Technical Memorandum No. 33-198

SPACE–Single Precision Cowell Trajectory Program

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January 15, 1965

Prepared Under Contract No. NAS 7-100
National Aeronautics & Space Administration

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ABSTRACT

SPACE, a Single Precision Cowell Trajectory Program, is a link under the JPL IBSYS-SFOF-JPTRAJ monitor. SPACE is a digital computer program written in the FAP language for the IBM 7094 computer. It is an updated version of the JPL Space Trajectories Program. Given a set of spacecraft initial conditions in one of several coordinate systems, SPACE can accurately compute the resulting trajectory. Included is the capability of considering perturbations due to a non-spherical Earth, Mars, and Moon, solar radiation pressure, attitude control forces, and a simple motor. The program forms the acceleration of the spacecraft with respect to some central body, integrates to obtain position and velocity, and then records time, position, and velocity on a spacecraft ephemeris file. Output parameters are computed in several coordinate systems. SPACE uses the double-precision JPL Ephemeris Tapes. The ephemerides of the Earth-Moon barycenter, Moon, Venus, Mars, Jupiter, and Saturn are used. The ephemeris tapes also provide the nutations in longitude and obliquity. All physical constants may be changed by input but the nominal values are those adopted by the Ad Hoc NASA Standard Constants Committee. A short historical background, equations solved, flow charts, descriptions of input and output parameters, hardware and software configurations, and interfaces between the program and the monitor are given.

I. INTRODUCTION

D. B. Holdridge developed a single precision Space Trajectory Program for the IBM 704 computer in 1959. Since that time JPL and other NASA contractors have made extensive use of the program as a research tool, in real-time mission support, and in routine trajectory computation. This has required constant modification and updating of the program because of computer hardware changes, system software changes, redevelopment of mathematical models and equations, and expanded application of the program. However, the basic structure of the program has not changed and Ref. 1 Section VIII is still used by most JPL trajectory engineers as a basic reference for trajectory computation.

In 1961 the JPL Powered-Flight Program and a linear search technique were combined with the Space Trajectories Program. A monitor was written to control this system and the entire package was called the JPL Trajectory Monitor System. This version of the program was documented (Ref. 8) and has been sent to over 40 NASA contractors. Its flexibility, capability and accuracy were sufficient to support the Ranger and Mariner-Venus missions and is currently being used to support Ranger VIII and IX missions.

The Trajectory Monitor System satisfied the linking of a powered flight program to a space flight program. But other applications of trajectory computation in the field of space research were being carried out at JPL (orbit determination, guidance and midcourse correction) and special versions of the space trajectory portion of the Trajectory Monitor System came into existence. Communication soon became a problem and it was apparent that a more general monitor system was needed. At the same time, mission support became more complex and it was apparent that more real-time communications and control were needed.

In 1963 JPTRAJ (Ref. 4) was born out of the first need and SFOF (Ref. 7) was born out of the second need. Hence, the trajectory program, among others, had to be modified to operate under this configuration.

This document describes SPACE, the current version of the JPL Space Trajectories Program under the IBSYS-SFOF-JPTRAJ monitor.

Several significant additions and deletions have been made. The Encke form of the equation of motion, on-line input capability, the computing and saving on tape of parameters along the trajectory, special computations for output and tracking station viewing periods and printing were lost because of core-storage limitations. The Mars equatorial coordinate system and the Mars oblateness perturbation were added. SPACE uses the double precision JPL Ephemeris Tapes (Ref. 2 and 3). The constants in the program are those currently adopted by NASA (Ref. 5 and 6) but they can be changed by input.

SPACE is currently being used in the Mariner-Mars mission and in Pioneer, Lunar Orbiter and Surveyor studies.

It is evident that SPACE will, in general, generate a different trajectory, given the same injection conditions, than one generated by an earlier version of the trajectory program. However, the JPL trajectory engineering staff can show that any difference in trajectories is due to state-of-the-art modifications and therefore there is every reason to believe that the use of SPACE will yield accurate trajectories to single precision. Successful Ranger and Mariner missions and comparison with other trajectory programs have borne this out.

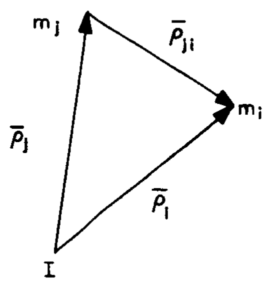
II. EQUATIONS OF MOTION AND FLOW CHARTS

A. EQUATIONS OF MOTION

Assume a small probe, body 0, in the gravitational field of n other bodies. In an inertial frame

$$\ddot{\bar{\rho}}_i = -k^2 \sum_{\substack{j=0 \\ j \neq i}}^{n} m_j \frac{\bar{\rho}_{ji}}{\rho_{ji}^3} \qquad i = 0, \cdots, n \tag{1}$$

where $\bar{\rho}_{ji} = \bar{\rho}_j - \bar{\rho}_i$; $\rho_{ji} = |\bar{\rho}_{ji}|$; i, j = 0, $\cdots$, n and k is the Gaussian gravitational constant.



Sketch 1. Relationship of i^{th} and j^{th} body in an inertial frame centered at I

The center of mass of the system, located by the vector $\bar{C}$ from the inertial origin is

$$\bar{C} = \frac{1}{M} \sum_{j=0}^{n} m_j \bar{\rho}_j$$

where

$$M = \sum_{j=0}^{n} m_j$$

The center of mass has the property that

$$\ddot{\bar{C}} = -\frac{k^2}{M}\sum_{j=0}^{n} m_j \sum_{\substack{i=0 \\ i \neq j}}^{n} m_i \frac{\bar{\rho}_{ij}}{\rho_{ij}^3} = 0$$

since $\bar{\rho}_{ij} = -\bar{\rho}_{ji}$ and $\rho_{ij} = \rho_{ji}$. Thus $\dot{\bar{C}}$ is constant and the center of mass is an inertial point (barycenter).

The motion of the probe, body 0, could be expressed as

$$\ddot{\bar{\rho}}_0 = -k^2 \sum_{j=1}^{n} m_j \frac{\bar{\rho}_{j0}}{\rho_{j0}^3}$$

where the coordinates are referred to the barycenter, and are inertial. In SPACE, however, this equation is rewritten so the coordinate system is referred to one of the n bodies, usually the dominant one.

The acceleration of the probe with respect to the designated central body is equivalent to the acceleration of the probe with respect to the inertial center C minus the acceleration of the central body with respect to the inertial center. In equation form this becomes

$$\ddot{\bar{R}}_0 = \ddot{\bar{\rho}}_0 - \ddot{\bar{\rho}}_{\ell}$$

or

$$\ddot{\bar{R}}_0 = -k^2 \sum_{j=1}^{n} m_j \frac{\bar{R}_{j0}}{R_{j0}^3} - \ddot{\bar{\rho}}_{\ell} \qquad (2)$$

with

$$\bar{R}_i = \bar{\rho}_i - \bar{\rho}_\ell = \bar{\rho}_{\ell i}$$

$$\bar{R}_{ij} = \bar{R}_j - \bar{R}_i = \bar{\rho}_j - \bar{\rho}_i = \bar{\rho}_{ij} \qquad i, j = 0, \cdots, n$$

$$R_{ij} = \left| \bar{R}_{ij} \right|$$

defined in the new coordinate system. $\ddot{\bar{\rho}}_\ell$ may be obtained from Eq. (1)

$$\ddot{\bar{\rho}}_\ell = -k^2 \sum_{\substack{j=0 \\ j \neq \ell}}^{n} m_j \frac{\bar{\rho}_{j\ell}}{\rho_{j\ell}^3} = k^2 \sum_{\substack{j=0 \\ j \neq \ell}}^{n} m_j \frac{\bar{R}_j}{R_j^3}$$

$$= -k^2 m_0 \frac{\bar{R}_0}{R_0^3} - k^2 \sum_{\substack{j=1 \\ j \neq \ell}}^{n} m_j \frac{\bar{R}_j}{R_j^3}$$

and $\ddot{\bar{\rho}}_0$ may be written as

$$\ddot{\bar{\rho}}_0 = -k^2 \sum_{j=1}^{n} m_j \frac{\bar{R}_{j0}}{R_{j0}^3} = -k^2 m_\ell \frac{\bar{R}_0}{R_0^3} - k^2 \sum_{\substack{j=1 \\ j \neq \ell}}^{n} m_j \frac{\bar{R}_{j0}}{R_{j0}^3}$$

hence $\ddot{\bar{R}}_0$ becomes

$$\ddot{\bar{R}}_0 = -k^2 (m_\ell + m_0) \frac{\bar{R}_0}{R_0^3} - k^2 \sum_{\substack{j=1 \\ j \neq \ell}}^{n} \left(m_j \frac{\bar{R}_{j0}}{R_{j0}^3} + m_j \frac{\bar{R}_j}{R_j^3} \right)$$

In SPACE, the mass m_0 of the probe is negligible, hence the basic n-body equation of motion which is integrated is

$$\ddot{\overline{R}} = -\mu_{\ell} \frac{\overline{R}}{R^3} - \sum_{\substack{j=1 \\ j \neq \ell}}^{n} \mu_j \left(\frac{\overline{R}_{jp}}{R_{jp}^3} + \frac{\overline{R}_j}{R_j^3} \right) \tag{3}$$

with $\overline{R} = \overline{R}_0 = \overline{R}_p$, $\overline{R}_{jp} = \overline{R}_{j0}$, p denoting the probe, and $\mu_j = k^2 m_j = GM_j$, $j = 1, \cdots, n$

In Eq. (3) the first term on the right is the accelerating effect of the central body on the probe. The summation term is henceforth referred to as the n-body perturbation, which consists of direct terms, $-\Sigma \mu_j \overline{R}_{jp}/R_{jp}^3$, and indirect terms, $-\Sigma \mu_j \overline{R}_j/\overline{R}_j^3$; the former terms represent the acceleration of the probe due to the n - 1 non-central bodies, and the latter terms represent the accelerations of the non-central bodies on the central body. Note that the indirect terms were not present in the barycentric form of the equation, as the barycenter is not accelerated.

In addition to the n-body effects of Eq. (3), there are perturbing terms which are added when the probe is in the vicinity of an oblate body. The form of this perturbation is given in detail in this Section in B. 1 for the cases of the Earth and Mars, and in B. 2 for the Moon.

It is often desirable to simulate the force acting on the probe due to the solar flux phenomenon. The equations for this calculation are enumerated in B. 3 of this Section.

A constant thrust, fixed flow rate motor which may be simulated is described in B. 4 of this Section.

The intermittent application of forces upon a probe due to an attitude control system may be simulated using polynomials to represent the forces. This option is described in B. 5 of this Section.

The complete equations of motion are written as

$$\ddot{\overline{R}} = -\mu_{\ell} \frac{\overline{R}}{R_{\ell}^3} - \sum_{\substack{j=1 \\ j \neq \ell}}^{n} \mu_j \left(\frac{\overline{R}_{jp}}{R_{jp}^3} + \frac{\overline{R}_j}{R_j^3} \right) + \sum_{k=1}^{m} \overline{P}_k \tag{4}$$

where the $\overline{P}_k$'s represent those perturbative accelerations other than the n-body perturbation which might be acting on a probe at a given time or point in space. m represents the total number of these additional effects.

B. PERTURBATIONS

The accelerative effects upon a probe other than the central body and n-body spherical contributions are considered herein.

1. Oblateness Calculations for Earth and Mars.

The expression for the potential of an oblate spheroidal body using second, third and fourth harmonics is given by

$$U_b = \frac{\mu_b}{R}\left[\frac{J_b a_b^2}{3R^2}(1 - 3\sin^2\phi) + \frac{H_b a_b^3}{5R^3}(3 - 5\sin^2\phi)\sin\phi + \frac{D_b a_b^4}{35R^4}(3 - 30\sin^2\phi + 35\sin^4\phi)\right]$$

where b denotes the body, either Earth or Mars, μ_b is the GM of the attracting body, J_b, H_b, and D_b are the second, third and fourth harmonic coefficients, R is the magnitude of the body-probe vector, and ϕ is the latitude of the probe referred to the body's true equatorial plane and center.

The perturbing acceleration due to this potential function is given by

$$\nabla U_b = \left(\frac{\partial U_b}{\partial X}, \frac{\partial U_b}{\partial Y}, \frac{\partial U_b}{\partial Z}\right)$$

where (X, Y, Z) are in the system of the mean Earth equator and equinox of 1950.0.

The actual equations programmed follow, where $u_1 = X$, $u_2 = Y$, $u_3 = Z$

$$P_{b_j} = \frac{\partial U_b}{\partial u_j} = -\frac{J_b \mu_b}{R^2} \frac{a_b^2}{R^2}\left[\left(1 - \frac{5z^2}{R^2}\right)\frac{u_j}{R} + 2\frac{z}{R}c_{3j}\right]$$

$$- \frac{H_b \mu_b}{R^2}\frac{a_b^3}{R^3}\left[\left(3 - 7\frac{z^2}{R^2}\right)\frac{z}{R}\frac{u_j}{R} + \left(-\frac{3}{5} + \frac{3z^2}{R^2}\right)c_{3j}\right]$$

$$- \frac{D_b \mu_b}{R^2}\frac{a_b^4}{R^4}\left[\left(\frac{3}{7} - 6\frac{z^2}{R^2} + 9\frac{z^4}{R^4}\right)\frac{u_j}{R}\right.$$

$$\left. + \left(\frac{12}{7} - 4\frac{z^2}{R^2}\right)\frac{z}{R}c_{3j}\right]$$

where j = 1, 2, 3, and b = 1 or 2 (Earth or Mars). The quantity $\sin\phi = z/R$, where z is the distance of the probe above the true equator of the body involved, is found by:

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}$$

The matrix $\left[c_{ij}\right]$ represents the rotations required to express a vector in a true equatorial of date coordinate system for the Earth or Mars, given the vector expressed in mean Earth equator and equinox of 1950.0 coordinates.

The form and determination of $\left[c_{ij}\right]$ is detailed in Section VI, subroutine 29.2, for the Earth and in 32 for Mars. The subroutines HARMN and MRBLAT, which evaluate the potentials for the Earth and Mars, respectively, are described in subroutine 28.

2. Oblateness Calculations for the Moon

The Moon is assumed to have the shape of a tri-axial ellipsoid with principle moments of inertia A, B, C. The potential function for a second harmonic is expressed as:

$$U_☾ = \frac{G}{R} \frac{(A + B + C - 3I)}{2R^2},$$

where $G = k^2$, the universal gravitational constant,

$$I = A\left(\frac{x}{R}\right)^2 + B\left(\frac{y}{R}\right)^2 + C\left(\frac{z}{R}\right)^2,$$

and where x, y, z are the components of the Moon-probe vector $\overline{R}$ expressed in the selenographic coordinate system.

The perturbing acceleration

$$\nabla U_☾ = \left(\frac{\partial U_☾}{\partial u_1}, \frac{\partial U_☾}{\partial u_2}, \frac{\partial U_☾}{\partial u_3}\right)$$

is formed as follows, where $u_1 = X, u_2 = Y, u_3 = Z$.

$$P_{3j} = \frac{\partial \overline{U}_☾}{\partial u_j} = \frac{G}{R^2}\left\{\left[-\frac{3}{2}\frac{A + B + C}{R^2} + \frac{15}{2}\frac{I}{R^2}\right]\frac{u_j}{R} - \frac{3}{R^3}\left[Am_{1j}x + Bm_{2j}y + Cm_{3j}z\right]\right\}$$

for j = 1, 2, 3

The selenographic coordinates (x, y, z) of the probe are related to the mean Earth equatorial coordinates of 1950.0 by

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}$$

The $\left[m_{ij}\right]$ is referred to in the program as the MNA matrix, and is described in Section VI, 33. 2.

The lunar potential is computed by subroutine XYZDD1 and is described in Section VI, subroutine 33. 3.

3. Solar Radiation Pressure

The accelerative effect of solar radiation pressure on the probe may be simulated. The formulation is given by

$$\overline{P}_4 = \frac{k}{R^2} \hat{S}, \quad \text{km/sec}^2$$

and

$$k = \frac{(SC)(A)}{m} \left[\frac{GB1 - GB2(EPS)}{A} + 1 + GB \right] \qquad \text{km}^3/\text{sec}^2$$

where

$\overline{P}_4$ = perturbative acceleration due to solar radiation pressure

SC = solar radiation constant defined as

$$SC = \frac{J}{C}\left(r_{SE}^2\right), \qquad \frac{\text{kg - km}}{\text{sec}^2} \times 10^{-6}$$

J = radiant energy per unit area per unit time,

= 1.37×10^3 watts/meter^2 or kg/sec^3

C = speed of light, km/sec

r_{SE} = mean Earth-Sun distance = 1 AU (km)

Note that J, C, r_{SE} are implied in SC and are defined here for information purposes only. The constant SC is input directly into the program and is not computed.

A = effective area of spacecraft, meters^2

m = mass of spacecraft, kilograms

EPS = Earth-probe-Sun angle, degrees

GB1 = constant coefficient of polynomial in EPS, radian-meter^2

GB2 = first order coefficient of polynomial in EPS, (radian-meter^2)/degree

GB = $\gamma\beta$, dimensionless

γ = fraction of reflected radiant energy, dimensionless

$$\beta = \begin{cases} 1 \text{ for specular reflection} \\ 2/3 \text{ for diffuse reflection} \end{cases} \qquad \text{dimensionless}$$

Note again, GB is the input quantity used. γ and β are introduced here for explanation.

$\hat{S}$ = unit Sun-spacecraft position vector

The solar pressure perturbation is applied if the value of SC is non-zero, and if the spacecraft is not in the shadow of any planet or of the Moon.

4. Constant Thrust Motor

A single constant thrust, constant flow rate motor may be simulated.

The acceleration of the spacecraft due to this motor burn is given by the expression

$$\overline{P}_5 = -\left[\frac{F}{m_0 - \dot{m}(t - t_0)}\right] g\hat{C}, \qquad \text{km/sec}^2$$

where

$\overline{P}_5$ = perturbative acceleration due to motor burn

F = thrust of motor, lb-force

m_0 = initial weight of spacecraft, motor and fuel, lb-force

$\dot{m}$ = weight flow rate of motor, lb-force/sec

t = current time

t_0 = ignition time of motor

g = gravitational acceleration at Earth's surface, 0.0098061976 km/sec^2

$\overline{C}$ = is a vector which determines the direction in which the thrust is applied. It may be specified in several ways:

a) $\overline{C} = \hat{R} \sin\mu + \hat{M} \cos\mu$ where R is the unit central body-probe position vector, μ is the bias angle, measured positive above the plane of the local horizontal. $\hat{M}$ is a unit vector in the instantaneous plane of the probe's trajectory, normal to $\hat{R}$ and hence in the local horizontal plane as well.

$$\hat{M} = \hat{W} \times \hat{R}, \qquad \hat{W} = \frac{\overline{R} \times \overline{V}}{|\overline{R} \times \overline{V}|}$$

$\overline{V}$ is the central body-probe velocity vector.

b) $\overline{C}$ may be an arbitrary unit vector in Earth equatorial true of-date coordinates, or the result of normalizing a non-unit vector in this coordinate system.

The burn may be initiated at a specified epoch or at a given altitude above a specified body.

The burn may be terminated at a specified value of energy or after a specified duration of time.

5. Attitude Control Force Simulation

Attitude control forces applied to a spacecraft may be computed to evaluate their effect upon the trajectory of the spacecraft. The forces are given in the form of polynomials of the second order with input coefficients, the forces being assumed to act along three spacecraft-fixed orthogonal axes defined herein.

Let $\hat{E} = (E_x, E_y, E_z)$ be a unit vector directed from the spacecraft toward a specified body (planet, Moon or Canopus), and $H = (H_x, H_y, H_z)$, a unit vector directed from the spacecraft toward the Sun.

The coordinate system $(\hat{A}, \hat{B}, \hat{C})$ is then defined as

$$\hat{C} = -\hat{H} = (C_x, C_y, C_z)$$

$$\hat{B} = \frac{\hat{E} \times \hat{H}}{|\hat{E} \times \hat{H}|} = (B_x, B_y, B_z)$$

$$\hat{A} = \hat{B} \times \hat{C} = (A_x, A_y, A_z)$$

These orthogonal unit vectors $(\hat{A}, \hat{B}, \hat{C})$ define the axis along which the attitude control forces will act. All the above vectors are referenced to the mean Earth equator and equinox of 1950.0.

The force $\overline{F}$ has components along the (A, B, C) axis system defined as

$$F_A = F_{A_0} + F_{A_1} t + F_{A_2} t^2,$$

$$F_B = F_{B_0} + F_{B_1} t + F_{B_2} t^2, \qquad \text{dynes}$$

$$F_C = F_{C_0} + F_{C_1} t + F_{C_2} t^2,$$

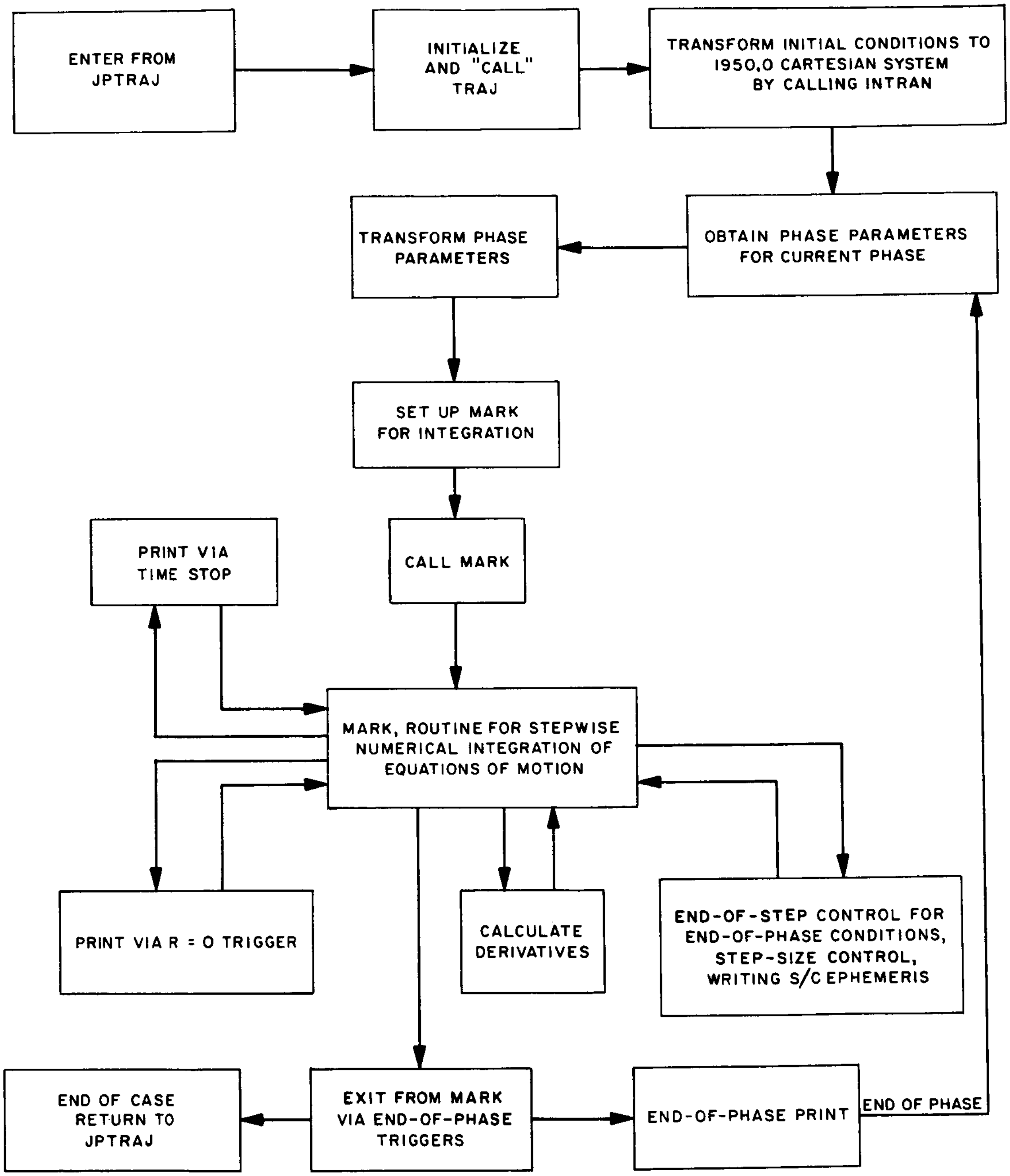
where t is time in seconds past starting time of attitude control forces. The acceleration due to these forces is given by

$$\overline{P}_6 = \begin{Bmatrix} \ddot{X} \\ \ddot{Y} \\ \ddot{Z} \end{Bmatrix} = \frac{10^{-8}}{m} \begin{bmatrix} A_x & B_x & C_x \\ A_y & B_y & C_y \\ A_z & B_z & C_z \end{bmatrix} \begin{Bmatrix} F_A \\ F_B \\ F_C \end{Bmatrix}, \qquad \mathrm{km/sec}^2$$

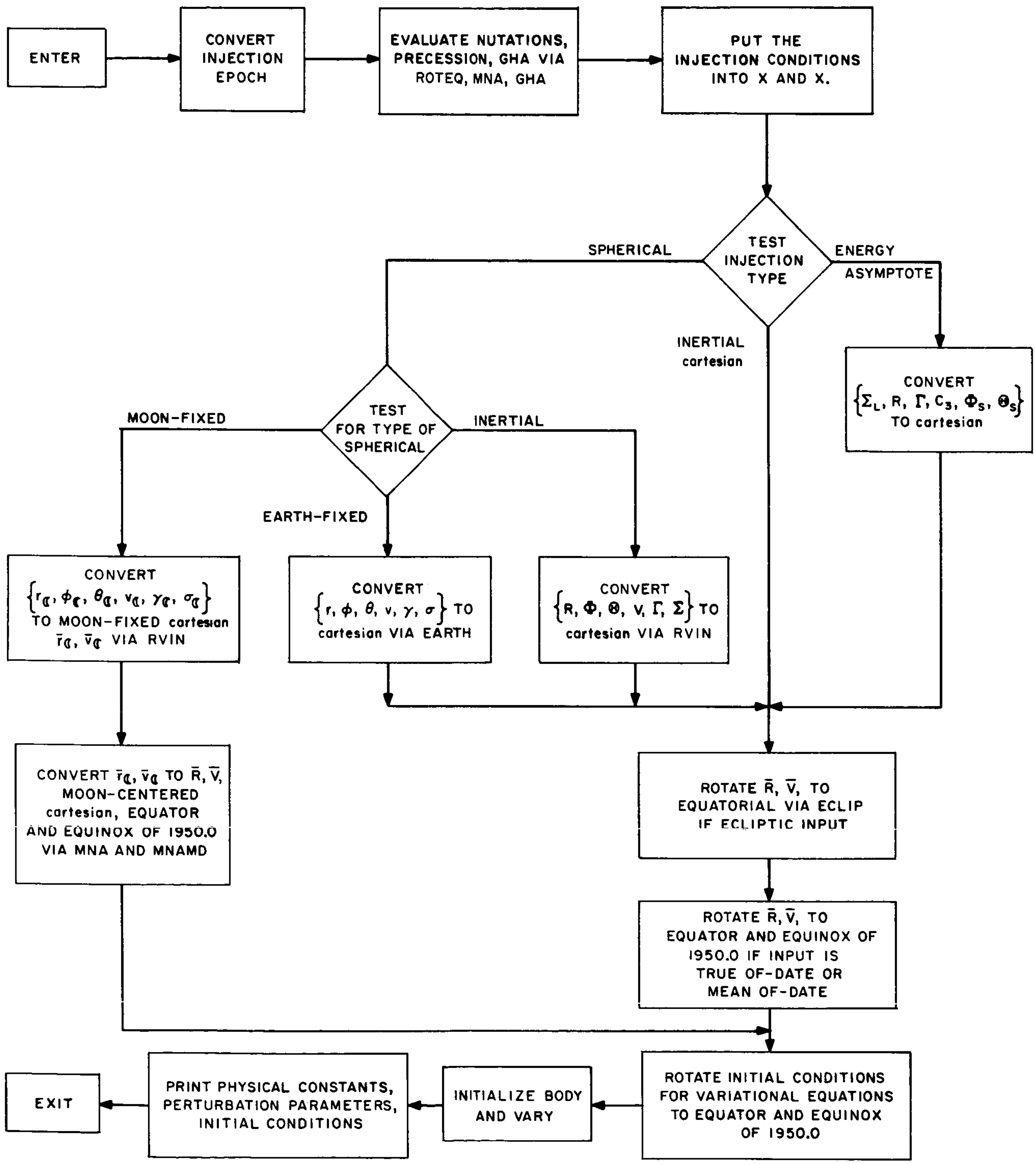
referenced to the mean Earth equator and equinox of 1950.0, where m is the mass of the spacecraft in kilograms.

C. FLOW CHARTS

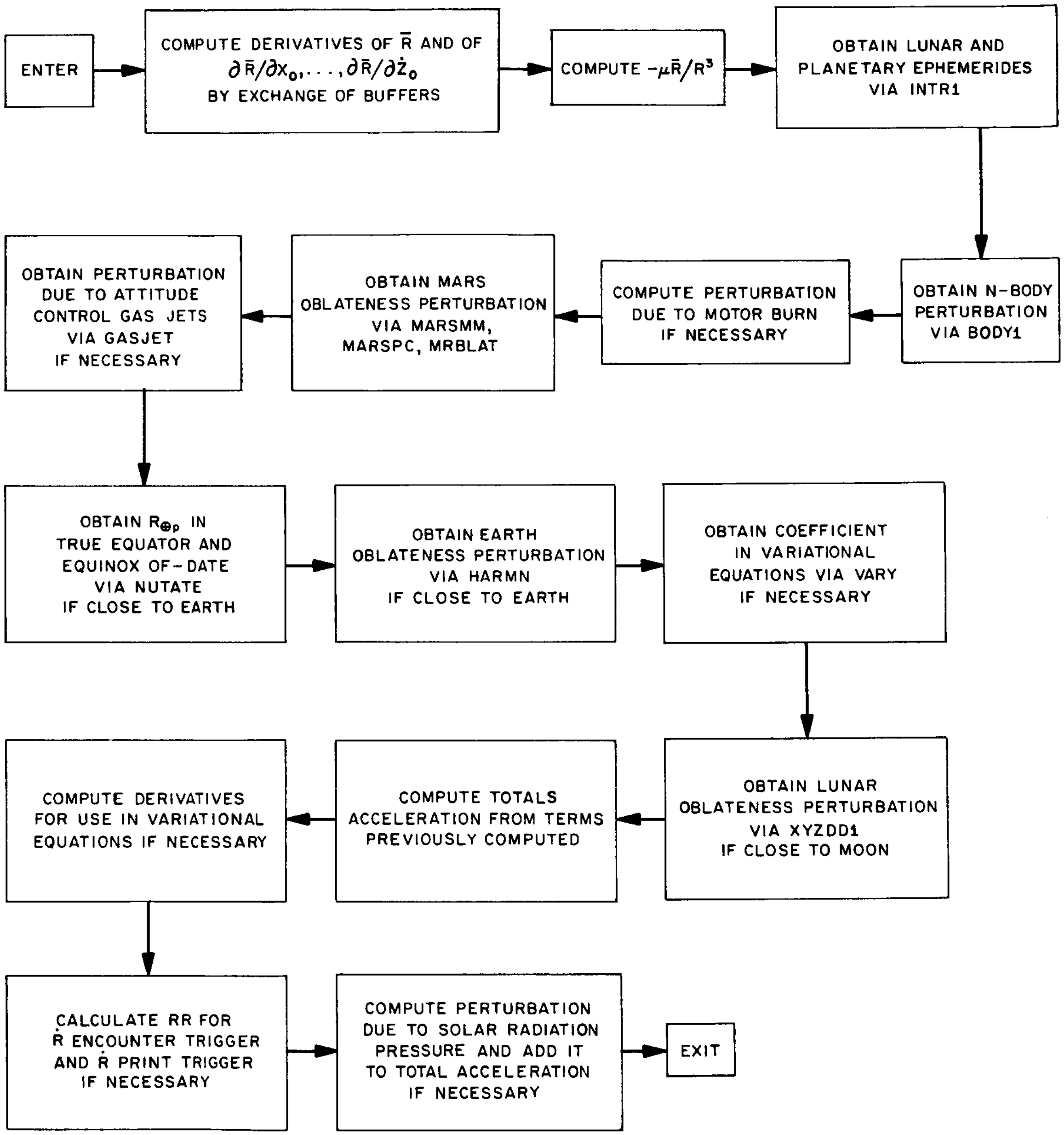
1. General Flow



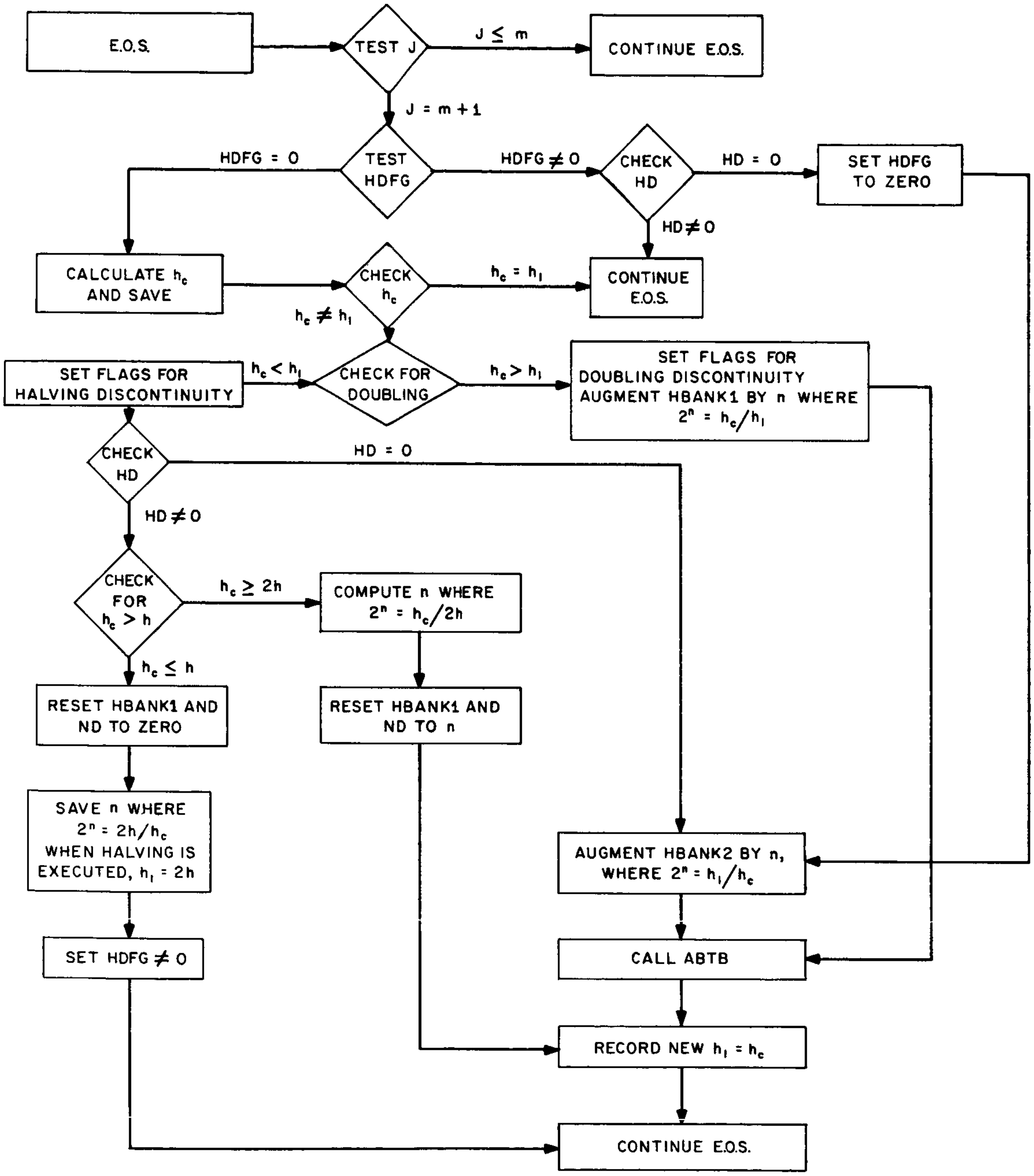
2. Transformation of Injection Condition (via INTRAN)



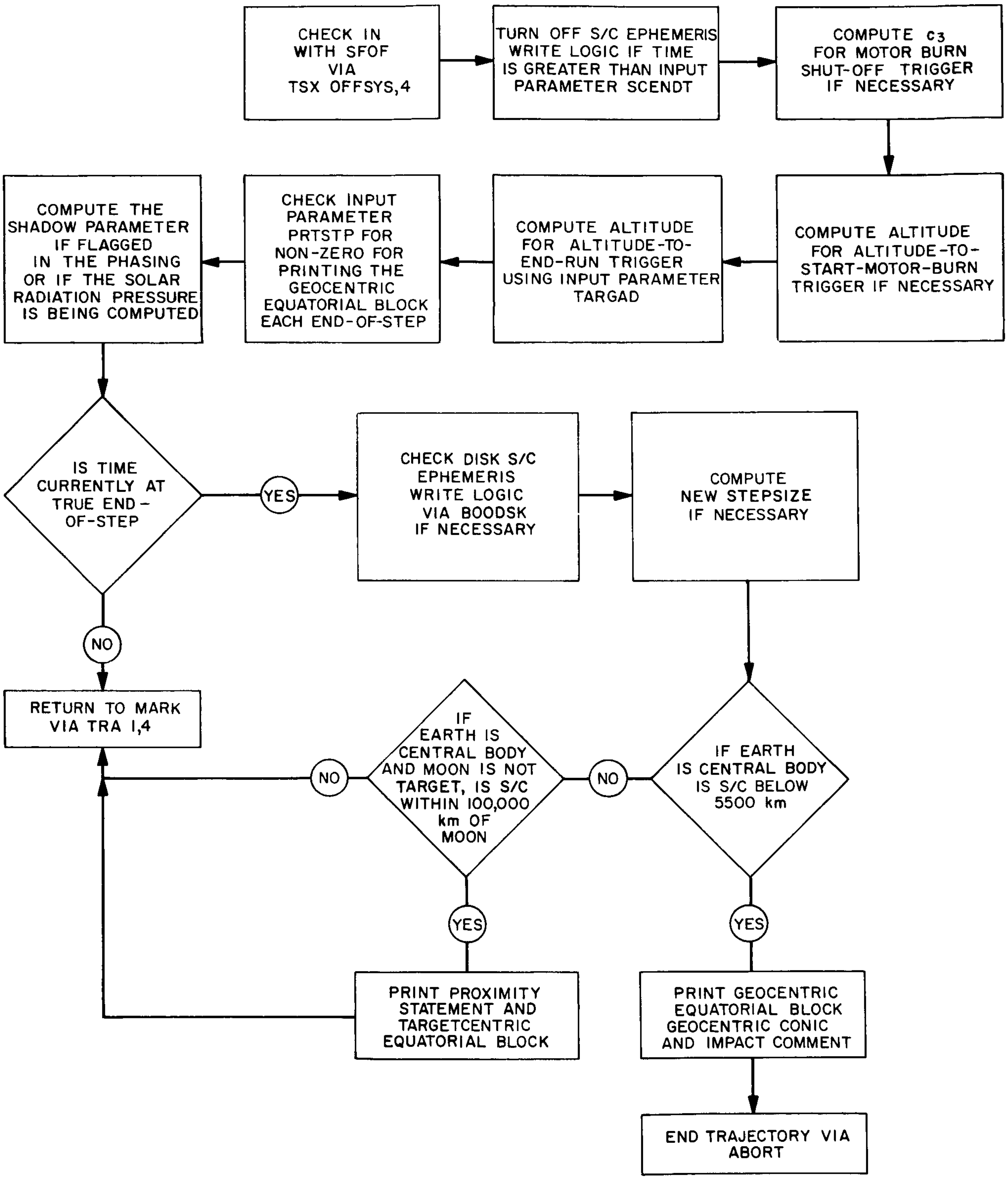
3. Derivative Calculations in Subroutine TRAJ



4. Step-Size Control in the End-of-Step (EOS) Calculations in Subroutine TRAJ



5. End-of-Step (EOS) Calculations in Subroutine TRAJ



III. MACHINE AND SYSTEM CONFIGURATION

There are two computer systems in use at the Jet Propulsion Laboratory. One is the standard IBM 7094 IBSYS job-shop system. It is used for daily checkout and production. The other system is the JPL SFOF system, which is used to process spacecraft data and to allow input, output, and control at remote user areas.

SPACE, under JPTRAJ, satisfies all the requirements of both systems and can therefore be used in any of the various modes of operation. Core storage is allocated as follows:

Octal Locations	Contents
0-3777	IBSYS
4000-21077	SFOF
21100-22277	JPTRAJ
22300-77777	SPACE

IV. INPUT

A. INPUT CAPABILITY

Data in the SPACE link of a JPTRAJ source deck is input by JPTRAJ just prior to the execution of SPACE. JPTRAJ does this with the aid of SPACE's symbol table. In addition, data can come from other links in the JPTRAJ source deck by proper use of the JPTRAJ "WANT" and "USE" control cards. Here again, JPTRAJ uses SPACE's symbol table. SPACE has no input subroutine so that when JPTRAJ transfers control to SPACE all input is completed (i.e., there is no on-line input capability in SPACE). This restriction is circumvented by using "WANT" control cards and a link named TRIO (Ref. 11, Section VIII).

The binary tape-read subroutines EPHSET and EPHEM have been included in SPACE for reading the n-body ephemeris tape.

Sense switches 4 and 6 on the 7094 console may be used to input a request to SPACE for on-line output. Section V describes the output one may request and the setting of the switches.

B. INPUT DEFINITION

```
SYMBOL      TYPE EXPLANATION                                       UNITS     NOM. VALUE

PAGBCD      BCC  TWO LINES (40 WORDS) OF PAGE HEADING                        BLANKS
TARBCD      BCC  TARGET BODY                                                 MOON
INJBCD      BCC  INJECTION CENTRAL BODY                                      EARTH
FAZFLG      FIX  NON-ZERO=USE PHASING OF DOMINANT BODY                       1
INJTYP      FIX  TYPE OF INJECTION CONDITIONS                                0
                   +,- 0  INERTIAL CARTESIAN
                   +,- 1  INERTIAL SPHERICAL
                     + 2  EARTH-FIXED SPHERICAL
                     + 3  SELENOGRAPHIC SPHERICAL
                     + 4  ENERGY ASYMPTOTE
                     + 5  ENERGY PSEUDO-ASYMPTOTE
                     + 6  ENERGY PSEUDO-ASYMPTOTE
                        +=EQUATORIAL  -=ECLIPTIC
INJT        SEG  INJECTION EPOCH                                             0.0
INJX        FLC  X  KM        R   KM        R   KM        AZL DEG            0.0
INJY        FLC  Y  KM        DEC DEG       LAT DEG       RAD KM             0.0
INJZ        FLC  Z  KM        RA  DEG       LON DEG       PTH DEG            0.0
INJDX       FLC  DX KM/SEC    V   KM/SEC    VP  KM/SEC    C3  KM2/SEC2       0.0
INJDY       FLC  DY KM/SEC    PTH DEG       PTP DEG       DAO DEG            0.0
INJDZ       FLC  DZ KM/SEC    AZ  DEG       AZP DEG       RAO DEG            0.0
RMAX        FLC  RAD. AT MAX. TURE ANOMALY (INJTYP=5,6)       KM             0.0
PHL         FLC  LAT. OF LAUNCH SITE (INJTYP=4,5,6)           DEG            28.309
INJTDT      FLC  DELTA T TO ADD TO INJT                       SEC            0.0
INJEQX      BCC  INJECTION EQUINOX  (      )=TRUE-OF-DATE                    BLANK
                                    (MEANOD)=MEAN-OF-DATE
                                    (1950.0)=MEAN 1950
```

THE 40 PHASE PARAMETERS MUST BE INPUT INTO THE PROPER BUFFERS AS FOLLOWS

```
WHERE XXXXXX IS REPLACED BY
        MOOPH1 TO MOOPH8 FOR MOON
        VENPH1 TO VENPH8 FOR VENUS
        MARPH1 TO MARPH8 FOR MARS
        MOOPH1 TO MOOPH8 FOR ALL OTHER TARGET BODIES
```

```
SYMBOL      TYPE EXPLANATION                                       UNITS     NOM. VALUE

XXXXXX+0    FIX  -=PRINT AT START OF PHASE
                 + = DO NOT PRINT AT START OF PHASE
                 SET TPRT=PHASE START       USE OLD TPRT
                 0          PRINT AT END          LAST PHASE  4
                 1          PRINT AT END      NOT LAST PHASE  5
                 2 DO NOT PRINT AT END            LAST PHASE  6
                 3 DO NOT PRINT AT END        NOT LAST PHASE  7
XXXXXX+1    BCC  BODY FROM WHICH TO COMPUTE R FOR R TEST
XXXXXX+2    FLC  VALUE OF R TO END PHASE
XXXXXX+3    BCC  BODY FROM WHICH TO COMPUTE R. FOR R.=0 TEST
XXXXXX+4    FLC  VALUE OF R TO TURN ON R.=0 TEST
                   + VALUE=TURN ON TEST WHEN (BODY-PROBE R) GR. THAN (+ VALUE)
                   - VALUE=TURN ON TEST WHEN (BODY-PROBE R) LESS THAN -(-VALUE)
XXXXXX+6    BCC  CENTRAL BODY FOR INTEGRATION
XXXXXX+7    SEC  STEPSIZE
XXXXXX+9    FIX  NO. OF STEPSIZE DOUBLES
XXXXXX+10   BCC  BODY USED IN LOOKUP FOR STEPSIZE
XXXXXX+11   SEC  PRINT END 1
XXXXXX+13   SEC  PRINT DELTA 1
XXXXXX+15   SEC  PRINT END 2
XXXXXX+17   SEC  PRINT DELTA 2
XXXXXX+19   SEC  PRINT END 3
XXXXXX+21   SEC  PRINT DELTA 3
XXXXXX+23   SEC  ODD PRINT 1
XXXXXX+25   SEC  ODD PRINT 2
XXXXXX+27   OCT  GROUP PRINT FLAGS WHERE THE FORMAT OF THE OCTAL WORD IS
                      G GC H HC 0 T TC R 0 0 0 U
                   WHERE G = GEOCENTRIC
                         GC= GEOCENTRIC CONIC (PLANE INDEPENDENT)
                         H = HELIOCENTRIC
                         HC= HELIOCENTRIC CONIC (PLANE INDEPENDENT)
                         T = TARGET
                         TC= TARGET CONIC (PLANE INDEPENDENT)
                         R = R DOT EQUAL ZERO
                         U = VARIATIONAL EQUATIONS
                   FLAG=1=EQUATORIAL
                        2=ECLIPTIC
                        4=ECLIPTIC AT START ONLY
                        5=EQUATORIAL AT START ONLY
                        6=ECLIPTIC AT END ONLY
                        7=EQUATORIAL AT END ONLY
XXXXXX+28   OCT  STATION PRINTS (15 STATIONS IN TWO WORDS, MAX OF 5 AT A TIME)
                   12 STATIONS ARE FLAGGED IN FIRST WORD, 3 IN SECOND AS FOLLOWS
                     59 11 12 41 51 14 13 15 42 61 08 91, 75 76 02


XXXXXX+38   OCT  CONIC PRINT FLAGS (PLANE DEPENDENT VARIABLES)
                   WHERE THE FORMAT OF THE OCTAL WORD IS
                     Q C O T Q C O T Q C O T
                     WHERE THE FIRST SET OF Q C O T IS USED IN THE GEO CONIC,
                     THE SECOND SET IS USED IN THE HELIO CONIC AND THE THIRD SET
                     IS USED IN THE TARGET CONIC AND WHERE
                       Q = EARTH EQUATORIAL PLANE
                       C = ECLIPTIC PLANE
                       O = ORBIT PLANE OF TARGET (X IS ALONG THE ASCENDING NODE
                             OF THE ORBIT PLANE OF THE TARGET ON THE TARGET
                             TRUE EQUATOR PLANE, IF THE TARGET TRUE EQUATOR
                             PLANE IS DEFINED. OTHERWISE, ON THE ECLIPTIC PLANE.
                       T = TRUE TARGET EQUATOR PLANE (DEFINED FOR MOON AND MARS)
                             X IS DEFINED THE SAME AS FOR THE ORBIT PLANE
XXXXXX+30   OCT  VIEW PERIODS ( 15 STATIONS IN TWO WORDS, MAX OF 5 AT A TIME )
                   12 STATIONS ARE FLAGGED IN FIRST WORD, 3 IN SECOND AS FOLLOWS
                     59 11 12 41 51 14 13 15 42 61 08 91, 75 76 02
XXXXXX+34   FIX  SHADOW PARAMETER FLAG  1=ON
XXXXXX+39   BCC  OUTPUT EQUINOX (      ) = TRUE-OF-DATE
                                (1950.0) = MEAN 1950.0
```

```
NOTE...THERE IS NO STATION PRINT OR VIEW PERIOD CAPABILITY IN SPACE BUT
       STORAGE HAS BEEN ALLOCATED FOR THEM. THIS ALLOWS ONE SET OF PHASING TO
       SUFFICE FOR BOTH SPACE AND SFPRO VIA WANT CARDS, IF DESIRED
```

SYMBOL	TYPE	EXPLANATICN	UNITS	NOM. VALUE
BRNCPT+C	FIX	BURN FLAG 0=NC BURN 1=BURN		0
BRNCPT+1	SEG	EPOCH CF START OF BURN		0,0
BRNCPT+3	FLC	DURATICN OF BURN (0=NO DT TEST)	SEC	0.0
BRNCPT+5	FLC	VALUE CF C3 TC END BURN	KM2/SEC2	10000Q.
BRNCPT+6	FLC	BIAS ANGLE	DEG	0.0
BRNCPT+7	FIX	C OPTICN 0=EVERY T 1=FIXED +,-2=INPUT C		0
BRNCPT+8	BCD	BCDY USED IN ALTITUDE START		MOCN
BRNCPT+9	FLC	ALTITUDE TC START BURN	KM	0.0
BRNOPT+10	FLC	INITIAL WEIGHT	LBS FORC	0.0
BRNCPT+11	FLC	WEIGHT FLOW RATE	LBSF/SEC	0.0
BRNOPT+12	FLC	THRUST	LBS FORC	0.0
BRNCPT+13	CCT	GROUP PRINT AT START, END OF BURN		0
BRNCPT+14	CCT	CCNIC PRINT AT START, END OF BURN		0
BRNCPT+15	FLC	OF-CATE C VECTOR, BRNOPT+7=+2=NON-UNIT C		0.0,0.0,0.0
		BRNOPT+7=-2=UNIT C		
RADCPT+C	FLC	SCLAR RADIATICN CONSTANT 0=NO RAD. PRES.		0.0
RADCPT+1	FLC	CCNSTANT TERM IN POLY. IN EPS ANGLE		0.0
RADOPT+2	FLC	LINEAR TERM IN POLY. IN EPS ANGLE		0.0
RADOPT+3	FLC	AREA CF SPACECRAFT	(METER)2	11.12
RADCPT+4	FLC	GAMMA BETA		0.096
RADCPT+5	FLC	MASS CF SPACECRAFT	KG	259.0
GASCPT+0	FIX	GAS JET FLAG C=OFF NON-ZERO=ON		0
GASCPT+1	BCD	REFERENCE BODY. PLANET, MCON, OR CANOPUS		EARTH
GASCPT+2	SEG	EPOCH CF START OF GAS JETS 0,0=INJ. EPOCH		0,0
GASOPT+4	FLC	DT TO ADD TO GASOPT+2	SEC	0.0
GASOPT+5	SEG	EPOCH CF ENC OF GASJETS C,0=NO END		0,0
GASCPT+7	FLC	COEF. CF FA PCLY., QUADRATIC TERM FIRST		0.C,0.0,0.0
GASCPT+10	FLC	CCEF. CF FB PCLY., QUADRATIC TERM FIRST		0.0,0.0,0.0
GASCPT+13	FLC	CCEF. CF FC PCLY., QUADRATIC TERM FIRST		0.0,0.C,0.0
GASCPT+16	FLC	MASS CF SPACECRAFT	KG	0.0
VARFLG	FIX	VARIATICNAL EQU. FLAG 0=NONE 1=CN		0
SCALE1-2	FLC	EARTH GM FOR SCALING EPHEMERIS	KM3/SEC2	398603.2
SCALE1-1	FLC	MCON GM FOR SCALING EPHEMERIS	KM3/SEC2	4902.7779
SCALE1	FLC	EARTH RADIUS FOR SCALING EPHEMERIS	KM	6378.3113
SCALE1+1	FLC	AU FOR SCALING EPHEMERIS	KM	149598500.
GRAV-2	FLC	EPHEMERIS TIME - UNIVERSAL TIME	SEC	35.
GRAV	FLC	EARTH GM	KM3/SEC2	398600.63
GRAV+1	FLC	MCON GM	KM3/SEC2	4902.6293
GRAV+2	FLC	SUN GM	KM3/SEC2	.13271411E12
GRAV+3	FLC	VENUS GM	KM3/SEC2	324766.27
GRAV+4	FLC	MARS GM	KM3/SEC2	42977.368
GRAV+5	FLC	SATURN GM	KM3/SEC2	379187CC.
GRAV+6	FLC	JUPITER GM	KM3/SEC2	126709350.
LUNGRV	FLC	UNIVERSAL GRAVITATICNAL CCNSTANT	KM3/SEC2-KG	.6671E-19
LUNGRV+1	FLC	MCMENT A, LUNAR PCTENTIAL	KGKM2	.88781798E29
LUNGRV+2	FLC	MCMENT B, LUNAR PCTENTIAL	KGKM2	.88800195E29
LUNGRV+3	FLC	MCMENT C, LUNAR PCTENTIAL	KGKM2	.88836978E29
HARMN+2	FLC	J, EARTH COEF. CF SECOND HARMONIC		.162345E-2
HARMN+3	FLC	H, EARTH COEF. OF THIRD HARMONIC		-.575E-5
HARMN+4	FLC	D, EARTH COEF. OF FCURTH HARMONIC		.7875E-5
HARMN+5	FLC	RE, EARTH RADIUS USED IN POTENTIAL	KM	6378.165
HARMN+6	FLC	RADIUS FROM EARTH FCR J TERM EFFECTIVE	KM	5E5
HARMN+7	FLC	RADIUS FROM EARTH FCR H TERM EFFECTIVE	KM	2E5
HARMN+8	FLC	RADIUS FROM EARTH FCR D TERM EFFECTIVE	KM	1E5
HARMN+9	FLC	JA, MARS COEF. CF SECOND HARMONIC		.00292
HARMN+10	FLC	HA, MARS COEF. CF THIRD HARMONIC		0.0
HARMN+11	FLC	DA, MARS COEF. OF FOURTH HARMONIC		0.C
HARMN+12	FLC	RA, MARS RADIUS USED IN POTENTIAL	KM	3417.
HARMN+13	FLC	RADIUS FROM MARS FCR JA TERM EFFECTIVE	KM	5E5
HARMN+14	FLC	RADIUS FROM MARS FOR HA TERM EFFECTIVE	KM	0.0
HARMN+15	FLC	RADIUS FROM MARS FCR DA TERM EFFECTIVE	KM	0.C
TARAD	FLC	EARTH RADIUS	KM	6378.
TARAD+1	FLC	MCON RADIUS	KM	1738.09
TARAD+2	FLC	SUN RADIUS	KM	621800.
TARAD+3	FLC	VENUS RADIUS	KM	62C0.
TARAD+4	FLC	MARS RADIUS	KM	3378.
TARAD+5	FLC	SATURN RADIUS	KM	57750.
TARAD+6	FLC	JUPITER RADIUS	KM	68860.
CAN50	FLC	195C.C UNIT CARTESIAN BODY-CANOPUS X		-.060340592
CAN50+1	FLC	1950.C UNIT CARTESIAN BODY-CANOPUS Y		.60342839
CAN50+2	FLC	1950.C UNIT CARTESIAN BODY-CANOPUS Z		-.79513092
DELTJC	FLC	J.D. 1950.0 - J.D. C HR JAN 1,1950	DAYS	-.076643
H	FLC	LOCATION CF STEPSIZE RANGE TABLFS		
SCFCRF	FIX	PROBE EPHEM C=NONE 1=A6 TAPE 2=DISK		0
RUNID	BCD	RUN I.C. USED WITH SCFORF=1		TRAJ01
SCBEGT	SEG	EPOCH TO BEGIN PROBE EPHEM 0,0=INJ. EPOCH		0,0
SCENDT	SEG	EPOCH TO END PROBE EPHEM 0,0=NO END		0,0
LAUNCH	SEG	LAUNCH EPOCH		0,0
TARGAD	FLC	ALTITUDE ABOVE TARGET TO END RUN		0.0
FLAG42	FIX	NCN-ZERO PUTS OUTPUT IN SC4020 MODE		0
PRTSWX	FIX	PRINT SWITCH NCN-ZERO=PRINT EVERY CASE		0
PRTSTP	FIX	NCN-ZERO=PRINT EVERY END-OF-STEP		0
PRTSTP+1	CCT	PRINT GROUP AT EACH END-OF-STEP		0
PRTSTP+2	CCT	CCNIC GROUP AT EACH END-OF-STEP		0
DEPCPT	FIX	0=NC DEP. VAR. 1=PRINT -1=END PHASE		0
DEPCPT+1	CCT	LOCATION OF DEPENDENT VARIABLE		0
DEPCPT+2	FLC	VALUE CF DEPENDENT VARIABLE		0.C
DTPCA	SEG	DT PAST CL.APP. TC END RUN(FL. PT. SEC. OK)		0,C
SECP50	CCT	D.P. SEC. PAST 1950 TO END RUN	SEC	0,0
NEWBOD	BCD	BCDY TO REPLACE SATURN		0
NEWBOD+1	FLC	1.0=MERCUR 7.C=NEPTUN 8.0=URANUS 9.0=PLUTO		0.0
NEWBOD+2	FLC	GM CF BODY	KM3/SEC2	0.C
NEWBOD+3	FLC	RADIUS CF BCDY	KM	0.C
OPTSWT	FIX	ON-LINE OUTPUT CONTROL		0
		C=NC REMOTE CONTROL, NC ON-LINE PRINT		
		-1=REMCTE CCNTRCL.HANG FOR S.S. SETTING		
		5=FINE PRINT ON-LINE		
		1=MINIMUM PRINT CN-LINE		
MNAET	FIX	0=CCMPUTE M,N,A EVERY T, ELSE USE DT TEST		0
NUTEPH	FIX	0=NUTATIONS FROM EPHEM, ELSE COMPUTE THEM		0
REWSC	FIX	NCN-ZERO REWINDS A6 BEFORE WRITING S/C EPHEMERIS		0

```
        THERE ARE MANY MORE SYMBOLS IN THE SYMBOL
        TABLE. THE FOLLOWING TABLE GIVES THE ADDITIONAL SYMBOLS,
        WHERE I AND/OR O INDICATES WHETHER THE
        DATA IS INPUT TO SPACE OR OUTPUT FROM SPACE.

SYMBOL I/O TYPE EXPLANATION                                UNITS

BTQ      O  FLO  B.T EARTH EQUATORIAL                       KM
BRQ      O  FLO  B.R EARTH EQUATORIAL                       KM
BTC      O  FLO  B.T ECLIPTIC                               KM
BRC      O  FLO  B.R ECLIPTIC                               KM
BTO      O  FLO  B.T, TARGET ORBITAL PLANE                  KM
BRO      O  FLO  B.R, TARGET ORBITAL PLANE                  KM
BTT      O  FLO  B.T, TARGET TRUE EQUATOR PLANE             KM
BRT      O  FLO  B.R, TARGET TRUE EQUATOR PLANE             KM
                   ALL B.T, B.R VALUES IN THE BUFFERS ARE
                   THE LAST ONES COMPUTED BY THE PROGRAM
C3       O  FLO  TARGET CONIC ENERGY CONSTANT               KM2/SEC2
VH       O  FLO  TARGET CONIC HYPERBOLIC EXCESS VELOCITY    KM/SEC
TFD      O  FLO  TIME OF FLIGHT                             DAYS
TFH      O  FLO  TIME OF FLIGHT                             HOURS
TFM      O  FLO  TIME OF FLIGHT                             MIN
TFLIND   O  FLO  LINEARIZED TIME OF FLIGHT                  DAYS
TFLINH   O  FLO  LINEARIZED TIME OF FLIGHT                  HOURS
TFI      O  FLO  TIME PAST INJECTION EPOCH                  SEC
SELAT    O       SELENOGRAPHIC LATITUDE OF S/C              DEG
SELON    O       SELENOGRAPHIC LONGITUDE OF S/C             DEG
JULD     O  FLO  JULIAN DATE (2 WORDS)                      DAYS
                 1ST WORD INTEGER DAYS
                 2ND WORD FRACTIONAL PART OF A DAY
LATIT    O       GEOCENTRIC LATITUDE OF S/C                 DEG
LONGY    O       GEOCENTRIC LONGITUDE OF S/C                DEG
CLPBTQ   O       'CLP' PREFIX STANDS FOR CLOSEST            KM
CLPBRQ   O       APPROACH. 'CLPBXY' FORM HAS                KM
CLPBTC   O       FOLLOWING MEANING  AT CLOSEST APPROACH     KM
CLPBRC   O       B-VECTOR IS DOTTED WITH X-VECTOR           KM
CLPBTO   O       WHERE X-VECTOR IS REFERENCED TO            KM
CLPBRO   O       Y-PLANE X CAN = T OR R VECTORS             KM
CLPBTT   O       Y CAN = Q(EARTH EQUATORIAL),C(ECLIPTIC)    KM
CLPBRT   O       O(TARGET ORBITAL PLANE),T(TARGET TRUE EQU)KM
CLPT     O       EPOCH OF CLOSEST APPROACH IN SEC PAST
                   0 HR JAN 1, 1950 U.T.                    SEC



COMFLG   I  OCT  FLAG TO SIGNIFY USE OF COMTRJ, COMTRK DATA
                   - = USE INJECTION CONDITIONS FROM COMTRJ
                   EACH OCTAL DIGIT FLAGS A CONSTANT, RESPECTIVELY,
                   GMS AU D H J GMJ GMA GMV GMM SC REM GME
                   OCTAL DIGIT = 0 = DO NOT USE CONSTANT
                   OCTAL DIGIT = 1 = USE CONSTANT FROM COMTRK
COMTRJ   I       INJECTION CONDITION BUFFER
            FLO  POSITION VECTOR                            KM
            FLO  VELOCITY VECTOR                            KM/SEC
            FLO  INJECTION EPOCH SEC PAST 0 HR JAN 1, 1950 SEC
            BCD  HEADING ( 5 WORDS )
COMTRK   I  FLO  12 WORD BUFFER OF PHYSICAL CONSTANTS
                 1. GME - GM OF EARTH                       KM3/SEC2
                 2. REM - EARTH RADIUS FOR SCALING EPHEM    KM
                 3. SC  - SOLAR FLUX CONSTANT               KG-KM/SEC2
                 4. GMM - GM OF MOON                        KM3/SEC2
                 5. GMV - GM OF VENUS                       KM3/SEC2
                 6. GMA - GM OF MARS                        KM3/SEC2
                 7. GMJ - GM OF JUPITER                     KM3/SEC2
                 8. J   - COEF. OF 2ND TERM EARTH HARMONIC
                 9. H   - COEF. OF 3RD TERM EARTH HARMONIC
                 10. D  - COEF. OF 4TH TERM EARH HARMONIC
                 11. AU - ASTRONOMICAL UNIT                 KM
                 12. GMS  GM OF SUN                         KM3/SEC2
TZERO    O  FLO  INJECTION EPOCH SEC PAST 0 HR JAN 1, 1950 SEC
XOP      O  FLO  42-WORD BUFFER CONTAINING 7                KM,KM/SEC
                 RECTANGULAR POSITON VECTORS FOLLOWED
                 BY 7 RECTANGULAR VELOCITY VECTORS
                 THE ORDER OF THE VECTORS IS
                 EARTH TO S/C
                 MOON TO S/C
                 SUN TO S/C
                 VENUS TO S/C
                 MARS TO S/C
                 SATURN TO S/C
                 JUPITER TO S/C
                 THE COORDINATE SYSTEM IS EARTH CENTERED,
                 EARTH EQUATORIAL, SPACE FIXED, WHERE THE
                 EQUINOX IS DEFINED BY THE INPUT PARAMETER
                 DEFINING THE OUTPUT EQUINOX
STATE    I  FIX  CONTAINS FLAGS FROM THE SEARCH PROGRAM
TAPEX   I/O      EPHEMERIS TAPE INFORMATION (6 WORDS)
            FIX     WORD 1   PZE SYSUT8
                    WORD 2   EMPTY
            FLO     WORD 3-4 J.D. OF MIN DATE ON TAPE
            FLO     WORD 5-6 J.D. OF MAX DATE ON TAPE
T        O  FLO  CURRENT EPOCH SEC PAST 0 HR JAN 1, 1950   SEC
```

C. JPTRAJ RESTRICTIONS

SPACE operates under the JPTRAJ monitor, which imposes three programming requirements. SPACE satisfies these requirements by providing:

1. A four-word Program Control Block (PCB) located at entry "......".
2. A Symbol Table, which immediately follows the PCB.
3. A zero (normal return via JEXIT) or a one (error return via ABORT) in the accumulator upon return to JPTRAJ.

A detailed description of the JPTRAJ programming requirements is found in Ref. 4 (Section VIII).

1. Program Control Block

```
...... BCI     1,SPACE
       ZERO    1,,1                    CLASS 1,,1 ERROR RETURN
       ZERO    LST                     LENGTH OF SYMBOL TABLE
       TRA     NS4
```

2. Symbol Table

```
ORG EQU      *                    BEGINNING OF SYMBOL TABLE
    SYM      TZERO,I
    SYM      TZERO,I
    SYM      BTQ
    SYM      BTC
    SYM      BTO
    SYM      BTT
    SYM      BRQ
    SYM      BRC
    SYM      BRO
    SYM      BRT
    SYM      C3,I
    SYM      VH,I
    SYM      TFD
    SYM      TFH
    SYM      TFM
    SYM      TFLIND
    SYM      TFLINH
    SYM      TFI,I
    SYM      SELON,I
    SYM      SFLAT,I
    SYM      JULD
    SYM      LATIT,I
    SYM      LONGY,I
    SYM      SCFCRF
    SYM      SCBEGT
    SYM      SCENDT
    SYM      TARGAC
    SYM      PAGBCC
    SYM      TARHCC
    SYM      INJBCC
    SYM      FAZFLG
    SYM      INJTYP
    SYM      INJT
    SYM      INJX
    SYM      INJY
    SYM      INJZ
    SYM      INJDX
    SYM      INJDY
    SYM      INJDZ
    SYM      RMAX
    SYM      PHL
    SYM      INJTOT
    SYM      INJEQX
    SYM      MOOPH1
    SYM      MOOPH2
    SYM      MOOPH3
    SYM      MOOPH4

    SYM      MOOPH5
    SYM      MOOPH6
    SYM      MOOPH7
    SYM      MOOPH8
    SYM      VENPH1
    SYM      VENPH2
    SYM      VENPH3
    SYM      VENPH4
    SYM      VENPH5
    SYM      VENPH6
    SYM      VENPH7
    SYM      VENPH8
    SYM      MARPH1
    SYM      MARPH2
    SYM      MARPH3
    SYM      MARPH4
    SYM      MARPH5
    SYM      MARPH6
    SYM      MARPH7
    SYM      MARPH8
    SYM      H
    SYM      XOP,I
    SYM      XOP,I
    SYM      T,I
    SYM      TARAD
    SYM      LONGRV
    SYM      SCALE1
    SYM      GRAV
    SYM      HARMN
    SYM      BRNOPT
    SYM      RADOPT
    SYM      DEPOPT
    SYM      PRTSTP
    SYM      FLAG42,I
    SYM      RUNID,I
    SYM      PRTSWX,I
    SYM      STATE,I
    SYM      DTPCA
    SYM      CASOPT
    SYM      VARFLG
    SYM      NEWBOC
    SYM      DELTJC
    SYM      MNALT
    SYM      NUTEPH
    SYM      CLPBTQ
    SYM      CLPBTC
    SYM      CLPBTO
    SYM      CLPBTT
    SYM      CLPBRQ
    SYM      CLPBRC
    SYM      CLPBRO
    SYM      CLPBRT
    SYM      CLPT
    SYM      SECP50
    SYM      SECP5C
    SYM      TAPEX
```

```
      SYM     OPTSWT,I
      SYM     LAUNCH
      SYM     REWSC,I
      SYM     COMFLG,I
      SYM     COMTRJ,I
      SYM     COMTRK,I
      SYM     CAN50
  LST EQU     *-ORG               LENGTH OF SYMBOL TABLE


    WHERE SYM IS DEFINED AS FOLLOWS

      MACRO
    Z SYM     X,Y
      BCI     1,X
      RMT
      IFF     1,Y
      MZE     $X
      IFF     0,Y
      PZE     X
      RMT   *
      END
```

D. COMMON MAP AND LOAD MAP

```
77152          COMMON  199
77152   COMMON COMMON  1
77316    BFF23 SYN     COMMON+100
77152      COM SYN     COMMON                 COMMON BLOCK
77151   PRTSWT COMMON  1            PRINT SUPP. SWITCH, 0=SUPPRESS,NON ZERO=NORMAL
77150   INPSWT COMMON  1
77147    OMEGA COMMON  1
77145          COMMON  1
77143          COMMON  2                      BUFFER FOR ,TIME,
77143       TT COMMON  1
77141          COMMON  1                      INJECTION EPOCH
77141     T(0) COMMON  1
77136          COMMON  2
77136     TARG COMMON  1
77135   LOMEGA COMMON  1                      EARTH,S RATE IN RAD/SEC
77134   GHA(T) COMMON  1                      GREENWICH HOUR ANGLE
77133    NUTRA COMMON  1                      NUTATION IN RIGHT ASCENSION
77124          COMMON  6
77124     YEAR COMMON  1
77123     MODE COMMON  1
77122   TARGET COMMON  1
77120          COMMON  1
77120      GJH COMMON  1
77116          COMMON  1
77116      RKH COMMON  1
77115    PHASE COMMON  1
77114        Q COMMON  1
77112          COMMON  1
77111          COMMON  1
77111    TBURN COMMON  1
77110       QK COMMON  1
77077          COMMON  8
77077       AA COMMON  1                      EARTH,S MEAN EQUATOR TO 1950.0
77076       ET COMMON  1                      TRUE OBLIQUITY
77075   CENTER COMMON  1                      CENTRAL BODY MEMBER
77064          COMMON  8
77064    (MNA) COMMON  1                      MOON,S TRUE EQUATOR MATRIX TO 1950.0
77053          COMMON  8
77053     (NA) COMMON  1                      EARTH,S TRUE EQUATOR TO 1950.0
77042          COMMON  8
77042       MM COMMON  1        MOON,S TRUE EQUATOR TO EARTH,S TRUE EQUATOR
77040          COMMON  1
77040      TOB COMMON  1                      OBSERVATION TIME
77036          COMMON  1
77036      TDR COMMON  1                      DRIVE TAPE TIME
77035     CODE COMMON  1
77034     MASS COMMON  1
77033    MASS. COMMON  1
77032     M(T) COMMON  1
77031      ACC COMMON  1
77030       RO COMMON  1
77027        R COMMON  1                      DISTANCE FROM CENTRAL BODY
77026     RB6P COMMON  1                      DISTANCE FROM NTH BODY TO PROBE
77025     RB5P COMMON  1                                  .
77024     RB4P COMMON  1                                  .
77023     RB3P COMMON  1                                  .


77022     RB2P COMMON  1                                  .
77021     RB1P COMMON  1                                  .
77020     RB0P COMMON  1                                  .
77017      RB6 COMMON  1                      DISTANCE FROM NTH BODY TO CENTRAL BODY
77016      RB5 COMMON  1                                  .
77015      RB4 COMMON  1                                  .
77014      RB3 COMMON  1                                  .
77013      RB2 COMMON  1                                  .
77012      RB1 COMMON  1                                  .
77011      RB0 COMMON  1                                  .
00007     6SEP SYN     RB0P-RB0               CARTESIAN VELOCITY COORDINATES
76764          COMMON  20                     OF THE N BODIES     1950.0
76764      XN. COMMON  1                      CARTESIAN POSITION COORDINATES
76737          COMMON  20                     OF THE N BODIES   1950.0
76737       XN COMMON  1
76736      KB6 COMMON  1                      GRAVITY COEFFICIENTS OF THE N BODIES
76735      KB5 COMMON  1                                  .
76734      KB4 COMMON  1                                  .
76733      KB3 COMMON  1                                  .
76732      KB2 COMMON  1                                  .
76731      KB1 COMMON  1                                  .
76730      KB0 COMMON  1                                  .
00014    NTAB1 SYN     XN.-XN-9               NUMBER OF COORDINATES
00044    NTAB2 SYN     3*NTAB1                ENTER CENTRAL DIFFERENCES
00330    NTAB3 SYN     6*NTAB2                ENTER TIME POINTS
01122    NTAB4 SYN     NTAB3+378
00052    SEPP1 SYN     2*XN.-2*XN
76727    JECAN COMMON  1                      BUFFERS FOR JEKYL, HYDE, ETAL
76726    MENAN COMMON  1                                  .
76725       NU COMMON  1                                  .
76724    ECCEN COMMON  1                                  .
76723     AVAL COMMON  1                                  .
76722     PVAL COMMON  1                                  .
76721     NORB COMMON  1                                  .
76717          COMMON  1                                  .
76717    1MINE COMMON  1                                  .
76716    FQFLG COMMON  1                      FREQUENCY FLAG, 0=OFF,  OTHERWISE ON
76715    VAFLG COMMON  1                      VARIATIONAL EQUATIONS FLAG
00007      AMM SYN     7
00064      AMN SYN     52                     6+6*6+5*2
00001      AME SYN     1
00011      BAM SYN     AMM+AME+1
                                              GENERAL BUFFER FOR MARK I
74524          COMMON  3*AMN+AMN*BAM+AMN*BAM+AMN*AME
74513          COMMON  9                      DERIVATIVES FOR
74513     FRQ. COMMON  1                      FREQUENCY
74447          COMMON  35                     DERIVATIVES FOR
74447     VAR. COMMON  1                      VARIATIONAL EQUATIONS,1950.0
74446     CZ.. COMMON  1                      COWELL BUFFER 1950.0
74445     CY.. COMMON  1                      COWELL BUFFER 1950.0
74444     CX.. COMMON  1                      COWELL BUFFER 1950.0
74440          COMMON  3                      DERIVATIVES FOR POSITIONS, 1950.0
74427          COMMON  9
74427      FRQ COMMON  1
74363          COMMON  35                     VARIATIONAL EQUATIONS, 1950.0
74363      VAR COMMON  1
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74362     CZ. COMMON  1                   COWELL BUFFER 1950.0
74361     CY. COMMON  1                   COWELL BUFFER 1950.0
74360     CX. COMMON  1                   COWELL BUFFER 1950.0
74357      CZ COMMON  1                   COWELL BUFFER 1950.0
74356      CY COMMON  1                   COWELL BUFFER 1950.0
74355      CX COMMON  1                   COWELL BUFFER 1950.0
74353         COMMON  1                   CURRENT EPOCH
74353       T COMMON  1                        .
74351         COMMON  1                   NUMBER OF EQUATIONS
74351   HBANK COMMON  1
74345         COMMON  3
74335         COMMON  8
74335  VARCFF COMMON  1
74271         COMMON  35
74271  VARTRU COMMON  1                   VARIATIONAL EQUATIONS, TRUE EQUATOR
74266         COMMON  2                   BUFFERS FOR THRUST
74266      CE COMMON  1                             .
74260         COMMON  5                   MOON - FIXED POSITION  1950.0
74260      CD COMMON  1                   LUNAR OBLATENESS PERTURBATION 1950.0
74256         COMMON  1                   EARTH OBLATENESS
74253         COMMON  3                   POSITION WITH RESPECT TO EARTH 1950.0
74251         COMMON  2          POSITION WITH RESPECT TO EARTH  MEAN OF DATE
74251      CC COMMON  1                             .                   .
74246         COMMON  2                   EARTH OBLATENESS PERTURBATION 1950.0
74246      CB COMMON  1                                  .
74243         COMMON  2                   N-BODY PERTURBATION  1950.0
74243      CA COMMON  1                             .
74240         COMMON  2                   DIRECTION COSINES OF CANOPUS
74240   CANOP COMMON  1                   TRUE EQUATOR AND EQUINOX OF DATE
74235         COMMON  2                                  .
74235      S3 COMMON  1                                  .
74232         COMMON  2                                  .
74232      S2 COMMON  1                                  .
74227         COMMON  2                                  .
74227      S1 COMMON  1                                  .
74202         COMMON  20                  TRUE EQUATOR AND EQUINOX OF DATE
74202    XOP. COMMON  1          VELOCITY COORDINATES OF PROBE IN N BODY SYSTEMS
74155         COMMON  20                  TRUE EQUATOR AND EQUINOX OF DATE
74155     XOP COMMON  1          POSITION COORDINATES OF PROBE IN N BODY SYSTEMS
74130         COMMON  20                  TRUE EQUATOR AND EQUINOX OF DATE
74130    XN.1 COMMON  1          VELOCITY COORDINATES OF NTH BODY
74103         COMMON  20                  TRUE EQUATOR AND EQUINOX OF DATE
74103     XN1 COMMON  1          POSITION COORDINATES OF NTH BODY
74102     Z). COMMON  1                   EARTH-FIXED CARTESIAN
74101     Y). COMMON  1                   EARTH-FIXED CARTESIAN
74100     X). COMMON  1                   EARTH-FIXED CARTESIAN
74077      Z) COMMON  1                   EARTH-FIXED CARTESIAN
74076      Y) COMMON  1                   EARTH-FIXED CARTESIAN
74075      X) COMMON  1                   EARTH-FIXED CARTESIAN
74074  SIGMA1 COMMON  1                   EARTH-FIXED SPHERICAL
74073  GAMMA1 COMMON  1                   EARTH-FIXED SPHERICAL
74072      V1 COMMON  1                   EARTH-FIXED SPHERICAL
74071  THETA1 COMMON  1                   EARTH-FIXED SPHERICAL
74070    PHI1 COMMON  1                   EARTH-FIXED SPHERICAL
74067      R1 COMMON  1                   EARTH-FIXED SPHERICAL
74064         COMMON  2                   BUFFER
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74064    XEP. COMMON  1                   BUFFER
74061         COMMON  2                   FOR ,,SPACE,,
74061     XEP COMMON  1                   FOR ,,SPACE,,
74060      Z. COMMON  1                   OUTPUT BUFFER
74057      Y. COMMON  1                   REFERENCED TO
74056      X. COMMON  1                   TRUE EQUATOR
74055       Z COMMON  1                   AND EQUINOX OF DATE
74054       Y COMMON  1
74053       X COMMON  1
74050         COMMON  2                   1950.0 EQUATOR
74050     CS3 COMMON  1                   1950.0 EQUATOR
74045         COMMON  2                   1950.0 EQUATOR TO EARTH
74045     CS2 COMMON  1                   1950.0 EQUATOR TO EARTH
74042         COMMON  2                   1950.0 EQUATOR TO SUN
74042     CS1 COMMON  1                   1950.0 EQUATOR TO SUN
74041    QZO. COMMON  1                   ENCKE BUFFER
74040    QYO. COMMON  1                   1950.0
74037    QXO. COMMON  1
74036     QZO COMMON  1                   TWO-BODY SOLUTION, 1950.0
74035     QYO COMMON  1                   TWO-BODY SOLUTION, 1950.0
74034     QXO COMMON  1                   TWO-BODY SOLUTION, 1950.0
74033     QZ. COMMON  1                   TRUE SOLUTION, 1950.0
74032     QY. COMMON  1                   TRUE SOLUTION, 1950.0
74031     QX. COMMON  1                   TRUE SOLUTION, 1950.0
74030      QZ COMMON  1                   TRUE SOLUTION, 1950.0
74027      QY COMMON  1                   TRUE SOLUTION, 1950.0
74026      QX COMMON  1                   TRUE SOLUTION, 1950.0
74012         COMMON  11
74012   GROPS COMMON  1
74007         COMMON  2
74007     CR1 COMMON  1
74004         COMMON  2
74003         COMMON  1
74003     CPT COMMON  1
74002     CPC COMMON  1
74001     CPM COMMON  1
74000     CPS COMMON  1
73777     CPE COMMON  1
73774         COMMON  2
73774   EULER COMMON  1
73773     IAS COMMON  1
73772     INA COMMON  1
73771    ACCD COMMON  1
73770    DESS COMMON  1
73767    DEMS COMMON  1
73766     ALP COMMON  1
73765    EST4 COMMON  1
73764    STE4 COMMON  1
73763    SET4 COMMON 1
73762    STP4 COMMON  1
73761    TSP4 COMMON  1
73760    TPS4 COMMON  1
73757    TEP4 COMMON  1
73756    ETP4 COMMON  1
73755    EPT4 COMMON  1
73754    ESM4 COMMON  1
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73753     EMS4 COMMON  1
73752     SEM4 COMMON  1
73751     SMP4 COMMON  1
73750     MSP4 COMMON  1
73747     MPS4 COMMON  1
73746     MEP4 COMMON  1
73745     EMP4 COMMON  1
73744     EPM4 COMMON  1
73743     SEP4 COMMON  1
73742     ESP4 COMMON  1
73741     EPS4 COMMON  1
73740     TALT COMMON  1
73737      RAO COMMON  1
73736     RAA3 COMMON  1
73735     RAA2 COMMON  1
73734     RAA1 COMMON  1
73723          COMMON  8
73723     MVEC COMMON  1
73720          COMMON  2
73720     B3UV COMMON  1
73715          COMMON  2
73715     B2UV COMMON  1
73712          COMMON  2
73712     B1UV COMMON  1
73711    B3MAG COMMON  1
73710    B2MAG COMMON  1
73707    B1MAG COMMON  1
73706     MTA3 COMMON  1
73705     MTA2 COMMON  1
73704     MTA1 COMMON  1
73703      DAO COMMON  1
73702      DA3 COMMON  1
73701      DA2 COMMON  1
73700      DA1 COMMON  1
73677    SHATC COMMON  1
73671          COMMON  5
73671     SARA COMMON  1
73663          COMMON  5
73663     ERIF COMMON  1
73660          COMMON  2
73660    JOSHT COMMON  1
73654          COMMON  3
73654     SCUM COMMON  1
73653      SHA COMMON  1
73652       VT COMMON  1
73651       RT COMMON  1
73650       VM COMMON  1
73647       RM COMMON  1
73646       VS COMMON  1
73645       RS COMMON  1
73642          COMMON  2
73642      VOT COMMON  1
73637          COMMON  2
73637      ROT COMMON  1
73636    R.A.M COMMON  1
73633          COMMON  2
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73633      VO1 COMMON  1
73630          COMMON  2
73630      RO1 COMMON  1
73627    R.A.S COMMON  1
73624          COMMON  2
73624      VO2 COMMON  1
73621          COMMON  2
73621      RO2 COMMON  1
73620      SIA COMMON  1
73617    RAWXR COMMON  1
73616    TSBP3 COMMON  1
73605          COMMON  8
73605    PEQW3 COMMON  1
73604     BAGE COMMON  1
73603     GARB COMMON  1
73564          COMMON  14
73564    GRUB8 COMMON  1
73545          COMMON  14
73545    GRUB6 COMMON  1
73533          COMMON  9
73533    GRUB5 COMMON  1
73523          COMMON  7
73523    GRAB6 COMMON  1
73515          COMMON  5
73515    GRAB5 COMMON  1
73513          COMMON  1
73513    MUSE3 COMMON  1
73505          COMMON  5
73505    TGSPH COMMON  1
73477          COMMON  5
73477    ERSPH COMMON  1
73476      MA3 COMMON  1
73475      EA3 COMMON  1
73474      TA3 COMMON  1
73473      SVL COMMON  1
73472      HNG COMMON  1
73471      HGE COMMON  1
73470      ADS COMMON  1
73467      DPT COMMON  1
73463          COMMON  3
73463    SCRUG COMMON  1
73462      DRT COMMON  1
73461    MA2   COMMON  1
73460    EA2   COMMON  1
73457    TA2   COMMON  1
73456    TSBP2 COMMON  1
73455    CRUD  COMMON  1
73444          COMMON  8
73444    PEQW2 COMMON  1
73443    BOSH  COMMON  1
73424          COMMON  14
73424    GRUB4 COMMON  1
73412          COMMON  9
73412    GRUB3 COMMON  1
73402          COMMON  7
73402   GRAB4  COMMON  1
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73374         COMMON  5
73374   GRAB3 COMMON  1
73372         COMMON  1
73372   MUSE2 COMMON  1
73370         COMMON  1
73367         COMMON  1
73362         COMMON  5
73362   JUICE COMMON  1
73350         COMMON  9
73350   SCMP. COMMON  1
73347   SCAMP COMMON  1
73335         COMMON  9
73335     MA1 COMMON  1
73334     EA1 COMMON  1
73333     TA1 COMMON  1
73332      DR COMMON  1
73331     ALT COMMON  1
73330     GED COMMON  1
73327   LONGS COMMON  1
73326   LONGM COMMON  1
73325   TSBP1 COMMON  1
73314         COMMON  8
73314    PEQW COMMON  1
73313   CRUMY COMMON  1
73312   CRUMB COMMON  1
73273         COMMON  14
73273   GRUB2 COMMON  1
73261         COMMON  9
73261   GRUB1 COMMON  1
73251         COMMON  7
73251   GRAB2 COMMON  1
73243         COMMON  5
73243   GRAB1 COMMON  1
73241         COMMON  1
73241   MUSE1 COMMON  1
73235         COMMON  3
73235     LTS COMMON  1
73234     ASD COMMON  1
73233   T(F)L COMMON  1
73232     SPN COMMON  1
73231   PRFLG COMMON  1
73227         COMMON  1
73227   37HED COMMON  1
        *             SPECIAL PRINT ONLINE OR 3070  SS6
73226    SP1A COMMON  1                    SINGLE SPACE
73225    SP2A COMMON  1                    DOUBLE SPACE
73224    SP3A COMMON  1                    SUPPRESS SPACE
73223   EJCTA COMMON  1                    EJECT PAGE
        *             FINE PRINT OFF LINE
73222    SP1B COMMON  1                    SINGLE SPACE
73221    SP2B COMMON  1                    DOUBLE SPACE
73220    SP3B COMMON  1                    SUPPRESS SPACE
73217   EJCTB COMMON  1                    EJECT PAGE
        *             FINE PRINT ONLINE OR 3070  SS6,SS4
73216    SP1C COMMON  1                    SINGLE SPACE
73215    SP2C COMMON  1                    DOUBLE SPACE




73214    SP3C COMMON  1                    SUPPRESS SPACE
73213   EJCTC COMMON  1                    EJECT PAGE
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$JOB  RJW,L0820CC,542-10401-1-3120,FC                                   121751 A    02/26/65    ******************

*       JPTRAJ
*       USE LIBE TAPE(10)
*       FAP
CARC-COUNT ESTIMATE MISSING.

                                                                                2/26/65     PAGE 1

                  000C5           ENTRY   DUMMY
                  000C6           ENTRY   EOS
                  000C2           ENTRY   CANCLK
                  0001C           ENTRY   DATCEL
                  0000C           ENTRY   RGGSAV
                  000C1           ENTRY   RGGSTR
                  000C7           ENTRY   EXPORT
                 C00775   REGSAV  BOOL    775
                 000776   REGSTR  BOOL    776
C0000  0021 00 C 00775   RGGSAV  TTR     REGSAV
C0001  0021 00 C 00776   RGGSTR  TTR     REGSTR
00002                    CANCLK  BSS     3
                  00005    DUMMY  EQU     *
00005 +00000000C000              DEC     0
00006  0020 00 4 000C1       EOS  TRA     1,4

C0007  0 00000 C 0000C   EXPORT  PZE                          ZERC=JPL    NCN-ZERC=EXPORT
                                                               USED IN SUBR PRSET AT LOC TIME
                                                               TC CONTROL SENSING OF CN-LINE PRINTER

00010  C0020206C605      CATCEL  CATE
                                  END

                                                                                2/26/65     PAGE 1
                  PCST PROCESSOR ASSEMBLY DATA

        11 IS THE FIRST LCCATION NOT USED BY THIS PROGRAM

NC ERRCR IN ABOVE ASSEMBLY.

        CATA

ENTRY POINTS TC SUBRCUTINES REQUESTED FROM LIBRARY,
    SETHI     WRITEB    ENCOUT    REWIND    OUTUS     ACTIND    BFLG      RESTKA    REQIND    PRCON
    CKIND     CKACT     WRITEC    UNLOAC    READB     BSREC

    THE NAME OF THIS PRCGRAM IS 'SPACE '     2/26/65

  ENTRY NAME   ENTRY ADC.   TRANSFER VECTCRS   LOAD ADD.   OCTAL LENGTH   DECIMAL LENGTH   COMMON BREAK
    CUMMY        22305          'NONE'          22300         00C12           00010
    ECS          22306
    CANCLK       223C2
    CATCEL       22310
    RGGSAV       223C0
    RGGSTR       223C1
    EXPCRT       22307
    LCG10        22312          'NONE'          22312         00074           00060           77151
    LN           22316
    SCRT         224C6          'NONE'          22406         00052           00042           77151
    SIN          22460          'NONE'          22460         00237           00159           77151
    CCS          22463
    CSIN         22467
    CCOS         22471
    CROSS        22747          SQRT            22717         00103           00067           77151
    PROC         22720
    UNIT         23CC1
    ARTAN        23C22          'NONE'          23022         00071           00057
    CAYS         23116          FIX             23113         00031           00025           77151
                                FLCAT
                                ADD
    ACD          23144          'NONE'          23144         00031           00025           77151
    FIXT         23176          FLOAT           23175         00257           00175
    FLOT         233C1
    FIX          23454          'NCNE'          23454         00012           00010
    FLCAT        23460
    CHANGE       23472          GROP            23466         00035           00029
                                ORBETT
                                SPRAY
                                PRINTO
    ECLIP        23526          COS             23523         00056           00046
                                SIN
                                MATRIX
    RVIN         23610          COS             23601         00310           00200
    RVOUT        23733          SIN
                                MATRIX
                                PRCD
                                ARTAN
                                UNIT
                                ARSIN
    GHA          24114          DAYS            24111         00105           00069
                                FIX
                                FLOAT
    GEOLAT       24220          SIN             24216         00056           00046           77151
                                SQRT
    GETTER       24276          PRCD            24274         00045           00037
                                ARCOS
    SPACE        24346          COS             24341         00161           00113
    EARTH        24435          SIN
                                MATRIX
                                RVOUT
                                RVIN
    CLUCK        24526          UNIT            24522         00111           00073
                                CROSS
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		PROD				
		ARTAN				
BCDNO	24636	PROUT	24633	00045	00037	
NEWBCD	24661	ERPRT				
		ABORT				
ARSIN	24704	'NONE'	24700	00141	00097	77151
ARCCS	24700					
WOLF	25050	OPRFLG	25041	00122	00082	
TIM	25160	PRSET				
MACH	25161	TIME1				
		GRUPPE				
		PROUT				
		TIME				
		KERN1				
ROTEQ	25164	MNAET	25163	00153	00107	
DELTJD	25330					
BODY	25342	SQRT	25336	00156	00110	
BODY1	25372	ERPRT				
		PROUT				
		ABORT				
GASJET	25530	BCDNO	25514	00356	00238	
GASSET	25660	CAN50				
GASCPT	26004	UNIT				
GASFLG	26003	CROSS				
GASTIM	26027	ADD				
		MATRIX				
		FLOTT				
		GASTM1				
		FLGWRD				
		GASTR1				
		GASTM2				
		GASTR2				
TIME1	26106	OPRFLG	26072	00356	00238	77123
TIME2	26111	EQUNX1				
TIME3	26114	TARBCD				
LAUNCH	26434	INJEQX				
		DAYS				
		FIXT				
		ADD				
		FIX				
		FLOAT				
		GRUPPE				
		PROUT				
MARSMM	26460	SIN	26450	00241	00161	
MARSPC	26571	COS				
MARFIX	26604	CROSS				
PMAT	26671	UNIT				
FPMAT	26660	FIX				
MHA	26655	FLOAT				
		MATRIX				
WRITE1	26766	VARFLG	26711	00354	00236	
WRITEN	27020	RITFLG				
WRITEC	27040	FLGWRD				
COD	27165	SETHI				
		WRITEB				
		GRUPPE				
		RUNID				
		PROUT				
		SCFORF				
		PAGBCD				
		TARBCD				
		INJBCD				
		INJTYP				
		INJT				
		INJX				
		INJDX				
		RMAX				
		PHL				
		INJTOT				
		INJEQX				
		BRNOPT				
		RADOPT				
		GASOPT				
		NEWBOD				
		TARAD				
		GRAV				
		LUNGRV				
		OUT				
		ECM				
		HARMN2				
		TIM				
		MACH				
		DELTJD				
		MNAET				
		NUTEPH				
		SCBEGT				
		SCENDT				
		KERN1				
		JJJJJ				
		HC				
		TTTTT				
		JJ				
		DISTIM				
		ERPRT				
		ABORT				
GRUPPE	27270	EJECT1	27265	00017	00015	
		LINES				
		SEITE				
SEITE	27306	DATCEL	27304	00123	00083	
CASE	27352	PROUT				
EJECT	27350					
PAGBCD	27356					
LINES	27353					
EJECT1	27351					
SPRAY	27430	GROP	27427	00012	00010	
EFFECT	27442	GROP1	27441	00050	00040	
HARMN	27512	PMAT	27511	00267	00183	77052
MRBLAT	27513					
HARMN2	27514					
SVARY	30000	'NONE'	30000	00345	00229	77074
VARY	30067					
PHL	32270	DAYS	30345	01753	01003	
RMAX	32271	E.T.				
ROT	31574	ROTEQ				
NUTATE	31522	MNA				
RESET	31746	GHA				
INTRAN	30412	RVIN				
CAN50	31765	EARTH				
INJBCD	31132	MNA1				
INJTYP	31133	MNAMD1				

INJX	31134	BODY				
INJY	31135	HARMN				
INJZ	31136	SVARY				
INJDX	31137	GRUPPE				
INJDY	31140	EPHSET				
INJDZ	31141	GRAV				
INJEQX	31142	LUNGRV				
CENTR5	31225	SCALE1				
		PROUT				
		RADOPT				
		BRNOPT				
		GASOPT				
		TIME2				
		ECLIP				
		MATRIX				
		MNAET				
		NUTMAT				
		INTR1				
		UNIT				
		EQUNX1				
		COS				
		SIN				
		SQRT				
		CROSS				
		ARCOS				
		ARSIN				
		ERPRT				
		ABORT				
XYZCC	32333	PROD	32320	02026	01046	77041
XYZCD1	32332	FIX				
MNA	32510	FLOAT				
MNA1	325C7	COS				
MNAMC	32540	SIN				
MNAMC1	32537	SQRT				
MATRIX	33721	ARTAN				
NUTMAT	34211	BODTAB				
LUNGRV	34C01	ANTR1				
NUTLCN	34207	NUTLOB				
NUTCBL	34210					
NUTEPH	34344					
MNAET	34343					
MARK	34350	PPOOR	34346	03156	01646	
HC	34502	DUBFLG				
NI	34503					
TGLC	34510					
Y	34540					
YDOT	34541					
Y(2)	34542					
YO	34543					
YO(2)	34544					
BABTB	34667					
DELX	34612					
J	345C4					
ND	34551					
HD	34567					
RUNIC	41063	PROUT	37524	01366	00758	73212
PRSET	37775	ENDOUT				
DPRSET	411C6	OPRFLG				
ERPRT	377C4	EXPORT				
JEXIT	40124	FLGWRD				
ABORT	40120	TWPP4				
......	40226	SCFORF				
TIME	40070	BODFIN				
PRTSWX	41067	WRITEC				
FLAG42	41062	GRUPPE				
COMTRJ	40460	INJT				
COMTRK	40516	INJTDT				
CCMFLG	41071	INJBCD				
		HBODY				
		FLUSH				
		BTQ				
		BTC				
		BTD				
		BTT				
		BRQ				
		BRC				
		BRD				
		BRT				
		TFD				
		TFH				
		TFM				
		TFLIND				
		TFLINH				
		JULD				
		SCBEGT				
		SCENDT				
		TARGAD				
		PAGBCD				
		TARBCD				
		FAZFLG				
		INJTYP				
		INJX				
		INJY				
		INJZ				
		INJDX				
		INJDY				
		INJDZ				
		RMAX				
		PHL				
		INJEQX				
		MOOPH1				
		MOOPH2				
		MOOPH3				
		MOOPH4				
		MOOPH5				
		MOOPH6				
		MOOPH7				
		MOOPH8				
		VENPH1				
		VENPH2				
		VENPH3				
		VENPH4				
		VENPH5				
		VENPH6				
		VENPH7				
		VENPH8				
		MARPH1				
		MARPH2				
		MARPH3				
		MARPH4				

		MARPH5				
		MARPH6				
		MARPH7				
		MARPH8				
		H				
		TARAD				
		LUNGRV				
		SCALE1				
		GRAV				
		HARMN				
		BRNOPT				
		RADOPT				
		DEPOPT				
		PRTSTP				
		OTPCA				
		GASOPT				
		VARFLG				
		NEWBOD				
		DELTJD				
		MNAET				
		NUTEPH				
		CLPBTQ				
		CLPBTC				
		CLPBTO				
		CLPBTT				
		CLPBRQ				
		CLPBRC				
		CLPBRO				
		CLPBRT				
		CLPT				
		SECP50				
		SECP50				
		TAPEX				
		LAUNCH				
		CAN50				
		PROUTA				
		PROUTB				
		PROUTC				
		PROUTD				
		REWIND				
		TMWD				
		TIM				
		MACH				
		FGDOUT				
		LABEL				
		TRAJ				
PROUT	41124	OUTUS	41112	02715	01485	
FGDOUT	42277	ACTIND				
PRCNV	41215	BFLG				
PROLT2	41202	RESTKA				
PROUT3	41206	REQIND				
TSXA	43167	PRCON				
SPRCUT	41124	CKIND				
LABEL	43757	CKACT				
TMWC	43760	WRITED				
FLUSH	43736					
PROUTA	42751					
PROUTB	42753					
PROUTC	43727					
PROLTC	43762					
CLASS	45462	SQRT	44027	02313	01227	76716
SPECL	46037	UNIT				
JEKYL	44171	CROSS				
		LN				
		ARTAN				
		ARCOS				
		SIN				
		HARMN				
		INJTYP				
		SAVA				
		RMAX				
ACCEL	46352	GRAV	46342	00142	00098	
		BODY				
		BODY1				
		PROD				
		CBM				
		CG				
		RADSO				
		MATRIX				
EPHSET	52613	NEWBOD	46504	04410	02312	
BNTR2	52613	FIX				
ANTR1	52700	TARAD				
INTR1	52700	CENTR5				
GRAV	52542	CENTE5				
SCALE1	52536	DAYS				
CUT	52540	EPHEM				
E.T.	53107	GRUPPE				
EGM	52534	PROUT				
NEWBOD	52530	ERPRT				
NUTLCB	46744	ABORT				
BODTAB	52567	UNLOAD				
		TAPEX				
		EPTAPE				
EPHEM	53120	REWIND	53114	01456	00814	
TAPEX	54300	READB				
EPTAPE	54452	BSREC				
BODDSK	54602	ROT	54572	01042	00546	
BODFIN	54675	ACCEL				
		NUTOBL				
		NUTLON				
		PROUT				
		ABORT				
		ERPRT				
CONIC	60576	SPRAY	55634	05232	02714	73212
USERV	61002	EFFECT				
PRINTC	55751	ROT				
TARAC	60177	PRSET				
CLAPP	62650	ORBETT				
SAC	60540	EQUNX1				
SAVA	60730	RESET				
IMPFLG	62651	TIME1				
PRNTC1	55750	DAYS				
GROP1	60150	ARTAN				
BTQ	60543	PROD				
BTC	60544	ARSIN				
BTO	60545	GETTER				
BTT	60546	SIN				
BRQ	60547	SPACE				
BRC	60550	RVOUT				
BRO	60551	GEOLAT				

BRT	60552	HC				
TFD	60554	CANCLK				
TFH	60555	CLUCK				
TFM	60556	ECLIP				
TFLIND	60557	GRUPPE				
TFLINH	60560	GRAV				
CLPBTQ	60561	PROUT				
CLPBTC	60562	RADOPT				
CLPBTO	60563	GASOPT				
CLPBTT	60564	UNIT				
CLPBRQ	60565	ARCOS				
CLPBRC	60566	CROSS				
CLPBRO	60567	CG				
CLPBRT	60570	MNA				
CLPT	60571	MNAMD1				
JULD	60573	MATRIX				
CENTE5	55741	MARSMM				
		MARSPC				
		MARFIX				
		MHA				
		INJFLG				
		NUTATE				
		ERPRT				
		ABORT				
		GROP				
		COS				
		CAN50				
		JEKYL				
		CLASS				
		SPECL				
		ADD				
		TIME3				
		INJBCD				
		BCOND				
		SQRT				
		LN				
		INJTYP				
JJ	67165	CASE	63066	05165	02677	73212
LOD1	67170	IMPFLG				
DISTIM	67166	CLAPP				
TWPP4	67062	BNTR2				
FLGWRD	67172	BCOND				
VARFLG	70144	FLOT				
TBEGSC	64160	EJECT				
TENDSC	64162	SEITE				
RITFLG	67171	GASFLG				
TTTTT	67162	GASOPT				
JJJJJ	67164	GASSET				
MOOPH1	67300	INJBCD				
MOOPH2	67350	INTRAN				
MOOPH3	67420	WRITE1				
MOOPH4	67470	INTR1				
MOOPH5	67540	PROD				
MOOPH6	67610	WOLF				
MOOPH7	67660	SPRAY				
MOOPH8	67730	GRAV				
VENPH1	67420	BODY1				
VENPH2	67470	ADD				
VENPH3	67540	NI				
VENPH4	67610	J				
VENPH5	67660	MARK				
VENPH6	67730	GASTIM				
VENPH7	67300	TIME1				
VENPH8	67350	GRUPPE				
MARPH1	67610	PROUT				
MARPH2	67660	PRSET				
MARPH3	67730	PRINTD				
MARPH4	67300	ERPRT				
MARPH5	67350	TARAD				
MARPH6	67420	HC				
MARPH7	67470	ABORT				
MARPH8	67540	BABTB				
INJTOT	70130	CHANGE				
TARBCD	70131	EOS				
RADOPT	70136	BOODSK				
LAST	70145	HD				
REND	70146	ND				
REND.	70150	PRNTD1				
MODE1	70152	RDT				
KERN1	70153	GETTER				
GJHO	70154	ARSIN				
RKHO	70156	SIN				
HBODY	70157	COS				
PRTO	70160	CROSS				
DPRTO	70162	UNIT				
OPRT	70174	NUTATE				
GROP	70200	MATRIX				
CODE1	70201	MARSMM				
VIEW	70203	MARSPC				
PASH	70207	MRBLAT				
ORBETT	70213	GASJET				
EQUNX1	70214	VARY				
OPRFLG	70132	HARMN				
H	64655	XYZDD1				
PPOOR	67176	SAC				
SCFORF	70215	TGLO				
SCBEGT	70216	COD				
SCENDT	70220	WRITEN				
BRNOPT	70106					
DEPOPT	70100					
DEPLOC	70101					
DEPVAL	70102					
DEPLAM	70100					
PRTSTP	70103					
INJFLG	70064					
BRNTYP	70115					
BRNBOD	70116					
BRNALT	70117					
H((0))	64655					
TRAJ1	63164					
TRAJ	63175					
TARN	67014					
BRNCNT	70106					
BRNTMS	70107					
BRNC3S	70113					
BRNDTM	70111					
BRNMUS	70114					
BRNACC	70122					
BRNMAS	70120					
BRNMS.	70121					

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TARGAD     70057
CBM        66141
FAZFLG     70135
INJT       70133
DTPCA      70066
CG         64247
GASTR1     64110
GASTR2     64112
GASTM1     64243
GASTM2     64245
FLOTT      64533
SECP50     70074
SECP50     70074
RADSO      67006
DUBFLG     67175
READD      70254          (IOU)      70253         00365         00245
READB      70256
WRITED     70261
WRITEB     70263
BSREC      70472
BSFILE     70475
REWIND     70500
UNLOAD     70503
ENDFIL     70506
SETLOW     70464
SETHI      70467
(UNIT)     70635
TAPEIO     70635
(IOU)      70643          'NONE'     70640         00030         00024
OUTUS      70672          RGGSAV     70670         02320         01232
BFLG       71526          RGGSTR
ENDOUT     71257
CKIND      73121
CKACT      73164
REQIND     73120
ACTIND     73117
RESTKA     73115
PL1CON     73200
PL2CON     73201
PL3CON     73202
PRCON      73203

'SPACE ' JUST LOADED.

 UNUSED CORE LIES FROM   73210   THROUGH   73212,  LEAVING   00003  OCTAL OR   00003   DECIMAL LOCATIONS.
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E. INPUT FORMS

JPL SPACE INJECTIØN CØNDITIØNS

NAME ______ DATE 12-1-64

12 NAME	VALUE		TYPE	NOMINAL VALUE	EXPLANATION			
PAGBCD✓✓✓=	( )	$	BCD	✓✓✓✓✓✓	PAGE HEADING			
PAGBCD+3✓=	( )	$	BCD	✓✓✓✓✓✓				
PAGBCD+6✓=	( )	$	BCD	✓✓✓✓✓✓	(A SECØND LINE ØF PAGE HEADING			
PAGBCD+9✓=	( )	$	BCD	✓✓✓✓✓✓	IS AVAILABLE BY INPUT INTØ			
PAGBCD+12=	( )	$	BCD	✓✓✓✓✓✓	PAGBCD+20 THRØUGH PAGBCD+39)			
PAGBCD+15=	( )	$	BCD	✓✓✓✓✓✓				
PAGBCD+18=	( )	$	BCD	✓✓✓✓✓✓				
		$						
TARBCD=	( )	$	BCD	MØØN✓✓	TARGET BØDY			
INJBCD=	( )	$	BCD	EARTH✓	INJECTIØN CENTRAL BØDY			
		$						
FAZFLG=		$	FIX	1	NØN-ZERØ = AUTØMATIC PHASING			
INJTYP=		$	FIX	0	TYPE ØF INJECTIØN CØNDITIØNS			
		$			±0 INERTIAL CARTESIAN			
		$			±1 INERTIAL SPHERICAL			
		$			+2 EARTH FIXED SPHERICAL			
		$			+3 SELENØGRAPHIC SPHERICAL			
		$			+4, +5, +6 ENERGY ASYMPTØTE			
		$			+= EQUATØRIAL, −= ECLIPTIC			
		$						
INJT=		$	SEG	0,0	INJECTIØN EPØCH			
	YYMMDDDHHMMSSFFF	$						
		$			±0	±1	2,3	4,5,6
INJX✓=		$	FLØ	0.0	X KM	R KM	R KM	Σ_L DEG
INJY✓=		$	FLØ	0.0	Y KM	Φ DEG	Ø DEG	R KM
INJZ✓=		$	FLØ	0.0	Z KM	Θ DEG	θ DEG	Γ DEG
INJDX=		$	FLØ	0.0	$\dot{X}$ KM/SEC	V KM/SEC	V KM/SEC	C_3 KM^2/SEC^2
INJDY=		$	FLØ	0.0	$\dot{Y}$ KM/SEC	Γ DEG	γ DEG	Φ_s DEG
INJDZ=		$	FLØ	0.0	$\dot{Z}$ KM/SEC	Σ DEG	σ DEG	Θ_s DEG
		$						
RMAX✓✓=		$	FLØ	0.0	R_{MAX} USED IN ENERGY PSEUDØ-ASYMP. KM			
PHL✓✓✓=		$	FLØ	28.309	$Ø_L$ USED IN ENERGY PSEUDØ-ASYMP. DEG			
		$						
INJTDT=		$	FLØ	0.0	DELTA TIME ADDED TØ INJT SEC			
		$						
INJEQX=	( )	$	BCD	✓✓✓✓✓✓	INJECTIØN EQUINØX			
		$			( )= TRUE ØF DATE			
		$			(MEANØD)= MEAN ØF DATE			
		$			(1950.0)= MEAN 1950.0			
		$						

JPL SPACE, SFPRØ PHASING   NAME ______ DATE ______

12 NAME	VALUE	TYPE	NOMINAL VALUE	EXPLANATION 12-1-64
++++++ =		FIX		USE MØØPHi VENPHi MARPHi
				FØR MØØN, VENUS, MARS AND 1≤i≤8
				ALSØ USE MØØPHi FØR EARTH, SUN,
				SATURN, JUPITER.
				− = PRINT AT START ØF PHASE
				RESET TPRT TØ TSTART ▼ USE ØLD TPRT
				±0 PRINT AT END, LAST PHASE ±4
				±1 PRINT AT END, NØT LAST PHASE ±5
				±2 DØNT PRINT AT END, LAST PHASE ±6
				±3 DØNT PRINT AT END, NØT LAST PHASE ±7
"	+1=( )	BCD		BØDY FRØM WHICH TØ CØMPUTE R FØR R TEST
"	+2=	FLØ		VALUE ØF R TØ END PHASE
"	+3=( )	BCD		BØDY FRØM WHICH TØ CØMPUTE Ṙ FØR Ṙ TEST
"	+4=	FLØ		VALUE ØF R TØ TURN ØN R TEST +=>, −=<
"	+6=( )	BCD		INTEGRATIØN CENTRAL BØDY
"	+7=	SEG		STEPSIZE
	DDDHHMMSSFFF			
"	+9=	FIX		NØ. ØF DØUBLES
"	+10=( )	BCD		BØDY FRØM WHICH TØ CØMPUTE STEPSIZE
"	+11=	SEG		PRINT END 1
"	+13=	SEG		PRINT DELTA 1
"	+15=	SEG		2
"	+17=	SEG		2
	YYMMDDDHHMMSSFFF			
"	+19=	SEG		3 1 = EQUATØRIAL
"	+21=	SEG		3 2 = ECLIPTIC
"	+23=	SEG		ØDD PRINT 1 4 = ECL. AT START ØNLY
"	+25=	SEG		2 5 = EQU AT START ØNLY
				6 = ECL. AT END ØNLY
"	+27= 0 0 0 /8	ØCT		GRØUP PRINT 7 = EQU. AT END ØNLY
	N C GEØ, N C HELIØ, N C TARG, R, PI, U			1 = GRØUP B (ALL)
"	+38= /8	ØCT		CØINIC PRINT 2 = GRØUP C (ALL BUT R, V)
	Q C Ø T GEØ, Q C Ø T HELIØ, Q C Ø T TARG			3 = GRØUP D (B.T, B.R LINE ØNLY)
"	+28= /8	ØCT		STATIØN PRINTS (MAXIMUM ØF 5)
	5 9 1 1 1 2 4 1 5 1 1 4 1 3 1 5 4 2 6 1 0 8 9 1			
"	+30= /8	ØCT		VIEW PERIØDS (MAXIMUM ØF 5)
"	+34=	FIX		SHADØW PARAMETER FLAG 1 = ØN
"	+39=( )	BCD		EQUINØX (✓✓✓✓✓✓) = TRUE ØF DATE
				(1950.0) = MEAN 1950.0

JPL SPACE ADDITIONAL ACCELERATION, INTEGRATION NAME ________ DATE ______

12 NAME	VALUE		TYPE	NOMINAL VALUE	EXPLANATION
$	MØTØR BURN	$			
BRNØPT ✓✓ =		$	FIX	0	BURN FLAG 0 = NØ BURN 1 = BURN
BRNØPT+1 ✓ =		$	SEG	0,0	EPØCH ØF START ØF BURN
	Y Y M M D D H H M M S S F F F	$			
BRNØPT+3 ✓ =		$	FLØ	0.0	DURATIØN ØF BURN SEC
BRNØPT+5 ✓ =		$	FLØ	100000.0	VALUE ØF C3 TØ END BURN (KM/SEC)2
BRNØPT+6 ✓ =		$	FLØ	0.0	BIAS ANGLE DEG
BRNØPT+7 ✓ =		$	FIX	0	$\bar{C}$ ØPTIØN 0=CØMPUTE EVERY T, 1=FIXED, ±2=INPUT ACCEL.
BRNØPT+8 ✓ =	( )	$	BCD	MØØN ✓✓	BØDY USED IN ALTITUDE START
BRNØPT+9 ✓ =		$	FLØ	0.0	ALTITUDE TØ START BURN KM
BRNØPT+10 =		$	FLØ	0.0	INITIAL WEIGHT LBS FØRCE
BRNØPT+11 =		$	FLØ	0.0	WEIGHT FLØW RATE LBS FØRCE/SEC
BRNØPT+12 =		$	FLØ	0.0	THRUST LBS FØRCE
BRNØPT+13 =	0 0 0 0 0 0/8	$	ØCT	0	GRØUP PRINT FLAG USED AT START, END ØF BURN
	N C GEØ | N C HELIØ | N C TARG	$			
BRNØPT+14 =	/8	$	ØCT	0	CØNIC PRINT FLAG USED AT START, END ØF BURN
	Q C Ø T GEØ | Q C Ø T HELIØ | Q C Ø T TARG	$			
BRNØPT+15 =		$	FLØ	0.0,0.0,0.0	ØF-DATE $\bar{C}$ VECTØR, USED WITH BRNØPT+7=±2
$	RADIATIØN PRESSURE	$			
RADØPT ✓✓ =		$	FLØ	0.0	SØLAR RADIATIØN CØNSTANT 0=NØ RAD. PRESS.
RADØPT+1 =		$	FLØ	0.0	CØNSTANT TERM IN PØLY IN EPS ANGLE
RADØPT+2 =		$	FLØ	0.0	LINEAR TERM IN POLY IN EPS ANGLE
RADØPT+3 =		$	FLØ	11.12	AREA ØF SPACECRAFT (METER)2
RADØPT+4 =		$	FLØ	.096	γB
RADØPT+5 =		$	FLØ	259.0	MASS ØF SPACECRAFT KG
$	GAS JET ACCELERATIØN	$			
GASØPT ✓✓ =		$	FIX	0	GAS JET FLAG 0=ØFF NØN-ZERØ=ØN
GASØPT+1 =	( )	$	BCD	EARTH ✓	REFERENCE BØDY PLANET, MØØN ØR CANØPUS
GASØPT+2 =		$	SEG	0,0	EPØCH ØF START ØF GASJETS
	Y Y M M D D H H M M S S F F F	$			
GASØPT+4 =		$	FLØ	0.0	ΔT TØ ADD TØ GASØPT+2 SEC
GASØPT+5 =		$	SEG	0,0	EPØCH ØF END ØF GASJETS 0,0=NØ END
	Y Y M M D D H H M M S S F F F	$			
GASØPT+7 =		$	FLØ	0.0,0.0,0.0	CØEF. ØF FA PØLY., QUADRATIC TERM FIRST
GASØPT+10 =		$	FLØ	0.0,0.0,0.0	CØEF. ØF FB PØLY., QUADRATIC TERM FIRST
GASØPT+13 =		$	FLØ	0.0,0.0,0.0	CØEF. ØF FC PØLY., QUADRATIC TERM FIRST
GASØPT+16 =		$	FLØ	0.0	MASS ØF SPACECRAFT KG
$	VARIATIØNAL EQUATIØNS	$			
VARFLG =		$	FIX	0	VARIATIØNAL EQUATIØNS FLAG 0=NØNE
		$			

JPL SPACE CONSTANTS NAME ______ DATE ______

12 NAME	VALUE		TYPE	NOMINAL VALUE	EXPLANATION 12-1-64
SCALE1-2=		$	FLØ	3.986032E5	EARTH GM FØR SCALING EPHEMERIS
SCALE1-1 =		$	FLØ	4.9027779E3	MØØN GM FØR SCALING EPHEMERIS
SCALE1// =		$	FLØ	6378.3115	EARTH RADIUS FØR SCALING EPHEMERIS
SCALE1+1 =		$	FLØ	149598500.	AU FØR SCALING EPHEMERIS
		$			
GRAV-2=		$	FLØ	35.	DUT = EPHEMERIS TIME-UNIVERSAL TIME
GRAV //=		$	FLØ	398600.63	EARTH GM
GRAV +1 =		$	FLØ	4902.6293	MØØN GM
GRAV +2 =		$	FLØ	.13271411E12	SUN GM
GRAV +3=		$	FLØ	324766.27	VENUS GM
GRAV+4=		$	FLØ	42977.368	MARS GM
GRAV +5=		$	FLØ	37918700.	SATURN GM
GRAV+6=		$	FLØ	126709350.	JUPITER GM
		$			
LUNGRV//=		$	FLØ	.6671E-19	UNIVERSAL GRAVITATIØNAL CØNSTANT
LUNGRV+1 =		$	FLØ	.88781798E29	MØMENT A, LUNAR PØTENTIAL
LUNGRV+2 =		$	FLØ	.88800195E29	MØMENT B, LUNAR PØTENTIAL
LUNGRV+3 =		$	FLØ	.88836978E29	MØMENT C, LUNAR PØTENTIAL
		$			
HARMN+2=		$	FLØ	.162345E-2	J EARTH CØEF. ØF SECØND HARMØNIC
HARMN+3 =		$	FLØ	-.575E-5	H EARTH CØEF. ØF THIRD HARMØNIC
HARMN+4=		$	FLØ	.7875E-5	D EARTH CØEF. ØF FØURTH HARMØNIC
HARMN+5 =		$	FLØ	6378.165	RE EARTH RADIUS USED IN PØTENTIAL
HARMN+6=		$	FLØ	5E5	RADIUS FRØM EARTH FØR J TERM EFFECTIVE
HARMN+7=		$	FLØ	2E5	RADIUS FRØM EARTH FØR H TERM EFFECTIVE
HARMN+8=		$	FLØ	1E5	RADIUS FRØM EARTH FØR D TERM EFFECTIVE
HARMN+9=		$	FLØ	.00292,0.0,0.0	JA, HA, DA, MARS CØEF. ØF 2ND, 3RD, 4TH HARMØNIC
HARMN+12=		$	FLØ	3417.	RA MARS RADIUS USED IN PØTENTIAL
HARMN+13=		$	FLØ	5E5,0.0,0.0	RADIUS FRØM MARS FØR JA, HA, DA EFFECTIVE
		$			
TARAD//=		$	FLØ	6378.	EARTH RADIUS
TARAD+1 =		$	FLØ	1738.09	MØØN RADIUS
TARAD+2=		$	FLØ	621800.	SUN RADIUS
TARAD+3=		$	FLØ	6200.	VENUS RADIUS
TARAD+4=		$	FLØ	3378.	MARS RADIUS
TARAD+5=		$	FLØ	57750.	SATURN RADIUS -.060340592
TARAD+6=		$	FLØ	68860.	JUPITER RADIUS .60342839
CAN5O =		$	FLØ		BØDY-CANØPUS UNIT 1950.0 PØSITIØN -.79513092
DELTJD=		$	FLØ	-.076643	J.D. 1950.0 - J.D. 0 HR JAN 1, 1950 DAYS
H+O =		$	FLØ		STEPSIZE RANGE TABLES

JPL SPACE SPECIAL ØUTPUT, CØNTRØL NAME ____ DATE 12-1-64

12 NAME	VALUE	TYPE	NOMINAL VALUE	EXPLANATION
SCFØRF=		FIX	0	PRØBE EPHEM. FØRMAT 0=NØNE 1=A6 TAPE 2=DISK
RUNID✓=	( )	BCD	TRAJ01	RUN I.D. (MUST INCREASE FØR MULT. CASES)
SCBEGT=	,	SEG	0,0	EPØCH TØ START WRITING PRØBE EPHEM. 0,0=T0
	Y Y M M D D D H H M M S S F F F			
SCENDT=	,	SEG	0,0	EPØCH TØ END WRITING PRØBE EPHEM. 0,0=∞
LAUNCH=	,	SEG	0,0	LAUNCH EPØCH
TARGAD=		FLØ	0.0	ALTITUDE ABØVE TARGET TØ END RUN
FLAG42=		FIX	0	NØN-ZERØ PUTS ØUTPUT IN SC4020 MØDE
PRTSWX=		FIX	0	PRINT SWITCH NØN-ZERØ=PRINT EVERY CASE
PRTSTP✓✓=		FIX	0	NØN-ZERØ=PRINT EVERY END-ØF-STEP
PRTSTP+1=	0 0 C 0 /8, /8	ØCT	0,0	PRINT GRØUP, CØNIC FLAGS USED AT EØS
	N/C GEØ, N/C HEL, N/C TAR, R, U, Q/C ØT GEØ, Q/C ØT HELIØ, Q/C ØT TARG			
DEPØPT✓✓=		FIX	0	0=NO DEP. VAR. +1=PRINT −1=END PHASE
DEPØPT+1=	/8	ØCT	0	LØCATIØN ØF DEPENDENT VARIABLE
DEPØPT+2=		FLØ	0.0	VALUE ØF DEPENDENT VARIABLE
DTPCA=	,	SEG	0,0	DT PAST CL. APP. TØ END RUN (SEC. ØK)
	Y Y M M D D D H H M M S S F F F			
SECP50=		ØCT	0,0	D.P. SEC. PAST 1950 TØ END RUN
NEWBØD✓✓=		BCD	0	BØDY TØ REPLACE SATURN
NEWBØD+1=		FLØ	0.0	CØDE NØ. ØF BØDY { 1.0 = MERCUR
NEWBØD+2=		FLØ	0.0	GM OF BØDY 7.0 = NEPTUN
NEWBØD+3=		FLØ	0.0	RADIUS OF BODY 8.0 = URANUS
				9.0 = PLUTØ
ØPTSWT=		FIX	0	ØN-LINE ØUTPUT CØNTRØL −1=EXTERNAL SET
				0=NØ ØN-LINE PRINT 5=FINE 1=MINIMUM
MNAET✓=		FIX	0	0=CØMPUTE M,N,A EVERY T; ≠0 USE ΔT TEST
NUTEPH=		FIX	0	0=TAKE NUTATIØNS FRØM EPHEM; ≠0 CØMPUTE
REWSC=		FIX	0	≠0 REWINDS A6 BEFØRE WRITING

V. OUTPUT

A. SPACECRAFT EPHEMERIS TAPE AND DISK FORMATS

TAPE IC RECORD

BUFFER NAME	NUMBER CF PARAMETERS	DESCRIPTION
RUNID	1	BCC S/C EPHEMERIS IDENTIFICATION
FLGWRD	1	CURRENT STATUS FLAG WORD
SCFGRF	1	DATA RECORD FORMAT FLAG
PAGBCD	40	SPACE PAGE HEADING
TARBCD	1	BCD TARGET NAME
INJBCD	1	BCD INJECTION CENTRAL BODY NAME
INJTYP	1	TYPE OF INJECTION CONDITIONS
INJT	2	SEXAGESIMAL INJECTION EPOCH
INJX	3	INJECTION CONDITIONS
INJDX	3	
RMAX	1	
PHL	1	
INJTDT	1	DELTA TIME ADDED TO INJT
INJECX	1	INJECTION EQUINOX
BRNOPT	18	MOTOR BURN INPUT PARAMETERS
RADOPT	6	RADIATION PRESSURE INPUT PARAMETERS
GASOPT	17	GAS JETS INPUT PARAMETERS
NEWBOD	4	BODY TC REPLACE SATURN OPTION
TARAD	7	TABLE OF BODY RADII
GRAV	7	N-BODY GM'S
LUNGRV	4	LUNAR POTENTIAL CONSTANTS
OMEGAO	1	ROTATION RATE OF THE EARTH
DUT	1	DIFFERENCE=ET-UT
EGM	4	GM'S USED FOR EPHEMERIS
HARMN2	14	OBLATENESS CONSTANTS FOR EARTH AND MARS
VARFLG	1	VARIATIONAL EQUATIONS FLAG
TIM	1	TIME OF DAY OF S/C EPHEMERIS GENERATION
MACH	1	MACHINE USED IN S/C EPHEMERIS GENERATION
SYSDAT	1	DATE OF S/C EPHEMERIS GENERATION
DELTJD	2	JD 1950.0 - JD 0 HR JAN 1, 1950
MNAET	1	FLAG TO DESIGNATE FREQ OF COMPUTATION OF MATRICES
NUTEPH	1	FLAG TO DESIGNATE WHERE TO GET NUTATIONS
SCBEGT	2	EPOCH TO START WRITING S/C EPHEMERIS
SCENDT	2	EPOCH TO STOP WRITING S/C EPHEMERIS
CX	6	INJECTION CONDITIONS MEAN 1950.0 EARTH EQ.

TAPE DATA RECORD

BUFFER NAME	NUMBER CF PARAMETERS	DESCRIPTION
RUNID	1	BCD S/C EPHEMERIS IDENTIFICATION
FLGWRD	1	CURRENT STATUS FLAG WORD
KERNI	1	BCD CENTRAL BODY NAME
JJJJJ	1	DIFFERENCE COUNT
HC	1	STEP SIZE FOR RECORD
TTTTT	2	END TIME FOR RECORD
JJ	1	NUMBER OF INTEGRATION STEPS TAKEN
DISTIM	2	DISCONTINUITY TIME IN RECORD
HBANK+4	6/42	POSITION
HBANK+108	6/42	VELOCITY
HBANK+264	6/42	DELTA 0
HBANK+316	6/42	DELTA 1
HBANK+368	6/42	DELTA 2
HBANK+420	6/42	DELTA 3
HBANK+472	6/42	DELTA 4
HBANK+524	6/42	DELTA 5
HBANK+576	6/42	DELTA 6

DISK RECORD

ALL VECTORS ARE REFERENCED TO AN EARTH TRUE EQUATOR AND EQUINOX OF-DATE COORDINATE SYSTEM

LOC	DESCRIPTION	UNITS
1	Z-COMPONENT OF SPACECRAFT ACCELERATION	KM/SEC2
2	Y-COMPONENT OF SPACECRAFT ACCELERATION	KM/SEC2
3	X-COMPONENT OF SPACECRAFT ACCELERATION	KM/SEC2
4	NUTATION IN OBLIQUITY	DEG
5	NUTATION IN LONGITUDE	DEG
6-41	VARIATIONAL EQUATIONS STORED ROW-WISE IN FORTRAN II ORDER. UNITS ARE KM AND SEC.	
42	Z-COMPONENT OF SPACECRAFT VELOCITY	KM/SEC
43	Y-COMPONENT OF SPACECRAFT VELOCITY	KM/SEC
44	X-COMPONENT OF SPACECRAFT VELOCITY	KM/SEC
45	Z-COMPONENT OF SPACECRAFT POSITION	KM
46	Y-COMPONENT OF SPACECRAFT POSITION	KM
47	X-COMPONENT OF SPACECRAFT POSITION	KM
48	SECOND PRECISION PART OF DOUBLE PRECISION SECONDS PAST ZERO HOURS JANUARY 1,1950	SEC
49	FIRST PRECISION PART OF DOUBLE PRECISION SECONDS PAST ZERO HOURS JANUARY 1,1950	SEC
50	NOT USED	

** NOTE THE ABOVE TABLE IS BUFFERED 8 AT A TIME INTO 'BUFFER' WITHIN 'BCDDSK'. THEREFORE THE DISK RECORDS ARE 400 WORDS LONG.

B. PRINTED OUTPUT FORMAT AND DEFINITIONS

CONSTANTS

```
LINE A
CASE (NO.)               IBSYS-JPTRAJ-SPACE (DATE)                  (PAGE NC.)
LINE B
 (FIRST LINE CF PAGE HEADING
LINE C
 (SECOND LINE OF PAGE HEADING
LINE D
 DOUBLE PRECISION EPHEMERIS TAPE - EPHEM1
LINE E
       GME GRAVITATIONAL COEFFICIENT FOR THE EARTH IN KM*3/SEC*2
         J CCEFFICIENT CF THE SECOND HARMONIC IN EARTHS OBLATENESS
         H COEFFICIENT OF THE THIRD HARMONIC IN EARTHS OBLATENESS
         D COEFFICIENT OF THE FOURTH HARMONIC IN EARTHS OBLATENESS
        RE EARTH RADIUS TO BE USED IN THE EARTHS OBLATE POTENTIAL, KM
       REM EARTH RADIUS TO CONVERT LUNAR EPHEMERIS TO KM
LINE F
         G UNIVERSAL GRAVITATIONAL CONSTANT FOR LUNAR OBLATENESS, KM*3/SEC*2-KG
         A MOMENTS OF INERTIA CF MOON FOR LUNAR OBLATE POTENTIAL,KG-KM*2
         B
         C
       OME RCTATION RATE OF THE EARTH IN DEG/SEC
        AU ASTRONOMICAL UNIT TC CONVERT PLANETARY EPHEMERIDES TO KM
LINE G
       GMM GRAVITATICNAL COEFFICIENT FOR THE MOON IN KM*3/SEC*2
       GMS GRAVITATICNAL COEFFICIENT FOR THE SUN IN KM*3/SEC*2
       GMV GRAVITATICNAL COEFFICIENT FOR VENUS IN KM*3/SEC*2
       GMA GRAVITATIONAL COEFFICIENT FOR MARS IN KM*3/SEC*2
       GMC GRAVITATIONAL COEFFICIENT FOR SATURN IN KM*3/SEC*2
       GMJ GRAVITATICNAL COEFFICIENT FOR JUPITER IN KM*3/SEC*2
LINE H
       EGM EARTHS GM, USED WITH EPHEMERIDES, NOT PERTURBATIONS, KM*3/SEC*2
       MGM  MOONS GM, USED WITH EPHEMERIDES, NOT PERTURBATIONS, KM*3/SEC*2
        JA CCEFFICIENT OF THE SECONC HARMONIC IN MARS OBLATENESS
        HA CCEFFICIENT OF THE THIRC HARMONIC IN MARS OBLATENESS
        DA CCEFFICIENT CF THE FOURTH HARMONIC IN MARS OBLATENESS
        RA MARS RACILS TO BE USED IN THE MARS OBLATE PCTENTIAL, KM
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ACCELERATIONS

```
LINE I (IF SOLAR RADIATION PRESSURE IS REQUESTED)
       RADIATICN PRESSURE INPUT
LINE J (IF SOLAR RACIATION PRESSURE IS REQUESTED)
       ARA AREA CF SPACECRAFT, SQUARE METERS
       GB  MULTIPLE CF PERCENT CF REFLECTED RADIANT ENERGY
       MAS MASS OF SPACECRAFT,KG
       GB1 CONSTANT COEFFICIENT OF PCLYNOMIAL, RADIANS-SQUARE METERS
       GB2 LINEAR COEFFICIENT CF POLYNOMIAL,RADIANS-SQUARE METERS/DEG
       SC  SCLAR RADIATION CONSTANT, (KG-KM/SQUARE SEC)E-6
LINE K (IF GAS JETS ARE REQUESTED)
       ATTITUDE CONTROL INPUT
LINE L (IF GAS JETS ARE REQUESTED)
       GAS FLAG
       GRB REFERENCE BCDY
       GS1 START TIME SEG. YYMMDDDHH
       GS2                 MMSSFFF
       GDT DELTA T ADDED TO START TIME,SEC
LINE M (IF GAS JETS ARE REQUESTED)
       GE1 END TIME SEG. YYMMDDDHH
       GE2               MMSSFFF
       GMS MASS,KG
       GA0 FA POLYNOMIAL QUADRATIC TERM
       GA1               LINEAR TERM
       GA2               CONSTANT TERM
LINE N (IF GAS JETS ARE REQUESTED)
       GB0 FB POLYNOMIAL QUADRATIC TERM
       GB1               LINEAR TERM
       GB2               CONSTANT TERM
       GC0 FC POLYNOMIAL QUADRATIC TERM
       GC1               LINEAR TERM
       GC2               CONSTANT TERM
LINE O (IF MOTOR BURN IS REQUESTED)
       MOTOR BURN INPUT
LINE P (IF MOTOR BURN IS REQUESTED)
       BRN FLAG FOR BURN IF ZERO NC BURN
       BT1 START TIME IN SEG. YYMMDDDHH
       BT2                    MMSSFFF
       BCT DURATION OF BURN,SEC
       BC3 VALUE OF ENERGY FOR SHUT OFF, KM2/SEC2
       BMU BIAS ANGLE,DEG
LINE Q (IF MOTOR BURN IS REQUESTED)
       BCF GUIDANCE FLAG
       BCD BODY FRCM WHICH TO MEASURE ALTITUDE TO START BURN
       BAL ALTITUDE ABCVE BODY TO START BURN,KM
       BWT WEIGHT OF VECHILE,POUNDS
       BW. FLOW RATE,PCUNDS/SEC
       BTH THRUST,POUNDS FORCE
LINE R (IF MOTOR BURN IS REQUESTED)
       BPG PRINT GROUPS DURING BURN
       BPC CCNIC GROUPS DURING BURN
       BCX X COMPONENT OF C VECTOR,KM
       BCY Y
       BCZ Z
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                          INJECTION CONDITIONS


LINE A
INJECTION CONDITIONS (EQUINOX) (TARGET) (DP SEC PAST 1950) (JD) (CALENDAR DATE)

LINE B    (INCLUDES ONE OF THE * LINES BELOW)
      (CENTRAL BODY)

*IF COORDINATES ARE INERTIAL CARTESIAN
       XO VERNAL EQUINOX CARTESIAN POSITION, KM
       YO
       ZO
      DXO VERNAL EQUINOX CARTESIAN VELOCITY, KM/SEC
      DYO
      DZO

*IF COORDINATES ARE SPHERICAL INERTIAL
      RAD RADIUS, KM
      DEC DECLINATION, DEG
       RA RIGHT ASCENSION, DEG
        V VELOCITY, KM/SEC
      PTI PATH ANGLE, DEG
      AZI AZIMUTH ANGLE, DEG

*IF COORDINATES ARE EARTH-FIXED OR SELENOGRAPHIC
      RAD RADIUS, KM
      LAT LATITUDE, DEG
      LON LONGITUDE, DEG
       VE VELOCITY RELATIVE TO ROTATING COORDINATE SYSTEM, KM/SEC
      PTR PATH ANGLE RELATIVE TO ROTATING COORDINATE SYSTEM, DEG
      AZR AZIMUTH ANGLE RELATIVE TO ROTATING COORDINATE SYSTEM, DEG

*IF COORDINATES ARE ENERGY-ASYMPTOTE
      AZL AZIMUTH AT LAUNCH SITE, DEG
      RAD RADIUS, KM
      PTH PATH ANGLE, DEG
       C3 ENERGY CONSTANT FROM VIS VIVA INTEGRAL, KM*2/SEC*2
      DAO DECLINATION OF OUTGOING ASYMPTOTE, DEG
      RAO RIGHT ASCENSION OF OUTGOING ASYMPTOTE, DEG

LINE C
     (TYPE)      (CARTESIAN,SPHERICAL,EARTH FIXED,SELENOGRAPHIC,ENERGY-
                  ASYMPTOTE,PSEUDO-ASYMPTOTE)
       TO SECONDS PAST MIDNIGHT OF INJECTION TIME, SEC
      GHA GREENWICH HOUR ANGLE OF VERNAL EQUINOX AT INJECTION EPOCH, DEG
      GHO GREENWICH HOUR ANGLE OF VERNAL EQUINOX AT PREVIOUS MIDNIGHT, DEG
       (ECLIPTIC) IS PRINTED IF APPLICABLE)

LINE D
      (DATE AND TIME OF RUN)   (CENTRAL BODY)   (EQUATIONS OF MOTION)



                              GEOCENTRIC


(TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)

GEOCENTRIC                                                (COORDINATE PLANE)

LINE A
        X VERNAL EQUINOX CARTESIAN POSITION, KM
        Y
        Z
       DX VERNAL EQUINOX CARTESIAN VELOCITY, KM/SEC
       DY
       DZ
LINE B
        R RADIUS, KM
      DEC DECLINATION, DEG
       RA RIGHT ASCENSION, DEG
        V INERTIAL SPEED, KM/SEC
      PTH INERTIAL PATH ANGLE, DEG
       AZ INERTIAL AZIMUTH ANGLE, DEG
LINE C
        R RADIUS, KM
      LAT GEOCENTRIC LATITUDE, DEG
      LON EARTH-FIXED LONGITUDE, DEG
       VE EARTH-FIXED SPEED, KM/SEC
      PTE EARTH-FIXED PATH ANGLE, DEG
      AZE EARTH-FIXED AZIMUTH ANGLE, DEG
LINE D
       XS THE GEOCENTRIC POSITION OF THE SUN, KM
       YS
       ZS
      DXS THE GEOCENTRIC VELOCITY OF THE SUN, KM/SEC
      DYS
      DZS
LINE E
       XM THE GEOCENTRIC POSITION OF THE MOON, KM
       YM
       ZM
      DXM THE GEOCENTRIC VELOCITY OF THE MOON, KM/SEC
      DYM
      DZM
LINE F
       XT THE GEOCENTRIC POSITION OF THE TARGET BODY, KM
       YT
       ZT
      DXT THE GEOCENTRIC VELOCITY OF THE TARGET BODY, KM/SEC
      DYT
      DZT
LINE G
       RS EARTH-SUN DISTANCE, KM
       VS GEOCENTRIC SPEED OF SUN, KM/SEC
       RM EARTH-MOON DISTANCE, KM
       VM GEOCENTRIC SPEED OF MOON, KM/SEC
       RT EARTH-TARGET DISTANCE, KM
       VT GEOCENTRIC SPEED OF TARGET, KM/SEC

      CONTINUED ON NEXT PAGE
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LINE H
      GEO GEOCETIC LATITUDE, DEG
      ALT ALTITUDE ABOVE THE EARTHS SURFACE, KM
      LOS LONGITUDE OF SUN, DEG
      RAS RIGHT ASCENSION OF SUN, DEG
      RAM RIGHT ASCENSION OF MOON, DEG
      LOM LONGITUDE OF MOON, DEG
LINE I
      DUT EPHEMERIS TIME MINUS UNIVERSAL TIME, SEC
       DT ADAMS-MOULTON STEP SIZE, SEC
       DR GEOCENTRIC RADIAL SPEED OF PROBE, KM/SEC
      SHA SUN SHADOW PARAMETER, KM
      DES DECLINATION OF THE SUN, DEG
      DEM DECLINATION OF THE MOON, DEG
LINE J
      CCL CANOPUS CLOCK ANGLE, DEG
      MCL MOON CLOCK ANGLE, DEG
      TCL TARGET CLOCK ANGLE, DEG
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                               HELIOCENTRIC


HELIOCENTRIC                                          (COORDINATE PLANE)

LINE A
        X VERNAL EQUINOX CARTESIAN POSITION, KM
        Y
        Z
       DX VERNAL EQUINOX CARTESIAN VELOCITY, KM/SEC
       DY
       DZ
LINE B
        R SUN-PROBE RADIUS, KM
      LAT CELESTIAL LATITUDE - OR DECLINATION - OF THE PROBE, DEG
      LON CELESTIAL LONGITUDE - OR RIGHT ASCENSION - OF THE PROBE, DEG
        V INERTIAL SPEED, KM/SEC
      PTH PATH ANGLE, DEG
       AZ AZIMUTH ANGLE, DEG
LINE C
       XE HELIOCENTRIC POSITION OF THE EARTH, KM
       YE
       ZE
      DXE HELIOCENTRIC VELOCITY OF THE EARTH, KM/SEC
      DYE
      DZE
LINE D
       XT HELIOCENTRIC POSITION OF THE TARGET, KM
       YT
       ZT
      DXT HELIOCENTRIC VELOCITY OF THE TARGET, KM/SEC
      DYT
      DZT
LINE E
      LTE CELESTIAL LATITUDE - OR DECLINATION - OF THE EARTH, DEG
      LCE CELESTIAL LONGITUDE - OR RIGHT ASCENSION - OF THE EARTH, DEG
      LTT CELESTIAL LATITUDE - OR DECLINATION - OF THE TARGET, DEG
      LOT CELESTIAL LONGITUDE - OR RIGHT ASCENSION - OF THE TARGET, DEG
      RST DISTANCE OF THE TARGET FROM THE SUN, KM
      VST SPEED OF THE TARGET WITH RESPECT TO THE SUN, KM/SEC

      EPS EARTH-PROBE-SUN ANGLE, DEG
      ESP EARTH-SUN-PROBE ANGLE, DEG
      SEP SUN-EARTH-PROBE ANGLE, DEG
      EPM EARTH-PROBE-MOON ANGLE, DEG
      EMP EARTH-MOON-PROBE ANGLE, DEG
      MEP MOON-EARTH-PROBE ANGLE, DEG
LINE G
      MPS MOON-PROBE-SUN ANGLE, DEG
      MSP MOON-SUN-PROBE ANGLE, DEG
      SMP SUN-MOON-PROBE ANGLE, DEG
      SEM SUN-EARTH-MOON ANGLE, DEG
      EMS EARTH-MOON-SUN ANGLE, DEG
      ESM EARTH-SUN-MOON ANGLE, DEG


LINE H  (NOT PRINTED IF TARGET=MOON)
      EPT EARTH-PROBE-TARGET ANGLE, DEG
      ETP EARTH-TARGET-PROBE ANGLE, DEG
      TEP TARGET-EARTH-PROBE ANGLE, DEG
      TPS TARGET-PROBE-SUN ANGLE, DEG
      TSP TARGET-SUN-PROBE ANGLE, DEG
      STP SUN-TARGET-PROBE ANGLE, DEG
LINE I  (ONLY RPM AND SPN ARE PRINTED IF TARGET=MOON)
      SET SUN-EARTH-TARGET ANGLE, DEG
      STE SUN-TARGET-EARTH ANGLE, DEG
      EST EARTH-SUN-TARGET ANGLE, DEG
      RPM PROBE-MOON DISTANCE, KM
      RPT PROBE-TARGET DISTANCE, KM
      SPN SUN-PROBE-NEAR LIMB OF EARTH ANGLE, DEG
LINE J (PRINTED IF RADIATION PRESSURE OPTION IS USED)
      SAC SOLAR RADIATION PRESSURE ACCELERATION MAGNITUDE
LINE K
      GCE CLOCK ANGLE OF EARTH, DEG
      GCT CLOCK ANGLE OF TARGET, DEG
      SIP SUN-PROBE-NEAR LIMB OF TARGET ANGLE, DEG
      CPT CANOPUS-PROBE-TARGET ANGLE, DEG
      SIN CANOPUS-PROBE-NEAR LIMB OF TARGET ANGLE, DEG
LINE L
      REP EARTH PROBE DISTANCE, KM
      VEP VELOCITY OF THE PROBE WITH RESPECT TO EARTH, KM/SEC
      CPE CANOPUS-PROBE-EARTH ANGLE, DEG
      CPS CANOPUS-PROBE-SUN ANGLE, DEG
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                              (TARGET)CENTRIC


(TARGET)CENTRIC                                           (COORDINATE PLANE)

LINE A
        X TARGET-CENTERED VERNAL EQUINOX POSITION, KM
        Y
        Z
       DX TARGET-CENTERED VERNAL EQUINOX VELOCITY, KM/SEC
       DY
       DZ
LINE B
        R RADIUS FROM TARGET CENTER, KM
      DEC DECLINATION - OR CELESTIAL LATITUDE, DEG
       RA RIGHT ASCENSION - OR CELESTIAL LONGITUDE, DEG
        V SPEED RELATIVE TO THE TARGET, KM/SEC
      PTH TARGET-BODY PATH ANGLE, DEG
       AZ TARGET-BODY AZIMUTH ANGLE, DEG
LINE C  (PRINTED ONLY IF TARGET=MOON)
        R RADIUS FROM TARGET CENTER, KM
      LAT TARGET-CENTERED LATITUDE, DEG
      LON TARGET-CENTERED LONGITUDE, DEG
       VP SPEED RELATIVE TO THE ROTATING TARGET, KM/SEC
      PTP ROTATING TARGET-BODY PATH ANGLE, DEG
      AZP ROTATING TARGET-BODY AZIMUTH ANGLE, DEG
LINE D  (PRINTED ONLY IF TARGET=MOON)
      LTS SELENOGRAPHIC LATITUDE OF THE SUN, DEG
      LNS SELENOGRAPHIC LONGITUDE OF THE SUN, DEG
      LTE SELENOGRAPHIC LATITUDE OF THE EARTH, DEG
      LNE SELENOGRAPHIC LONGITUDE OF THE EARTH, DEG
LINE E
      ALT ALTITUDE ABOVE THE TARGET BODYS SURFACE, KM
      SHA SUNS SHADOW PARAMETER, KM
          SHA = -ABS(RTP X 1RTS)*SGN(RTP DOT RTS)
      ALP ILLUMINATED CRESCENT ORIENTATION VIEWING ANGLE, DEG
          ALP = ARCCS(A DOT V) WHERE -S3 = 1RTP   W = 1(S3 XS4)   V = WXS3
                                      S4 = 1RTS   U = (0,0,1)     A = 1(UXS3)
       DR RADIAL RATE, KM/SEC
       DP TRANSVERSE ANGULAR VELOCITY, DEG/SEC
      ASD ANGULAR SEMIDIAMETER OF TARGET AS SEEN FROM S/C, DEG
LINE F
      HGE RIGHT ASCENSION OF EARTH IN SPACECRAFT COORDINATE SYSTEM, DEG
      SVL DECLINATION OF TARGET IN SPACECRAFT COORDINATE SYSTEM, DEG
      HNG RIGHT ASCENSION OF TARGET IN SPACECRAFT COORDINATE SYSTEM, DEG
      SIA EARTH-PROBE-NEAR LIMB OF TARGET ANGLE, DEG
LINE G (PRINTED IF RADIATION PRESSURE OPTION IS USED)
      SAC SOLAR RADIATION PRESSURE ACCELERATION MAGNITUDE


      THE FOLLOWING ADDITIONAL LINES ARE PRINTED
      IF MARS IS THE TARGET. ALL VARIABLES ARE
      REFERENCED TO A MARS EQUATORIAL INERTIAL COORDINATE
      SYSTEM OR TO A MARS FIXED COORDINATE SYSTEM

LINE H
                                       AREOCENTRIC EQUATORIAL COORDINATES
LINE I
        X MARS EQUATORIAL, MARS-PROBE POSITION, KM
        Y
        Z
       DX MARS EQUATORIAL, MARS-PROBE VELOCITY, KM/SEC
       DY
       DZ
LINE J
        R RADIUS FROM MARS CENTER, KM
      DEC DECLINATION, DEG
       RA RIGHT ASCENSION, DEG
        V SPEED RELATIVE TO MARS, KM/SEC
      PTH PATH ANGLE, DEG
       AZ AZIMUTH ANGLE, DEG
LINE K
        R RADIUS FROM MARS CENTER, KM
      LAT MARS-CENTERED LATITUDE, DEG
      LON MARS-FIXED LONGITUDE, DEG
       VP SPEED RELATIVE TO ROTATING MARS, KM/SEC
      PTP PATH ANGLE RELATIVE TO ROTATING MARS, DEG
      AZP AZIMUTH ANGLE RELATIVE TO ROTATING MARS, DEG
LINE L
      RAE RIGHT ASCENSION OF THE EARTH, DEG
      DEE DECLINATION OF THE EARTH, DEG
      RAS RIGHT ASCENSION OF THE SUN, DEG
      DES DECLINATION OF THE SUN, DEG
      LOE LONGITUDE OF THE EARTH, DEG
      LOS LONGTITUDE OF THE SUN, DEG
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```
                         GEO OR HELIO OR TARGET CONIC


GROUP A

                                       (BODY) CONIC

EPOCH OF PERICENTER PASSAGE (EP SEC PAST 1950) (JD) (CALENDAR DATE)
LINE A
        SMA SEMIMAJOR AXIS,KM
        ECC ECCENTRICITY,UNITLESS
        B   MAGNITUDE OF B VECTOR,KM
        SLR SEMILATUS RECTUM,KM
        APO APOCENTER DISTANCE,KM
        RCA CLOSEST APPROACH DISTANCE,KM
LINE B
        VH  HYPERBOLIC EXCESS SPEED,VELOCITY AT APOGEE FOR ELLIPSE,KM/SEC
        C3  TWICE TOTAL ENERGY PER UNIT MASS OR VIS VIVA INTEGRAL,KM*2/SEC*2
        C1  ANGULAR MOMENTUM,KM*2/SEC
        TFP TIME FROM PERICENTER PASSAGE,SEC
        TF  TIME FROM INJ TO PERICENTER PASSAGE IN HRS FOR EARTH-MOON TRAJ,
                IN DAYS OTHERWISE

        PER PERIOD, MIN EXCEPT DAYS IF HELIO, PRINTED ONLY IF C3 IS -
        LTF LINEARIZED TIME-OF-FLIGHT IN HRS FOR EARTH-MOON TRAJ, IN DAYS
                OTHERWISE   PRINTED ONLY IF C3 IS + IN PLACE OF PER
LINE C
        TA  TRUE ANOMALY,DEG
        MTA MAXIMUM TRUE ANOMALY,DEG
        EA  ECCENTRIC ANOMALY,DEG
        MA  MEAN ANOMALY,DEG
        C3J JACOBI CONSTANT, KM*2/SEC*2, PRINTED IN GEO AND SELENO CONICS ONLY
        TFI TIME FROM INJECTION IN HRS FOR EARTH-MOON TRAJ, IN DAYS OTHERWISE
LINE D    (PRINTED ONLY IF C3 IS + AND IF CONIC IS TARGET CONIC)
        ZAE ANGLE BETWEEN IN. ASYMPTOTE AT TARG AND TARG-EARTH VECTOR,DEG
        ZAP ANGLE BETWEEN IN. ASYMPTOTE AT TARG AND TARG-SUN VECTOR,DEG
        ZAC ANGLE BETWEEN IN. ASYMPTOTE AT TARG AND TARG-CANOPUS VECTOR,DEG
        DEF ANGLE BETWEEN INCOMING AND OUTGOING ASYMPTOTES,DEG
        IR  IMPACT RADIUS,KM
        GP  ANGLE BETWEEN IN. ASYMPTOTE AND ITS PROJ. ON ORB. PLANE OF TARG,DEG


GROUPS B,C,D

                                       ALL VECTORS REFERENCED TO (       ) PLANE

LINE A
        X   BODY-PROBE POSITION VECTOR IN COORD. SYSTEM GIVEN ABOVE,KM
        Y
        Z
        DX  BODY-PROBE VELOCITY VECTOR IN COORD. SYSTEM GIVEN ABOVE, KM/SEC
        DY
        DZ
LINE B
        INC INCLINATION OF PROBE ORBIT PLANE TO PLANE GIVEN ABOVE,DEG
        LAN LONGITUDE OR RIGHT ASCENSION OF ASCENDING NODE,DEG
        APF ARGUMENT OF PERICENTER,DEG
        MX  UNIT M VECTOR      M = W X 1RO
        MY
        MZ
LINE C
        WX  UNIT W VECTOR
        WY
        WZ
        PX  UNIT P VECTOR
        PY
        PZ
LINE D
        QX  UNIT Q VECTOR
        QY
        QZ
        RX  UNIT R VECTOR
        RY
        RZ
LINE E
        SX  UNIT S VECTOR
        SY
        SZ
        TX  UNIT T VECTOR    T = R X S
        TY
        TZ
LINE F    (PRINTED ONLY IF C3 IS +)
        SXI UNIT INCOMING ASYMPTOTE VECTOR
        SYI
        SZI
        DAI DECLINATION OR LATITUDE OF INCOMING ASYMPTOTE,DEG
        RAI RIGHT ASCENSION OR LONGITUDE OF INCOMING ASYMPTOTE,DEG


LINE G    (PRINTED ONLY IF C3 IS +)
        SXO UNIT OUTGOING ASYMPTOTE VECTOR
        SYO
        SZO
        DAO DECLINATION OR LATITUDE OF OUTGOING ASYMPTOTE,DEG
        RAO RIGHT ASCENSION OR LONGITUDE OF OUTGOING ASYMPTOTE,DEG
LINE H    (PRINTED ONLY IF C3 IS + AND IF CONIC IS TARGET CONIC)
        ETE ANGLE BETWEEN T AND PROJ. OF EARTH-TARG VECTOR ON R-T PLANE,DEG
        ETS ANGLE BETWEEN T AND PROJ. OF SUN-TARG VECTOR ON R-T PLANE,DEG
        ETC ANGLE BETWEEN T AND PROJ. OF CANOPUS-TARG VECTOR ON R-T PLANE,DEG
LINE I    (PRINTED ONLY IF C3 IS -)
        DAP DECLINATION OF ASYMPTOTE,DEG
        RAP RT. ASCENSION OF ASYMPTOTE,DEG
LINE J
        BTX T COMPONENT OF B,KM  WHERE X=Q FOR EARTH EQU., X=C FOR ECLIPTIC
        BRX R COMPONENT OF B,KM        X=O FOR TARG ORBIT, X=T FOR TARG EQU
        B   MAGNITUDE OF B,KM
        THA DIRECTION ANGLE OF IMPACT PARAMETER IN R-T PLANE MEASURED + FROM T
        T VECTOR IN (      ) PLANE
```

```
              OUTPUT DESIGNATING BEGINNING OF TRAJECTORY BURN


LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  START BURN


              OUTPUT DESIGNATING END OF TRAJECTORY BURN

LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  END BURN


              OUTPUT DESIGNATING BEGINNING OF GAS JET COMPUTATION

LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  START GAS JETS


              OUTPUT DESIGNATING END OF GAS JET COMPUTATION


LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  END GAS JETS
```

```
                           SHADOW PARAMETERS


* WHEN PROBE ENTERS, LEAVES,IS IN, OR OUT OF A BODYS SHADOW
  ONE OF THE FOLLOWING SET OF TWO LINES WILL BE OUTPUT


LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  PROBE IS ENTERING (BODY) SHADOW

LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  PROBE IS LEAVING (BODY) SHADOW

LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  PROBE IS IN (BODY) SHADOW

LINE A
  (TIME PAST INJECTION) (EQUINOX)  (DP SEC PAST 1950)  (JD)  (CALENDAR DATE)
LINE B
  PROBE IS OUT OF (BODY) SHADOW
```

C. JOB-SHOP OUTPUT CAPABILITY

1. In the job-shop mode of operation, printed output is put on tape SYSOU1. Or, by proper use of input parameter FLAG42, the output is put on low density tape SYSPL1. The latter tape can be processed by the S-C 4020 High-Speed Microfilm Recorder. Subroutine PROUT is utilized to produce the line images for SYSOU1 or SYSPL1.

2. Output also appears on the 7094 on-line printer. The progress of the trajectory and the occurrence of errors are noted. Subroutine ERPRT is utilized to produce the on-line print. Additional on-line print capability is available by proper use of the 7094 console sense switches or by input. A minimum on-line print (defined as on-line printing of injection conditions, phase changes and encounter conditions) is obtained by depressing sense switch 6. A detailed or fine on-line print (defined as the duplication, on-line, of all output on SYSOU1 or SYSPL1) is obtained by depressing sense switches 4 and 6. The sense switches, hence the on-line print request, may be changed at will during the computation of the trajectory. If desired, input parameter OPTSWT may be used to preset the on-line print request in the source deck.

3. The spacecraft ephemerides may be put on disk file or on high density binary tape SYSUT5. Input parameter SCFORF controls which option is to be used.

4. Debugging output (SNAP) may be used (Ref. 4, Section VIII). SPACE's FILE control card must have the following format:

Column

1	8	16
$	FILE	147

D. SFOF OUTPUT CAPABILITY

The SFOF output capability is similar to the job-shop output capability. The normal output is put on SYSOU1. The on-line output control and printing are done at remote user area 5, instead of at the 7094 console and printer. The progress of the trajectory and the occurrence of errors are printed on the remote administrative printer. The minimum or fine print of the trajectory is printed on the remote SC-3070 printer. This minimum or fine on-line SC-3070 print is controlled by the remote console option switches 33 and 35 (corresponding to sense switches 4 and 6). If desired, input parameter OPTSWT may be used to preset the on-line print request in the source deck.

The spacecraft ephemerides are treated the same as in the job-shop mode but the debugging output capability (SNAP) does not exist.

VI. SUBROUTINES

SPACE is made up of 45 closed subroutines, some of which have more than one entry and perform more than one function. Many subroutines have not changed in function from Ref. 1 (Section VIII) but the documentation was repeated in this Technical Memorandum (TM 33-198) for completeness. All subroutines were documented according to the following specifications:

IDENTIFICATION

Entry name(s)
Programmer(s)
Coding language
Date

PURPOSE

Defines the task performed by this subroutine.

RESTRICTIONS

Cites the error conditions, external buffers used, COMMON used, subroutines used, etc., (COMMON names and subroutine names are capitalized).

METHOD

Gives a detailed description of how the subroutine accomplishes its task. Includes a flow chart when applicable.

USE

Defines all calling sequences, including the definition and use of input and output parameters.

CODING INFORMATION

Gives the decimal and octal sizes of the subroutine excluding COMMON storage or external buffer storage.

REFERENCES

Gives Requests for Programming (RFP) number, Inter-Office Memoranda (IOM's) and technical references if applicable.

IDENTIFICATION

ABORT/ERPRT/JEXIT/PRSET/....../TIME
Nicholas S. Newhall, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

To handle communication between SPACE and the various systems, I/O devices, switches, flags and subroutines.

RESTRICTIONS

a. Entries RUNID, PRTSWX, FLAG42, COMTRJ, COMTRK and COMFLG are provided for those input parameters.
b. The on-line printer is sensed to obtain the date and time-of-day if the parameter EXPORT is zero.
c. The print flags are in COMMON locations SP1A, · · · , SP3C, EJCTA, EJCTB, EJCTC, 37HED, PRFLG and PRTSWT.
d. Subroutines TYPWRT and PROUT are used for on-line printing.

METHOD

a. PRSET examines the input flags, the 7094 sense-switches, the SFOF mode cell SFMODE, and user area option switches in order to set the appropriate COMMON print flags for PROUT.
b. ERPRT prints the on-line messages. The 7094 on-line printer or the remote user area administrative printer will print the message, depending on the contents of parameter SFMODE.
c. TIME provides the user with the BCD time-of-day in the AC and the computer code letter A, B or C left adjusted in the MQ and followed by blanks.
d. JEXIT prints "END TRAJECTORY (SPACE)", closes the output files used by PROUT and returns control to JPTRAJ with a zero in the accumulator, designating a normal return.
e. ABORT prints "END TRAJECTORY (SPACE)", closes the output files used by PROUT and returns control to JPTRAJ with a one in the accumulator, designating the error return.
f. ...... is the location of the Program Control Block (PCB) and contains the information JPTRAJ needs to set up for and transfer control to SPACE.

USE

Calling sequences:

a. CALL PRSET
   return

b. TSX $ERPRT, 4, N
   PZE A, , B
   return
   where

A, · · · , A+(B-1)	contain BCD text
B	is the number of words of text, $B \leq 12$
N = 0	means message not printed off-line
= 2	means message printed off-line after a double space
= 3	means message printed off-line after a page eject.

c. CALL TIME
   return

d. CALL JEXIT
   (transfers control to JPTRAJ)

e. CALL ABORT
   (transfers control to JPTRAJ)

CODING INFORMATION

Length of subroutine is 757(10) or 1365(8) words.

2

IDENTIFICATION

ACCEL

Peter S. Fisher, JPL

IBM 7094 Fap

December 2, 1964

PURPOSE

To obtain the acceleration of the probe referenced to a true-of-date Earth equatorial, Earth centered, space fixed coordinate system.

RESTRICTIONS

a. The subroutines BODY, BODY1, PROD, and MATRIX are used.
b. The entries GRAV, CBM, CG, and RADSO are referenced.

METHOD

The following accelerations are taken into account:

a. Earth oblateness
b. Mars oblateness
c. Lunar oblateness
d. Gas jets
e. Motor burn
f. Radiation pressure
g. N-bodies
h. Central body

The sum of these accelerations is multiplied by the (NA) matrix to rotate it from a mean 1950.0 coordinate system to a true-of-date coordinate system. This system is inertial and centered at the Earth.

USE

Calling sequence:

```
CALL    ACCEL
PZE     A
return
```

where A is the location of the (output) acceleration vector.

CODING INFORMATION

Length of subroutine is 98(10) or 142(8) words.

IDENTIFICATION 3

ADD
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To perform double precision addition of two double precision floating point numbers.

RESTRICTIONS

a. If the numbers involved are sufficiently large so as to cause overflow, erroneous results will be obtained.
b. Uses COMMON to COMMON + 3.

METHOD

The contents of the AC-MQ registers and/or the contents of specified cells in core storage (see USE) are added using the DFAD machine instruction. The high order part of the result is placed in the AC and the low order part in the MQ.

USE

Calling sequences:

a.
```
CALL    ADD
return
```
Enter with one of the double precision numbers in the AC-MQ and the other number in COMMON and COMMON + 1. Exit with the result in the AC-MQ.

b.
```
CALL    ADD        or        CALL    ADD, YI, 0
TSX     YI, 0
TSX     0, 0
return
```
Enter with one of the double precision numbers in the AC-MQ and the other number in YI and YI + 1. Exit with the result in the AC-MQ.

c.
```
CALL    ADD        or        CALL    ADD, YI, ZI
TSX     YI, 0
TSX     ZI, 0
return
```
Enter with one of the double precision numbers in YI and YI + 1 and the other number in ZI and ZI + 1. Exit with the result in the AC-MQ.

CODING INFORMATION

Length of the subroutine is 25(10) or 31(8) words.

IDENTIFICATION 4

ARCOS/ARSIN
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute arcsine x or arccosine x for a floating point, single precision x, in degrees.

RESTRICTIONS

If $|x| > 1.0$ the result will be ±90.0 for the arcsine, taking the same sign as the argument, and will be 180.0 for the arccosine for a negative argument and 0.0 for the arccosine for a positive argument.

METHOD

$\mathrm{Sin}^{-1}\, x = \pi/2 - \sqrt{1-x}\ F(x)$, $\cos^{-1} x = \sqrt{1-x}\ F(x)$

where $F(x) = \sum_{i=o}^{7} C_i x^i$, and

$C_0 = 1.570796327$	$C_4 = 0.0308918810$
$C_1 = -0.2145988016$	$C_5 = -0.0170881256$
$C_2 = 0.0889789874$	$C_6 = 0.0066700901$
$C_3 = -0.0501743046$	$C_7 = -0.0012624911$

Accuracy: 7 significant decimal digits.

USE

Enter with the argument in the accumulator. Exit with the result in the accumulator in degrees.

Calling sequences:

for arccosine:

```
CLA    X
CALL   ARCOS
return
```

for arcsine:

```
CLA    X
CALL   ARSIN
return
```

CODING INFORMATION

Length of subroutine is 96(10) or 140(8) words.

IDENTIFICATION

5

ARTAN
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute arctangent (y/x) in degrees for floating point, single precision x and y.

RESTRICTIONS

Uses COMMON to COMMON + 4.

METHOD

The following Rand approximating polynomial is used:

$$\text{Arctan } (y/x) = \text{Arctan } D = \pi/4 + \sum_{i=0}^{7} C_{2i+1}\left(\frac{D-1}{D+1}\right)^{2i+1}$$

where:

$$C_1 = 0.9999993329 \qquad C_9 = 0.0964200441$$
$$C_3 = -0.3332985605 \qquad C_{11} = -0.0559098861$$
$$C_5 = 0.1994653599 \qquad C_{13} = 0.0218612288$$
$$C_7 = -0.1390853351 \qquad C_{15} = -0.0040540580$$

Accuracy: 7 significant figures.

USE

Enter with y in the accumulator and x in the MQ. Exit with Arctan (y/x) in the accumulator in degrees normalized to lie in the range 0 to 360.

Calling sequence:

```
CLA    Y
LDQ    X
CALL   ARTAN
return
```

CODING INFORMATION

Length of subroutine is 57(10) or 71(8) words.

IDENTIFICATION

BCDNO/NEWBCD
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To replace a BCD word (the name of a celestial body) in the accumulator with a fixed point number scaled 35. This number will be used as a reference number in locating data pertinent to that body.

RESTRICTIONS

a. An error is possible if the BCD word is not recognized (see USE), in which case a comment to this effect is printed and control is given to ABORT.
b. ERPRT, PROUT and ABORT may be called.
c. NEWBCD is provided so that SATURN may be replaced by some other body name.

METHOD

The accumulator is compared with each of seven BCD words until equality occurs. Each comparison is counted and, at equality, this count, in fixed point scaled 35, replaces the accumulator.

USE

Calling sequence:

```
CAL     L(BCD word)
CALL    BCDNO
return
```

If (BCD word) =	EARTH	return with accumulator	= 0
	MOON		= 1
	SUN		= 2
	VENUS		= 3
	MARS		= 4
	SATURN		= 5
	JUPITE		= 6

CODING INFORMATION

Length of subroutine is 36(10) or 44(8) words.

IDENTIFICATION

BODY/BODY1
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the negative of the n-body perturbation term.

RESTRICTIONS

a. Subroutine SQRT is used in forming the magnitude cubed of the position vectors. If a negative square root is attempted, the subroutines ERPRT and PROUT are called to print the error message:

NEGATIVE SQUARE ROOT IN BODY

and then subroutine ABORT is called.

b. COMMON through COMMON +13 are used.

METHOD

The negative of the n-body perturbation, $-\overline{P}$, is given by:

$$-\overline{P} = \sum_{j=1}^{n} \mu_j \left(\frac{\overline{R}_{jp}}{R_{jp}^3} + \frac{\overline{R}_j}{R_j^3} \right)$$

where

μ_j is the gravitational coefficient (GM) of body j

$\overline{R}_{jp}$ is the (j-body)-probe position vector and R_{jp} is its magnitude

$\overline{R}_j$ is the central body-(j-body) position vector and R_j is its magnitude.

Since the central body-probe position vector and the central body-(j-body) position vector are given as input, a vector subtraction is made to get the (j-body)-probe position vectors. In addition, a zero μ_j causes no computation to be made for body j.

USE

Calling sequences:

a. Setup entry:

```
CALL   BODY
PZE    A,, B
```

```
PZE    C,,D
PZE    E,,F
PZE    G
return
```

where

A, A+1, A+2	contain the input central body-probe position vector.
B	is the maximum number of non-central bodies.
C, $\cdots$, C+3 (B-1) +2	contain the input central body-(j-body) position vectors.
D, $\cdots$, D+ (B-1)	contain the input gravitational coefficients μ_j.
E, $\cdots$, E+ (B-1)	contain the magnitudes of the output central body-(j-body) position vectors for all j-bodies whose μ_j is non-zero.
F, $\cdots$, F+ (B-1)	contain the magnitudes of the output (j-body)-probe position vectors for all j-bodies whose μ_j is non-zero.
G, G+1, G+2	contain the output perturbation vector $-\overline{P}$.

and where the order for the position vectors, magnitudes and μ_j is:

Earth
Moon
Sun
Venus
Mars
Saturn
Jupiter

b. Execution entry:

```
CALL   BODY1
return
```

CODING INFORMATION

Length of subroutine is 109 (10) or 155 (8) words.

IDENTIFICATION

8

BOODSK/BOOFIN
Peter S. Fisher, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

To provide the ODP with a spacecraft ephemeris on disk. The data includes epoch, probe position, velocity, and acceleration with respect to the Earth, the variational equations and the nutations in obliquity and longitude at each end-of-step in a format compatible with both FORTRAN COMMON and the disk read routine DISCBU.

RESTRICTIONS

a. ROT, ACCEL, ERPRT, PROUT, and ABORT are called.
b. The nutation in obliquity and longitude are assumed to be stored in the locations NUTOBL and NUTLON, respectively. The total probe acceleration is assumed to be stored in location ACCEL.

METHOD

The true-of-date position and velocity are obtained via differencing and the use of the (NA) matrix. The acceleration is obtained from ACCEL. The variational equations and epoch are obtained from the HBANK in COMMON.

USE

Calling sequences:

CALL BOODSK	CALL BOOFIN
return	return

BOOFIN is used to dump the last record.
BOODSK must be called every end-of-step.

CODING INFORMATION

Length of subroutine is 546(10) or 1042(8) words.

9

IDENTIFICATION

CHANGE
Peter S. Fisher, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

To call PRINTD with special group and conic print flags.

RESTRICTIONS

The subroutines SPRAY and PRINTD are called, and GROP and ORBETT are referenced indirectly.

METHOD

The current group and conic print flags are saved and the desired replacements are substituted. SPRAY is called to prepare the GROPS flags for PRINTD and then PRINTD is called. Then the group and conic flags are reset and SPRAY is again called to restore the GROPS flags.

USE

Calling sequence:

```
CALL    CHANGE
OCT     A
OCT     B
return
```

where A is one word of twelve octal digits (designating the desired group options) and B is one word of twelve octal digits (designating the desired conic options).

CODING INFORMATION

Length of subroutine is 28(10) or 34(8) words.

IDENTIFICATION

CLASS
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

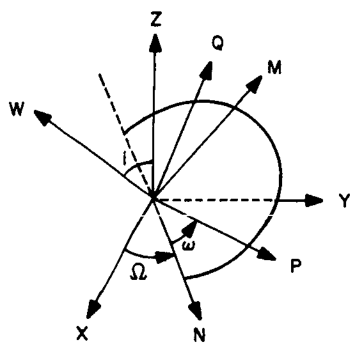
To calculate conic orbital elements.

RESTRICTIONS

a. CLASS is a subset of a rectangular-to-orbital elements package and uses other subroutines in the package.
b. COMMON through COMMON+3 are used.
c. An error can occur if the input value of c_3 is zero.
d. Subroutines SQRT, ARCOS and SIN are called.
e. Location HARMN is referenced indirectly to obtain the Earth's oblateness constants.

METHOD

The following sketch illustrates the relationship between the orbital elements and the reference $\hat{P}$, $\hat{Q}$, $\hat{W}$ and $\overline{X}$, $\overline{Y}$, $\overline{Z}$ frames:



Hence, $i = \cos^{-1} W_z$, where $0 \leqq i \leqq 180$ deg for the inclination

$$\left\{ \begin{array}{l} \sin \Omega = \dfrac{W_x}{\sin i} \\[2ex] \cos \Omega = \dfrac{-W_y}{\sin i} \end{array} \right.$$

where $0 \leqq \Omega < 360$ deg for the right ascension of the ascending node

$$\begin{cases} \sin\omega = \dfrac{P_z}{\sin i} \\ \\ \cos\omega = \dfrac{Q_z}{\sin i} \end{cases}$$

where $0 \leqq \omega < 360$ deg for the argument of the pericenter.

The formulas for Ω may be derived by constructing the unit vector $\hat{N}$ at the ascending node:

$$\hat{N} = \frac{\hat{U} \times \hat{W}}{|\hat{U} \times \hat{W}|}$$

where $\hat{U} = (0, 0, 1)$ and $\sin i = |\hat{U} \times \hat{W}|$. $\hat{N}$ is then projected onto the X and Y axes to give the formulas for the cosine and the sine.

Next, the auxiliary unit vector $\hat{M} = \hat{W} \times \hat{N}$ is constructed so that ω is given by:

$$\begin{cases} \sin\omega = \hat{P} \cdot \hat{M} = \hat{P} \cdot (\hat{W} \times \hat{N}) = -\hat{N} \cdot (\hat{W} \times \hat{P}) = -\hat{N} \cdot \hat{Q} \\ \\ \cos\omega = \hat{P} \cdot \hat{N} \end{cases}$$

The conic parameters are given by the standard formulas for $c_1 \neq 0$:

$q = \dfrac{p}{1 + \epsilon}$	the closest approach distance
$V_p = \dfrac{\mu(1 + \epsilon)}{c_1}$	the velocity at closest approach
$V_a = \dfrac{\mu(1 - \epsilon)}{c_1}$	velocity at farthest departure($c_3 < 0$)
$V_h = \sqrt{c_3}$	hyperbolic excess velocity ($c_3 > 0$)
$q_2 = a(1 + \epsilon)$	farthest departure distance ($c_3 < 0$)
$p = \dfrac{2\pi}{n}$	the period

For an Earth satellite, the quantities $\dot{\omega}$ and $\dot{\Omega}$ are also computed:

$$\dot{\omega} = \frac{nJa_{\oplus}^2}{p^2}\left(2 - \frac{5}{2}\sin^2 i\right)$$

$$\dot{\Omega} = \frac{-nJa_{\oplus}^2}{p^2}\cos i$$

where

- J is the coefficient of the second harmonic in the Earth's oblateness expression
- $a_{\oplus}$ is the Earth radius, km
- n is the mean motion, rad/sec
- p is the semilatus rectum, km

so that $\dot{\omega}$ and $\dot{\Omega}$ may be converted to deg/day for output.

USE

Calling sequence:

```
CALL    CLASS
PZE     A,,B
PZE     C
NOP
error return
normal return
```

where

A, ···, A+8	contain the input vectors $\hat{P}$, $\hat{Q}$, $\hat{W}$.
B, ···, B+7	contain the input parameters c_1, c_3, μ, ϵ, $1 - \epsilon$, a, p and n, respectively, as computed by JEKYL.
C, ···, C+9	contain the output parameters:
i,	inclination, radians
Ω,	right ascension of the ascending node, radians
ω,	argument of pericenter, radians
q,	closest approach distance, km
V_p,	velocity at closest approach, km/sec
V_a,	(or V_h if $c_3 > 0$), velocity at farthest departure (or hyperbolic excess velocity), km/sec
q_2,	(or zero if $c_3 > 0$), farthest departure distance, km
P	period, sec
$\dot{\omega}$	derivative of ω, deg/day
$\dot{\Omega}$	derivative of Ω, deg/day

The error exit will be taken if the input c_3 is zero.

CODING INFORMATION

Length of subroutine (includes CLASS as a subset) is 1226 (10) or 2312 (8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION

JEKYL
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the $\hat{P}$, $\hat{Q}$ and $\hat{W}$ vectors, the epoch of closest approach, and c_1 and c_3 from cartesian position and velocity vectors.

RESTRICTIONS

a. COMMON through COMMON+14 are used.
b. An error can occur if the logarithm or square root of a negative number is attempted.
c. Subroutines SQRT, UNIT, CROSS and LN are called.
d. JEKYL is a subset of a rectangular-to-orbital-elements package and uses several other subroutines in the package.
e. COMMON locations ECCEN, 1MINE, AVAL, PVAL, NORB, NU, JECAN and MENAN are used.

METHOD

Given the cartesian position and velocity vectors $\overline{R}$ and $\overline{V}$ compute:

$$p = \frac{R^2V^2 - (R\dot{R})^2}{\mu} \qquad \text{the semilatus rectum}$$

where

$$R\dot{R} = \overline{R} \cdot \overline{V}$$

$$c_1 = \sqrt{R^2V^2 - (R\dot{R})^2} \qquad \text{the angular momentum}$$

$$\frac{1}{a} = \frac{2\mu - RV^2}{R\mu}$$

$$c_3 = -\frac{\mu}{a} \qquad \text{the "energy" or vis viva integral}$$

At this point a test is made with the help of the I. D. input to determine whether or not a is an acceptable parameter. a* is defined by

$$a^* = \begin{cases} 10^{10} \text{ km for the planets} \\ 10^{9} \text{ km for the Sun} \\ 10^{12} \text{ km for the Moon} \end{cases}$$

The motion is considered parabolic and c_3 is set to zero whenever $|a| > a^*$.

$$1 - \epsilon^2 = \frac{p}{a}$$

$$\epsilon = \sqrt{1 - (1 - \epsilon^2)} \qquad \text{the eccentricity}$$

$$\begin{cases} \cos \nu = \dfrac{p - R}{\epsilon R} \\ \sin \nu = \dfrac{\dot{R}}{\epsilon}\sqrt{\dfrac{p}{\mu}} \end{cases} \qquad \text{true anomaly}$$

$$q = \frac{p}{1 + \epsilon} \qquad \text{closest approach distance}$$

$$\hat{W} = \frac{\overline{R} \times \overline{V}}{c_1} \qquad \text{unit angular momentum vector}$$

$$\hat{U}_1 = \frac{\overline{R}}{R}$$

$$\hat{V}_1 = \frac{R}{c_1}\overline{V} - \frac{\dot{R}}{c_1}\overline{R}$$

$$\hat{P} = \cos \nu \overline{U}_1 - \sin \nu \overline{V}_1$$

$$\hat{Q} = \sin \nu \overline{U}_1 + \cos \nu \overline{V}_1$$

If $c_3 \neq 0$, $T - T_p$ is computed from Kepler's equation according to the sign of a:

If $a > 0$:

$$\begin{cases} \cos E = \dfrac{R}{p}(\cos \nu + \epsilon) \\ \sin E = \dfrac{R}{p}\sqrt{1 - \epsilon^2} \sin \nu \end{cases}$$

$$M = E - \epsilon \sin E$$

if $1 - \epsilon > 0.1$ or if $1 - \epsilon \leqq 0.1$ and $|\sin E| > 0.1$

$$M = (1 - \epsilon) \sin E + \left(\frac{\sin^3 E}{6} + \frac{3 \sin^5 E}{40}\right)$$

if $1 - \epsilon \leqq 0.1$ and $\cos E > 0$, $|\sin E| \leqq 0.1$

$$M = n(T - T_p)$$

where

$$n = \sqrt{\mu} a^{-3/2}$$

if $a < 0$:

$$\sinh F = \frac{R\dot{R}}{\epsilon \sqrt{\mu |a|}}$$

$$M = \epsilon \sinh F - F$$

if $\epsilon - 1 > 0.1$ or if $\epsilon - 1 \leqq 0.1$ and $|\sinh F| > 0.1$

$$M = (\epsilon - 1) \sinh F - \left(\frac{3 \sinh^5 F}{40} - \frac{\sinh^3 F}{6}\right)$$

if $\epsilon - 1 \leqq 0.1$ and $|\sinh F| \leqq 0.1$

$$M = n(T - T_p)$$

where

$$n = \sqrt{\mu} |a|^{-3/2}$$

If $c_3 = 0$, the formula for the parabola is used:

$$M = \sqrt{\mu}(T - T_p) = qD + \frac{1}{6} D^3$$

where

$$D = R\dot{R}/\sqrt{\mu} = \sqrt{2q} \tan \nu/2$$

USE

Calling sequence:

```
CALL   JEKYL
PZE    0,,A
PZE    B,,C
```

PZE D
PZE E,,F
PZE G
error return
normal return

where

A	contains the μ (gravitational coefficient) of the body from which the input position and velocity vectors are measured.
A+1	contains an integer I.D. used in the parabola test: 0 = planets 1 = Moon 2 = Sun
B, B+1, B+2	contain the input cartesian position vector, $\overline{R}$.
C, C+1, C+2	contain the input cartesian velocity vector, $\overline{V}$.
D, ⋯, D+8	contain the output unit vectors $\hat{P}$, $\hat{Q}$, $\hat{W}$.
E	contains the input epoch T.
F	contains the output epoch of closest approach, T_p.
G, G+1, G+2	contain the output $\Delta T = T - T_p$, the angular momentum, c_1, and the energy or vis viva integral, c_3.

In addition, the following quantities are computed and stored in the COMMON locations given:

Location	Symbol	Description
ECCEN	ϵ	eccentricity
1MINE	$1-\epsilon$	1 minus eccentricity
AVAL	a	semimajor axis
PVAL	p	semilatus rectum
NORB	n	mean motion
NU	ν	true anomaly
JECAN	E(or F)	eccentric anomaly
MENAN	M	mean anomaly

The error exit is taken if a negative square root is attempted or if the logarithm of a negative number is attempted.

CODING INFORMATION

Length of subroutine (includes JEKYL as a subset) is 714(10) or 2312(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION

SPECL
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the reference unit vectors $\hat{R}$, $\hat{S}$, $\hat{T}$ and $\hat{B}$ and the impact parameters B · T, B · R.

RESTRICTIONS

a. COMMON through COMMON+3 are used.
b. Subroutines SQRT, ARCOS and SIN are called.
c. COMMON location PVAL and ECCEN are used.
d. SPECL is a subset of a rectangular-to-orbital-elements package and uses several other subroutines in the package.
e. External locations SAVA, INJTYP and RMAX are referenced indirectly.
f. An error will occur if a negative square root is attempted.

METHOD

The computation of the $\overline{S}$ and $\overline{B}$ vectors depends on the value of the eccentricity, ϵ:

a. $\epsilon \geq 1$, the hyperbolic case with $a < 0$:

$$\overline{S} = \begin{cases} \frac{1}{\epsilon}\overline{P} + \frac{\sqrt{\epsilon^2 - 1}}{\epsilon}\overline{Q} & \text{for the incoming asymptote} \\ \frac{-1}{\epsilon}\overline{P} + \frac{\sqrt{\epsilon^2 - 1}}{\epsilon}\overline{Q} & \text{for the outgoing asymptote} \end{cases}$$

$$\overline{B} = \begin{cases} \frac{|a|(\epsilon^2 - 1)}{\epsilon}\overline{P} - \frac{|a|\sqrt{\epsilon^2 - 1}}{\epsilon}\overline{Q} & \text{for the incoming asymptote} \\ \frac{|a|(\epsilon^2 - 1)}{\epsilon}\overline{P} + \frac{|a|\sqrt{\epsilon^2 - 1}}{\epsilon}\overline{Q} & \text{for the outgoing asymptote} \end{cases}$$

b. $\epsilon < 1$, the elliptic case with $a > 0$

$$\left.\begin{aligned} \overline{S} &= \overline{P} \\ \overline{B} &= a\sqrt{|\epsilon^2 - 1|}\,\overline{Q} \end{aligned}\right\}$$ for both the incoming and outgoing asymptote options

The remaining two reference vectors T and R are given in either the hyperbolic or elliptic case by

$$\overline{T} = \left(\frac{S_y}{\sqrt{S_x^2 + S_y^2}}, \frac{-S_x}{\sqrt{S_x^2 + S_y^2}}, 0 \right)$$

$$\overline{R} = \overline{S} \times \overline{T}$$

USE

Calling sequence:

```
CALL    SPECL
PZE     A, , B
PZE     C
error return
normal return
```

Enter with the semimajor axis, a, in the AC and the eccentricity, ϵ, in the MQ.

Where

A, ···, A+8 contain the input vectors $\hat{P}$, $\hat{Q}$, $\hat{W}$.

B contains zero for reference to an incoming asymptote and 1 for reference to an outgoing asymptote.

C, ···, C+14 contain the output B · T, B · R and vectors $\hat{S}$, $\hat{B}$, $\hat{T}$ and $\hat{R}$, respectively.

The error return is taken if a negative square root is attempted.

CODING INFORMATION

Length of subroutine (includes SPECL as a subset) is 714(10) or 2312(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision 1, Jet Propulsion Laboratory, Pasadena, California, **September** 1, 1962.

IDENTIFICATION 11

CLUCK

Peter S. Fisher, JPL

IBM 7094 Fap

December 2, 1964

PURPOSE

To compute the Canopus clock angle, Moon clock angle, and target clock angle.

RESTRICTIONS

The subroutines UNIT, CROSS, PROD, and ARTAN are called.

METHOD

$$\text{Clock} \measuredangle \triangleq \text{Tan}^{-1}\left(\frac{-\overline{A}\cdot\overline{C}}{\overline{B}\cdot\overline{C}}\right)$$

where:

$$\overline{A} = \frac{\overline{R}_{sp} \times \overline{R}_{ip}}{|\overline{R}_{sp} \times \overline{R}_{ip}|}$$

$$\overline{B} = \frac{\overline{A} \times \overline{R}_{sp}}{|\overline{A} \times \overline{R}_{sp}|}$$

$$\overline{C} = \frac{(\overline{N} \times \overline{R}_{sp}) \times \overline{R}_{sp}}{|(\overline{N} \times \overline{R}_{sp}) \times \overline{R}_{sp}|}$$

$\overline{R}_{sp} \triangleq$ True of-date Sun-probe position vector

$\overline{R}_{ip} \triangleq$ True of-date observation point-probe position vector

$\overline{N}$ $\begin{cases} \triangleq \text{True of-date probe-Canopus position vector for the Canopus clock angle} \\ \triangleq \text{True of-date Moon-probe position vector for the Moon clock angle} \\ \triangleq \text{True of-date target-probe position vector for the target clock angle} \end{cases}$

USE

Calling sequence:

```
Call CLUCK
PZE A, , B
return
```

where A is the location of the input $\overline{R}_{ip}$ vector and where B is the location where the three output clock angles will be stored.

CODING INFORMATION

Length of subroutine is 72(10) or 110(8) words

IDENTIFICATION 12

COS/SIN/QCOS/QSIN
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute sin x or cos x for a floating point, single precision x (x in radians or degrees).

RESTRICTIONS

a. Loops for large argument or small unnormalized argument.
b. Uses COMMOM to COMMON +2.

METHOD

The argument is reduced to a first quadrant equivalent and then a thirteenth order polynomial approximation, employing fixed point arithmetic, is used.
The cosine is computed by first adding $\pi/2$ to the argument.

USE

Enter with the argument in the accumulator.
Exit with the result in the accumulator.
Calling sequences:

for COS X				for SIN X			
X in radians		X in degrees		X in radians		X in degrees	
CLA	X	CLA	X	CLA	X	CLA	X
CALL	QCOS	CALL	COS	CALL	QSIN	CALL	SIN
return		return		return		return	

CODING INFORMATION

Length of subroutine is 159(10) or 237(8) words.

IDENTIFICATION

CROSS/PROD/UNIT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute: (1) the cross product of two vectors; or (2) the dot product of two vectors, or the magnitude and magnitude squared of one vector; or (3) a unit vector.

RESTRICTIONS

a. All vectors must be stored BES 3.
b. In the calling sequences to the CROSS and UNIT option the location given for the output vector may be the same as the location given for an input vector.

METHOD

The vector operations of vector product and scalar product and the multiplication of a vector by a scalar ($1/|v|$ to obtain a unit vector) are performed in a manner indicated by their definitions.

USE

Calling sequences:

a. To compute the vector product of two vectors $\overline{C} = \overline{A} \times \overline{B}$:

```
CALL    CROSS
PZE     A,,B
PZE     C
return
```

b. To compute the scalar product of two vectors $\overline{A} \cdot \overline{B}$:

```
CALL    PROD
MZE     A,,B
return
```

Exit with the result in the accumulator.

c. To compute the magnitude and magnitude squared of a vector A:

```
CALL    PROD
PZE     A
return
```

Exit with the magnitude in the AC and the magnitude squared in the MQ.

d. To obtain a unit vector $\overline{B} = \overline{A}/|\overline{A}|$;

```
CALL    UNIT
PZE     A,,B
return
```

CODING INFORMATION

Length of subroutine is 66(10) or 102(8) words.

IDENTIFICATION 14

DAYS
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To convert the double precision floating point seconds located in the AC and MQ to single precision integer days and residual seconds.

RESTRICTIONS

a. A double precision number is assumed to be two floating point words.
b. Subroutines FIX, FLOAT, and ADD are called.
c. Uses COMMON to COMMON +5.

METHOD

The double precision seconds are divided by 86,400 and the integral part of the result in single precision replaces the MQ. The residual seconds replace the AC.

USE

Enter with the seconds in the AC and MQ in double precision floating point. Exit with the residual seconds in floating point in the AC and the integral days in floating point in the MQ.

Calling sequence:

```
CLA     L(SECONDS A)
LDQ     L(SECONDS B)
CALL    DAYS
return
```

CODING INFORMATION

Length of subroutine is 25(10) or 31(8) words.

IDENTIFICATION 15

DUMMY/EOS/CANCLK/DATCEL/RGGSAV/RGGSTR/EXPORT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To allow certain parameters to be defined at program load time, and to provide storage and definition of miscellaneous quantities.

METHOD

EOS, RGGSAV and RGGSTR are defined. CANCLK is a three-word buffer for clock angles. DUMMY is provided for name only. DATCEL contains the BCD date of loading of the program in a format as follows: YYMMDD. EXPORT is a flag which controls the sensing of the 7094 on-line printer to read the JPL printer board and clock. If EXPORT is non-zero, no sensing of the on-line printer is made by the program. This is to allow non-JPL installations to use the program even if their printer board or clock hardware is different.

USE

This subroutine is always left symbolic and is the first physical subroutine in the deck. This allows for the word DATCEL and other parameters to be updated at load time, if necessary.

CODING INFORMATION

Length of subroutine is 9(10) or 11(8) words.

IDENTIFICATION

EARTH/SPACE
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

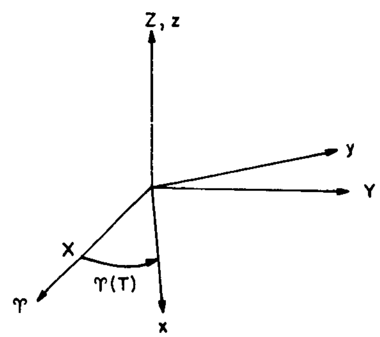
To rotate from space-fixed cartesian coordinates to Earth-fixed sphericals, and vice versa.

RESTRICTIONS

a. Subroutines COS, SIN, RVIN, RVOUT and MATRIX are called.
b. COMMON through COMMON+11 are used.
c. The COMMON locations GHA(T) and LOMEGA are assumed to contain the Greenwich hour angle in degrees and the Earth's rotation rate in radians/sec, respectively.

METHOD

At the epoch T a "space-fixed" cartesian coordinate system is defined, centered at the Earth with the X - Y plane the equator, the X axis the direction of the vernal equinox, and the Z axis the spin axis of the Earth. The "Earth-fixed" frame is obtained from the space-fixed by rotating about the Z axis by an angle ♈(T), the Greenwich hour angle of the vernal equinox, to bring the x axis in coincidence with the Greenwich meridian as shown in the following sketch:



The coordinates are then related by

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos ♈(T) & \sin ♈(T) \\ -\sin ♈(T) & \cos ♈(T) \end{pmatrix} \begin{pmatrix} X \\ Y \end{pmatrix}$$

$$z = Z,$$

and

$$\begin{pmatrix} \dot{x} \\ \dot{y} \end{pmatrix} = \begin{pmatrix} \cos\Upsilon(T) & \sin\ (T) \\ -\sin\Upsilon(T) & \cos\ (T) \end{pmatrix} \begin{pmatrix} \dot{X} \\ \dot{Y} \end{pmatrix} + \omega \begin{pmatrix} -\sin\Upsilon(T) & \cos\Upsilon(T) \\ -\cos\Upsilon(T) & -\sin\Upsilon(T) \end{pmatrix} \begin{pmatrix} X \\ Y \end{pmatrix}$$

$$\dot{z} = \dot{Z},$$

where ω is the rotation rate of the Earth.

The inverse transformation is

$$\begin{pmatrix} X \\ Y \end{pmatrix} = \begin{pmatrix} \cos\Upsilon(T) & -\sin\Upsilon(T) \\ \sin\Upsilon(T) & \cos\Upsilon(T) \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

$$Z = z$$

and

$$\begin{pmatrix} \dot{X} \\ \dot{Y} \end{pmatrix} = \begin{pmatrix} \cos\Upsilon(T) & -\sin\Upsilon(T) \\ \sin\Upsilon(T) & \cos\Upsilon(T) \end{pmatrix} \begin{pmatrix} \dot{x} \\ \dot{y} \end{pmatrix} + \omega \begin{pmatrix} -\sin\Upsilon(T) & -\cos\Upsilon(T) \\ \cos\Upsilon(T) & -\sin\Upsilon(T) \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

$$\dot{Z} = \dot{z}$$

SPACE performs the rotation from space-fixed cartesian to Earth-fixed cartesian and then calls subroutine RVOUT to obtain the Earth-fixed spherical set.

EARTH calls subroutine RVIN to make the transformation from Earth-fixed spherical to Earth-fixed cartesian and then performs the rotation from Earth-fixed cartesian to space-fixed cartesian.

USE

Calling sequences:

a. To rotate from space-fixed cartesian coordinates to Earth-fixed sphericals:

```
CALL   SPACE
PZE    A,,B
PZE    C,,D
```

where A, A+1, A+2 contain the input space-fixed cartesian position.

B, B+1, B+2 contain the input space-fixed cartesian velocity.

C, $\cdots$, C+5 contain the output Earth-fixed spherical set r, ϕ, θ, v, γ, σ.

D, $\cdots$, D+5 contain the output Earth-fixed cartesian set x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$.

b. To rotate from Earth-fixed sphericals to space-fixed cartesian coordinates:

```
CALL   EARTH
PZE    A
PZE    B,,C
```

where A, $\cdots$, A+5 contain the input Earth-fixed spherical set r, ϕ, θ, v, γ, σ.

B, B+1, B+2 contain the output space-fixed cartesian position coordinates X, Y, Z.

C, C+1, C+2 contain the output space-fixed cartesian velocity coordinates $\dot{X}$, $\dot{Y}$, $\dot{Z}$.

and where both entries assume that COMMON location GHA(T) and LOMEGA contain the Greenwich hour angle in degrees and the Earth's rotation rate in radians/sec, respectively.

CODING INFORMATION

Length of subroutine is 112(10) or 160(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION

ECLIP
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

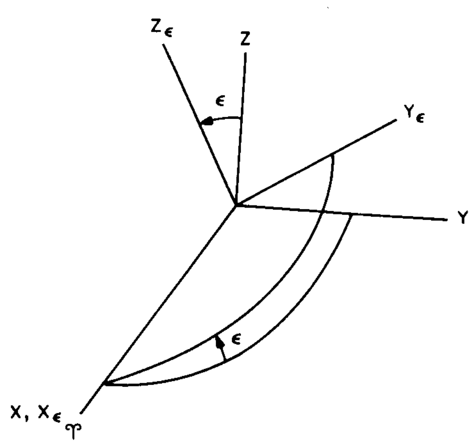
To rotate Earth equatorial coordinates to ecliptic and vice versa.

RESTRICTIONS

a. Subroutines SIN, COS and MATRIX are called.
b. COMMON+10 through COMMON+12 are used.
c. The cell ET in COMMON is assumed to contain the mean or true obliquity of the ecliptic.

METHOD

The ecliptic plane is characterized by its inclination to the Earth's equator, ϵ, the obliquity of the ecliptic, and its ascending node on the Earth's equator, the vernal equinox, as shown in the following sketch:



where X, Y, Z is the Earth equatorial frame and X_ϵ, Y_ϵ, Z_ϵ is the ecliptic. The coordinates are related by

$$\begin{pmatrix} X_\epsilon \\ Y_\epsilon \\ Z_\epsilon \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\epsilon & \sin\epsilon \\ 0 & -\sin\epsilon & \cos\epsilon \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}.$$

where ϵ can be the mean or true obliquity.

USE

Calling sequence:

```
CALL  ECLIP
PFX   X,,Y
return
```

where

X-3, X-2, X-1 contain the input vector.

Y-3, Y-2, Y-1 contain the output vector.

PFX = PZE assumes equatorial input and rotates to ecliptic.

PFX = MZE assumes ecliptic input and rotates to equatorial.

X = Y is permitted.

And where the COMMON location ET contains the input true of-date obliquity or the mean 1950.0 obliquity.

CODING INFORMATION

Length of subroutine is 45(10) or 55(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION 18

EFFECT

JPL Staff

IBM 7094 Fap

December 2, 1964

PURPOSE

To replace each of the output flags GROPS to GROPS +11 with a 0, 2, or 4 for the suppression, ecliptic, or equatorial output option, respectively.

RESTRICTIONS

a. It is assumed that subroutine SPRAY has previously been called so that GROPS to GROPS +11 contain the group output flags.

b. PHASE, GROPS and CODE, in COMMON, are used and GROP1 is referenced indirectly.

METHOD

The value of PHASE is found to be 0, 1 or >1 according as the start-of-phase, normal, or end-of-phase print condition has been met at the print epoch. At the same time each flag will be a one digit octal integer. Each of the resulting 24 possible combinations is considered and each branch replaces the flag with 0, 2, or 4 scaled 35.

The following table summarizes the combinations and results:

Initial value of octal flag	Resulting value of octal flag
0	0 for all values of PHASE
1	4 for all values of PHASE
2	2 for all values of PHASE
3	0 for all values of PHASE
4	2 for PHASE = 0, 0 otherwise
5	4 for PHASE = 0, 0 otherwise
6	2 for PHASE > 1, 0 otherwise
7	4 for PHASE > 1, 0 otherwise

USE

Calling sequence:

```
CALL    EFFECT
return
```

CODING INFORMATION

Length of subroutine is 40(10) or 50(8) words.

IDENTIFICATION

EPHEM
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

The ephemeris interpolation routine EPHEM is designed to read a JPL Ephemeris Tape and to interpolate for the position and/or velocity of any subset of the planets and Moon at any Julian date within the time interval spanned by the tape.

The ephemeris data carried on tape are in heliocentric coordinates for the planets and geocentric coordinates for the Moon. EPHEM, however, may be used to obtain coordinates referenced to any of the bodies as center. In particular, data are furnished for the Earth-Moon barycenter rather than for the Earth, and EPHEM performs the necessary calculations for obtaining geocentric coordinates of the planets and Sun.

The data on the ephemeris tape and the results of the interpolation are expressed in the coordinate system of the mean Earth equator and equinox of 1950.0.

RESTRICTIONS

a. Subroutines READB, BSREC, REWIND are called.
b. A buffer of 1862 cells must be provided by the user for storage of the raw ephemeris from the tape. Buffers of 36, 13, and 150 cells are also required by EPHEM, as described in USE.
c. EPHEM makes extensive use of 7094 double precision instructions, hence all tables must start in even core locations.
d. The ephemeris tape must be in the format described in Appendix A of Ref. 1.

METHOD

Everett's formula

$$x(T_j) = ux_0 + tx_1 + \frac{u(u^2-1)}{3!}\Delta_m^2 x_0 + \frac{t(t^2-1)}{3!}\Delta_m^2 x_1 + \frac{u(u^2-1)(u^2-4)}{5!}\Delta_m^4 x_1 + \frac{t(t^2-1)(t^2-4)}{5!}\Delta_m^4 x_1$$

is used for interpolation, where

T_j = the desired Julian date, $T \leq T_j < T + h$

h = step size of data

T = point in time at which data are tabulated

$t = (T_j - T)/h, 0 \leq t \leq 1$

$u = 1 - t$

$x_0 = x(T)$

$x_1 = x(T + h)$

$\Delta^n_m = n^{th}$ modified difference

It is assumed that the Julian date specified by the user as the epoch for which data are requested is in Universal Time. Since the ephemerides are tabulated in Ephemeris Time, the specified epoch is modified by

$$ET = UT + \Delta t$$

to convert to Ephemeris Time.

Planetary coordinates for centers other than the Sun are obtained by the vector subtraction

$$\overline{P} = \overline{P}_0 - \overline{C}$$

where

$\overline{P}$ = planetary coordinates referred to the desired center

$\overline{P}_0$ = planetary coordinates referred to the Sun

$\overline{C}$ = heliocentric coordinates of the desired center

A similar vector subtraction is performed for velocity vectors.

Calculation of the heliocentric coordinates of the Earth and/or Moon or the geocentric or selenocentric coordinates of the Sun and planets requires additional manipulations. Heliocentric lunar and Earth coordinates are obtained as

$$\overline{M} = \overline{B} + \mu_m \overline{L}$$

$$\overline{E} = \overline{B} - \mu_e \overline{L}$$

where

$\overline{M}$ = heliocentric coordinates of the Moon

$\overline{E}$ = heliocentric coordinates of the Earth

$\overline{B}$ = heliocentric coordinates of the Earth-Moon barycenter

$\overline{L}$ = geocentric coordinates of the Moon

$$\mu_m = \frac{\mu_E}{\mu_E + \mu_M}$$

$$\mu_e = \frac{\mu_M}{\mu_E + \mu_M}$$

μ_E = the GM of the Earth

μ_M = the GM of the Moon

Both μ_E and μ_M are obtained from TAB1, as described in the next section.

USE

The subroutine EPHEM may be used by either the FORTRAN II or the FAP programs. The calling sequence for a FORTRAN II program is

CALL EPHEM (JD, CENT, TAB1, TAB2, TAB3, TAB4, NTAPE)

and for the FAP program is

CALL EPHEM, JD, CENT, TAB1, TAB2, TAB3, TAB4, NTAPE

The arguments in the calling sequence are interpreted as follows:

JD = double-precision floating point Julian date T_j, assumed to be in Universal Time, at which data are required.

CENT = control-word floating point integer identifying the desired center of the coordinate system according to the scheme given in Table 1.

TAB1 = 36-word table of physical constants with the structure given in Table 2.

TAB2 = 13 floating point integers that control the data output for each body according to the scheme given in Table 3. The control-word sequence is given in Table 4.

TAB3 = 1862-word buffer used by EPHEM to store a record of ephemeris data as it is read from the ephemeris tape.

TAB4 = 150-word block of storage containing the output information listed in Table 5. The control-word integer in TAB4 is interpreted as shown in Table 6.

NTAPE = location of word containing a fixed-point number designating the logical tape unit on which the JPL Ephemeris Tape is mounted.

The nutations and nutation rates are always in units of radians and radians/day. The units of the planetary and lunar data are determined by the value of the output control word found in location TAB1 +34. If this single precision word is zero the output will be in kilometers and kilometers/sec; if this word is 1.0 the planetary data will be in AU and AU/day and the lunar data will be in "Earth-radii" and "Earth-radii"/day.

The output is always cartesian, referenced to the mean Earth equator and equinox of 1950.0.

CODING INFORMATION

a. When the routine is part of a new core load it will automatically rewind the ephemeris tape the first time called to allow it to retrieve the data in the identification records. This data defines the time span of data on the tape. The criterion for this rewind is comparison of the current tape unit designation with that of the previous call. Only if they are the same **will a rewind not** be issued. To prevent rewinds when chain type jobs are run, the entry TAPEX is provided. The six quantities starting at TAPEX may be "wanted" (see Ref. 2) from link to link in any compatible fashion to prevent rewinding. To deliberately cause a rewind, the entry EPTAPE is provided. If a zero is stored in this cell, the ephemeris tape will rewind the next time EPHEM is called.

b. Length of subroutine is 813(10) or 1455(8) words.

Table 1. Central body identification

Body	Control integer	Body	Control integer
Mercury	1.0	Neptune	8.0
Venus	2.0	Pluto	9.0
Earth	3.0	Sun	10.0
Mars	4.0	Moon	11.0
Jupiter	5.0	Earth-Moon barycenter	12.0
Saturn	6.0		
Uranus	7.0		

Table 2. TAB1 structure

Word in record	Physical constant and unit	Word format
TAB1	k = universal gravitational constant, $AU^{3/2}/day$	Double-precision floating point
TAB1+2	GM of Mercury, km^3/sec^2	↓
+4	GM of Venus, km^3/sec^2	
+6	GM of Earth, km^3/sec^2	
+8	GM of Mars, km^3/sec^2	
+10	GM of Jupiter, km^3/sec^2	
+12	GM of Saturn, km^3/sec^2	
+14	GM of Uranus, km^3/sec^2	
+16	GM of Neptune, km^3/sec^2	
+18	GM of Pluto, km^3/sec^2	
+20	GM of Sun, km^3/sec^2	
+22	GM of Moon, km^3/sec^2	
+24	Astronomical unit, km	
+26	Earth radius for lunar ephemeris conversion, km	
+28	Speed of light, km/sec	

Table 2 (Cont'd)

Word in record	Physical constant and unit	Word format
TAB1 +30	Solar-flux constant, lb-force/m^2	Double-precision floating point
+32	Seconds per mean solar day	Double-precision floating point
+34	Output-unit control word	Single-precision floating point
+35	Δt = ET - UT, sec	Single-precision floating point

Table 3. TAB2 output control interpretation

Control word	Meaning
0.0	No data, this body
1.0	Position data only, this body
2.0	Velocity data only, this body
3.0	Both position and velocity data, this body

Table 4. TAB2 structure

Word position	Body controlled	Word position	Body controlled
TAB2	Mercury	TAB2+7	Neptune
TAB2+1	Venus	+8	Pluto
+2	Earth	+9	Sun
+3	Mars	+10	Moon
+4	Jupiter	+11	Earth-Moon barycenter
+5	Saturn		
+6	Uranus	+12	Nutations

Table 5. TAB4 structure

Word position	Contents
TAB4	Floating point control-word integer indicating type of error, if any
TAB4+1	Zero cell for double-precision compatibility
+2	Mercury position and velocity in double-precision floating point
+14	11 more sub-blocks of position and velocity data for each of the other bodies in double-precision floating point, each sub-block consisting of 12 words, in the same order as given in TAB2
+146	Nutation in longitude and nutation in latitude in single-precision floating point
+148	Nutation rates in single-precision floating point

Table 6. TAB4 error code interpretation

Control word	Meaning
0.0	Successful return
1.0	Specified date T_j smaller than starting date of data available
2.0	T_j greater than final date of data available
3.0	Reading error (redundancy)
4.0	A TAB2 control word is negative or greater than 3
5.0	CENTER control word is in error

REFERENCES

1. Peabody, P. R., Scott, J. F., Orozco, E. G., User's Description of JPL Ephemeris Tapes, Technical Report No. 32-580, Jet Propulsion Laboratory, Pasadena, California, March 2, 1964.

2. Newhall, N. S., User's Guide for JPTRAJ (JPL Trajectory Monitor), Engineering Document No. 199, Jet Propulsion Laboratory, Pasadena, California, January 4, 1964.

IDENTIFICATION

EPHSET/E. T. /INTR1
Alan D. Rosenberg, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

a. EPHSET performs initialization of the calling sequence to the subroutine EPHEM.

b. INTR1 obtains positions and velocities of the Moon, Sun, and planets at a given epoch from the double precision JPL Ephemeris Tape and arranges this information in a manner compatible with the program SPACE. Results are referenced to the mean Earth equator and equinox of 1950.0.

c. E. T. converts a given universal time epoch to the corresponding ephemeris time epoch.

RESTRICTIONS

a. FIX, DAYS, EPHEM, GRUPPE, PROUT, ERPRT, ABORT and UNLOAD are called.

b. NEWBCD, TARAD, CENTR5, CENTE5, TAPEX and EPTAPE are external cells which are referenced.

c. Subroutine INTR1 has the following error conditions:
   1. Unknown central body reference for EPHEM: (CENTER).
   2. Unknown control word for EPHEM: (CONTRL).
   3. Redundancy reading ephemeris tape: (REDUN).
   4. Input epoch earlier than data on ephemeris tape: (EARLY).
   5. Input epoch later than data on ephemeris tape: (LATE).

The word in parenthesis above is printed in the error message: PLANETARY EPHEMERIS ERROR = (error word) on a device appropriate to the mode of SFOF operation and always on the off-line output.

Conditions 1. and 2. cause CALL ABORT in SFOF mode 4 and non-SFOF mode of operation, and TSX ENDSYS, 4 in SFOF mode 2. Conditions 3., 4., and 5. allow one re-try in mode 4 and non-SFOF mode by pressing START, then CALL ABORT in case of a second failure. In SFOF mode 2, TSX ENDSYS, 4 occurs and a comment TURN ON-----AFTER OPERATOR ACTION is printed, where the name of the program currently operating is inserted above.

d. The ephemeris tape is assumed to be mounted on SYSUT8, which corresponds to FORTRAN logical tape 12 and physical unit B6.

e. The COMMON cells T, KB0, XN, XN., CENTER, TARG, PRFLG, 37HED, SP1A, SP2A, SP3A, EJCTA, SP1B, SP2B, SP3B, EJCTB, SP1C, SP2C, EJCTC are referenced.

f. The system low-core cells (PAUSE, ENDSYS, SFMODE and JPTRAJ) are referenced.

g. The buffer NEWBOD through NEWBOD +3 and entry BODTAB are provided to allow substitution of any of the normally unused planets, i. e. Mercury, Neptune, Uranus and Pluto, in place of Saturn.

h. The buffers EGM, SCALE1, DUT and GRAV contain physical constants which may be modified by input. Entry NUTLOB has been provided so the computed nutations are accessible.

