HILTOP Supplement

HELIOCENTRIC INTERPLANETARY LOW THRUST TRAJECTORY OPTIMIZATION PROGRAM

Supplement # 1

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SUMMARY

This report is the first supplement to the primary HILTOP program document published in January, 1973, and describes the modifications and improvements made to the HILTOP electric propulsion trajectory optimization computer program up through the end of 1974.

New program features include the simulation of power degradation, housekeeping power, launch asymptote declination optimization, and powered and unpowered ballistic multiple swingby missions with an optional deep space burn.

The report contains the new analysis describing these features, a complete description of program input quantities, and sample cases of computer output illustrating the new program capabilities.

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I. INTRODUCTION

This document describes the modifications and improvements made to the HILTOP electric propulsion trajectory optimization computer program [1] during calendar years 1973 and 1974. New program features include the simulation of power degradation, housekeeping power, launch asymptote declination optimization, and powered and unpowered ballistic multiple swingby missions with an optional deep space burn.

The power degradation model has been hypothesized by the authors in earlier publications [2, 3]. The model allows a single parameter (denoted "characteristic degradation time") to describe the power degradation behavior of an electric propulsion spacecraft to a degree which fundamentally affects the solution to the trajectory optimization problem.

The option of simulating spacecraft housekeeping power applies to solar electric propulsion with specified reference power. The housekeeping power is a specified constant power generated by the solar arrays and shunted away from the thruster power-conditioners and directly to the spacecraft payload for "housekeeping" purposes.

The launch asymptote declination optimization model was first hypothesized by the authors in the appendix of [1], and later a more thorough treatment of the subject was put forth in [4]. A solution to the problem of optimizing electric propulsion heliocentric trajectories, including the effects of geocentric launch asymptote declination on launch vehicle performance capability, is developed using variational calculus techniques. The model of the launch vehicle performance includes a penalty associated with a non-easterly launch plus another penalty arising from a non-coplanar launch from the parking orbit. Provisions for range safety constraints are included. Optimal trajectories will generally have the launch excess velocity offset from the initial primer vector.

Extra-ecliptic mission simulations now involve launches from the Earth in which the Earth's ephemeris is generated by the program's analytic ephemeris capability; previously, extra-ecliptic missions were generated simply by starting the trajectory on the x-axis at one astronomical unit from the sun. This improved extra-ecliptic capability allows the launch date to be optimized together with the launch asymptote declination. Also, an additional set of boundary conditions has been added to the program for simulating extra-ecliptic missions.

The program's ability to simulate all-ballistic missions has been expanded to include powered and unpowered multiple swingby missions with an optional deep space burn. This capability renders HILTOP a powerful tool for ballistic mission design and optimization, with tremendous flexibility for creating imaginative multi-target mission profiles.

This report contains the analysis describing these new program features, a complete description of program input quantities, and sample cases of computer output illustrating the new program capabilities.

II. FORMULATION

A. SPACECRAFT AND TRAJECTORY MODELS

The assumed spacecraft and trajectory models are as described in [1] and are not repeated here; the nomenclature used in the following analysis is also described in [1], except for the introduction of new symbols which are described in the text as they appear.

1. Power Degradation. Historically, this electric propulsion power degradation model first appeared in the literature in [2], and then soon afterward an improved discussion appeared in [3], in which several of the ramifications and consequences of the theory are also discussed. For deeper insight into the analysis, the reader is therefore referred to [3], from which much of the analysis below is extracted.

The model discussed here is concerned with the manner in which the performance of a solar array degrades due to high energy particle damage. It is assumed that one can define a damage factor q which has a value of unity at the initial time and which decreases in value with time during the course of the mission such that the power output, p, of the arrays at any time may be written

$$p = q\gamma p_{ref}$$

where p_{ref} is the reference power and γ is the power factor which is a function of solar distance and array orientation relative to the sun. The damage factor q may also be thought of as a time-dependent efficiency. The derivative $\dot{q}$ is negative, and is assumed to be linearly proportional to q and to the density of particles impinging on the solar cells. For simplicity, it is assumed that the particle density d is of the same form as the density of photons striking the surface of the array, i.e.,

$$d = \frac{\bar{e}_r \cdot \bar{n}}{r^2} \tag{1}$$

where $\bar{e}_r$ is a unit vector along the sun-spacecraft line, $\bar{n}$ is a unit vector normal to the arrays such that $\bar{e}_r \cdot \bar{n} > 0$ implies the front of the panels faces the sun, and r is the solar distance of the spacecraft. In the discussion to follow, an upper case symbol will denote a vector, a lower case symbol will denote a scalar, and a lower case symbol with a bar will denote a unit vector. Then

$$\overset{\circ}{q} = - kqd \tag{2}$$

and

$$q = e^{-k\int_0^t d\,dt'} \tag{3}$$

where k is the constant of proportionality. It is convenient to introduce a parameter s, called degradation time,

$$s = \int_0^t d\,dt' \tag{4}$$

or

$$\overset{\circ}{s} = d \tag{5}$$

Thus, under the above assumptions the degradation time accumulates at a faster rate when the spacecraft is nearer the sun, which is a characteristic one might expect. Note that when the spacecraft is maintained at 1 AU with the panels normal to the sun line, $\overset{\circ}{s} = 1$ and the degradation time is equal to the flight time. Then k may conveniently be thought of as the inverse of a reference time, called the characteristic degradation time denoted by τ_d, and the degradation factor q becomes

$$q = e^{-s/\tau_d} . \tag{6}$$

Actually, there is little reason to allow the degradation time s to continue to accumulate during coast phases since the arrays may be turned edgewise to the sun and the degradation process may be effectively halted. Therefore, we adjust equation (5) to read

$$\overset{\circ}{s} = h_\sigma d \tag{7}$$

where h_σ is a step function equal to one during thrust phases and equal to zero during coast phases.

The characteristic degradation time τ_d is an engineering parameter that must be determined experimentally. For example, by exposing a solar cell to the particle emission of a solar simulator and measuring the performance of the cell over a period of time, one should be able to estimate a reasonable value of τ_d. Another source of information would be measurements from actual spacecraft which employ solar cells for power supply.

The assumed exponential form of the degradation factor, although intended for use with SEP systems, is applicable for NEP systems as well. The principal difference is in the definition of $\dot{s}$; for example, $\dot{s} = h_\sigma$. The exponential form also permits one to evaluate radio-isotope systems by defining $\dot{s} = 1$ and letting τ_d represent the time for the radioactivity to dissipate to $1/e$ of its initial level.

In the development which follows, the formulation applicable to SEP is used exclusively. The equations of motion and adjoint equations are given in [1]; the equations affected by the inclusion of power degradation in the model are given below.

Power degradation affects the problem in a very fundamental sense, beginning with the rocket-thrust term in the equations of motion:

$$\dot{V} = \ddot{R} = a\,\bar{e}_t - \frac{\mu}{r^3} R \qquad \dot{R} = V \tag{8}$$

where R is the position vector, r is the magnitude of R, V is the velocity vector, μ is the gravitational constant of the sun, a is the magnitude of the thrust acceleration and $\bar{e}_t$ is a unit vector in the direction of thrust. The thrust acceleration a is a function of several variables and may be written as follows:

$$a = h_\sigma \frac{g\gamma q}{\nu}$$

where g is a reference thrust acceleration evaluated under a prescribed set of conditions, ν is the ratio of current to initial mass, and q is the degradation factor defined above. The power factor γ is assumed to be a function of the density, d, of photons incident on the arrays, where d is as written in equation (1). The general form of γ is

$$\gamma = d \sum_{i=0}^{4} a_i d^{i/4} \tag{9}$$

The coefficients a_i are chosen so that this equation will adequately describe the power output of a given array. The only restriction on the a_i is that their sum is equal to one. Then at $r = 1$ AU, with the arrays normal to the sun line, $\gamma = d = 1$. The summation term in (9) represents the temperature effect.

The mass ratio satisfies the differential equation

$$\dot{\nu} = - h_\sigma \frac{g\gamma q}{c}, \tag{10}$$

using $\nu = 1$ as an initial condition, where c is the jet exhaust speed which is assumed to be constant over the trajectory.

The variational Hamiltonian becomes

$$h_v = \Lambda \cdot \ddot{R} - \mathring{\Lambda} \cdot \mathring{R} + \lambda_\nu \dot{\nu} + \lambda_\tau \mathring{\tau} + \lambda_s \dot{s} + \lambda_g \dot{g} + \lambda_c \mathring{c}$$

$$= h_\sigma \left[\frac{g\gamma q}{\nu} \left(\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu \right) + \lambda_s d + \lambda_\tau \right] - \frac{\mu}{r^3} (\Lambda \cdot R) - \mathring{\Lambda} \cdot \mathring{R} \tag{11}$$

and the adjoint equations are

$$\ddot{\Lambda} = -\frac{\mu}{r^3} \Lambda + \frac{3\mu}{r^5} (R \cdot \Lambda) R + h_\sigma \left[\frac{g\gamma^* q}{\nu} \left(\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu \right) + \lambda_s \right] \frac{\partial d}{\partial R}$$

$$\dot{\lambda}_\nu = h_\sigma \frac{g\gamma q}{\nu^2} (\Lambda \cdot \bar{e}_t) \tag{12}$$

$$\dot{\lambda}_g = -h_\sigma \frac{\gamma q}{\nu} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu)$$

$$\dot{\lambda}_c = -h_\sigma \frac{g\gamma q}{c^2} \lambda_\nu \qquad \text{(12) (cont.)}$$

$$\dot{\lambda}_s = h_\sigma \frac{g\gamma q}{\nu \tau_d} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu)$$

where

$$\gamma* = \partial\gamma/\partial d = \sum_{i=0}^{4} a_i \left(1 + \frac{i}{4}\right) d^{i/4}$$

$$\frac{\partial d}{\partial R} = \frac{1}{r^3} \left[\bar{n} - 3(\bar{e}_r \cdot \bar{n})\, \bar{e}_r\right]$$

The control variables are the thrust direction $\bar{e}_t$, the switch step function h_σ, and, providing the array orientation is not constrained to yield maximum power, the normal direction $\bar{n}$. According to the Maximum Principle, these controls are chosen to maximize the variational Hamiltonian (11). The maximum of h_v with respect to h_σ is seen to depend totally on the sign of the term in square brackets. That is, denoting

$$\sigma = \frac{g\gamma q}{\nu} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu) + \lambda_s d + \lambda_\tau \qquad (13)$$

then choose

$$h_\sigma = \begin{cases} 1 & \text{if } \sigma > 0 \\ 0 & \text{if } \sigma < 0 \end{cases} . \qquad (14)$$

Maximizing h_v with respect to $\bar{e}_t$ is also accomplished by inspection. Since $\bar{e}_t$ appears only in the dot product with Λ and since the coefficient of that dot product is non-negative, i.e.,

$$h_\sigma g \gamma q/\nu \geq 0$$

then h_v is maximized with respect to $\bar{e}_t$ by making $\Lambda \cdot \bar{e}_t$ as large as possible, which is the same result as when there is no degradation. The control vector $\bar{n}$ appears explicitly in (11) through the density d as given by equation (1). In fact, since $\bar{n}$ only appears in h_v through d, $\bar{n}$ only affects h_v through its dot product with $\bar{e}_r$. Letting the angle between $\bar{n}$ and $\bar{e}_r$ be denoted χ such that $\bar{e}_r \cdot \bar{n} = \cos \chi$, then it is clear that there will be a "best" angle χ between $\bar{n}$ and $\bar{e}_r$ to maximize h_v, but that $\bar{n}$ may lie along any element of a right circular cone of half angle χ about $\bar{e}_r$. For the moment, we will put aside the question of the explicit direction of $\bar{n}$ and concentrate on defining the optimum χ or, alternatively, the optimum d. The optimum value of d is determined by maximizing h_v with respect to d, i.e., by solving for the root of the equation

$$\frac{\partial h_v}{\partial d} = h_\sigma \frac{\partial \sigma}{\partial d} = 0 \tag{15}$$

Performing the indicated differentiation yields

$$\frac{g\gamma^* q}{\nu} \sigma_r + \lambda_s = 0 \tag{16}$$

or

$$\gamma^* = -\frac{\lambda_s \nu}{g q \sigma_r} \tag{17}$$

where, using (9),

$$\gamma^* = \sum_{i=0}^{4} a_i \left(1 + \frac{i}{4}\right) d^{i/4} \tag{18}$$

and

$$\sigma_r = \Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu$$

Because of the form of (18) equation (16) is a quartic in the variable $d^{i/4}$, and is solved by iteration in the program. A more detailed discussion of the solution to (16) is given in reference [3] for a specific set of coefficients a_i. For now, assume that the optimum value of d is found from (16). Then the optimum angle χ is immediately obtained

$$\cos \chi = d r^2 \tag{19}$$

Of course, equation (16) does not take into consideration the fact that d can never exceed the inverse square of the solar distance. Consequently, the right hand side of (19) may exceed unity, under which condition the program sets $\cos \chi \equiv 1$ (i.e., $\chi = 0$) implying that $\bar{n}$ is directed along $\bar{e}_r$.

If the d that represents the solution to (16) exceeds the upper limit allowed for d whether that limit is imposed by the problem or by nature (i.e., $1/r^2$), the correct choice for d is that upper-limiting value. Likewise, on the lower side, d is physically limited to be non-negative. Therefore, a negative solution to (16) is disregarded, and d is set to zero which corresponds to $\chi = \pi/2$ (panels oriented edgewise to the sun), and the engines are shut down.

The precise definition of $\bar{n}$ has no bearing on the solution of the problem, except as it affects d as defined in (1). The appearance of $\bar{n}$ in the state and adjoint equations and the variational Hamiltonian is solely through the density d except in the equation for $\ddot{\Lambda}$ where $\bar{n}$ appears explicitly as part of the partial $\partial d/\partial R$, defined following equations (12). Actually, this partial is valid only if d is permitted to vary with R. That is, if either $d = 0$ or $d =$ constant is imposed then $\partial d/\partial R$ becomes the null vector and the entire term drops from the equation for $\ddot{\Lambda}$. Furthermore, if d is the solution to (16), then the last term of $\ddot{\Lambda}$ in (12) again drops out because the term in square brackets is the left side of (16). Therefore, the only time the term in question remains in the equation for $\ddot{\Lambda}$ is when $d = 1/r^2$ which corresponds to $\cos \chi = \bar{e}_r \cdot \bar{n} = 1$ and implies $\bar{n} \equiv \bar{e}_r$. Under this condition

$$\frac{\partial d}{\partial R} = - \frac{2}{r^3} \bar{e}_r .$$

The boundary condition pertaining to the initial degradation time is

$$s(t_o) = 0$$

Although transversality conditions are discussed in the next section, the transversality condition associated with degradation time is stated here for the sake of completeness. If the final degradation time, s_f, is unspecified,

$$\lambda_{s_f} = 0 .$$

The initial value of λ_s is unknown and therefore becomes one of the independent parameters of the boundary value problem. From equations (12), it follows that

$$\dot{\lambda}_s = - \frac{g}{\tau_d} \dot{\lambda}_g$$

and, therefore,

$$\lambda_{s_f} - \lambda_{s_o} = - \frac{g}{\tau_d} (\lambda_{g_f} - \lambda_{g_o})$$

Using the boundary conditions $\lambda_{s_f} = \lambda_{g_o} = 0$, it follows that

$$\lambda_{s_o} = \frac{g}{\tau_d} \lambda_{g_f} .$$

Thus, if an approximate value of λ_{g_f} is available from a trajectory similar to the one of interest, a reasonable guess of λ_{s_o} is readily available.

2. Housekeeping Power. This program option applies only to solar electric propulsion and is currently not integrated with the power degradation option. The program therefore does not allow the use of both options simultaneously. The new program input-quantity controlling the housekeeping power simulation is DPOW, which is the ratio of housekeeping power to reference power and is given the symbol Δp:

$$\Delta p = p_h / p_{ref}$$

The reference power p_{ref} is defined as the power input to the power conditioners* under reference conditions. (For solar electric propulsion, reference conditions are equivalent to having the total spacecraft in a perfect solar-simulator such

*When the thrusters are at full-throttle.

that the simulated solar distance is one astronomical unit, the solar arrays are oriented normal to the source of energy, and no radiation damage or other degradation effects have occurred to any components).

This spacecraft model assumes that the powers required by the operating components at each instant of time exactly match the power developed by the solar arrays:

$$p_a = p + p_h$$

where p_a is the power developed by the arrays, p is the instantaneous power delivered to the power conditioners, and p_h is the housekeeping power, which is constant with time. Currently, all trajectories generated by the program using the housekeeping power simulation must satisfy the condition that $p_a > p_h$, so that p remains positive; in other words, engine shutdown when $p \to 0$ is not coded into the program.

The power factor γ is defined as the ratio of instantaneous power to reference power,

$$\gamma = p/p_{ref} = (1 + \Delta p) \sum a_i d^{(i+4)/4} - \Delta p$$

where the summation quantity Σ is the power factor when $p_h = 0$.

The spacecraft model has been expanded by deleting the old, total propulsion system specific mass α and replacing it with α_a, the specific mass of the solar arrays, and α_t, the specific mass of the thruster subsystem. The quantity previously called the "propulsion system mass" is now expressed,

$$m_{ps} = \alpha_a p_{ao} + \alpha_t p_{ref} = (\alpha_t + \alpha_a (1 + \Delta p))\, p_{ref}$$

where p_{ao} is p_a evaluated under reference conditions (i.e., $p_{ao} = p_{ref} + p_h$), and the total specific mass α has been replaced by $(\alpha_t + \alpha_a (1 + \Delta p))$, also a constant since the housekeeping power option is intended to be used only in simulations where the reference power is specified. The remainder of the analysis describing the optimization problem remains unchanged.

B. BOUNDARY AND TRANSVERSALITY CONDITIONS

The basic boundary conditions and transversality conditions are described in [1]; the nomenclature used in the following analysis is also described in [1], except for the introduction of new symbols which are described in the text as they appear.

In summary, when no intermediate-targets are present, individual transversality conditions are derived from the general equation

$$d\pi + \left[\Lambda \cdot dV - \dot{\Lambda} \cdot dR + \lambda_{\nu} d\nu + \lambda_{s} ds + \lambda_{\tau} d\tau + \lambda_{g} dg + \lambda_{c} dc - h_{v} dt \right]_{o}^{n} = 0$$

where π denotes the performance index which is assumed to be of the form

$$\pi = \pi(v_{\infty o}, v_{\infty n}, \nu_{n}, g, c, t_{o}, t_{f})$$

such that

$$d\pi = \pi_{v_{\infty o}} dv_{\infty o} + \pi_{v_{\infty n}} dv_{\infty n} + \pi_{\nu_{n}} d\nu_{n} + \pi_{g} dg + \pi_{c} dc + \pi_{t_{o}} dt_{o} + \pi_{t_{n}} dt_{n}$$

where π_{x} denotes $\partial \pi / \partial x$. The individual transversality conditions are obtained by equating to zero the coefficients of all independent differentials.

1. Deep Space Burn. In simulations of trajectories which are all-ballistic, the program is capable of simulating a single deep-space burn, or impulsive velocity-change, at any point prior to arrival at the primary target. The three components of the incremental velocity ΔV are independent variables of the boundary value problem, such that, at a specified time, the spacecraft velocity is incremented:

$$\dot{R}^{+} = \dot{R}^{-} + \Delta V$$

The use of this program option is described in the Sample Problems and Results section under sample Case C, Multiple Ballistic Swingby Mission.

2. $\underline{V_\infty}$ Optimization in LVI Mode. The optimization of the launch excess velocity V_∞ when using the Launch Vehicle Independent (LVI) mode of simulation is accomplished when the initial primer vector is forced to vanish:

$$\Lambda_o = 0.$$

This is accomplished by setting the values of these three independent variables of the boundary value problem to zero and turning their triggers off; the three components of the departure heliocentric velocity become independent variables instead. The program contains special logic to circumvent the numerical singularity associated with the null primer vector.

3. Launch Asymptote Declination Optimization. This section contains the equations employed in the optimization of the launch asymptote declination. A more thorough exposition of this subject is found in [4], in which some of the ramifications of the theory are discussed. Historically, an incomplete form of this analysis was first published in the appendix of [1].

The assumed spacecraft and propulsion system models are as described in [1] and will not be repeated here. The launch vehicle payload capability is assumed to follow the simple exponential law

$$m_o = b_1 e^{-(v_c/b_2)} - b_3 , \tag{20}$$

where b_1, b_2, and b_3 are pre-determined constants for each launch vehicle and v_c is a characteristic speed representative of the energy required to achieve a specific escape trajectory.

The velocity penalty incurred with non-due-East launches from the ETR is shown graphically in Reference [5] as a function of the parking orbit inclination. This velocity penalty Δv_i is adequately approximated with a quadratic curve fit of the form

$$\Delta v_i = c_1 i^2 + c_2 i + c_3 \tag{21}$$

Given a reference orbit inclination i and a circular orbit speed v_o, the velocity penalty Δv_g associated with a non-coplanar departure from this circular orbit to the desired hyperbolic excess velocity at a declination δ is defined as follows. Assuming the line of nodes of this reference orbit is an open variable, one may choose this variable to minimize the angle between the excess velocity and the orbital plane. This minimum angle is $\delta - i$. Gunther [6] has shown that the minimum incremental velocity required to achieve a given v_∞ along an asymptote not lying in the orbital plane from a specified circular orbit is obtained from the solution to a quartic equation in the sine of the out-of-plane angle. Defining

$$s = \sin(\delta - i); \quad \rho = v_\infty / v_o ;$$

$$p = s^2 (\rho^2 + 4) ;$$

$$q = s^2 (1 - s^2) \rho^2 ;$$

$$x = \left[\sqrt{(q/2)^2 + (p/3)^3} + q/2\right]^{\frac{1}{3}} - \left[\sqrt{(q/2)^2 + (p/3)^3} - q/2\right]^{\frac{1}{3}} ;$$

$$y = \sqrt{\rho^2/4 - x} ; \tag{22}$$

$$w = \frac{1}{2}\left[\rho/2 + y + \sqrt{(\rho/2 + y)^2 + 4\left(x/2 + \sqrt{x^2/4 + s^2}\right)}\right] ,$$

then Gunther's solution for the magnitude of the minimum velocity impulse required to accomplish the maneuver is

$$v_g = v_o \sqrt{\rho^2 + 3 - 2\sqrt{(1 + \rho w - w^2)(2 + \rho w)}} , \tag{23}$$

and the penalty Δv_g is the difference between v_g and the velocity increment required if the out-of-plane angle were zero, i.e.,

$$\Delta v_g = v_g - \left(\sqrt{v_\infty^2 + 2v_o^2} - v_o\right) .$$

Thus, the definition of the characteristic speed for those cases in which the asymptote declination lies outside the interval [-i, i] is

$$v_c = \sqrt{v_\infty^2 + 2v_o^2} + \Delta v_i + \Delta v_g$$

$$= v_o + v_g + \Delta v_i. \tag{24}$$

The transversality conditions which optimize the launch phase are developed as follows. The state and adjoint equations for the problem under consideration are precisely as formulated in [1]. The only difference in the optimality conditions is the format and content of certain of the transversality conditions. Specifically, these differences are due solely to the new definition of v_c which is now a function of the direction of V_∞ as well as its magnitude. Whereas before the differential of v_c was, simply

$$d v_c = (v_\infty / v_c)\, d v_\infty ,$$

it follows from (24) that the equivalent formula now is

$$d v_c = (\partial v_g / \partial v_\infty)\, d v_\infty + (\partial v_g / \partial \delta)\, d\delta$$

$$+ (\partial v_g / \partial i + \partial \Delta v_i / \partial i)\, d i$$

where, from (21)

$$\partial \Delta v_i / \partial i = 2 c_1 i + c_2,$$

and, from (22) and (23),

$$\partial v_g / \partial i = - \partial v_g / \partial \delta .$$

The derivation of the partial derivatives $\partial v_g / \partial v_\infty$ and $\partial v_g / \partial \delta$ is straightforward although somewhat cumbersome. The equations for these partial derivatives are as follows:

$$\frac{\partial v_g}{\partial v_\infty} = \frac{v_o^2}{v_g}\left\{\rho \frac{\partial \rho}{\partial v_\infty} - \frac{w(3+2\rho w - w^2)(\partial \rho/\partial v_\infty) + (3\rho + 2\rho^2 w - 3\rho w^2 - 4w)(\partial w/\partial v_\infty)}{2\sqrt{(1+\rho w - w^2)(2+\rho w)}}\right\},$$

$$\frac{\partial v_g}{\partial \delta} = - \frac{v_o^2 (3\rho + 2\rho^2 w - 3\rho w^2 - 4w)}{2v_g\sqrt{(1+\rho w - w^2)(2+\rho w)}} \frac{\partial w}{\partial \delta},$$

where

$$\partial \rho/\partial v_\infty = 1/v_o,$$

$$\frac{\partial w}{\partial v_\infty} = \frac{1}{2}\left\{\frac{1}{2}\frac{\partial \rho}{\partial v_\infty} + \frac{\partial y}{\partial v_\infty} + \left[\left(1 + \frac{x}{2\sqrt{x^2/4+s^2}}\right)\frac{\partial x}{\partial v_\infty} + \left(\frac{\rho}{2} + y\right)\left(\frac{1}{2}\frac{\partial \rho}{\partial v_\infty} + \frac{\partial y}{\partial v_\infty}\right)\right]/(2w - \rho/2 - y)\right\},$$

$$\frac{\partial w}{\partial \delta} = \frac{1}{2}\left\{\frac{\partial y}{\partial \delta} + \left[\frac{\partial x}{\partial \delta} + \frac{x(\partial x/\partial \delta) + 4s(\partial s/\partial \delta)}{2\sqrt{x^2/4+s^2}} + \left(\frac{\rho}{2} + y\right)\frac{\partial y}{\partial \delta}\right]/(2w - \rho/2 - y)\right\},$$

$$\partial s/\partial \delta = \cos(\delta - i),$$

$$\partial y/\partial v_\infty = \left[(\rho/2)\,\partial \rho/\partial v_\infty - \partial x/\partial v_\infty\right]/2y,$$

$$\partial y/\partial \delta = -(\partial x/\partial \delta)/2y,$$

$$\frac{\partial x}{\partial u} = \frac{1}{6}\left[\frac{(q/2)(\partial q/\partial u) + (p/3)^2(\partial p/\partial u)}{\sqrt{(q/2)^2 + (p/3)^3}} + \frac{\partial q}{\partial u}\right]\left[\sqrt{(q/2)^2 + (p/3)^3} + q/2\right]^{-2/3}$$

$$- \frac{1}{6}\left[\frac{(q/2)(\partial q/\partial u) + (p/3)^2(\partial p/\partial u)}{\sqrt{(q/2)^2 + (p/3)^3}} - \frac{\partial q}{\partial u}\right]\left[\sqrt{(q/2)^2 + (p/3)^3} - q/2\right]^{-2/3},$$

with $u = v_\infty$ or δ,

$$\partial q/\partial v_\infty = 2\rho s^2 (1 - s^2)(\partial \rho/\partial v_\infty) ,$$

$$\partial q/\partial \delta = 2\rho^2 s(1 - 2s^2)(\partial s/\partial \delta) ,$$

$$\partial p/\partial v_\infty = 2\rho s^2 (\partial \rho/\partial v_\infty),$$

$$\partial p/\partial \delta = 2s(\rho^2 + 4)(\partial s/\partial \delta).$$

This concludes the computation of these two partial derivatives. Some symbols used in this section of the document apply to this section only; for example, p and q here are intermediate quantities in the analysis, and have no relation to power or degradation factor discussed elsewhere.

The differential of g, the reference thrust acceleration, is

$$d g = - (g/m_o) \, d m_o$$

where

$$d m_o = - (b_1/b_2) e^{-(v_c/b_2)} d v_c ,$$

and the differential of V_∞ may be written

$$d V_\infty = (V_\infty/v_\infty) \, d v_\infty + (\bar{n}_p \times V_\infty) \, d\alpha + [(V_\infty \times \bar{n}_p) \times V_\infty / |V_\infty \times \bar{n}_p|] \, d\delta ,$$

where $\bar{n}_p$ is a unit vector along the North Pole and α is the geocentric right ascension of V_∞, and therefore the transversality conditions associated with V_∞ are as follows:

For optimum launch parking orbit inclination:

$$f(\partial \Delta v_i/\partial i - \partial v_g/\partial \delta) = 0. \qquad (25)$$

For optimum launch excess speed:

$$f(\partial v_g/\partial v_\infty) - (\Lambda_o \cdot V_\infty)/v_\infty = 0. \tag{26}$$

For optimum launch asymptote declination:

$$f(\partial v_g/\partial \delta) - \Lambda_o \cdot [(V_\infty x \bar{n}_p) x V_\infty / |V_\infty x \bar{n}_p|] = 0. \tag{27}$$

For optimum launch asymptote right ascension:

$$- \Lambda_o \cdot (\bar{n}_p \times V_\infty) = 0. \tag{28}$$

In the above equations f is given by

$$f = [k_s + k_t - (1 + k_t)\nu_f - g\lambda_g/m_o] \, dm_o/dv_c$$

Due to the complexity of the equations defining $\partial v_g/\partial \delta$, the solution of equation (25) for the optimum value of i must be obtained using an iterative technique.

The approach to the solution of the problem as formulated above differs in three basic respects from that of the problem where asymptote declination is ignored: (1) the condition (25) must be solved for the optimum parking orbit inclination, given values of v_∞ and δ; (2) the asymptote declination δ must be introduced as an independent parameter and (27) added as an end condition of the problem; and (3) the evaluation of V_∞ becomes somewhat more involved. The computation of V_∞ given v_∞, Λ_o and δ, proceeds as follows: Denote as ϵ the obliquity of the ecliptic such that the matrix

$$\Phi = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\epsilon & -\sin\epsilon \\ 0 & \sin\epsilon & \cos\epsilon \end{bmatrix},$$

operating on a vector expressed in ecliptic Cartesian coordinates yields the same vector in Earth equatorial coordinates. Then the right ascension α_λ of the initial primer Λ_o may be written

$$\alpha_\lambda = \tan^{-1}\left[(\lambda_{yo}\cos\epsilon - \lambda_{zo}\sin\epsilon)/\lambda_{xo}\right],$$

where λ_{xo}, λ_{yo}, λ_{zo} are the given ecliptic coordinates of Λ_o. Then, the right ascension of the asymptote is set

$$\alpha = \alpha_\lambda \quad \text{or} \quad \alpha = \alpha_\lambda + \pi ,$$

and V_∞ is evaluated

$$V_\infty = v_\infty \Phi^T \begin{bmatrix} \cos\alpha\cos\delta \\ \sin\alpha\cos\delta \\ \sin\delta \end{bmatrix} .$$

4. Extra-Ecliptic Missions. An additional set of boundary conditions has been added to the program for simulating extra-ecliptic missions.

The original set of boundary conditions is given on pp. 25-26 of reference [1], which is now invoked by employing the program input quantity IOUT = 1 and corresponds to i, e, and r_p specified, Ω and ω optimized and f = 0, where i is inclination to the ecliptic, e is eccentricity, r_p is perihelion distance, Ω is ascending node angle, ω is argument of perihelion, and f is true anomaly, all evaluated at the final time.

The new set of end conditions for extra-ecliptic missions is invoked by IOUT = 2 and is similar to the original set except that the final true anomaly is optimized rather than specified as zero, which corresponds to having the spacecraft arrive at the optimum point of the extra-ecliptic orbit rather than being constrained to arrive at perihelion. The specified final conditions are i, e, and a, where a is the final semi-major axis (in place of r_p). Ω and ω are optimized as before, using the transversality conditions

$$T(\Omega) = \bar{k} \cdot C = 0 \tag{29}$$

$$T(\omega) = \bar{h} \cdot C = 0 \tag{30}$$

which are identical to equations (47) and (48) of reference [1]. $C = R \times \overset{\circ}{\Lambda} - \dot{R} \times \Lambda$ is the vector constant of the motion on a given trajectory segment, $\bar{h}$ is a unit vector along the angular momentum of the final orbit, and $\bar{k}$ is the z-axis unit vector. Optimizing f is accomplished by satisfying the transversality condition associated with f:

$$T(f) = \frac{\mu}{r} (\Lambda \cdot R) + r^2 (\overset{\circ}{\Lambda} \cdot \overset{\circ}{R}) = 0 \tag{31}$$

The program attempts to satisfy equations (29), (30), and (31) directly, since no closed-form solution has yet been found for casting these end conditions in the form of ΔR and $\Delta \overset{\circ}{R}$ similar to equations (54) and (55) of reference [1]. These end conditions possess poor convergence properties, a fact which the authors have experienced directly in attempting to obtain converged solutions using IOUT = 2.

5. Multiple Target Missions - Errata. Two equations in the section, Extension of Formulation for Multiple-Target Missions of reference [1] are in error. Equation (116) of reference [1] should read

$$\pi = j_r m_{rs} + m_o \Big\{ k_s + k_t - (1 + k_t) \nu_n + j_r (1 + k_{rt}) e_x \Big[(1 + j_t k_t) \nu_n$$

$$- j_t k_t (1 + \sum_{i=1}^{n-1} (k_{samp\,i} - k_{drop\,i})) \Big] + (1 + k_t) \sum_{i=1}^{n-1} k_{samp\,i}$$

$$- k_t \sum_{i=1}^{n-1} k_{drop\,i} \Big\} + m_{ps} \Big[1 - j_r j_{ps} (1 + k_{rt}) e_x \Big]$$

and equation (117) should read

$$\pi_{m_o} = \frac{\partial \pi}{\partial m_o} = k_s + k_t + j_p \frac{\alpha g c}{2\eta} - (1+k_t)\,\nu_n + (1+k_t) \sum_{i=1}^{n-1} k_{samp\,i}$$

$$- k_t \sum_{i=1}^{n-1} k_{drop\,i} + g_x \Big[(1 + j_t k_t)\,\nu_n - j_t k_t \,(1 + \sum_{i=1}^{n-1} (k_{samp\,i} - k_{drop\,i}))$$

$$- j_p j_{ps} \frac{\alpha g c}{2\eta} \Big].$$

C. AUXILIARY COMPUTATIONS

This section presents equations employed in computations which are made after the iteration sequence involving the primary target is completed.

1. Additional Block Print Variables. A standard print block is employed for printing information at various points along a trajectory. Each standard block contains a total of forty parameters, which are described in [1].

The standard block may be augmented in two ways. When power degradation, as indicated by the input variable TPOWER, is simulated, a single line of information is automatically added to each block, as displayed in the Sample Problems and Results section, Case B, Comet Rendezvous Mission. When the input variable MPRINT is 2 or 3, three extra lines of information are generated per block, as displayed in the Sample Problems and Results section, Case C, Multiple Ballistic Swingby Mission. These two types of additionally printed lines may appear simultaneously.

(a). Power Degradation. The single line of power degradation information contains eight parameters as follows:

S	Degradation time, s, since departure, in days, given by expression (4).
LS	Degradation time adjoint variable, λ_s.
DENSITY	Density parameter, d, used in expression (9) for the power ratio γ, and given by expression (1), in AU^{-2}.
DPOWR	$\partial\gamma/\partial r$, in AU^{-1}.
DPOWD	$\partial\gamma/\partial d$.
DEGRAD	The degradation factor, q, given by expression (6).
CHI	Solar array orientation angle χ as given by, for example, expression (19), in degrees.

CHI REF — Solar array orientation anglc which the arrays would have if oriented for maximum power, in degrees.

(b). Target-Relative Coordinates and Comet Magnitudes. The three extra lines which may appear via using MPRINT contain the following information:

R1 REL
R2 REL
R3 REL — Cartesian components of current spacecraft position vector, with respect to the next astronomical body to be encountered along the trajectory in a moving coordinate system generated by that body, with the x-axis pointing outward along the body's heliocentric radius vector, the y-axis in the body's orbit plane in the direction of the body's motion, and the z-axis completing the right-handed orthogonal system, in kilometers, with the origin of coordinates at the body.

V1 REL
V2 REL
V3 REL — Cartesian components of current spacecraft velocity vector, in kilometers/second, in the target-relative coordinate system described directly above (see R1 REL).

RMAG REL — Magnitude of R1 REL, R2 REL, R3 REL, in kilometers.

VMAG REL — Magnitude of V1 REL, V2 REL, V3 REL, in kilometers/second.

S/C NUC MAG — Nuclear magnitude (of comet) of the next astronomical body to be encountered along the trajectory, as seen by the spacecraft.

$$M_N = M_o + M_1 \log_{10} |R - R_{targ}| + M_2 \log_{10} |R_{targ}|$$

$$+ .03 \cos^{-1} \left[\frac{R_{targ} \cdot (R_{targ} - R)}{|R_{targ}| \; |R_{targ} - R|} \right] C^o$$

where M_o, M_1, and M_2 are magnitude constants

(Continued on next page)

S/C NUC MAG (continued) — associated with the target, and C^o is the radians-to-degrees conversion factor. The arc-cosine term is the phase angle.

S/C TOT MAG — Total magnitude of the next astronomical body to be encountered along the trajectory, as seen by the spacecraft.

$$M_T = M_3 + M_4 \log_{10} |R - R_{targ}| + M_5 \log_{10} |R_{targ}|$$

where M_3, M_4, and M_5 are magnitude constants associated with the target.

GEO NUC MAG — Same as S/C NUC MAG, except as seen by the Earth.

GEO TOT MAG — Same as S/C TOT MAG, except as seen by the Earth.

ANG(V, R) — Angle which (V1 REL, V2 REL, V3 REL) makes with the positive x-axis in the target-relative coordinate system described under R1 REL, in degrees.

$$ANG(V, R) = \cos^{-1} (V1\ REL/VMAG\ REL)$$

ANG(V, XY) — Angle which (V1 REL, V2 REL, V3 REL) makes with the xy plane in the target-relative coordinate system described under R1 REL, in degrees.

$$ANG(V, XY) = \sin^{-1} (V3\ REL/VMAG\ REL)$$

R1 REL ECL
R2 REL ECL
R3 REL ECL — Same as R1 REL, R2 REL, R3 REL except expressed in the ecliptic coordinate system of date.

V1 REL ECL
V2 REL ECL
V3 REL ECL — Same as V1 REL, V2 REL, V3 REL except expressed in the ecliptic coordinate system of date.

RMAG ECL — Magnitude of R1 REL ECL, R2 REL ECL, R3 REL ECL, in kilometers.

VMAG ECL — Magnitude of V1 REL ECL, V2 REL ECL, V3 REL ECL, in kilometers/second.

2. Swingby Continuation Analysis. Auxiliary computations are optionally provided, invoked by the NAMELIST input vector MOPT4, whereby ballistic swingbys past the primary target may be simulated.

In one mode of program operation, invoked by MOPT4(1) > 0, single swingbys past the primary target may be simulated to up to ten post-swingby targets per case.

In another mode of program operation, invoked by MOPT4(1) < 0, multiple swingbys along a single trajectory may be simulated, first swinging past the primary target and then subsequently swinging past more targets downstream along the trajectory. One multiple swingby trajectory may be simulated per case.

In either mode of operation, the following basic assumptions are made. The swingby continuation computations are independent of the trajectory leg leading up to the swingby target, which may consist of an optimized electric propulsion trajectory segment (if the swingby target is the primary target), except that the arrival V_∞ and arrival time at the swingby target are used in the determination of the swingby passage conditions. Each swingby maneuver is calculated under the assumption of the patched-conic approximation, and the swingby planet's sphere-of-influence is assumed to have zero radius as seen from interplanetary space and infinite radius as seen from the planetary vantage point. The passage time in the swingby planet's sphere-of-influence is neglected (taken to be zero in the heliocentric frame).

Each swingby maneuver may be either unpowered or powered, and these two cases are discussed in the following sections. Since the unpowered swingby solutions are embedded in the wider class of powered-swingby solutions, tending to appear in pairs which are separated by a region of braking powered swingbys, the more general case of powered swingbys is discussed first.

(a). Powered Swingbys. This type of swingby maneuver is restricted to occur at the mutual perifoci of the approach and departure hyperbolic arcs; the powered phase is impulsive and the thrust is colinear (pro or con) to the velocity at closest approach. Whether the swingby is powered or unpowered, the trajectory segment leading up to the swingby planet has been pre-determined, this being the method by which the program has been designed to obtain swingby solutions. Therefore the swingby time and the arrival hyperbolic excess velocity $V_{\infty A}$ are known. In the following analysis, subscript A pertains to arrival at the swingby planet and subscript D pertains to departure.

A basic assumption of the powered swingby problem posed here is that the flight time from the swingby planet to the next target is specified. This being so, the program is able to converge, by iteration, on some ballistic trajectory from the swingby planet to the next target having the specified transfer time, implying that the departure hyperbolic excess velocity $V_{\infty D}$ at the swingby planet is thereby determined. Therefore, the heliocentric trajectory before and after the swingby planet is determined, and it then remains to perform the required computations pertaining to the hyperbolic arcs within the swingby planet's sphere of influence.

The closest approach distance is found by iteration as follows. Let

$$\alpha_A = 1 + \frac{r_p v_{\infty A}^2}{\mu}$$

and

$$\alpha_D = 1 + \frac{r_p v_{\infty D}^2}{\mu}$$

where $v_{\infty A} = |V_{\infty A}|$, $v_{\infty D} = |V_{\infty D}|$, r_p is the (unknown) passage distance, and μ is the swingby planet's gravitational parameter. Then the approach and departure hyperbolic bend angles are given by

$$\frac{\delta_A}{2} = \text{cosec}^{-1}\, \alpha_A = \sin^{-1}\, (1/\alpha_A)$$

$$\frac{\delta_D}{2} = \text{cosec}^{-1}\, \alpha_D = \sin^{-1}\, (1/\alpha_D)$$

and these must sum up to the total bend angle, which is specified in terms of $V_{\infty A}$ and $V_{\infty D}$:

$$\delta_T = \frac{\delta_A}{2} + \frac{\delta_D}{2} = \cos^{-1}\left[\frac{V_{\infty A} \cdot V_{\infty D}}{v_{\infty A}\, v_{\infty D}}\right]$$

Therefore, using r_p as the independent variable, the zero of the quantity

$$F = \sin^{-1}\, (1/\alpha_a) + \sin^{-1}\, (1/\alpha_D) - \cos^{-1}\left[\frac{V_{\infty A} \cdot V_{\infty D}}{v_{\infty A}\, v_{\infty D}}\right]$$

is obtained by Newton's iteration, using the derivative

$$\frac{\partial F}{\partial r_p} = \left(\frac{-1}{\mu}\right)\left[\frac{v_{\infty A}^2/\alpha_A}{\sqrt{\alpha_A^2 - 1}} + \frac{v_{\infty D}^2/\alpha_D}{\sqrt{\alpha_D^2 - 1}}\right]$$

When the iteration is converged, the passage distance r_p is in hand, and the impulsive velocity increment is computed,

$$\Delta v = \sqrt{\frac{2\mu}{r_p} + v_{\infty D}^2} - \sqrt{\frac{2\mu}{r_p} + v_{\infty A}^2}$$

where the square-root-quantities are the hyperbolic speeds at closest approach. The remaining parameters defining the planetocentric transfer are computed as follows. The inclination of the swingby orbit plane to the planet's equator is given by

$$i = \cos^{-1}\, (\bar{h} \cdot \bar{n}_p)$$

where $\bar{h}$ is the unit vector along the angular momentum of the hyperbolic passage trajectory and $\bar{n}_p$ is a unit vector pointing toward the swingby planet's north pole.

The ascending node angle of the swingby orbit plane is computed as

$$\Omega = \tan^{-1} (-h_x/h_y)$$

and is placed in the proper quadrant by using the system library routine DATAN2. The argument of perifocus is given by

$$\omega = \cos^{-1} (\hat{r}_p \cdot \hat{r}_n)$$

where $\hat{r}_p$ is the unit vector pointing toward the closest approach point and $\hat{r}_n$ is the unit vector lying along the line of nodes and pointing toward the ascending node. This is adjusted for the proper quadrant by the test,

$$\text{If } h_z (\hat{r}_n \times \hat{r}_p)_z < 0, \qquad \omega \rightarrow 2\pi - \omega$$

In the right-handed planetary reference frame, the z-axis is toward the planet's north and the x-axis points toward the ascending node of the planet's equator on the ecliptic plane.

(b). Unpowered Swingbys. This type of swingby maneuver is considered to be a powered swingby having $\Delta v = 0$. The program adjusts the post-swingby heliocentric trajectory segment, by iteration, until the swingby departure V_∞ magnitude equals the given arrival V_∞ magnitude. The primary independent variable in this iteration is the post-swingby transfer time to the specified target, which was held constant in the powered swingby case. Thus $v_{\infty D} = v_{\infty A} = v_\infty$, and the swingby passage distance is obtained from the formula,

$$r_p = \frac{\mu}{v_\infty^2} \left(\frac{2 v_\infty}{|V_{\infty A} - V_{\infty D}|} - 1 \right)$$

The other orbital parameters are obtained from the same relations given above in the section, Powered Swingbys.

The program can generate multiple-revolution ballistic arcs, and a particular solution obtained by the program may not be unique, even for the same transfer time. All solutions are reachable, however, by means of inputting an appropriate initial velocity guess for the trajectory segment in question.

III. PROGRAM INPUT

The following consists of a complete description of program inputs. With respect to the basic HILTOP report [1], several input quantities have been added, some have been deleted, and some definitions have been modified. The input quantities which have been deleted are CALPHA, DIGIT, HALT, and WEIGHT, and so these names must no longer appear in NAMELIST MINPUT input data sets. CALPHA has been replaced by ALPHAA and ALPHAT. Also, Yi(4) and Yi(5) for $i = 1, 2, 3, \ldots, 70$ have been deleted (See the description of "dependent parameters" in the section just ahead, Definitions of Input Parameters) and should therefore also be removed from input data sets.

A. NAMELIST

Inputs to HILTOP are given through the NAMELIST feature of the IBM Fortran IV programming language. The input NAMELIST is named MINPUT, and every input required or used in the program is declared by name in the list. The general form for assigning an input value to a quantity is, simply,

NAME = VALUE

where NAME is the name assigned to the variable and is included in the NAMELIST, and VALUE is a numerical or logical quantity consistent in form (i.e., logical, integer, or real) with NAME. Unless otherwise specified, all MINPUT names commencing with one of the letters I through N represent integers, whereas all names commencing with one of the letters A through H or O through Z are double precision floating point numbers. Each NAMELIST case must begin with the characters

&MINPUT

commencing in card column 2 and followed by at least one blank, and end with the characters

&END

preceded by at least one blank. Card column 1 is ignored on all NAMELIST input cards. Multiple data assignments on a single card are permissible if separated by commas. Blanks in the variable field, VALUE, are taken as zeroes. A comma following the last VALUE on a card is optional on the IBM system. The order of the input data assignments is arbitrary; i.e., they need not be in the same order as listed in the NAMELIST. In fact, there is no requirement that any specific input parameter be represented in the input data set. If no value is included in the inputs for a particular parameter, the default value is used (see Default Values). For other details regarding the NAMELIST feature, the reader is referred to the IBM System 360/Fortran IV

Language manual. NAMELIST cases may be stacked back-to-back indefinitely. A single NAMELIST error may wipe-out the remaining NAMELIST inputs.

B. DEFINITIONS OF INPUT PARAMETERS

Specific examples of the program inputs are given in the Sample Problems and Results section. Default-values of inputs are given in the next section.

The program inputs, in alphabetical order, are:

AAI	Desired final extra-ecliptic inclination. Related to AE, AR, and IOUT. [deg]
AE	Desired final extra-ecliptic eccentricity. Related to AAI, AR, and IOUT.
ALPHAA	Specific mass of solar arrays, α_a. [kg/kw]
ALPHAT	Specific mass of thruster subsystem, α_t. [kg/kw]
ALTITU	This input variable is associated with program logic which has not been kept up-to-date, specifically, logic pertaining to optimum departure of a NERVA-type rocket from Earth orbit. This variable should be ignored.
AN	Trajectory-integration exponent in expression (37) of reference [1].
AR	Desired final extra-ecliptic perihelion distance. Related to AAI, AE, and IOUT. [AU]
ASOL	Array of five elements consisting of the solar power law coefficients a_i in expression (17) of reference [1]. ASOL(1) > 0 tells the program to use the input coefficients rather than the internal coefficients. The coefficients are normalized internally, and the program executes the iterations to produce the required remarkable points of the power curve (which are printed).
BI	Efficiency coefficient b in expression (15) of reference [1]. Related to DI and EI.
B1 B2 B3	Launch vehicle coefficients b_1, b_2, and b_3 in expression (2) of reference [1]. Used only if MBOOST is negative. [kg, m/sec, kg]

CNI — Inclination to ecliptic of primary-target orbit. Input only when MOPT3 = 11. Related to ECI, OMI, SAI, SOI, TPI, EMUODD, and RADODD. [deg]

CNIX — Array of five elements, the first three of which may be currently used. Inclinations to ecliptic of intermediate-target orbits. Input CNIX(i) only when MOPTX(i) = 11. Related to ECIX, OMIX, SAIX, SOIX, TPIX, EMUODX, and RADODX. [deg]

CSTR — Structural factor, k_s, in expression (7) of reference [1].

CTANK — Propellant tankage factor, k_t, in expression (6) of reference [1].

CTRET — Retro tankage factor, k_{rt}, in expression (10) of reference [1].

DI — Efficiency coefficient d in expression (15) of reference [1]. Related to BI and EI. [km/sec]

DMRETR — Retro engine mass, m_{rs}, in expression (10) of reference [1]. [kg]

DPOW — Ratio of housekeeping power p_h to reference power p_{ref}. The power transmitted to the propulsion system is that generated by the arrays less housekeeping power which is constant along the trajectory. The power output of the arrays normal to the sun at 1 AU is $p_{ref} + p_h$.

ECI — Eccentricity of primary-target orbit. Must be less than unity. Input only when MOPT3 = 11. Related to CNI, OMI, SAI, SOI, TPI, EMUODD, and RADODD.

ECIX — Array of five elements, the first three of which may be currently used. Eccentricities of intermediate-target orbits. Input ECIX(i) only when MOPTX(i) = 11. Related to CNIX, OMIX, SAIX, SOIX, TPIX, EMUODX, and RADODX.

EI — Efficiency coefficient e in expression (15) of reference [1]. Related to BI and DI.

EMUODD — Gravitational constant of primary-target. Input only when MOPT3 = 11. Related to ECI, CNI, OMI, SAI, SOI, TPI, and RADODD. $[m^3/sec^2]$

EMUODX — Array of five elements pertaining to the gravitational constants of intermediate-targets. These inputs must be ignored at present.

GAMMAX — Maximum permissible value of the power function γ when MODE = 5. At solar distances less than the value for which γ = GAMMAX, the solar arrays are assumed to be tilted such that γ is maintained at the limiting value.

GAP — Propulsion-corner proximity tolerance-interval, $\Delta\sigma$. See the discussion in the section Avoiding Corners in the Propulsion-time Function in reference [1]. Whenever the thrust switch function σ grazes the zero-axis within the tolerance $|\Delta\sigma|$ on any trajectory, an internal counter is incremented, and the trajectory is considered to be in the neighborhood of a propulsion-time corner. Positive value of GAP causes forced-thrusting case to be inserted, negative value causes bypass to next case, whenever the internal counter reaches the related input variable NHUNG.

HOUR — Hour-of-day of reference date (e.g., 17.342D0). Related to MYEAR, MONTH, and MDAY.

IBAL — Ballistic option indicator. Setting IBAL $\neq 0$ invokes option 1 discussed in the section Ballistic Trajectory Option of reference [1].

INTPR — Indicator which specifies print-length when the iteration in subroutine INTERP fails. Value of 0 causes short-print and 1 causes detailed-print.

IOUT — Extra-ecliptic mission indicator. IOUT = 1 or 2 indicates that extra-ecliptic target conditions are desired, in which the iterator dependent variable triggers Y1(2) through Y6(2) are set equal to 1, and for which the input LAUNCH (which see) should probably be set to 1, and parameters related to LAUNCH also set appropriately. Ordinarily MOPT2 = 3. No retro stage may be employed. (Continued on next page).

IOUT (cont)	= 1	i, e, r_p specified; f = 0.
	= 2	i, e, a specified; f optimized.

In the above, i = final extra-ecliptic inclination, e = final eccentricity, r_p = final perihelion distance, a = final semi-major axis, and f = true anomaly at the final time. Final Ω and ω are optimized in both cases. Related to AE, AR, and AAI.

IRK — Numerical integration option (currently not used).

IRL — Primer-origin-proximity step-size-control indicator. Value of zero causes bypass of control, leaving the step-size Δu constant. See discussion in the section, Integration (Thrust) of reference [1].

IROT — A non-zero value of IROT causes the input ecliptic projection of the primer vector and its time derivative to be rotated about the z-axis through an angle equal to the difference in longitudes of the spacecraft between the last trajectory of the previous case (or zero if no previous case) and the first trajectory of the current case. This feature permits one to use the initial adjoint variables from a 2-dimensional trajectory as the initial-guess inputs for a 3-dimensional trajectory using the ephemeris option. IROT must be set back to zero to avoid undesirable rotations on subsequent cases.

ISPIN — Spinner indicator. Not used at present.

ITF — Provides normal termination conditions for runs which require more machine time than is estimated. The value specifies the number of machine-time seconds (CPU and I/O) required to execute the summary trajectory after halting the iteration-sequence. [sec] Does not apply if subroutine REMTIM is dummied.

ITPRNT — Indicator for special print from MINMX3 iterator. Non-zero value invokes print.

JPP — Jettison indicator j_{ps} for electric propulsion system prior to primary-target retro-maneuver, as used in expression (8) of reference [1]. (Continued on next page).

JPP (cont)		= 0 Propulsion system not jettisoned = 1 Propulsion system jettisoned prior to retro maneuver.
JPRINT	Unit 11 printout-length indicator. A value of zero causes the iterator independent and dependent variables to be output only for each summary-trajectory; a value of one causes the same output additionally at each iteration of an iteration-sequence.	
JT	Jettison indicator j_t for electric propulsion tankage prior to primary-target retro-maneuver, as used in expression (8) of reference [1].	
		= 0 Tankage not jettisoned = 1 Tankage jettisoned prior to retro-maneuver.
KPART	Option for automatically selecting improved independent parameter perturbations for generating the iterator's partial derivative matrix. The option is invoked by setting KPART = N (N > 0), where N is the maximum number of allowed steps, as discussed in the section, Perturbation Step Size Selector of reference [1]. KPART must be set back to zero if not desired on subsequent cases.	
LAUNCH	Launch mode selector, pertaining to the optimization of the departure asymptote declination, invoked by LAUNCH = 1. Related to X10, Y10, X17, and Y17.	
LOADX	Intermediate-target initial-guess feature. Should be used with NSET(5) = 1, and then set to zero on the subsequent case. A non-zero value of LOADX will invoke this feature, whereby the primer Λ and its derivative $\dot{\Lambda}$ will be loaded into the iterator independent-variable arrays at each intermediate-target (Continued on next page).	

LOADX (cont)	provided that the trigger of the independent variable is on. The sole purpose of this capability is merely to generate an initial-guess for a multiple-target mission, where the values loaded into the iterator arrays represent continuous Λ and $\mathring{\Lambda}$ at each target.
MAXHAM	Maximum number of times that the program will print the warning message BAD HAMILTONIAN on any given computer run.
MBOOST	Launch vehicle selector.

= 0	ATLAS (SLV3X)/CENTAUR
1	TITAN III C
2	TITAN III C (1207)
3	TITAN III X/CENTAUR
4	TITAN III X (1207)
5	TITAN III X (1207)/CENTAUR
6	SATURN IB/LM
7	SATURN IB/CENTAUR
8	SATURN IC/SIVB/CENTAUR
9	TITAN III X (1205)/CENTAUR
10	TITAN III B (CORE)/CENTAUR
11	TITAN III D (1205)/CENTAUR
12	DELTA
13	TITAN III D
14	TITAN III D (1205)/CENTAUR/TE364 (2250)
15	TITAN III E/CENTAUR
16	SHUTTLE/TRANSTAGE
17	SHUTTLE/DELTA
18	SHUTTLE/AGENA
19	SHUTTLE/CENTAUR
20	SHUTTLE/CENTAUR/BURNER II (2300)
NEG	Use input booster coefficients b_1, b_2, and b_3.

MDAY	Day-of-month of reference date (e.g., 26). Related to MYEAR, MONTH and HOUR.
MODE	Power variation option selector. The value of MODE is equal to the option-number of the power-curve, discussed in the section, Electric Propulsion System of reference [1] (which see). Possibly related to ASOL and GAMMAX. MODE = 1 has been eliminated.
MONTH	Month-of-year of reference date (e.g., 8). Related to MYEAR, MDAY, and HOUR.

MOPT — Ballistic option indicator. Using MOPT invokes option 2, discussed in the section, Ballistic Trajectory Option, of reference [1], as follows:

= 0 No action (use input Λ_o, $\dot{\Lambda}_o$, and $v_{\infty o}$).

= 1 Generate ballistic solution with flyby end conditions.

= 2 Generate ballistic solution with orbiter end conditions.

Related to REVS.

MOPTX — Array of five elements, the first three of which may be currently used. This array specifies the target-number, or planet-number, of the successive intermediate-targets, and a value of zero indicates absence of the intermediate-target. A zero-entry must not precede a non-zero entry. Planet selection is the same as for MOPT2. MOPTX(1) pertains to iterator parameters X41-X50 and Y41-Y50; MOPTX(2) pertains to X51-X60 and Y51-Y60; and MOPTX(3) pertains to X61-X70 and Y61-Y70. