IN RADIANS                                    RHMSZ019
C                                                                       RHMSZ020
C                    TIME MUST BE AVAILABLE IN CALLING PROGRAM IN       RHMSZ021
C                    DOUBLE PRECISION FORM.                             RHMSZ022
C                                                                       RHMSZ023
C     OUTPUT                                                            RHMSZ024
C             ID   = INTEGRAL NUMBER OF DAYS CONTAINED IN THE TIME      RHMSZ025
C             IH   = NUMBER OF HOURS                                    RHMSZ026
C             IM   = NUMBER OF MINUTES                                  RHMSZ027
C             TS   = NUMBER OF SECONDS AND DECIMALS OF A SECOND         RHMSZ028
C                                                                       RHMSZ029
C     REFERENCE                                                         RHMSZ030
C             ******                                                    RHMSZ031
C                                                                       RHMSZ032
C     METHOD                                                            RHMSZ033
C             ******                                                    RHMSZ034
C                                                                       RHMSZ035
C     RESTRICTIONS                                                      RHMSZ036
C             ******                                                    RHMSZ037
C                                                                       RHMSZ038
C     ACCURACY                                                          RHMSZ039
C             CONVERSION IS ACCURATE TO AT LEAST .001 SECONDS OF TIME.  RHMSZ040
C                                                                       RHMSZ041
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          RHMSZ042
C             (DFDP),DMOD,(DFMP),(DFSB)                                 RHMSZ043
C                                                                       RHMSZ044
C     REQUIRED SUBPROGRAMS - OTHER                                      RHMSZ045
C             NONE                                                      RHMSZ046
C                                                                       RHMSZ047
C     STORAGE REQUIREMENTS                                              RHMSZ048
C             316 WITHOUT REQUIRED SUBPROGRAMS                          RHMSZ049
C                                                                       RHMSZ050
C     TIMING                                                            RHMSZ051
C             NO ESTIMATE AVAILABLE                                     RHMSZ052
C                                                                       RHMSZ053
C     ANALYSIS                                                          RHMSZ054
C                                                                       RHMSZ057
C                                                                       RHMSZ060
C     PROGRAM MODIFICATIONS                                             RHMSZ061
C             03/02/64  MOD. 1   BY S. STATEN - CHANGED UPPER LIMIT OF  RHMSZ063
C                       TS FROM 59.0005 TO 59.9995                      RHMSZ064
C                                                                       RHMSZ065
C***** START PROGRAM ***************************************************RHMSZ066
C                                                                       RHMSZ067
D   5 ID=TR/6.283185307179586                                           RHMSZ068
D   6 TR=MODF(TR,6.283185307179586)                                     RHMSZ069
D   7 IH=TR*3.81971863420548                                            RHMSZ070
    8 T1=IH                                                             RHMSZ071
D   9 A=T1/3.81971863420548                                             RHMSZ072
D  10 B=TR-A                                                            RHMSZ073
D  11 IM=B*229.183118052329                                             RHMSZ074
D  12 T2=IM                                                             RHMSZ075
   13 IM=XABSF(IM)                                                      RHMSZ076
D  14 C=T2/229.183118052329                                             RHMSZ077
D  15 D=B-C                                                             RHMSZ078
D  16 TS=ABSF(D*13750.9870831397)                                       RHMSZ079
D  17 IF (TS-59.9995) 20,18,18                                          RHMSZ080
   18 TS=ABSF(TS-60.)                                                   RHMSZ081
   19 IM=IM+1                                                           RHMSZ082
   20 IF (IM-60) 23,21,21                                               RHMSZ083
   21 IM=IM-60                                                          RHMSZ084
   22 IH=IH+XSIGNF(1,IH)                                                RHMSZ085
   23 IF (XABSF(IH)-24) 26,24,24                                        RHMSZ086
   24 IH=IH-XSIGNF(24,IH)                                               RHMSZ087
   25 ID=ID+XSIGNF(1,ID)                                                RHMSZ088
   26 RETURN                                                            RHMSZ089
      END                                                               RHMSZ090
*     SUBROUTINE RVELZ  FORTRAN SOURCE PROGRAM                          RVELZ000
*     CARDS COLUMN                                                      RVELZ001
*     LISTB                                                             RVELZ002
*     LABEL
      SUBROUTINE RVELZ(X,VX,A,P,EN,GM)                                  RVELZ003
C                                                                       RVELZ004
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C      VERSION OF 07/22/63                                              RVELZ0005
C                FORTRAN SUBROUTINE                                     RVELZ0006
C                FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094       RVELZ0007
C                                                                       RVELZ0008
C      PURPOSE                                                          RVELZ0009
C                CONVERTS GEOCENTRIC EQUATORIAL INERTIAL RECTANGULAR    RVELZ0010
C                COORDINATES OF POSITION AND COMPONENTS OF VELOCITY INTO RVELZ0011
C                OSCULATING ORBITAL ELEMENTS                            RVELZ0012
C                                                                       RVELZ0013
C      CALLING SEQUENCE                                                 RVELZ0014
C         D      DIMENSION X(3),VX(3),A(6)                              RVELZ0015
C         D      CALL RVELZ(X,VX,A,P,EN,GM)                             RVELZ0016
C                                                                       RVELZ0017
C                                                                       RVELZ0018
C      INPUT                                                            RVELZ0019
C                X(1)                                                   RVELZ0020
C                X(2)   THE 3 RECTANGULAR COORDINATES OF POSITION       RVELZ0021
C                X(3)                                                   RVELZ0022
C                                                                       RVELZ0023
C                VX(1)                                                  RVELZ0024
C                VX(2)  THE 3 RECTANGULAR COMPONENTS OF VELOCITY        RVELZ0025
C                VX(3)                                                  RVELZ0026
C                                                                       RVELZ0027
C                GM   = THE PRODUCT OF G, THE GAUSSIAN CONSTANT SQUARED, RVELZ0028
C                       AND M, THE MASS OF THE EARTH                    RVELZ0029
C                                                                       RVELZ0030
C                UNITS OF INPUT ARGUMENTS X, VX, AND GM ARE ARBITRARY BUT RVELZ0031
C                MUST BE MUTUALLY CONSISTENT.                           RVELZ0032
C                INPUT ARGUMENTS MUST BE AVAILABLE IN CALLING PROGRAM IN RVELZ0033
C                DOUBLE PRECISION FORM.                                 RVELZ0034
C                                                                       RVELZ0035
C      OUTPUT                                                           RVELZ0036
C                A(1) = SEMI-MAJOR AXIS                                 RVELZ0037
C                A(2) = ECCENTRICITY                   - DIMENSIONLESS  RVELZ0038
C                A(3) = INCLINATION                    - RADIANS        RVELZ0039
C                A(4) = RIGHT ASCENSION OF ASCENDING NODE - RADIANS     RVELZ0040
C                A(5) = ARGUMENT OF PERIGEE            - RADIANS        RVELZ0041
C                A(6) = MEAN ANOMALY                   - RADIANS        RVELZ0042
C                                                                       RVELZ0043
C                P    = ANOMALISTIC PERIOD                              RVELZ0044
C                EN   = MEAN ANGULAR MOTION                             RVELZ0045
C                                                                       RVELZ0046
C                UNITS OF OUTPUT ARGUMENTS A(1), P, AND EN WILL DEPEND UPON RVELZ0047
C                THE UNITS EMPLOYED FOR X, VX, AND GM.                  RVELZ0048
C                ALL ANGLES ARE IN RADIANS.                             RVELZ0049
C                OUTPUT ARGUMENTS ARE RETURNED TO CALLING PROGRAM IN DOUBLE RVELZ0050
C                FORM.                                                  RVELZ0051
C                                                                       RVELZ0052
C                                                                       RVELZ0053
C      REFERENCE                                                        RVELZ0054
C                REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP RVELZ0055
C                                                                       RVELZ0056
C      METHOD                                                           RVELZ0057
C                REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP RVELZ0058
C                                                                       RVELZ0059
C      RESTRICTIONS                                                     RVELZ0060
C                ECCENTRICITY MUST BE LESS THAN 1.0.                    RVELZ0061
C                                                                       RVELZ0062
C      ACCURACY                                                         RVELZ0063
C                REFER TO ACCURACY TESTS IN SUBPROGRAM WRITEUP.         RVELZ0064
C                INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.  RVELZ0065
C                                                                       RVELZ0066
C      REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                         RVELZ0067
C                DEXP(2,(DFAD),DSQRT,(DFMP),(DFSB),(DFDP)               RVELZ0068
C                                                                       RVELZ0069
C      REQUIRED SUBPROGRAMS - OTHER                                     RVELZ0070
C                07/22/63  ALLOTZ                                       RVELZ0071
C                07/22/63  ATANZ                                        RVELZ0072
C                                                                       RVELZ0073
C      STORAGE REQUIREMENTS                                             RVELZ0074
C                1015 WITHOUT REQUIRED SUBPROGRAMS                      RVELZ0075
C                                                                       RVELZ0076
C      TIMING                                                           RVELZ0077
C                NO ESTIMATE AVAILABLE                                  RVELZ0078
C                                                                       RVELZ0079
C                                                                       RVELZ0083
C      PROGRAM MODIFICATIONS                                            RVELZ0086
C                          NO MODIFICATIONS TO DATE                     RVELZ0088
C                                                                       RVELZ0089
C***** START PROGRAM ****************************************************RVELZ0090
C                                                                       RVELZ0091
D    2 DIMENSION X(3),VX(3),A(6),Y(3),VY(3)                             RVELZ0092
C                                                                       RVELZ0093
  500 DO 502 N=1,3                                                      RVELZ0094
D 501 Y(N)=X(N)                                                         RVELZ0095
D 502 VY(N)=VX(N)                                                       RVELZ0096
D     R2=Y(1)**2+Y(2)**2+Y(3)**2                                        RVELZ0097
D   3 R=SQRTF(R2)                                                       RVELZ0098
D   4 V2=VY(1)**2+VY(2)**2+VY(3)**2                                     RVELZ0099
D   5 V1=SQRTF(V2)                                                      RVELZ0100
D   6 RRDOT=Y(1)*VY(1)+Y(2)*VY(2)+Y(3)*VY(3)                            RVELZ0101
D   7 H1=Y(2)*VY(3)-Y(3)*VY(2)                                          RVELZ0102
D   8 H2=Y(3)*VY(1)-Y(1)*VY(3)                                          RVELZ0103
D   9 H3=Y(1)*VY(2)-Y(2)*VY(1)                                          RVELZ0104
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D  10 C2=H1**2+H2**2
D  11 C1=SQRTF(C2)
D  12 H=SQRTF(H3**2+C2)
D  13 RC1=R*C1
D  14 RTGM=SQRTF(GM)
D  15 A(1)=GM*R/(GM+GM-R*V2)
D  16 RTA=SQRTF(A(1))
D  17 F1=RRDOT/(RTGM*RTA)
D  18 AR=A(1)/R
D  19 F2=1.0-R/A(1)
D     E2=F1**2+F2**2
D  21 A(2)=SQRTF(E2)
D  22 SI=C1/H
D  23 CI=H3/H
D  24 SN=H1/C1
D  25 CN=-H2/C1
D  26 SU=H*Y(3)/RC1
D  27 CU=(Y(2)*H1-Y(1)*H2)/RC1
D  28 SE=F1/A(2)
D  29 CE=F2/A(2)
D     SF=AR*SE*SQRTF(1.0-E2)
D     CF=AR*(CE-A(2))
D  30 A(3)=ATANZ(SI,CI)
D  31 A(4)=ATANZ(SN,CN)
D  32 U=ATANZ(SU,CU)
D     F=ATANZ(SF,CF)
D  33 E=ATANZ(SE,CE)
D     A5=U-F
D     A(5)=ALLOTZ(A5)
D  34 A6=E-A(2)*SE
D  35 A(6)= ALLOTZ(A6)
D  36 EN=RTGM/(RTA*A(1))
D  37 P=6.283185307179586/EN
      RETURN
      END
*     SUBROUTINE R13Z    FORTRAN SOURCE PROGRAM
*     CARDS COLUMN
*     LIST8
*     LABEL
      SUBROUTINE R13Z(Y,B,A,X)
C
C     VERSION OF 07/18/63
C           FORTRAN SUBROUTINE
C           FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C           SOLVES THE MATRIX EQUATION -
C                 Y = R1(B) R3(A) X
C           WHERE -
C
C                        COS A   SIN A    0
C           R3(A)=      -SIN A   COS A    0
C                         0       0       1
C
C
C                         1       0       0
C           R1(B)=        0      COS B   SIN B
C                         0     -SIN B   COS B
C
C
C     CALLING SEQUENCE
C      D    DIMENSION Y(3),X(3)
C      D    CALL R13Z(Y,B,A,X)
C
C     INPUT
C           VECTOR X IN ANY UNITS
C           ROTATION ANGLES A AND B IN RADIANS
C
C           INPUT ARGUMENTS MUST BE AVAILABLE IN CALLING PROGRAM IN
C           DOUBLE PRECISION FORM.
C
C     OUTPUT
C
C           VECTOR Y IN SAME UNITS AS VECTOR X
C           OUTPUT ARGUMENTS ARE RETURNED TO CALLING PROGRAM IN DOUBLE
C           FORM.
C
C     REFERENCE
C           REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C     METHOD
C           REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C     RESTRICTIONS
C           ******
C
C     ACCURACY
C           INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.
C
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C           DSIN,DCOS,(DFMP),(DFSB),(DFAD).
C
C     REQUIRED SUBPROGRAMS - OTHER
C           NONE
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C                                                                      R13Z 058
C     STORAGE REQUIREMENTS                                             R13Z 059
C              248 WITHOUT REQUIRED SUBPROGRAMS                        R13Z 060
C                                                                      R13Z 061
C     TIMING                                                           R13Z 062
C              NO ESTIMATE AVAILABLE                                   R13Z 063
C                                                                      R13Z 064
C     ANALYSIS                                                         R13Z 065
C                                                                      R13Z 068
C                                                                      R13Z 071
C     PROGRAM MODIFICATIONS                                            R13Z 072
C                             NO MODIFICATIONS TO DATE                 R13Z 074
C                                                                      R13Z 075
C***** START PROGRAM ***************************************************R13Z 076
C                                                                      R13Z 077
D   2 DIMENSION Y(3),X(3)                                              R13Z 078
C                                                                      R13Z 079
D   3 SA=SINF(A)                                                       R13Z 080
D   4 CA=COSF(A)                                                       R13Z 081
D   5 SB=SINF(B)                                                       R13Z 082
D   6 CB=COSF(B)                                                       R13Z 083
D   7 Z=X(2)*CA-X(1)*SA                                                R13Z 084
D   8 Y(1)=X(1)*CA+X(2)*SA                                             R13Z 085
D   9 Y(2)=CB*Z+X(3)*SB                                                R13Z 086
D  10 Y(3)=X(3)*CB-SB*Z                                                R13Z 087
      RETURN                                                           R13Z 088
      END                                                              R13Z 089
*     SUBROUTINE TIMEC FORTRAN SOUTCE PROGRAM                          TIMEC
*     CARDS COLUMN
*     LIST8
*     LABEL
      SUBROUTINE TIMEC(DJO,TSEP,S,F,DT)
C     USES TAPE A3
C
C     VERSION OF 7/22/63
C
C     READS A CARD FROM CARD READER CONTAINING CALENDAR DATE AND UT2 OF
C     DESIRED START AND END TIMES FOR CALCULATION OF AN EPHEMERIS, AND
C     THE TIME INCREMENT OF THE EPHEMERIS IN SECONDS.  CALCULATES TIME
C     INTERVAL IN SECONDS FROM SOME EPOCH (DJO,TSEP) TO THE START AND
C     END TIMES.
C     WRITES CALENDAR DATE AND UT2 ON TAPE UNIT A3.
C
C     INPUT FROM CALLING SEQUENCE
C             DJO = EPOCH JULIAN DATE AT O HOURS UT2.
C             TSEP = EPOCH UT2 IN SECONDS
C
C     INPUT FROM CARD READER
C             NMS,NDS,NYS = MONTH, DAY, YEAR OF START DATE
C             NMF,NDF,NYF = MONTH, DAY, AND YEAR OF END DATE
C
C             NHS,NMNS,TSS = HOUR, MINUTE, SECOND (UT2) OF START TIME
C             NHF,NMNF,TSF = HOUR, MINUTE, SECOND (UT2) OF END DATE
C             DT = TIME INCREMENT OF EPHEMERIS IN SECONDS
C
C     OUTPUT
C             S = TIME IN SECONDS FROM EPOCH TO START TIME
C             F = TIME IN SECONDS FROM EPOCH TO END TIME
C             DT = TIME INCREMENT OF EPHEMERIS IN SECONDS
C
C     REQUIRED SUBPROGRAMS
C
C     DJUL, JULCAL  07/22/60 - FAP DOUBLE ENTRY PROGRAM
C
 6015 FORMAT (2(1XI2) ,1X,I4,2I3,F7.3,I3,1X,I2,1X,I4,2I3,F7.3,F11.3  )
 6016 FORMAT (1XI2,1H/I2,1H/I4,7X11H START DATE/1XI2,I3,F7.3,5X,
     1 15H START TIME-UT2/1XF12.3,5X23H TIME INCREMENT-SECONDS//1XI2,
     2 1H/I2,1H/I4,7X9H END DATE/1XI2,I3,F7.3,5X13H END TIME-UT2   )
      READ             6015,NMS,NDS,NYS,NHS,NMNS,TSS,NMF,NDF,NYF,NHF,
     1 NMNF,TSF,DT
      WRITE OUTPUT TAPE 3,6016,NMS,NDS,NYS,NHS,NMNS,TSS,DT,NMF,NDF,NYF,
     1 NHF,NMNF,TSF
      IF (SENSE SWITCH 6) 1,2
    1 PRINT 6016,NMS,NDS,NYS,NHS,NMNS,TSS,DT,NMF,NDF,NYF,NHF,NMNF,TSF
    2 DJSO=DJUL(NMS,NDS,NYS)
      DJFO=DJUL(NMF,NDF,NYF)
      THS=NHS*3600
      TMNS=NMNS*60
      TS=THS+TMNS+TSS-TSEP
      THF=NHF*3600
      TMNF=NMNF*60
      TF=THF+TMNF+TSF-TSEP
      DJS=DJSO-DJO
      DJF=DJFO-DJO
D     S=DJS*86400.+TS
      F=DJF*86400.+TF
      RETURN
      END
*     SUBROUTINE VFUZ    FORTRAN SOURCE PROGRAM                        VFUZ 000
*     CARDS COLUMN                                                     VFUZ 001
*     LIST8                                                            VFUZ 002
*     LABEL
      SUBROUTINE VFUZ(SC,RE,F,U)                                       VFUZ 003
C                                                                      VFUZ 004
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```
C     VERSION OF 07/22/63
C              FORTRAN SUBROUTINE
C              FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094
C
C     PURPOSE
C              CONVERTS GEODETIC LATITUDE, LONGITUDE, AND HEIGHT OF A
C              STATION ABOVE A COMPUTATIONAL SPHEROID (ALONG A NORMAL TO
C              THE SPHEROID) INTO GEOCENTRIC RECTANGULAR COORDINATES OF
C              POSITION.  THE ORIGIN OF THE RECTANGULAR COORDINATE SYSTEM
C              (THE U SYSTEM) IS LOCATED AT THE GEOMETRICAL CENTER OF THE
C              COMPUTATIONAL SPHEROID.  THE U1 AXIS IS DIRECTED TOWARDS
C              THE INTERSECTION OF THE GREENWICH MERIDIAN AND THE
C              EQUATORIAL PLANE.  THE U3 AXIS IS PERPENDICULAR TO THE
C              EQUATORIAL PLANE AND IS DIRECTED NORTH.  THE U2 AXIS IS
C              LOCATED IN THE EQUATORIAL PLANE 90 DEGREES EAST OF THE U1
C              AXIS.
C
C     CALLING SEQUENCE
C      D       DIMENSION SC(3),U(3)
C      D       CALL VFUZ(SC,RE,F,U)
C
C     INPUT
C              SC(1)= GEODETIC LATITUDE  - RADIANS
C              SC(2)= GEODETIC LONGITUDE - RADIANS
C              SC(3)= HEIGHT ABOVE COMPUTATIONAL SPHEROID ALONG A NORMAL
C                     TO THE SPHEROID
C
C              RE    = EQUATORIAL RADIUS OF COMPUTATIONAL SPHEROID
C              F     = INVERSE OF FLATTENING OF COMPUTATIONAL SPHEROID
C                      (DIMENSIONLESS) - E.G. IF FLATTENING = 1/298.3,
C                      THEN F = 298.3
C
C              UNITS OF INPUT ARGUMENTS SC(3) AND RE ARE ARBITRARY BUT
C              MUST BE MUTUALLY CONSISTENT.
C              INPUT ARGUMENTS MUST BE AVAILABLE IN CALLING PROGRAM IN
C              DOUBLE PRECISION FORM.
C
C     OUTPUT
C              U(1)
C              U(2)    THE 3 RECTANGULAR COORDINATES OF POSITION
C              U(3)
C
C              UNITS OF OUTPUT ARGUMENTS.U WILL DEPEND UPON THE UNITS
C              EMPLOYED FOR SC(3) AND RE.
C              OUTPUT ARGUMENTS ARE RETURNED TO CALLING PROGRAM IN DOUBLE
C              FORM.
C
C     REFERENCE
C              REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C     METHOD
C              REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP
C
C     RESTRICTIONS
C              ******
C
C     ACCURACY
C              INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.
C
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR
C              DSIN,DCOS,(DFOP),(DFSB),DEXP(2,DSQRT,(DFMB),(DFAD)
C
C     REQUIRED SUBPROGRAMS - OTHER
C              NONE
C
C     STORAGE REQUIREMENTS
C              305 WITHOUT REQUIRED SUBPROGRAMS
C
C     TIMING
C              NO ESTIMATE AVAILABLE
C
C
C
C     PROGRAM MODIFICATIONS
C                        NO MODIFICATIONS TO DATE
C
C***** START PROGRAM *****************************************************
C
D    2 DIMENSION SC(3),U(3)
C
D    3 SAL=SINF(SC(1))
D    4 CAL=COSF(SC(1))
D    5 C1=(1.0-1./F)**2
D    6 EN=RE/SQRTF(CAL**2+C1*SAL**2)
D    7 C2=(EN+SC(3))*CAL
D    8 U(1)=C2*COSF(SC(2))
D    9 U(2)=C2*SINF(SC(2))
D   10 U(3)=(EN*C1+SC(3))*SAL
       RETURN
       END
*      SUBROUTINE VROZ   FORTRAN SOURCE PROGRAM
*      CARDS COLUMN
*      LIST8
*      LABEL
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```
      SUBROUTINE VRDZ(N,Z,E,A,R                                         VRDZ 003
C                                                                       VRDZ 004
C     VERSION OF 07/16/63                                               VRDZ 005
C             FORTRAN SUBROUTINE                                        VRDZ 006
C             FOR USE WITH FORTRAN 2 MONITOR ON IBM 7090, 7094          VRDZ 007
C                                                                       VRDZ 008
C     PURPOSE                                                           VRDZ 009
C             CONVERTS RECTANGULAR POSITION COORDINATES OF A POINT TO THEVRDZ 010
C             SPHERICAL COORDINATES OF THE POINT.                       VRDZ 011
C                                                                       VRDZ 012
C                                                                       VRDZ 013
C     CALLING SEQUENCE                                                  VRDZ 014
C       D     DIMENSION Z(3)                                            VRDZ 015
C       D     CALL VRDZ(1,Z,E,A,R)                                      VRDZ 016
C       D     CALL VRDZ(2,Z,E,A,R)                                      VRDZ 017
C                                                                       VRDZ 018
C     INPUT                                                             VRDZ 019
C             Z(1)                                                      VRDZ 020
C             Z(2)    THE 3 RECTANGULAR COORDINATES OF POSITION         VRDZ 021
C             Z(3)                                                      VRDZ 022
C                                                                       VRDZ 023
C             N     = OPTION NUMBER TO DETERMINE TYPE OF SPHERICAL      VRDZ 024
C                     COORDINATE DESIRED                                VRDZ 025
C                                                                       VRDZ 026
C     OUTPUT                                                            VRDZ 027
C             R     = MAGNITUDE OF POSITION VECTOR                      VRDZ 028
C             E     = ANGULAR DISTANCE IN RADIANS OF VECTOR FROM Z1-Z2  VRDZ 029
C                     PLANE (E.G. ELEVATION, DECLINATION, LATITUDE)     VRDZ 030
C                     E IS RESTRICTED TO LIE BETWEEN 0 AND + PI/2 RADIANS VRDZ 031
C                     OR BETWEEN 0 AND - PI/2 RADIANS                   VRDZ 032
C                                                                       VRDZ 033
C     N=1     A     = ANGULAR DISTANCE IN RADIANS OF PROJECTION OF VECTOR VRDZ 034
C                     ONTO THE Z1-Z2 PLANE, MEASURED POSITIVELY COUNTER-  VRDZ 035
C                     CLOCKWISE FROM THE Z1 AXIS (E.G. RIGHT ASCENSION, VRDZ 036
C                     LONGITUDE MEASURED POSITIVE EAST FROM GREENWICH)  VRDZ 037
C                                                                       VRDZ 038
C     N=2     A     = ANGULAR DISTANCE IN RADIANS OF PROJECTION OF VECTOR VRDZ 039
C                     ONTO THE Z1-Z2 PLANE, MEASURED POSITIVELY CLOCKWISE VRDZ 040
C                     FROM THE Z2 AXIS (E.G. AZIMUTH MEASURED POSITIVE  VRDZ 041
C                     CLOCKWISE FROM NORTH)                             VRDZ 042
C                                                                       VRDZ 043
C                     A IS RESTRICTED TO LIE BETWEEN 0 AND + 2 PI RADIANS VRDZ 044
C                                                                       VRDZ 045
C             OUTPUT ARGUMENTS ARE RETURNED TO CALLING PROGRAM IN DOUBLE VRDZ 046
C             FORM.                                                     VRDZ 047
C                                                                       VRDZ 048
C                                                                       VRDZ 049
C     REFERENCE                                                         VRDZ 050
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP   VRDZ 051
C                                                                       VRDZ 052
C     METHOD                                                            VRDZ 053
C             REFER TO MATHEMATICAL DESCRIPTION IN SUBPROGRAM WRITEUP   VRDZ 054
C                                                                       VRDZ 055
C     RESTRICTIONS                                                      VRDZ 056
C             ******                                                    VRDZ 057
C                                                                       VRDZ 058
C     ACCURACY                                                          VRDZ 059
C             INTERNAL ARITHMETIC IS PERFORMED IN DOUBLE PRECISION.     VRDZ 060
C                                                                       VRDZ 061
C     REQUIRED SUBPROGRAMS - FORTRAN 2 MONITOR                          VRDZ 062
C             DSQRT,DEXP(2,(DFAD),(DFDP),(DFMP),DATAN2                  VRDZ 063
C                                                                       VRDZ 064
C     REQUIRED SUBPROGRAMS - OTHER                                      VRDZ 065
C             07/22/63  ATANZ                                           VRDZ 066
C                                                                       VRDZ 067
C     STORAGE REQUIREMENTS                                              VRDZ 068
C             298 WITHOUT REQUIRED SUBPROGRAMS                          VRDZ 069
C                                                                       VRDZ 070
C     TIMING                                                            VRDZ 071
C             NO ESTIMATE AVAILABLE                                     VRDZ 072
C                                                                       VRDZ 073
C                                                                       VRDZ 077
C                                                                       VRDZ 080
C     PROGRAM MODIFICATIONS                                             VRDZ 081
C                          NO MODIFICATIONS TO DATE                     VRDZ 083
C                                                                       VRDZ 084
C***** START PROGRAM ****************************************************VRDZ 085
C                                                                       VRDZ 086
D   2 DIMENSION Z(3)                                                    VRDZ 087
C                                                                       VRDZ 088
D   3 R=SQRTF(Z(1)**2+Z(2)**2+Z(3)**2)                                  VRDZ 089
D   4 SE=Z(3)/R                                                         VRDZ 090
D   5 CE=SQRTF(1.0-SE**2)                                               VRDZ 091
D   6 C=R*CE                                                            VRDZ 092
      GO TO (7,9), N                                                    VRDZ 093
D   7 CA=Z(1)/C                                                         VRDZ 094
D   8 SA=Z(2)/C                                                         VRDZ 095
      GO TO 11                                                          VRDZ 096
D   9 SA=Z(1)/C                                                         VRDZ 097
D  10 CA=Z(2)/C                                                         VRDZ 098
D  11 E=ATAN2F(SE,CE)                                                   VRDZ 099
D  12 A=ATANZ(SA,CA)                                                    VRDZ 100
      RETURN                                                            VRDZ 101
      END                                                               VRDZ 102
```

```
*      FUNCTION XKEP                                                      XKEP
*      CARDS COLUMN
*      LISTB
*      LABEL
       FUNCTION XKEP(AM,ECC,SE,CE,ERR)
       E1 = AM + (ECC * SINF(AM)    )
       N = 0
     1 E2 = E1
       N = N + 1
       SE = SINF(E1)
       CE = COSF(E1)
       E1 = E1 + ((AM - E1 + ECC*SE) / (1.0 - ECC*CE))
       G = ABSF((E1 - E2) / E1)
       IF( N - 25) 2,2,3
     2 IF(G - ERR    ) 5,5,1
     3 PRINT 4
       PRINT 6,AM,E1,E2,G,N
     4 FORMAT (36HONO CONVERGENCE IN KEPLERS EQUATION
     6 FORMAT (4E16.8,I5)
       SENSE LIGHT 2
     5 XKEP = E1
       RETURN
       END
*      FUNCTION XKEPZ                                                     XKEPZ
*      CARDS COLUMN
*      LISTB
*      LABEL
       FUNCTION XKEPZ(AM,ECC,SE,CE,ERR)
D      E1 = AM + (ECC* SINF(AM))
       N = 0
D    1 E2 = E1
       N = N + 1
D      SE =  SINF(E1)
D      CE =  COSF(E1)
D      E1 = E1 + ((AM - E1 + ECC*SE) / (1.0 - ECC*CE))
D      G = ABSF((E1 - E2) / E1)
       IF(N - 25) 2,2,3
D    2 IF(G - ERR    ) 5,5,1
     3 PRINT 4
       PRINT 6,AM,E1,E2,G,N
     4 FORMAT (36HONO CONVERGENCE IN KEPLERS EQUATION
     6 FORMAT (4E16.8,I5)
       SENSE LIGHT 2
D    5 XKEPZ = E1
       RETURN
       END
*      SUBROUTINE BACK
*      CARDS COLUMN
*      LISTB
*      FAP
        COUNT   82
        LBL     BACK,X
        REM     SUBROUTINE BACK
        REM     PROGRAM IN CORE A. MOVES AN ARRAY FROM CORE B TO
        REM       DESIGNATED LOCATIONS CORE A.
        ENTRY   BACK
 BACK   EFT                          TEST FOR A OR B CORE
        TRA     ERROR                ERROR - B CORE
        SXA     STOIR,1              STORE MACHINE CONDITIONS
        SXD     STOIR,2                X
        STI     STOIND                 X
        AXT     0,2                  ZERO I.R. 2
        CAL*    3,4                  FORTRAN ADDRESS BLOCK FROM CORE B
        ARS     18                   SHIFT TO ADDRESS PORTION OF WORD
        STA     ARRAY                STORED FOR REFERENCE
        SUB     ADDR1                SETTING UP TRANSFER OF THREE WORDS
        STA     ARRAY+1                AT A TIME
        SUB     ADDR1                  X
        STA     ARRAY+2                X
        CAL*    2,4                  ARRAY LENGTH
        PDX     0,1                  PLACED IN I.R. 1
        TXL     SMLARY,1,2           SMALL ARRAY, LENGTH EQUAL TO 1 OR 2
        CAL     1,4                  FORTRAN ADDRESS BLOCK IN CORE A
        STA     STORE                STORED FOR REFERENCE
        SUB     ADDR1                WILL BE STORING THREE WORDS AT A TIME
        STA     STORE+1                X
        SUB     ADDR1                  X
        STA     STORE+2                X
 RESET  SEB                            X
 ARRAY  CLA     **,2                 TRANSFER OF WORDS
        LDQ     **,2                   X
        LDI     **,2                   X
        SEA                            X
 STORE  STO     **,2                 STORED
        STQ     **,2                   X
        STI     **,2                   X
        TXI     *+1,2,3              MOVE DOWN THROUGH BLOCK
        TIX     RESET,1,3            REDUCE BLOCK BY 3
        TXH     ARRAY3,1,2           IF 3 WORDS, SET I.R. 1 = 0
        TXH     TWOWDS,1,1           TEST FOR REMAINING (1 OR 2) WORDS
        TXL     RETURN,1,0            X
 ONEWD  CAL*    3,4                  TRANSFERRING TOTAL OF 1 WORD, OR
        ARS     18                     REMAINING WORD FROM A TO B CORE
        STA     ARRAY1                 REMAINING WORD FROM A TO B CORE
```

```
         CAL    1,4                  X
         STA    STORE1               X
         SEB                         X
 ARRAY1  CLA    **,2                 X
         SEA                         X
 STORE1  STO    **,2                 X
 RETURN  LXA    STOIR,1              RETURN TO FORTRA
         LXD    STOIR,2              X
         LDI    STOIND               X
         TRA    4,4                  X
 SMLARY  TXL    ONEWD,1,             TEST FOR 1 OR 2 WORDS IN ARRAY
 TWOWDS  CAL*   3,4                  TRANSFERRING TOTAL OF 2 WORDS, OR
         ARS    18                     REMAINING 2 WORDS FROM A TO B COR
         STA    ARRAY2                 X
         SUB    ADDR1                  X
         STA    ARRAY2+1               X
         CLA    1,4                    X
         STA    STORE2                 X
         SUB    ADDR1                  X
         STA    STORE2+1               X
         SEB                           X
 ARRAY2  CLA    **,2                   X
         LDQ    **,2                   X
         SEA                           X
 STORE2  STO    **,2                   X
         STQ    **,2                   X
         TRA    RETURN                 X
 ARRAY3  AXT    0,1                  3 WORDS, ZERO I.R. 1
         TRA    RESET                  X
  ERROR  WTDA   3
         RCHA   READ
         TCOA   *
         TRA    4,4
  READ   IOCD   WORDS,1,9
  WORDS  BCI    9,1** SUBROUTINE BACK CANNOT BE EXECUTED FROM B CORE **
  ADDR1  OCT    1
 STOIND  BSS    1
  STOIR  BSS    1
         END
*       SUBROUTINE STASH
*       CARDS COLUMN
*       LIST8
*       FAP
         COUNT  80
         LBL    STASH,X
         REM    SUBROUTINE STASH
         REM    PROGRAM IN CORE A, MOVES AN ARRAY FROM CORE A TO
         REM       DESIGNATED LOCATIONS CORE B.
         ENTRY  STASH
  STASH  EFT                         TEST FOR A OR B CORE
         TRA    ERROR                ERROR - B CORE
         SXA    STOIR,1              STORE MACHINE CONDITIONS
         SXD    STOIR,2                X
         STI    STOIND                 X
         AXT    0,2                  ZERO I.R. 2
         CAL    1,4                  FORTRAN ADDRESS BLOCK FROM
         STA    ARRAY                STORED FOR REFERENCE
         SUB    ADDR1                SETTING UP TRANSFER OF THREE WORDS
         STA    ARRAY+1                AT A TIME
         SUB    ADDR1                  X
         STA    ARRAY+2                X
         CAL*   2,4                  ARRAY LENGTH
         PDX    0,1                  PLACED IN I.R. 1
         TXL    SMLARY,1,2           SMALL ARRAY, LENGTH EQUAL TO 1 OR 2
         CAL*   3,4                  FORTRAN ADDRESS BLOCK TO
         ARS    18                   SHIFT TO ADDRESS PORTION OF WORD
         STA    STORE                STORED FOR REFERENCE
         SUB    ADDR1                WILL BE STORING THREE WORDS AT A TIME
         STA    STORE+1                X
         SUB    ADDR1                  X
         STA    STORE+2                X
  ARRAY  CLA    **,2                 TRANSFER OF WORDS
         LDQ    **,2                   X
         LDI    **,2                   X
         SEB                           X
  STORE  STO    **,2                 STORED
         STQ    **,2                   X
         STI    **,2                   X
         TXI    *+1,2,3              MOVE DOWN THROUGH BLOCK
         SEA                           X
         TIX    ARRAY,1,3            REDUCE BLOCK BY 3
         TXH    ARRAY3,1,2           IF 3 WORDS, SET I.R. 1 = 0
         TXH    TWOWDS,1,1           TEST FOR REMAINING (1 OR 2) WORDS
         TXL    RETURN,1,0             X
  ONEWD  CAL    1,4                  TRANSFERRING TOTAL OF 1 WORD, OR
         STA    ARRAY1                 REMAINING WORD FROM A TO B CORE
         CAL*   3,4                    X
         ARS    18                     X
         STA    STORE1                 X
 ARRAY1  CLA    **,2                   X
         SEB                           X
 STORE1  STO    **,2                   X
  RESET  SEA                           X
 RETURN  LXA    STOIR,1              RETURN TO FORTRAN
```

```
        LXO      STOIR,2          X
        LDI      STOIND           X
        TRA      4,4              X
 SMLARY TXL      ONEHD,1,1        TEST FOR 1 OR 2 WORDS IN ARRAY
 TWOWDS CAL      1,4              TRANSFERRING TOTAL OF 2 WORDS, OR
        STA      ARRAY2           REMAINING 2 WORDS FROM A TO B CORE
        SUB      ADDR1            X
        STA      ARRAY2+1         X
        CLA*     3,4              X
        ARS      18               X
        STA      STORE2           X
        SUB      ADDR1            X
        STA      STORE2+1         X
 ARRAY2 CLA      **,2             X
        LDQ      **,2             X
        SEB
 STORE2 STO      **,2             X
        STQ      **,2             X
        TRA      RESET            X
 ARRAY3 AXT      0,1              3 WORDS, ZERO I.R. 1
        TRA      ARRAY            X
  ERROR WTDA     3
        RCHA     READ
        TCOA     *
        TRA      4,4
  READ  IOCD     WORDS,1,9
  WORDS BCI      9,1** SUBROUTINE STASH CANNOT BE EXECUTED FROM B CORE *
  ADDR1 OCT      1
 STOIND BSS      1
  STOIR BSS      1
        END
*      SUBROUTINE TIMC4
*      CARDS COLUMN
*      LIST8
*      LABEL
       SUBROUTINE TIMC4(DJO,TSEP,S,F,DT)
C      USES SUBROUTINE TIMEC AND GIVES OUTPUT ON
C      TAPES A3 AND A8.
C
C      VERSION OF 7/22/63
C
C      READS A CARD FROM CARD READER CONTAINING CALENDAR DATE AND UT2 OF
C      DESIRED START AND END TIMES FOR CALCULATION OF AN EPHEMERIS, AND
C      THE TIME INCREMENT OF THE EPHEMERIS IN SECONDS.  CALCULATES TIME
C      INTERVAL IN SECONDS FROM SOME EPOCH (DJO,TSEP) TO THE START AND
C      END TIMES.
C      WRITES CALENDAR DATE AND UT2 ON TAPE UNIT A3.
C
C      INPUT FROM CALLING SEQUENCE
C              DJO = EPOCH JULIAN DATE AT 0 HOURS UT2.
C              TSEP = EPOCH UT2 IN SECONDS
C
C      INPUT FROM CARD READER
C              NMS,NDS,NYS = MONTH, DAY, YEAR OF START DATE
C              NMF,NDF,NYF = MONTH, DAY, AND YEAR OF END DATE
C
C              NHS,NMNS,TSS = HOUR, MINUTE, SECOND (UT2) OF START TIME
C              NHF,NMNF,TSF = HOUR, MINUTE, SECOND (UT2) OF END DATE
C              DT = TIME INCREMENT OF EPHEMERIS IN SECONDS
C
C      OUTPUT
C              S = TIME IN SECONDS FROM EPOCH TO START TIME
C              F = TIME IN SECONDS FROM EPOCH TO END TIME
C              DT = TIME INCREMENT OF EPHEMERIS IN SECONDS
C
C      REQUIRED SUBPROGRAMS
C
C      DJUL, JULCAL  07/22/60 - FAP DOUBLE ENTRY PROGRAM
C
 6015 FORMAT (2(1XI2) ,1X,I4,2I3,F7.3,I3,1X,I2,1X,I4,2I3,F7.3,F11.3  )
 6016 FORMAT (1XI2,1H/I2,1H/I4,7X11H START DATE/1XI2,I3,F7.3,5X,
     1 15H START TIME-UT2/1XF12.3,5X23H TIME INCREMENT-SECONDS//1XI2,
     2 1H/I2,1H/I4,7X9H END DATE/1XI2,I3,F7.3,5X13H END TIME-UT2   )
      READ             6015,NMS,NDS,NYS,NHS,NMNS,TSS,NMF,NDF,NYF,NHF,
     1 NMNF,TSF,DT
      WRITE OUTPUT TAPE 3,6016,NMS,NDS,NYS,NHS,NMNS,TSS,DT,NMF,NDF,NYF,
     1 NHF,NMNF,TSF
      WRITE OUTPUT TAPE 8,6016,NMS,NDS,NYS,NHS,NMNS,TSS,DT,NMF,NDF,NYF,
     1 NHF,NMNF,TSF
      PRINT 6016,NMS,NDS,NYS,NHS,NMNS,TSS,DT,NMF,NDF,NYF,NHF,NMNF,TSF
      IF (SENSE SWITCH 6) 1,2
    1 PRINT 6016,NMS,NDS,NYS,NHS,NMNS,TSS,DT,NMF,NDF,NYF,NHF,NMNF,TSF
    2 DJSO=DJUL(NMS,NDS,NYS)
      DJFO=DJUL(NMF,NDF,NYF)
      THS=NHS*3600
      TMNS=NMNS*60
      TS=THS+TMNS+TSS-TSEP
      THF=NHF*3600
      TMNF=NMNF*60
      TF=THF+TMNF+TSF-TSEP
      DJS=DJSO-DJO
      DJF=DJFO-DJO
      S=DJS*86400.+TS
      F=DJF*86400.+TF
```

```
      RETURN
      END
*     SUBROUTINE SUN
*     CARDS COLUMN
*     LIST8
*     LABEL
      SUBROUTINE SUN(DJ,ET,CL)
C
C     THEORY AND ANALYSIS OFFICE - GSFC
C     ONLY COMPUTES LONGITUDE IN RADIANS - ECLIPTIC
C     VERSION OF 9/15/64
C
C     WOOLARD'S ABBREVIATED VERSION OF NEWCOMB'S THEORY OF THE SUN.
C
C     INPUT
C                DJ  = JULIAN DATE AT 0 HOURS EPHEMERIS TIME.
C                ET  = EPHEMERIS TIME IN RADIANS (24 HOURS = 2 PI RADIANS).
C                      ET IS RESTRICTED TO LIE BETWEEN 0 AND +2 PI RADIANS.
C
C     OUTPUT
C                      GEOMETRIC COORDINATES OF THE SUN, TRUE EQUINOX
C                      AND ECLIPTIC OF DATE.
C
C                CL  = LONGITUDE IN RADIANS.
C
C     REFERENCES -
C                ASTRONOMICAL PAPERS PREPARED FOR THE USE OF THE AMERICAN
C                EPHEMERIS AND NAUTICAL ALMANAC. VOLUME 15, PART 1 (THEORY
C                OF THE ROTATION OF THE EARTH AROUND ITS CENTER OF MASS -
C                BY EDGAR N. WOOLARD - PAGES 53, 64 - 66 ).
C
C     RESTRICTIONS
C                WOOLARD HAS USED NEWCOMB'S THEORY OF THE SUN, NEGLECTING
C                ALL PERIODIC TERMS WITH COEFFICIENTS GREATER THAN .001
C                SECONDS OF ARC IN LONGITUDE AND LATITUDE, AND GREATER
C                THAN 7 UNITS IN THE 8TH DECIMAL OF THE LOGARITHM
C                OF THE RADIUS VECTOR.
C
C COMPUTE TIME IN JULIAN CENTURIES ELAPSED SINCE 1900 JAN. 0.5 ET
C
      DIMENSION S8(35),C(35),C8(23),E(23),S9(28),H(28),C9(41),G(45)
      PRT1=DJ-2415020.0
      PRT2=ET/6.28318531
D     T=(PRT1+PRT2)/36525.0
      T2=T*T
      T3=T2*T
C COMPUTE FUNDAMENTAL ARGUMENTS
C
C     MEAN LONGITUDE - SUN
C
      X = 0.5284469 E-5 *T2
D     CL1 = 4.881627934112 + 628.331950990909*T + X
C
C     MEAN ANOMALY - VENUS
C
      X = 0.22446873 E-4 *T2
D     G1 = 3.710626228126 + 1021.328348655046*T + X
C
C     MEAN ANOMALY - EARTH
C
      X = 0.2617994 E-5 *T2 + 0.58178 E-7 *T3
D     G2 = 6.256583580497 + 628.301945726741*T - X
C
C     MEAN ANOMALY - MARS
C
      X = 0.3156137 E-5 *T2
D     G3 = 5.576840377809 + 334.053549190822*T + X
C
C     MEAN ANOMALY - JUPITER
C
D     G4 = 3.932889060231 + 52.965367620264*T
C
C     MEAN ANOMALY - SATURN
C
D     G5 = 3.062637351924 + 21.320095075899*T
C
C     MEAN ANOMALY - MOON
C
      X = 0.160424846 E-3 *T2 + 0.251133 E-6 *T3
D     SL = 5.168000345744 + 8328.691103668024*T + X
C
C     MEAN ANOMALY - SUN
C
      X = 0.2617994 E-5 *T2 + 0.58178 E-7 *T3
D     SL1 = 6.256583580497 + 628.301945726741*T - X
C
C     MEAN ARGUMENT OF LATITUDE - MOON
C
      X = 0.56044461E-4*T2 + 0.5818E-8*T3
D     F = 0.196365054887 + 8433.466291171947*T - X
C
C     MEAN ELONGATION OF MOON FROM SUN
C
      X = 0.32967E-7*T3 - 0.25064867E-4*T2
```

```
D.     D = 6.121523942807 + 7771.377193934485 *T+X
C
C      LONGITUDE OF MEAN ASCENDING NODE - MOON
C
       X = 0.36264063E-4*T2 + 0.38785E-7*T3
D      W = 4.523601514852 - 33.757146246551*T + X
C
C REDUCE ALL ANGLES BY MODULUS 2 PI
C
C
D      CL1 = MODF (CL1,6.283185307179586)
D      G1  = MODF (G1 ,6.283185307179586)
D      G3  = MODF (G3 ,6.283185307179586)
D      G4  = MODF (G4 ,6.283185307179586)
D      G5  = MODF (G5 ,6.283185307179586)
D      SL  = MODF (SL ,6.283185307179586)
D      SL1 = MODF (SL1,6.283185307179586)
D      D   = MODF (D  ,6.283185307179586)
D      F   = MODF (F  ,6.283185307179586)
D      W   = MODF (W  ,6.283185307179586)
C
C COMPUTE EXCEPTIONAL ARGUMENTS
C
 1400 EA1 =8.0*SL1-15.0*G3
      EA2 =3.0*G4-8.0*G3+4.0*SL1
      EA3 =.7853981633974483E-1+T-8.0*G1+13.0*SL1
      EA4 =7.0*SL1-(3.0*G1+4.0*G3)
      EA5 =(F+W)+(F+W)
      EA6 =EA5-(D+D)
C COMPUTE SINES AND/OR COSINES OF 16 ARGUMENTS
 1500 SSL1 =SINF(SL1)
      CSL1 =COSF(SL1)
      SSL = SINF(SL)
      CSL = COSF(SL)
      SG1  =SINF(G1)
      CG1  =COSF(G1)
      SG3  =SINF(G3)
      CG3  =COSF(G3)
      SG4  =SINF(G4)
      CG4  =COSF(G4)
      SG5  =SINF(G5)
      CG5  =COSF(G5)
      SF   =SINF(F)
      SD   =SINF(D)
      CD   =COSF(D)
      SW   =SINF(W)
      CW   =COSF(W)
      C28  =COSF(EA1)
      S49  =SINF(EA2)
      C49  =COSF(EA2)
      S51  =SINF(EA3)
      C51  =COSF(EA3)
      C52  =COSF(EA4)
      S46  =SINF(EA5)
      S47  =SINF(EA6)
      S44A = SSL*CD
      S44B = CSL*SD
      S44 = S44A+S44B
      S45 = S44A-S44B
      C45A = CSL*CD
      C45B = SSL*SD
      C45 = C45A+C45B
      C75 = C45A-C45B
      C76 = C45A*(4.0*CD*CD-3.0)+C45B*(3.0-4.0*SD*SD)
C EVALUATE ALL OTHER SINES AND COSINES IN TERMS OF ABOVE
      X    =2.0*CSL1
      S01  =X  *SSL1
      C01  =X  *CSL1-1.0
      X    =2.0*C01
      S02  =(X  +1.0)*SSL1
      C02  =(X  -1.0)*CSL1
      S03  =2.0*SW*CW
      S04  =SSL1*CG1-CSL1*SG1
      C04  =CSL1*CG1+SSL1*SG1
      S05  =S04 *CG1-C04 *SG1
      C05  =C04 *CG1+S04 *SG1
      X    =2.0*C04
      S06  =X  *S04
      C06  =X  *C04-1.0
      S07  =SSL1*C06+CSL1*S06
      C07  =CSL1*C06-SSL1*S06
      X    =2.0*C06
      S08  =(X  +1.0)*S04
      C08  =(X  -1.0)*C04
      S09  =SSL1*C08+CSL1*S08
      C09  =CSL1*C08-SSL1*S08
      S10  =SSL1*C09+CSL1*S09
      C10  =CSL1*C09-SSL1*S09
      X    =2.0*C06
      S11  =X  *S06
      C11  =X  *C06-1.0
      S12  =SSL1*C11+CSL1*S11
      S13  =S01 *C11+C01 *S11
      C13  =C01 *C11-S01 *S11
```

```
      S14  =S11 *C04+C11 *S04
      C14  =C11 *C04-S11 *S04
      S15  =S01 *C14+C01 *S14
      C16  =C02 *C14-S02 *S14
      C17  =C04 *C14-S04 *S14
      S18  =SSL1*CG3-CSL1*SG3
      C18  =CSL1*CG3+SSL1*SG3
      S19  =S18 *CG3-C18 *SG3
      C19  =C18 *CG3+S18 *SG3
      X    =2.0*C18
      S20  =X  *S18
      C20  =X  *C18-1.0
      S21  =S20*CG3-C20*SG3
      C21  =C20*CG3+S20*SG3
      C22  =C18*C20-S18*S20
      S23  =S21*CG3-C21*SG3
      C23  =C21*CG3+S21*SG3
      S24  =SSL1*C23+CSL1*S23
      C24  =CSL1*C23-SSL1*S23
      S25  =S24 *CG3-C24 *SG3
      C25  =C24 *CG3+S24 *SG3
      C26  =CSL1*C25-SSL1*S25
      S27  =S18*C25+C18*S25
      C27  =C18*C25-S18*S25
      S29  =SSL1*CG4-CSL1*SG4
      C29  =CSL1*CG4+SSL1*SG4
      S30  =SSL1*C29+CSL1*S29
      C30  =CSL1*C29-SSL1*S29
      S31  =S29 *CG4-C29 *SG4
      C31  =C29 *CG4+S29 *SG4
      X    =2.0 *C29
      S32  =X    *S29
      C32  =X    *C29-1.0
      C33  =CSL1*C32-SSL1*S32
      S34  =S31 *CG4-C31 *SG4
      C34  =C31 *CG4+S31 *SG4
      S35  =S32 *CG4-C32 *SG4
      C35  =C32 *CG4+S32 *SG4
      S36  =S29 *C32+C29 *S32
      C36  =C29 *C32-S29 *S32
      C37  =C35 *CG4+S35 *SG4
      S38  =S36 *CG4-C36 *SG4
      C39  =CSL1*CG4-SSL1*SG4
      S40  =SSL1*CG5-CSL1*SG5
      C40  =CSL1*CG5+SSL1*SG5
      C41  =C40 *CG5+S40 *SG5
      X    =2.0 *C40
      C42  =X    *C40-1.0
      S43  =SSL1*CD -CSL1*SD
      C77A = CSL1*CD
      C77B = SSL1*SD
      C77 = C77A-C77B
      C78 = C77A+C77B
      X    =CSL1*C49
      Y    =SSL1*S49
      C48  =X +Y
      C50  =X -Y
C COMPUTE LONGITUDE OF SUN (MEAN LONG. + TABLE 8) MODULO 2PI
 1800 C(1 )=SSL1*(+33502.E-6)
      C(2 )=S01 *(+  351.E-6)
      C(3 )=S02 *(+    5.E-6)
      C(4 )=S49 *(+   25.E-6)
      C(5 )=S04 *(-   20.E-6)
      C(6 )=S06 *(+   14.E-6)
      C(7 )=S07 *(-    8.E-6)
      C(8 )=S09 *(-    2.E-6)
      C(9 )=S10 *(-    3.E-6)
      C(10)=S51 *(+    7.E-6)
      C(11)=S18 *(+    1.E-6)
      C(12)=S20 *(+    3.E-6)
      C(13)=S19 *(+    3.E-6)
      C(14)=S21 *(+    1.E-6)
      C(15)=S24 *(-    2.E-6)
      C(16)=S23 *(+    1.E-6)
      C(17)=S25 *(-    1.E-6)
      C(18)=SG4 *(-   13.E-6)
      C(19)=S32 *(-   13.E-6)
      C(20)=S31 *(-    7.E-6)
      C(21)=S35 *(-    3.E-6)
      C(22)=S34 *(-    1.E-6)
      C(23)=S40 *(-    2.E-6)
      C(24)=SG5 *(-    2.E-6)
      C(25)=SSL1*(- 8358.E-8)*T
      C(26)=S01 *(-  175.E-8)*T
      C(27)=SSL1*(-   25.E-8)*T*T
      C(28)=SD  *(+   31.E-6)
      C(29)=S44 *(+    1.E-6)
      C(30)=S45 *(+    2.E-6)
      C(31)=S43 *(-    1.E-6)
      C(32)=SW  *(-   84.E-6)
      C(33)=S03 *(+    1.E-6)
      C(34)=S47 *(-    6.E-6)
      C(35)=S46 *(-    1.E-6)
 1900 E(1 )=C04 *(+   11.E-6)
```

```
      E(2 )=C06 *(-    23.E-6)
      E(3 )=C07 *(+     9.E-6)
      E(4 )=C08 *(-     3.E-6)
      E(5 )=C09 *(+     7.E-6)
      E(6 )=C10 *(+     4.E-6)
      E(7 )=C11 *(-     1.E-6)
      E(8 )=C13 *(+     1.E-6)
      E(9 )=C16 *(+     1.E-6)
      E(10)=C51 *(+     6.E-6)
      E(11)=C49 *(+    18.E-6)
      E(12)=C18 *(-     1.E-6)
      E(13)=C20 *(+    10.E-6)
      E(14)=C19 *(-     8.E-6)
      E(15)=C21 *(+     2.E-6)
      E(16)=C23 *(+     3.E-6)
      E(17)=C28 *(+     1.E-6)
      E(18)=C30 *(-     1.E-6)
      E(19)=C29 *(-    35.E-6)
      E(20)=C64 *(-     1.E-6)
      E(21)=C31 *(-     3.E-6)
      E(22)=C36 *(-     1.E-6)
      E(23)=C52 *(-     1.E-6)
      TBS = C(1)
      DO 1930  J=2,35
 1930 TBS = TBS+C(J)
      TBC = E(1)
      DO 1940 J=2,23
 1940 TBC = TBC+E(J)
      TAB8 = TBS + TBC
 1950 CL  =MODF(TAB8+CL1,  6.283185307179586)
 9000 RETURN
      END
*     SUBROUTINE ARKTAN
*     CARDS COLUMN                                                      ALLOT001
*     LIST8                                                             ALLOT002
*     LABEL
      SUBROUTINE ARKTAN(Y,X,Z,N)
      IF (X) 6,5,6
    5 IF (Y) 7,8,9
    7 IF (N) 10,11,10
   11 Z = -90.
      GO TO 500
   10 Z = -1.5707964
      GO TO 500
    8 Z = 0.
      GO TO 500
    9 IF (N) 12,13,12
   13 Z = 90.
      GO TO 500
   12 Z = 1.5707964
      GO TO 500
    6 IF (Y) 14,15,14
   15 IF (X) 16,17,17
   16 IF (N) 18,19,18
   19 Z = 180.
      GO TO 500
   18 Z = 3.1415927
      GO TO 500
   17 Z = 0.
      GO TO 500
   14 IF ACCUMULATOR OVERFLOW 30,30
   30 IF QUOTIENT OVERFLOW 31,31
   31 IF DIVIDE CHECK 32,32
   32 A = ABSF (Y)
      B = ABSF (X)
      Z = A/B
      IF DIVIDE CHECK 33,34
   33 Z = 0.
      GO TO 500
   34 Z = ATANF(Z)
      IF (Y) 50,51,51
   50 IF (X) 52,53,53
   52 Z = Z-3.1415927
      GO TO 600
   53 Z = -Z
      GO TO 600
   51 IF (X) 54,600,600
   54 Z = 3.1415927-Z
      GO TO 600
  600 IF (N) 500,55,500
   55 Z = (180./3.1415927)*Z
  500 RETURN
      END
*     SUBROUTINE TESCOV       CONVERTS 3 DIGIT INTEGER INTO BCD FORM
*     CARDS COLUMN
*     LIST8
*     FAP
       COUNT    20
       LBL      TESCOV,X
       ENTRY    TESCOV
TESCOV CLA*     1,4
BCVDEC ARS      18
       ANA      IBADR
       LDQ      BLNKS
```

```
         VDP      BCVDT-,6
         VDP      BCVDT+1-,6
         VDP      BCVDT+2,,
         VDP      BCVDT+3,,6
         VDP      BCVDT+4,,6
         RQL      18
         STQ*     2,4
         TRA      3,4
BCVDT    DEC      -640000,-4096000,-26214400,-167772160,-1073741824
IBADR    OCT      000000077777
BLNKS    BCI      1,
         END
*        SUBROUTINE CH65K        TESTS FOR 65K.
*        CARDS COLUMN
*        LIST8
*        FAP
         COUNT    20
         LBL      CH65K,X                      FORTRAN CALLING SEQUENCE =
         ENTRY    CH65K                        CALL CH65K(N)
CH65K    SEB
         EFT
         TRA      *+4
XN32K    CLA      B32                          MACHINE IS IN 32K -- N
         STO*     1,4
         TRA      2,4
         SEA
         EFT
         TRA      XN32K
         STZ*     1,4
         TRA      2,4                          MACHINE IS IN 65K -- N = 0
B32      OCT      000004000000
         END
```

APPENDIX VIII (PART A)

SAMPLE INPUT

FOR MAIN PROGRAM ONE

```
      RELAY 2  12 STATI0N TEST
+04+01+01-01           +4  5000.
 33333 640114 2157 00000                                                    00000
+17470063+01+23653052+00+81153895+00+62823296+01+32527117+01+38506655+01  TEST
 33333 640114 2157 00000 +00000000+00
 01/15/1964 20 00 00.000 01/16/1964 20 00 00.000 +120.
+12+00+00
  90.0    0.0 178.    25.
 C0MNUT  -75 00   0.000 +40 00  0.000     0.0
 C0MAND -068 40 00.000 +44 54 00.000  38.
 C0MHIL  -05 10 29.0   +50 02 58.0    350.0
 C0MGER  +10 00 00.000 +51 00 00.000   50.
 C0MTEL  +13 36   5.000 +41 58 41.000  2168.6
 C0MRI0  -43 22   7.000 -22 57  9.000     0.0
 C0MNUT  -75 00   0.000 +40 00  0.000     0.0
 C0MAND -068 40 00.000 +44 54 00.000  38.
 C0MHIL  -05 10 29.0   +50 02 58.0    350.0
 C0MNUT  -75 00   0.000 +40 00  0.000     0.0
 C0MAND -068 40 00.000 +44 54 00.000  38.
 C0MHIL  -05 10 29.0   +50 02 58.0    350.0
```

APPENDIX VIII (PART B)

MAIN PROGRAM ONE OUTPUT

RELAY 2 12 STATION TEST

RELAY 2 12 STATION TEST

```
6.07999998E 03          FEET PER NAUTICAL MILE

6378.388                EQUATORIAL RADIUS OF EARTH IN KM
297.0                   INVERSE OF FLATTENING
3.98626876E 05          GM (KM. CUBED/SECONDS SQUARED)

                        HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL
1.082190E-03            J2
-2.285000E-06           J3
-2.123000E-06           J4
-2.320000E-07           J5

EPOCH  64  1 14 21 57  0.

      A              E              I              M              OMEGA          THETA
1.74700063E 00 2.3653052E-01 8.1153895E-01 6.2823296E 00 3.2527117E 00 3.8506655E 00

DRAG EFFECTS     T (P.Q)       N (2.Q)        N (3.Q)
             64 114 2157 0    0.

LOOK ANGLE CALCULATIONS - START AND END TIMES

 1/15/1964          START DATE
20  0  0.           START TIME-UT2
    120.000         TIME INCREMENT-SECONDS

 1/16/1964          END DATE
20  0  0.           END TIME-UT2
```

LOCAL STATION PREDICTIONS FOR --

STATION	LONGITUDE	LATITUDE	HEIGHT (METERS)
COMNUT	-75 0 0.	40 0 0.	0.
COMAND	-68 40 0.	44 54 0.	38.30
COMHIL	-5 10 29.000	50 2 58.000	350.30
COMGER	10 0 0.	51 0 0.	50.30
COMTEL	13 36 5.000	41 58 41.000	2168.50
COMRIO	-43 22 7.000	-22 57 9.000	0.
COMNUT	-75 0 0.	40 0 0.	0.
COMAND	-68 40 0.	44 54 0.	38.30
COMHIL	-5 10 29.000	50 2 58.000	350.30
COMNUT	-75 0 0.	40 0 0.	0.
COMAND	-68 40 0.	44 54 0.	38.30
COMHIL	-5 10 29.000	50 2 58.000	350.30

```
CONTROL STATIONS ARE
    COMNUT
    COMAND
    COMHIL
    COMGER

NO STATION PRINT OUT IF --

ELEVATION IS LESS THAN              0 DEGREES

 5 IS PRINTED IF THE ELEVATION IS GREATER THAN OR EQUAL TO    0 AND LESS THAN 5 DEGREES
 9 IS PRINTED IF THE ELEVATION IS GREATER THAN OR EQUAL TO    5  AND LESS THAN 10 DEGREES
 A IS PRINTED IF THE ELEVATION IS GREATER THAN OR EQUAL TO   10  DEGREES

A T IS PRINTED OF RANGE IS GREATER THAN   0.50000000E 04NAUTICAL MILES

                SPIN AXIS COORDINATES ARE
                    178.0 DEGREES RIGHT ASCENSION
                     25.0 DEGREES DECLINATION

THE 3 DIGIT NUMBERS UNDER THE STATION NAMES ARE THE SPACECRAFT LOOK ANGLES.
```

ORBIT NUMBER 0

MUTUAL VISIBILITY OF 33333 FOR THE FOLLOWING STATIONS

DATE(MM/DD/YY) = 1/15/64

HHMM	NUT	AND	HIL	GER	TEL	RIO	NUT	AND	HIL	NUT	AND	HIL
20 0	068 A	072 A					068 A	072 A		068 A	072 A	
20 2	071 A	075 A					071 A	075 A		071 A	075 A	
20 4	075 A	079 A					075 A	079 A		075 A	079 A	
20 6	078 A	083 A					078 A	083 A		078 A	083 A	
20 8	083 A	087 A					083 A	087 A		083 A	087 A	
2010	088 A	093 A					088 A	093 A		088 A	093 A	
2012	094 A	099 A					094 A	099 A		094 A	099 A	
2014	101 A	106 A	114 5				101 A	106 A	114 5	101 A	106 A	114 5
2016	108 A	114 A	119 5				108 A	114 A	119 5	108 A	114 A	119 5
2018	116 A	123 A	124 5				116 A	123 A	124 5	116 A	123 A	124 5
2020	123 A	132 A	131 5				123 A	132 A	131 5	123 A	132 A	131 5
2022	128 A	139 A	137 5				128 A	139 A	137 5	128 A	139 A	137 5
2024	131 A	142 A	144 5				131 A	142 A	144 5	131 A	142 A	144 5
2026	132 A	143 A	152 5				132 A	143 A	152 5	132 A	143 A	152 5
2028	131 A	141 A	160 5				131 A	141 A	160 5	131 A	141 A	160 5
2030	128 A	137 A	168 5				128 A	137 A	168 5	128 A	137 A	168 5
2032	126 9	133 9	177 5			087 5	126 9	133 9	177 5	126 9	133 9	177 5
2034		129 5				088 9		129 5			129 5	
2036						088 9						
2038						088 A						
2040						087 A						
2042						086 A						
2044						083 A						
2046						081 A						
2048						078 A						
2050						075 9						
2052						072 5						
2054						070 5						

******

TAPE A8

WORLD MAP

LOCAL STATION PREDICTIONS

SUN LIGHT HISTORY

RELAY 2 12 STATION TEST

```
6.07999998E 03          FEET PER NAUTICAL MILE

5378.388             EQUATORIAL RADIUS OF EARTH IN KM
 297.0               INVERSE OF FLATTENING
3.98626876E 05       GM (KM. CUBED/SECONDS SQUARED)

                     HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL
 1.082190E-03        J2
-2.285000E-06        J3
-2.123000E-06        J4
-2.320000E-07        J5

EPOCH   64  1 14 21 57  0.

       A              E              I              M            OMEGA          THETA
 1.7470063E 00 2.3653052E-01 8.1153895E-01 6.2823296E 00 3.2527117E 00 3.8506655E 00

DRAG EFFECTS       T (P.Q)          N (2.Q)            N (3.Q)
              64 114 2157 0     0.

LOOK ANGLE CALCULATIONS - START AND END TIMES

 1/15/1954           START DATE
20  0  0.            START TIME-UT2
      120.000        TIME INCREMENT-SECONDS

 1/16/1964           END DATE
20  0  0.            END TIME-UT2

                CONTROL STATIONS ARE
                    COMNUT
                    COMAND
                    COMHIL
                    COMGER

 S IS PRINTED WHEN THE SATELLITE IS IN THE SUNLIGHT
```

ORBIT NUMBER 0

LOCAL STATION PREDICTIONS AND SATELLITE WORLD MAP FOR 33333

RANGE AZI. ELEV. S/C LOOK LAT. LONG. HEIGHT

YYMMDD HHMM STAT. (KM) ------------DEGREES------------------ (KM)

YYMMDD HHMM	STAT.	RANGE (KM)	AZI.	ELEV.	S/C LOOK	LAT.	LONG.	HEIGHT (KM)	
64 115 20 0	COMNUT	6619.0	295.1	29.8	68.9	46.0	-116.7	4863.8	S
	COMAND	6864.6	289.3	26.2	72.9				
	COMNUT	6619.0	295.1	29.8	68.9				
	COMAND	6864.6	289.3	26.2	72.9				
	COMNUT	6619.0	295.1	29.8	68.9				
	COMAND	6864.6	289.3	26.2	72.9				
64 115 20 2	COMNUT	6166.2	295.8	33.9	71.9	46.4	-112.1	4694.3	S
	COMAND	6402.8	288.6	30.1	76.0				
	COMNUT	6166.2	295.8	33.9	71.9				
	COMAND	6402.8	288.6	30.1	76.0				
	COMNUT	6166.2	295.8	33.9	71.9				
	COMAND	6402.8	288.6	30.1	76.0				
64 115 20 4	COMNUT	5715.0	296.5	38.6	75.2	46.6	-107.2	4522.5	S
	COMAND	5941.3	287.5	34.4	79.5				
	COMNUT	5715.0	296.5	38.6	75.2				
	COMAND	5941.3	287.5	34.4	79.5				
	COMNUT	5715.0	296.5	38.6	75.2				
	COMAND	5941.3	287.5	34.4	79.5				
64 115 20 6	COMNUT	5270.4	297.3	43.9	79.0	46.5	-102.2	4348.9	S
	COMAND	5484.4	286.0	39.3	83.4				
	COMNUT	5270.4	297.3	43.9	79.0				
	COMAND	5484.4	286.0	39.3	83.4				
	COMNUT	5270.4	297.3	43.9	79.0				
	COMAND	5484.4	286.0	39.3	83.4				
64 115 20 8	COMNUT	4839.1	298.4	50.0	83.4	46.2	-97.0	4174.3	S
	COMAND	5038.4	283.9	44.8	88.0				
	COMNUT	4839.1	298.4	50.0	83.4				
	COMAND	5038.4	283.9	44.8	88.0				
	COMNUT	4839.1	298.4	50.0	83.4				
	COMAND	5038.4	283.9	44.8	88.0				
64 115 2010	COMNUT	4430.5	299.8	57.0	88.4	45.6	-91.7	3999.5	S
	COMAND	4611.7	280.5	51.1	93.3				

SUNLIGHT HISTORY OF 33333

SATELLITE WILL BE IN SUNLIGHT AT ALL TIMES EXCEPT WHEN IT WILL
ENTER SHADOW AT AND LEAVE SHADOW AT

YYMMDD HHMM YYMMDD HHMM DURATION (MIN) PERCENT IN SUNLIGHT

NO OUTPUT INDICATES THAT SPACECRAFT IS IN SUNLIGHT 100% OF TIME

APPENDIX VIII

PART C

OUTPUT OF MAIN PROGRAM TWO

TAPE A3

WORLD MAP AND BAR GRAPHS

```
SANDTRACKS ORBITAL COMPUTING SYSTEM

    ELAY TEST 12 STATIONS

10.0E-09              TOLERANCE REQUIRED FOR KEPZ SUBROUTINE

6378.388              EQUATORIAL RADIUS OF EARTH IN KM
 297.0                INVERSE OF FLATTENING
3.98626876E 05        GM (KM. CUBED/SECONDS SQUARED)

                      HARMONICS OF EARTHS GRAVITATIONAL POTENTIAL
 1.082190E-03         J2
-2.285000E-06         J3
-2.123000E-06         J4
-2.320000E-07         J5

                      BROUWER HARMONICS COMPUTED FROM J2,J3,J4, AND J5
2.20138180E 04        K2 (KILOMETERS SQUARED)
5.92951238E 05        K3 (KILOMETERS CUBED)
1.31772552E 09        K4 (KILOMETERS FOURTH POWER)
2.44950354E 12        K5 (KILOMETERS FIFTH POWER)

 1/14/1964            EPOCH DATE OF PARAMETERS
21 57 -0.             EPOCH TIME OF PARAMETERS-UT2

                      INPUT OPTION NUMBER
                      INPUT PARAMETERS ARE---

BROUWER MEAN ELEMENTS
REQUIRED UNITS - ALL ANGLES IN DEGREES,SEMI-MAJOR AXIS IN KILOMETERS

  11143.0840          SEMI-MAJOR AXIS-KILOMETERS
     0.23653051       ECCENTRICITY
    46.497756         INCLINATION    -DEGREES
   220.626879         R.A. ASC. NODE -DEGREES
   186.366648         ARG. OF PERIGEE-DEGREES
   359.950966         MEAN ANOMALY   -DEGREES

WORLD MAP CALCULATIONS - START AND END TIMES

 1/15/1964            START DATE
20  0  0.             START TIME-UT2
     120.000          TIME INCREMENT-SECONDS

 1/16/1964            END DATE
20  0  0.             END TIME-UT2

LOOK ANGLE CALCULATIONS - START AND END TIMES

 1/15/1964            START DATE
10  0  0.             START TIME-UT2
     120.000          TIME INCREMENT-SECONDS

 1/16/1964            END DATE
10  0  0.             END TIME-UT2
```

SANDTRACKS ORBITAL COMPUTING SYSTEM

RELAY TEST 12 STATIONS

QUANTITIES COMPUTED FROM INPUT

1/14/1964	EPOCH DATE OF PARAMETERS
21 57 -0.	EPOCH TIME OF PARAMETERS-UT2

POSITION AND VELOCITY VECTORS - GEOCENTRIC EQUATORIAL INERTIAL

5996.52051	X1 - KILOMETERS	0.94013103	X1	- VANGUARD UNITS
5996.32159	X2 - KILOMETERS	0.94009985	X2	- VANGUARD UNITS
-682.69296	X3 - KILOMETERS	-0.10703221	X3	- VANGUARD UNITS
-4.02792889	VX1 - KM/SEC	-0.50951149	VX1	- VANGUARD UNITS
3.40607378	VX2 - KM/SEC	0.43085013	VX2	- VANGUARD UNITS
-5.48964036	VX3 - KM/SEC	-0.69441018	VX3	- VANGUARD UNITS
8507.65540	R - KILOMETERS	1.33382532	R	- VANGUARD UNITS
7.61325824	V - KM/SEC	0.96303649	V	- VANGUARD UNITS

TRUNCATION FACTORS USED IN COMPUTING BROUWER
MEAN ELEMENTS FROM OSCULATING ELEMENTS

5.0E-04	SEMI-MAJOR AXIS - KILOMETERS
5.0E-06	ECCENTRICITY
5.0E-06	INCLINATION - DEGREES
5.0E-06	R.A. ASC. NODE - DEGREES
5.0E-06	ARG. OF PERIGEE - DEGREES
5.0E-06	MEAN ANOMALY - DEGREES

ORBITAL ELEMENTS

OSCULATING ELEMENTS	BROUWER MEAN ELEMENTS	
11150.8829	11143.0840	SEMI-MAJOR AXIS - KILOMETERS
0.23704214	0.23653051	ECCENTRICITY
46.509814	46.497756	INCLINATION - DEGREES
220.619141	220.626875	R.A. ASC. NODE - DEGREES
186.266777	186.366640	ARG. OF PERIGEE - DEGREES
0.050050	359.950958	MEAN ANOMALY - DEGREES

3.251240	PERIOD	-HOURS
195.0744		-MINUTES
110.726969	MEAN MOTION	-DEGREES/HOUR
-1.092296	MOTION OF NODE	- DEGREES/DAY
1.085400	MOTION OF PERIGEE	- DEGREES/DAY

WORLD MAP

DATE	UNIVERSAL TIME			GEODETIC COORDINATES		
MO/DY/YR	H	M	SEC.	LATITUDE-DMS	LONGITUDE-DMS	HEIGHT-KM.
1/15/64	20	0	0.000	45 58 3.44	-116 41 9.76	4863.764
1/15/64	20	2	0.000	46 23 44.19	-112 3 29.31	4694.303
1/15/64	20	4	0.000	46 35 36.75	-107 12 31.30	4522.467
1/15/64	20	6	0.000	46 32 5.89	-102 10 21.52	4348.900
1/15/64	20	8	0.000	46 11 43.08	-96 59 43.31	4174.323
1/15/64	20	10	0.000	45 33 11.46	-91 43 48.92	3999.537
1/15/64	20	12	0.000	44 35 30.19	-86 26 5.46	3825.429
1/15/64	20	14	0.000	43 17 57.62	-81 9 58.17	3652.979
1/15/64	20	16	0.000	41 40 12.74	-75 58 33.43	3483.259
1/15/64	20	18	0.000	39 42 15.16	-70 54 25.40	3317.437
1/15/64	20	20	0.000	37 24 23.77	-65 59 27.44	3156.770
1/15/64	20	22	0.000	34 47 14.74	-61 14 49.10	3002.603
1/15/64	20	24	0.000	31 51 39.51	-56 40 58.13	2856.350
1/15/64	20	26	0.000	28 38 43.12	-52 17 45.57	2719.480
1/15/64	20	28	0.000	25 9 43.10	-48 4 32.26	2593.492
1/15/64	20	30	0.000	21 26 9.20	-44 0 15.90	2479.878
1/15/64	20	32	0.000	17 29 43.00	-40 3 36.58	2380.086
1/15/64	20	34	0.000	13 22 18.25	-36 13 2.11	2295.473
1/15/64	20	36	0.000	9 6 0.61	-32 26 51.37	2227.256
1/15/64	20	38	0.000	4 43 7.11	-28 43 16.82	2176.462
1/15/64	20	40	0.000	0 16 5.05	-25 0 26.26	2143.883
1/15/64	20	42	0.000	-4 12 30.38	-21 16 23.33	2130.034
1/15/64	20	44	0.000	-8 39 57.52	-17 29 9.25	2135.135
1/15/64	20	46	0.000	-13 3 31.88	-13 36 42.88	2159.090
1/15/64	20	48	0.000	-17 20 28.68	-9 37 2.52	2201.503
1/15/64	20	50	0.000	-21 28 5.68	-5 28 8.20	2261.690
1/15/64	20	52	0.000	-25 23 45.58	-1 8 5.78	2338.718
1/15/64	20	54	0.000	-29 4 58.28	3 24 47.24	2431.448
1/15/64	20	56	0.000	-32 29 23.01	8 11 52.97	2538.579
1/15/64	20	58	0.000	-35 34 50.78	13 14 2.16	2658.705
1/15/64	21	0	0.000	-38 19 27.46	18 31 21.17	2790.355
1/15/64	21	2	0.000	-40 41 37.96	24 2 58.79	2932.042
1/15/64	21	4	0.000	-42 40 11.25	29 46 56.24	3082.288
1/15/64	21	6	0.000	-44 14 25.80	35 40 4.06	3239.665

1/15/64	21	8	0.000	-45	24	14.38	41	38	9.97	3402.803
1/15/64	21	1C	0.COQ	-46	10	6.51	47	36	18.24	3570.416
1/15/64	21	12	0.COQ	-46	33	7.64	53	29	18.83	3741.303
1/15/64	21	14	0.000	-46	34	54.49	59	12	19.32	3914.355
1/15/64	21	1C	0.COC	-46	17	27.11	64	41	12.54	4088.556
1/15/64	21	1E	0.000	-45	42	59.38	69	52	53.88	4262.983
1/15/64	21	2C	0.000	-44	53	49.54	74	45	26.98	4436.798
1/15/64	21	22	C.C00	-43	52	12.25	79	17	58.76	4609.247
1/15/64	21	24	0.C0G	-42	40	12.84	83	30	28.57	4779.653
1/15/64	21	2E	0.000	-41	19	43.93	87	23	34.53	4947.410
1/15/64	21	2E	0.000	-39	52	23.91	90	58	20.69	5111.977
1/15/64	21	3C	0.000	-38	19	36.97	94	16	6.06	5272.871
1/15/64	21	32	0.000	-36	42	33.88	97	18	16.56	5429.663
1/15/64	21	34	0.000	-35	2	13.38	100	6	18.94	5581.974
1/15/64	21	3E	0.000	-33	19	23.70	102	41	37.30	5729.465

LCCAL STATICN PREDICTIONS FOR --

STATICN	LONCITUCE			LATITUDE			HEIGHT (METERS)
COMNUT	-75	C	C.	40	C	0.	0.
COMANI	-68	4G	0.	44	54	C.	38.0C
COMHIL	-5	1C	29.CCC	5C	2	58.0QC	350.00
COMGEF	10	C	C.	51	0	0.	50.00
COMTEL	13	26	5.000	41	5E	41.CCQ	2168.6C
COMRIC	-43	22	7.C00	-22	57	9.C00	0.
COMNUT	-75	C	C.	40	0	0.	0.
COMANC	-68	40	C.	44	54	0.	38.C0
COMHIL	-5	10	29.000	5C	2	58.000	350.00
COMNUT	-75	C	0.	4C	C	0.	0.
COMANC	-68	40	C.	44	54	0.	38.00
COMHIL	-5	1C	29.C00	50	2	58.0C0	350.00

NO STATICN PRINT OUT IF --

1. ELEVATICN IS LESS THAN 0 DEGREES
2. RANGE IS CREATER THAN 1CCCCCO. KILOMETERS
3. RADAR ANGLE IS CREATER THAN 90.C DEGREES
   OR LESS THAN C. DEGREES

SPIN AXIS COCRCINATES ARE 178.C DEGREES RIGHT ASCENSION
25.C DEGREES DECLINATION

LOCAL STATICN PRECICTICNS

MUTUAL VISIBILITY

DATE MO/DY/YR	UNIVERSAL TIME H	M	SEC.	NUT	AND	HIL	GER	TEL	RIO	NUT	AND	HIL	NUT	AND	HIL
1/15/64	1C	0	C.CCC			*	*	*				*			*
1/15/64	10	2	C.CCO			*	*	*				*			*
1/15/64	10	4	C.CCC				*	*							
1/15/64	10	6	C.CCC				*	*							
1/15/64	1C	8	C.CCO					*							
1/15/64	10	10	C.CCO					*							
******															
1/15/64	11	52	0.000						*						
1/15/64	11	54	C.CCC						*						
1/15/64	11	56	C.CCC						*						
1/15/64	11	58	C.CCO						*						
1/15/64	12	C	C.CCO						*						
1/15/64	12	2	C.CCC						*						
1/15/64	12	4	0.CCG						*						
1/15/64	12	6	C.CCO						*						
1/15/64	12	8	C.000	*					*	*			*		
1/15/64	12	10	C.CCO	*					*	*			*		
1/15/64	12	12	C.CCO	*					*	*			*		
1/15/64	12	14	C.0CO	*	*				*	*	*		*	*	
1/15/64	12	16	0.CCO	*	*				*	*	*		*	*	
1/15/64	12	18	C.C00	*	*				*	*	*		*	*	
1/15/64	12	20	0.CCO	*	*				*	*	*		*	*	
1/15/64	12	22	0.CCO	*	*				*	*	*		*	*	
1/15/64	12	24	C.CCO	*	*				*	*	*		*	*	
1/15/64	12	26	C.0CO	*	*				*	*	*		*	*	
1/15/64	12	28	C.CCO	*	*				*	*	*		*	*	
1/15/64	12	30	C.CCO	*	*				*	*	*		*	*	
1/15/64	12	32	C.000	*	*				*	*	*		*	*	
1/15/64	12	34	C.CCC	*	*				*	*	*		*	*	
1/15/64	12	36	C.CCO	*	*				*	*	*		*	*	

1/15/64	12 38	0.000	*	*				*	*	*		*	*	
1/15/64	12 40	0.000	*	*				*	*	*		*	*	
1/15/64	12 42	0.000	*	*				*	*	*		*	*	
1/15/64	12 44	0.000	*	*				*	*	*		*	*	
1/15/64	12 46	0.000	*	*				*	*	*		*	*	
1/15/64	12 48	0.000	*	*	*			*	*	*	*	*	*	*
1/15/64	12 50	0.000	*	*	*			*	*	*	*	*	*	*
1/15/64	12 52	0.000	*	*	*			*	*	*	*	*	*	*
1/15/64	12 54	0.000	*	*	*			*	*	*	*	*	*	*

LOCAL STATION PREDICTIONS

DATE MO/DY/YR	UNIVERSAL TIME H M	SEC.	NUT	AND	HIL	GER	TEL	RIO	NUT	AND	HIL	NUT	AND	HIL
1/15/64	12 56	0.000	*	*	*			*	*	*	*	*	*	*
1/15/64	12 58	0.000	*	*	*	*		*	*	*	*	*	*	*
1/15/64	13 0	0.000	*	*	*	*		*	*	*	*	*	*	*
1/15/64	13 2	0.000	*	*	*	*	*	*	*	*	*	*	*	*
1/15/64	13 4	0.000	*	*	*	*	*	*	*	*	*	*	*	*
1/15/64	13 6	0.000	*	*	*	*	*	*	*	*	*	*	*	*
1/15/64	13 8	0.000	*	*	*	*	*	*	*	*	*	*	*	*
1/15/64	13 10	0.000	*	*	*	*	*	*	*	*	*	*	*	*
1/15/64	13 12	0.000		*	*	*	*	*		*	*		*	*
1/15/64	13 14	0.000			*	*	*				*			*
1/15/64	13 16	0.000			*	*	*				*			*
1/15/64	13 18	0.000			*	*	*				*			*
1/15/64	13 20	0.000			*	*	*				*			*
1/15/64	13 22	0.000			*	*	*				*			*
1/15/64	13 24	0.000			*	*	*				*			*
1/15/64	13 26	0.000			*	*	*				*			*
1/15/64	13 28	0.000			*	*	*				*			*
1/15/64	13 30	0.000			*	*	*				*			*
1/15/64	13 32	0.000				*	*							
1/15/64	13 34	0.000					*							
1/15/64	13 36	0.000					*							
1/15/64	13 38	0.000					*							

******

1/15/64	15 46	0.000	*						*			*		
1/15/64	15 48	0.000	*						*			*		
1/15/64	15 50	0.000	*						*			*		
1/15/64	15 52	0.000	*	*					*	*		*	*	
1/15/64	15 54	0.000	*	*					*	*		*	*	
1/15/64	15 56	0.000	*	*					*	*		*	*	
1/15/64	15 58	0.000	*	*					*	*		*	*	
1/15/64	16 0	0.000	*	*					*	*		*	*	
1/15/64	16 2	0.000	*	*					*	*		*	*	
1/15/64	16 4	0.000	*	*					*	*		*	*	
1/15/64	16 6	0.000	*	*					*	*		*	*	
1/15/64	16 8	0.000	*	*					*	*		*	*	
1/15/64	16 10	0.000	*	*					*	*		*	*	
1/15/64	16 12	0.000	*	*					*	*		*	*	
1/15/64	16 14	0.000	*	*					*	*		*	*	
1/15/64	16 16	0.000	*	*					*	*		*	*	
1/15/64	16 18	0.000	*	*					*	*		*	*	

TAPE A6

LOCAL STATION PREDICTIONS

LOCAL STATION PREDICTIONS

MUTUAL VISIBILITY

DATE MO/DY/YR	UT2 H. M	STATION	RANGE (KM)	AZ (DEG)	EL (DEG)	RADAR ANGLE (DEG)
1/15/64	10 0	COMFIL	6356.7	149.6	62.6	84.3
		COMCER	6368.5	201.7	62.2	75.7
		COMTEL	6144.1	245.3	72.2	69.0
		COMHIL	6356.7	149.6	62.6	84.3
		COMFIL	6356.7	149.6	62.6	84.3
1/15/64	10 2	COMHIL	6214.4	138.5	62.6	87.9
		COMCER	6141.3	193.8	65.5	79.0
		COMTEL	5931.2	246.3	77.3	72.3
		COMFIL	6214.4	138.5	62.6	87.9
		COMHIL	6214.4	138.5	62.6	87.9
1/15/64	10 4	COMCER	5931.5	182.7	68.4	82.6
		COMTEL	5736.9	248.2	82.7	75.9
1/15/64	10 6	COMCER	5743.3	167.9	70.3	86.6
		COMTEL	5565.1	261.2	88.4	79.8
1/15/64	10 8	COMTEL	5420.3	59.9	85.4	84.0
1/15/64	10 10	COMTEL	5307.1	63.6	79.0	88.5
1/15/64	11 52	COMRIC	10353.6	244.9	0.4	55.9
1/15/64	11 54	COMRIC	10285.1	247.3	2.5	53.0
1/15/64	11 56	COMRIC	10225.0	249.8	4.5	50.2
1/15/64	11 58	COMRIC	10173.0	252.3	6.4	47.4
1/15/64	12 0	COMRIO	10128.8	254.9	8.2	44.7
1/15/64	12 2	COMRIO	10092.0	257.5	9.9	42.0
1/15/64	12 4	COMRIO	10062.2	260.2	11.5	39.5
1/15/64	12 6	COMRIC	10038.9	262.9	13.0	37.0
1/15/64	12 8	COMNUT	11465.3	201.0	0.1	71.4
		COMRIO	10021.8	265.7	14.3	34.6
		COMNUT	11465.3	201.0	0.1	71.4
		COMNUT	11465.3	201.0	0.1	71.4

N65-30479

URBAN EMPLOYMENT MULTIPLIERS AND THEIR APPLICATION TO THE AEROSPACE INDUSTRY IN ST. LOUIS

Se-Hark Park

Washington University
St. Louis, Missouri

June 1965