METHOD

a. INTR1 takes the double precision seconds past 0^h January 1, 1950 U. T. which it assumes to be in T and T+1, converts it to double precision Julian date and calls EPHEM; upon return, the double precision positions and velocities of the bodies are rounded off and stored in the XN and XN. buffers in COMMON. The nutation in longitude and obliquity and their rates in radians and radians/day are placed in NUTOBL through NUTOBL +3.

b. E. T. adds T, the double precision seconds past 0^h January 1, 1950 U. T. to ΔT, the difference between Universal and Ephemeris time, and returns with the results in the AC-MQ.

USE

a. CALL EPHSET
 return

b. CALL INTR1
 return

Assumption is that T and T+1 contain the double precision seconds past 0^h January 1, 1950 U. T., and CENTER contains a fixed point integer scaled 35, of value 0 through 6, corresponding to the names EARTH, MOON, SUN, VENUS, MARS, SATURN, JUPITER, respectively.

c. CALL E. T.
 return

Assumption is as above for cells T and T+1. Results are double precision seconds past 0^h January 1, 1950 E. T. in the AC-MQ.

CODING INFORMATION

Length of subroutine is 2311 (10) or 4407 (8) words.

REFERENCE

Cary, C.; Inter-Office Memorandum 312. 3-176, Physical Constants and Other Parameters to be used in MA-C Computations-Updated Version, October 30, 1964.

IDENTIFICATION 21

FIX/FLOAT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To convert a single precision floating point number to a fixed point integer scaled 35 or vice versa.

RESTRICTIONS

Conversion will be made mod 2^{27}.

METHOD

The unnormalized add and floating point add instructions are used with masks.

USE

Enter with the number to be converted in the accumulator. Exit with the result in the accumulator.

Calling sequences:

To float a fixed point integer:

```
CLA     L(INTEGER)
CALL    FLOAT
return
```

To fix a floating point number:

```
CLA     L(NUMBER)
CALL    FIX
return
```

CODING INFORMATION

Length of subroutine is 9(10) or 11(8) words.

IDENTIFICATION

FIXT/FLOT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the number of seconds that have elapsed since 0^h January 1, 1950, given a Greenwich Mean Time (GMT) between the years 1950 and 2000 or vice versa.

RESTRICTIONS

a. The locations YEAR to YEAR +6, in COMMON, are used in the FIXT option.
b. A double precision number is considered to be two floating point words.

METHOD

The double precision floating point number is decoded into the various lengths of time and vice versa, taking into account leap years and leap centuries.

USE

a. GMT to seconds: on entrance the AC must contain YYMM0DDHH and the MQ must contain NNSSFFF, where

YY = last two digits of the year
MM = month of the year, January being 1
0 = zero
DD = days
HH = hours
NN = minutes
SS = seconds
FFF = milliseconds

Exit with the double precision floating point seconds past 0^h, January 1, 1950, in the AC and MQ. If YY = MM = 0, then (AC - MQ) is converted to an interval in double precision seconds.

Calling sequence:

```
CLA     L(YYMM0DDHH)
LDQ     L(NNSSFFF)
CALL    FLOT
return
```

b. Seconds to GMT: on entrance the AC and MQ must contain the double precision floating point seconds past 0^h, January 1, 1950. Exit with the GMT in location YEAR to YEAR +6, where

YEAR = YY = last two digits of year
+1 = MM = month, January being 1
+2 = DD = days
+3 = HH = hours
+4 = NN = minutes
+5 = SS = seconds
+6 = FFF = milliseconds

YEAR through YEAR +5 are fixed point integers scaled 35. YEAR +6 is fixed point scaled 0.

Calling sequence:

```
CLA     L(SECONDS A)
LDQ     L(SECONDS B)
CALL    FIXT
return
```

CODING INFORMATION

Length of subroutine is 175(10) or 257(8) words.

IDENTIFICATION

GASJET/GASSET/GASOPT/GASFLG/GASTIM

JPL Staff

IBM 7094 Fap

December 2, 1964

PURPOSE

To handle the attitude control option.

RESTRICTIONS

a. Subroutines BCDNO, UNIT, CROSS, ADD, MATRIX and FLOTT are called.
b. Locations CAN50, GASTM1, GASTM2, GASTR1, GASTR2 and FLGWRD are referenced indirectly.
c. T, T (0), QX and XN in COMMON are used.

METHOD

If the input flag GASOPT is non-zero then the attitude control effects are considered as a perturbation on the spacecraft, between a given start time $T_S + \Delta T$ and a given end time T_E. T_S may be an epoch earlier than the injection epoch or may be zero. If zero, the injection epoch is put into T_S. If T_E is zero then the attitude control option is never turned off.

The GASFLG is set non-zero during the $T_S + \Delta T$ to T_E interval of time and is the flag used by the subroutine TRAJ as an indication of when to include the attitude control effects as a perturbation. Communication is also made between this subroutine and TRAJ in the handling of the triggers associated with the two times $T_S + \Delta T$ and T_E.

To compute the perturbation on the spacecraft define:

a. $\overline{E}$ = unit vector directed from the probe to a body specified by input into GASOPT + 1

b. $\overline{H}$ = unit vector directed from the probe to the Sun

c. $\overline{B} = \dfrac{\overline{E} \times \overline{H}}{|\overline{E} \times \overline{H}|}$

e. $\overline{C} = -\overline{H}$

f. $\overline{A} = \dfrac{\overline{B} \times \overline{C}}{|\overline{B} \times \overline{C}|}$

g. $t = T - (T_S + \Delta T)$, where the times used in the computation are:

T_S = (input) epoch of start of computation

ΔT = (input) time in seconds to add to T_S to get a final time of start of computation.

T_E = (input) epoch to end computation

T = (input) trajectory epoch

Next define the force to be:

h. $F_A = F_{A0} + F_{A1}t + F_{A2}t^2$

i. $F_B = F_{B0} + F_{B1}t + F_{B2}t^2$

j. $F_C = F_{C0} + F_{C1}t + F_{C2}t^2$

where F_A, F_B, and F_C are in units of dynes.

If m is the (input) mass of the spacecraft in kg then the (output) perturbative accelerations $\ddot{x}$, $\ddot{y}$, $\ddot{z}$ due to attitude control forces are given in units of km/sec^2 by:

k. $$\begin{pmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{pmatrix} = \frac{10^{-8}}{m} \begin{pmatrix} A_x & B_x & C_x \\ A_y & B_y & C_y \\ A_z & B_z & C_z \end{pmatrix} \begin{pmatrix} F_A \\ F_B \\ F_C \end{pmatrix}$$

USE

Calling sequences:

a. initialization entry:

```
CALL    GASSET
return
```

b. execution entry:

```
CALL    GASJET
PZE     P
return
```

where the output acceleration is stored into P, P + 1, P + 2 and where the following input parameters have been previously input into GASOPT through GASOPT +16:

GASOPT	flag; 0 = no attitude control effects
GASOPT +1	reference body; planet, Moon, or Canopus
+2, 3	epoch of start of attitude control effects
+4	delta T in sec, added to GASOPT +2, 3
+5, 6	epoch of end of attitude control effects
+7, 8, 9	coefficients of F_A polynominal; F_{A2}, F_{A1}, F_{A0}
+10, 11, 12	coefficients of F_B polynominal; F_{B2}, F_{B1}, F_{B0}
+13, 14, 15	coefficients of F_C polynominal; F_{C2}, F_{C1}, F_{C0}
+16	mass of spacecraft, kg

CODING INFORMATION

Length of subroutine is 238(10) or 356(8).

REFERENCES

JPL Section 312 RFP 179 (with a correction to the definition of $\bar{A}$ to give a right-handed coordinate system).

IDENTIFICATION

GEDLAT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute ϕ', the geodetic latitude of the probe, and ρ', the distance from the geocenter to the point on the surface of the Earth lying on the Earth-probe line.

RESTRICTIONS

a. Subroutines SIN and SQRT are called.
b. COMMOM through COMMON+9 are used.

METHOD

a. ϕ' is given by:

$$\phi' = \phi + b_1 \sin 2\phi + b_2 \sin 4\phi + b_3 \sin 6\phi$$

where ϕ is the input geocentric latitude of the probe,

$$b_1 = 0.19456624 \text{ deg}$$

$$b_2 = 0.00033036 \text{ deg}$$

$$b_3 = 0.00000075 \text{ deg.}$$

b. ρ' is given by:

$$\rho' = a\sqrt{1 - \epsilon^2 \sin^2 \phi}$$

where ϕ is the input geocentric latitude of the probe,

$\epsilon^2 = 0.006768657997$, eccentricity squared,

$a = 6378.2064$, equatorial radius, kilometers.

USE

Calling sequence:

CALL GEDLAT

Enter with the geocentric latitude of the probe, ϕ, in the accumulator in degrees.
Exit with the geodetic latitude of the probe, ϕ', in the AC in degrees and the radius, ρ', in the MQ in kilometers.

CODING INFORMATION

Length of subroutine is 46(10) or 56(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report 32-223, Revision 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION 25

GETTER
JPL Staff
IBM 7094 Fap

PURPOSE

To compute, in floating point, the angle, in degrees, between two vectors, where each vector is the difference of two other vectors.

RESTRICTIONS

a. All vectors must be stored, BES 3.
b. Subroutines ARCOS and PROD are called.
c. The formula used to compute the angle does not hold, in general, for unit vectors since

$$\frac{\overline{A} - \overline{B}}{|\overline{A} - \overline{B}|} \neq \frac{\hat{A} - \hat{B}}{|\hat{A} - \hat{B}|}$$

for all $\overline{A}$, $\overline{B}$ where $\wedge$ signifies a unit vector.

METHOD

The desired angle is computed using the following formula:

$$\text{ANGLE} = \text{ARCOS}\left[\frac{(\overline{A} - \overline{B})\cdot(\overline{C} - \overline{B})}{|\overline{A} - \overline{B}||\overline{C} - \overline{B}|}\right]$$

Note: For $\overline{B} = \overline{0}$, either $\overline{A}$ or $\overline{C}$ may be unit vectors and give a correct result.

USE

Calling sequence:

```
CALL   GETTER
PZE    A,,C
PZE    B,,D
return
```

The angle between the vectors $\overline{A} - \overline{B}$ and $\overline{C} - \overline{B}$ is computed in degrees and stored in D.

CODING INFORMATION

Length of subroutine is 37(10) or 45(8) words.

IDENTIFICATION

GHA
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the Earth's rotation rate and the Greenwich hour angle of the vernal equinox.

RESTRICTIONS

a. COMMON locations T, T+1, NUTRA, LOMEGA, OMEGA and GHA(T) contain input and output quantities.
b. COMMON through COMMON+6 are used.
c. Subroutines DAYS, FIX and FLOAT are called.

METHOD

The mean value of the Greenwich hour angle is computed as follows:

$$\Upsilon_m(T) = 100^\circ.07554260 + 0^\circ.9856473460\, d + (2^\circ.9015)\, 10^{-13} d^2 + \omega t \pmod{360 \text{ deg}}$$

$$0 \leq \Upsilon_m(T) < 360 \text{ deg}$$

where

T is the epoch under consideration in U.T.
d is integer days past 0 hr January 1, 1950
t is seconds past 0 hr of epoch T
ω is the Earth's rotation rate and is given by:

$$\omega = \frac{0.00417807417}{1 + (5.21)\, 10^{-13} d} \text{ deg/sec.}$$

Given the nutation in right ascension, $\delta\alpha$, the true value of the hour angle is:

$$\Upsilon(T) = \Upsilon_m(T) + \delta\alpha$$

USE

Calling sequence:

```
CALL   GHA
return
```

where

T, T+1	contain the input double precision seconds past 0 hr January 1, 1950 U.T.
NUTRA	contains $\delta\alpha$, the input nutation in right ascension in degrees.
OMEGA	contains the output Earth's rotation rate in deg/sec.

LOMEGA contains the output Earth's rotation rate in rad/sec.

GHA(T) contains the output true Greenwich hour angle in degrees.

CODING INFORMATION

Length of subroutine is 68(10) or 104(8) words.

IDENTIFICATION 27

GRUPPE
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To maintain a count of the number of lines of output made on a page and to use this count to control page ejects.

RESTRICTIONS

Subroutine SEITE is called to give the page eject and page heading.

METHOD

If the print suppress flag indicates no printing, the subroutine exits. N, the number of lines of output that are going to be printed in the following group, is added to the current line count C. If $N + C > 63$ subroutine SEITE is called to get a page eject and page heading. If $N + C \leq 63$, $N + C$ becomes the new line count C.

USE

Calling sequence:

```
CALL   GRUPPE
PZE    N
```

where N is the number of lines of output that will be requested before the next CALL GRUPPE.

CODING INFORMATION

Length of subroutine is 14(10) or 16(8) words.

IDENTIFICATION

HARMN/HARMN2/MRBLAT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the oblate potential of the Earth and Mars.

RESTRICTIONS

a. Location PMAT is referenced indirectly to obtain the space-fixed Earth equatorial to space-fixed Mars equatorial rotation matrix.
b. Entry HARMN2 is provided so the beginning of the constant buffer is accessible.
c. The mean Earth equator and equinox of 1950.0 to true-of-date rotation matrix is assumed to be in COMMON location (NA) through (NA)+8.
d. COMMON through COMMON+14 are used.

METHOD

The oblate potential of the Earth and Mars are assumed to contain the second, third, and fourth spherical harmonics:

$$U_B = \frac{\mu_B}{R}\left\{\frac{Ja_B^2}{3R^2}(1 - 3\sin^2\phi) + \frac{Ha_B^3}{5R^3}(3 - 5\sin^2\phi)\sin\phi + \frac{Da_B^4}{35R^4}(3 - 30\sin^2\phi + 35\sin^4\phi)\right\}$$

where μ_B is the gravitational coefficient of the body (Earth or Mars) and a_B is the equatorial radius of the body.

$R = (X, Y, Z)$ is the position vector from the body's center of mass expressed in the mean equator and equinox of 1950.0. To obtain ϕ, the latitude, the z-component of the position vector expressed in the true equator and equinox of date coordinate system must be supplied. Thus, $\sin\phi = z/R$.

To obtain the perturbing acceleration, ∇U_B is formed:

$$\nabla U_B = \left(\frac{\partial U_B}{\partial u_1}, \frac{\partial U_B}{\partial u_2}, \frac{\partial U_B}{\partial u_3}\right)$$

where $u_1 = X$, $u_2 = Y$, and $u_3 = Z$.

$$\frac{\partial U_B}{\partial u_j} = - \frac{J_B \mu_B}{R^2} \frac{a_B^2}{R^2} \left\{ \left(1 - \frac{5z^2}{R^2}\right)\frac{u_j}{R} + 2\frac{z}{R} a_{3j} \right\}$$

$$- \frac{H_B \mu_B}{R^2} \frac{a_B^3}{R^3} \left\{ \left(3 - 7\frac{z^2}{R^2}\right)\frac{z}{R}\frac{u_j}{R} + \left(-\frac{3}{5} + \frac{3z^2}{R^2}\right) a_{3j} \right\}$$

$$- \frac{D_B \mu_B}{R^2} \frac{a_B^4}{R^4} \left\{ \left(\frac{3}{7} - 6\frac{z^2}{R^2} + 9\frac{z^4}{R^4}\right)\frac{u_j}{R} + \left(\frac{12}{7} - 4\frac{z^2}{R^2}\right)\frac{z}{R} a_{3j} \right\}$$

where $j = 1, 2, 3$.

The third row of the (NA) matrix is used for the a_{3j} for the Earth and the third row of the PMAT matrix is used for Mars.

The second, third and fourth harmonic terms are computed only if the body-probe distance, R_B is less than some constant value. The following table gives the nominal values of the constants used in the Earth and Mars calculations:

Location	Quantity	Description	Nominal Value
HARMN+2	$J_\oplus$	Earth coefficient for second harmonic	0.162345E-2
+3	$H_\oplus$	Earth coefficient for third harmonic	-0.575E-5
+4	$D_\oplus$	Earth coefficient for fourth harmonic	0.7875E-5
+5	$a_\oplus$	Earth radius	6378.165 km
+6	R_2	$R_\oplus > R_2$ suppresses Earth second harmonic	5E5
+7	R_3	$R_\oplus > R_3$ suppresses Earth third harmonic	2E5
+8	R_4	$R_\oplus > R_4$ suppresses Earth fourth harmonic	1E5
+9	$J_♂$	Mars coefficient for second harmonic	0.292E-2
+10	$H_♂$	Mars coefficient for third harmonic	0

Location	Quantity	Description	Nominal Value
HARMN+11	$D_{♂}$	Mars coefficient for fourth harmonic	0
+12	$a_{♂}$	Mars radius	3417.0 km
+13	R_2	$R_{♂} > R_2$ suppresses Mars second harmonic	5E5
+14	R_3	$R_{♂} > R_3$ suppresses Mars third harmonic	0
+15	R_4	$R_{♂} > R_4$ suppresses Mars fourth harmonic	0

The gravitational coefficient $\mu_{\oplus}$ or $\mu_{♂}$ is obtained via the calling sequence.

USE

Calling sequences:

```
a.  CALL   HARMN
    PZE    A,,B
    PZE    C,,D
    PZE    E
```

for the Earth

```
b.  CALL   MRBLAT
    PZE    A,,B
    PZE    C,,D
    PZE    E
```

for Mars

where, for both the Earth and Mars calling sequences:

A, A+1, A+2	contain the input body-probe position vector in the mean Earth equator and equinox of 1950.0 coordinate system.
B, B+1, B+2	contain the (output) negative of the perturbing acceleration, $-\nabla U_B$
C	contains the input body gravitational coefficient, μ_B.
D	contains the input distance above the true equator of the body.
E	contains the input magnitude of the vector in A, A+1, A+2.

and where the (NA) and PMAT matrices have been updated to the current epoch and are available.

CODING INFORMATION

Length of subroutine is 183(10) or 267(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION 29.1

INTRAN
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To transform the trajectory initial conditions to the mean Earth equator and equinox of 1950.0 coordinate system, to initialize certain subroutines and to print the trajectory heading.

RESTRICTIONS

a. INTRAN is a subset of a rotation package and uses other subroutines in the package.
b. Subroutines DAYS, E.T., ROTEQ, MNA, MNA1, MNAMD1, GHA, RVIN, EARTH, ECLIP, INTR1, UNIT, COS, SIN, SQRT, CROSS, ARCOS and ARSIN are used in the transformations.
c. Entry CAN50 is provided so the unit mean 1950.0 position vector of Canopus is accessible. Entry CENTR5 is provided so the NEWBOD option can locate the BCD for Saturn. Entries PHL, RMAX, INJBCD, INJTYP, INJX, INJY, INJZ, INJDX, INJDY, INJDZ and INJEQX are provided for these input parameters.
d. HARMN, GRAV, LUNGRV, SCALE1, RADOPT, BRNOPT, GASOPT and EQUNX1 are referenced indirectly to locate the parameters that are to be printed.
e. PROUT, TIME2, GRUPPE and ERPRT are used to control printing.
f. BODY, SVARY and EPHSET, initialization entries to the three subroutines BODY1, VARY and INTR1, are called.

METHOD

SPACE allows the injection conditions to be referenced to one of several coordinate systems. The injection conditions input form (see IVE1) shows them under EXPLANATION of parameter INJTYP. Flow Chart IIC2 shows what subroutines are used to rotate the given set to the 1950.0 frame. Details of the rotation can therefore be found in those rotation subroutine writeups.

USE

Calling sequence:

```
CALL    INTRAN
return
```

CODING INFORMATION

Length of subroutine (includes INTRAN as a subset) is 1003(10) or 1753 (8) words.

IDENTIFICATION 29.2

NUTATE
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To update the precession A and nutation N matrices and apply the product matrix NA to the Earth-probe vector.

RESTRICTIONS

a. NUTATE is a subset of a rotation package and uses other parameters in the package.
b. MNAET is tested to determine if the .1 day delta-time option is to be used in computing the N matrix. A zero MNAET forces recomputation of N.
c. Locations XEP, CC, (NA), AA and TARG (epoch in days past 0 hr January 1 1950), in COMMON, are referenced.
d. Subroutines ROTEQ, MNA and MATRIX are called.
e. COMMON through COMMON+2 are used.
f. NUTMAT, the location of the nutation matrix, is referenced indirectly.

METHOD

Subroutine ROTEQ is called to update the A matrix. The N matrix is updated if MNAET = 0 or if MNAET is non-zero and time has increased by .1 day since the last computation. N is updated by calling subroutine MNA. Then subroutine MATRIX is called to form the product NA. The CC+3 vector is then multiplied by NA to give the Earth-probe position vector in the space fixed Earth true equator and equinox of date coordinate system (XEP).

USE

Calling sequence:

```
CALL    NUTATE
return
```

CODING INFORMATION

Length of subroutine (includes NUTATE as a subset) is 1003(10) or 1753(8) words.

IDENTIFICATION 29.3

RESET
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To set the obliquity of the ecliptic to the 1950.0 value and to set the NA matrix to unity.

RESTRICTIONS

a. RESET is a subset of a rotation package and uses other parameters in the package.
b. COMMON locations ET and (NA) are used.

METHOD

The mean obliquity of 1950.0 is put into ET and the (NA) matrix is set to unity so any use of these quantities will cause the results to be in the mean 1950.0 coordinate system.

USE

Calling sequence:

```
CALL    RESET
return
```

CODING INFORMATION

Length of subroutine (includes RESET as a subset) is 1003(10) or 1753(8) words.

IDENTIFICATION 29.4

ROT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To update the planetary ephemerides, the Greenwich hour angle and the (n-body)-probe vector and to rotate several sets of vectors to the output coordinate system.

RESTRICTIONS

a. ROT is a subset of a rotation package and uses other subroutines in the package.
b. Subroutines INTR1, GHA, UNIT, MATRIX, RESET and NUTATE are called.
c. Location EQUNX1 is referenced indirectly.
d. CX, CX., QX, QX., XN, XN., CS2, (NA), XEP, XEP., X, X., S2, CANOP, XN1, XN.1, X0P, X0P. and VAFLG, in COMMON, are used.

METHOD

a. The planetary ephemerides are updated by calling subroutine INTR1.
b. Subroutine NUTATE is called (which calls MNA to update the nutation in rt. ascension and the M and N matrices) and then GHA is called to compute the current value of the true Greenwich hour angle.
c. The true of-date Earth-probe position and velocity vector are computed and stored in XEP and XEP. .
d. RESET is called if the output equinox is 1950.0.
e. The X, X., S1, S2, CANOP, and the variational coefficients are rotated to the desired output reference system, determined by the contents of location EQUNX1.
f. The Earth-(n-body) position and velocity vectors are formed.
g. The N and A matrices are recomputed, if RESET was called earlier.

USE

Calling sequence:

```
CALL   ROT
return
```

CODING INFORMATION

Length of subroutine (includes ROT as a subset) is 1003(10) or 1753(8) words.

IDENTIFICATION 30

LN/LOG10

JPL Staff

IBM 7094 Fap

December 2, 1964

PURPOSE

To compute $\log_{10} x$ or $\log_e x$ for a floating point, single precision x.

RESTRICTIONS

a. An error will occur if $x \leq 0$.

b. Uses COMMON to COMMON +3.

METHOD

Represent x as $2^k F$ where $1/2 \leq F < 1$.

Therefore, $\log_e x = \log_e (2^k F) = k \log_e 2 + \log_e F$.

The following continued fraction is used to compute $\log_e F$:

$$\log_e F = \log_e 0.725 + \cfrac{r}{0.725 + \cfrac{r}{2 + \cfrac{r}{2.175 + \cfrac{r}{1 + \cfrac{r}{3.625 + \cfrac{r}{\frac{2}{3} + \cfrac{r}{5.075 + \cfrac{r}{0.5}}}}}}}}$$

where $r = (F - 0.725)$.

$\mathrm{Log}_{10}\, x$ is computed by obtaining $\log_e x$, using the above approximation, and then using the relation:

$$\log_{10} x = (\log_e x)(\log_{10} e)$$

Accuracy: This method gives 26 significant binary digits except near $x = 1$, where the result is accurate to 26 binary places.

USE

Enter with a floating point argument in the accumulator, exit with the floating point logarithm in the accumulator.

Calling sequences:

For $\log_e x$:	CLA	X	For $\log_{10} x$:	CLA	X
	CALL	LN		CALL	LOG10
	error return			error return	
	normal return			normal return	

CODING INFORMATION

Length of subroutine is 59(10) or 73(8) words.

IDENTIFICATION

MARK
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To solve the first n of a set, N, of first order differential equations simultaneously utilizing Adams-Moulton open or open and closed formula types. A Runge-Kutta 4th order integrator is used as a starting routine to generate backward differences initially. Provision is made for interrupting the integration process at specified values of either the independent or the dependent variables. The order of differences (m) used in the Adams-Moulton mode is six.

RESTRICTIONS

a. Changes in H must be accomplished by the use of a "doubling" or "halving" procedure in MARK that will double (set H = 2H) or halve (set H = 0. 5 H) the integration step size.
b. Underflow and overflow are not checked internally.
c. The user must provide the necessary interruption subroutines, an auxiliary program to evaluate the n first order derivatives, and a bank of storage for internal calculations.
d. The external cell DUBFLG is set non-zero at a double (hence at the end of 6 steps). This forces the probe ephemeris write logic to set the step counter to 3, to compensate for the doubled step-size.
e. Subroutine PPOOR is called to force a probe ephemeris record to be counted. This occurs at the Runge-Kutta to Adams-Moulton change and at each step when under Adams-Moulton control.

METHOD

a. MARK permits the user to solve the N differential equations by one of two options:
   1. Runge-Kutta 4th order.
   2. Adams-Moulton with a fixed step-size, H, and the ability to alter H by the doubling and/or halving procedure using Runge-Kutta to initially generate backward differences. This applies either a predictor or a predictor with q corrections (open or open/closed type formulas).
b. Both the independent and the dependent variables are automatically carried internally in partial double precision to control round-off error locally. The user, however, will recognize the variables only as single precision quantities. However, the user may carry the independent variable in full double precision by option.

c. Equations:

1. The classical Runge-Kutta 4th order equations: Let the system of equations to be solved be in the form

$$y_j' = f_j(t, y_1, y_2, \cdots, y_n) \qquad j = 1, 2, \cdots, N$$

Let $y_{j,\eta}$ be the value of y_j at $t = t_\eta$ and $f_{j,\eta}$ be the derivative of y_j at $t = t_\eta$. Let h be the step-size of the independent variable t. Then

$$K_1 = hf_j(t_\eta, y_{j,\eta})$$

$$K_2 = hf_j(t_\eta + 1/2h, y_{j,\eta} + \frac{K_1}{2})$$

$$K_3 = hf_j(t_\eta + 1/2h, y_{j,\eta} + \frac{K_2}{2})$$

$$K_4 = hf_j(t_\eta + \Delta t, y_{j,\eta} + K_3)$$

$$y_{j,\eta+1} = y_{j,\eta} + (1/6)(K_1 + 2K_2 + 2K_3 + K_4)$$

2. The Adams-Moulton predictor-corrector equations: Let y_j, y_j' be defined as above. Then

$$y^P_{j,\eta+1} = y_{j,\eta} + h(a_0\nabla^0 + a_1\nabla^1 +, \cdots, + a_m\nabla^m)y_j' \qquad \text{(open type)}$$

where ∇ is a backward difference operator operating on $y_{j,\eta}'$ where

$$\nabla y_{j,\eta}' = y_{j,\eta}'$$

The predictor coefficients a_m are:

$a_0 = 1.0$ $\qquad a_5 = 0.329861111$

$a_1 = 0.5$ $\qquad a_6 = 0.315591936$

$a_2 = 0.416666666$ $\qquad a_7 = 0.304224539$

$a_3 = 0.375$ $\qquad a_8 = 0.294868003$

$a_4 = 0.348611111$ $\qquad a_9 = 0.2870754484$

$$y'^{P}_{j,\eta+1} = f_j(t_\eta, y_j) \qquad j = 1, \cdots, N$$

$$y^{1}_{j,\eta+1} = y_{j,\eta} + h(b_0\nabla^0 + b_1\nabla^1 + , \cdots, + b_m\nabla^m)y'^{P}_{j,\eta+1} \qquad \text{(closed type)}$$

where ∇ is defined as above, 1 is the first corrector application, and the corrector coefficients b_m are:

$b_0 = 1.0$	$b_5 = -0.01875$
$b_1 = -0.5$	$b_6 = -0.0142691795$
$b_2 = -0.0833333333$	$b_7 = -0.0113673950$
$b_3 = -0.0416666666$	$b_8 = -0.0093565362$
$b_4 = -0.0263888888$	$b_9 = -0.0078925542$

NOTE: $$b_{m+1} = a_{m+1} - a_m$$

continuing

$$y^{2}_{j,\eta+1} = y_{j,\eta} + h(b_0\nabla^0 + b_1\nabla^1 + , \cdots, + b_m\nabla^m)y'^{1}_{j,\eta+1}$$

$$y^{(i+1)}_{j,\eta+1} = y^{(i)}_{j,\eta+1} + h\sigma\epsilon^{(i)}$$

where $\sigma = \sum_{\ell=0}^{m} b_m$; $\epsilon^{(i)} = y'^{(i)}_{j,\eta+1} - y'^{(i-1)}_{j,\eta+1}$

i is the i th correction on the predictor formula.

3. The formula for interpolation to interruption on a dependent variable in the Adams-Moulton mode is:

$$q_j = (-1)^q \left| \begin{matrix} \mu \\ j \end{matrix} \right|$$

where

$$\mu = \frac{t_{\eta+1} - t_\mu}{h_c} \geq 0$$

• and

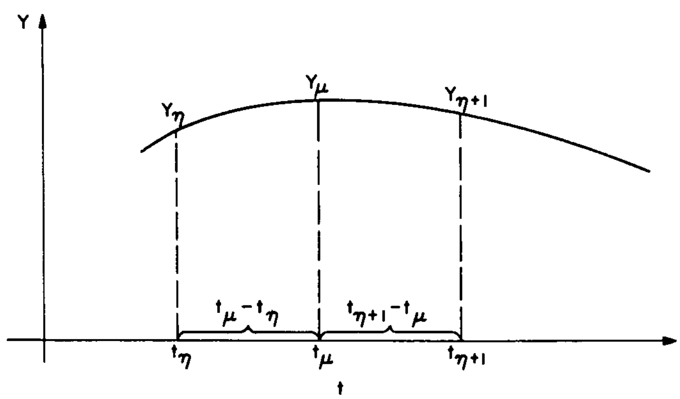
$$\left|\begin{matrix}\mu \\ j\end{matrix}\right| = \frac{(\mu-1)(\mu-2),\cdots,(\mu-j)}{(j+1)\,!} \qquad j = 1,\cdots,m$$

$$c_j = b_j + \sum_{i=1}^{j} q_i b_{j-i} \qquad j = 1,\cdots,m$$

b_j = corrector coefficients described in 2 above

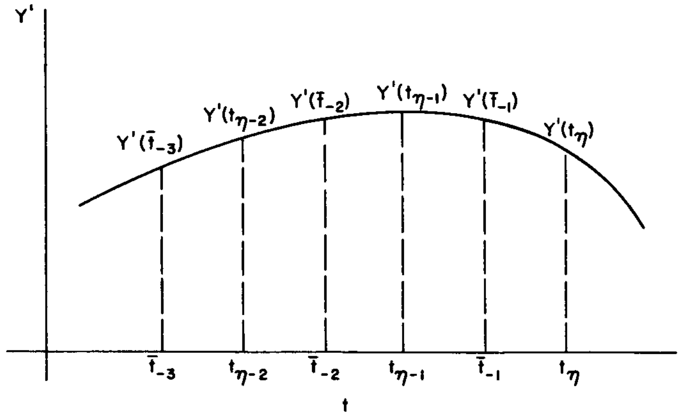
$$d_j = c_j \nabla^j \qquad j = 1,\cdots,m$$

$$y_{\ell,\mu} = y_{\ell,\eta+1} - h\mu\left(y'_{\ell,\eta+1} + \sum_{j=1}^{m} d_j\right) \qquad \ell = 1,\cdots,n$$



4. The formula for interpolation to halve the step-size (H), dropping the subscript j, is as follows:

$$y'(\bar{t}) = \sum_{k=0}^{m} q_{-k}^{(m)}(\mu)\,y'(t_{\eta-k})$$



where:

$$q_{-k}^{(m)}(\mu) = \frac{1}{m!} \prod_{i=1}^{m} (i + \mu)$$

$$\bar{t} = t_{\eta} - n\ell h$$

$$n = 1, 2, \cdots;$$

$$\ell = \frac{1}{2}, \frac{1}{3}, \cdots$$

$$\mu = \frac{t_{\eta} - n\ell h - t_{\eta}}{h} = -n\ell$$

Let $\ell = 1/2$ then $\mu = -(1/2)n$ where n represents the absolute value of the subscript of $\bar{t}$ in sketch 2.

In the program:

$$q_0 = \frac{1}{m!} \prod_{i=1}^{m} (i + \mu)$$

and

$$q_{k+1} = - q_k \frac{(\mu + k)(m - k)}{(\mu + k + 1)(k + 1)} .$$

USE

a. Calling sequence:

```
        CALL    MARK
        PZE     HBANK, P, EOS
        PZE     DERI, Φ, DER2
    ERROR RETURN
        Pfx     B1, , Y1
        PZE     Z1
        Pfx     B2, , Y2
        PZE     Z2
        .
        .
        .
        Pfx     BJ, , YJ
        PZE     ZJ
        PZE     0
```

where the symbols are defined as follows:

HBANK - The location of a bank of storage to be described below.

P:
- 0 - The independent variable is carried in partial double precision (single precision to the user).
- 1 - The independent variable is carried in full double precision.

EOS - The location of a user "end of step" routine. The command, TRA 1, 4, terminates the EOS as a normal return. The command TRA 2, 4, permits the user to execute a "restart" procedure from the EOS routine. Restart capability will be discussed subsequently. It is used to evaluate variables that are needed only after a full integration step is completed.

DERl - The location of the entry to the user's derivative routine that carries out all calculations that involve the independent variable. This routine must terminate with a TRA 1, 4 command.

DER2 - The location of the entry to that portion of the user's derivative routine that carries out all calculations that do not involve the independent variable but are required to evaluate the derivatives.

A simple example of the use of DERl, DER2 follows:

Suppose we are to solve:

$$\frac{dy}{dx} = ax^2 + by$$

Then:

DERl ax^2

DER2 by

$\frac{dy}{dx}$

TRA 1, 4

Thus the DER1 entry calculates the extra term involving the independent variable x. This provides a saving of real machine time, particularly during the Runge-Kutta phase of integration, but also saves machine time when the closed type formula is used with Adams-Moulton integration.

$$\Phi = \begin{cases} 0 - \text{Adams-Moulton integration with fixed-step size} \\ 2 - \text{Runge-Kutta integration only} \end{cases}$$

The pairs of locations in the calling sequence specified as:

$$\left.\begin{array}{ll} \text{Pfx} & \text{BJ,, YJ} \\ \text{PZE} & \text{ZJ} \end{array}\right\} \text{ are defined as "triggers".}$$

These triggers are the linkage control to the user's interruption subroutines. The triggers state that control is transferred to location BJ when the contents of location YJ are equal to the contents of location ZJ. Thus BJ is the location of a user's interruption subroutine, YJ is the location of a variable being checked, and ZJ is the location that contains the desired value for YJ.

b. Triggers:

1. Independent variable triggers, called T-stops: These triggers interrupt on values of the independent variable of integration. All T-stops <u>must</u> have YJ = 0. That is, they must have the following format in the calling sequence:

   Pfx BJ

   PZE ZJ

   The logic used to execute T-stops is as follows:

   Let

   $$t_{s1}, \quad t_{s2}, \quad t_{s3}, \ldots\ldots t_{sk}$$

   be a set of values of the independent variable for which interruptions are desired. MARK sets

   $$t_m = \text{Min}\left\{t_{s1}, \quad t_{s2}, \ldots\ldots, t_{sk}\right\}$$

   Integration continues normally until the independent variable reaches the condition:

   $$t_\eta < t_m \leq t_{\eta+1}$$

The step size is set = $(t_{\eta+1} - t_m)$ and integration is carried to t_m where all the values of the variables including derivatives and end of step values are calculated and control is then transferred to the user's corresponding interruption subroutine. After control is returned from the user's interruption routine, all values are reset to station $t_{\eta+1}$ and the next t_m is determined. If no other t_m exists within this step, integration continues. Thus, interruption routines for all t_m within a given step are executed before integration continues. There is no limitation on the number of T-stops permitted (except for machine size, of course).

Dependent variable triggers, called Y-stops: These triggers are interrogated at the beginning of an integration step and a value

$$L_j = y_\eta - y_j$$

is calculated and saved for each of the j Y-stops. At the end of the integration step the difference

$$R_j = y_{\eta+1} - y_j$$

is calculated and the algebraic sign of R_j is compared to L_j: If

$$\operatorname{sgn} L_j \neq \operatorname{sgn} R_j$$

Then the condition $y = y_j$ has occurred within the integration step and a linear interpolation search procedure is executed to determine the value of the independent variable, t, such that $y = y_j$. When the Δt calculated by the search procedure is such that $|\Delta t| \leq \delta\mu$ where

$$\delta\mu = \begin{cases} 2^{-26} \text{ Max } |H, t_{\eta+1}| & \text{for } P = 0 \\ 2^{-42} \text{ Max } |H, t_{\eta+1}| & \text{for } P = 1 \end{cases}$$

then convergence to t_j is assured. At this point all values of the dependent variable including their respective derivatives and any end of step calculations are determined and control for the corresponding Y-stop is returned to the user's interruption routine. If more than one Y-stop trigger occurs within an integration step, then the triggers are executed in the order of the smallest value of the independent variable determined for the respective Y-stops. Thus, the order of execution is determined by the independent variable. After all Y-stops within an integration step have been determined and executed, the conditions at station $t_{\eta+1}$ are restored for all dependent variables and their derivatives and end of step calculations, if any. Integration then continues normally.

Up to and including fifty dependent variable triggers are permitted. However, this number may be altered by changing the symbolic card "OMAR EQU 50" in the symbolic program deck to the desired number.

It remains to define Pfx of the trigger pair. This is utilized to permit the user to render triggers "active" or "inactive". Active means that a trigger is to be interrogated and executed if necessary. Inactive means that the trigger is to be ignored.
Thus, if:

$$\text{Pfx} = \begin{cases} \text{PZE trigger is active} \\ \text{MZE trigger is inactive} \end{cases}$$

The interruption routines provided by the user must terminate with either a TRA 1, 4 command or a TRA 2, 4 command.

TRA 1, 4 is used when the interruption <u>does</u> <u>not</u> constitute a discontinuity in any of the calculations.

TRA 2, 4 is used when a discontinuity exists. Under this condition a "restart" procedure is instigated by MARK by continuing beyond the discontinuity point using Runge-Kutta until a sufficient number of backward differences are determined to switch to Adams-Moulton integration.

c. Comments on triggers:

1. There is no limitation on how many times a trigger may be executed.
2. In all cases where more than one trigger is to be executed at a single point (t_j) the triggers will be executed in order of their ascending appearance in the calling sequence.
3. Control is returned to the error return of the calling sequence whenever $t_m < (t_\eta - \delta_\mu)$, or when the number of Y-stops exceeds fifty. The entire list of triggers <u>must</u> be terminated with

   PZE 0

d. Comments on restart capability:

1. Restart should only be executed when there is a definite discontinuity in the differential equations of integration.
2. When restarting from the Runge-Kutta mode, the nominal step-size, Δt, is set = H from the HBANK.
3. When restarting from the Adams-Moulton mode, the nominal step-size, Δt, is set = h_c; h_c is the last step-size resulting from using NH or ND in the fixed Adams-Moulton mode. This situation may be overridden by introducing the desired step-size to MARK via the entry point $HC discussed subsequently in the section on ENTRY POINTS by using the command

   STO* $HC
4. Restarting is accomplished by m + 1 integration steps in the Runge-Kutta mode to generate a new set of backward differences.
5. Restart is possible in both integration modes from an independent variable trigger, a dependent variable trigger, or the end of step box.
6. <u>All</u> dependent variable triggers that occur <u>simultaneously</u> will be executed before the restart procedure is commenced from one of these dependent variable triggers.

e. The bank of storage specified by the location HBANK is as follows:

```
         PZE   m
         PZE   NH
         PZE   ND
HBANK    DEC   H
         PZE   N, , n
         DEC   t1
         DEC   t2
         DEC   y1
         DEC   y2
         .
         .
         .
         DEC   yn
         .
         .
         .
         DEC   yN
         DEC   y'1
         DEC   y'2
         .
         .
         .
         DEC   y'n
         .
         .
         .
         DEC   y'N
         BSS         3N + 2N(m + 1) for Φ 0, 2
```

where:

m = order of differences to be carried in the Adams-Moulton mode. $m \leq 9$ (fixed point in the address portion of the word) for $\Phi = 0$.

NH = number of times to sequentially halve the step-size in the Adams-Moulton mode. (fixed point in the address portion of the word.)

ND = number of times to sequentially double the step-size in the Adams-Moulton mode. (fixed point in the address portion of the word.)

NOTE 1:

NH takes precedence over ND and doubling is not executed until the number of times to halve is completed. If these numbers are introduced initially in the HBANK, the procedure is commenced automatically when conversion from Runge-Kutta to Adams-Moulton is completed. NH and ND are ignored when using the automatic variable step-size mode. NH and ND may be set by dependent variable or independent variable interruption routines in the Adams-Moulton fixed mode. Anytime control is returned to the user through an interruption routine the number of times halving and/or doubling have/has been completed is available in the decrement portion of NH and/or ND. If additional halving and/or doubling requests are entered in the address portions of NH and/or ND before a preceding request is completed, the sum of the additional request and those remaining uncompleted will be executed.

H = nominal step-size (floating point).

N = total number of 1st order differential equations (fixed point).

n = total number of the first n 1st order differential equations to be integrated by MARK, $n \leq N$ (fixed point).

NOTE 2:

H and N must not be altered unless a restart procedure is executed after the initial entry to MARK. n may be altered after the initial entry to MARK through an interruption routine. If n is increased, MARK restarts. Care should be exercised in setting the initial conditions corresponding to the additional equations to be integrated. If n is decreased, MARK continues normally integrating the new n set of differential equations.

t_1 = single precision value of the independent variable in floating point.

t_2 = second precision value of the independent variable in floating point. If P = 0 (single precision), and the restart mode is not being initiated, then t_2 is set to zero before integration is started.

y'_1 to y'_N values of the N differential equations for the dependent variables. The initial or starting values must be predetermined and set by the user (floating point).

y'_1 to y'_N values of the derivatives of the dependent variables calculated and stored by the user's derivative routine (DER1, DER2). An initial pass is executed through DER1, DER2, and EOS by MARK before the integration process is commenced (floating point).

f. Entry points: 31-12 of 13

Provision is made through entry points to MARK to transmit certain information to MARK or to render certain information available to the user that is stored internally in MARK:

HC By using the command

```
CLA*    $HC
```

the user has direct access to the current step-size being used in the integration process. This is not necessarily the nominal step-size, H, introduced by the user in the HBANK (floating point).

NI By using the command

```
STO*    $NI
```

the user informs MARK that he desired i corrections to be performed on the predictor formula used in the Adams-Moulton fixed mode of integration.

TGLO By using the command

```
CLA*    $TGLO
```

the user has direct access to the most recent $t_{\eta+1}$ calculated, where $t_{\eta+1}$ represents the value of the independent variable at the end of an integration step (floating point).

Y The command

```
CLA*    $Y
```

gives the user access to the location of the dependent variables (single precision) in the HBANK. This appears as L(Y), 1 where index register 1 set to n and counted down renders all the variables to the user (floating point).

YDOT The command

```
CLA*    $YDOT
```

performs the same function as Y for the derivatives of the dependent variables (floating point).

Y(2) The command

```
CLA*    $Y(2)
```

renders the location of the second precision part of the dependent variables available to the user (floating point).

YO
YO(2) The commands

```
CLA*    $YO
CLA*    $YO(2)
```

render the locations of the single and double precision values of the dependent variables at t_η available to the user. t_η represents the value of the independent variable at the beginning of an integration step (floating point).

g. Storage:
The user must supply 5N + 7 + 2N(m + 1) storage location for $\Phi = 0, 2$. N = maximum number of differential equations. m = order of differences to be carried in Adams-Moulton mode. Also, whatever storage is required for the user's derivative box and trigger control must be supplied.

CODING INFORMATION

Length of subroutine is 1646(10) or 3156(8) words.

REFERENCES

a. Hildebrand, F. B., Introduction to Numerical Analysis, Chapter 6.

b. Ford, L. R., Differential Equations, Chapter 6.

c. Causey, R. L., Tobey Jean, RWDE2F, "Floating Point Adams-Moulton, Runge-Kutta Integration." The Ramo-Wooldridge Company, Los Angeles, California, February 10, 1958.

IDENTIFICATION

MARSMM/MARSPC/MARFIX/MHA/PMAT/PPMAT
Alan D. Rosenberg, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

a. To compute the Mars hour angle and the matrices PMAT and PPMAT which rotate from a space-fixed mean Earth equator and equinox of 1950.0 coordinate system to a space-fixed Mars equatorial coordinate system, and from the latter system to a Mars-fixed Mars equatorial coordinate system, respectively.
b. To apply the PMAT matrix to an input vector.
c. To apply the PPMAT matrix to input position and velocity vectors.

RESTRICTIONS

a. Subroutines SIN, COS, CROSS, UNIT, FIX, FLOAT and MATRIX are called.
b. COMMON locations XN, XN., T and T+1 are assumed to contain the planetary positions and velocities and double precision seconds past 0 hr January 1, 1950, respectively.
c. MARSMM must be called before MARSPC or MARFIX may be called.
d. COMMON+4, COMMON+5 and cells 77764_8 through 77777_8 are used.
e. Entries MHA, PMAT and PPMAT are provided so the computed Mars hour angle and two rotation matrices are accessible.

METHOD

a. The orientation of the Mars spin axis is defined relative to the mean Earth equator and equinox of 1950.0 by the angles:

$$\alpha_0 = 317.7934 \text{ deg}$$

$$\delta_0 = 54.6575 \text{ deg}$$

which correspond to the direction cosines:

$$\hat{P} = \cos \delta_0 \cos \alpha_0, \cos \delta_0 \sin \alpha_0, \sin \delta_0$$

A unit vector normal to the Mars-orbital plane is computed by:

$$\hat{N} = \frac{\overline{R}_{\odot\male} \times \overline{V}_{\odot\male}}{\left|\overline{R}_{\odot\male} \times \overline{V}_{\odot\male}\right|}$$

where $\overline{R}_{\odot\male}$ and $\overline{V}_{\odot\male}$ are the Sun-Mars position and velocity vectors referenced to the Earth equator and equinox of 1950.0 coordinate system. Next, define

$$\hat{I} = \frac{\hat{P} \times \hat{N}}{|\hat{P} \times \hat{N}|}$$

$$\hat{K} = \hat{P}$$

$$\hat{J} = \hat{K} \times \hat{I}$$

where $\hat{I}$, $\hat{J}$, $\hat{K}$ are the unit vectors defining the X, Y, Z axes, respectively, of the space-fixed Mars equator and equinox of 1950.0 coordinate system. Hence the matrix to rotate from the space-fixed Earth mean equator and equinox of 1950.0 frame to the space-fixed Mars equatorial frame is as follows:

$$\text{PMAT} = \begin{pmatrix} I_x & I_y & I_z \\ J_x & J_y & J_z \\ K_x & K_y & K_z \end{pmatrix}.$$

Since no precession or nutation of the Mars equator has been defined, the above matrix is sufficient to express the relationship between the Earth and Mars equators as stated.

b. The rotation from a space-fixed Mars equatorial coordinate system to a Mars-fixed Mars equatorial coordinate system involves only a rotation about the Z-axis by the Mars hour angle, MHA:

$$\text{MHA} = \text{MHA}_{ref} + \omega_M T_D \qquad 0 \text{ deg} \leq \text{MHA} < 360 \text{ deg}$$

where

MHA_{ref} = 145.042501 deg

ω_M = angular rotation rate

= 350.891962 deg/day

= $0.7088217655 \times 10^{-4}$ rad/sec

T_D = days past 0 hr January 1, 1950, U. T.

The rotation matrix is therefore:

$$PPMAT = \begin{pmatrix} \cos MHA & \sin MHA & 0 \\ -\sin MHA & \cos MHA & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

and position and velocity vectors may be expressed in the Mars-fixed Mars equatorial coordinate system as follows:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} PPMAT \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix} = \begin{pmatrix} PPMAT \end{pmatrix} \begin{pmatrix} \dot{X} + \omega_M Y \\ \dot{Y} - \omega_M X \\ \dot{Z} \end{pmatrix}$$

MARSMM computes the Mars hour angle MHA and the two matrices PMAT and PPMAT.

MARSPC rotates an input vector from space-fixed Earth mean equator and equinox of 1950.0 coordinates to space-fixed Mars equatorial coordinates.

MARFIX rotates an input position and velocity vector from space-fixed Mars equatorial coordinates to Mars-fixed Mars equatorial coordinates.

USE

Calling sequences:

a. CALL MARSMM
   return

Exit with the Mars hour angle computed and stored in MHA, the Earth-equatorial to Mars-equatorial rotation matrix stored row-wise in PMAT through PMAT+8 and the space-fixed Mars equatorial to Mars-fixed Mars equatorial rotation matrix stored row-wise in PPMAT through PPMAT+8.

b. CALL MARSPC
   PZE A,, B
   return

where A, A+1, A+2 contain the input vector referenced to the space-fixed mean Earth equator and equinox of 1950.0 coordinate system.

B, B+1, B+2 contain the output vector referenced to the space-fixed Mars equatorial coordinate system

and where the matrix used is assumed to have been previously computed and stored internally in PMAT through PMAT+8.

c. CALL MARFIX

PZE A,, B

return

where A, ..., A+5 contain the input position and velocity vectors referenced to the space-fixed Mars equatorial coordinate system.

B, ..., B+5 contain the output position and velocity vectors referenced to the Mars-fixed Mars equatorial coordinate system

and where the matrix used is assumed to have been previously computed and stored internally in PPMAT through PPMAT+8.

CODING INFORMATION

Length of subroutine is 160(10) or 240(8) words.

REFERENCE

JPL Section 312 RFP 141, July 4, 1963.

IDENTIFICATION

33.1

MATRIX
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To perform the matrix multiplication C = (A)(B).

RESTRICTIONS

a. The matrix A must be m x 3 and B must be 3 x n.

b. MATRIX is a subset of a package of several subroutines.

METHOD

The multiplication is performed in the manner indicated by the mathematical definition of matrix multiplication.

USE

Calling sequence:

```
CALL   MATRIX
PZE    M,,A
PZE    N,,B
PZE    ,,C
```

where

M	contains the fixed point m dimension of matrix A.
A, ···, A+8	contain the A matrix, stored row-wise with A_{11} the first element.
N	contains the fixed point n dimension of matrix B.
B, ···, B+8	contain the B matrix, stored row-wise with B_{11} the first element.
C, ···, C+8	contain the matrix product C = (A)(B), stored row-wise with C,, the first element.

CODING INFORMATION

Length of subroutine (includes MATRIX as a subset) is 1046(10) or 2026(8) words.

IDENTIFICATION

MNA/MNA1/MNAMD/MNAMD1/NUTEPH/NUTLON/NUTOBL
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

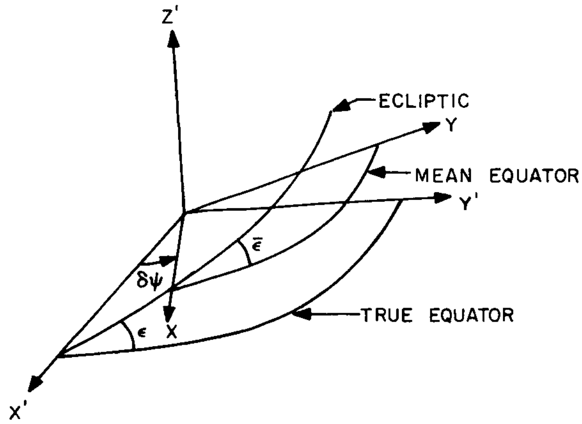
To rotate true Earth equator of-date coordinates to true lunar equator of-date coordinates and vice versa via the M and $\dot{M}$ matrices, and to form the matrix N, which rotates mean Earth equator of-date coordinates to true Earth equator of-date coordinates.

RESTRICTIONS

a. MNA, et. al., is a subset of the lunar model package and uses other subroutines in the package.
b. The input parameter NUTEPH is an internal cell and is accessible via an entry. If NUTEPH is non-zero then the nutation in longitude and nutation in obliquity are computed. If NUTEPH is zero, then the nutations are obtained by interpolation of the nutation data on the double precision JPL Ephemeris Tapes obtained by calling subroutine ANTR1.
c. Entries NUTLON and NUTOBL have been provided so that the output parameters, nutation in longitude and nutation in obliquity, respectively, are accessible.
d. It is assumed that the matrix A, which rotates mean Earth equator of 1950.0 coordinates to mean Earth equator of-date coordinates, has been updated and is in COMMON locations AA through AA+8.
e. The output N matrix is stored in NUTMAT through NUTMAT+8 and is accessible via the entry NUTMAT, the output product matrix MNA is stored in COMMON locations (MNA) through (MNA)+8 and the output matrix M is stored in COMMON locations MM through MM+8.
f. $\delta\alpha$, the nutation in right ascension used in the calculation of the true value of the Greenwich hour angle, is computed and stored in COMMON location NUTRA.

METHOD

a. The nutation matrix N: To describe the nutation of the Earth about its precessing mean equator, it is convenient to construct the nutation matrix N which relates the cartesian coordinates expressed in the true equator and equinox to those in the mean equator and equinox as shown in the following sketch:



where:

1. $\bar{\epsilon}$ is the mean obliquity and is given by:

$$\bar{\epsilon} = 23^\circ\!.4457587 - 0^\circ\!.01309404T - 0^\circ\!.0088 \times 10^{-4}T^2 + 0^\circ\!.0050 \times 10^{-4}T^3$$

where T is the number of Julian centuries of 36, 525 days past the epoch 0 hr January 1, 1950, E. T.

The nutations $\delta\epsilon$ and $\delta\psi$ may be obtained by interpolation of the nutation data on the double precision JPL Ephemeris Tapes or they may be computed as follows:

$$\Omega = 12^\circ\!.1127902 - 0^\circ\!.0529539222d + 20^\circ\!.795 \times 10^{-4}T + 20^\circ\!.81 \times 10^{-4}T^2 + 0^\circ\!.02 \times 10^{-4}T^3$$

$$☾ = 64^\circ\!.37545167 + 13^\circ\!.1763965268d - 11^\circ\!.31575 \times 10^{-4}T - 11^\circ\!.3015 \times 10^{-4}T^2 + 0^\circ\!.019 \times 10^{-4}T^3$$

$$\Gamma' = 208^\circ\!.8439877 + 0^\circ\!.1114040803d - 0^\circ\!.010334T - 0^\circ\!.010343T^2 - 0^\circ\!.12 \times 10^{-4}T^3$$

$$L = 280^\circ\!.08121009 + 0^\circ\!.9856473354d + 3^\circ\!.03 \times 10^{-4}T + 3^\circ\!.03 \times 10^{-4}T^2$$

$$\Gamma = 282^\circ\!.08053028 + 0^\circ\!.470684 \times 10^{-4}d + 4^\circ\!.5525 \times 10^{-4}T + 4^\circ\!.575 \times 10^{-4}T^2 + 0^\circ\!.03 \times 10^{-4}T^3$$

where T is the number of Julian centuries of 36, 525 days past the epoch 0 hr January 1, 1950, E. T., and d is the number of days past the same epoch. The program uses d in double precision.

2. $\delta\psi$ is the nutation in longitude measured from the true vernal equinox at the X' axis to the mean vernal equinox at the X axis.

$\delta\psi = \Delta\psi + d\psi$, where $\Delta\psi$ denotes the long period terms and $d\psi$ denotes the short period terms. They are given by:

$$\Delta\psi = -(47\overset{\circ}{.}8927 + 0\overset{\circ}{.}0482T) \times 10^{-4}\sin\Omega + 0\overset{\circ}{.}5800 \times 10^{-4}\sin 2\Omega$$
$$- 3\overset{\circ}{.}5361 \times 10^{-4}\sin 2L - 0\overset{\circ}{.}1378 \times 10^{-4}\sin(3L - \Gamma) + 0\overset{\circ}{.}0594 \times 10^{-4}$$
$$\times \sin(L + \Gamma) + 0.0344 \times 10^{-4}\sin(2L - \Omega) + 0.0125 \times 10^{-4}\sin(2\Gamma' - \Omega)$$
$$+ 0\overset{\circ}{.}3500 \times 10^{-4}\sin(L - \Gamma) + 0\overset{\circ}{.}0125 \times 10^{-4}\sin(2L - 2\Gamma')$$

$$d\psi = - 0\overset{\circ}{.}5658 \times 10^{-4}\sin 2☾ - 0\overset{\circ}{.}0950 \times 10^{-4}\sin(2☾ - \Omega) - 0\overset{\circ}{.}0725 \times 10^{-4}$$
$$\times \sin(3☾ - \Gamma') + 0\overset{\circ}{.}0317 \times 10^{-4}\sin(☾ + \Gamma') + 0\overset{\circ}{.}0161 \times 10^{-4}$$
$$\times \sin(☾ - \Gamma' + \Omega) + 0\overset{\circ}{.}0158 \times 10^{-4}\sin(☾ - \Gamma' - \Omega) - 0\overset{\circ}{.}0144 \times 10^{-4}$$
$$\times \sin(3☾ + \Gamma' - 2L) - 0\overset{\circ}{.}0122 \times 10^{-4}\sin(3☾ - \Gamma' - \Omega) + 0\overset{\circ}{.}1875 \times 10^{-4}$$
$$\times \sin(☾ - \Gamma') + 0\overset{\circ}{.}0078 \times 10^{-4}\sin(2☾ - 2\Gamma') + 0\overset{\circ}{.}0414 \times 10^{-4}$$
$$\times \sin(☾ + \Gamma' - 2L) + 0\overset{\circ}{.}0167 \times 10^{-4}\sin(2☾ - 2L) - 0\overset{\circ}{.}0089 \times 10^{-4}$$
$$\times \sin(4☾ - 2L)$$

3. $\delta\epsilon$ = is the nutation in obliquity. $\delta\epsilon = \Delta\epsilon + d\epsilon$, where $\Delta\epsilon$ denotes the long-period terms and $d\epsilon$ the short-period terms. They are given by:

$$\Delta\epsilon = 25\overset{\circ}{.}5844 \times 10^{-4}\cos\Omega - 0\overset{\circ}{.}2511 \times 10^{-4}\cos 2\Omega + 1\overset{\circ}{.}5336 \times 10^{-4}$$
$$\times \cos 2L + 0\overset{\circ}{.}0666 \times 10^{-4}\cos(3L - \Gamma) - 0\overset{\circ}{.}0258 \times 10^{-4}\cos(L + \Gamma)$$
$$- 0\overset{\circ}{.}0183 \times 10^{-4}\cos(2L - \Omega) - 0\overset{\circ}{.}0067 \times 10^{-4}\cos(2\Gamma' - \Omega)$$

$$d\epsilon = 0\overset{\circ}{.}2456 \times 10^{-4}\cos 2☾ + 0\overset{\circ}{.}0508 \times 10^{-4}\cos(2☾ - \Omega) + 0\overset{\circ}{.}0369 \times 10^{-4}$$
$$\times \cos(3☾ - \Gamma') - 0\overset{\circ}{.}0139 \times 10^{-4}\cos(☾ + \Gamma') - 0\overset{\circ}{.}0086 \times 10^{-4}$$
$$\times \cos(☾ - \Gamma' + \Omega) + 0\overset{\circ}{.}0083 \times 10^{-4}\cos(☾ - \Gamma' - \Omega) + 0\overset{\circ}{.}0061 \times 10^{-4}$$
$$\times \cos(3☾ + \Gamma' - 2L) + 0\overset{\circ}{.}0064 \times 10^{-4}\cos(3☾ - \Gamma' - \Omega)$$

4. The true obliquity is computed as follows:

$$\epsilon = \bar{\epsilon} + \delta\epsilon$$

5. $\delta\alpha$ is the nutation in right ascension used in the calculation of the true value of the Greenwich hour angle of the vernal equinox and is given by:

$$\delta\alpha = \delta\psi \cos\bar{\epsilon}$$

If N is defined in the sense

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = N \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

where the primed system is the true equator and equinox and the unprimed is the mean equator and equinox, then the N_{ij} are given by

$N_{11} = \cos\delta\psi$

$N_{12} = -\sin\delta\psi \cos\bar{\epsilon}$

$N_{13} = -\sin\delta\psi \sin\bar{\epsilon}$

$N_{21} = \sin\delta\psi \cos\epsilon$

$N_{22} = \cos\delta\psi \cos\epsilon \cos\bar{\epsilon} + \sin\epsilon \sin\bar{\epsilon}$

$N_{23} = \cos\delta\psi \cos\epsilon \sin\bar{\epsilon} - \sin\epsilon \cos\bar{\epsilon}$

$N_{31} = \sin\delta\psi \sin\epsilon$

$N_{32} = \cos\delta\psi \sin\epsilon \cos\bar{\epsilon} - \cos\epsilon \sin\bar{\epsilon}$

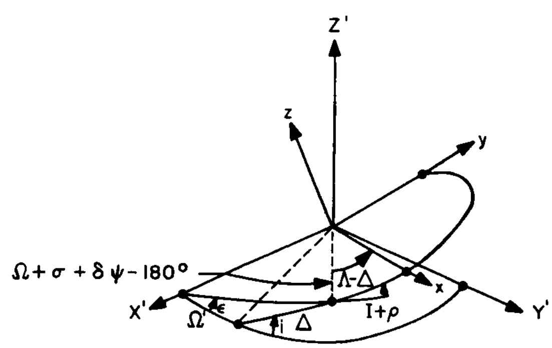
$N_{33} = \cos\delta\psi \sin\epsilon \sin\bar{\epsilon} + \cos\epsilon \cos\bar{\epsilon}$

Since $|\delta\psi| < 10^{-4}$ and $|\delta\epsilon| < 10^{-4}$, the N_{ij} are expanded to first order in $\delta\psi$ and $\delta\epsilon$ to obtain a form which is better behaved for numerical calculation:

$$N = \begin{pmatrix} 1 & -\delta\psi \cos\bar{\epsilon} & -\delta\psi \sin\bar{\epsilon} \\ \delta\psi \cos\bar{\epsilon} & 1 & -\delta\epsilon \\ \delta\psi \sin\bar{\epsilon} & \delta\epsilon & 1 \end{pmatrix}$$

b. The true Earth equator of-date to true lunar equator of-date matrix, M:

The relationship between the two planes is shown in the following sketch:



where the X', Y', Z' frame is the Earth's true equator and equinox; the x - y plane lies in Moon's true equator with z completing the right-hand system by lying along the Moon's spin axis. i is the inclination of the Moon's true equator to the Earth's true equator. Ω' is the right ascension of the ascending node of the Moon's true equator; Λ is the anomaly from the node to the x axis; Δ is the anomaly from the node to the ascending node of the Moon's true equator on the ecliptic; ϵ is the true obliquity of the ecliptic; $\delta\psi$ is the nutation in longitude; Ω is the mean longitude of the descending node of the Moon's mean equator on the ecliptic; ☾ is the mean longitude of the Moon; I is the inclination of the Moon's mean equator to the ecliptic; σ is the libration in the node; τ is the libration in the mean longitude; and ρ is the libration in the inclination. The anomalies are related by $\Lambda - \Delta = (☾ + \tau) - (\Omega + \sigma)$.

The librations are given by

$$\sigma \sin I = -0.^\circ 0302777 \sin g + 0.^\circ 0102777 \sin(g + 2\omega) - 0.^\circ 00305555 \sin(2g + 2\omega)$$

$$\tau = -0.^\circ 003333 \sin g + 0.^\circ 0163888 \sin g' + 0.^\circ 005 \sin 2\omega$$

$$\rho = -0.^\circ 0297222 \cos g + 0.^\circ 0102777 \cos(g + 2\omega) - 0.^\circ 00305555 \cos(2g + 2\omega)$$

$$I = 1.^\circ 535$$

The following expressions have been programmed for g, g', and ω:

$$g = 215.^\circ 54013 + 13.^\circ 064992\,d$$

$$g' = 358.^\circ 009067 + 0.^\circ 9856005\,d$$

$$\omega = 196.^\circ 745632 + 0.^\circ 1643586\,d$$

Evidently $g = ☾ - \Gamma'$, the mean anomaly of the Moon; $g' = L - \Gamma$, the mean anomaly of the Sun; and $\omega = \Gamma' - \Omega$, the argument of the perigee of the Moon. All quantities relate to mean motions of the Sun and the Moon.

$$\cos i = \cos(\Omega + \sigma + \delta\psi) \sin\epsilon \sin(I + \rho) + \cos\epsilon \cos(I + \rho), \qquad 0 < i < 90^\circ$$

$$\sin\Omega' = -\sin(\Omega + \sigma + \delta\psi) \sin(I + \rho) \csc i, \qquad -90^\circ < \Omega' < 90^\circ$$

$$\sin\Delta = -\sin(\Omega + \sigma + \delta\psi) \sin\epsilon \csc i$$

$$\cos\Delta = -\sin(\Omega + \sigma + \delta\psi) \sin\Omega' \cos\epsilon - \cos(\Omega + \sigma + \delta\psi) \cos\Omega', \qquad 0 \leqq \Delta < 360^\circ$$

$$\Lambda = \Delta + (☾ + \tau) - (\Omega + \sigma)$$

The two rectangular systems are related through Λ, Ω', and i by the rotation:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{pmatrix} \begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix}$$

where

$$m_{11} = \cos\Lambda \cos\Omega' - \sin\Lambda \sin\Omega' \cos i$$

$$m_{12} = \cos\Lambda \sin\Omega' + \sin\Lambda \cos\Omega' \cos i$$

$$m_{13} = \sin\Lambda \sin i$$ 33.2-6 of 9

$$m_{21} = -\sin\Lambda \cos\Omega' - \cos\Lambda \sin\Omega' \cos i$$

$$m_{22} = -\sin\Lambda \sin\Omega' + \cos\Lambda \cos\Omega' \cos i$$

$$m_{23} = \cos\Lambda \sin i$$

$$m_{31} = \sin\Omega' \sin i$$

$$m_{32} = -\cos\Omega' \sin i$$

$$m_{33} = \cos i$$

Combining the above m_{ij} (M) rotation matrix with the N and A matrices gives the MNA matrix used to rotate a position vector from Earth mean equator of 1950.0 coordinates, (X, Y, Z), to true lunar equator of-date coordinater, (x, y, z):

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = MNA \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

and inversely,

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = (MNA)' \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

for the position transformation in the other direction.

c. The derivative of M, $\dot{M}$: In computing $\dot{M}$ the rates for the slowly varying angles Ω' and i are taken to be zero.

Thus

$$\dot{M}_{11} = (-\sin\Lambda \cos\Omega' - \cos\Lambda \sin\Omega' \cos i)\dot{\Lambda}$$

$$\dot{M}_{12} = (-\sin\Lambda \sin\Omega' + \cos\Lambda \cos\Omega' \cos i)\dot{\Lambda}$$

$$\dot{M}_{13} = (\cos\Lambda \sin i)\dot{\Lambda}$$

$$\dot{M}_{21} = (-\cos\Lambda \cos\Omega' + \sin\Lambda \sin\Omega' \cos i)\dot{\Lambda}$$

$$\dot{M}_{22} = (-\cos\Lambda \sin\Omega' - \sin\Lambda \cos\Omega' \cos i)\dot{\Lambda}$$

$$\dot{M}_{23} = (-\sin\Lambda \sin i)\dot{\Lambda}$$

$$\dot{M}_{31} = 0$$ 33.2-7 of 9

$$\dot{M}_{32} = 0$$

$$\dot{M}_{33} = 0$$

From the formula

$$\Lambda = \Delta + (\text{☾} + \tau) - (\Omega + \sigma)$$

obtain

$$\dot{\Lambda} = \dot{\Delta} + \dot{\text{☾}} + \dot{\tau} - \dot{\Omega} - \dot{\sigma}$$

The adopted numerical expressions for the rates are

$$\dot{\Delta} = \frac{-\cos(\Omega + \sigma + \delta\psi)\sin\epsilon\,(\dot{\Omega} + \dot{\sigma})}{\sin i \cos\Delta}$$

$$\dot{\text{☾}} = 0.266170762 \times 10^{-5} - 0.12499171 \times 10^{-13}\, T \text{ rad/sec}$$

$$\dot{\Omega} = -0.1069698435 \times 10^{-7} + 0.23015329 \times 10^{-13}\, T \text{ rad/sec}$$

$$\dot{\tau} = -0.1535272946 \times 10^{-9}\cos g + 0.569494067 \times 10^{-10}\cos g' + 0.579473484 \times 10^{-11}\cos 2\omega \text{ rad/sec}$$

$$\dot{\sigma} = -0.520642191 \times 10^{-7}\cos g + 0.1811774451 \times 10^{-7}\cos(g + 2\omega) - 0.1064057858 \times 10^{-7}\cos(2\omega + 2g) \text{ rad/sec}$$

To obtain velocity transformations the approximation is made that

$$\dot{N} = \dot{A} = \dot{O}$$

thus

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix} = MNA \begin{pmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{pmatrix} + \dot{M}NA \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

and for the inverse transformation

$$\begin{pmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{pmatrix} = (MNA)' \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix} + (\dot{MNA})' \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

A definition of the A matrix can be found in subroutine ROTEQ.

USE

Calling sequences:

a. Position vector transformation:

```
CALL    MNA or MNA1
PZE     1,,A
PZE     n,,B
```

where A, A+1, A+2 contain the input vector
B, B+1, B+2 contain the output vector

n = 0 rotates true lunar equator of-date to mean Earth equator of 1950.0
= 1 rotates mean Earth equator of 1950.0 to true lunar equator of-date.

Enter with the fractional part of the day past 0 hr of the epoch, E. T., in the AC and the integer days past 0 hr January 1, 1950, E. T., of the epoch T, in the MQ.

It is assumed that the A matrix has been previously computed and stored in COMMON locations AA through AA+8.

The N matrix is computed and stored in locations NUTMAT through NUTMAT+8. The M matrix is computed and stored in COMMON locations MM through MM+8. The product matrices NA and MNA are formed and stored in COMMON locations (NA) through (NA)+8 and (MNA) through (MNA)+8, respectively. The nutation in right ascension is computed and stored in COMMON location NUTRA. The nutations in longitude and obliquity are stored in locations NUTLON and NUTOBL, respectively.

If CALL MNA1 is used, the contents of MNAET are used to determine whether or not the .01 day test is to be used as criteria for recomputing the matrices M and N, MNAET = 0 forces recomputation.

b. Velocity vector transformation:

```
CALL    MNAMD
PZE     1,,A
PZE     1,,B
PZE     n,,C
```

where A, A+1, A+2 contain the input position vector

B, B+1, B+2 contain the input velocity vector

C, C+1, C+2 contain the output velocity vector

n = 0 rotates true lunar equator of-date to mean Earth equator of 1950.0

= 1 rotates mean Earth equator of 1950.0 to true lunar equator of-date.

Enter with the fractional part of the day past 0 hr of the epoch, E. T., in the AC and the integer days past 0 hr January 1, 1950, E. T. of the epoch T, in the MQ.

It is assumed that the A matrix has been previously computed and stored in COMMON locations AA through AA+8.

The N matrix is computed and stored in locations NUTMAT through NUTMAT+8. The M matrix is computed and stored in COMMON locations MM through MM+8. The product matrices NA and MNA are formed and stored in COMMON locations (NA) through (NA) +8 and (MNA) through (MNA) +8, respectively. The nutation in right ascension is computed and stored in COMMON location NUTRA. The nutations in longitude and obliquity are stored in locations NUTLON and NUTOBL, respectively.

If CALL MNAMD1 is used then the contents of MNAET are used to determine whether or not the .01 day test is to be used as criteria for recomputing the matrices M and N. MNAET = 0 forces recomputation.

CODING INFORMATION

Length of subroutine (includes MNA, et. al., as a subset) is 1046 (10) or 2026 (8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION

XYZDD/XYZDD1/LUNGRV
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute the oblate potential due to the Moon.

RESTRICTIONS

a. XYZDD, XYZDD1 is a subset of the lunar model package and uses other subroutines in the package.
b. The input parameter MNAET is an internal cell and is accessible via an entry.
c. Subroutine PROD is used.
d. The acceleration vector is set to zero if the distance from the Moon's center to the probe is greater than 40,000 km.
e. The entry LUNGRV has been provided so the universal gravitational constant, G, and the moments of inertia, A, B, C, are accessible.
f. The option of using the .01 day delta-time test to force recomputation of the matrices used in the transformations is provided via the entry XYZDD1 and the internal flag MNAET. A non-zero MNAET causes the matrices to be recomputed only if time since the last computation has changed by .01 days.
g. It is assumed that the matrix A, which rotates mean Earth equator of 1950.0 coordinates to mean Earth equator of-date coordinates, has been updated and is in COMMON locations AA through AA+8.

METHOD

The following form of the potential function which accounts for a second harmonic has been adopted:

$$U_{☾} = \frac{G}{R} \frac{(A + B + C - 3I)}{2R^2}$$

where

$$G = \frac{\mu_{☾}}{m_{☾}} = k^2,$$

the universal gravitational constant, $km^3/kg\text{-}sec^2$

$$I = A\left(\frac{x}{R}\right)^2 + B\left(\frac{y}{R}\right)^2 + C\left(\frac{z}{R}\right)^2$$

R = Moon-probe distance, km

A, B, C = moments of inertia, kg - km^2.

To obtain an expression for the perturbing acceleration,

$$\nabla U_{☾} = \left(\frac{\partial U_{☾}}{\partial u_1}, \frac{\partial U_{☾}}{\partial u_2}, \frac{\partial U_{☾}}{\partial u_3}\right)$$

is formed, where $u_1 = X, u_2 = Y$, and $u_3 = Z$.

$$\frac{\partial U_{☾}}{\partial u_j} = \frac{G}{R^2}\left\{\left[-\frac{3}{2}\frac{A + B + C}{R^2} + \frac{15}{2}\frac{I}{R^2}\right]\frac{u_j}{R} - \frac{3}{R^3}\left[Am_{1j}x + Bm_{2j}y + Cm_{3j}z\right]\right\}$$

where j = 1, 2, 3

and where X, Y, Z is the Moon-probe vector referenced to the Earth mean equator and equinox of 1950.0 coordinate system.

x, y, z is the Moon-probe vector referenced to the true lunar equator of-date coordinate system.

m_{ij} are the elements of the MNA matrix, where

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \text{MNA} \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

USE

Calling sequence:

```
CALL   XYZDD or XYZDD1
PZE    1,,A
PZE    0,,B
return
```

where A, A+1, A+2 contain the input Moon-probe position vector referenced to the Earth mean equator and equinox of 1950.0 coordinate system.

B, B+1, B+2 contain the output perturbing acceleration.

and where the contents of the location MNAET is tested to determine whether or not the 0.01day test is to be used (XYZDD1 entry only). A zero MNAET deletes the 0.01 day test and hence forces recomputation of the MNA matrix.

Enter with the fractional days past 0 hr of epoch in the AC and the integer days past 0 hr January 1, 1950, E. T. in the MQ.

The output vector in B, B+1, B+2 will be set to zero if the magnitude of the input vector in A, A+1, A+2 is greater than 40,000 km.

CODING INFORMATION

Length of subroutine (includes XYZDD, XYZDD1 as a subset) is 1046 (10) or 2026 (8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION

PRINTD/PRNTD1/CONIC
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

a. PRINTD sets up and prints groups of output quantities whenever certain output control words are set.
b. PRNTD1 sets flags that override the output control words and then goes to PRINTD. The effect is to force computation and printing of the output quantities.
c. CONIC sets up and prints conic parameters.

RESTRICTIONS

a. It is assumed that the subroutine SPRAY has previously been called.
b. COMMON through COMMON +100 are used for temporary storage.
c. The following subroutines are called: SPRAY, EFFECT, ROT, PRSET, RESET, TIME1, DAYS, ARTAN, PROD, ARSIN, GETTER, SIN, SPACE, RVOUT, GEDLAT, ECLIP, GRUPPE, PROUT, UNIT, ARCOS, CROSS, MNA, MNAMD1, MATRIX, MARSMM, MARSPC, MARFIX, NUTATE, ERPRT, ABORT, COS, JERYL, CLASS, SPECL, ADD, TIME3, BCDNO, SQRT, and LN.
d. The following entries are referenced indirectly: HC, CANCLK, CLUCK, GRAV, CG, MHA, INJFLG, GROP, CAN50, CASE, INJBCD and INJTYP.

METHOD

Each FLAG at GROPS to GROPS +3 and GROPS +5 to GROPS +6 is examined; if any cell is zero the corresponding group is not printed. If the cell has the value of two, the output is in ecliptic coordinates; a value of four gives equatorial coordinates. The following groups may be printed:

Geocentric
Geocentric Conic
Heliocentric
Heliocentric Conic
Target Centered
Target Centered Conic

The conic output quantities are in two groups: those independent of the reference coordinate system and those dependent on the reference coordinate system. The possible coordinate systems are earth equatorial, ecliptic, orbit plane of target and target true equator.

USE

Calling sequences:

a. CALL PRINTD
   return

b. CALL PRNTD1
   return

c. CLA I
   CALL CONIC
   return

where I = 0 for geocentric conic
I = 1 for heliocentric conic
I = 2 for tar etcentric conic

CODING INFORMATION

Length of subroutine is 2714(10) or 5232(8) words.

IDENTIFICATION

PROUT/FLUSH
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To convert to specific output format from 1 to N lines of single or double precision information, convert the output data on one or several of the following output devices:

a. User Area Printer (SC 3070)
b. Peripheral Output Tape (SYSOU1)
   1. 1401 off-line printer or punch
   2. SC 4020 off-line microfilm recorder.

RESTRICTIONS

a. Care must be exercised if single and double precision numbers are intermixed within a repeated line format, to ensure that the address modifier ΔL will give the correct location for data in lines subsequent to the first.
b. Requires the SFOF subroutine OUTUS, an output coordinator of SFOF subroutines that require disk write operations. OUTUS includes the necessary buffers to be shared.
c. Requires the SFOF subroutine TAPEIO for off-line output requests.

USE

a. Calling sequence:

```
        CALL    PROUT
         BCI    1,XXXX
           P    FLAG, T, PROGID
         ZZZ                        }
          .                         }
          .                         }  Conversion control pseudo instructions
          .                         }  (see Conversion Parameters below)
          .                         }
          .                         }
          .                         }
         FVE    CODE, T, 1000A+B    }
         ZZZ                        }
          .                         }
          .                         }
          .                         }  Conversion control psuedo instructions
          .                         }
          .                         }
          .                         }
         FVE    CODE, T, 1000A+B    }
```

```
        ZZZ                            \
         .                             |
         .                             |
         .                             > As many conversion control groups as desired
         .                             |
         .                             |
         .                             |
        FVE     CODE, T, 1000A+B       /
        FVE     0, 0, 0
```

where,

XXXX	4 BCD characters of identification (symbols may not start with Z)
P = PZE	specifies SC 3070 output with or without peripheral output
= MZE	peripheral output only
FLAG, T	is the location of the flag word where the status of the request will be placed
PROGID	is the beginning location of 12 BCD characters of program identification to be used as part of the SC 3070 page headings; if PROGID = 0, page headings, page numbers, and page ejects (upon 53-line count) will be omitted. The provision for page headings, page numbers, and blocked output is the responsibility of the user program

For User Area Printing (SC 3070),

CODE = 0	indicates user area printing
T = 0	indicates user area printing
A = 0	indicates no post-print control
B = 1	indicates 15 line pre-print paper advance
= 10	indicates single space
= 20	indicates double space

For Peripheral Output Tape (1401-Printing or Punching),

CODE	is the location of the system tape address or logical tape number for printing or punching
T = 0	indicates printing
= 7	indicates punching
A or B = 0	indicates suppress post-print spacing, pre-print spacing, respectively
= I	where $1 \leq I \leq 9$, indicates skip to Channel I.
= 10K	indicates K spaces (K < 100)

For Peripheral Output Tape (SC 4020),

CODE	is the location of a control word that has the following format: PZE L(system tape address or logical tape number), 0, Line Count
T = 1	indicates SC 4020 printing

A or B =	0	indicates suppress post-print spacing, pre-print spacing, respectively
=	I	where $1 \leq I \leq 9$, indicates skip to Channel I.
=	10K	indicates K spaces (K < 100)

The calling sequence must be terminated by the "end" instructions:

FVE 0, 0, 0

b. Conversion parameters:

Function	Code
FLOATING TO FIXED	SVN L, T, 1000D+PP
FLOATING TO FLOATING	SIX L, T, 1000D+PP
FIXED TO FIXED	FOR L, T, 1000D+PP
BCD TO HOLLERITH	PTH L, T, 1000N+PP
FULL WORD OCTAL	PTW L, T, PP
ADDRESS TO OCTAL	PTW L, T, 1000+PP
DECREMENT TO OCTAL	PTW L, T, 2000+PP
REPEAT LINE FORMAT	PTW ΔL, 0, 3000+K
TTY BINARY CODE	PTW L, T, 4000+N
SET BINARY POINT	PZE BP, 0, 1
NO-OPERATION	PZE 0, 0, 0
REPEAT FIELD FORMAT	PZE ΔL, 0, 1000N+ΔP
INDIRECT ADDRESS	PON L, T, E
END	FVE 0, 0, 0

In these pseudo-instructions, PP represents the rightmost print position which will be used. PP may not exceed 132 for the off-line printer, 128 for the SC 4020, 120 for the SC 3070, and 72 for the off-line punch and teletypewriter. Characters before print position 2 will be lost, except for a teletypewriter line. Characters after limiting print position will result in an error indication. If fields should overlap, the later word will take precedence.

A tag (T) can be used for address modification in any pseudo-instruction except those with a prefix of FVE or PZE. A tag entry in the FVE code is interpreted as a flag only. The tag may be any number of the set 0, 1, 2, 3, 5, 6, 7. Index register 4 may not be used for address modification.

c. Parameter specifications:

Floating to Fixed SVN L, T, 1000D+PP

The floating binary word in L, T will be rounded to D decimal places and converted to fixed decimal. If D is zero, there will be no decimal point. If the absolute value of the number is greater than $2^{35} - 1$, it will be printed in floating decimal as described below. D must be less than or equal to 8. An error indication occurs when $D > 8$ unless $n > 2^{35} - 1$ (floating point) or n = integer.

Floating to Floating   SIX L, T, 1000D+PP   35-4 of 8

The floating binary word at L, T will be rounded to D decimal digits and converted to floating decimal. If D is less than or equal to 8, the number is taken as a single-precision number. If D is greater than 8 and less than or equal to 16, the number is considered to be in double-precision, floating-point form: the high-order part in L, T and the low order part in L+1, T. Any number less than 10^{-32} in absolute value will print as a single-precision zero. D must not be zero.

Fixed to Fixed   FOR L, T, 1000D+PP

The fixed-point word used in L, T will be rounded to D decimal places and converted to fixed decimal. The location of the binary point is set by the last prior pseudo-instruction "SET BINARY POINT" (see below). If D is zero, there will be no decimal point. D must not exceed 8.

BCD to Hollerith   PTH L, T, 1000N+PP

The N BCD words starting in L, T will be set for printing such that the last character will be in print position PP. N must be in the range permissible for the output device to be used.

Full Word Logical Octal   PTW L, T, PP

The word in L, T will be converted to 12 logical octal digits.

Address in Octal   PTW L, T, 1000+PP

The address portion of the word in L, T will be converted to octal.

Decrement in Octal   PTW L, T, 2000+PP

The decrement portion of the word in L, T will be converted to octal.

Repeat Line Format   PTW ΔL, 0, 3000+K

The string of data pseudo-instructions immediately following this instruction, defining a line image and terminating with one or more FVE code instructions, will produce K lines of output. After each line is formed the address fields of each data pseudo-instruction will be effectively incremented by ΔL for the next memory references.

Teletype Binary Code   PTW L, T, 4000+N

The N six-bit characters starting in L, T will be placed on disk without conversion. This instruction cannot be indirectly addressed. Neither repeat command can be used in conjunction with this instruction. N must not exceed 999. No FVE code is used with this instruction since no line image is set up.

Set Binary Point   PZE BP, 0, 1

The binary point for the following "FIXED TO FIXED" pseudo-instructions will be set at BP. Entry to the subroutine automatically performs PZE 35, , 1.

No-Operation   PZE 0, 0, 0

This instruction is provided to facilitate modifying the calling sequence.

Repeat Field Format PZE ΔL, 0, 1000N+ΔP 35-5 of 8

If the immediately preceding effective pseudo-instruction is "SET BINARY POINT" or either "REPEAT" instruction, error action is taken. Otherwise, the immediately preceding effective pseudo-instruction will be repeated with L + n (ΔL) and PP + n (ΔP) for n = 1, 2, . . . , N. In the case of indirect addressing, the word repeated is the effective pseudo-instruction. FVE codes will not be repeated. N must not be zero.

Indirect Addressing PON L, T, E

The word at L, T will be used at this point in the calling sequence as a pseudo-instruction. If E is not equal to zero, it will be used as the decrement in place of the decrement in L, T.

End FVE 0, 0, 0

This pseudo-instruction signals the end of the calling sequence. Control is returned to the user program at the next instruction.

d. Coding information:

1. The user area printer (SC 3070) output is formatted as follows: a 15 line skip; a page header containing the 12 BCD characters of program identification beginning at PROGID, the 4 BCD characters of identification, date and page number; 2 blank lines; 50 lines, including spacing, specified by the user program. Each line image will be formatted, 5 BCD characters per word, with all necessary control indicators for the 7288 output subchannel.
2. Line images for peripheral output devices will be formed in standard format for off-line processing.
3. The BCD name specified in the calling sequence identifies a print output file which is to be placed on the disk. The user area is notified of the availability of the print output file when the file is closed. The size of the file should be arranged so that the print output is made available to the user area at frequent intervals, but not so frequent that the user area would have to make a request through the message composer for every few lines of output; this should be controlled by the frequency of closing the print output file. When the BCD name changes, the previous output file is closed and made available at the user area. When the user program has operated its minimum time and OFFSYS initiates a program interchange, all print output files are closed.

   When ENDSYS or FINSYS are called, the print output files are also closed. If it is desired to close a print output file at a specific time other than those above, it may be accomplished by giving the following instruction:

```
CALL   ENDOUT
PZE    N
```

where,

N = 1 means to close print files
= 2 means to close plot files
= 3 means to close print and plot files
= 4 means to close teletype files
= 5 means to close teletype and print files
= 6 means to close teletype and plot files
= 7 means to close teletype, print, and plot files

4. Before the subroutine FLUSH (described later) has been called, the completion flag of the last PROUT request must be checked to ensure that the file remains open until the output has been completed.
5. A page eject occurs and a new heading is printed (unless PROGID = 0) when any one of the following occurs:
   (a) Change of data name.
   (b) Change of ID heading (page numbers are not reset).
   (c) Calling ENDOUT.
6. When an MZE prefix, denoting off-line output only, is used, FVE codes specifying 3070 output cannot be contained in the calling sequence.
7. All off-line output is to be labeled. The label will consist of the 4-character user program name.
8. In MODE IV all PROUT 3070 output will be printed on the on-line printer under sense switch control:

   SSW No. 6 UP = no 3070 output

   DOWN = 3070 output printed on the on-line printer
9. User areas for which PROUT output is intended are not specified in the PROUT calling sequence. When data has been placed on disk, a message is sent to the appropriate used area(s) that this specific type of data is available. The user area can request the data when it is desirable. User areas receive only those data availability messages they designate at 7094 initialization.
10. All peripheral output processed by PROUT will be placed on the same output tape (SYSOU1). The BCD data name normally designated in the PROUT calling sequence is ignored.
11. FGDOUT option: Three types of floating to floating output are available in PROUT depending upon the contents of location FGDOUT:
    (a) c(FGDOUT) = 0 indicates no leading +, and no + in the exponent field.
    = 1 indicates leading +, and + in the exponent field.
    > 1 indicates leading +, and E+ in the exponent field.
    (b) c(FGDOUT) is initially > 1.

e. Suggestions for output efficiency:
   1. Use buffering techniques wherever possible.
   2. Organize and group output so that the number of output requests is minimized.
   3. Organize output formats to print full lines or as full as possible under format requirements.
   4. Arrange user program to continue computations during output processing if it becomes necessary to wait for a free output buffer within OUTUS.
   5. Care should be taken not to modify a calling sequence or loop through a calling sequence until the flag word has been tested to determine the status of the previous request.

f. Operational description:

   The type of request is determined and processed in one of the following ways:

   1. User Area Printer Request

      The request is queued, and control is given to an output coordinating routine (OUTUS) which coordinates printing, plotting, and teletype requests, and their usage of output buffers, the calling of conversion routines, and making the necessary disk write requests. When OUTUS obtains a print (or plot or teletype) request from the queue, if an output buffer is available, OUTUS calls the proper conversion routine, and the converted output is placed in the output buffer. When the buffer is filled, or the data completed, a disk write request is then made by OUTUS to the disk control program (DCP), and control is returned to the user program. When the data has been written on disk, an interrupt occurs and control is routed to OUTUS to continue output of the request or initiate a new request. Then control is returned to the point of interruption. In this way, the print output (or plot output or teletype output) to be converted and placed on disk can be processed to make optimum usage of buffers and efficient requests of disk write operations. During the operation, if a buffer is filled or the queue is emptied or OUTUS has processed output requests as far as possible, control is returned to the user program.

   2. IBM 1401 Off-Line Printer or Punch Request

      The proper conversion routine is initiated and output is written on the 1401 output tape. The tape operation will be asynchronous under the supervision of IOEX. When the request has been initiated, control is returned to the user program.

   3. SC 4020 Off-Line Microfilm Recorder Request

      The proper conversion routine is initiated and output is written on the 4020 output tape. The tape operation will be asynchronous under the supervision of IOEX. When the request has been initiated, control is returned to the user program.

   In each option listed above, the results of the output request can be found in the flag word specified by the calling sequence.

g. Output:

1. Output Data:

   (a) 1401 - Print:

   Print lines may contain up to 132 characters.

   (b) 1401 - Punch:

   Card images may contain up to 72 characters.

   (c) SC 4020:

   Line images may contain up to 128 characters.

   (d) SC 3070:

   An integral number of lines of up to 120 characters each will be packed in each 128 word disk output buffer. The printed output is then available to the actual printer in the user area upon request.

2. Flags:

   (a) Upon entry, PROUT sets the user program flag word to zero. The user program can determine if the request has been completed by testing the flag word for zero or non-zero.

   (b) Upon completion of the request, the user program flag word is set with the results of the output operation as follows:

(1) Sign Bit	= 0:	No unusual conditions occurred.
	= 1:	At least one unusual condition occurred. The address will indicate the condition.
Bit 32	= 1:	A pseudo-instruction specifies too many (> 132) characters for one line of output.
Bit 31	= 1:	There is an error in the repeat data pseudo-instruction.
Bit 30	= 1:	The binary point exceeds bit position 35.
(2) Decrement	= 1:	Processing has been successfully completed.

   (3) When the address contains a flag bit; the decrement will contain the complement of the address of the pseudo-instruction in question.

3. The Entry Point FLUSH:

   PROUT, being a buffered output routine, must have some means of emptying its buffer when desired, even though it may be only partially filled. For this purpose an entry to PROUT has been provided whose calling sequence is simply

   ```
   CALL    FLUSH
   return
   ```

   If the buffer in use by PROUT is empty, return is immediate to the next sequential instruction. If there are any words waiting to be written, the buffer is emptied. At the completion of the I/O, return is made to the location after the call.

CODING INFORMATION

Length of subroutine is 1484(10) or 2714(8) words

IDENTIFICATION

ROTEQ/DELTJD
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To rotate mean Earth equator and equinox of-date coordinates to mean Earth equator and equinox of 1950.0 and vice versa.

RESTRICTIONS

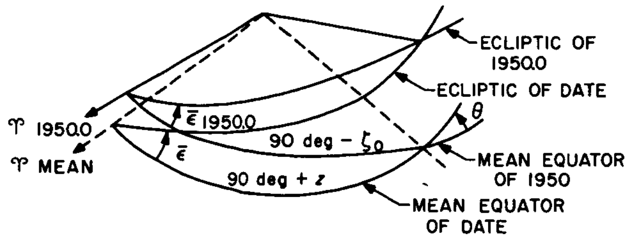
a. The matrix is stored in the COMMON locations AA through AA+8.
b. The subroutine uses COMMON through COMMON+2.
c. The option of recomputing the matrix only if time has changed by at least 1/64 day is controlled by the contents of the external quantity MNAET. Nominally MNAET is zero which turns off the 1/64 day test which forces a recomputation of the matrix.
d. An entry has been provided for access to DELTJD, the difference between the J.D. of 1950.0 and the J.D. of 0 hr January 1, 1950, in days.

METHOD

The general precession of the Earth's equator and the consequent retrograde motion of the equinox on the ecliptic may be represented by the rotation matrix:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

where X, Y, and Z are expressed in the mean equator and equinox of 1950.0 and X', Y', Z' are the coordinates in the mean equator and equinox of date. The geometry of the precession has been represented by the three small parameters ζ_0, z, and θ in the following sketch.



where $\Upsilon_{1950.0}$ is the mean equinox of 1950.0; $\bar{\epsilon}_{1950.0}$ is the mean obliquity of 1950.0; Υ_{mean} is the mean equinox of date; $\bar{\epsilon}$ is the mean obliquity of date. Measured in the mean equator of 1950.0 from the mean equinox of 1950.0, 90 deg - ζ_0 is the right ascension of the ascending node of the mean equator of date on the mean equator of 1950.0. 90 deg + z is the right ascension of the node measured in the mean equator of date from the mean equinox of date. θ is the inclination of the mean equator of date to the mean equator of 1950.0.

In terms of ζ_0, z, and θ, (α_{ij}) is given by

$$\alpha_{11} = -\sin\zeta_0 \sin z + \cos\zeta_0 \cos z \cos\theta$$
$$\alpha_{12} = -\cos\zeta_0 \sin z - \sin\zeta_0 \cos z \cos\theta$$
$$\alpha_{13} = -\cos z \sin\theta$$

$$\alpha_{21} = \sin\zeta_0 \cos z + \cos\zeta_0 \sin z \cos\theta$$
$$\alpha_{22} = \cos\zeta_0 \cos z - \sin\zeta_0 \sin z \cos\theta$$
$$\alpha_{23} = -\sin z \sin\theta$$

$$\alpha_{31} = \cos\zeta_0 \sin\theta$$
$$\alpha_{32} = -\sin\zeta_0 \sin\theta$$
$$\alpha_{33} = \cos\theta$$

$$\zeta_0 = 2304''.997T + 0''.302T^2 + 0''.0179T^3$$
$$z = 2304''.997T + 1''.093T^2 + 0''.0192T^3$$
$$\theta = 2004''.298T - 0''.426T^2 - 0''.0416T^3$$

with T the number of Julian centuries of 36,525 days past the epoch 1950.0.

The actual computational form of (α_{ij}) is obtained by expanding the α_{ij} in power series in ζ_0, z, θ and replacing the arguments by the above time series. The results are

$$\alpha_{11} = 1 - 0.00029697T^2 - 0.00000013T^3$$
$$\alpha_{12} = -\alpha_{21} = -0.02234988T - 0.00000676T^2 + 0.00000221T^3$$
$$\alpha_{13} = -\alpha_{31} = -0.00971711T + 0.00000207T^2 + 0.00000096T^3$$
$$\alpha_{22} = 1 - 0.00024976T^2 - 0.00000015T^3$$
$$\alpha_{23} = \alpha_{32} = -0.00010859T^2 - 0.00000003T^3$$
$$\alpha_{33} = 1 - 0.00004721T^2 + 0.00000002T^3$$

USE

Calling sequence:

Enter with days past 0 hr January 1, 1950 E. T. in the AC-MQ.

```
CALL   ROTEQ
PFX    X,,Y
return
```

where

X-3, X-2, X-1 contain the input vector.

Y-3, Y-2, Y-1 contain the output vector.

PFX = PZE assumes mean 1950.0 input and rotates to mean of-date.

PFX = MZE assumes mean of-date input and rotates to mean 1950.0.

X = Y is permitted.

CODING INFORMATION

Length of subroutine is 107(10) or 153(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION

RVIN/RVOUT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

a. RVIN transforms a set of input spherical coordinates R, Φ, Θ, V, Γ, Σ, to a set of cartesian coordinates X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$.

b. RVOUT transforms a set of input cartesian coordinates X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$, to a set of spherical coordinates R, Φ, Θ, V, Γ, Σ.

RESTRICTIONS

a. Subroutines called are SIN, COS, MATRIX, PROD, ARTAN, UNIT, and ARSIN.

b. All angles are assumed to be in degrees.

METHOD

a. RVIN computes the cartesian components of the vector $\overline{R}$ by

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} R\cos\Phi\cos\Theta \\ R\cos\Phi\sin\Theta \\ R\sin\Phi \end{pmatrix}$$

where Θ is the longitude measured clockwise in the X - Y plane from the X-axis and Φ is the latitude measured positive above the X - Y plane. The quantities Γ, the path angle, and Σ, the azimuth angle determine the orientation of the velocity vector with respect to the plane of the local horizontal, that is, perpendicular to the $\overline{R}$ vector.

$\overline{V}$ is expressed in the local horizontal system as

$$\overline{V} = \begin{pmatrix} \dot{X}' \\ \dot{Y}' \\ \dot{Z}' \end{pmatrix} = \begin{pmatrix} V\sin\Gamma \\ V\cos\Gamma\sin\Sigma \\ V\cos\Gamma\cos\Sigma \end{pmatrix}$$

and finally the results in the original system are

$$\overline{V} = \begin{pmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{pmatrix} = \begin{pmatrix} \cos\Theta & -\sin\Theta & 0 \\ \sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\Phi & 0 & -\sin\Phi \\ 0 & 1 & 0 \\ \sin\Phi & 0 & \cos\Phi \end{pmatrix} \begin{pmatrix} \dot{X}' \\ \dot{Y}' \\ \dot{Z}' \end{pmatrix}$$

b. RVOUT performs the computations which follow:

$$R = \sqrt{X^2 + Y^2 + Z^2}$$

$$\Phi = \arcsin \frac{Z}{R}, \qquad -90 \text{ deg} \leq \Phi < 90 \text{ deg}$$

$$\Theta = \arctan \frac{Y}{X}, \qquad 0 \text{ deg} \leq \Theta \leq 360 \text{ deg}$$

which gives R, the magnitude of $\overline{R}$, the latitude Φ and longitude Θ. The cartesian velocity components ($\dot{X}$, $\dot{Y}$, $\dot{Z}$) are rotated to the local horizontal system where the components are called ($\dot{X}'$, $\dot{Y}'$, $\dot{Z}'$) by

$$\begin{pmatrix} \dot{X}' \\ \dot{Y}' \\ \dot{Z}' \end{pmatrix} = \begin{pmatrix} \cos\Phi & 0 & \sin\Phi \\ 0 & 1 & 0 \\ -\sin\Phi & 0 & \cos\Phi \end{pmatrix} \begin{pmatrix} \cos\Theta & \sin\Theta & 0 \\ -\sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{pmatrix}$$

the spherical set may then be obtained as follows:

$$V = \sqrt{\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2}$$

$$\Gamma = \arcsin \frac{\dot{X}'}{V}, \qquad -90 \text{ deg} \leq \Gamma \leq 90 \text{ deg}$$

$$\Sigma = \arctan \frac{\dot{Y}'}{\dot{Z}}, \qquad 0 \text{ deg} \leq \Sigma < 360 \text{ deg}$$

USE

Calling sequences:

a. Spherical to cartesian:

```
CALL   RVIN
PZE    ,,A
PZE    ,,B
PZE    ,,C
```

where A, $\cdots$, A + 5 contain the input R, Φ, Θ, V, Γ, Σ; the output variables X, Y, Z are placed in B, B + 1, B + 2 and $\dot{X}$, $\dot{Y}$, $\dot{Z}$ are placed in C, C + 1, C + 2.

b. Cartesian to spherical:

```
CALL   RVOUT
PZE    1,,A
PZE    1,,B
PZE    1,,C
```

where A, A + 1, A + 2 contain the input X, Y, Z and B, B + 1, B + 2 contain the input $\dot{X}$, $\dot{Y}$, $\dot{Z}$. The output variables R, Φ, Θ, V, Γ, Σ are placed in C, $\cdots$, C + 5.

CODING INFORMATION

Length of subroutine is 200(10) or 310(8) words.

REFERENCE

Holdridge, D. B., Space Trajectories Program for the IBM 7090 computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

IDENTIFICATION 38

SEITE/CASE/EJECT/EJECT1/LINES/PAGBCD
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To eject the page, set up and print the first three lines (heading) of each page.

RESTRICTIONS

a. Subroutine PROUT is called. DATCEL is referenced indirectly and contains the BCD date of loading of the program.
b. Entries are provided for locations CASE, EJECT, EJECT1, LINES and PAGBCD, where

   C(CASE) = case number
   C(EJECT) = page count
   C(EJECT1) = line count
   C(LINES) = 63: number of lines to be put on a page
   C(PAGBCD through PAGBCD+39) = page heading.

METHOD

a. The page number, N, is incremented by 1.
b. The case number, C, is computed.
c. A page eject is given.
d. "Case C IBSYS-JPTRAJ-SPACE C(DATCEL) N" is printed.
e. The 40 BCD words at PAGBCD are printed on two lines.
f. The line count is set to 3.

USE

Calling sequence:

```
CALL    SEITE
return
```

CODING INFORMATION

Length of subroutine is 82(10) or 122(8) words

IDENTIFICATION 39

SPRAY
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To decode the input quantity GROP into twelve flags and to store the flags into GROPS to GROPS +11 before and after transformation by EFFECT.

RESTRICTIONS

a. It is assumed that parameter GROP contains 12 octal group output option flags, each octal digit being a flag.
b. GROPS to GROPS +11, in COMMON, are used. GROP is referenced indirectly.

METHOD

Each of the twelve octal digits in GROP is placed in bits 33 - 35 in an otherwise zero accumulator. These twelve words are stored sequentially into GROPS to GROPS +11.

USE

Calling sequence:

```
CALL    SPRAY
return
```

CODING INFORMATION

Length of subroutine is 10(10) or 12(8) words.

IDENTIFICATION 40

SQRT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To compute $\sqrt{x}$ for a normalized floating point, single precision x.

RESTRICTIONS

a. An error return will occur if the argument is negative, in which case the accumulator will contain $\sqrt{|x|}$.
b. Uses COMMON to COMMON +3.

METHOD

The Newton Raphson method is used to compute the square root of x where

$$0 \le x \le 2^{128}$$

Accuracy: The result is accurate to 8 decimal digits.

USE

Enter with the argument in the accumulator. Exit with the result in the accumulator.

Calling sequence:

```
CLA          X
CALL         SQRT
error return
normal return
```

CODING INFORMATION

Length of subroutine is 41(10) or 51(8) words.

IDENTIFICATION

TIME1/TIME2/TIME3/LAUNCH

JPL Staff

IBM 7094 Fap

December 2, 1964

PURPOSE

To compute and print the calendar date, the Julian date and the trajectory time, given the double precision seconds past 0^h January 1, 1950.

RESTRICTIONS

a. DAYS, FIXT, ADD, FIX, FLOAT, GRUPPE and PROUT are called.

b. OPRFLG, EQUNX1, TARBCD and INJEQX are used.

c. A double precision number is assumed to be two floating point words.

d. The entry LAUNCH is provided to allow access to the launch epoch if it is input.

METHOD

a. Subroutine DAYS is used to obtain the integral days and residual seconds past 0^h January 1, 1950. The Julian date (JD) is then computed as a one word floating point integer and a one word floating point fraction using the following relations:

integral JD = integral days from 0^h January 1, 1950, to date +2433282, the Julian date of 12^h January 0, 1950 +I

fractional JD = residual days -0.5 + (1-I)

where I = 0 if residual days < 0.5

= 1 if residual days ≥ 0.5

b. The calendar date is computed by calling subroutine FIXT.

c. The trajectory time is computed using the following relation:

trajectory time = current epoch minus injection epoch.

USE

Enter with the time in double precision seconds past 0^h January 1, 1950, in the AC and MQ.

The three entries provide for three output formats as follows:

TIME1: X DAYS X HRS. X MIN. X.XXX SEC., C(EQUNX1), Octal sec past 50, JD, calendar date

TIME2: INJECTION CONDITIONS, C(INJEQX), C(TARBCD), Octal sec past 50, JD, calendar date

TIME3: EPOCH OF PERICENTER PASSAGE, Octal sec past 50,
JD, calendar date

Calling sequence:

```
CLA     L(SECONDS A)
LDQ     L(SECONDS B)
CALL    TIME1 (or TIME2 or TIME3)
return
```

CODING INFORMATION

Length of subroutine is 238(10) or 356(8) words.

IDENTIFICATION 42.1

TRAJ

JPL Staff

IBM 7094 Fap

December 2, 1964

PURPOSE

To provide the control and closed subroutines needed to drive the subroutine MARK.

RESTRICTIONS

Since TRAJ is the driver subroutine for SPACE, numerous entries and transfer vectors are used for communication and control.

METHOD

TRAJ performs the following tasks:

a. Initializes triggers on the basis of input parameters.
b. Converts BCD input to integers via subroutine BCDNO.
c. Converts sexagesimal input to seconds past 0 hr January 1, 1950 via subroutines FLOT or FLOTT.
d. Rotates the injection conditions to the 1950.0 coordinate system by calling subroutine INTRAN.
e. Initializes the n-body ephemerides by calling EPHSET and INTR1.
f. Sets control flags and branches on the basis of input parameters.
g. Obtains the proper set of phase parameters and initializes triggers on the basis of those parameters.
h. Calls MARK.
i. Supplies MARK with derivative, end-of-step, step-size control and trigger subroutines as required.
j. Terminates a phase (and repeats starting at g above) or terminates the run and returns to JPTRAJ via JEXIT or ABORT.

USE

Calling sequence:

```
CALL    TRAJ
return
```

CODING INFORMATION

Length of subroutine is 2676(10) or 5164(8) words.

IDENTIFICATION 42.2

FLOTT
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To convert a sexagesimal date or an interval past the initial epoch, to seconds past 0 hr January 1, 1950.

RESTRICTIONS

a. FLOTT is a subset of the driver, TRAJ.
b. Subroutine FLOT is called to make the time conversion.
c. T(0) in COMMON is used.

METHOD

Subroutine FLOT is called to get the time in seconds past 0 hr January 1, 1950. However, if this number is less than 1×10^8 then the assumption is made that the input time was a time interval past the initial epoch. In this case the input interval, converted to seconds, is added to T(0), the initial epoch.

USE

Calling sequence:

```
CALL    FLOTT
PPP     A, N, B
```

where

A, N and A+1, N	contain the input time
B, PPP and B+1, PPP	contain the output seconds past 0 hr January 1, 1950

and PPP is the FAP code for 0, 1, ···, 7 designating the index register to use to locate the output storage cell.

CODING INFORMATION

Length of subroutine (includes FLOTT as a subset) is 2676(10) or 5164(8) words.

IDENTIFICATION

VARY/SVARY
JPL Staff
IBM 7094 Fap
December 2, 1964

PURPOSE

To calculate the partial derivatives, $\partial\ddot{\overline{R}}/\partial u_j$, where

$$\{u_j\} = \{X_0, Y_0, Z_0, \dot{X}_0, \dot{Y}_0, \dot{Z}_0\}.$$

RESTRICTIONS

a. The execution entry VARY must be preceded by a call to the setup entry SVARY.
b. The COMMON location CENTER is referenced and must contain the number corresponding to the current central body.
c. COMMON through COMMON+29 are used.

METHOD

The $\partial\ddot{\overline{R}}/\partial u_j$ may be expressed in the form:

$$\frac{\partial\ddot{\overline{R}}}{\partial u_j} = (A + B)\frac{\partial\overline{R}}{\partial u_j}$$

where the matrix A arises from the central body term and the n-body perturbation. B approximates the effect of the Earth's oblateness and is not used if $R > 3a_{\oplus}$, or if the Earth is not the center.

The form of A is obtained by differentiating $\ddot{\overline{R}}$ with respect to u_j and exchanging the order of differentiation where:

$$\ddot{\overline{R}} = -\mu\frac{\overline{R}}{R^3} - \sum_{k=1}^{n} \mu k\left\{\frac{\overline{R}_{kp}}{R_{kp}^3} + \frac{\overline{R}_k}{R_k^3}\right\}$$

$$\cdot\frac{\partial\ddot{\overline{R}}}{\partial u_j} = -\sum_{k=0}^{n} \mu k\left\{\frac{1}{R_{kp}^3}\frac{\partial\overline{R}}{\partial u_j} - \frac{3}{R_{kp}^5}\left(\overline{R}_{kp}\cdot\frac{\partial\overline{R}}{\partial u_j}\right)\overline{R}_{kp}\right\}$$

with $\mu_0 = \mu$ and $\overline{R}_{0p} = \overline{R}$. Expanding the dot products, the computational form of A results:

$$A_{11} = -\sum_{k=0}^{n} \mu k \left\{ \frac{1}{R_{kp}^3} - \frac{3X_{kp}^2}{R_{kp}^5} \right\}$$

$$A_{12} = A_{21} = 3 \sum_{k=0}^{n} \mu k \frac{X_{kp} Y_{kp}}{R_{kp}^5}$$

$$A_{13} = A_{31} = 3 \sum_{k=0}^{n} \mu k \frac{X_{kp} Z_{kp}}{R_{kp}^5}$$

$$A_{22} = -\sum_{k=0}^{n} \mu k \left\{ \frac{1}{R_{kp}^3} - \frac{3Y_{kp}^2}{R_{kp}^5} \right\}$$

$$A_{23} = A_{32} = 3 \sum_{k=0}^{n} \mu k \frac{Y_{kp} Z_{kp}}{R_{kp}^5}$$

$$A_{33} = -\sum_{k=0}^{n} \mu k \left\{ \frac{1}{R_{kp}^3} - \frac{3Z_{kp}^2}{R_{kp}^5} \right\}$$

To obtain an approximate expression for the oblateness contribution B, choose the perturbation which retains just the second harmonic term:

$$\left(g_1 \frac{X}{R}, \; g_1 \frac{Y}{R}, \; g_2 \frac{Z}{R} \right)$$

where

$$g_1 = -\frac{J a_{\oplus}^2 \mu_{\oplus}}{R^4} \left(1 - \frac{5Z^2}{R^2} \right)$$

$$g_2 = -\frac{J a_\oplus^2 \mu_\oplus}{R^4}\left(3 - \frac{5Z^2}{R^2}\right).$$

At this point a further approximation is made in that the coordinates are regarded as being expressed in the reference system, the mean equator and equinox of 1950.0.

Forming the partial derivatives:

$$\frac{\partial \ddot{X}}{\partial u_j} = g_1 \frac{X}{R}\left(\frac{1}{X}\frac{\partial X}{\partial u_j} - \frac{3}{R^2}\overline{R}\cdot\frac{\partial \overline{R}}{\partial u_j}\right) + \frac{\mu_\oplus X}{R^3}\frac{J a_\oplus^2}{R^4}\left\{10Z\frac{\partial Z}{\partial u_j} + 2\left(1 - \frac{10Z^2}{R^2}\right)\overline{R}\cdot\frac{\partial \overline{R}}{\partial u_j}\right\}$$

$$\frac{\partial \ddot{Y}}{\partial u_j} = g_1 \frac{Y}{R}\left(\frac{1}{Y}\frac{\partial Y}{\partial u_j} - \frac{3}{R^2}\overline{R}\cdot\frac{\partial \overline{R}}{\partial u_j}\right) + \frac{\mu_\oplus Y}{R^3}\frac{J a_\oplus^2}{R^4}\left\{10Z\frac{\partial Z}{\partial u_j} + 2\left(1 - \frac{10Z^2}{R^2}\right)\overline{R}\cdot\frac{\partial \overline{R}}{\partial u_j}\right\}$$

$$\frac{\partial \ddot{Z}}{\partial u_j} = g_2 \frac{Z}{R}\left(\frac{1}{Z}\frac{\partial Z}{\partial u_j} - \frac{3}{R^2}\overline{R}\cdot\frac{\partial \overline{R}}{\partial u_j}\right) + \frac{\mu_\oplus Z}{R^3}\frac{J a_\oplus^2}{R^4}\left\{10Z\frac{\partial Z}{\partial u_j} + 2\left(3 - \frac{10Z^2}{R^2}\right)\overline{R}\cdot\frac{\partial \overline{R}}{\partial u_j}\right\}$$

where $\partial\ddot{\overline{R}}/\partial u_j$ represents the contribution arising from the oblateness only. The final form of B is obtained by the expansion of the dot products:

$$B_{11} = g_1 \frac{X}{R}\left(\frac{1}{X} - \frac{3X}{R^2}\right) + 2\mu_\oplus \frac{X^2}{R^3}\frac{Ja_\oplus^2}{R^4}\left(1 - \frac{10Z^2}{R^2}\right)$$

$$B_{12} = g_1 \frac{X}{R}\left(-\frac{3Y}{R^2}\right) + 2\mu_\oplus \frac{XY}{R^3}\frac{Ja_\oplus^2}{R^4}\left(1 - \frac{10Z^2}{R^2}\right)$$

$$B_{13} = g_1 \frac{X}{R}\left(-\frac{3Z}{R^2}\right) + 2\mu_\oplus \frac{XZ}{R^3}\frac{Ja_\oplus^2}{R^4}\left(6 - \frac{10Z^2}{R^2}\right)$$

$$B_{21} = g_1 \frac{Y}{R}\left(-\frac{3X}{R^2}\right) + 2\mu_\oplus \frac{XY}{R^3}\frac{Ja_\oplus^2}{R^4}\left(1 - \frac{10Z^2}{R^2}\right)$$

$$B_{22} = g_1 \frac{Y}{R}\left(\frac{1}{Y} - \frac{3Y}{R^2}\right) + 2\mu_\oplus \frac{Y^2}{R^3}\frac{Ja_\oplus^2}{R^4}\left(1 - \frac{10Z^2}{R^2}\right)$$

$$B_{23} = g_1 \frac{Y}{R}\left(-\frac{3Z}{R^2}\right) + 2\mu_\oplus \frac{YZ}{R^3}\frac{Ja_\oplus^2}{R^4}\left(6 - \frac{10Z^2}{R^2}\right)$$

$$B_{31} = g_2 \frac{Z}{R}\left(-\frac{3X}{R^2}\right) + 2\mu_\oplus \frac{XZ}{R^3}\frac{Ja_\oplus^2}{R^4}\left(3 - \frac{10Z^2}{R^2}\right)$$

$$B_{32} = g_2 \frac{Z}{R}\left(-\frac{3Y}{R^2}\right) + 2\mu_\oplus \frac{YZ}{R^3}\frac{Ja_\oplus^2}{R^4}\left(3 - \frac{10Z^2}{R^2}\right)$$

$$B_{33} = g_2 \frac{Z}{R}\left(\frac{1}{Z} - \frac{3Z}{R^2}\right) + 2\mu_\oplus \frac{Z^2}{R^3}\frac{Ja_\oplus^2}{R^4}\left(8 - \frac{10Z^2}{R^2}\right)$$

The vector $(g_1X/R,\ g_1Y/R,\ g_2Z/R)$ is assumed to be calculated externally while the parts of B which do not contain g_1 or g_2 are replaced by zero whenever $R > 3a_\oplus$.

USE

Calling sequences:

a. Setup entry:

CALL SVARY, A, B, C, D, E, F, G, H, I, J, K

where

A-3, A-2, A-1	contain the position of the probe with respect to the central body.
B-3n, ···, B-1	contain the (n-body)-probe position vectors, $\overline{R}_1, \cdots, \overline{R}_n$.
C	contains the magnitude of the central body-probe vector.
D-n, ···, D-1	contain the magnitudes of the (n-body)-probe position vectors.
E	contains the μ of the central body.
F-n, ···, F-1	contain the μ_j of the non-central bodies. A zero μ_j causes no computation to be made for body j.
G-3, G-2, G-1	contain the input oblateness perturbation.
H's decrement	contains n, the maximum number of perturbing bodies.
I	is not used.
J	is not used.
K-9, ···, K-1	contain the output matrix A + B.

b. Execution entry:

CALL VARY

return

CODING INFORMATION

Length of subroutine is 229(10) or 345(8) words.

IDENTIFICATION

WRITE1/WRITEN/WRITEC/COD
Peter S. Fisher, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

To write a spacecraft ephemeris tape for use by a processor.

RESTRICTIONS

a. TAPIO and PROUT are used for input-output.
b. The RUNID on each S/C ephemeris must be in ascending order according to BCD code.
c. Entry COD is provided to locate the I/O list for the data record.

METHOD

a. WRITE1 writes the ID record.
b. WRITEN writes the data record. This record has two formats depending on whether or not the variational equations are being integrated.
c. WRITEC writes the last record on the S/C ephemeris tape along with two dummy ID records with (RUNID) = 777777777777 (8) to facilitate finding the requested RUNID in READ1. The tape is then back-spaced two records so that another S/C ephemerides can be written.

On each data record there is a code word with flags indicating what conditions are in effect in the trajectory.

The flags are as follows:

BIT 35   0 = no discontinuity this record
1 = discontinuity this record

BIT 34   0 = no phase change this record
1 = phase change this record

If BIT 34 = 1 the next 4 bits contain information

BIT 33   0 = no radius stop
1 = radius stop

BIT 32   0 = no $\dot{R} = 0$ stop
1 = $\dot{R} = 0$ stop

BIT 31   0 = no time stop
1 = time stop

BIT 30   0 = no dependent variable stop
1 = dependent variable stop

BIT 29   0 = no burn in progress
1 = burn in progress

BIT 28	0 = probe out of shadow 1 = probe in shadow (checked only if PASH $\neq$ 0 or RADOPT $\neq$ 0)
BIT 27	0 = gas jets off 1 = gas jets on
BIT 26	0 = normal 1 = job has been aborted
BIT 25	0 = probe has not impacted target 1 = probe has impacted target
BITS 2-24	Not in use
BIT 1	0 = this is a data record 1 = this is an ID record
SIGN BIT	0 = this is not the last record of S/C ephemeris 1 = this is the last record

USE

Calling sequences:

```
CALL    WRITE1        CALL    WRITEN        CALL    WRITEC
return                return                return
```

CODING INFORMATION

Length of subroutine is 235(10) or 353(8) words.

IDENTIFICATION 45

WOLF/TIM/MACH
Peter S. Fisher, JPL
IBM 7094 Fap
December 2, 1964

PURPOSE

To print an explanatory comment at injection and at each phase change.

RESTRICTIONS

a. Subroutines PRSET, TIME1, PROUT, GRUPPE and TIME are called.
b. OPRFLG is set non-zero to signify that if on-line print has been requested then the line generated by this subroutine is also to be printed on-line. KERN1 is referenced to obtain the BCD name of the central body for integration.
c. Entries TIM and MACH have been provided to allow access to the time of day and computer I. D. character.
d. It is assumed that the date has been provided by the system at SYSDAT, octal location 101.

METHOD

A test is made to see if the current epoch, T, is injection epoch. If so, then subroutine TIME is called to obtain the time of day and computer I. D. character. Then the following comments are printed on one line:

DATE OF RUN MMDDYYC TTTRRS BBBBBB IS THE CENTRAL BODY FOR INTEGRATION COWELL EQUATIONS OF MOTION

Where MM is the month, DD is the day, YY is the year, C is the computer I. D. character, TTT is the hour of day, RR is minutes, and S is the tens of seconds. BBBBBB is the name of the body currently used as the central body for integration.

If the current epoch is not injection epoch then TIME1 is called to print the time line and then the following comments are printed on one line:

CHANGE OF PHASE OCCURS AT THIS POINT BBBBBB IS THE CENTRAL BODY FOR INTEGRATION COWELL EQUATIONS OF MOTION

Where BBBBBB is the name of the body currently used as the central body for integration.

USE

```
Calling sequence:  CALL    WOLF
                   return
```

CODING INFORMATION

Length of subroutine is 81 (10) or 121 (8) words.

VII. CHECK CASES

Four check cases have been used for several years by JPL trajectory engineers to confirm that the version of the trajectory program being released for use is computationally correct. In addition, other trajectories are run which check the options not used by the four standard cases.

```
$JOB  RJW,1082000,542-10401-1-3120,FC                          124451 A    02/26/65    *****************

*       JPTRAJ
*       CATA



      SCURCE PRCGRAM LISTING                                    2/26/65     PAGE 1

*       SPACE   I
            PAGBCD=(EARTH-MOON FINE PRINT CHECK 1)                           C
            TARBCD=(MCCN) INJBCD =(EARTH)                                    C
            FAZFLG=1 INJTYP=C INJEQX=(1950.0)                                C
            INJT=6301C1318,4201297                                           C
            INJX=21556303632C/8,214523646526/8,612554325025/8                C
            INJDX=603416475431/8,204420666560/8,603534774303/8               C
            MOCPH1+11=2,C,0,30C0C00,20C,0,4,0,4C0,0,40C,0                    C
            MOCPH1+27=11CC00C0C0CC/8                                         C
            MOCPH1+38=101000000CC/8                                          C
            MOOPH2+11=4CC,0,0,3000000                                        C
            MOOPH2+11=40C,0,4,0                                              C
            MOOPH2+27=11CC000/8                                              C
            MOOPH2+38=1C11/8                                                 C
            MOOPH2+38=1111/8                                                 C
            MCOPH2+27=1111011C000C/8                                         C
* I
*       SPACE   J
        PAGBCD=(EARTH-VENUS, RADIATION PRES. ON)
            PAGBCC+8=(  CHECK 2  )
        INJBCD=(EARTH) TARBCD=(VENUS) INJTYP=0
        INJT=6209C050C,2332000
        INJX=62553503C676/8,625730425255/8,621606475633/8
        INJDX=601700261755/8,6C2465443457/8,575673744666/8
        INJECX=(1950.C)
        RADOPT=.1C2E9,C,C,3.83,.383,198.22
        VENPH1+11=400C,C,1000,C,20000,0,20000,0
        VENPH1+27=1524CCC0000C/8  VENPH1+38=100001000000/8
        VENPH2+0=5,(VENUS),2.5E6,(VENUS),0
        VENPH2+11=600C,C,10CC,0,2C000,0,20C00,0
        VENPH2+27=1524C000000C/8  VENPH2+38=100001000000/8
        VENPH3+11=200CC,C,20C,C
        VENPH3+27=1524C220000C/8  VENPH3+38=100001000100/8
* J
*       SPACE   K
            PAGBCD = (   EARTH - MARS                  CHECK 3  )
            TARBCD=(MARS)  INJBCD=(EARTH)  FAZFLG =1   INJTYP=0
            INJT=235677237016/8,2C26054C00C0/8    $ 641101116,3923043
            INJX=215522623366/8,213675042633/8,61463012730б/8
            INJDX=602532206172/8,204542657366/8,200624303772/8
            INJECX=(1950.0)
            MARPH1+27=11C000CC0C0C/8  MARPH1+38=101000000000/8
            MARPH2+27=C0210CCC0000/8   MARPH2+38=01100000/8
            MARPH3+27=1C200210C0CC/8    MARPH3+38=0100/8
            MARPH3+27=1C200210000C/8    MARPH3+38=1011/8
* K
*       SPACE   L
        PAGBCD=(EARTH-MCCN)
        PAGBCD+7=(CHECK 4)
        TARBCD=(MCON) INJBCD=(EARTH) INJTYP=0
        INJT=6308C0617,C4557C7
      INJX=61557б114C61/8,614444767212/8,612420651171/8
        INJDX=202703617723/8,6044315375C1/8,603535320551/8
        INJEQX=(1950.C)
    MOOPH1+27=11100CCC0C00/8  MOOPH1+38=1C3000000000/8
        MOOPH2+27=151CC1100CC0/8  MOOPH2+38=100000001031/8
        MARPH2+4=234711607OCC/8
        MARPH3+2=2146531C000C/8



      SCURCE PRCGRAM LISTING                                    2/26/65     PAGE 2

* L
*       END

            THERE WERE NC GLARING SOURCE DECK ERRCRS.

            THE OBJECT STRING HAS 00367 OCTAL OR  247 DECIMAL WCRDS.
```

A. Check case 1 is an Earth-Moon trajectory with a fine print. The spacecraft injects near the Earth on January 13, 1963 and impacts the Moon after a 66.08-hour flight time.

```
     START TRAJECTORY (SPACE)        12451       A

CASE  1                                    IBSYS-JPTRAJ-SPACE 022665                                        1

EARTH-MOON FINE PRINT CHECK 1

DOUBLE PRECISION EPHEMERIS TAPE - EPHEM1

  GME  .39860063 06     J  .16234500-02     H -.57499999-05     D  .78749999-05    RE  .63781650 04   REM  .63783112 04
    G  .66709998-19     A  .88781796 29     B  .88800194 29     C  .88836976 29   OME  .41780741-02    AU  .14959850 09
  GMM  .49026293 04   GMS  .13271411 12   GMV  .32476627 06   GMA  .42977367 05   GMC  .37918700 08   GMJ  .12670935 09
  EGM  .39860320 06   MGM  .49027779 04    JA  .29200000-02    HA  .00000000 00    OA  .00000000 00    RA  .34170000 04

INJECTION CONDITIONS   1950.0    MOON           23561021527620224601000O J.D.= 2438043.27918167  JAN. 13,1963 18 42 01.297

GEOCENTRIC         XO .59369501 04  YO .27186042 04  ZO-.72883219 03 DXO-.42284408 01 DYO .85267773 01 DZO-.54530145 01
CARTESIAN          TO .67321297 05 GHA .33026725 02 GHO .11175336 03
DATE OF RUN 022665A  12454                EARTH    IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

   0 DAYS  0 HRS.  0 MIN.  0.000 SEC.      23561021527620224601000O J.D.= 2438043.27918167  JAN. 13,1963 18 42 01.297

       GEOCENTRIC                                                                              EQUATORIAL COORDINATES

    X  .59300736 04     Y  .27355045 04     Z -.72154210 03    DX -.42459721 01    DY  .85145659 01    DZ -.54584696 01
    R  .65703410 04   DEC -.63048288 01    RA  .24763570 02     V  .10969093 02   PTH  .16309296 01    AZ  .11984846 03
    R  .65703408 04   LAT -.63048288 01   LON  .35173684 03    VE  .10558881 02   PTE  .16943087 01   AZE  .12113527 03
   XS  .57180881 08    YS -.12437799 09    ZS -.53932928 08   DXS  .27928580 02   DYS  .10710362 02   DZS  .46452518 01
   XM -.36756323 06    YM  .12677916 06    ZM  .79800081 05   DXM -.40581204 00   DYM -.85550278 00   DZM -.29049915 00
   XT -.36756323 06    YT  .12677916 06    ZT  .79800081 05   DXT -.40581204 00   DYT -.85550278 00   DZT -.29049915 00
   RS  .14713360 09    VS  .30270378 02    RM  .39691779 06    VM  .99043331 00    RT  .39691779 06    VT  .99043331 00
  GED -.63474453 01   ALT  .19239502 03   LOS  .26166316 03   RAS  .29468988 03   RAM  .16096976 03   LOM  .12794304 03
  DUT  .35000000 02    DT  .75000000 01    DR  .31219417 00   SHA -.65653256 04   DES -.21503466 02   DEM  .11598331 02
  CCL  .10757921 03   MCL  .19058408 03   TCL  .19058408 03

                                                    GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    23561021526520256712026O J.D.= 2438043.27878392  JAN. 13,1963 18 41 26.931
  SMA  .39375140 06   ECC  .98332711 00     B  .71601938 05   SLR  .13020490 05   APO  .78093781 06   RCA  .65649734 04
   VH  .92249958-01    C3 -.10123155 01    C1  .72041484 05   TFP  .34366084 02    TF -.95461342-02   PER  .40981966 05
   TA  .32895214 01   MTA  .18000000 03    EA  .30168731 00    MA  .50313959-02   C3J -.12654839 01   TFI  .00000000 00

                                                        ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X  .59300736 04     Y  .27355045 04     Z -.72154210 03    DX -.42459721 01    DY  .85145659 01    DZ -.54584696 01
  INC  .30446938 02   LAN  .19392943 03   APF  .18922662 03    MX -.41294010 00    MY  .76469263 00    MZ -.49469753 00
   WX -.12198597 00    WY  .49183847 00    WZ  .86209881 00    PX  .92475982 00    PY  .37177615 00    PZ -.81250653-01
   QX -.36046997 00    QY  .78732290 00    QZ -.50018393 00    RX -.75386593-01    RY -.30307261-01    RZ -.99669364 00
   BX  .36046999 00    BY -.78732294 00    BZ  .50018395 00    TX  .37300945 00    TY -.92782754 00    TZ  .00000000 00
  DAP -.46604583 01   RAP  .21901339 02

  BTQ  .61932714 05   BRQ -.35932944 05     B  .71601938 05   THA  .32987798 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                        ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X -.97860076 03     Y -.63914189 04     Z -.11668206 04    DX  .70016068 01    DY  .14831276 00    DZ -.84425398 01
  INC  .51745311 02   LAN  .73114849 02   APF  .18978106 03    MX  .64280273 00    MY  .41223896-01    MZ -.76492172 00
   WX  .75141259 00    WY -.22808386 00    WZ  .61915820 00    PX -.18558175 00    PY -.97353106 00    PZ -.13340412 00
   QX  .63319705 00    QY -.14662935-01    QZ -.77385168 00    RX  .24980654-01    RY  .13104436 00    RZ -.99106171 00
   BX -.63319707 00    BY  .14662936-01    BZ  .77385171 00    TX -.98231125 00    TY  .18725550 00    TZ  .00000000 00
  DAP -.76663494 01   RAP  .25920733 03

  BTO  .44731612 05   BRO -.55907575 05     B  .71600099 05   THA  .30866328 03    T VECTOR IN  ORBIT PLANE OF TARGET

   0 DAYS  0 HRS. 30 MIN.  0.000 SEC.      23561021620020224601000O J.D.= 2438043.30001501  JAN. 13,1963 19 12 01.297


CASE  1                                    IBSYS-JPTRAJ-SPACE 022665                                        2

EARTH-MOON FINE PRINT CHECK 1


       GEOCENTRIC                                                                              EQUATORIAL COORDINATES

    X -.64378004 04     Y  .10748353 05     Z -.70365115 04    DX -.68642236 01    DY  .18130742 01    DZ -.20008014 01
    R  .14369581 05   DEC -.29319621 02    RA  .12091979 03     V  .73761785 01   PTH  .47189491 02    AZ  .81460855 02
    R  .14369581 05   LAT -.29319621 02   LON  .80372532 02    VE  .67959470 01   PTE  .52772510 02   AZE  .79570004 02
   XS  .57231149 08    YS -.12435870 09    ZS -.53924563 08   DXS  .27924342 02   DYS  .10719672 02   DZS  .46492854 01
   XM -.36828984 06    YM  .12523797 06    ZM  .79276364 05   DXM -.40153671 00   DYM -.85692245 00   DZM -.29140573 00
   XT -.36828984 06    YT  .12523797 06    ZT  .79276364 05   DXT -.40153671 00   DYT -.85692245 00   DZT -.29140573 00
   RS  .14713378 09    VS  .30270383 02    RM  .39699710 06    VM  .99018437 00    RT  .39699710 06    VT  .99018437 00
  GED -.29486055 02   ALT  .79965527 04   LOS  .25416511 03   RAS  .29471237 03   RAM  .16121925 03   LOM  .12067200 03
  DUT  .35000000 02    DT  .59999999 02    DR  .54112033 01   SHA  .11194083 05   DES -.21499938 02   DEM  .11518834 02
  CCL  .19864886 03   MCL  .27964880 03   TCL  .27964880 03

                                                    GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    23561021526520261602100O J.D.= 2438043.27878598  JAN. 13,1963 18 41 27.110
  SMA  .37239032 06   ECC  .98236781 00     B  .69621550 05   SLR  .13016341 05   APO  .73821458 06   RCA  .65660576 04
   VH  .97573257-01    C3 -.10703840 01    C1  .72030006 05   TFP  .18341874 04    TF -.94964876-02   PER  .37692696 05
   TA  .95501059 02   MTA  .18000000 03    EA  .11855552 02    MA  .29196966 00   C3J -.13245463 01   TFI  .50000000 00

                                                        ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.64378004 04     Y  .10748353 05     Z -.70365115 04    DX -.68642236 01    DY  .18130742 01    DZ -.20008014 01
  INC  .30431388 02   LAN  .19387282 03   APF  .18930823 03    MX -.88573875 00    MY -.44576431 00    MZ  .12946433 00
   WX -.12144386 00    WY  .49173155 00    WZ  .86223631 00    PX  .92460809 00    PY  .37200548 00    PZ -.81925175-01
   QX -.36104184 00    QY  .78728136 00    QZ -.49983677 00    RX -.76004171-01    RY -.30579408-01    RZ -.99663844 00
   BX  .36104185 00    BY -.78728138 00    BZ  .49983678 00    TX  .37326021 00    TY -.92772669 00    TZ  .00000000 00
  DAP -.46992333 01   RAP  .21916826 02

  BTQ  .60232702 05   BRQ -.34916783 05     B  .69621550 05   THA  .32989921 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                        ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .93177677 04     Y  .11378919 04     Z -.10879762 05    DX  .41303026 01    DY  .52923522 01    DZ -.30560760 01
  INC  .51730000 02   LAN  .73077271 02   APF  .18983655 03    MX  .12398145 00    MY  .97031129 00    MZ  .20766445 00
   WX  .75110449 00    WY -.22852845 00    WZ  .61936802 00    PX -.18557264 00    PY -.97343368 00    PZ -.13412519 00
   QX  .63356514 00    QY -.14195721-01    QZ -.77355907 00    RX  .25116913-01    RY  .13175244 00    RZ -.99096434 00
   BX -.63356517 00    BY  .14195722-01    BZ  .77355909 00    TX -.98230949 00    TY  .18726470 00    TZ  .00000000 00
  DAP -.77080383 01   RAP  .25920679 03

  BTO  .43514059 05   BRO -.54346838 05     B  .69620777 05   THA  .30868332 03    T VECTOR IN  ORBIT PLANE OF TARGET

   0 DAYS  1 HRS.  0 MIN.  0.000 SEC.      23561021710220224601000O J.D.= 2438043.32084834  JAN. 13,1963 19 42 01.297

       GEOCENTRIC                                                                              EQUATORIAL COORDINATES

    X -.17560347 05     Y  .12524493 05     Z -.96155400 04    DX -.56012699 01    DY  .45820013 00    DZ -.10498419 01
    R  .23615404 05   DEC -.24027331 02    RA  .14450255 03     V  .57171968 01   PTH  .57756951 02    AZ  .70737336 02
    R  .23615404 05   LAT -.24027331 02   LON  .96434764 02    VE  .51090483 01   PTE  .71168201 02   AZE  .52398568 02
   XS  .57281410 08    YS -.12433940 09    ZS -.53916191 08   DXS  .27920100 02   DYS  .10728981 02   DZS  .46533183 01
   XM -.36900876 06    YM  .12369424 06    ZM  .78751022 05   DXM -.39725542 00   DYM -.85832345 00   DZM -.29230572 00
   XT -.36900876 06    YT  .12369424 06    ZT  .78751022 05   DXT -.39725542 00   DYT -.85832345 00   DZT -.29230572 00
   RS  .14713396 09    VS  .30270388 02    RM  .39707613 06    VM  .98993617 00    RT  .39707613 06    VT  .98993617 00
  GED -.24172374 02   ALT  .17240778 05   LOS  .24666707 03   RAS  .29473486 03   RAM  .16146849 03   LOM  .11340070 03
  DUT  .35000000 02    DT  .12000000 03    DR  .48355625 01   SHA  .19093397 05   DES -.21496406 02   DEM  .11439160 02
  CCL  .22582774 03   MCL  .30592996 03   TCL  .30592996 03

                                                    GEOCENTRIC CONIC
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                        3

EARTH-MOCN FINE PRINT CHECK 1

EPOCH OF PERICENTER PASSAGE                 235610215265202607632000 J.D.= 2438043.27878542  JAN. 13,1963 18 41 27.061
  SMA  .37205792 06   ECC  .98235115 00     B  .69591952 05   SLR  .13016892 05   APO  .73754945 06   RCA  .65663906 04
   VH  .97663317-01    C3 -.10713402 01    C1  .72031531 05   TFP  .36342360 04    TF -.95100104-02   PER  .37642240 05
   TA  .11718464 03   MTA  .18000000 03    EA  .17569177 02    MA  .57928050 00   C3J -.13239474 01   TFI  .10000000 01

                                                                  ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.17560347 05     Y  .12524493 05     Z -.96155400 04    DX -.56012699 01    DY  .45820013 00    DZ -.10498419 01
  INC  .30433413 02   LAN  .19386406 03   APF  .18931736 03    MX -.65751894 00    MY -.69056407 00    MZ  .30131392 00
   WX -.12137596 00    WY  .49177971 00    WZ  .86221840 00    PX  .92460810 00    PY  .37198683 00    PZ -.82009821-01
   QX -.36106468 00    QY  .78726012 00    QZ -.49985377 00    RX -.76083232-01    RY -.30609682-01    RZ -.99663148 00
   BX  .36106468 00    BY -.78726012 00    BZ  .49985377 00    TX  .37324410 00    TY -.92773318 00    TZ  .00000000 00
  DAP -.47040997 01   RAP  .21915830 02

  BTQ  .60206265 05   BRQ -.34903369 05     B  .69591952 05   THA  .32989785 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                  ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .15311712 05     Y  .10204333 05     Z -.14802373 05    DX  .27560775 01    DY  .47503466 01    DZ -.15888903 01
  INC  .51732033 02   LAN  .73070762 02   APF  .18984160 03    MX -.12431851 00    MY  .87236354 00    MZ  .47278626 00
   WX  .75109962 00    WY -.22862019 00    WZ  .61934015 00    PX -.18563194 00    PY -.97341250 00    PZ -.13419712 00
   QX  .63355362 00    QY -.14173943-01    QZ -.77356897 00    RX  .25138660-01    RY  .13182153 00    RZ -.99095464 00
   BX -.63355361 00    BY  .14173943-01    BZ  .77356896 00    TX -.98229773 00    TY  .18732638 00    TZ  .00000000 00
  DAP -.77121970 01   RAP  .25920320 03

  BTO  .43494155 05   BRO -.54325119 05     B  .69591379 05   THA  .30868170 03    T VECTOR IN  ORBIT PLANE OF TARGET

   0 DAYS  1 HRS. 30 MIN.  0.000 SEC.       235610220004202246010000 J.D.= 2438043.34168167  JAN. 13,1963 20 12 01.297

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.26909438 05     Y  .12891467 05     Z -.11140858 05    DX -.48458458 01    DY  .13495163-01    DZ -.68978222 00
    R  .31850063 05   DEC -.20474518 02    RA  .15440238 03     V  .48947118 01   PTH  .62480509 02    AZ  .66977448 02
    R  .31850063 05   LAT -.20474518 02   LON  .98814059 02    VE  .44310940 01   PTE  .78419512 02   AZE  .35391095 03
   XS  .57331665 08    YS -.12432007 09    ZS -.53907812 08   DXS  .27915854 02   DYS  .10738288 02   DZS  .46573509 01
   XM -.36971996 06    YM  .12214801 06    ZM  .78224065 05   DXM -.39296826 00   DYM -.85970578 00   DZM -.29319913 00
   XT -.36971996 06    YT  .12214801 06    ZT  .78224065 05   DXT -.39296826 00   DYT -.85970578 00   DZT -.29319913 00
   RS  .14713413 09    VS  .30270392 02    RM  .39715486 06    VM  .98968873 00    RT  .39715486 06    VT  .98968873 00
  GED -.20602362 02   ALT  .25474498 05   LOS  .23916902 03   RAS  .29475734 03   RAM  .16171748 03   LOM  .10612916 03
  DUT  .35000000 02    DT  .12000000 03    DR  .43408934 01   SHA  .26744537 05   DES -.21492873 02   DEM  .11359310 02
  CCL  .23711064 03   MCL  .31662791 03   TCL  .31662791 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 235610215265202602004000 J.D.= 2438043.27878490  JAN. 13,1963 18 41 27.016
  SMA  .37196284 06   ECC  .98234627 00     B  .69583701 05   SLR  .13017132 05   APO  .73735914 06   RCA  .65665280 04
   VH  .97689426-01    C3 -.10716141 01    C1  .72032195 05   TFP  .54342813 04    TF -.95225721-02   PER  .37627811 05
   TA  .12700795 03   MTA  .18000000 03    EA  .21439325 02    MA  .86653158 00   C3J -.13233752 01   TFI  .15000000 01

                                                                  ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.26909438 05     Y  .12891467 05     Z -.11140858 05    DX -.48458458 01    DY  .13495163-01    DZ -.68978222 00
  INC  .30434307 02   LAN  .19386203 03   APF  .18931955 03    MX -.52100999 00    MY -.77091448 00    MZ  .36638715 00
   WX -.12136180 00    WY  .49179717 00    WZ  .86221050 00    PX  .92460784 00    PY  .37198286 00    PZ -.82031061-01
   QX -.36107014 00    QY  .78725114 00    QZ -.49986401 00    RX -.76103047-01    RY -.30617336-01    RZ -.99662977 00
   BX  .36107013 00    BY -.78725113 00    BZ  .49986400 00    TX  .37324077 00    TY -.92773452 00    TZ  .00000000 00
  DAP -.47053206 01   RAP  .21915625 02

  BTQ  .60198679 05   BRQ -.34900008 05     B  .69583701 05   THA  .32989711 03    T VECTOR IN  EARTH EQUATOR PLANE
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                        4

EARTH-MOCN FINE PRINT CHECK 1

                                                                  ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .19672863 05     Y  .18301019 05     Z -.17101970 05    DX  .21540860 01    DY  .42715453 01    DZ -.10353782 01
  INC  .51732910 02   LAN  .73068588 02   APF  .18984280 03    MX -.23309050 00    MY  .78584616 00    MZ  .57281283 00
   WX  .75109991 00    WY -.22865144 00    WZ  .61932815 00    PX -.18565762 00    PY -.97340515 00    PZ -.13421490 00
   QX  .63354565 00    QY -.14174141-01    QZ -.77357541 00    RX  .25145529-01    RY  .13183831 00    RZ -.99095224 00
   BX -.63354568 00    BY  .14174141-01    BZ  .77357545 00    TX -.98229270 00    TY  .18735275 00    TZ  .00000000 00
  DAP -.77132250 01   RAP  .25920166 03

  BTO  .43488317 05   BRO -.54319335 05     B  .69583216 05   THA  .30868093 03    T VECTOR IN  ORBIT PLANE OF TARGET

   0 DAYS  2 HRS.  0 MIN.  0.000 SEC.       235610220706202246010000 J.D.= 2438043.36251501  JAN. 13,1963 20 42 01.297

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.35157458 05     Y  .12708409 05     Z -.12197376 05    DX -.43488279 01    DY -.19455838 00    DZ  .50112047 00
    R  .39323358 05   DEC -.18070164 02    RA  .16012653 03     V  .43819264 01   PTH  .65289371 02    AZ  .65085562 02
    R  .39323357 05   LAT -.18070165 02   LON  .97017682 02    VE  .41922472 01   PTE  .71719592 02   AZE  .30593274 03
   XS  .57381912 08    YS -.12430074 09    ZS -.53899425 08   DXS  .27911605 02   DYS  .10747595 02   DZS  .46613828 01
   XM -.37042345 06    YM  .12059931 06    ZM  .77695507 05   DXM -.38867531 00   DYM -.86106942 00   DZM -.29408592 00
   XT -.37042345 06    YT  .12059931 06    ZT  .77695507 05   DXT -.38867531 00   DYT -.86106942 00   DZT -.29408592 00
   RS  .14713431 09    VS  .30270397 02    RM  .39723332 06    VM  .98944204 00    RT  .39723332 06    VT  .98944204 00
  GED -.18185229 02   ALT  .32947229 05   LOS  .23167097 03   RAS  .29477983 03   RAM  .16196623 03   LOM  .98857371 02
  DUT  .35000000 02    DT  .24000000 03    DR  .39806763 01   SHA  .33869685 05   DES -.21489336 02   DEM  .11279286 02
  CCL  .24347842 03   MCL  .32255119 03   TCL  .32255119 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 235610215265202600414000 J.D.= 2438043.27878477  JAN. 13,1963 18 41 27.004
  SMA  .37193592 06   ECC  .98234481 00     B  .69581529 05   SLR  .13017265 05   APO  .73730524 06   RCA  .65665996 04
   VH  .97697066-01    C3 -.10716917 01    C1  .72032561 05   TFP  .72342928 04    TF -.95258056-02   PER  .37623727 05
   TA  .13292118 03   MTA  .18000000 03    EA  .24446767 02    MA  .11536804 01   C3J -.13229198 01   TFI  .20000000 01

                                                                  ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.35157458 05     Y  .12708409 05     Z -.12197376 05    DX -.43488279 01    DY -.19455838 00    DZ -.50112047 00
  INC  .30434890 02   LAN  .19386105 03   APF  .18932061 03    MX -.43119463 00    MY -.80850589 00    MZ  .40048646 00
   WX -.12135547 00    WY  .49180767 00    WZ  .86220535 00    PX  .92460772 00    PY  .37198077 00    PZ -.82041699-01
   QX -.36107255 00    QY  .78724550 00    QZ -.49987107 00    RX -.76112974-01    RY -.30621162-01    RZ -.99662888 00
   BX  .36107256 00    BY -.78724552 00    BZ  .49987108 00    TX  .37323900 00    TY -.92773523 00    TZ  .00000000 00
  DAP -.47059320 01   RAP  .21915516 02

  BTQ  .60196495 05   BRQ -.34899443 05     B  .69581529 05   THA  .32989661 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                  ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .23215760 05     Y  .25658274 05     Z -.18681743 05    DX  .18088820 01    DY  .39207859 01    DZ -.74609459 00
  INC  .51733462 02   LAN  .73067059 02   APF  .18984340 03    MX -.29546520 00    MY  .72246759 00    MZ  .62509277 00
   WX  .75109962 00    WY -.22867325 00    WZ  .61932058 00    PX -.18567820 00    PY -.97339997 00    PZ -.13422403 00
   QX  .63354004 00    QY -.14178723-01    QZ -.77357996 00    RX  .25150059-01    RY  .13184675 00    RZ -.99095099 00
   BX -.63354004 00    BY  .14178723-01    BZ  .77357996 00    TX -.98228870 00    TY  .18737374 00    TZ  .00000000 00
  DAP -.77137526 01   RAP  .25920043 03

  BTC  .43486597 05   BRO -.54318172 05     B  .69581235 05   THA  .30868042 03    T VECTOR IN  ORBIT PLANE OF TARGET

   0 DAYS  6 HRS.  0 MIN.  0.000 SEC.       235610227726202246010000 J.D.= 2438043.52918168  JAN. 14,1963 00 42 01.297
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CASE  1                                      IBSYS-JPTRAJ-SPACE 022665                                          5

EARTH-MOON FINE PRINT CHECK 1

      GEOCENTRIC                                                                             EQUATORIAL COORDINATES

  X -.84114400 05     Y  .65059352 04     Z -.15548877 05    DX -.28179711 01    DY -.52034270 00    DZ -.99636187-01
  R  .85786519 05   DEC -.10442625 02    RA  .17557719 03     V  .28673411 01   PTH  .72971953 02    AZ  .61241663 02
  R  .85786518 05   LAT -.10442626 02   LON  .52304021 02    VE  .60837608 01   PTE  .26785337 02   AZE  .27426584 03
 XS  .57783604 08    YS -.12414543 09    ZS -.53832072 08   DXS  .27877475 02   DYS  .10822000 02   DZS  .46936177 01
 XM -.37577210 06    YM  .10812474 06    ZM  .73410790 05   DXM -.35413399 00   DYM -.87130586 00   DZM -.30094165 00
 XT -.37577210 06    YT  .10812474 06    ZT  .73410790 05   DXT -.35413399 00   DYT -.87130586 00   DZT -.30094165 00
 RS  .14713573 09    VS  .30270437 02    RM  .39785018 06    VM  .98749717 00    RT  .39785018 06    VT  .98749717 00
GED -.10512209 02   ALT  .79409021 05   LOS  .17168650 03   RAS  .29495966 03   RAM  .16394734 03   LOM  .40674176 02
OUT  .35000000 02    DT  .48000000 03    DR  .27416413 01   SHA  .79254281 05   DES -.21460932 02   DEM  .10633072 02
CCL  .25991151 03   MCL  .33699600 03   TCL  .33699600 03

                                              GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE               23561021526520264571000 J.D.= 2438043.27878814  JAN. 13,1963 18 41 27.296
 SMA  .37210488 06   ECC  .98235293 00     B  .69597264 05   SLR  .13017238 05   APO  .73764320 06   RCA  .65665591 04
  VH  .97652204-01    C3 -.10712050 01    C1  .72032487 05   TFP  .21634001 05    TF -.94447134-02   PER  .37649367 05
  TA  .14971167 03   MTA  .18000000 03    EA  .38438245 02    MA  .34477074 01   C3J -.13210443 01   TFI  .59999999 01

                                                             ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
  X -.84114400 05     Y  .65059352 04     Z -.15548877 05    DX -.28179711 01    DY -.52034270 00    DZ -.99636187-01
INC  .30442654 02   LAN  .19385364 03   APF  .18932776 03    MX -.15454728 00    MY -.86732156 00    MZ  .47314763 00
 WX -.12131985 00    WY  .49193702 00    WZ  .86213670 00    PX  .92461349 00    PY  .37194855 00    PZ -.82123048-01
 QX -.36106977 00    QY  .78718004 00    QZ -.49997633 00    RX -.76189429-01    RY -.30649075-01    RZ -.99662220 00
 BX  .36106974 00    BY -.78717999 00    BZ  .49997630 00    TX  .37320917 00    TY -.92774723 00    TZ  .00000000 00
DAP -.47106089 01   RAP  .21913674 02

BTQ  .60205711 05   BRQ -.34914917 05     B  .69597264 05   THA  .32988939 03     T VECTOR IN  EARTH EQUATOR PLANE

                                                             ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
  X  .41175304 05     Y  .71487404 05     Z -.23525935 05    DX  .93534122 00    DY  .27071772 01    DZ -.13405399 00
INC  .51741021 02   LAN  .73054934 02   APF  .18984685 03    MX -.45324335 00    MY  .50319649 00    MZ  .73577426 00
 WX  .75112934 00    WY -.22885599 00    WZ  .61921698 00    PX -.18586293 00    PY -.97335636 00    PZ -.13428465 00
 QX  .63345061 00    QY -.14224354-01    QZ -.77365234 00    RX  .25186659-01    RY  .13190147 00    RZ -.99094279 00
 BX -.63345062 00    BY  .14224354-01    BZ  .77365236 00    TX -.98225282 00    TY  .18756172 00    TZ  .00000000 00
DAP -.77172582 01   RAP  .25918947 03

BTO  .43489594 05   BRO -.54336085 05     B  .69597091 05   THA  .30867313 03     T VECTOR IN  ORBIT PLANE OF TARGET

 0 DAYS 10 HRS.  0 MIN.  0.000 SEC.       23561023674620224601000 J.D.= 2438043.69584834  JAN. 14,1963 04 42 01.297

      GEOCENTRIC                                                                             EQUATORIAL COORDINATES

  X -.12038556 06     Y -.11858323 04     Z -.16261956 05    DX -.22807968 01    DY -.53816650 00    DZ -.13566510-01
  R  .12148473 06   DEC -.76927096 01    RA  .18056436 03     V  .23434678 01   PTH  .75345235 02    AZ  .60432451 02
  R  .12148473 06   LAT -.76927105 01   LON  .35712693 03    VE  .85737837 01   PTE  .15333528 02   AZE  .27202766 03
 XS  .58184803 08    YS -.12398905 09    ZS -.53764255 08   DXS  .27843110 02   DYS  .10896324 02   DZS  .47258164 01
 XM -.38062099 06    YM  .95511378 05    ZM  .69030420 05   DXM -.31927256 00   DYM -.88034611 00   DZM -.30737028 00
 XT -.38062099 06    YT  .95511378 05    ZT  .69030420 05   DXT -.31927256 00   DYT -.88034611 00   DZT -.30737028 00
 RS  .14713719 09    VS  .30270480 02    RM  .39844693 06    VM  .98560677 00    RT  .39844693 06    VT  .98560677 00
GED -.77445006 01   ALT  .11510691 06   LOS  .11170200 03   RAS  .29513943 03   RAM  .16591331 03   LOM  .34247588 03
OUT  .35000000 02    DT  .48000000 03    DR  .22672296 01   SHA  .11447679 06   DES -.21432318 02   DEM  .99767607 01
CCL  .26498468 03   MCL  .34093882 03   TCL  .34093882 03

                                              GEOCENTRIC CONIC


CASE  1                                      IBSYS-JPTRAJ-SPACE 022665

EARTH-MOON FINE PRINT CHECK 1

EPOCH OF PERICENTER PASSAGE               23561021526620220441000 J.D.= 2438043.27880827  JAN. 13,1963 18 41 29.035
 SMA  .37241584 06   ECC  .98237085 00     B  .69620343 05   SLR  .13015004 05   APO  .73826632 06   RCA  .65653729 04
  VH  .97561411-01    C3 -.10703106 01    C1  .72026306 05   TFP  .36032262 05    TF -.89615583-02   PER  .37696572 05
  TA  .15535241 03   MTA  .18000000 03    EA  .46694800 02    MA  .57350989 01   C3J -.13200759 01   TFI  .10000000 02

                                                             ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
  X -.12038556 06     Y -.11858323 04     Z -.16261956 05    DX -.22807968 01    DY -.53816650 00    DZ -.13566510-01
INC  .30464137 02   LAN  .19384033 03   APF  .18933858 03    MX -.57482837-01    MY -.87038283 00    MZ  .46900833 00
 WX -.12128280 00    WY  .49227853 00    WZ  .86194666 00    PX  .92463905 00    PY  .37185250 00    PZ -.82269809-01
 QX -.36101673 00    QY  .78701159 00    QZ -.50027925 00    RX -.76328626-01    RY -.30696292-01    RZ -.99661008 00
 BX  .36101680 00    BY -.78701174 00    BZ  .50027934 00    TX  .37311734 00    TY -.92778416 00    TZ  .00000000 00
DAP -.47190468 01   RAP  .21908003 02

BTQ  .60213148 05   BRQ -.34948090 05     B  .69620343 05   THA  .32986885 03     T VECTOR IN  EARTH EQUATOR PLANE

                                                             ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
  X  .52632178 05     Y  .10674526 06     Z -.24368819 05    DX  .68707836 00    DY  .22404781 01    DZ -.45491792-02
INC  .51762303 02   LAN  .73038647 02   APF  .18985119 03    MX -.49786965 00    MY  .41884523 00    MZ  .75940403 00
 WX  .75128417 00    WY -.22913658 00    WZ  .61892529 00    PX -.18613935 00    PY -.97329003 00    PZ -.13438261 00
 QX  .63318576 00    QY -.14246840-01    QZ -.77386869 00    RX  .25242856-01    RY  .13199047 00    RZ -.99092952 00
 BX -.63318579 00    BY  .14246841-01    BZ  .77386872 00    TX -.98219904 00    TY  .18784318 00    TZ  .00000000 00
DAP -.77229221 01   RAP  .25917305 03

BTO  .43484158 05   BRO -.54370099 05     B  .69620254 05   THA  .30865215 03     T VECTOR IN  ORBIT PLANE OF TARGET

 0 DAYS 14 HRS.  0 MIN.  0.000 SEC.       23561024576620224601000 J.D.= 2438043.86251501  JAN. 14,1963 08 42 01.297

      GEOCENTRIC                                                                             EQUATORIAL COORDINATES

  X -.15085768 06     Y -.88699365 04     Z -.16157990 05    DX -.19742425 01    DY -.52734149 00    DZ  .23835855-01
  R  .15197959 06   DEC -.61030421 01    RA  .18336493 03     V  .20435975 01   PTH  .76593858 02    AZ  .60053228 02
  R  .15197959 06   LAT -.61030421 01   LON  .29976323 03    VE  .10796389 02   PTE  .10610265 02   AZE  .27127716 03
 XS  .58585506 08    YS -.12383160 09    ZS -.53695974 08   DXS  .27808508 02   DYS  .10970566 02   DZS  .47579784 01
 XM -.38496583 06    YM  .82776450 05    ZM  .64560577 05   DXM -.28413486 00   DYM -.88819066 00   DZM -.31336824 00
 XT -.38496583 06    YT  .82776450 05    ZT  .64560577 05   DXT -.28413486 00   DYT -.88819066 00   DZT -.31336824 00
 RS  .14713866 09    VS  .30270527 02    RM  .39902218 06    VM  .98377584 00    RT  .39902218 06    VT  .98377584 00
GED -.61443159 01   ALT  .14560163 06   LOS  .51717424 02   RAS  .29531912 03   RAM  .16786486 03   LOM  .28426317 03
OUT  .35000000 02    DT  .95999999 03    DR  .19879115 01   SHA  .14462524 06   DES -.21403552 02   DEM  .93112143 01
CCL  .26780095 03   MCL  .34292233 03   TCL  .34292233 03

                                              GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE               23561021526720231575000 J.D.= 2438043.27886120  JAN. 13,1963 18 41 33.609
 SMA  .37281702 06   ECC  .98239812 00     B  .69641901 05   SLR  .13009046 05   APO  .73907177 06   RCA  .65622774 04
  VH  .97432780-01    C3 -.10691589 01    C1  .72009819 05   TFP  .50427688 05    TF -.76910257-02   PER  .37757500 05
  TA  .15855770 03   MTA  .18000000 03    EA  .52917723 02    MA  .80134045 01   C3J -.13193548 01   TFI  .14000000 02

                                                             ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
  X -.15085768 06     Y -.88699365 04     Z -.16157990 05    DX -.19742425 01    DY -.52734149 00    DZ  .23835855-01
INC  .30505725 02   LAN  .19382076 03   APF  .18935274 03    MX -.21224571-02    MY -.86811068 00    MZ  .49636590 00
 WX -.12126403 00    WY  .49292740 00    WZ  .86157843 00    PX  .92469112 00    PY  .37167308 00    PZ -.82495185-01
 QX -.36088967 00    QY  .78669020 00    QZ -.50087616 00    RX -.76543465-01    RY -.30766107-01    RZ -.99659146 00
 BX  .36088972 00    BY -.78669029 00    BZ  .50087622 00    TX  .37294428 00    TY -.92785375 00    TZ  .00000000 00
DAP -.47320045 01   RAP  .21897315 02

BTQ  .60207184 05   BRQ -.35001275 05     B  .69641901 05   THA  .32982854 03     T VECTOR IN  EARTH EQUATOR PLANE
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                             7

EARTH-MOON FINE PRINT CHECK 1

                                                                   ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .61536196 05     Y  .13687808 C6     Z -.23989056 05     DX  .55819511 00     DY  .19652243 01     DZ  .51000346-01
  INC  .51803762 02   LAN  .73018046 C2   APF  .18985587 03     MX -.52068252 00     MY  .36901151 00     MZ  .76988296 00
   WX  .75162963 00    WY -.22953736 00    WZ  .61835676 00     PX -.18653071 00     PY -.97319575 00     PZ -.13452231 00
   QX  .63266011 00    QY -.14231440-01    QZ -.77429854 00     RX  .25322711-01     RY  .13211741 00     RZ -.99091052 00
   BX -.63266025 00    BY  .14231443-C1    BZ  .77429871 00     TX -.98212273 00     TY  .18824173 00     TZ  .00000000 00
  DAP -.77309988 01   RAP  .25914980 C3

  BTO  .43458500 05   BRO -.54418184 05     B  .69641799 05    THA  .30861095 03    T VECTOR IN  ORBIT PLANE OF TARGET

  0 CAYS 18 HRS.  0 MIN.  0.000 SEC.       23561025500620224601000O J.D.= 2438044.02918167  JAN. 14,1963 12 42 01.297

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.17770549 06     Y -.16349802 05     Z -.15653149 05     DX -.17660922 01     DY -.51121891 00     DZ  .44518640-01
    R  .17914122 06   DEC -.50128303 C1    RA  .18525670 03      V  .18391325 01    PTH  .77380777 02     AZ  .59800106 02
    R  .17914122 06   LAT -.50128311 C1   LON  .24149074 03     VE  .12794071 02    PTE  .80638391 01    AZE  .27091419 03
   XS  .58985706 08    YS -.12367309 09    ZS -.53627230 08    DXS  .27773670 02    DYS  .11044726 02    DZS  .47901037 01
   XM -.38880297 06    YM  .69937162 05    ZM  .60007481 05    DXM -.24876397 00    DYM -.89484113 00    DZM -.31893244 00
   XT -.38880297 06    YT  .69937162 05    ZT  .60007481 05    DXT -.24876397 00    DYT -.89484113 00    DZT -.31893244 00
   RS  .14714016 09    VS  .30270577 02    RM  .39957459 06     VM  .98200919 00     RT  .39957459 06     VT  .98200919 00
  GED -.50468166 01   ALT  .17276318 06   LOS  .35173278 03    RAS  .29549874 03    RAM  .16980278 03    LOM  .22603682 03
  DUT  .35000000 02    DT  .95999999 03    DR  .17947056 01    SHA  .17149115 06    DES -.21374574 02    DEM  .86372676 01
  CCL  .26969944 03   MCL  .34415151 03   TCL  .34415151 03

                                                    GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE               23561021527120263531000O J.D.= 2438043.27897256  JAN. 13,1963 18 41 43.230
  SMA  .37331979 06   ECC  .98243756 00     B  .69658332 05    SLR  .12997666 05    APO  .74008317 06    RCA  .65564062 04
   VH  .97257058-01    C3 -.10677190 01    C1  .71978314 05    TFP  .64818067 05     TF -.50187110-02    PER  .37833904 05
   TA  .16073869 03   MTA  .18000000 03    EA  .58032496 02     MA  .10279362 02    C3J -.13187499 01    TFI  .18000000 02

                                                                   ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.17770549 06     Y -.16349802 05     Z -.15653149 05     DX -.17660922 01     DY -.51121891 00     DZ  .44518640-01
  INC  .30574359 02   LAN  .19379488 C3   APF  .18936975 03     MX  .35414987-01     MY -.86466739 00     MZ  .50109422 00
   WX -.12128732 00    WY  .49398366 00    WZ  .86096973 00     PX  .92477547 00     PY  .37139268 00     PZ -.82811715-01
   QX -.36066566 00    QY  .78615962 00    QZ -.50186919 00     RX -.76846193-01     RY -.30861669-01     RZ -.99656519 00
   BX  .36066577 00    BY -.78615988 00    BZ  .50186935 00     TX  .37267274 00     TY -.92796284 00     TZ  .00000000 00
  DAP -.47502019 01   RAP  .21880548 02

  BTQ  .60180443 05   BRQ -.35079874 05     B  .69658332 05    THA  .32976159 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                   ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .68968952 05     Y  .16372239 C6     Z -.23018075 05     DX  .47611210 00     DY  .17745784 01     DZ  .81218655-01
  INC  .51872269 02   LAN  .72993168 C2   APF  .18986032 03     MX -.53471193 00     MY  .33435978 00     MZ  .77607103 00
   WX  .75223636 00    WY -.23007977 00    WZ  .61741666 00     PX -.18705802 00     PY -.97306873 00     PZ -.13470900 00
   QX  .63178269 00    QY -.14159631-01    QZ -.77501594 00     RX  .25430191-01     RY  .13228689 00     RZ -.99088518 00
   BX -.63178284 00    BY  .14159634-01    BZ  .77501611 00     TX -.98201966 00     TY  .18877870 00     TZ  .00000000 00
  DAP -.77417948 01   RAP  .25911847 C3

  BTO  .43403805 05   BRO -.54482885 05     B  .69658274 05    THA  .30854259 03    T VECTOR IN  ORBIT PLANE OF TARGET

  0 CAYS 22 HRS.  0 MIN.  0.000 SEC.       23561026402620224601000O J.D.= 2438044.19584834  JAN. 14,1963 16 42 01.297


CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                             8

EARTH-MOON FINE PRINT CHECK 1

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.20197367 06     Y -.23590486 05     Z -.14912014 05     DX -.16112623 01     DY -.49446968 00     DZ  .57519812-01
    R  .20389272 06   DEC -.41941613 C1    RA  .18666195 03      V  .16864089 01    PTH  .77925660 02     AZ  .59581681 02
    R  .20389272 06   LAT -.41941613 C1   LON  .18273172 03     VE  .14618480 02    PTE  .64772868 01    AZE  .27070455 03
   XS  .59385405 08    YS -.12351350 09    ZS -.53558024 08    DXS  .27738596 02    DYS  .11118802 02    DZS  .48221919 01
   XM -.39212934 06    YM  .57010689 C5    ZM  .55377399 05    DXM -.21320225 00    DYM -.90030021 00    DZM -.32406026 00
   XT -.39212934 06    YT  .57010689 05    ZT  .55377399 05    DXT -.21320225 00    DYT -.90030021 00    DZT -.32406026 00
   RS  .14714168 09    VS  .30270629 02    RM  .40010285 06     VM  .98031154 00     RT  .40010285 06     VT  .98031154 00
  GED -.42226405 01   ALT  .19751463 06   LOS  .29174806 03    RAS  .29567829 03    RAM  .17172787 03    LOM  .16779764 03
  DUT  .35000000 02    DT  .95999999 03    DR  .16491006 01    SHA  .19596997 06    DES -.21345405 02    DEM  .79557309 01
  CCL  .27111373 03   MCL  .34500428 C3   TCL  .34500428 03

                                                    GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE               23561021527620216601000O J.D.= 2438043.27917733  JAN. 13,1963 18 42 00.922
  SMA  .37394621 06   ECC  .98249295 00     B  .69666085 05    SLR  .12978771 05    APO  .74134573 06    RCA  .65466920 04
   VH  .97020826-01    C3  .10659304 01    C1  .71925978 05    TFP  .79200374 05     TF -.10395050-03    PER  .37929169 05
   TA  .16236954 03   MTA  .18000000 C3    EA  .62428375 02     MA  .12528675 02    C3J -.13182134 01    TFI  .22000000 02

                                                                   ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.20197367 06     Y -.23590486 05     Z -.14912014 05     DX -.16112623 01     DY -.49446968 00     DZ  .57519812-01
  INC  .30678652 02   LAN  .19376253 03   APF  .18938914 03     MX  .63262731-01     MY -.86082503 00     MZ  .50495360 00
   WX -.12138116 00    WY  .49557412 00    WZ  .86004242 00     PX  .92489906 00     PY  .37098963 00     PZ -.83237212-01
   QX -.36031698 00    QY  .78534898 00    QZ -.50338718 00     RX -.77254108-01     RY -.30987677-01     RZ -.99652977 00
   BX  .36031698 00    BY -.78534898 00    BZ  .50338718 00     TX  .37228153 00     TY -.92811985 00     TZ  .00000000 00
  DAP -.47746651 01   RAP  .21856396 02

  BTC  .60124433 05   BRQ -.35191135 05     B  .69666085 05    THA  .32965935 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                   ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .75414606 05     Y  .18818541 06     Z -.21705243 05     DX  .41806925 00     DY  .16307159 01     DZ  .99789828-01
  INC  .51976518 02   LAN  .72963995 02   APF  .18986397 03     MX -.54396204 00     MY  .30801712 00     MZ  .78053240 00
   WX  .75319225 00    WY -.23079157 00    WZ  .61598437 00     PX -.18774776 00     PY -.97290240 00     PZ -.13495069 00
   QX  .63043816 00    QY -.14005840-01    QZ -.77611315 00     RX  .25570602-01     RY  .13250598 00     RZ -.99085231 00
   BX -.63043815 00    BY  .14005839-01    BZ  .77611313 00     TX -.98188438 00     TY  .18948108 00     TZ  .00000000 00
  DAP -.77557702 01   RAP  .25907749 03

  BTC  .43309357 05   BRO -.54567880 C5     B  .69666017 05    THA  .30843828 03    T VECTOR IN  ORBIT PLANE OF TARGET

  1 CAYS  2 HRS.  0 MIN.  0.000 SEC.       23561027304620224601000O J.D.= 2438044.36251501  JAN. 14,1963 20 42 01.297

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.22426698 06     Y -.30593316 05     Z -.14016070 05     DX -.14894586 01     DY -.47827064 00     DZ  .66408229-01
    R  .22677759 06   DEC -.35434440 01    RA  .18776804 03      V  .15657713 01    PTH  .78326461 02     AZ  .59353992 02
    R  .22677759 06   LAT -.35434440 01   LON  .12367354 03     VE  .16305768 02    PTE  .53960372 01    AZE  .27056998 03
   XS  .59784595 08    YS -.12335286 09    ZS -.53488356 08    DXS  .27703284 02    DYS  .11192795 02    DZS  .48542427 01
   XM -.39494248 06    YM  .44014164 05    ZM  .50676633 05    DXM -.17749132 00    DYM -.90457156 00    DZM -.32874950 00
   XT -.39494248 06    YT  .44014164 05    ZT  .50676633 05    DXT -.17749132 00    DYT -.90457156 00    DZT -.32874950 00
   RS  .14714323 09    VS  .30270684 C2    RM  .40060570 06     VM  .97868743 00     RT  .40060570 06     VT  .97868743 00
  GED -.35675297 01   ALT  .22039947 C6   LOS  .23176327 03    RAS  .29585776 03    RAM  .17364094 03    LOM  .10954645 03
  DUT  .35000000 02    DT  .95999999 03    DR  .15333855 01    SHA  .21859221 06    DES -.21316048 02    DEM  .72673895 01
  CCL  .27223388 03   MCL  .34564152 03   TCL  .34564152 03

                                                    GEOCENTRIC CONIC
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CASE 1                                   IBSYS-JPTRAJ-SPACE 022665                                      9

EARTH-MOON FINE PRINT CHECK 1

EPOCH OF PERICENTER PASSAGE              23561021530520263031C000 J.D.= 2438043.27952766  JAN. 13,1963 18 42 31.191
  SMA  .37472880 06   ECC  .98256930 00    B  .69660839 05   SLR  .12949718 05   APO  .74292581 06   RCA  .65317859 04
   VH  .96706058-01    C3 -.10637043 01   C1  .71845430 05   TFP  .93570106 05    TF  .83038806-02   PER  .38048298 05
   TA  .16366297 03   MTA  .18000000 03   EA  .66307598 02    MA  .14755473 02   C3J -.13177218 01   TFI  .26000000 02

                                                           ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.22426698 06     Y -.30593316 05    Z -.14016070 05   DX -.14894586 01    DY -.47827064 00    DZ  .66408229-01
  INC  .30830375 02   LAN  .19372335 03  APF  .18941050 03   MX  .85070010-01    MY -.85669632 00    MZ  .50875798 00
   WX -.12158215 00    WY  .49786782 00   WZ  .85868830 00   PX  .92507084 00    PY  .37043490 00    PZ -.83797006-01
   QX -.35980784 00    QY  .78415929 00   QZ -.50560126 00   RX -.77791771-01    RY -.31150898-01    RZ -.99648283 00
   BX  .35980783 00    BY -.78415926 00   BZ  .50560124 00   TX  .37174238 00    TY -.92833593 00    TZ  .00000000 00
  DAP -.48068514 01   RAP  .21823116 02

  BTQ  .60028069 05   BRQ -.35344919 05    B  .69660839 05   THA  .32951014 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                           ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .81140989 05     Y  .21080132 06    Z -.20174349 05   DX  .37438849 00    DY  .15162157 01    DZ  .11208100 00
  INC  .52128210 02   LAN  .72930370 02  APF  .18986624 03   MX -.55003496 00    MY  .28678324 00    MZ  .78435768 00
   WX  .75461303 00    WY -.23171147 00   WZ  .61389659 00   PX -.18863579 00    PY -.97268761 00    PZ -.13526032 00
   QX  .62847095 00    QY -.13733659-01   QZ -.77771181 00   RX  .25751592-01    RY  .13278633 00    RZ -.99081009 00
   BX -.62847095 00    BY  .13733659-01   BZ  .77771181 00   TX -.98170943 00    TY  .19038541 00    TZ  .00000000 00
  DAP -.77736747 01   RAP  .25902471 03

  BTO  .43161171 05   BRO -.54678515 05    B  .69660798 05   THA  .30828624 03    T VECTOR IN  ORBIT PLANE OF TARGET

  1 DAYS  6 HRS.  0 MIN.  0.000 SEC.     23561030206620224601C000 J.D.= 2438044.52918168  JAN. 15,1963 00 42 01.297

      GEOCENTRIC                                                                               EQUATORIAL COORDINATES

    X -.24497662 06     Y -.37368612 05    Z -.13010890 05   DX -.13899911 01    DY -.46287676 00    DZ  .72894213-01
    R  .24815164 06   DEC -.30054642 01   RA  .18867301 03    V  .14668482 01   PTH  .78635463 02    AZ  .59085315 02
    R  .24815164 06   LAT -.30054642 01  LON  .64414211 02   VE  .17881174 02   PTE  .46129782 01   AZE  .27047738 03
   XS  .60183277 08    YS -.12319114 09   ZS -.53418227 08  DXS  .27667737 02   DYS  .11266703 02   DZS  .48862560 01
   XM -.39724057 06    YM  .30964657 05   ZM  .45911510 05  DXM -.14167205 00   DYM -.90765972 00   DZM -.33299838 00
   XT -.39724057 06    YT  .30964657 05   ZT  .45911510 05  DXT -.14167205 00   DYT -.90765972 00   DZT -.33299838 00
   RS  .14714479 09    VS  .30270740 02   RM  .40108196 06   VM  .97714125 00    RT  .40108196 06    VT  .97714125 00
  GED -.30259078 01   ALT  .24177350 06  LOS  .17177836 03  RAS  .29603716 03   RAM  .17554284 03   LOM  .51284040 02
  DUT  .35000000 02    DT  .95999999 03   DR  .14380882 01  SHA  .23970624 06   DES -.21286500 02   DEM  .65730077 01
  CCL  .27315868 03   MCL  .34614435 03  TCL  .34614435 03

                                                GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE              23561021532202110310000 J.D.= 2438043.28009913  JAN. 13,1963 18 43 20.566
  SMA  .37571466 06   ECC  .98267342 00    B  .69636995 05   SLR  .12906903 05   APO  .74491946 06   RCA  .65098484 04
   VH  .96287670-01    C3 -.10609132 01   C1  .71726563 05   TFP  .10792073 06    TF  .22019148-01   PER  .38198547 05
   TA  .16473160 03   MTA  .18000000 03   EA  .69787217 02    MA  .16951545 02   C3J -.13172613 01   TFI  .30000000 02

                                                           ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.24497662 06     Y -.37368612 05    Z -.13010890 05   DX -.13899911 01    DY -.46287676 00    DZ  .72894213-01
  INC  .31046062 02   LAN  .19367679 03  APF  .18943334 03   MX  .10274311 00    MY -.85218454 00    MZ  .51305435 00
   WX -.12194079 00    WY  .50110303 00   WZ  .85675295 00   PX  .92530329 00    PY  .36968754 00    PZ -.84527670-01
   QX -.35908803 00    QY  .78244892 00   QZ -.50875226 00   RX -.78494652-01    RY -.31361064-01    RZ -.99642111 00
   BX  .35908815 00    BY -.78244916 00   BZ  .50875242 00   TX  .37101536 00    TY -.92862672 00    TZ  .00000000 00
  DAP -.48488639 01   RAP  .21778253 02

  BTQ  .59876006 05   BRQ -.35555236 05    B  .69636995 05   THA  .32929755 03    T VECTOR IN  EARTH EQUATOR PLANE


CASE 1                                   IBSYS-JPTRAJ-SPACE 022665                                     10

EARTH-MOON FINE PRINT CHECK 1

                                                           ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .86316282 05     Y  .23191945 06    Z -.18495561 05   DX  .34020546 00    DY  .14217424 01    DZ  .12063117 00
  INC  .52343858 02   LAN  .72892010 02  APF  .18986603 03   MX -.55360104 00    MY  .26889734 00    MZ  .78817511 00
   WX  .75666063 00    WY -.23289466 00   WZ  .61092118 00   PX -.18977354 00    PY -.97241115 00    PZ -.13565612 00
   QX  .62566011 00    QY -.13291064-01   QZ -.77998245 00   RX  .25984140-01    RY  .13314431 00    RZ -.99075599 00
   BX -.62566015 00    BY  .13291066-01   BZ  .77998251 00   TX -.98148400 00    TY  .19154418 00    TZ  .00000000 00
  DAP -.77965626 01   RAP  .25895708 03

  BTO  .42939624 05   BRO -.54822382 05    B  .69636951 05   THA  .30806982 03    T VECTOR IN  ORBIT PLANE OF TARGET

  1 DAYS 10 HRS.  0 MIN.  0.000 SEC.     23561031110620224601C000 J.D.= 2438044.69584834  JAN. 15,1963 04 42 01.297

      GEOCENTRIC                                                                               EQUATORIAL COORDINATES

    X -.26437573 06     Y -.43927890 05    Z -.11923683 05   DX -.13066445 01    DY -.44824937 00    DZ  .77920893-01
    R  .26826547 06   DEC -.25474829 01   RA  .18943391 03    V  .13835891 01   PTH  .78884791 02    AZ  .58743026 02
    R  .26826546 06   LAT -.25474829 01  LON  .50108444 01   VE  .19363027 02   PTE  .40205823 01   AZE  .27041055 03
   XS  .60581443 08    YS -.12302836 09   ZS -.53347636 08  DXS  .27631951 02   DYS  .11340526 02   DZS  .49182314 01
   XM -.39902232 06    YM  .17879167 05   ZM  .41088381 05  DXM -.10578462 00   DYM -.90957011 00   DZM -.33680550 00
   XT -.39902232 06    YT  .17879167 05   ZT  .41088381 05  DXT -.10578462 00   DYT -.90957011 00   DZT -.33680550 00
   RS  .14714639 09    VS  .30270798 02   RM  .40153048 06   VM  .97567725 00    RT  .40153048 06    VT  .97567725 00
  GED -.25648203 01   ALT  .26188730 06  LOS  .11179342 03  RAS  .29621649 03   RAM  .17743443 03   LOM  .35301137 03
  DUT  .35000000 02    DT  .95999999 03   DR  .13576351 01  SHA  .25955771 06   DES -.21256762 02   DEM  .58733265 01
  CCL  .27394551 03   MCL  .34655822 03  TCL  .34655822 03

                                                GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE              23561021534520264301C000 J.D.= 2438043.28101011  JAN. 13,1963 18 44 39.274
  SMA  .37697399 06   ECC  .98281512 00    B  .69586635 05   SLR  .12845176 05   APO  .74746973 06   RCA  .64782519 04
   VH  .95729411-01    C3 -.10573690 01   C1  .71554840 05   TFP  .12224202 06    TF  .43882846-01   PER  .38390761 05
   TA  .16564213 03   MTA  .18000000 03   EA  .72937569 02    MA  .19104912 02   C3J -.13168218 01   TFI  .34000000 02

                                                           ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.26437573 06     Y -.43927890 05    Z -.11923683 05   DX -.13066445 01    DY -.44824937 00    DZ  .77920893-01
  INC  .31350122 02   LAN  .19362201 03  APF  .18945700 03   MX  .11736732 00    MY -.84706748 00    MZ  .51836459 00
   WX -.12253097 00    WY  .50563186 00   WZ  .85400401 00   PX  .92561465 00    PY  .36868698 00    PZ -.85483703-01
   QX -.35808332 00    QY  .78000422 00   QZ -.51319582 00   RX -.79415662-01    RY -.31632516-01    RZ -.99633958 00
   BX  .35808329 00    BY -.78000415 00   BZ  .51319577 00   TX  .37004149 00    TY -.92901523 00    TZ  .00000000 00
  DAP -.49038401 01   RAP  .21718177 02

  BTQ  .59645586 05   BRQ -.35842766 05    B  .69586635 05   THA  .32899712 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                           ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X  .91055950 05     Y  .25178535 06    Z -.16711966 05   DX  .31282303 00    DY  .13417828 01    DZ  .12680315 00
  INC  .52647988 02   LAN  .72848472 02  APF  .18986310 03   MX -.55483514 00    MY  .25325107 00    MZ  .79247826 00
   WX  .75957138 00    WY -.23442258 00   WZ  .60671023 00   PX -.19123658 00    PY -.97205318 00    PZ -.13616612 00
   QX  .62167501 00    QY -.12597343-01   QZ -.78317392 00   RX  .26284758-01    RY  .13360510 00    RZ -.99068603 00
   BX -.62167504 00    BY  .12597344-01   BZ  .78317397 00   TX -.98119198 00    TY  .19303450 00    TZ  .00000000 00
  DAP -.78260571 01   RAP  .25887007 03

  BTO  .42615809 05   BRO -.55010759 05    B  .69586570 05   THA  .30776428 03    T VECTOR IN  ORBIT PLANE OF TARGET

  1 DAYS 14 HRS.  0 MIN.  0.000 SEC.     23561032012620224601C000 J.D.= 2438044.86251501  JAN. 15,1963 08 42 01.297
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                          11

EARTH-MOCN FINE PRINT CHECK 1

        GEOCENTRIC                                                                              EQUATORIAL COORDINATES

   X -.28266672 06     Y -.50281177 05     Z -.10770919 05    DX -.12355833 01    DY -.43423497 00    DZ  .82081237-01
   R  .28730590 06   DEC -.21484846 01    RA  .19008636 03     V  .13122360 01   PTH  .79097325 02    AZ  .58284026 02
   R  .28730590 06   LAT -.21484846 01   LON  .30549903 03    VE  .20765244 02   PTE  .35576730 01   AZE  .27036072 03
  XS  .60979092 08    YS -.12286453 09    ZS -.53276585 08   DXS  .27595929 02   DYS  .11414262 02   DZS  .49501687 01
  XM -.40028703 06    YM  .47746130 04    ZM  .36213617 05   DXM -.69868463-01   DYM -.91030888 00   DZM -.34016981 00
  XT -.40028703 06    YT  .47746130 04    ZT  .36213617 05   DXT -.69868463-01   DYT -.91030888 00   DZT -.34016981 00
  RS  .14714800 09    VS  .30270858 02    RM  .40195016 06    VM  .97429941 00    RT  .40195016 06    VT  .97429941 00
 GED -.21631122 01   ALT  .28092772 06   LOS  .51808410 02   RAS  .29639574 03   RAM  .17931661 03   LOM  .29472928 03
 DUT  .35000000 02    DT  .95999999 03    DR  .12885500 01   SHA  .27832947 06   DES -.21226836 02   DEM  .51690606 01
 CCL  .27463043 03   MCL  .34691034 03   TCL  .34691034 03

                                                 GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 23561021540420276061000O J.D.= 2438043.28245232  JAN. 13,1963 18 46 43.881
 SMA  .37861584 06   ECC  .98300879 00     B  .69498163 05   SLR  .12756975 05   APO  .75079853 06   RCA  .64331408 04
  VH  .94977210-01    C3 -.10527838 01    C1  .71308753 05   TFP  .11651741 06    TF  .78495979-01   PER  .38641839 05
  TA  .16643766 03   MTA  .18000000 03    EA  .75798285 02    MA  .21197347 02   C3J -.13163941 01   TFI  .38000000 02

                                                          ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X -.28266672 06     Y -.50281177 05     Z -.10770919 05    DX -.12355833 01    DY -.43423497 00    DZ  .82081237-01
 INC  .31781082 02   LAN  .19355781 03   APF  .18948050 03    MX  .12957496 00    MY -.84096911 00    MZ  .52533931 00
  WX -.12346662 00    WY  .51199887 00    WZ  .85006662 00    PX  .92603266 00    PY  .36733906 00    PZ -.86749742-01
  QX -.35667841 00    QY  .77647875 00    QZ -.51948179 00    RX -.80637086-01    RY -.31987156-01    RZ -.99623013 00
  BX  .35667840 00    BY -.77647873 00    BZ  .51948177 00    TX  .36872912 00    TY -.92953689 00    TZ  .00000000 00
 DAP -.49766499 01   RAP  .21637262 02

 BTQ  .59301625 05   BRQ -.36239647 05     B  .69498163 05   THA  .32857060 03     T VECTOR IN  EARTH EQUATOR PLANE

                                                          ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
   X  .95445647 05     Y  .27058126 06     Z -.14851533 05    DX  .29068467 00    DY  .12728703 01    DZ  .13140203 00
 INC  .53078989 02   LAN  .72799048 02   APF  .18985507 03    MX -.55352363 00    MY  .23904040 00    MZ  .79779177 00
  WX  .76370743 00    WY -.23642079 00    WZ  .60071342 00    PX -.19314268 00    PY -.97158245 00    PZ -.13683362 00
  QX  .61599291 00    QY -.11522565-01    QZ -.78766767 00    RX  .26676356-01    RY  .13420749 00    RZ -.99059404 00
  BX -.61599279 00    BY  .11522563-01    BZ  .78766752 00    TX -.98080789 00    TY  .19497662 00    TZ  .00000000 00
 DAP -.78646630 01   RAP  .25875663 03

 BTO  .42144854 05   BRO -.55261191 05     B  .69498115 05   THA  .30733089 03     T VECTOR IN  ORBIT PLANE OF TARGET

  1 DAYS 18 HRS.  0 MIN.  0.000 SEC.        23561032714620224601000O J.D.= 2438045.02918167  JAN. 15,1963 12 42 01.297

        GEOCENTRIC                                                                              EQUATORIAL COORDINATES

   X -.30000779 06     Y -.56435753 05     Z -.95618061 04    DX -.11744021 01    DY -.42060585 00    DZ  .85814440-01
   R  .30541954 06   DEC -.17940585 01    RA  .19065365 03     V  .12503974 01   PTH  .79292513 02    AZ  .57641404 02
   R  .30541953 06   LAT -.17940585 01   LON  .24590205 03    VE  .22098914 02   PTE  .31870960 01   AZE  .27032287 03
  XS  .61376221 08    YS -.12269963 09    ZS -.53205074 08   DXS  .27559669 02   DYS  .11487912 02   DZS  .49820675 01
  XM -.40103458 06    YM -.83321843 04    ZM  .31293600 05   DXM -.33962371-01   DYM -.90988291 00   DZM -.34309058 00
  XT -.40103458 06    YT -.83321843 04    ZT  .31293600 05   DXT -.33962371-01   DYT -.90988291 00   DZT -.34309058 00
  RS  .14714964 09    VS  .30270918 02    RM  .40233996 06    VM  .97301155 00    RT  .40233996 06    VT  .97301155 00
 GED -.18062765 01   ALT  .29904135 06   LOS  .35182332 03   RAS  .29657492 03   RAM  .18119024 03   LOM  .23643865 03
 DUT  .35000000 02    DT  .95999999 03    DR  .12286261 01   SHA  .29616432 06   DES -.21196720 02   DEM  .44609135 01
 CCL  .27523752 03   MCL  .34721735 03   TCL  .34721735 03

                                                 GEOCENTRIC CONIC


CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                          12

EARTH-MOCN FINE PRINT CHECK 1


EPOCH OF PERICENTER PASSAGE                 23561021546620225261000O J.D.= 2438043.28473766  JAN. 13,1963 18 50 01.334
 SMA  .38081990 06   ECC  .98327692 00     B  .69353690 05   SLR  .12630457 05   APO  .75527131 06   RCA  .63684789 04
  VH  .93945401-01    C3 -.10466906 01    C1  .70954268 05   TFP  .15071996 06    TF  .13334370 00   PER  .38979752 05
  TA  .16714846 03   MTA  .18000000 03    EA  .78383379 02    MA  .23199731 02   C3J -.13159679 01   TFI  .42000000 02

                                                          ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X -.30000779 06     Y -.56435753 05     Z -.95618061 04    DX -.11744021 01    DY -.42060585 00    DZ  .85814440-01
 INC  .32402870 02   LAN  .19348238 03   APF  .18950222 03    MX  .13969666 00    MY -.83325221 00    MZ  .53495429 00
  WX -.12493616 00    WY  .52110191 00    WZ  .84430106 00    PX  .92660240 00    PY  .36548874 00    PZ -.88464571-01
  QX -.35468141 00    QY  .77127899 00    QZ -.52851702 00    RX -.82294132-01    RY -.32460070-01    RZ -.99607932 00
  BX  .35468134 00    BY -.77127884 00    BZ  .52851691 00    TX  .36692734 00    TY -.93024960 00    TZ  .00000000 00
 DAP -.50752813 01   RAP  .21526244 02

 BTQ  .58785859 05   BRQ -.36798873 05     B  .69353690 05   THA  .32795419 03     T VECTOR IN  EARTH EQUATOR PLANE

                                                          ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
   X  .99553975 05     Y  .28844897 06     Z -.12932931 05    DX  .27294258 00    DY  .12127590 01    DZ  .13494879 00
 INC  .53700903 02   LAN  .72742661 02   APF  .18983976 03    MX -.54898183 00    MY  .22555830 00    MZ  .80482420 00
  WX  .76965569 00    WY -.23909248 00    WZ  .59200045 00    PX -.19568529 00    PY -.97094692 00    PZ -.13772932 00
  QX  .60773101 00    QY -.98416972-02    QZ -.79408167 00    RX  .27210923-01    RY  .13501456 00    RZ -.99046992 00
  BX -.60773115 00    BY  .98416995-02    BZ  .79408186 00    TX -.98028916 00    TY  .19756813 00    TZ  .00000000 00
 DAP -.79164734 01   RAP  .25860521 03

 BTO  .41452436 05   BRO -.55602358 05     B  .69353634 05   THA  .30670511 03     T VECTOR IN  ORBIT PLANE OF TARGET

  1 DAYS 22 HRS.  0 MIN.  0.000 SEC.        23561033616620224601000O J.D.= 2438045.19584834  JAN. 15,1963 16 42 01.297

        GEOCENTRIC                                                                              EQUATORIAL COORDINATES

   X -.31653008 06     Y -.62394955 05     Z -.82995664 04    DX -.11217080 01    DY -.40703204 00    DZ  .89533161-01
   R  .32272791 06   DEC -.14736312 01    RA  .19115127 03     V  .11966286 01   PTH  .79491225 02    AZ  .56697807 02
   R  .32272790 06   LAT -.14736312 01   LON  .18623541 03    VE  .23373436 02   PTE  .28853382 01   AZE  .27029411 03
  XS  .61772826 08    YS -.12253366 09    ZS -.53133104 08   DXS  .27523172 02   DYS  .11561474 02   DZS  .50139278 01
  XM -.40126538 06    YM -.21424506 05    ZM  .26334720 05   DXM  .18955440-02   DYM -.90829977 00   DZM -.34556741 00
  XT -.40126538 06    YT -.21424506 05    ZT  .26334720 05   DXT  .18955440-02   DYT -.90829977 00   DZT -.34556741 00
  RS  .14715131 09    VS  .30270978 02    RM  .40269893 06    VM  .97181731 00    RT  .40269893 06    VT  .97181731 00
 GED -.14836692 01   ALT  .31634971 06   LOS  .29183815 03   RAS  .29675401 03   RAM  .18305625 03   LOM  .17814039 03
 DUT  .35000000 02    DT  .95999999 03    DR  .11765576 01   SHA  .31317932 06   DES -.21166414 02   DEM  .37495646 01
 CCL  .27578364 03   MCL  .34748894 03   TCL  .34748894 03

                                                 GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 23561021560620212021000O J.D.= 2438043.28843318  JAN. 13,1963 18 55 20.627
 SMA  .38390618 06   ECC  .98365649 00     B  .69124322 05   SLR  .12446199 05   APO  .76153797 06   RCA  .62743723 04
  VH  .92490215-01    C3 -.10382761 01    C1  .70434812 05   TFP  .16480067 06    TF  .22203636 00   PER  .39454566 05
  TA  .16779803 03   MTA  .18000000 03    EA  .80676696 02    MA  .25061839 02   C3J -.13155282 01   TFI  .46000000 02

                                                          ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X -.31653008 06     Y -.62394955 05     Z -.82995664 04    DX -.11217080 01    DY -.40703204 00    DZ  .89533161-01
 INC  .33331057 02   LAN  .19339308 03   APF  .18951938 03    MX  .14778767 00    MY -.82273719 00    MZ  .54887301 00
  WX -.12727523 00    WY  .53453153 00    WZ  .83550962 00    PX  .92740189 00    PY  .36286063 00    PZ -.90872875-01
  QX -.35174802 00    QY  .76328729 00    QZ -.54190870 00    RX -.84625815-01    RY -.33111186-01    RZ -.99586249 00
  BX  .35174817 00    BY -.76328760 00    BZ  .54190892 00    TX  .36436821 00    TY -.93125497 00    TZ  .00000000 00
 DAP -.52138257 01   RAP  .21368708 02

 BTQ  .57994008 05   BRQ -.37614718 05     B  .69124322 05   THA  .32703269 03     T VECTOR IN  EARTH EQUATOR PLANE
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CASE  1                                IBSYS-JPTRAJ-SPACE 022665                                    13

EARTH-MOCN FINE PRINT CHECK 1

                                                                ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
   X  .10344153 06      Y  .30550418 06      Z -.10968566 05     DX  .25931991 00     DY  .11600335 01     DZ  .13782209 00
 INC  .54629141 02    LAN  .72677591 02    APF  .18981315 03     MX -.53972122 00     MY  .21199654 00     MZ  .81471371 00
  WX  .77843838 00     WY -.24279053 00     WZ  .57886649 00     PX -.19920705 00     PY -.97005254 00     PZ -.13897705 00
  QX  .59527320 00     QY -.71292128-02     QZ -.80349170 00     RX  .27956510-01     RY  .13613616 00     RZ -.99029559 00
  BX -.59527323 00     BY  .71292131-02     BZ  .80349173 00     TX -.97955856 00     TY  .20115918 00     TZ  .00000000 00
 DAP -.79886574 01    RAP  .25839524 03

 BTO  .40405835 05    BRO -.56085046 05      B  .69124265 05    THA  .30577043 03    T VECTOR IN  ORBIT PLANE OF TARGET

  2 DAYS  0 HRS.  0 MIN.  0.000 SEC.        23561034157620224601 0000 J.D.= 2438045.27918167  JAN. 15,1963 18 42 01.297

      GEOCENTRIC                                                                                 EQUATORIAL COORDINATES

   X -.32452114 06      Y -.65300771 05      Z -.76477978 04     DX -.10983640 01     DY -.40011004 00     DZ  .91542422-01
   R  .33111425 06    DEC -.13234866 01     RA  .19137723 03      V  .11725491 01    PTH  .79600267 02     AZ  .56048426 02
   R  .33111424 06    LAT -.13234866 01    LON  .15637924 03     VE  .23991241 02    PTE  .27553358 01    AZE  .27028264 03
  XS  .61970931 08     YS -.12245029 09     ZS -.53096948 08    DXS  .27504834 02    DYS  .11598222 02    DZS  .50298433 01
  XM -.40118728 06     YM -.27960045 05     ZM  .23842704 05    DXM  .19794696-01    DYM -.90707679 00    DZM -.34663930 00
  XT -.40118728 06     YT -.27960045 05     ZT  .23842704 05    DXT  .19794696-01    DYT -.90707679 00    DZT -.34663930 00
  RS  .14715215 09     VS  .30271009 02     RM  .40286656 06     VM  .97125636 00     RT  .40286656 06     VT  .97125636 00
 GED -.13325026 01    ALT  .32473605 06    LOS  .26184554 03    RAS  .29684354 03    RAM  .18398668 03    LOM  .14898868 03
 DUT  .35000000 02     DT  .95999999 03     DR  .11532869 01    SHA  .32141168 06    DES -.21151193 02    DEM  .33928972 01
 CCL  .27603786 03    MCL  .34761284 03    TCL  .34761284 03

                                                     GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 23561021570020203161 0000 J.D.= 2438043.29111344  JAN. 13,1963 18 59 12.201
 SMA  .38595647 06    ECC  .98390672 00      B  .68963812 05    SLR  .12322652 05    APO  .76570162 06    RCA  .62113059 04
  VH  .91529582-01     C3 -.10327606 01     C1  .70084353 05    TFP  .17176910 06     TF  .28636265 00    PER  .39771055 05
  TA  .16810641 03    MTA  .18000000 03     EA  .81696404 02     MA  .25913684 02    C3J -.13152964 01    TFI  .48000000 02

                                                                ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X -.32452114 06      Y -.65300771 05      Z -.76477978 04     DX -.10983640 01     DY -.40011004 00     DZ  .91542422-01
 INC  .33974277 02    LAN  .19334201 03    APF  .18952475 03     MX  .15098952 00     MY -.81575430 00     MZ  .55834295 00
  WX -.12895533 00     WY  .54373785 00     WZ  .82928852 00     PX  .92792951 00     PY  .36110393 00     PZ -.92470128-01
  QX -.34973903 00     QY  .75759675 00     QZ -.55111668 00     RX -.86174984-01     RY -.33535010-01     RZ -.99571542 00
  BX  .34973906 00     BY -.75759681 00     BZ  .55111673 00     TX  .36265777 00     TY -.93192239 00     TZ  .00000000 00
 DAP -.53057284 01    RAP  .21263510 02

 BTQ  .57436994 05    BRQ -.38170654 05      B  .68963812 05    THA  .32639335 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
   X  .10532131 06      Y  .31375881 06      Z -.99715801 04     DX  .25414384 00     DY  .11361910 01     DZ  .13911048 00
 INC  .55272449 02    LAN  .72640962 02    APF  .18979365 03     MX -.53243060 00     MY  .20482654 00     MZ  .82131851 00
  WX  .78443744 00     WY -.24521199 00     WZ  .56967476 00     PX -.20152205 00     PY -.96945588 00     PZ -.13980041 00
  QX  .58655526 00     QY -.51373503-02     QZ -.80989311 00     RX  .28452274-01     RY  .13687447 00     RZ -.99017970 00
  BX -.58655517 00     BY  .51373495-02     BZ  .80989299 00     TX -.97907065 00     TY  .20352069 00     TZ  .00000000 00
 DAP -.80362980 01    RAP  .25825708 03

 BTO  .39676542 05    BRO -.56407202 05      B  .68963762 05    THA  .30512236 03    T VECTOR IN  ORBIT PLANE OF TARGET

  2 DAYS 10 HRS. 46 MIN. 13.046 SEC.        23561036453320245371 2157 J.D.= 2438045.72794378  JAN. 16,1963 05 28 14.343
  CHANGE OF PHASE OCCURS AT THIS POINT    MOON     IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

  2 DAYS 10 HRS. 46 MIN. 13.046 SEC.        23561036453320245371 2157 J.D.= 2438045.72794378  JAN. 16,1963 05 28 14.343


CASE  1                                IBSYS-JPTRAJ-SPACE 022665                                    14

EARTH-MOCN FINE PRINT CHECK 1

      GEOCENTRIC                                                                                 EQUATORIAL COORDINATES

   X -.36523824 06      Y -.79984804 05      Z -.37911594 04     DX -.10184934 01     DY -.35201941 00     DZ  .11197415 00
   R  .37391297 06    DEC -.58094002 00     RA  .19235240 03      V  .10834134 01    PTH  .80653605 02     AZ  .45730103 02
   R  .37391296 06    LAT -.58094002 00    LON  .35535771 03     VE  .27160095 02    PTE  .22557630 01    AZE  .27025929 03
  XS  .63035470 08     YS -.12199675 09     ZS -.52900267 08    DXS  .27405061 02    DYS  .11795732 02    DZS  .51153816 01
  XM -.39855843 06     YM -.62934252 05     ZM  .10317100 05    DXM  .11562157 00    DYM -.89559930 00    DZM -.35050410 00
  XT -.39855843 06     YT -.62934252 05     ZT  .10317100 05    DXT  .11562157 00    DYT -.89559930 00    DZT -.35050410 00
  RS  .14715677 09     VS  .30271171 02     RM  .40362852 06     VM  .96866896 00     RT  .40362852 06     VT  .96866896 00
 GED -.58489873 00    ALT  .36753476 06    LOS  .10033062 03    RAS  .29732531 03    RAM  .18897318 03    LOM  .35197849 03
 DUT  .35000000 02     DT  .12000000 03     DR  .10690307 01    SHA  .36322043 06    DES -.21068411 02    DEM  .14646888 01
 CCL  .27724801 03    MCL  .34808360 03    TCL  .34808360 03

                                                     GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 23561021757020267111 2157 J.D.= 2438043.33522507  JAN. 13,1963 20 02 43.446
 SMA  .41596048 06    ECC  .98686110 00      B  .67207116 05    SLR  .10858714 05    APO  .82645569 06    RCA  .54652607 04
  VH  .79604680-01     C3 -.95826562 00     C1  .65789743 05    TFP  .20673089 06     TF  .13450417 01    PER  .44497717 05
  TA  .16970044 03    MTA  .18000000 03     EA  .84120820 02     MA  .27875258 02    C3J -.13134935 01    TFI  .58770290 02
    HELIOCENTRIC                                                                                 EQUATORIAL COORDINATES

   X -.63400707 08      Y  .12191676 09      Z  .52896477 08     DX -.28423554 02     DY -.12147752 02     DZ -.50034074 01
   R  .14724600 09    LAT  .21053455 02    LON  .11747590 03      V  .31312943 02    PTH  .70083631 00     AZ  .10013326 03
  XE -.63035470 08     YE  .12199675 09     ZE  .52900267 08    DXE -.27405061 02    DYE -.11795732 02    DZE -.51153816 01
  XT -.63434028 08     YT  .12193381 09     ZT  .52910585 08    DXT -.27289439 02    DYT -.12691332 02    DZT -.54658857 01
 LTE  .21068411 02    LOE  .11732530 03    LTT  .21054316 02    LOT  .11748495 03    RST  .14727953 09    VST  .30588548 02
 EPS  .76123524 02    ESP  .14127420 00    SEP  .10373514 03    EPM  .13596537 03    EMP  .40084709 02    MEP  .39499116 01
 MPS  .14696276 03    MSP  .27453512-18    SMP  .33028751 02    SEM  .10763194 03    EMS  .72218416 02    ESM  .14968061 00
 RPM  .39999999 05    SPN  .75146158 02
 GCE  .82751986 02    GCT  .25083558 03    SIP  .14447234 03    CPT  .88422178 02    SIN  .85931763 02
 REP  .37391297 06    VEP  .10834134 01    CPE  .86484485 02    CPS  .10389195 03
                                                    HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 23560763327320206271 2157 J.D.= 2438037.54273608   JAN. 8,1963 01 01 32.398
 SMA  .16142968 09    ECC  .88703843-01      B  .16079307 09    SLR  .16015949 09    APO  .17574911 09    RCA  .14711025 09
  VH  .26232624 02     C3 -.82211713 03     C1  .46103605 10    TFP  .70720194 06     TF -.13767469 03    PER  .40943282 03
  TA  .86267643 01    MTA  .18000000 03     EA  .78950760 01     MA  .71969675 01                         TFI  .58770290 02
   SELENOCENTRIC                                                                                 EQUATORIAL COORDINATES

   X  .33320198 05      Y -.17050552 05      Z -.14108259 05     DX -.11341150 01     DY  .54357988 00     DZ  .46247825 00
   R  .39999999 05    DEC -.20652945 02     RA  .33290034 03      V  .13399933 01    PTH -.88527701 02     AZ  .25193470 03
   R  .39999995 05    LAT -.95993432 01    LON  .32067773 03     VP  .13467491 01    PTP -.84073395 02    AZP  .27107525 03
 LTS  .91549292-01    LNS  .28895195 03    LTE -.63668248 01    LNE  .10455312 01
 ALT  .38261909 05    SHA -.21802391 05    ALP  .13846899 02     DR -.13395509 01     DP  .49314625-04    ASD  .24904141 01
 HGE  .28387647 03    SVL -.64635958 01    HNG  .14753070 03    SIA  .13347496 03

                                                    SELENOCENTRIC CONIC
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                        15

EARTH-MOCN FINE PRINT CHECK 1

EPOCH OF PERICENTER PASSAGE                    23561040141520240201 2157 J.D.= 2438046.03247703  JAN. 16,1963 12 46 46.016
  SMA -.31620675 04   ECC  .10594037 01    B  .11059719 04   SLR  .38683569 03   APO  .00000000 00   RCA  .18783868 03
   VH  .12451709 01    C3  .15504505 01   C1  .13771391 04   TFP -.26311673 05    TF  .66079088 02   LTF  .66038381 02
   TA -.15919563 03   MTA  .16072189 03   EA -.18607764 03    MA -.59364785 03   C3J -.13134935 01   TFI  .58770290 02
  ZAE  .14143332 03   ZAP  .14547150 03  ZAC  .88754508 02   DEF  .14144382 03    IR  .37433771 04    GP  .63179035 01

                                                                ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X  .33320198 05     Y -.17050552 05    Z -.14108259 05    DX -.11341150 01    DY  .54357988 00    DZ  .46247825 00
  INC  .15282254 03   LAN  .20013795 03  APF  .29751826 02    MX -.53044422 00    MY -.79649823 00    MZ -.29016846 00
   WX -.15724180 00    WY  .42880291 00   WZ -.88959617 00    PX -.96709445 00    PY  .11557205 00    PZ  .22664807 00
   QX  .19999401 00    QY  .89596468 00   QZ  .39652248 00    RX -.31111935 00    RY  .14875513 00    RZ -.93865684 00
   BX -.50807510 00    BY -.80757765 00   BZ -.29946290 00    TX  .43135854 00    TY  .90218059 00    TZ  .00000000 00
  SXI -.84683798 00   SYI  .40489764 00  SZI  .34485263 00   DAI  .20172800 02   RAI  .15444619 03
  SXO  .97889550 00   SYO  .18671445 00  SZO -.83025914-01   DAO -.47625167 01   RAO  .10798880 02
  ETE  .15534899 03   ETS  .35188020 03  ETC  .23880145 03

  BTQ -.10481775 04   BRQ  .35284216 03    B  .11059719 04   THA  .16139551 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                ALL VECTORS REFERENCED TO ECLIPTIC PLANE
    X  .33320198 05     Y -.21255887 05    Z -.61604857 04    DX -.11341150 01    DY  .68270048 00    DZ  .20805109 00
  INC  .17065987 03   LAN  .25589910 03  APF  .87401248 02    MX -.53043529 00    MY -.84617797 00    MZ  .50654120-01
   WX -.15723914 00    WY  .39498343-01   WZ -.98674230 00    PX -.96709254 00    PY  .19619996 00    PZ  .16196162 00
   QX  .19998046 00    QY  .97974701 00   QZ  .73510846-02    RX -.13313504 00    RY  .79970214-01    RZ -.98786629 00
   BX -.50807475 00    BY -.86005494 00   BZ  .46535447-01    TX  .51491795 00    TY  .85723947 00    TZ  .00000000 00
  SXI -.84683798 00   SYI  .50867009 00  SZI  .15530671 00   DAI  .89345865 01   RAI  .14900803 03
  SXO  .97888854 00   SYO  .13827382 00  SZO -.15045267 00   DAO -.86531606 01   RAO  .80401767 01
  ETE  .17665351 03   ETS  .13184719 02  ETC  .26010596 03

  BTC -.11047440 04   BRC -.52099039 02    B  .11059718 04   THA  .18270003 03    T VECTOR IN  ECLIPTIC PLANE

                                                                ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X -.34936237 05     Y -.18967891 05    Z -.44359930 04    DX  .11536559 01    DY  .66550951 00    DZ  .14750169 00
  INC  .17339225 03   LAN  .10296419 03  APF  .53759416 02    MX -.47390972 00    MY  .88003798 00    MZ -.30622630-01
   WX  .11211723 00    WY  .25810518-01   WZ -.99335722 00    PX  .64813837 00    PY  .75584742 00    PZ  .92792701-01
   QX  .75322326 00    QY -.65423562 00   QZ  .68014970-01    RX  .95269299-01    RY  .55078411-01    RZ -.99392658 00
   BX -.49700623 00    BY  .86709756 00   BZ -.33565706-01    TX  .50050873 00    TY -.86573149 00    TZ  .00000000 00
  SXI  .86047355 00   SYI  .49746893 00  SZI  .11004486 00   DAI  .63179018 01   RAI  .30033660 02
  SXO -.36311845 00   SYO -.92946225 00  SZO -.65134412-01   DAO -.37345698 01   RAO  .24866061 03
  ETE  .17201818 03   ETS  .85493964 01  ETC  .25547064 03

  BTO -.11053411 04   BRO  .37349521 02    B  .11059719 04   THA  .17806470 03    T VECTOR IN  ORBIT PLANE OF TARGET

                                                                ALL VECTORS REFERENCED TO TRUE TARGET EQU. PLANE
    X -.34936237 05     Y -.18302078 05    Z -.66702963 04    DX  .11536559 01    DY  .64312123 00    DZ  .22595300 00
  INC  .16946995 03   LAN  .14215393 03  APF  .93335775 02    MX -.47390974 00    MY  .87739358 00    MZ  .74733871-01
   WX  .11211723 00    WY  .14430097 00   WZ -.98315922 00    PX  .64813837 00    PY  .73934828 00    PZ  .18242844 00
   QX  .75322326 00    QY -.65767596 00   QZ -.10633056-01    RX  .14726263 00    RY  .82277772-01    RZ -.98566932 00
   BX -.49700607 00    BY  .86489749 00   BZ  .70265966-01    TX  .48774886 00    TY -.87298399 00    TZ  .00000000 00
  SXI  .86047355 00   SYI  .48075910 00  SZI  .16868881 00   DAI  .97115931 01   RAI  .29192725 02
  SXO -.36311845 00   SYO -.91502409 00  SZO -.17570984 00   DAO -.10119970 02   RAO  .24835482 03
  ETE  .17804142 03   ETS  .14572627 02  ETC  .26149387 03

  BTT -.11031585 04   BRT -.78842095 02    B  .11059723 04   THA  .18408794 03    T VECTOR IN  TRUE TARGET EQU. PLANE

   2 CAYS 14 HRS. 46 MIN. 13.046 SEC.          23561037355320245371 2157 J.D.= 2438045.89461044  JAN. 16,1963 09 28 14.343
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                        16

EARTH-MCCN FINE PRINT CHECK 1

       GEOCENTRIC                                                                                   EQUATORIAL COORDINATES

    X -.38002094 06     Y -.84781086 05    Z -.20042063 04    DX -.10510077 01    DY -.30554540 00    DZ  .14315054 00
    R  .38936841 06   DEC -.29492244 00   RA  .19257649 03     V  .11038421 01   PTH  .81448086 02    AZ  .24997337 02
    R  .38936840 06   LAT -.29492244 00  LON  .29541755 03    VE  .28344867 02   PTE  .22070219 01   AZE  .27030094 03
   XS  .63429840 08    YS -.12182636 09   ZS -.52826378 08   DXS  .27367567 02   DYS  .11868919 02   DZS  .51470764 01
   XM -.39663938 06    YM -.75786597 05   ZM  .52648547 04   DXM  .15087609 00   DYM -.88926003 00   DZM -.35112140 00
   XT -.39663938 06    YT -.75786597 05   ZT  .52648547 04   DXT  .15087609 00   DYT -.88926003 00   DZT -.35112140 00
   RS  .14715853 09    VS  .30271229 02   RM  .40384914 06    VM  .96790145 00    RT  .40384914 06    VT  .96790145 00
  GED -.29693224 00   ALT  .38299020 06  LOS  .40345138 02   RAS  .29750409 03   RAM  .19081722 03   LOM  .29365827 03
  OUT  .35000000 02    DT  .24000000 03   DR  .10915691 01   SHA  .37812480 06   DES -.21037321 02   DEM  .74696826 00
  CCL  .27765387 03   MCL  .34791781 03  TCL  .34791781 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    23561022271020275711 2157 J.D.= 2438043.41004477  JAN. 13,1963 21 50 27.868
  SMA  .48084759 06   ECC  .98928614 00    B  .70198728 05   SLR  .10248266 05   APO  .95654345 06   RCA  .51517305 04
   VH  .66817385-01    C3 -.82895419 00   C1  .63913734 05   TFP  .21466647 06    TF  .31407142 01   PER  .55305814 05
   TA  .16980938 03   MTA  .18000000 03   EA  .78912623 02    MA  .23288669 02   C3J -.13116061 01   TFI  .62770290 02

      HELIOCENTRIC                                                                                  EQUATORIAL COORDINATES

    X -.63809861 08     Y  .12174157 09    Z  .52824374 08    DX -.28418574 02    DY -.12174464 02    DZ -.50039259 01
    R  .14725191 09   LAT  .21022512 02  LON  .11766091 03     V  .31318880 02   PTH  .83140136 00    AZ  .10018118 03
   XE -.63429840 08    YE  .12182636 09   ZE  .52826378 08   DXE -.27367567 02   DYE -.11868919 02   DZE -.51470764 01
   XT -.63826480 08    YT  .12175057 09   ZT  .52831643 08   DXT -.27216691 02   DYT -.12758179 02   DZT -.54981978 01
  LTE  .21037321 02   LOE  .11750409 03  LTT  .21022962 02   LOT  .11766531 03   RST  .14726915 09   VST  .30557316 02
  EPS  .76050275 02   ESP  .14720910 00  SEP  .10380259 03   EPM  .13463025 03   EMP  .43325135 02   MEP  .20445681 01
  MPS  .14840544 03   MSP  .27453512-18  SMP  .31590432 02   SEM  .10582256 03   EMS  .74026270 02   ESM  .15130585 00
  RPM  .20246302 05   SPM  .75111707 02
  GCE  .82346128 02   GCT  .25026394 03  SIP  .14348068 03   CPT  .88131120 02   SIN  .83206370 02
  REP  .38936841 06   VEP  .11038421 01  CPE  .86121187 02   CPS  .10388202 03

                                                 HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    23560754513320272071 2157 J.D.= 2438036.25832907   JAN. 6,1963 18 11 59.632
  SMA  .16151694 09   ECC  .89494023-01    B  .16086875 09   SLR  .16022333 09   APO  .17597174 09   RCA  .14706214 09
   VH  .26204656 02    C3 -.82167297 03   C1  .46112792 10   TFP  .83257471 06    TF -.16850046 03   PER  .40976486 03
   TA  .10162292 02   MTA  .18000000 03   EA  .92941036 01    MA  .84659801 01                        TFI  .62770290 02

     SELENOCENTRIC                                                                                  EQUATORIAL COORDINATES

    X  .16618444 05     Y -.89944889 04    Z -.72690611 04    DX -.12018839 01    DY  .58371463 00    DZ  .49427194 00
    R  .20246302 05   DEC -.21040731 02   RA  .33157618 03     V  .14246235 01   PTH -.87529330 02    AZ  .25302176 03
    R  .20246300 05   LAT -.94878634 01  LON  .31717110 03    VP  .14278818 01   PTP -.85408324 02   AZP  .27278094 03
  LTS  .88137612-01   LNS  .28692690 03  LTE -.64515772 01   LNE  .83822898 00
  ALT  .18508212 05   SHA -.10605897 05  ALP  .14520480 02    DR -.14232992 01    DP  .17379453-03   ASD  .49247499 01
  HGE  .28394972 03   SVL -.62957729 01  HNG  .14897526 03   SIA  .12970550 03

                                                 SELENOCENTRIC CONIC
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CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                     17

EARTH-MOON FINE PRINT CHECK 1

EPOCH OF PERICENTER PASSAGE                    23561040141520232O132157 J.D.= 2438046.03247252  JAN. 16,1963 12 46 45.626
  SMA -.31727021 04   ECC  .10485189 01    B   .10002417 04   SLR  .31534100 03   APO  .00000000 00   RCA  .15393609 03
   VH  .12430823 01    C3  .15452535 01   C1   .12433825 04   TFP -.11911283 05    TF  .66078979 02   LTF  .66045389 02
   TA -.15986293 03   MTA  .16250177 03   EA  -.15124078 03    MA -.26739407 03   C3J -.13116061 01   TFI  .62770290 02
  ZAE  .13929939 03   ZAP  .14581398 03   ZAC  .88732472 02   DEF  .14500352 03    IR  .37483117 04    GP  .63427407 01

                                                       ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X  .16618444 05     Y -.89944889 04     Z -.72690611 04    DX -.12018839 01    DY  .58371463 00    DZ  .49427194 00
  INC  .15320783 03   LAN  .20119881 03   APF  .32660967 02    MX -.54744621 00    MY -.79121799 00    MZ -.27253899 00
   WX -.16299586 00    WY  .42025423 00    WZ -.89264747 00    PX -.95910654 00    PY  .14470652 00    PZ  .24325828 00
   QX  .23140233 00    QY  .89579424 00    QZ  .37948207 00    RX -.31177721 00    RY  .15027411 00    RZ -.93819648 00
   BX -.50907484 00    BY -.81083228 00    BZ -.28877988 00    TX  .43418891 00    TY  .90082185 00    TZ  .00000000 00
  SXI -.84514789 00   SYI  .40735450 00   SZI  .34610307 00   DAI  .20249145 02   RAI  .15426630 03
  SXO  .98430228 00   SYO  .13133370 00   SZO -.11790053 00   DAO -.67709534 01   RAO  .75999864 01
  ETE  .15594766 03   ETS  .35210166 03.  ETC  .23886763 03

  BTQ -.95168008 03   BRQ  .30787750 03    B  .10002417 04   THA  .16207311 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                       ALL VECTORS REFERENCED TO ECLIPTIC PLANE
    X  .16618444 05     Y -.11143933 05     Z -.30907656 04    DX -.12018839 01    DY  .73217098 00    DZ  .22125359 00
  INC  .17045377 03   LAN  .25942098 03   APF  .92840171 02    MX -.54744327 00    MY -.83432980 00    MZ  .64728320-01
   WX -.16299502 00    WY  .30441862-01    WZ -.98615214 00    PX -.95910595 00    PY  .22953801 00    PZ  .16561040 00
   QX  .23139799 00    QY  .97282000 00    QZ -.82160951-02    RX -.13301820 00    RY  .80492880-01    RZ -.98783955 00
   BX -.50907457 00    BY -.85879083 00    BZ  .57631549-01    TX  .51771731 00    TY  .85555175 00    TZ  .00000000 00
  SXI -.84514786 00   SYI  .51142164 00   SZI  .15547651 00   DAI  .89444348 01   RAI  .14882074 03
  SXO  .98430030 00   SYO  .73589000-01   SZO -.16041731 00   DAO -.92311200 01   RAO  .42756343 01
  ETE  .17721913 03   ETS  .13373134 02   ETC  .26013909 03

  BTC -.99853784 03   BRC -.58355180 02    B  .10002415 04   THA  .18334459 03    T VECTOR IN  ECLIPTIC PLANE

                                                       ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X -.17898265 05     Y -.91911943 04     Z -.22553648 04    DX  .12302910 01    DY  .70081077 00    DZ  .15747996 00
  INC  .17352846 03   LAN  .10823257 03   APF  .60970087 02    MX -.45500618 00    MY  .89032310 00    MZ -.17430116-01
   WX  .10709153 00    WY  .35277370-01    WZ -.99362798 00    PX  .67334504 00    PY  .73272656 00    PZ  .98586392-01
   QX  .73153273 00    QY -.67961375 00    QZ  .54714629-01    RX  .95832273-01    RY  .54964307-01    RZ -.99387880 00
   BX -.49522198 00    BY  .86847403 00    BZ -.22540245-01    TX  .49752356 00    TY -.86745046 00    TZ  .00000000 00
  SXI  .86214063 00   SYI  .49447812 00   SZI  .11047579 00   DAI  .63427441 01   RAI  .29836292 02
  SXO -.42223364 00   SYO -.90316365 00   SZO -.77573162-01   DAO -.44490844 01   RAO  .24494366 03
  ETE  .17257501 03   ETS  .87290175 01   ETC  .25549498 03

  BTO -.99998404 03   BRO  .22684570 02    B  .10002413 04   THA  .17870047 03    T VECTOR IN  ORBIT PLANE OF TARGET

                                                       ALL VECTORS REFERENCED TO TRUE TARGET EQU. PLANE
    X -.17898265 05     Y -.88558833 04     Z -.33373730 04    DX  .12302910 01    DY  .67697488 00    DZ  .24008477 00
  INC  .16920086 03   LAN  .14514047 03   APF  .98247403 02    MX -.45500379 00    MY  .88602322 00    MZ  .89070176-01
   WX  .10709094 00    WY  .15374263 00    WZ -.98229010 00    PX  .67334467 00    PY  .71569824 00    PZ  .16542631 00
   QX  .73153143 00    QY -.68127719 00    QZ -.26876957-01    RX  .14761624 00    RY  .81798300-01    RZ -.98565635 00
   BX -.49522218 00    BY  .86494579 00    BZ  .81386586-01    TX  .48468852 00    TY -.87468682 00    TZ  .00000000 00
  SXI  .86214063 00   SYI  .47773632 00   SZI  .16876468 00   DAI  .97160038 01   RAI  .28992064 02
  SXO -.42223235 00   SYO -.88742408 00   SZO -.18492721 00   DAO -.10656890 02   RAO  .24455510 03
  ETE  .17861089 03   ETS  .14764895 02   ETC  .26153086 03

  BTT -.99682555 03   BRT -.82590861 02    B  .10002412 04   THA  .18473635 03    T VECTOR IN  TRUE TARGET EQU. PLANE

   2 DAYS 17 HRS. 56 MIN. 20.068 SEC.         23561040121720225656 5164 J.D.= 2438046.02663616  JAN. 16,1963 12 38 21.365
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CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                     18

EARTH-MOON FINE PRINT CHECK 1

       GEOCENTRIC                                                                          EQUATORIAL COORDINATES

    X -.39370375 06     Y -.87062974 05     Z  .51784053 03    DX -.19409183 01    DY  .41802673 00    DZ  .64834569 00
    R  .40321566 06   DEC  .73585041-01    RA  .19246961 03     V  .20886029 01   PTH  .59831455 02    AZ  .30798739 03
    R  .40321564 06   LAT  .73585041-01   LON  .24765127 03    VE  .30290947 02   PTE  .34175406 01   AZE  .27122424 03
   XS  .63741859 08    YS -.12169063 09    ZS -.52767523 08   DXS  .27337696 02   DYS  .11926830 02   DZS  .51721552 01
   XM -.39475985 06    YM -.85897950 05    ZM  .12583334 04   DXM  .17863677 00   DYM -.88345073 00   DZM -.35129676 00
   XT -.39475985 06    YT -.85897950 05    ZT  .12583334 04   DXT  .17863677 00   DYT -.88345073 00   DZT -.35129676 00
   RS  .14715993 09    VS  .30271275 02    RM  .40399923 06    VM  .96737050 00    RT  .40399923 06    VT  .96737050 00
  GED  .74086506-01   ALT  .39683745 06   LOS  .35282732 03   RAS  .29764565 03   RAM  .19227594 03   LOM  .24745760 03
  OUT  .35000000 02    DT  .30000000 02    DR  .18057034 01   SHA  .39094342 06   DES -.21012561 02   DEM  .17846004 00
  CCL  .27800318 03   MCL  .33402653 03   TCL  .33402653 03

                                                GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    23561025233520263476 5164 J.D.= 2438043.96804659  JAN. 14,1963 11 13 59.226
  SMA -.16711740 06   ECC  .19206555 01    B   .27403774 06   SLR  .44936490 06   APO  .00000000 00   RCA  .15385755 06
   VH  .15443942 01    C3  .23851533 01   C1   .42322232 06   TFP  .17786214 06    TF  .16532758 02   LTF -.30851336 01
   TA  .86583683 02   MTA  .12137624 03   EA   .67455208 02    MA  .94176516 02   C3J -.12929574 01   TFI  .65938907 02

      HELIOCENTRIC                                                                         EQUATORIAL COORDINATES

    X -.64135562 08     Y  .12160357 09     Z  .52768041 08    DX -.29278615 02    DY -.11508803 02    DZ -.45238095 01
    R  .14725917 09   LAT  .20997946 02   LON  .11780784 03     V  .31782930 02   PTH  .29341348 01    AZ  .99923428 02
   XE -.63741859 08    YE  .12169063 09    ZE  .52767523 08   DXE -.27337696 02   DYE -.11926830 02   DZE -.51721552 01
   XT -.64136618 08    YT  .12160474 09    ZT  .52768782 08   DXT -.27159060 02   DYT -.12810280 02   DZT -.55234519 01
  LTE  .21012561 02   LOE  .11764566 03   LTT  .20998002 02   LOT  .11780800 03   RST  .14726086 09   VST  .30532382 02
  EPS  .75675643 02   ESP  .15211196 00   SEP  .10417224 03   EPM  .11668619 03   EMP  .63093561 02   MEP  .22017590 00
  MPS  .16612275 03   MSP  .00000000 00   SMP  .13877082 02   SEM  .10439096 03   EMS  .75456784 02   ESM  .15211196 00
  RPM  .17380899 04   SPN  .74769311 02
  GCE  .81996811 02   GCT  .23602335 03   SIP  .76122749 02   CPT  .84107641 02   SIN -.58923587 01
  REP  .40321566 06   VEP  .20886029 01   CPE  .85891898 02   CPS  .10387388 03

                                                HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    23560642041420243456 5164 J.D.= 2438022.11539611  DEC. 23,1962 14 46 10.224
  SMA  .16750454 09   ECC  .13111133 00    B   .16605854 09   SLR  .16462511 09   APO  .18946628 09   RCA  .14554279 09
   VH  .24670312 02    C3 -.79230157 03   C1   .46741923 10   TFP  .20659311 07    TF -.50793085 03   PER  .43276033 03
   TA  .25914518 02   MTA  .18000000 03   EA   .22802376 02    MA  .19891024 02                       TFI  .65938907 02

      SELENOCENTRIC                                                                        EQUATORIAL COORDINATES

    X  .10560991 04     Y -.11650243 04     Z -.74049290 03    DX -.21195550 01    DY  .13014775 01    DZ  .99964245 00
    R  .17380899 04   DEC -.25216403 02    RA  .31219243 03     V  .26806048 01   PTH -.74743889 02    AZ  .26078864 03
    R  .17380897 04   LAT -.73609024 01   LON  .29706478 03    VP  .26818005 01   PTP -.74650484 02   AZP  .27793066 03
  LTS  .85465302-01   LNS  .28532264 03   LTE -.65132043 01   LNE  .67274375 00
  ALT -.45776367-04   SHA -.41686305 03   ALP  .30377679 02    DR -.25861384 01    DP  .23251989-01   ASD  .90000000 02
  HGE  .28432435 03   SVL -.60294826 01   HNG  .16747784 03   SIA  .26686194 02

                                                SELENOCENTRIC CONIC
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CASE  1                                           IBSYS-JPTRAJ-SPACE 022665                                    19

EARTH-MOON FINE PRINT CHECK 1

EPOCH OF PERICENTER PASSAGE                  235610401415202155327764 J.D.= 2438046.03246359  JAN. 16,1963 12 46 44.855
  SMA -.31747777 04   ECC  .10471702 01    B  .98656127 03   SLR  .30657376 03   APO  .00000000 00   RCA  .14975489 03
   VH  .12426759 01    C3  .15442433 01   C1  .12259761 04   TFP -.50348978 03    TF  .66078766 02   LTF  .66046055 02
   TA -.14186097 03   MTA  .16273738 03   EA -.53987633 02    MA -.11291661 02   C3J -.12929574 01   TFI  .65938907 02
  ZAE  .13770351 03   ZAP  .14599427 03  ZAC  .88726667 02   DEF  .14547475 03    IR  .37492740 04    GP  .63501737 01

                                                             ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X  .10560991 04     Y -.11650243 04    Z -.74049290 03    DX -.21195550 01    DY  .13014775 01    DZ  .99464245 00
  INC  .15325757 03   LAN  .20135351 03  APF  .33086642 02    MX -.77714300 00    MY -.61243373 00    MZ -.14482228 00
   WX -.16384731 00    WY  .41908968 00   WZ -.89303848 00    PX -.95784397 00    PY  .14897102 00    PZ  .24564717 00
   QX  .23598499 00    QY  .89564019 00   QZ  .37701405 00    RX -.31196709 00    RY  .15070544 00    RZ -.93606417 00
   BX -.50959702 00    BY -.81108836 00   BZ -.28713506 00    TX  .43498463 00    TY  .90043788 00    TZ  .00000000 00
  SXI -.84466851 00   SYI  .40804349 00  SZI  .34646153 00   DAI  .20271038 02   RAI  .15421568 03
  SXC  .98472650 00   SYO  .12352237 00  SZO -.12270225 00   DAO -.70480841 01   RAO  .71497390 01
  ETE  .15635854 03   ETS  .35220839 03  ETC  .23888631 03

  BTQ -.93920787 03   BRQ  .30197967 03    B  .98656127 03   THA  .16217605 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                             ALL VECTORS REFERENCED TO ECLIPTIC PLANE
    X  .10560991 04     Y -.13634529 04    Z -.21588749 03    DX -.21195550 01    DY  .15917410 01    DZ  .39936096 00
  INC  .17041953 03   LAN  .25988900 03  APF  .93589395 02    MX -.77714299 00    MY -.61949734 00    MZ  .11077731 00
   WX -.16384732 00    WY  .29218065-01   WZ -.98605283 00    PX -.95784399 00    PY  .23440102 00    PZ  .16610562 00
   QX  .23598504 00    QY  .97170070 00   QZ -.10419622-01    RX -.13299074 00    RY  .80643914-01    RZ -.98783097 00
   BX -.50959710 00    BY -.85837121 00   BZ  .59242432-01    TX  .51850609 00    TY  .85507394 00    TZ  .00000000 00
  SXI -.84466852 00   SYI  .51219637 00  SZI  .15553128 00   DAI  .89476109 01   RAI  .14876790 03
  SXC  .98472653 00   SYO  .64511701-01  SZO -.16171536 00   DAO -.93064775 01   RAO  .37482217 01
  ETE  .17762070 03   ETS  .13470561 02  ETC  .26014847 03

  BTC -.98478553 03   BRC -.59166277 02    B  .98656128 03   THA  .18343822 03    T VECTOR IN  ECLIPTIC PLANE

                                                             ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X -.17072027 04     Y -.26328510 03    Z -.19260247 03    DX  .24311512 01    DY  .10884874 01    DZ  .30056464 00
  INC  .17353626 03   LAN  .10897661 03  APF  .62006959 02    MX -.15457317 00    MY  .98778217 00    MZ  .19630499-01
   WX  .10645493 00    WY  .36606773-01   WZ -.99364332 00    PX  .67707782 00    PY  .72916713 00    PZ  .99402598-01
   QX  .72817092 00    QY -.68335567 00   QZ  .52837809-01    RX  .96003769-01    RY  .54924237-01    RZ -.99386447 00
   BX -.49444642 00    BY  .86895537 00   BZ -.20959839-01    TX  .49658148 00    TY -.86799011 00    TZ  .00000000 00
  SXI  .86266453 00   SYI  .49353469 00  SZI  .11060468 00   DAI  .63501754 01   RAI  .29774086 02
  SXC -.43049277 00   SYO -.89910845 00  SZO -.79245274-01   DAO -.45451852 01   RAO  .24441491 03
  ETE  .17297407 03   ETS  .88239332 01  ETC  .25550184 03

  BTC -.98634243 03   BRO  .20805829 02    B  .98656184 03   THA  .17879158 03    T VECTOR IN  ORBIT PLANE OF TARGET

                                                             ALL VECTORS REFERENCED TO TRUE TARGET EQU. PLANE
    X -.17072027 04     Y -.23838514 03    Z -.22268204 03    DX  .24311512 01    DY  .10447752 01    DZ  .42847257 00
  INC  .16915818 03   LAN  .14553108 03  APF  .98928698 02    MX -.15457314 00    MY  .97833566 00    MZ  .13771661 00
   WX  .10645491 00    WY  .15507303 00   WZ -.98215024 00    PX  .67707777 00    PY  .71206567 00    PZ  .18581723 00
   QX  .72817097 00    QY -.68477315 00   QZ -.29193567-01    RX  .14772316 00    RY  .81644573-01    RZ -.98565308 00
   BX -.49444650 00    BY  .86523426 00   BZ  .83020126-01    TX  .48372284 00    TY -.87522124 00    TZ  .00000000 00
  SXI  .86266451 00   SYI  .47678290 00  SZI  .16878379 00   DAI  .97171146 01   RAI  .28928827 02
  SXC -.43049266 00   SYO -.88319800 00  SZO -.18611027 00   DAO -.10725871 02   RAO  .24401424 03
  ETE  .17901415 03   ETS  .14864007 02  ETC  .26154192 03

  BTT -.98305602 03   BRT -.83096680 02    B  .98656181 03   THA  .18483166 03    T VECTOR IN  TRUE TARGET EQU. PLANE
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CASE  1                                           IBSYS-JPTRAJ-SPACE 022665                                    20

EARTH-MOON FINE PRINT CHECK 1

  215563036320   214523646526   612554325025   603416475431   204420666560   603534774303                      EARTH
                    630101318                       4201297                  000000000000                    INITIAL

  213406755133   613444001540   612562723572   602416525766   201516557516   201400455161                       MOON
                                                              235610401217   202256565164                        END


     END TRAJECTORY (SPACE)        12483      A
```

B. Check case 2 is an Earth-Venus trajectory made during the Mariner II mission. The spacecraft injects near Earth-Sun phase change on September 5, 1962 and encounters Venus 100.81 days later with a miss of 41,000 km. Radiation pressure was included as a perturbation on the spacecraft.

```
START TRAJECTORY (SPACE)          12483          A


CASE  1                                   IBSYS-JPTRAJ-SPACE 022665                                                  1

EARTH-VENUS, RADIATION PRES. ON                   CHECK 2

DOUBLE PRECISION EPHEMERIS TAPE - EPHEM1

  GME  .39860063 06     J  .16234500-02    H -.57499999-05     D  .78749999-05    RE  .63781650 04    REM  .63783112 04
    G  .66709998-19     A  .88781796 29    B  .88800194 29     C  .88836976 29   OME  .41780741-02     AU  .14959850 09
  GMM  .49026293 04   GMS  .13271411 12  GMV  .32476627 06   GMA  .42977367 05   GMC  .37918700 08    GMJ  .12670935 09
  EGM  .39860320 06   MGM  .49027779 04   JA  .29200000-02    HA  .00000000 00    DA  .00000000 00     RA  .34170000 04
RADIATION PRESSURE INPUT
  ARA  .38300000 01    GB  .38300000 00  MAS  .19822000 03   GB1  .00000000 00   GB2  .00000000 00     SC  .10200000 09

INJECTION CONDITIONS   1950.0    VENUS        23557540064120200000000 J.D.= 2437912.51634260  SEPT. 5,1962 00 23 32.000

GEOCENTRIC          X0-.14297030 07  Y0-.19355307 07  Z0-.99998901 05 DX0-.17513577 01 DY0-.24185118 01 DZ0-.10838549 00
CARTESIAN           T0 .14120000 04 GHA .34951873 03 GHO .34361929 03
DATE OF RUN 022665A  12485                   EARTH     IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

   PROBE IS OUT OF EARTH'S    SHADOW

   0 DAYS  0 HRS.  0 MIN.  0.000 SEC.        23557540064120200000000 J.D.= 2437912.51634260  SEPT. 5,1962 00 23 32.000

       GEOCENTRIC                                                                                   EQUATORIAL COORDINATES

     X -.14242090 07     Y -.19394898 07     Z -.10167162 06    DX -.17445130 01    DY -.24233612 01    DZ -.11043330 00
     R  .24083872 07   DEC -.24194955 01    RA  .23370936 03     V  .29880095 01   PTH  .89380552 02    AZ  .60890383 02
     R  .24083872 07   LAT -.24194955 01   LON  .24419063 03    VE  .17546302 03   PTE  .97569593 00   AZE  .27000513 03
    XS -.14343227 09    YS  .42810504 08    ZS  .18564279 08   DXS -.87218607 01   DYS -.25899198 02   DZS -.11230749 02
    XM -.27632510 06    YM -.27943325 06    ZM -.81923071 05   DXM  .72901663 00   DYM -.58854660 00   DZM -.27195625 00
    XT -.88139502 08    YT -.41412272 08    ZT -.22861356 08   DXT  .21205738 02   DYT -.90988722 01   DZT -.55559090 01
    RS  .15083166 09    VS  .29546049 02    RM  .40143479 06    VM  .97560880 00    RT  .10003094 09    VT  .23734804 02
   GED -.24359640 01   ALT  .24020091 07   LOS  .17386238 03   RAS  .16338111 03   RAM  .22532043 03   LOM  .23580169 03
   DUT  .35000000 02    DT  .38400000 04    DR  .29878348 01   SHA -.22746660 07   DES  .70698621 01   DEM -.11775395 02
   CCL  .60726652 02   MCL  .18216895 03   TCL  .33871826 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                   23557461301520223700000 J.D.= 2437903.65617178  AUG. 27,1962 03 44 53.242
   SMA -.46364059 05   ECC  .11521704 01     B  .26532672 05   SLR  .15184072 05   APO  .00000000 00   RCA  .70552368 04
    VH  .29320965 01    C3  .85971900 01    C1  .77797048 05   TFP  .76551875 06    TF -.88601707 01   LTF -.88860944 01
    TA  .14959338 03   MTA  .15021865 03    EA  .25901344 03    MA  .27738008 04                       TFI  .00000000 00

                                                            ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
     X -.14242090 07     Y -.19394898 07     Z -.10167162 06    DX -.17445130 01    DY -.24233612 01    DZ -.11043330 00
   INC  .29204733 02   LAN  .23804503 03   APF  .20544248 03    MX  .69203714 00    MY -.53365642 00    MZ  .48603182 00
    WX -.41393320 00    WY  .25820200 00    WZ  .87288176 00    PX  .15975330 00    PY  .96464240 00    PZ -.20958783 00
    QX -.89615450 00    QY  .52662800-01    QZ -.44054739 00    RX  .21561014-01    RY  .29956762-01    RZ -.99931859 00
    BX -.69847270 00    BY  .52485511 00    BZ -.48648022 00    TX -.81163524 00    TY  .58416456 00    TZ  .00000000 00
   SXI -.30645804 00   SYI  .86339652 00   SZI -.40072310 00   DAI -.23623391 02   RAI  .10954205 03
   SXO -.58376651 00   SYO -.81108219 00   SZO -.36909144-01   DAO -.21152182 01   RAO  .23425600 03

   BTQ  .25279208 05   BRQ -.80585985 04     B  .26532672 05   THA  .34231856 03    T VECTOR IN  EARTH EQUATOR PLANE




CASE  1                                   IBSYS-JPTRAJ-SPACE 022665                                                  2

EARTH-VENUS, RADIATION PRES. ON                   CHECK 2

       HELIOCENTRIC                                                                                   ECLIPTIC COORDINATES

     X  .14200807 09     Y -.48482164 08     Z  .67773075 06    DX  .69773477 01    DY  .25962118 02    DZ  .86299610 00
     R  .15005755 09   LAT  .25877623 00   LON  .34114987 03     V  .26897207 02   PTH -.37969422 01    AZ  .88140099 02
    XE  .14343227 09    YE -.46662315 08    ZE -.58024999 03   DXE  .87218607 01   DYE  .28229385 02   DZE  .22435188-03
    XT  .55292774 08    YT -.93751323 08    ZT -.44998112 07   DXT  .29927599 02   DYT  .17671232 02   DZT -.14772718 01
   LTE -.22041709-03   LOE  .34197892 03   LTT -.23674050 01   LOT  .30053131 03   RST  .10893507 09   VST  .34786721 02
   EPS  .10831392 03   ESP  .86857472 00   SEP  .70817518 02   EPM  .24704802 01   EMP  .16501275 03   MEP  .12516767 02
   MPS  .10696074 03   MSP  .73425371 00   SMP  .72305030 02   SEM  .64412562 02   EMS  .11544974 03   ESM  .13759044 00
   EPT  .14907056 03   ETP  .70903655 00   TEP  .30220393 02   TPS  .46474513 02   TSP  .40692629 02   STP  .92832855 02
   SET  .46190403 02   STE  .92306648 02   EST  .41502947 02   RPM  .20183694 07   RPT  .97957366 08   SPN  .10816219 03
   SAC  .12104807-09
   GCE  .29927335 03   GCT  .97991616 02   SIP  .46470888 02   CPT  .90244641 02   SIN  .90241014 02
   REP  .24083872 07   VEP  .29880095 01   CPE  .65410268 02   CPS  .82023973 02

                                                  HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                   23560757030720200000000 J.D.= 2438036.71365741   JAN. 7,1963 05 07 40.000
   SMA  .12695262 09   ECC  .19329428 00     B  .12455838 09   SLR  .12220933 09   APO  .15149183 09   RCA  .10241340 09
    VH  .26584071 02    C3 -.10453830 04    C1  .40272698 10   TFP -.10730648 08    TF  .12419731 03   PER  .28554204 03
    TA -.16376220 03   MTA  .18000000 03    EA -.16031381 03    MA -.15658301 03                       TFI  .00000000 00

                                                            ALL VECTORS REFERENCED TO ECLIPTIC PLANE
     X  .14200807 09     Y -.48482164 08     Z  .67773075 06    DX  .69773477 01    DY  .25962118 02    DZ  .86299610 00
   INC  .18778179 01   LAN  .33323168 03   APF  .17168458 03    MX  .32278481 00    MY  .94591574 00    MZ  .32455293-01
    WX -.14758198-01    WY -.29256456-01    WZ  .99946298 00    PX -.81834785 00    PY  .57470334 00    PZ  .47389887-02
    QX -.57453335 00    QY -.81783844 00    QZ -.32423543-01    RX -.38781855-02    RY  .27235437-02    RZ -.99998855 00
    BX  .57453348 00    BY  .81783862 00    BZ  .32423550-01    TX  .57470991 00    TY  .81835721 00    TZ  .00000000 00
   DAP  .27152563 00   RAP  .14492068 03

   BTC  .12449267 09   BRC -.40386689 07     B  .12455837 09   THA  .35814192 03    T VECTOR IN  ECLIPTIC PLANE

    0 DAYS  8 HRS. 31 MIN. 27.578 SEC.       23557541763020271201742S J.D.= 2437912.87152289  SEPT. 5,1962 08 54 59.578
    CHANGE OF PHASE OCCURS AT THIS POINT    SUN       IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

   10 DAYS  0 HRS.  0 MIN.  0.000 SEC.       23557624654120200000000 J.D.= 2437922.51634260 SEPT. 15,1962 00 23 32.000

       GEOCENTRIC                                                                                   EQUATORIAL COORDINATES

     X -.29459900 07     Y -.39596960 07     Z -.18561650 06    DX -.18101584 01    DY -.22479057 01    DZ -.83382606-01
     R  .49388766 07   DEC -.21538386 01    RA  .23335097 03     V  .28873355 01   PTH  .87750933 02    AZ  .28278032 03
     R  .49388763 07   LAT -.21538386 01   LON  .23397583 03    VE  .36001616 03   PTE  .45916459 00   AZE  .27000399 03
    XS -.14886089 09    YS  .19932581 08    ZS  .86430340 07   DXS -.38169667 01   DYS -.26933975 02   DZS -.11680031 02
    XM  .35565800 06    YM  .31766000 05    ZM -.15071250 05   DXM -.67912161-01   DYM  .10293403 01   DZM  .38498199 00
    XT -.70143962 08    YT -.46752834 08    ZT -.26364873 08   DXT  .20130531 02   DYT -.33992765 01   DZT -.25942825 01
    RS  .15043795 09    VS  .29604584 02    RM  .35739170 06    VM  .11010743 01    RT  .88323888 08    VT  .20579691 02
   GED -.21685026 01   ALT  .49324984 07   LOS  .17299827 03   RAS  .17237341 03   RAM  .51038925 01   LOM  .57287521 01
   DUT  .35000000 02    DT  .86399999 05    DR  .28851113 01   SHA -.43277103 07   DES  .32935974 01   DEM -.24168855 01
   CCL  .58092838 02   MCL  .18001176 03   TCL  .33497854 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                   23557456407120261000000 J.D.= 2437903.11304470  AUG. 26,1962 14 42 47.063
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CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                         3

EARTH-VENUS, RADIATION PRES. ON                        CHECK 2

  SMA -.48756741 05   ECC  .41369374 01     B  .19572246 06   SLR  .78567839 06   APO  .00000000 00   RCA  .15294685 06
   VH  .28592468 01    C3  .81752926 01    C1  .55961764 06   TFP  .16764449 07    TF -.94032976 01   LTF -.96835467 01
   TA  .10172830 03   MTA  .10398835 03    EA  .22349110 03    MA  .56328593 04                       TFI  .10000000 02

                                                         ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.29459900 07     Y -.39596960 07     Z -.18561650 06    DX -.18101584 01    DY -.22479057 01    DZ -.83382606-01
  INC  .16704314 03   LAN  .22394341 03   APF  .24862290 03    MX -.78739501 00    MY  .57545474 00    MZ  .22105781 00
   WX -.15560377 00    WY  .16145121 00    WZ -.97453917 00    PX  .89220516 00    PY -.40047031 00    PZ -.20880321 00
   QX -.42398209 00    QY -.90197519 00    QZ -.81732758-01    RX  .18089954-01    RY  .22456009-01    RZ -.99958412 00
   BX  .76325760 00    BY -.60662230 00    BZ -.22236733 00    TX -.77874728 00    TY  .62733776 00    TZ  .00000000 00
  SXI -.19574081 00   SYI -.97203057 00   SZI -.12978186 00   DAI -.74569887 01   RAI  .25861443 03
  SXO -.62707687 00   SYO -.77842342 00   SZO -.28836067-01   DAO -.16524131 01   RAO  .23114601 03

  BTC -.19236558 06   BRC  .36093837 05     B  .19572246 06   THA  .16937306 03    T VECTOR IN  EARTH EQUATOR PLANE

    HELIOCENTRIC                                                                                   ECLIPTIC COORDINATES

    X  .14591490 09     Y -.25432486 08     Z  .14052119 07    DX  .20068083 01    DY  .27261957 02    DZ  .81851411 00
    R  .14812139 09   LAT  .54356693 00   LON  .35011285 03     V  .27347971 02   PTH -.56579194 01    AZ  .88222545 02
   XE  .14886089 09    YE -.21725787 08    ZE  .21093750 03   DXE  .38169667 01   DYE  .29357488 02   DZE  .72395800-03
   XT  .78716934 08    YT -.75108355 08    ZT -.55886490 07   DXT  .23947498 02   DYT  .25206705 02   DZT -.10270783 01
  LTE  .80337629-04   LOE  .35169648 03   LTT -.29404613 01   LOT  .31634385 03   RST  .10894427 09   VST  .34783839 02
  EPS  .11713199 03   ESP  .16742844 01   SEP  .61193737 02   EPM  .29580944 01   EMP  .45491967 02   MEP  .13154992 03
  MPS  .12009008 03   MSP  .17042457 01   SMP  .58205690 02   SEM  .16725533 03   EMS  .12714714 02   ESM  .27976454-01
  EPT  .15400725 03   ETP  .14042330 01   TEP  .24588486 02   TPS  .46490702 02   TSP  .33935479 02   STP  .99573822 02
  SET  .45688628 02   STE  .98852535 02   EST  .35458835 02   RPM  .51828306 07   RPT  .83858056 08   SPN  .11705800 03
  SAC  .12423331-09
  GCE  .30190716 03   GCT  .96885707 02   SIP  .46486466 02   CPT  .90610493 02   SIN  .90606257 02
  REP  .49388766 07   VEP  .28873355 01   CPE  .65333436 02   CPS  .83681660 02

                                                 HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                     2356076010072024200000000 J.D.= 2438036.91812644   JAN. 7,1963 10 02 06.125
  SMA  .12711439 09   ECC  .19174311 00     B  .12475574 09   SLR  .12244098 09   APO  .15148770 09   RCA  .10274108 09
   VH  .26609980 02    C3 -.10440525 04    C1  .40310850 10   TFP -.98843141 07    TF  .12440178 03   PER  .28608802 03
   TA -.15471579 03   MTA  .18000000 03    EA -.14952899 03    MA -.14395794 03                       TFI  .10000000 02

                                                         ALL VECTORS REFERENCED TO ECLIPTIC PLANE
    X  .14591490 09     Y -.25432486 08     Z  .14052119 07    DX  .20068083 01    DY  .27261957 02    DZ  .81851411 00
  INC  .18587005 01   LAN  .33311393 03   APF  .17172312 03    MX  .17133551 00    MY  .98472437 00    MZ  .31016013-01
   WX -.14667434-01    WY -.28928544-01    WZ  .99947385 00    PX -.81755167 00    PY  .57583563 00    PZ  .46691575-02
   QX -.57566772 00    QY -.81705306 00    QZ -.32096611-01    RX -.38173207-02    RY  .26886977-02    RZ -.99998870 00
   BX  .57566795 00    BY  .81705339 00    BZ  .32096624-01    TX  .57584214 00    TY  .81756091 00    TZ  .00000000 00
  DAP  .26752399 00   RAP  .14484137 03

  BTC  .12469147 09   BRC -.40042805 07     B  .12475575 09   THA  .35816066 03    T VECTOR IN  ECLIPTIC PLANE

  20 DAYS  0 HRS.  0 MIN.  0.000 SEC.         2355771144412020000000000 J.D.= 2437932.51634260 SEPT. 25,1962 00 23 32.000
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CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                         4

EARTH-VENUS, RADIATION PRES. ON                        CHECK 2

      GEOCENTRIC                                                                                EQUATORIAL COORDINATES

    X -.45979200 07     Y -.58249573 07     Z -.25234737 06    DX -.20370900 01    DY -.20667682 01    DZ -.75129508-01
    R  .74252727 07   DEC -.19475678 01    RA  .23171426 03     V  .29029141 01   PTH  .83685795 02    AZ  .27412052 03
    R  .74252723 07   LAT -.19475678 01   LON  .22248272 03    VE  .54147272 03   PTE  .30530860 00   AZE  .27000243 03
   XS -.14998374 09    YS -.35242665 07    ZS -.15280270 07   DXS  .12410337 01   DYS -.27232441 02   DZS -.11807568 02
   XM -.30698800 06    YM  .23379312 06    ZM  .10962314 06   DXM -.65192325 00   DYM -.70124340 00   DZM -.21031082 00
   XT -.53836485 08    YT -.47594874 08    ZT -.27452569 08   DXT  .17380964 02   DYT  .12471919 01   DZT -.13378858-02
   RS  .15003292 09    VS  .29707989 02    RM  .40114597 06    VM  .98029427 00    RT  .76923876 08    VT  .17425654 02
  GEC -.19608297 01   ALT  .74188945 07   LOS  .17211453 03   RAS  .18134607 03   RAM  .14270815 03   LOM  .13347661 03
  DUT  .35000000 02    DT  .86399999 05    DR  .28853043 01   SHA -.57189833 07   DES -.58354574 00   DEM  .15859237 02
  CCL  .54908527 02   MCL  .17902846 03   TCL  .32988437 03

    HELIOCENTRIC                                                                                   ECLIPTIC COORDINATES

    X  .14538582 09     Y -.16032802 07     Z  .20856723 07    DX -.32781237 01    DY  .27755994 02    DZ  .75229430 00
    R  .14540962 09   LAT  .82184592 00   LON  .35936818 03     V  .27959028 02   PTH -.73417984 01    AZ  .88339303 02
   XE  .14998374 09    YE  .38412655 07    ZE -.16750000 03   DXE -.12410337 01   DYE  .29682056 02   DZE -.10054111-02
   XT  .96147259 08    YT -.50746559 08    ZT -.62519542 07   DXT  .16139931 02   DYT  .30825770 02   DZT -.49840641 00
  LTE -.63966244-04   LOE  .14670947 01   LTT -.32912470 01   LOT  .33217489 03   RST  .10889718 09   VST  .34799049 02
  EPS  .12737365 03   ESP  .22540303 01   SEP  .50372315 02   EPM  .30935140 01   EMP  .87329832 02   MEP  .89576652 02
  MPS  .12438191 03   MSP  .23480519 01   SMP  .53270038 02   SEM  .41534790 02   EMS  .13836342 03   ESM  .10159538 00
  EPT  .15635381 03   ETP  .22187835 01   TEP  .21427371 02   TPS  .45843535 02   TSP  .27490426 02   STP  .10666604 03
  SET  .44126349 02   STE  .10641343 03   EST  .29460212 02   RPM  .74331404 07   RPT  .70064357 08   SPN  .12732443 03
  SAC  .12891021-09
  GCE  .30509147 03   GCT  .94975840 02   SIP  .45838464 02   CPT  .90458623 02   SIN  .90453552 02
  REP  .74252727 07   VEP  .29029141 01   CPE  .65895949 02   CPS  .85551184 02

  30 DAYS  0 HRS.  0 MIN.  0.000 SEC.        2355777623412020000000000 J.D.= 2437942.51634260   OCT. 5,1962 00 23 32.000

      GEOCENTRIC                                                                                EQUATORIAL COORDINATES

    X -.65251300 07     Y -.75245952 07     Z -.32267187 06    DX -.24711197 01    DY -.18707223 01    DZ -.94630717-01
    R  .99649872 07   DEC -.18555933 01    RA  .22906903 03     V  .31008046 01   PTH  .78063383 02    AZ  .27032214 03
    R  .99649881 07   LAT -.18555933 01   LON  .20998124 03    VE  .72692499 03   PTE  .23911980 00   AZE  .27000028 03
   XS -.14670615 09    YS -.26886199 08    ZS -.11658137 08   DXS  .63318507 01   DYS -.26704604 02   DZS -.11580656 02
   XM -.68798000 05    YM -.36469700 06    ZM -.13060500 06   DXM  .98580331 00   DYM -.89724778-01   DZM -.10839414 00
   XT -.40459242 08    YT -.44982925 08    ZT -.26523195 08   DXT  .13416546 02   DYT  .45558889 01   DZT  .20502792 01
   RS  .14960440 09    VS  .29788250 02    RM  .39343961 06    VM  .99579515 00    RT  .66059772 08    VT  .14316545 02
  GED -.18682299 01   ALT  .99586090 07   LOS  .17129732 03   RAS  .19038511 03   RAM  .25931701 03   LOM  .24022923 03
  DUT  .35000000 02    DT  .86399999 05    DR  .30337560 01   SHA -.62315695 07   DES -.44693872 01   DEM -.19387594 02
  CCL  .50252467 02   MCL  .18124768 03   TCL  .32224025 03
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                        5

EARTH-VENUS, RADIATICN PRES. ON                      CHECK 2

     HELICCENTRIC                                                                                     ECLIPTIC COORDINATES

   X  .14018102 09     Y  .22273076 08      Z  .26971427 07     DX -.88029703 01     DY  .27353559 02     DZ  .65822661 00
   R  .14196508 09   LAT  .10886058 01    LON  .90281427 01      V  .28742699 02    PTH -.87820086 01     AZ  .88503715 02
  XE  .14670615 09    YE  .29304946 08     ZE -.34662500 03    DXE -.63318507 01    DYE  .29107516 02    DZE  .81241129-03
  XT  .10624691 09    YT -.22516788 08     ZT -.64386054 07    DXT  .70846950 01    DYT  .34103020 02    DZT  .69377898-01
 LTE -.13275111-03   LOE  .11296307 02    LTT -.33927342 01    LOT  .34803441 03    RST  .10879737 09    VST  .34831217 02
 EPS  .13877656 03   ESP  .25157991 01    SEP  .38707622 02    EPM  .13205838 01    EMP  .14428713 03    MEP  .34392275 02
 MPS  .13981677 03   MSP  .23858315 01    SMP  .37797382 02    SEM  .68658262 02    EMS  .11120125 03    ESM  .14040588 00
 EPT  .15442676 03   ETP  .37334930 01    TEP  .21839739 02    TPS  .44352715 02    TSP  .21457243 02    STP  .11419003 03
 SET  .41039022 02   STE  .11546660 03    EST  .23494375 02    RPM  .96428862 07    RPT  .56930815 08    SPN  .13873989 03
 SAC  .13524168-09
 GCE  .30974753 03   GCT  .91987786 02    SIP  .44346476 02    CPT  .89687298 02    SIN  .89681058 02
 REP  .99649872 07   VEP  .31008046 01    CPE  .67059296 02    CPS  .87620699 02

40 CAYS  0 HRS.  0 MIN.  0.000 SEC.        2356006302412020000000000 J.D.= 2437952.51634260  OCT. 15,1962 00 23 32.000

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

   X -.89645690 07     Y -.90925694 07      Z -.43980175 06     DX -.32316777 01     DY -.18013377 01     DZ -.19977844 00
   R  .12776218 08   DEC -.19727080 01     RA  .22540614 03      V  .37051950 01    PTH  .73706996 02     AZ  .26572977 03
   R  .12776217 08   LAT -.19727072 01    LON  .19646200 03     VE  .93214765 03    PTE  .21859935 00    AZE  .26999523 03
  XS -.13909721 09    YS -.49439307 08     ZS -.21438519 08    DXS  .11238484 02    DYS -.25377741 02    DZS -.11004352 02
  XM  .26497800 06    YM  .23467300 06     ZM  .67616500 05    DXM -.70543385 00    DYM  .76178503 00    DZM  .33864558 00
  XT -.30873043 08    YT -.40179650 08     ZT -.24108129 08    DXT  .86948349 01    DYT  .62786872 01    DZT  .34134386 01
  RS  .14917067 09    VS  .29856808 02     RM  .36035642 06     VM  .10920779 01     RT  .56113733 08     VT  .11254938 02
 GED -.19861400 01   ALT  .12769839 08    LOS  .17062259 03    RAS  .19956673 03    RAM  .41529130 02    LOM  .12584992 02
 DUT  .35000000 02    DT  .86399999 05     DR  .35563928 01    SHA -.56965965 07    DES -.82630526 01    DEM  .10814963 02
 CCL  .41557154 02   MCL  .17956780 03    TCL  .30900056 03

     HELICCENTRIC                                                                                     ECLIPTIC COORDINATES

   X  .13013264 09     Y  .45370412 08      Z  .32141952 07     DX -.14470161 02     DY  .25928771 02     DZ  .53328121 00
   R  .13785249 09   LAT  .13360396 01    LON  .19220979 02      V  .29697999 02    PTH -.99150500 01     AZ  .88721579 02
  XE  .13909721 09    YE  .53887430 08     ZE  .37475000 03    DXE -.11238484 02    DYE  .27660901 02    DZE -.61273575-04
  XT  .10822417 09    YT  .74332876 07     ZT -.61330476 07    DXT -.25436489 01    DYT  .34779311 02    DZT  .63375914 00
 LTE  .14393977-03   LOE  .21176789 02    LTT -.32358661 01    LOT  .39291406 01    RST  .10865237 09    VST  .34877962 02
 EPS  .15115231 03   ESP  .23683655 01    SEP  .26479337 02    EPM  .26318715 00    EMP  .93802329 01    MEP  .17035637 03
 MPS  .15131390 03   MSP  .24163492 01    SMP  .26269722 02    SEM  .15819706 03    EMS  .21751645 02    ESM  .51396029-01
 EPT  .14878812 03   ETP  .67759441 01    TEP  .24435940 02    TPS  .41815304 02    TSP  .15954735 02    STP  .12222996 03
 SET  .35698980 02   STE  .12676150 03    EST  .17539519 02    RPM  .13131621 08    RPT  .44794839 08    SPN  .15112370 03
 SAC  .14343145-09
 GCE  .31844284 03   GCT  .87443398 02    SIP  .41807374 02    CPT  .88201058 02    SIN  .88193128 02
 REP  .12776218 08   VEP  .37051950 01    CPE  .68955252 02    CPS  .89872999 02

50 CAYS  0 HRS.  0 MIN.  0.000 SEC.        2356014761412020000000000 J.D.= 2437962.51634260  OCT. 25,1962 00 23 32.000
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CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                        6

EARTH-VENUS, RADIATICN PRES. ON                      CHECK 2

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

   X -.12182598 08     Y -.10732624 08      Z -.71985525 06     DX -.42535830 01     DY -.20558824 01     DZ -.48200572 00
   R  .16251865 08   DEC -.25386711 01     RA  .22137940 03      V  .47488892 01    PTH  .74116570 02     AZ  .25756036 03
   R  .16251864 08   LAT -.25386711 01    LON  .18257882 03     VE  .11852195 04    PTE  .22080721 00    AZE  .26998646 03
  XS -.12735948 09    YS -.70529325 08     ZS -.30582920 08    DXS  .15878383 02    DYS -.23311213 02    DZS -.10107572 02
  XM -.40167300 06    YM  .36811000 05     ZM  .44580750 05    DXM -.13040566 00    DYM -.90233684 00    DZM -.32850051 00
  XT -.25464137 08    YT -.34625345 08     ZT -.20852825 08    DXT  .38591230 01    DYT  .63074891 01    DZT  .39913620 01
  RS  .14876201 09    VS  .29961621 02     RM  .40581238 06     VM  .96908718 00     RT  .47772137 08     VT  .84028697 01
 GED -.25559488 01   ALT  .16245486 08    LOS  .17017628 03    RAS  .20897687 03    RAM  .17476380 03    LOM  .13596321 03
 DUT  .35000000 02    DT  .86399999 05     DR  .45675791 01    SHA -.43232363 07    DES -.11863622 02    DEM  .63069898 01
 CCL  .19765540 02   MCL  .17739505 03    TCL  .28021402 03

     HELIOCENTRIC                                                                                     ECLIPTIC COORDINATES

   X  .11517688 09     Y  .66741462 08      Z  .36090507 07     DX -.20131966 02     DY  .23330238 02     DZ  .37499619 00
   R  .13316592 09   LAT  .15530142 01    LON  .30090971 02      V  .30817797 02    PTH -.10676357 02     AZ  .88997368 02
  XE  .12735948 09    YE  .76874577 08     ZE -.29725000 03    DXE -.15878383 02    DYE  .25408181 02    DZE -.68032741-03
  XT  .10189534 09    YT  .36811345 08     ZT -.53568093 07    DXT -.12019260 02    DYT  .32782931 02    DZT  .11519040 01
 LTE -.11448601-03   LOE  .31115308 02    LTT -.28306284 01    LOT  .19863077 02    RST  .10847318 09    VST  .34935799 02
 EPS  .16271230 03   ESP  .18604239 01    SEP  .15427260 02    EPM  .10706862 01    EMP  .13155425 03    MEP  .47375062 02
 MPS  .16198915 03   MSP  .19073919 01    SMP  .16103431 02    SEM  .38573790 02    EMS  .14132854 03    ESM  .97165341-01
 EPT  .14165444 03   ETP  .12184370 02    TEP  .26161183 02    TPS  .38059895 02    TSP  .11124842 02    STP  .13081526 03
 SET  .27162146 02   STE  .14123952 03    EST  .11598330 02    RPM  .15979840 08    RPT  .33949931 08    SPN  .16268981 03
 SAC  .15370481-09
 GCE  .34023446 03   GCT  .80448473 02    SIP  .38049433 02    CPT  .85932632 02    SIN  .85922168 02
 REP  .16251865 08   VEP  .47488892 01    CPE  .71495392 02    CPS  .92277241 02

60 CAYS  0 HRS.  0 MIN.  0.000 SEC.        2356023440412020000000000 J.D.= 2437972.51634260   NOV. 4,1962 00 23 32.000

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

   X -.16374399 08     Y -.12775431 08      Z -.13410055 07     DX -.54786100 01     DY -.27682576 01     DZ -.10034053 01
   R  .20811796 08   DEC -.36944057 01     RA  .21796162 03      V  .62197459 01    PTH  .77591234 02     AZ  .24268670 03
   R  .20811795 08   LAT -.36944057 01    LON  .16930462 03     VE  .15156661 04    PTE  .22963010 00    AZE  .26997681 03
  XS -.11178401 09    YS -.89502878 08     ZS -.38810484 08    DXS  .20083005 02    DYS -.20488341 02    DZS -.88854037 01
  XM  .16354000 06    YM -.31999500 06     ZM -.13356550 06    DXM  .89676070 00    DYM  .47770286 00    DZM  .10968220 00
  XT -.24075564 08    YT -.29725462 08     ZT -.17432042 08    DXT -.53176284 00    DYT  .47914760 01    DZT  .38026625 01
  RS  .14836672 09    VS  .30034140 02     RM  .38338215 06     VM  .10219638 01     RT  .42037031 08     VT  .61401347 01
 GEC -.37195119 01   ALT  .20805418 08    LOS  .17002645 03    RAS  .21868345 03    RAM  .29707023 03    LOM  .24841323 03
 DUT  .35000000 02    DT  .86399999 05     DR  .60744492 01    SHA -.41462561 07    DES -.15164120 02    DEM -.20388711 02
 CCL  .32567589 03   MCL  .18399321 03    TCL  .21489162 03
```

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CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                               7

EARTH-VENUS, RADIATION PRES. ON                      CHECK 2

    HELIOCENTRIC                                                                                      ECLIPTIC COORDINATES

    X  .95409609 08     Y  .85300785 08     Z  .38521260 07    DX -.25561615 02    DY  .19393148 02    DZ  .18180579 00
    R  .12803928 09   LAT  .17240311 01   LON  .41798249 02     V  .32086187 02   PTH -.10999625 02    AZ  .89333904 02
   XE  .11178401 09    YE  .97555208 08    ZE -.21500000 02   DXE -.20083005 02   DYE  .22332096 02   DZE  .10894537-02
   XT  .87708444 08    YT  .63348316 08    ZT -.41674830 07   DXT -.20614768 02   DYT  .28240895 02   DZT  .15836764 01
  LTE -.83028001-05   LOE  .41111584 02   LTT -.22058770 01   LOT  .35839082 02   RST  .10827349 09   VST  .35000354 02
  EPS  .16665256 03   ESP  .18557237 01   SEP  .11491716 02   EPM  .10379981 01   EMP  .10045162 03   MEP  .78510362 02
  MPS  .16620530 03   MSP  .19113637 01   SMP  .11883337 02   SEM  .74141950 02   EMS  .10571553 03   ESM  .14213722 00
  EPT  .13533242 03   ETP  .20367428 02   TEP  .24300146 02   TPS  .33140288 02   TSP  .71373136 01   STP  .13972239 03
  SET  .14859359 02   STE  .15942650 03   EST  .57141354 01   RPM  .20738833 08   RPT  .24607579 08   SPN  .16663500 03
  SAC  .16625977-09
  GCE  .34324107 02   GCT  .69215731 02   SIP  .33125852 02   CPT  .82900689 02   SIN  .82886251 02
  REP  .20811796 08   VEP  .62197459 01   CPE  .74275088 02   CPS  .94776907 02

  95 DAYS 14 HRS. 20 MIN. 28.240 SEC.       23560530165420203655742 3 J.D.= 2438008.11389166   DEC. 9,1962 14 44 00.240

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.38114915 08     Y -.32470177 08     Z -.10737317 08    DX -.69861474 01    DY -.11839936 02    DZ -.59359685 01
    R  .51208876 08   DEC -.12103416 02    RA  .22042775 03     V  .14974180 02   PTH  .68705464 02    AZ  .12448577 03
    R  .51208875 08   LAT -.12103417 02   LON  .28156642 03    VE  .36467468 04   PTE  .21920553 00   AZE  .26995161 03
   XS -.33001654 08    YS -.13173211 09    ZS -.57122265 08   DXS  .29507771 02   DYS -.60166951 01   DZS -.26084710 01
   XM  .21883650 06    YM  .27911400 06    ZM  .88068499 05   DXM -.85077953 00   DYM  .59187484 00   DZM  .29572740 00
   XT -.38807242 08    YT -.33876662 08    ZT -.12684747 08   DXT -.55834932 01   DYT -.87147205 01   DZT -.16056958 01
   RS  .14732756 09    VS  .30227691 02    RM  .36544507 06    VM  .10777738 01    RT  .53052172 08    VT  .10473777 02
  GED -.12183443 02   ALT  .51202499 08   LOS  .31707434 03   RAS  .25593566 03   RAM  .51902136 02   LOM  .11304081 03
  DUT  .35000000 02    DT  .86399999 05    DR  .13951831 02   SHA -.29675361 08   DES -.22812884 02   DEM  .13944961 02
  CCL  .27278204 03   MCL  .17997888 03   TCL  .61752691 02

    HELIOCENTRIC                                                                                      ECLIPTIC COORDINATES

    X -.51132605 07     Y  .10952209 09     Z  .30669425 07    DX -.36493919 02    DY -.66663640 01    DZ -.73618439 00
    R  .10968427 09   LAT  .16022864 01   LON  .92673030 02     V  .37105101 02   PTH -.77066202 01    AZ  .90930744 02
   XE  .33001654 08    YE  .14358377 09    ZE  .38800000 03   DXE -.29507771 02   DYE  .65577999 01   DZE -.45493245-03
   XT -.58055881 07    YT  .10745695 09    ZT  .18397960 07   DXT -.35091265 02   DYT -.20763944 01   DZT  .19933603 01
  LTE  .15089344-03   LOE  .77055806 02   LTT  .97944912 00   LOT  .93092518 02   RST  .10762939 09   VST  .35209114 02
  EPS  .12888771 03   ESP  .15697150 02   SEP  .35415132 02   EPM  .79129368-01   EMP  .11248619 02   MEP  .16867161 03
  MPS  .12896576 03   MSP  .15755508 02   SMP  .35278724 02   SEM  .15557318 03   EMS  .24368171 02   ESM  .58516955-01
  EPT  .13656699 03   ETP  .41576438 02   TEP  .18565540 01   TPS  .34345651 02   TSP  .75079015 00   STP  .14490348 03
  SET  .34155269 02   STE  .12977892 03   EST  .16065797 02   RPM  .51567251 08   RPT  .25000002 07   SPN  .12888057 03
  SAC  .22656087-09
  GCE  .87217960 02   GCT  .32897066 03   SIP  .34203558 02   CPT  .72723142 02   SIN  .72581048 02
  REP  .51208876 08   VEP  .14974180 02   CPE  .80194516 02   CPS  .10226701 03

  95 DAYS 14 HRS. 20 MIN. 28.240 SEC.       23560530165420203655742 3 J.D.= 2438008.11389166   DEC. 9,1962 14 44 00.240
   CHANGE OF PHASE OCCURS AT THIS POINT   VENUS    IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

  97 DAYS 14 HRS. 20 MIN. 28.240 SEC.       23560542615420203655742 3 J.D.= 2438010.11389166  DEC. 11,1962 14 44 00.240


CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                               8

EARTH-VENUS, RADIATION PRES. ON                      CHECK 2

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.39292249 08     Y -.34585063 08     Z -.11798440 08    DX -.66286404 01    DY -.12640377 02    DZ -.63478138 01
    R  .53658276 08   DEC -.12702049 02    RA  .22135425 03     V  .15620907 02   PTH  .67168156 02    AZ  .12255903 03
    R  .53658275 08   LAT -.12702050 02   LON  .28052158 03    VE  .38119831 04   PTE  .21639405 00   AZE  .26995096 03
   XS -.27883219 08    YS -.13269048 09    ZS -.57537650 08   DXS  .29723858 02   DYS -.50734308 01   DZS -.21989640 01
   XM  .51533499 05    YM  .34426450 06    ZM  .12676712 06   DXM -.10448186 01   DYM  .14998627 00   DZM  .14414164 00
   XT -.39740388 08    YT -.35456520 08    ZT -.12997606 08   DXT -.52048405 01   DYT -.95668209 01   DZT -.20150284 01
   RS  .14729161 09    VS  .30233803 02    RM  .37046410 06    VM  .10653256 01    RT  .54821537 08    VT  .11075864 02
  GED -.12785775 02   ALT  .53651898 08   LOS  .31730000 03   RAS  .25813268 03   RAM  .81486513 02   LOM  .14065384 03
  DUT  .35000000 02    DT  .76800000 04    DR  .14396972 02   SHA -.31822035 08   DES -.22994183 02   DEM  .20010029 02
  CCL  .27295560 03   MCL  .17997039 03   TCL  .56240365 02

                                                    GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                  23560241426520276655742 3 J.D.= 2437973.47138803   NOV. 4,1962 23 18 47.927
  SMA -.16336234 04   ECC  .12745618 05     B  .20821537 08   SLR  .26538339 12   APO  .00000000 00   RCA  .20819906 08
   VH  .15620431 02    C3  .24399787 03    C1  .32524142 09   TFP  .31659123 07    TF  .60955044 02   LTF  .60943602 02
   TA  .67172295 02   MTA  .90004494 02    EA  .91665289 02    MA  .17344532 07                       TFI  .97597547 02

                                                                  ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.39292249 08     Y -.34585063 08     Z -.11798440 08    DX -.66286404 01    DY -.12640377 02    DZ -.63478138 01
  INC  .34693322 02   LAN  .22352561 02   APF  .13555276 03    MX  .64569879 00    MY -.55448232 00    MZ -.52499747 00
   WX  .21646323 00    WY -.52641590 00    WZ  .82221037 00    PX -.87921653 00    PY  .26099523 00    PZ  .39857208 00
   QX -.42440772 00    QY -.80917720 00    QZ -.40633771 00    RX  .18872320 00    RY  .35988790 00    RZ -.91370904 00
   BX -.87924986 00    BY  .26093175 00    BZ  .39854021 00    TX -.88561853 00    TY  .46441341 00    TZ  .00000000 00
  SXI -.42447670 00   SYI -.80915672 00   SZI -.40630644 00   DAI -.23973022 02   RAI  .24231888 03
  SXO -.42433874 00   SYO -.80919767 00   SZO -.40636898 00   DAO -.23976943 02   RAO  .24232773 03

  BTQ  .18735902 08   BRQ -.90830828 07     B  .20821537 08   THA  .33413609 03    T VECTOR IN  EARTH EQUATOR PLANE

    HELIOCENTRIC                                                                                      ECLIPTIC COORDINATES

    X -.11409030 08     Y  .10820414 09     Z  .29346385 07    DX -.36352499 02    DY -.85929000 01    DZ -.79604676 00
    R  .10884352 09   LAT  .15449947 01   LON  .96019018 02     V  .37362760 02   PTH -.73091441 01    AZ  .91033023 02
   XE  .27883219 08    YE  .14462829 09    ZE  .26950000 03   DXE -.29723858 02   DYE  .55294794 01   DZE -.90044736-03
   XT -.11857169 08    YT  .10692755 09    ZT  .21811440 07   DXT -.34928699 02   DYT -.40493277 01   DZT  .19563566 01
  LTE  .10483430-03   LOE  .79087698 02   LTT  .11614574 01   LOT  .96327662 02   RST  .10760506 09   VST  .35217018 02
  EPS  .12662666 03   ESP  .16999598 02   SEP  .36373740 02   EPM  .24787221 00   EMP  .38850396 02   MEP  .14090146 03
  MPS  .12687366 03   MSP  .16993096 02   SMP  .36133232 02   SEM  .17568275 03   EMS  .43064117 01   ESM  .00000000 00
  EPT  .13814754 03   ETP  .40772486 02   TEP  .10799443 01   TPS  .36651964 02   TSP  .49218042 00   STP  .14285578 03
  SET  .35659721 02   STE  .12706242 03   EST  .17277850 02   RPM  .53946285 08   RPT  .15486327 07   SPN  .12661984 03
  SAC  .23007446-09
  GCE  .87044397 02   GCT  .32328476 03   SIP  .36422580 02   CPT  .72903288 02   SIN  .72673901 02
  REP  .53658276 08   VEP  .15620907 02   CPE  .80256417 02   CPS  .10247121 03

                                                   HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                  23560760457120231655742 3 J.D.= 2438037.00636128    JAN. 7,1963 12 09 09.615
  SMA  .12728584 09   ECC  .19193415 00     B  .12491931 09   SLR  .12259680 09   APO  .15171634 09   RCA  .10285535 09
   VH  .26586780 02    C3 -.10426462 04    C1  .40336490 10   TFP -.23235094 07    TF  .12449002 03   PER  .28666702 03
   TA -.48826488 02   MTA  .18000000 03    EA -.40984314 02    MA -.33771896 02                       TFI  .97597547 02
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CASE  1                              IBSYS-JPTRAJ-SPACE 022665                                     9

EARTH-VENUS, RADIATION PRES. ON                 CHECK 2

                                                        ALL VECTORS REFERENCED TO ECLIPTIC PLANE
  X -.11409030 08    Y  .10820414 09    Z  .29346385 07   DX -.36352499 02   DY -.85929000 01   DZ -.79604676 00
INC  .18584504 01  LAN  .33224521 03  APF  .17258636 03   MX -.99437648 00   MY -.10435814 00   MZ -.18022150-01
 WX -.15102577-01   WY -.28699463-01   WZ  .99947400 00   PX -.81749394 00   PY  .57592164 00   PZ  .41845776-02
 QX -.57573879 00   QY -.81700073 00   QZ -.32159537-01   RX -.34208974-02   RY  .24100104-02   RZ -.99999103 00
 BX  .57573890 00   BY  .81700090 00   BZ  .32159544-01   TX  .57592680 00   TY  .81750127 00   TZ  .00000000 00
DAP  .23975927 00  RAP  .14483543 03

BTC  .12485467 09  BRC -.40173818 07    B  .12491929 09  THA  .35815706 03    T VECTOR IN  ECLIPTIC PLANE

 APHRODIOCENTRIC                                                                          ECLIPTIC COORDINATES

  X  .44813947 06    Y  .12765891 07    Z  .75349489 06   DX -.14238000 01   DY -.45435722 01   DZ -.27524033 01
  R  .15486327 07  DEC  .29114400 02   RA  .70656657 02    V  .54997253 01  PTH -.88076883 02   AZ  .24107256 03
ALT  .15424327 07  SHA  .93510054 06  ALP  .44169141 02   DR -.54966278 01   DP  .68282368-05  ASD  .22938678 00
HGE  .23337333 03  SVL  .29755004 02  HNG  .22464570 02  SIA  .13791816 03
SAC  .23007446-09

                                             APHRODIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                  23560563546320201715 7423 J.D.= 2438013.32310322  DEC. 14,1962 19 45 16.119
SMA -.10888129 05  ECC  .49093327 01    B  .52332792 05  SLR  .25153263 06  APO  .00000000 00  RCA  .42565318 05
 VH  .54614609 01   C3  .29827556 02   C1  .28581342 06  TFP -.27727588 06   TF  .10080676 03  LTF  .10077004 03
 TA -.99823254 02  MTA  .10175304 03   EA -.23297472 03   MA -.79687521 04                     TFI  .97597547 02
ZAE  .13737671 03  ZAP  .36622976 02  ZAC  .72228841 02  DEF  .23506073 02   IR  .13170148 05   GP -.30196549 02

                                                        ALL VECTORS REFERENCED TO ECLIPTIC PLANE
  X  .44813947 06    Y  .12765891 07    Z  .75349489 06   DX -.14238000 01   DY -.45435722 01   DZ -.27524033 01
INC  .13987522 03  LAN  .20929608 03  APF  .23079818 03   MX  .90377507 00   MY -.67839262-01   MZ -.42258339 00
 WX -.31534191 00   WY  .56202240 00   WZ -.76464279 00   PX  .84115457 00   PY -.20748265 00   PZ -.49939815 00
 QX -.43932598 00   QY -.80067352 00   QZ -.40732552 00   RX  .14960904 00   RY  .47762633 00   RZ -.86573101 00
 BX  .91301253 00   BY -.40041880-01   BZ -.40596154 00   TX -.95428022 00   TY  .29891348 00   TZ  .00000000 00
SXI -.25877867 00  SYI -.82614998 00  SZI -.50050952 00  DAI -.30033716 02  RAI  .25260764 03
SXO -.60145228 00  SYO -.74162469 00  SZO -.29706229 00  DAO -.17281242 02  RAO  .23095819 03
ETE  .31588812 03  ETS  .47608824 02  ETC  .26220584 03

BTC -.46222361 05  BRC  .24540072 05    B  .52332798 05  THA  .15203557 03    T VECTOR IN  ECLIPTIC PLANE

99 DAYS 14 HRS. 20 MIN. 28.240 SEC.          235605552454202036557423 J.D.= 2438012.11389166  DEC. 13,1962 14 44 00.240

     GEOCENTRIC                                                                        EQUATORIAL COORDINATES

  X -.40401515 08    Y -.36840644 08    Z -.12933012 08   DX -.62034065 01   DY -.13476355 02   DZ -.67974975 01
  R  .56185213 08  DEC -.13307983 02   RA  .22236052 03    V  .16318712 02  PTH  .65605731 02   AZ  .12098424 03
  R  .56185212 08  LAT -.13307983 02  LON  .27955649 03   VE  .39813214 04  PTE  .21388054 00  AZE  .26995005 03
 XS -.22730310 08   YS -.13348523 09   ZS -.57882082 08  DXS  .29906197 02  DYS -.41233147 01  DZS -.17867313 01
 XM -.12793600 06   YM  .33046900 06   ZM  .13650800 06  DXM -.99311662 00  DYM -.30104887 00  DZM -.31415671-01
 XT -.40601382 08   YT -.37181991 08   ZT -.13381116 08  DXT -.47487231 01  DYT -.10398957 02  DZT -.24227590 01
 RS  .14725933 09   VS  .30241936 02   RM  .37975230 06   VM  .10382187 01   RT  .56657099 08   VT  .11685822 02
GED -.13395416 02  ALT  .56178835 08  LOS  .31753213 03  RAS  .26033617 03  RAM  .11116315 03  LOM  .16835911 03
DUT  .35000000 02   DT  .38400000 04   DR  .14861859 02  SHA -.34020608 08  DES -.23145176 02  DEM  .21067397 02
CCL  .27320710 03  MCL  .17997388 03  TCL  .47981662 02
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CASE  1                              IBSYS-JPTRAJ-SPACE 022665                                    10

EARTH-VENUS, RADIATION PRES. ON                 CHECK 2

    HELIOCENTRIC                                                                          ECLIPTIC COORDINATES

  X -.17671205 08    Y  .10654955 09    Z  .27908750 07   DX -.36109603 02   DY -.10574465 02   DZ -.87625891 00
  R  .10804104 09  LAT  .14802061 01  LON  .99416771 02    V  .37636293 02  PTH -.69360767 01   AZ  .91164229 02
 XE  .22730310 08   YE  .14549448 09   ZE  .92500000 02  DXE -.29906197 02  DYE  .44937880 01  DZE -.11229217-02
 XT -.17871072 08   YT  .10605811 09   ZT  .25155560 07  DXT -.34654920 02  DYT -.60106769 01  DZT  .19131060 01
LTE  .35989975-04  LOE  .81120568 02  LTT  .13398415 01  LOT  .99564643 02  RST  .10758265 09  VST  .35224305 02
EPS  .12438064 03  ESP  .18353928 02  SEP  .37265422 02  EPM  .35200672 00  EMP  .65374236 02  MEP  .11427372 03
MPS  .12473202 03  MSP  .18283875 02  SMP  .36984094 02  SEM  .15141594 03  EMS  .28513518 02  ESM  .69941139-01
EPT  .14195066 03  ETP  .37676784 02  TEP  .37266289 00  TPS  .39820246 02  TSP  .20367177 00  STP  .13997590 03
SET  .37029535 02  STE  .12447948 03  EST  .18490979 02  RPM  .56342391 08  RPT  .59771421 06  SPN  .12437414 03
SAC  .23350494-09
GCE  .66792896 02  GCT  .31477456 03  SIP  .39225915 02  CPT  .74211037 02  SIN  .73616706 02
REP  .56185213 08  VEP  .16318712 02  CPE  .80294715 02  CPS  .10263574 03

 APHRODIOCENTRIC                                                                          ECLIPTIC COORDINATES

  X  .19986693 06    Y  .49144134 06    Z  .27531963 06   DX -.14546834 01   DY -.45637881 01   DZ -.27893649 01
  R  .59771420 06  DEC  .27427178 02   RA  .67868646 02    V  .55429975 01  PTH -.85207307 02   AZ  .23340268 03
ALT  .59151421 06  SHA  .38439586 06  ALP  .35237906 02   DR -.55236167 01   DP  .44393976-04  ASD  .59433147 00
HGE  .23561935 03  SVL  .28408768 02  HNG  .29165777 02  SIA  .14135633 03
SAC  .23350494-09

                                             APHRODIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                  235605635703202176457423 J.D.= 2438013.32977995  DEC. 14,1962 19 54 52.989
SMA -.10957719 05  ECC  .47467921 01    B  .50846749 05  SLR  .23594199 06  APO  .00000000 00  RCA  .41056295 05
 VH  .54440910 01   C3  .29638127 02   C1  .27681402 06  TFP -.10505275 06   TF  .10081344 03  LTF  .10077715 03
 TA -.97325690 02  MTA  .10216153 03   EA -.18054374 03   MA -.29904413 04                     TFI  .99597547 02
ZAE  .13758818 03  ZAP  .38744029 02  ZAC  .71997602 02  DEF  .24323087 02   IR  .13202868 05   GP -.30414798 02

                                                        ALL VECTORS REFERENCED TO ECLIPTIC PLANE
  X  .19986693 06    Y  .49144134 06    Z  .27531963 06   DX -.14546834 01   DY -.45637881 01   DZ -.27893649 01
INC  .13544702 03  LAN  .21605784 03  APF  .23628756 03   MX  .84714916 00   MY -.48073528-01   MZ -.52917325 00
 WX -.41294321 00   WY  .56716239 00   WZ -.71260215 00   PX  .79759734 00   PY -.15251871 00   PZ -.58358692 00
 QX -.43967468 00   QY -.80936020 00   QZ -.38938698 00   RX  .15259088 00   RY  .47991695 00   RZ -.86394197 00
 BX  .87232406 00   BY  .21410553-01   BZ -.48845915 00   TX -.95298885 00   TY  .30300536 00   TZ  .00000000 00
SXI -.26177905 00  SYI -.82332708 00  SZI -.50359136 00  DAI -.30237889 02  RAI  .25236179 03
SXO -.59783565 00  SYO -.75906543 00  SZO -.25770509 00  DAO -.14933933 02  RAO  .23177622 03
ETE  .31441521 03  ETS  .43093204 02  ETC  .26214139 03

BTC -.41939799 05  BRC  .28747954 05    B  .50846747 05  THA  .14557101 03    T VECTOR IN  ECLIPTIC PLANE

100 DAYS 19 HRS. 31 MIN. 50.356 SEC.         235605635712202455507515 J.D.= 2438013.33011986  DEC. 14,1962 19 55 22.357
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CASE  1                                      IBSYS-JPTRAJ-SPACE 022665                                        11

EARTH-VENUS, RADIATICN PRES. CN                   CHECK 2

      GEOCENTRIC                                                                           EQUATORIAL COORDINATES

   X -.41051522 08    Y -.38296840 08    Z -.13673227 08    DX -.74023303 01    DY -.14859380 02    DZ -.72436947 01
   R  .57782631 08  DEC -.13687849 02   RA  .22301170 03     V  .18112614 02   PTH  .68235511 02    AZ  .12000563 03
   R  .57782630 08  LAT -.13687850 02  LON  .20116672 03    VE  .40881274 04   PTE  .23575764 00   AZE  .26995292 03
  XS -.19582444 08   YS -.13388803 09   ZS -.58056638 08   DXS  .30000255 02   DYS -.35421509 01   DZS -.15347133 01
  XM -.22577100 06   YM  .28624600 06   ZM  .12788150 06   DXM -.85772726 00   DYM -.53310859 00   DZM -.13084948 00
  XT -.41084044 08   YT -.38300817 08   ZT -.13648677 08   DXT -.44341004 01   DYT -.10892721 02   DZT -.26687897 01
  RS  .14724146 09   VS  .30247602 02   RM  .38634569 06    VM  .10183430 01    RT  .57802575 08    VT  .12059645 02
 GEC -.13777587 02  ALT  .57776254 08  LCS  .23983393 03   RAS  .26167892 03   RAM  .12826393 03   LOM  .10641894 03
 DUT  .35000000 02   DT  .24000000 03   DR  .16821471 02   SHA -.35392949 08   DES -.23222040 02   DEM  .19329651 02
 CCL  .27338419 03  MCL  .17998013 03  TCL  .32630208 03

    HELICCENTRIC                                                                          ECLIPTIC COORDINATES

   X -.21469078 08    Y  .10535806 C9    Z  .26909640 07    DX -.37402585 02    DY -.12654299 02    DZ -.73542869 00
   R  .10755688 09  LAT  .14336311 C1  LON  .10151762 03     V  .39492093 02   PTH -.71978411 01    AZ  .90894727 02
  XE  .19582444 08   YE  .14593346 C9   ZE -.26000000 02   DXE -.30000255 02   DYE  .38603337 01   DZE -.11356771-02
  XT -.21501601 08   YT  .10536418 09   ZT  .27150700 07   DXT -.34434355 02   DYT -.71950176 01   DZT  .18838057 01
 LTE -.10117328-04  LOE  .82357275 02  LTT  .14463002 01   LOT  .10153394 03   RST  .10756998 09   VST  .35228423 02
 EPS  .12301625 03  ESP  .19211890 02  SEP  .37771855 02   EPM  .37813586 00   EMP  .80750821 02   MEP  .98871065 02
 MPS  .12339400 03  MSP  .19108989 C2  SMP  .37497010 02   SEM  .13659432 03   EMS  .43302563 02   ESM  .10326686 00
 EPT  .11913395 03  ETP  .60830594 02  TEP  .35663121-01   TPS  .10864178 03   TSP  .19782341-01   STP  .71337549 02
 SET  .37800169 02  STE  .12297074 03  EST  .19229084 02   RPM  .57843469 08   RPT  .40941986 05   SPN  .12300993 03
 SAC  .23561189-09
 GCE  .86615805 02  GCT  .23291788 C3  SIP  .99931756 02   CPT  .11913896 03   SIN  .11042893 03
 REP  .57782631 08  VEP  .18112614 C2  CPE  .80314032 02   CPS  .10271886 03

  APHRODICCENTRIC                                                                         ECLIPTIC COORDINATES

   X  .32522779 05    Y -.61173124 C4    Z -.24105883 05    DX -.29682299 01    DY -.54592814 01    DZ -.26192343 01
   R  .40941986 05  DEC -.36070585 C2   RA  .34934751 03     V  .67434806 01   PTH  .12660726-06    AZ  .24127988 03
 ALT  .34741986 05  SHA -.38789263 C5  ALP  .12302172 02    DR  .47704695-07    DP  .94370840-02   ASD  .87100270 01
 HGE  .23698374 03  SVL -.31715798 C2  HNG  .11207159 03   SIA  .11042393 03
 SAC  .23561189-09

                                              APHRODIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 235605635712202455501126 J.D.= 2438013.33011986  DEC. 14,1962 19 55 22.356
 SMA -.10968193 05  ECC  .47327923 C1    B  .50738202 05   SLR  .23471190 06   APO  .00000000 00   RCA  .40941986 05
  VH  .54414910 01   C3  .29609825 C2   C1  .27609149 06   TFP  .98943083-04    TF  .10081377 03   LTF  .10077751 03
  TA  .25613208-05  MTA  .10219806 C3   EA  .00000000 00    MA  .28124896-05                       TFI  .10081377 03
 ZAE  .13776095 03  ZAP  .39980848 C2  ZAC  .71962126 02   DEF  .24396129 02    IR  .13207785 05    GP -.30447669 02

                                                           ALL VECTORS REFERENCED TO ECLIPTIC PLANE
   X  .32522779 05    Y -.61173124 C4    Z -.24105883 05    DX -.29682299 01    DY -.54592814 01    DZ -.26192343 01
 INC  .13514175 03  LAN  .21640519 C3  APF  .23658779 03    MX -.44016288 00    MY -.80956431 00    MZ -.38840984 00
  WX -.41862255 00   WY  .56769796 C0   WZ -.70885411 00    PX  .79436250 00    PY -.14941416 00    PZ -.58878147 00
  QX -.44016288 00   QY -.80956431 C0   QZ -.38840984 00    RX  .15312781 00    RY  .48022248 00    RZ -.86367711 00
  BX  .86943101 00   BY  .25013427-C1   BZ -.49342078 00    TX -.95273657 00    TY  .30379766 00    TZ  .00000000 00
 SXI -.26238309 00  SYI -.82285679 C0  SZI -.50404540 00   DAI -.30268004 02   RAI  .25231415 03
 SXO -.59806759 00  SYO -.75971682 C0  SZO -.25523606 00   DAO -.14787573 02   RAO  .23178931 03
 ETE  .31364342 03  ETS  .40579462 C2  ETC  .26212929 03
```

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CASE  1                                      IBSYS-JPTRAJ-SPACE 022665                                        12

EARTH-VENUS, RADIATICN PRES. CN                   CHECK 2

 BTC -.41642857 05   BRC  .28986852 05    B  .50738202 05   THA  .14515891 03    T VECTOR IN  ECLIPTIC PLANE

 625535C30676   675730425255   621606475633   601700261755   602465443457   575673744666                  EARTH
                    62090C5CC                      2332000                  000000000000                 INITIAL

 217773675412   214745625452   6176CC155411   602576054657   602772507364   603444441742                  VENUS
                                                             235605635712   202455507515                   END


    END TRAJECTCRY (SPACE)        12495       A
```

C. Check case 3 is an Earth-Mars trajectory made during the design phase of the Mariner C mission. The spacecraft injects near the Earth on November 11, 1964 and encounters Mars 258.97 days later with a miss of 236,205 km. A minimum print was requested. Earth and Mars oblateness perturbations were included.

```
START TRAJECTORY (SPACE)          12500          A


CASE  1                                   IBSYS-JPTRAJ-SPACE 022665                                   1

  EARTH - MARS                 CHECK 3

DOUBLE PRECISION EPHEMERIS TAPE - EPHEM1

  GME  .39860063 06     J  .16234500-02      H -.57499999-05      D  .78749999-05     RE  .63781650 04    REM  .63783112 04
    G  .66709998-19     A  .88781196 29      B  .88800194 29      C  .88836976 29    CME  .41780741-02     AU  .14959850 09
  GMM  .49026293 04   GMS  .13271411 12    GMV  .32476627 06    GMA  .42977367 05    GMC  .37918700 08    GMJ  .12670935 09
  EGM  .39860320 06   MGM  .49027779 04     JA  .29200000-02     HA  .00000000 00     DA  .00000000 00     RA  .34170000 04

INJECTION CONDITIONS   1950.0     MARS         2356772370162026054000000 J.D.= 2438711.19401670  NOV. 11,1964 16 39 23.043

GEOCENTRIC          XO .54206087 04  YO .17802719 04  ZO-.32653654 04 DXO-.27051733 01 DYO .11088835 02 DZO .78981014 00
CARTESIAN           TO .59963042 05 GHA .30069470 03 GHO .50164659 02
DATE OF RUN 022665A  12504                  EARTH    IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

  0 DAYS  0 HRS.  0 MIN.  0.000 SEC.           2356772370162026054000000 J.D.= 2438711.19401670  NOV. 11,1964 16 39 23.043

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X  .54194063 04      Y  .17978477 04      Z -.32577224 04     DX -.27422009 01     DY  .11080006 02     DZ  .78601700 00
    R  .65738098 04    DEC -.29706737 02     RA  .18352879 02      V  .11441330 02    PTH  .19036053 01     AZ  .84370138 02
    R  .65738097 04    LAT -.29706737 02    LON  .77658181 02     VE  .11027283 02    PTE  .19751097 01    AZE  .84157781 02
   XS -.96481613 08     YS -.10304310 09     ZS -.44685264 08    DXS  .23091572 02    DYS -.17704550 02    DZS -.76783640 01
   XM  .25834946 06     YM -.26971397 06     ZM -.14600498 06    DXM  .71534795 00    DYM  .62824798 00    DZM  .20905980 00
   XT -.20584371 09     YT  .93772019 08     ZT  .48581444 08    DXT  .23841343 01    DYT -.25932608 02    DZT -.10896690 02
   RS  .14806538 09     VS  .30093671 02     RM  .40100812 06     VM  .97474315 00     RT  .23135467 09     VT  .28229808 02
  GED -.29874521 02    ALT  .20090686 03    LOS  .28618882 03    RAS  .22688352 03    RAM  .31376712 03    LOM  .13072418 02
  DUI  .35000000 02     DT  .75000000 01     DR  .38005925 00    SHA  .53646702 04    DES -.17565394 02    DEM -.21351886 02
  CCL  .12196123 03    MCL  .40309905 02    TCL  .22181517 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    235677237005202701077320 J.D.= 2438711.19360542  NOV. 11,1964 16 38 47.509
  SMA -.41371199 05    ECC  .11587349 01      B  .24217758 05    SLR  .14176526 05    APO  .00000000 00    RCA  .65670527 04
   VH  .31039873 01     C3  .96347370 01     C1  .75171618 05    TFP  .35534189 02     TF -.41127532-03    LTF -.23138793-01
   TA  .35463618 01    MTA  .14965626 03     EA  .96198518 00     MA  .15275339 00                         TFI  .00000000 00

                                                        ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X  .54194063 04      Y  .17978477 04      Z -.32577224 04     DX -.27422009 01     DY  .11080006 02     DZ  .78601700 00
  INC  .30187601 02    LAN  .97102443 02    APF  .27620986 03     MX -.26720727 00     MY  .95986447 00     MZ  .85208403-01
   WX  .49897454 00     WY  .62172189-01     WZ  .86438362 00     PX  .83934326 00     PY  .21358914 00     PZ -.49988248 00
   QX -.21570174 00     QY  .97494319 00     QZ  .54391734-01     RX -.41039010 00     RY  .15917511 00     RZ -.88849715 00
   BX  .23787213 00     BY  .94928829 00     BZ -.20559328 00     TX  .34687618 00     TY  .93791093 00     TZ  .00000000 00
  SXI  .61539216 00    SYI  .67685777 00    SZI -.40392570 00    DAI -.23823823 02    RAI  .47723207 02
  SXO -.83333138 00    SYO  .30819857 00    SZO  .45888164 00    DAO  .27314967 02    RAO  .15970363 03

  BTC  .22883276 05    BRC  .79281443 04      B  .24217758 05    THA  .19109166 02     T VECTOR IN  EARTH EQUATOR PLANE

                                                        ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X -.43043936 03      Y  .54986291 04      Z -.35769783 04     DX -.10319329 02     DY -.29379116 01     DZ -.39729283 01
  INC  .39497019 02    LAN  .22258649 03    APF  .23526778 03     MX -.90025614 00     MY -.28472285 00     MZ -.32935052 00
   WX -.43040854 00     WY  .46828726 00     WZ  .77165766 00     PX -.96661136-02     PY  .85245496 00     PZ -.52271129 00
   QX -.90258244 00     QY -.23243833 00     QZ -.36237738 00     RX -.12453859 00     RY -.23734787 00     RZ -.96340857 00
   BX -.78382108 00     BY  .23005201 00     BZ -.57680203 00     TX -.88550389 00     TY  .46463197 00     TZ  .00000000 00
  SXI -.46431434 00    SYI  .61825267 00    SZI -.63417333 00    DAI -.39358697 02    RAI  .12690694 03
  SXO -.44763043 00    SYO -.85310204 00    SZO  .26803707 00    DAO  .15547494 02    RAO  .24231359 03

  BTC  .24169738 05    BRO -.15243946 04      B  .24217763 05    THA  .35639111 03     T VECTOR IN  ORBIT PLANE OF TARGET



CASE  1                                   IBSYS-JPTRAJ-SPACE 022665                                   2

  EARTH - MARS                 CHECK 3

  8 DAYS 18 HRS. 36 MIN. 50.283 SEC.         235700021177202251634634 J.D.= 2438719.96959868  NOV. 20,1964 11 16 13.327
  CHANGE OF PHASE OCCURS AT THIS POINT      SUN      IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

  8 DAYS 18 HRS. 36 MIN. 50.283 SEC.         235700021177202251634634 J.D.= 2438719.96959868  NOV. 20,1964 11 16 13.327

      HELIOCENTRIC                                                                                   ECLIPTIC COORDINATES

    X  .75834779 08      Y  .12674386 09      Z  .73327850 06     DX -.28404373 02     DY  .17028954 02     DZ  .93162268 00
    R  .14770056 09    LAT  .28445432 00    LON  .59106609 02      V  .33130976 02    PTH  .58065999-01     AZ  .88388930 02
   XE  .77915722 08     YE  .12556816 09     ZE  .19450000 03    DXE -.25786643 02    DYE  .15595867 02    DZE -.12002587-02
   XT -.12476316 09     YT  .21041414 09     ZT  .74879929 07    DXT -.19898495 02    DYT -.10308557 02    DZT  .26993591 00
  LTE  .75410806-04    LOE  .58180174 02    LTT  .17533010 01    LCT  .12066543 03    RST  .24473665 09    VST  .22411812 02
  EPS  .91281422 02    ESP  .96904339 00    SEP  .87749482 02    EPM  .82792716 01    EMP  .89955360 02    MEP  .81765360 02
  MPS  .99534452 02    MSP  .94382735 00    SMP  .79521710 02    SEM  .16857908 03    EMS  .11393339 02    ESM  .27088086-01
  EPT  .16331898 03    ETP  .18701907 00    TEP  .16493998 02    TPS  .81760879 03    TSP  .61563838 02    STP  .36675276 02
  SET  .80900794 02    STE  .36599970 02    EST  .62499229 02    RPM  .24742262 07    RPT  .21745316 09    SPN  .91135248 02
  GCE  .83114704 02    GCT  .27833776 03    SIP  .81759989 02    CPT  .83250368 02    SIN  .83249478 02
  REP  .25000009 07    VEP  .31267247 01    CPE  .82997996 02    CPS  .99625016 02

                                                  HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                    235700005055202157734634 J.D.= 2438719.68135271  NOV. 20,1964 04 21 08.874
  SMA  .18975202 09    ECC  .22161493 00      B  .18503367 09    SLR  .18043270 09    APO  .23180390 09    RCA  .14770014 09
   VH  .21110349 02     C3 -.69940812 03     C1  .48934615 10    TFP  .24904457 05     TF  .84873359 01    PER  .52177972 03
   TA  .32007631 00    MTA  .18000000 03     EA  .25549602 00     MA  .19887424 00                         TFI  .87755818 0.

                                                        ALL VECTORS REFERENCED TO ECLIPTIC PLANE
    X  .75834779 08      Y  .12674386 09      Z  .73327850 06     DX -.28404373 02     DY  .17028954 02     DZ  .93162268 00
  INC  .16360204 01    LAN  .49096162 02    APF  .96943709 01     MX -.85785656 00     MY  .51311950 00     MZ  .28114367-01
   WX  .21577872-01     WY -.18693866-01     WZ  .99959236 00     PX  .51822002 00     PY  .85523351 00     PZ -.48074947-02
   QX -.85497475 00     QY  .51790505 00     QZ  .28141655-01     RX  .24913695-02     RY  .41115792-02     RZ -.99998816 00
   BX  .85497501 00     BY -.51790521 00     BZ -.28141663-01     TX  .85524362 00     TY -.51822615 00     TZ  .00000000 00
  DAP  .27545128 00    RAP  .58786660 02

  BTC  .18496035 09    BRC  .52072131 07      B  .18503364 09    THA  .16126311 01     T VECTOR IN  ECLIPTIC PLANE

                                                        ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
    X -.12881936 09      Y  .72256647 08      Z -.80723250 05     DX -.16237126 02     DY -.28879098 02     DZ -.12251162 00
  INC  .21432149 00    LAN  .32230268 03    APF  .18808858 03     MX -.48920532 00     MY -.87216079 00     MZ -.36772450-02
   WX -.22853953-02     WY -.29572432-02     WZ  .99999300 00     PX -.86941899 00     PY  .49407495 00     PZ -.52586998-03
   QX -.49406994 00     QY -.86941412 00     QZ -.37002400-02     RX  .45720147-03     RY -.25981925-03     RZ -.99999972 00
   BX  .49407002 00     BY  .86941425 00     BZ  .37002406-02     TX  .49407509 00     TY  .86941924 00     TZ  .00000000 00
  DAP -.30131379-01    RAP  .15039122 03

  BTC  .18503239 09    BRO -.68466903 06      B  .18503365 09    THA  .35978799 03     T VECTOR IN  ORBIT PLANE OF TARGET

252 DAYS 17 HRS. 35 MIN. 56.563 SEC.           235724105155202715400556 J.D.= 2438963.92731024  JULY 22,1965 10 15 19.605
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CASE  1                                   IBSYS-JPTRAJ-SPACE 022665                                          3

  EARTH - MARS              CHECK 3

    HELIOCENTRIC                                                                         ECLIPTIC COORDINATES

      X -.14180703 09     Y -.18080550 09     Z -.35318550 06    DX  .16289198 02    DY -.13676694 02    DZ -.60002750 00
      R  .22978248 09   LAT -.88067603-01   LON  .23189265 03     V  .21277922 02   PTH  .19117819 01    AZ  .91613891 02
     XE  .74579961 08    YE -.13242884 09    ZE  .20050000 03   DXE  .25477438 02   DYE  .14502661 02   DZE -.89907645-03
     XT -.14380243 09    YT -.18092580 09    ZT -.29060200 06   DXT  .19907202 02   DYT -.13014897 02   DZT -.76160687 00
    LTE  .75584905-04   LOE  .29938691 03   LTT -.72044834-01   LOT  .23152181 03   RST  .23111333 09   VST  .23796308 02
    EPS  .39290480 02   ESP  .67494279 02   SEP  .73215238 02   EPM  .41964682-01   EMP  .25188631 02   MEP  .15476932 03
    MPS  .39248762 02   MSP  .67636768 02   SMP  .73114468 02   SEM  .81740242 02   EMS  .98117059 02   ESM  .14282388 00
    EPT  .17065761 03   ETP  .92592317 01   TEP  .82755473-01   TPS  .13152908 03   TSP  .37115026 00   STP  .48099727 02
    SET  .73133797 02   STE  .39001090 02   EST  .67865111 02   RPM  .22207495 09   RPT  .20000010 07   SPN  .39288832 02
    GCE  .25862492 03   GCT  .81135185 02   SIP  .13143231 03   CPT  .89055796 02   SIN  .88959022 02
    REP  .22172902 09   VEP  .29645552 02   CPE  .90548312 02   CPS  .81532245 02

                                               HELIOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                     23570000665620241540O556 J.D.= 2438719.72289474  NOV. 20,1964 05 20 58.105
    SMA  .18894964 09   ECC  .21854539 00     B  .18438208 09   SLR  .17992501 09   APO  .23024371 09   RCA  .14765556 09
     VH  .21223477 02    C3 -.70237821 03    C1  .48865721 10   TFP  .21099261 08    TF  .85288772 01   PER  .51847363 03
     TA  .17313130 03   MTA  .18000000 03    EA  .17142858 03    MA  .16956231 03                       TFI  .25273329 03

                                                                ALL VECTORS REFERENCED TO ECLIPTIC PLANE
      X -.14180703 09     Y -.18080550 09     Z -.35318550 06    DX  .16289198 02    DY -.13676694 02    DZ -.60002750 00
    INC  .16162992 01   LAN  .48770084 02   APF  .99924968 01    MX  .78657053 00    MY -.61685783 00    MZ -.28163934-01
     WX  .21212796-01    WY -.18589970-01    WZ  .99960213 00    PX  .51863735 00    PY  .85498019 00    PZ  .48942548-02
     QX -.85473100 00    QY  .51832717 00    QZ  .27777972-01    RX  .25383740-02    RY  .41845415-02    RZ -.99998791 00
     BX  .85473111 00    BY -.51832724 00    BZ -.27777977-01    TX  .85499053 00    TY -.51864362 00    TZ  .00000000 00
    DAP  .28042110 00   RAP  .58758688 02

    BTC  .18431093 09   BRC  .51218221 07     B  .18438208 09   THA  .15917862 01    T VECTOR IN  ECLIPTIC PLANE

                                                                ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
      X  .18467584 09     Y -.13672901 09     Z -.16253000 05    DX  .13224500 02    DY  .16668983 02    DZ  .86890876-01
    INC  .23406796 00   LAN  .32447593 03   APF  .18587749 03    MX  .59503198 00    MY  .80369163 00    MZ  .40882519-02
     WX -.23758132-02    WY -.33278099-02    WZ  .99999166 00    PX -.86909249 00    PY  .49464899 00    PZ -.41870715-03
     QX -.49464346 00    QY -.86908623 00    QZ -.40673682-02    RX  .36389535-03    RY -.20711313-03    RZ -.99999969 00
     BX  .49464357 00    BY  .86908641 00    BZ  .40673690-02    TX  .49464914 00    TY  .86909276 00    TZ  .00000000 00
    DAP -.23990185-01   RAP  .15035338 03

    BTC  .18438054 09   BRO -.74994980 06     B  .18438206 09   THA  .35976695 03    T VECTOR IN  ORBIT PLANE OF TARGET

  252 DAYS 17 HRS. 35 MIN. 56.563 SEC.          23572410515520271540O556 J.D.= 2438963.92731024  JULY 22,1965 10 15 19.605
    CHANGE OF PHASE OCCURS AT THIS POINT     MARS     IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

  258 DAYS 23 HRS. 17 MIN. 28.762 SEC.          235724514260202747054442 J.D.= 2438970.16448848  JULY 28,1965 15 56 51.805


CASE  1                                   IBSYS-JPTRAJ-SPACE 022665                                          4

  EARTH - MARS              CHECK 3

      GEOCENTRIC                                                                      EQUATORIAL COORDINATES

      X -.22069152 09     Y -.58437119 08     Z -.26078223 08    DX -.67759752 01    DY -.26997936 02    DZ -.12361472 02
      R  .22978189 09   DEC -.65166083 01    RA  .19483103 03     V  .30456663 02   PTH  .29023970 02    AZ  .11381592 03
      R  .22978189 09   LAT -.65166083 01   LON  .95120270 01    VE  .16623345 05   PTE  .50931866-01   AZE  .26996292 03
     XS -.87878015 08    YS  .11366779 09    ZS  .49293696 08   DXS -.23821953 02   DYS -.15721361 02   DZS -.68170658 01
     XM -.21864600 06    YM  .24773650 06    ZM  .13595050 06   DXM -.87000686 00   DYM -.64006138 00   DZM -.21641982 00
     XT -.22073127 09    YT -.58214939 08    ZT -.26008592 08   DXT -.31068882 01   DYT -.26372385 02   DZT -.12262985 02
     RS  .15189727 09    VS  .29344829 02    RM  .35729817 06    VM  .11015571 01    RT  .22975578 09    VT  .29249552 02
    GEC -.65606317 01   ALT  .22977551 09   LOS  .30238905 03   RAS  .12770806 03   RAM  .13143081 03   LOM  .30611180 03
    DUT  .35000000 02    DT  .95999999 03    DR  .14776826 02   SHA -.21702920 09   DES  .18936493 02   DEM  .22364405 02
    CCL  .10096057 03   MCL  .17998949 03   TCL  .35149954 03

    HELIOCENTRIC                                                                         ECLIPTIC COORDINATES

      X -.13281351 09     Y -.18788445 09     Z -.67584800 06    DX  .17045978 02    DY -.12551548 02    DZ -.60018460 00
      R  .23008792 09   LAT -.16829842 00   LON  .23474391 03     V  .21177038 02   PTH  .11137503 01    AZ  .91621096 02
     XE  .87878015 08    YE -.12389606 09    ZE -.33300000 03   DXE  .23821953 02   DYE  .17135739 02   DZE -.62513351-03
     XT -.13285326 09    YT -.18765291 09    ZT -.70036300 06   DXT  .20715065 02   DYT -.11938455 02   DZT -.75871021 00
    LTE -.12560788-03   LOE  .30534763 03   LTT -.17452841 00   LOT  .23470252 03   RST  .22992193 09   VST  .23921042 02
    EPS  .38574496 02   ESP  .70603794 02   SEP  .70821708 02   EPM  .83050504-01   EMP  .11152290 03   MEP  .68394220 02
    MPS  .38491877 02   MSP  .70597944 02   SMP  .70910179 02   SEM  .48867179 01   EMS  .17510177 03   ESM  .98911702-02
    EPT  .83624309 02   ETP  .96317149 02   TEP  .58097472-01   TPS  .45330583 02   TSP  .41964682-01   STP  .13462755 03
    SET  .70763497 02   STE  .38591306 02   EST  .70645197 02   RPM  .22965057 09   RPT  .23620497 06   SPN  .38572905 02
    GCE  .25903942 03   GCT  .70538979 02   SIP  .44511159 02   CPT  .69922116 02   SIN  .69102693 02
    REP  .22978189 09   VEP  .30456663 02   CPE  .89749999 02   CPS  .81061030 02

     AREOCENTRIC                                                                         ECLIPTIC COORDINATES

      X  .39749151 05     Y -.23154230 06     Z  .24514323 05    DX -.36690870 01    DY -.61309294 00    DZ  .15852540 00
      R  .23620496 06   DEC  .59571193 01    RA  .27974108 03     V  .37233336 01   PTH  .14331472-07    AZ  .27245343 03
    ALT  .23282697 06   SHA  .16810431 06   ALP  .17384013 03    DR  .16537543-07    DP  .90316174-03   ASD  .81942291 00
    HGE  .32142550 03   SVL -.60343030 01   HNG  .45014140 02   SIA  .82804886 02

                                                                             AREOCENTRIC EQUATORIAL COORDINATES

      X  .22979118 06     Y  .29207460 05     Z  .46213904 05    DX  .71223004 00    DY -.33713025 01    DZ -.14107658 01
      R  .23620497 06   DEC  .11282797 02    RA  .72437015 01     V  .37233335 01   PTH  .28662945-06    AZ  .24727144 03
      R  .23620497 06   LAT  .11282797 02   LON  .30645975 03    VP  .19905394 02   PTP  .71843381-06   AZP  .26585560 03
    RAE  .10944998 03   DEE  .23958425 02   RAS  .14864074 03   DES  .13037049 02   LOE  .48666033 02   LOS  .87856794 02

                                               AREOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                     23572451426020274702O326 J.D.= 2438970.16448848  JULY 28,1965 15 56 51.805
    SMA -.31836705 04   ECC  .75192653 02     B  .23936746 06   SLR  .17997083 08   APO  .00000000 00   RCA  .23620497 06
     VH  .36741412 01    C3  .13499314 02    C1  .87946988 06   TFP  .42952848-03    TF  .25897047 03   LTF  .25892714 03
     TA  .25613208-05   MTA  .90762007 02    EA  .00000000 00    MA  .28401568-04                       TFI  .25897047 03
    ZAE  .17354659 03   ZAP  .13547478 03   ZAC  .91406690 02   DEF  .15241199 01    IR  .57375745 04    GP  .13530178 01
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CASE  1                                          IBSYS-JPTRAJ-SPACE 022665                                           5

  EARTH - MARS                 CHECK 3

                                                                  ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X  .39749151 05    Y -.22218080 06    Z -.69631051 05   DX -.36690870 01   DY -.62555059 00   DZ -.98487204-01
 INC  .16278397 03  LAN  .18477665 03  APF  .26487261 03   MX -.98543065 00   MY -.16800820 00   MZ -.26451349-01
  WX -.24646413-01   WY  .29494718 00   WZ -.95519564 00   PX  .16828246 00   PY -.94062713 00   PZ -.29479079 00
  QX -.98543064 00   QY -.16800820 00   QZ -.26451351-01   RX  .29870185-01   RY  .54843099-02   RZ -.99953872 00
  BX  .18137299 00   BY -.93830958 00   BZ -.29441294 00   TX -.18058620 00   TY  .98355917 00   TZ  .00000000 00
 SXI -.98310547 00  SYI -.18050290 00  SZI -.30369485-01  DAI -.17403100 01  RAI  .19040390 03
 SXO -.98758150 00  SYO -.15548378 00  SZO -.22528538-01  DAO -.12908989 01  RAO  .18894714 03
 ETE  .13235197 03  ETS  .15412666 03  ETC  .23280338 03

 BTQ -.22874827 06  BRQ  .70505397 05    B  .23936746 06  THA  .16286951 03    T VECTOR IN  EARTH EQUATOR PLANE

                                                                  ALL VECTORS REFERENCED TO ORBIT PLANE OF TARGET
   X  .22979118 06    Y  .45471979 05    Z  .30349612 05   DX  .71222989 00   DY -.36536678 01   DZ  .81561729-01
 INC  .17251061 03  LAN  .91436507 02  APF  .80324851 02   MX  .19128822 00   MY -.98128942 00   MZ  .21905565-01
  WX  .13030142 00   WY  .32675759-02   WZ -.99146904 00   PX  .97284652 00   PY  .19251069 00   PZ  .12848846 00
  QX  .19128823 00   QY -.98128942 00   QZ  .21905566-01   RX  .48232219-02   RY -.23114559-01   RZ -.99972117 00
  BX  .97021651 00   BY  .20554400 00   BZ  .12818577 00   TX -.97891536 00   TY -.20426632 00   TZ  .00000000 00
 SXI  .20420937 00  SYI -.97864240 00  SZI  .23612419-01  DAI  .13530169 01  RAI  .28178655 03
 SXO  .17833326 00  SYO -.98376287 00  SZO  .20194839-01  DAO  .11571570 01  RAO  .28027481 03
 ETE  .15684929 03  ETS  .17862398 03  ETC  .25730070 03

 BTO -.23739161 06  BRO -.30692058 05    B  .23936746 06  THA  .18736683 03    T VECTOR IN  ORBIT PLANE OF TARGET

                                                            ALL VECTORS REFERENCED TO AREOCENTRIC EQUATOR PLANE
   X  .22979118 06    Y  .29207449 05    Z  .46213904 05   DX  .71222989 00   DY -.33713025 01   DZ -.14107658 01
 INC  .15475869 03  LAN  .16220799 03  APF  .15268954 03   MX  .19128822 00   MY -.90545272 00   MZ -.37889858 00
  WX  .13030142 00   WY  .40603604 00   WZ -.90451990 00   PX  .97284651 00   PY  .12365298 00   PZ  .19565170 00
  QX  .19128823 00   QY -.90545272 00   QZ -.37889858 00   RX -.82930786-01   RY  .36701005 00   RZ -.92651284 00
  BX  .97021651 00   BY  .13568382 00   BZ  .20067343 00   TX -.97540813 00   TY -.22040640 00   TZ  .00000000 00
 SXI  .20420936 00  SYI -.90372816 00  SZI -.37626306 00  DAI -.22102400 02  RAI  .28273290 03
 SXO  .17833325 00  SYO -.90701712 00  SZO -.38146707 00  DAO -.22424586 02  RAO  .28112333 03
 ETE  .16199128 03  ETS  .18376597 03  ETC  .26244269 03

 BTT -.23368551 06  BRT -.51844599 05    B  .23936746 06  THA  .19250882 03    T VECTOR IN  TRUE TARGET EQU. PLANE

215522623366   213675042633   614630127306   602532206172   204542657366   200624303772                     EARTH
                21189443086                   17550409728                  000000000000                   INITIAL

220457633260   622662154022   621420154524   602725735144   600471673266   575575031600                      MARS
                                                            235724514260   202747054442                       END




     END TRAJECTORY (SPACE)          12524       A
```

D. Check case 4 is an Earth-Moon trajectory with a minimum print requested. The spacecraft injects near the Earth on August 6, 1963 and impacts the Moon after a 66.37-hour flight time.

```
START TRAJECTORY (SPACE)        12525          A


CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                         1

EARTH-MOON                                  CHECK 4

DOUBLE PRECISION EPHEMERIS TAPE - EPHEM1

  GME  .39860063 06     J  .16234500-02     H -.57499999-05     D  .78749999-05    RE  .63781650 04   REM  .63783112 04
    G  .66709998-19     A  .88781796 29     B  .88800194 29     C  .88836976 29   OME  .41780741-02    AU  .14959850 09
  GMM  .49026293 04   GMS  .13271411 12   GMV  .32476627 06   GMA  .42977367 05   GMC  .37918700 08   GMJ  .12670935 09
  EGM  .39860320 06   MGM  .49027779 04    JA  .29200000-02    HA  .00000000 00    DA  .00000000 00    RA  .34170000 04

INJECTION CONDITIONS   1950.0    MOON        23563112275520273237560O J.D.= 2438248.21175586   AUG. 6,1963 17 04 55.707

GEOCENTRIC        X0-.61143780 04  Y0-.23438636 04  Z0-.54566108 03 DX0 .35295397 01 DY0-.88027116 01 DZ0-.54594941 01
CARTESIAN         T0 .61495706 05 GHA .21074440 03 GHO .31381078 03
DATE OF RUN 022665A  12535                 EARTH    IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

   0 DAYS  0 HRS.  0 MIN.  0.000 SEC.        235631122755202732375600 J.D.= 2438248.21175586   AUG. 6,1963 17 04 55.707

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.61066757 04     Y -.23620296 04     Z -.55352189 03    DX  .35627327 01    DY -.87922516 01    DZ -.54547870 01
    R  .65709252 04   DEC -.48322111 01    RA  .20114620 03     V  .10943100 02   PTH  .16181000 01    AZ  .11987157 03
    R  .65709251 04   LAT -.48322111 01   LON  .35040180 03    VE  .10531934 02   PTE  .16812886 01   AZE  .12116592 03
   XS -.10447122 09    YS  .10094874 09    ZS  .43774450 08   DXS -.21109202 02   DYS -.18709376 02   DZS -.81139758 01
   XM  .32552845 06    YM -.16238938 06    ZM -.94397182 05   DXM  .48530280 00   DYM  .87985646 00   DZM  .30392424 00
   XT  .32552845 06    YT -.16238938 06    ZT -.94397182 05   DXT  .48530280 00   DYT  .87985646 00   DZT  .30392424 00
   RS  .15172701 09    VS  .29350907 02    RM  .37583228 06    VM  .10497791 01    RT  .37583228 06    VT  .10497791 01
  GED -.48649840 01   ALT  .19287213 03   LOS  .28523799 03   RAS  .13598239 03   RAM  .33348775 03   LOM  .12274335 03
  DUT  .35000000 02    DT  .75000000 01    DR  .30900503 00   SHA -.60875954 04   DES  .16768649 02   DEM -.14546660 02
  CCL  .78939548 02   MCL  .18709179 03   TCL  .18709179 03

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 235631122745202256467720 J.D.= 2438248.21135838   AUG. 6,1963 17 04 21.364
  SMA  .25371170 06   ECC  .97412174 00     B  .57344925 05   SLR  .12961326 05   APO  .50085777 06   RCA  .65656162 04
   VH  .14350904 00    C3 -.15710770 01    C1  .71877622 05   TFP  .34342862 02    TF -.95396840-02   PER  .21196803 05
   TA  .32791989 01   MTA  .18000000 03    EA  .37554599 00    MA  .97211439-02   C3J -.19874077 01   TFI  .00000000 00

                                                            ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X -.61066757 04     Y -.23620296 04     Z -.55352189 03    DX  .35627327 01    DY -.87922516 01    DZ -.54547870 01
  INC  .30224249 02   LAN  .12802531 02   APF  .18635416 03    MX  .35195159 00    MY -.79361762 00    MZ -.49628737 00
   WX  .11154605 00    WY -.49087135 00    WZ  .86406182 00    PX -.94795842 00    PY -.31348205 00    PZ -.55711692-01
   QX  .29821515 00    QY -.81288025 00    QZ -.50029331 00    RX  .52894519-01    RY  .17491782-01    RZ -.99844686 00
   BX -.29821515 00    BY  .81288026 00    BZ  .50029332 00    TX -.31396968 00    TY  .94943301 00    TZ  .00000000 00
  DAP -.31936974 01   RAP  .19829862 03

  BTC  .49626634 05   BRC -.28733908 05     B  .57344925 05   THA  .32992908 03    T VECTOR IN  EARTH EQUATOR PLANE

  BTO  .56783067 05   BRO -.80009986 04     B  .57343986 05   THA  .35197955 03    T VECTOR IN  ORBIT PLANE OF TARGET



CASE  1                                        IBSYS-JPTRAJ-SPACE 022665                                         2

EARTH-MOON                                  CHECK 4

      HELIOCENTRIC                                                                                  EQUATORIAL COORDINATES

    X  .10446511 09     Y -.10095110 09     Z -.43775003 08    DX  .24671935 02    DY  .99171242 01    DZ  .26591888 01
    R  .15172454 09   LAT -.16769149 02   LON  .31598005 03     V  .26723117 02   PTH  .21102723 02    AZ  .76838918 02
   XE  .10447122 09    YE -.10094874 09    ZE -.43774450 08   DXE  .21109202 02   DYE  .18709376 02   DZE  .81139758 01
   XT  .10479674 09    YT -.10111112 09    ZT -.43868847 08   DXT  .21594505 02   DYT  .19589232 02   DZT  .84179001 01
  LTE -.16768649 02   LOE  .31598239 03   LTT -.16764987 02   LOT  .31602545 03   RST  .15208646 09   VST  .30346692 02
  EPS  .11211055 03   ESP  .98911702-02   SEP  .67887145 02   EPM  .50291134 02   EMP  .77056544 00   MEP  .12893820 03
  MPS  .16224048 03   MSP  .44234658-01   SMP  .17715845 02   SEM  .16300448 03   EMS  .16954125 02   ESM  .40178123-01
  RPM  .37999636 06   SPN  .36028888 02
  GCE  .28106045 03   GCT  .28815224 03   SIP  .16197841 03   CPT  .96371983 02   SIN  .96109912 02
  REP  .65709252 04   VEP  .10943100 02   CPE  .84659921 02   CPS  .77642693 02

   2 DAYS 10 HRS. 26 MIN. 41.238 SEC.        235631271546202170747003 J.D.= 2438250.64695538   AUG. 9,1963 03 31 36.945
   CHANGE OF PHASE OCCURS AT THIS POINT    MOON      IS THE CENTRAL BODY FOR INTEGRATION   COWELL EQUATIONS OF MOTION

   2 DAYS 10 HRS. 26 MIN. 41.238 SEC.        235631271546202170747003 J.D.= 2438250.64695538   AUG. 9,1963 03 31 36.945

      GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X  .33731393 06     Y  .62030704 05     Z -.75559509 04    DX  .83209578 00    DY  .28275366 00    DZ  .66862292-01
    R  .34305333 06   DEC -.12620747 01    RA  .10420049 02     V  .88136461 00   PTH  .79945668 02    AZ  .56020465 02
    R  .34305333 06   LAT -.12620747 01   LON  .60359662 00    VE  .24897457 02   PTE  .19975127 01   AZE  .27019802 03
   XS -.10882430 09    YS  .96928550 08    ZS  .42031089 08   DXS -.20263164 02   DYS -.19499615 02   DZS -.84560510 01
   XM  .36799422 06    YM  .38832118 05    ZM -.18535277 05   DXM -.97790682-01   DYM  .97846287 00   DZM  .39709176 00
   XT  .36799422 06    YT  .38832118 05    ZT -.18535277 05   DXT -.97790682-01   DYT  .97846287 00   DZT  .39709176 00
   RS  .15167229 09    VS  .29365551 02    RM  .37050132 06    VM  .10604878 01    RT  .37050132 06    VT  .10604878 01
  GEO -.12706726 01   ALT  .33667513 06   LOS  .12849246 03   RAS  .13830891 03   RAM  .60237696 01   LOM  .35620731 03
  DUT  .35000000 02    DT  .12000000 03    DR  .86782920 00   SHA  .27545618 06   DES  .16088259 02   DEM -.28675644 01
  CCL  .25589520 03   MCL  .95146813 01   TCL  .95146813 01

                                                  GEOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                 235631126074202141547003 J.D.= 2438248.28649031   AUG. 6,1963 18 52 32.763
  SMA  .25765422 06   ECC  .98634146 00     B  .42439092 05   SLR  .69902918 04   APO  .51178926 06   RCA  .35191793 04
   VH  .10313960 00    C3 -.15470370 01    C1  .52785743 05   TFP  .20394418 06    TF  .17936268 01   PER  .21692795 05
   TA  .17330892 03   MTA  .18000000 03    EA  .10963569 03    MA  .56408823 02   C3J -.20625021 01   TFI  .58444788 02

                                                            ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
    X  .33731393 06     Y  .62030704 05     Z -.75559509 04    DX  .83209578 00    DY  .28275366 00    DZ  .66862292-01
  INC  .34000198 02   LAN  .12291775 02   APF  .18443371 03    MX -.13787149 00    MY  .81778764 00    MZ  .55876084 00
   WX  .11904706 00    WY -.54637588 00    WZ  .82903562 00    PX -.96050819 00    PY -.27487318 00    PZ -.43229019-01
   QX  .25149897 00    QY -.79114921 00    QZ -.55752134 00    RX  .41560678-01    RY  .11893616-01    RZ -.99906518 00
   BX -.25149912 00    BY  .79114966 00    BZ  .55752166 00    TX -.27513038 00    TY  .96140692 00    TZ  .00000000 00
  DAP -.24776118 01   RAP  .19596978 03

  BTC  .35216459 05   BRQ -.23682852 05     B  .42439092 05   THA  .32607941 03    T VECTOR IN  EARTH EQUATOR PLANE
```

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CASE  1                                      IBSYS-JPTRAJ-SPACE 022665                                        3
EARTH-MOCN                               CHECK 4

   HELICCENTRIC                                                                          EQUATORIAL COORDINATES

   X  .10916161 09    Y -.96866519 08    Z -.42038645 08    DX  .21095260 02    DY  .19782369 02    DZ  .85229133 01
   R  .15187702 09  LAT -.16068951 02  LON  .31841518 03     V  .30149497 02   PTH  .35350583 00    AZ  .72784577 02
  XE  .10882430 09   YE -.96928550 08   ZE -.42031089 08   DXE  .20263164 02   DYE  .19499615 02   DZE  .84560510 01
  XT  .10919230 09   YT -.96889718 08   ZT -.42049624 08   DXT  .20165373 02   DYT  .20478078 02   DZT  .88531429 01
 LTE -.16088259 02  LOE  .31830891 03  LTT -.16068927 02   LOT  .31841635 03   RST  .15191690 09   VST  .30072780 02
 EPS  .53309242 02  ESP  .10397499 00  SEP  .12658684 03   EPM  .13094631 03   EMP  .44376237 02   MEP  .46774429 01
 MPS  .17568140 03  MSP  .27453512-18  SMP  .43174719 01   SEM  .13126360 03   EMS  .48631357 02   ESM  .10514460 00
 RPM  .39999998 05  SPN  .52243946 02
 GCE  .10410479 03  GCT  .29361948 03  SIP  .17319097 03   CPT  .10027956 03   SIN  .97789149 02
 REP  .34305333 06  VEP  .88136461 00  CPE  .93813447 02   CPS  .77962564 02

   SELENCCENTRIC                                                                         EQUATORIAL COORDINATES

   X -.30680285 05    Y  .23198585 05    Z  .10979326 05    DX  .92988647 00    DY -.69570921 00    DZ -.33022947 00
   R  .39999998 05  DEC  .15931216 02   RA  .14290562 03     V  .12073739 01   PTH -.89713153 02    AZ  .28162655 03
   R  .39999992 05  LAT  .19721915 C1  LON  .31342552 03    VP  .12126119 01   PTP -.84664762 02   AZP  .26956365 03
 LTS  .68027659 00  LNS  .30930468 03  LTE  .64762768 01   LNE  .35771092 03
 ALT  .38261908 05  SHA -.30113121 04  ALP  .16060174 02    DR -.12073587 01    DP  .86493654-05   ASD  .24904141 01
 HGE  .30669076 03  SVL  .71320920 00  HNG  .17574058 03   SIA  .12845590 03

                                            SELENCCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                  23563130750120270314700З J.D.= 2438250.97712412   AUG. 9,1963 11 27 03.525
 SMA -.40430050 04  ECC  .10014713 01    B  .21933935 03   SLR  .11905448 02   APO  .00000000 00   RCA  .59483483 01
  VH  .11011903 01   C3  .12126201 01   C1  .24159470 03   TFP -.28526580 05    TF  .66368837 02   LTF  .66367338 02
  TA -.17659408 03  MTA  .17689390 03   EA -.17634126 03    MA -.44517467 03   C3J -.20625021 01   TFI  .58444788 02
 ZAE  .13592348 03  ZAP  .17538636 03  ZAC  .10020075 03   DEF  .17378765 03    IR  .41322112 04    GP  .13820341 01

                                                           ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X -.30680285 05    Y  .23198585 05    Z  .10979326 05    DX  .92988647 00    DY -.69570921 00    DZ -.33022947 00
 INC  .16032753 03  LAN  .19605032 03  APF  .23137774 03    MX  .63472325 00    MY  .74773151 00    MZ  .19374390 00
  WX -.92875261-01   WY  .32282394 00   WZ -.94163243 00    PX  .80336104 00    PY -.53451784 00    PZ -.26248813 00
  QX -.58803500 00   QY -.78086688 00   QZ -.20970842 00    RX -.21900350 00    RY  .16377081 00    RZ -.96188179 00
  BX  .63085453 00   BY  .75093929 00   BZ  .19522484 00    TX -.59887180 00    TY -.80084491 00    TZ  .00000000 00
 SXI  .77031814 00  SYI -.57604388 00  SZI -.27346556 00   DAI -.15870591 02   RAI  .32321085 03
 SXO -.83404353 00  SYO  .49142129 00  SZO  .25073945 00   DAO  .14521272 02   RAO  .14949326 03
 ETE  .19264150 03  ETS  .31222783 C1  ETC  .29697975 03

 BTQ -.21477422 03  BRQ -.44517253 02    B  .21933935 03   THA  .19171014 03    T VECTOR IN  EARTH EQUATOR PLANE

 BTO -.21915344 03  BRO  .90286635 01    B  .21933934 03   THA  .17764086 03    T VECTOR IN  ORBIT PLANE OF TARGET

                                                           ALL VECTORS REFERENCED TO TRUE TARGET EQU. PLANE
   X  .34622885 05    Y  .19983999 05    Z  .13765779 04    DX -.10420426 01    DY -.60835827 00    DZ -.42408749-01
 INC  .17160407 03  LAN  .19652166 03  APF  .34298301 03    MX  .49907036 00    MY -.85486461 00    MZ -.14212226 00
  WX -.41584554-01   WY  .14019235 00   WZ -.98928273 00    PX -.83440279 00    PY -.54949129 00    PZ -.42794802-01
  QX -.54959927 00   QY  .82368209 00   QZ  .13982727 00    RX  .30357878-01    RY  .17732608-01    RZ -.99938177 00
  BX  .50357630 00   BY -.85221194 00   BZ -.14193568 00    TX -.50437699 00    TY  .86348356 00    TZ  .00000000 00
 SXI -.86294973 00  SYI -.50406517 00  SZI -.35157448-01   DAI -.20147871 01   RAI  .21029000 03
 SXO  .80340555 00  SYO  .59330378 00  SZO  .50306485-01   DAO  .28835658 01   RAO  .36445351 02
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CASE  1                                      IBSYS-JPTRAJ-SPACE 022665                                        4
EARTH-MOCN                               CHECK 4

 ETE  .17276643 03  ETS  .34324716 03  ETC  .27710467 03

 BTT -.21711745 03  BRT  .31151555 02    B  .21934085 03   THA  .17183504 03    T VECTOR IN  TRUE TARGET EQU. PLANE

  2 CAYS 18 HRS. 14 MIN. 47.467 SEC.         23563130732320262621736４ J.D.= 2438250.97202747   AUG. 9,1963 11 19 43.174

     GEOCENTRIC                                                                          EQUATORIAL COORDINATES

   X  .36277700 06    Y  .67175656 05    Z -.68605143 04    DX  .18221274 01    DY -.55879889 00    DZ -.31984808 00
   R  .36900784 06  DEC -.10652918 01   RA  .10490673 02     V  .19325390 01   PTH  .61328497 02    AZ  .25187967 03
   R  .36900783 06  LAT -.10652918 01  LON  .24332788 03    VE  .27838229 02   PTE  .34919521 01   AZE  .26940535 03
  XS -.10939180 09   YS  .96379418 08   ZS  .41792963 08   DXS -.20147588 02   DYS -.19603023 02   DZS -.85007954 01
  XM  .36410058 06   YM  .66155687 05   ZM -.73387963 04   DXM -.17937539 00   DYM  .96620799 00   DZM  .39978709 00
  XT  .36410058 06   YT  .66155687 05   ZT -.73387963 04   DXT -.17937539 00   DYT  .96620799 00   DZT  .39978709 00
  RS  .15166479 09   VS  .29367794 02   RM  .37013466 06    VM  .10609256 01    RT  .37013466 06    VT  .10609256 01
 GED -.10725498 01  ALT  .36262964 06  LOS  .11455612 02   RAS  .13861840 03   RAM  .10298081 02   LOM  .24313529 03
 DUT  .35000000 02   DT  .30000000 02   DR  .16955806 01   SHA  .29561149 06   DES  .15995472 02   DEM -.11360978 01
 CCL  .25600418 03  MCL  .11460550 02  TCL  .11460550 02

    HELIOCENTRIC                                                                         EQUATORIAL COORDINATES

   X  .10975458 09    Y -.96312243 08    Z -.41799823 08    DX  .21969716 02    DY  .19044224 02    DZ  .81809473 01
   R  .15188595 09  LAT -.15974251 02  LON  .31873228 03     V  .30203953 02   PTH  .29378274 01    AZ  .72734647 02
  XE  .10939180 09   YE -.96379418 08   ZE -.41792963 08   DXE  .20147588 02   DYE  .19603023 02   DZE  .85007954 01
  XT  .10975590 09   YT -.96313263 08   ZT -.41800302 08   DXT  .19968213 02   DYT  .20569231 02   DZT  .89005825 01
 LTE -.15995472 02  LOE  .31861840 03  LTT -.15974251 02   LOT  .31873232 03   RST  .15188768 09   VST  .30017381 02
 EPS  .53123580 02  ESP  .11146784 00  SEP  .12676490 03   EPM  .13031147 03   EMP  .49483367 02   MEP  .20522700 00
 MPS  .17649157 03  MSP  .27453512-18  SMP  .35083872 01   SEM  .12697004 03   EMS  .52918404 02   ESM  .11146784 00
 RPM  .17380899 04  SPN  .52133219 02
 GCE  .10399582 03  GCT  .29545637 03  SIP  .86491559 02   CPT  .10046924 03   SIN  .10469241 02
 REP  .36900784 06  VEP  .19325390 01  CPE  .93699617 02   CPS  .78005014 02

   SELENOCENTRIC                                                                         EQUATORIAL COORDINATES

   X -.13235805 04    Y  .10199694 04    Z  .47828197 03    DX  .20015028 01    DY -.15250069 01    DZ -.71963517 00
   R  .17380899 04  DEC  .15972547 02   RA  .14238165 03     V  .26171614 01   PTH -.89698277 02    AZ  .27232310 03
   R  .17380898 04  LAT  .18427696 01  LON  .30865416 03    VP  .26171886 01   PTP -.89600169 02   AZP  .25699724 03
 LTS  .68990118 00  LNS  .30533973 03  LTE  .66009133 01   LNE  .35806582 03
 ALT -.45776367-04  SHA -.10636180 03  ALP  .17841795 02    DR -.26171252 01    DP  .45415473-03   ASD  .90000000 02
 HGE  .30687642 03  SVL  .69668185 00  HNG  .17656135 03   SIA  .40311468 02

                                            SELENOCENTRIC CONIC

EPOCH OF PERICENTER PASSAGE                  23563130750620255704016４ J.D.= 2438250.97734800   AUG. 9,1963 11 27 22.868
 SMA -.40580137 04  ECC  .10000144 01    B  .21782637 02   SLR  .11697804 00   APO  .00000000 00   RCA  .58488602-01
  VH  .10991520 01   C3  .12081352 01   C1  .23947860 02   TFP -.45969361 03    TF  .66374210 02   LTF  .66374195 02
  TA -.17926753 03  MTA  .17969241 03   EA -.51297603 02    MA -.71340369 01   C3J -.20830222 01   TFI  .66246518 02
 ZAE  .13093467 03  ZAP  .17606693 03  ZAC  .10029423 03   DEF  .17938447 03    IR  .41385194 04    GP  .13916920 01
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CASE  1                                  IBSYS-JPTRAJ-SPACE 022665                                       5

EARTH-MOON                               CHECK 4

                                                              ALL VECTORS REFERENCED TO EARTH EQUATOR PLANE
   X -.13235805 04     Y  .10199694 04     Z  .47828197 03   DX  .20015028 01   DY -.15250069 01   DZ -.71963517 00
 INC  .16384507 03   LAN  .22399531 03   APF  .26120797 03   MX  .61867379 00   MY  .78456081 00   MZ  .38965625-01
  WX -.19302659 00    WY  .19991755 00    WZ -.96051286 00   PX  .76936109 00   PY -.57675598 00   PZ -.27465616 00
  QX -.60888781 00    QY -.79199797 00    QZ -.42479812-01   RX -.21901752 00   RY  .16610380 00   RZ -.96147844 00
  BX  .61306750 00    BY  .78896549 00    BZ  .41008683-01   TX -.60427698 00   TY -.79677433 00   TZ  .00000000 00
 SXI  .76608134 00   SYI -.58099930 00   SZI -.27488024 00  DAI -.15954877 02  RAI  .32282316 03
 SXC -.77261865 00   SYC  .57249603 00   SZO  .27442416 00  DAO  .15927699 02  RAO  .14346224 03
 ETE  .19274747 03   ETS  .84490592 00   ETC  .29680645 03

 BTQ -.21762816 02   BRQ -.92905826 00     B  .21782637 02  THA  .18244448 03    T VECTOR IN  EARTH EQUATOR PLANE

 BTC -.21339909 02   BRC  .43456509 01     B  .21777888 02  THA  .16848969 03    T VECTOR IN  ORBIT PLANE OF TARGET

                                                              ALL VECTORS REFERENCED TO TRUE TARGET EQU. PLANE
   X  .15113746 04     Y  .85649227 03     Z  .55891532 02   DX -.22691506 01   DY -.13010370 01   DZ -.88264561-01
 INC  .16257850 03   LAN  .20366310 03   APF  .35311024 03   MX  .47900334 00   MY -.82580294 00   MZ -.29807107 00
  WX -.12032760 00    WY  .27459414 00    WZ -.95412808 00   PX -.86336763 00   PY -.50329218 00   PZ -.35963861-01
  QX -.49007664 00    QY  .81943721 00    QZ  .29763575 00   RX  .29778356-01   RY  .17155122-01   RZ -.99940932 00
  BX  .48537910 00    BY -.82202738 00    BZ -.29778877 00   TX -.49918313 00   TY  .86649651 00   TZ  .00000000 00
 SXI -.86598469 00   SYI -.49888828 00   SZI -.34366389-01  DAI -.19694364 01  RAI  .20994596 03
 SXC  .86072571 00   SYC  .50768159 00   SZO  .37560297-01  DAO  .21525520 01  RAO  .30533364 02
 ETE  .17296761 03   ETS  .34106506 03   ETC  .27702658 03

 BTT -.20786950 02   BRT  .64885049 01     B  .21776088 02  THA  .16266460 03    T VECTOR IN  TRUE TARGET EQU. PLANE

 615576114061   614444767212   612420651171   202703617723   604431537501   603535320551                 EARTH
                    63080C617                        455707                 000000000000                 INITIAL

 613511766202   212777744203   211740002016   201776767451   601607727077   600561622465                  MOON
                                                             235631307323   202626217364                  END




     END TRAJECTORY (SPACE)          12562       A




        5 LINES,      0 CARDS OUTPUT THIS JOB. 125621




     FORTRAN MONITOR RETURNING TO IBSYS
            $STOP

           PERIPHERAL UNIT POSITIONS AT END OF JOBS

           SYSPP1  IS     A3      REC. 00002, FILE 00003
           SYSOU1  IS     A3      REC. 00002, FILE 00003
           SYSIN1  IS     A2      REC. 00001, FILE 00003

           END OF JOBS
```

REFERENCES

1. Holdridge, D. B., Space Trajectories Program for the IBM 7090 Computer, Technical Report No. 32-223, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, September 1, 1962.

2. Peabody, P. R., Scott, J. F., and Orozco, E. G., Users' Description of JPL Ephemeris Tapes, Technical Report No. 32-580, Jet Propulsion Laboratory, Pasadena, California, March 2, 1964.

3. Peabody, P. R., Scott, J. F., and Orozco, E. G., JPL Ephemeris Tapes E9510, E9511, and E9512, Technical Memorandum No. 33-167, Jet Propulsion Laboratory, Pasadena, California, March 2, 1964.

4. Newhall, N. S., Users' Guide for JPTRAJ, Engineering Document 199, Jet Propulsion Laboratory, Pasadena, California, January 4, 1964.

5. Clarke, Victor C., Jr., Constants and Related Data for Use in Trajectory Calculations as Adopted by the Ad Hoc NASA Standard Constants Committee, Technical Report No. 32-604, Jet Propulsion Laboratory, Pasadena, California, March 6, 1964.

6. Cary, C., Physical Constants and Other Parameter to be Used in MA-C Computation--Updated Version, Interoffice Memorandum 312. 3-176, Jet Propulsion Laboratory, Pasadena, California, October 30, 1964.

7. Hansen, R. R., Programming Standards for SFOF User Programs, Engineering Planning Document No. 125, Revision No. 1, Jet Propulsion Laboratory, Pasadena, California, April 1, 1964.

8. Scott, J. F., et. al., User Guide for the JPL Trajectory Monitor System Under the IBM Fortran II, Version 2 Monitor, Section Report No. 372-11, Jet Propulsion Laboratory, Pasadena, California, August 9, 1963.

9. Explanatory Supplement to the Astronomical Ephemeris and the American Ephemeris and Nautical Almanac, London, Her Majesty's Stationery Office, 1961.

10. Rosenberg, A. D., et. al., SFPRO-Single Precision Cowell Trajectory Processor, Technical Memorandum No. 33-199, Jet Propulsion Laboratory, Pasadena, California, January 15, 1965.

11. Roek, D. J., Rosenberg, A. D., TRIO-Trajectory Input-Output Program, Section Report No. 317-101, Jet Propulsion Laboratory, Pasadena, California, February 15, 1965.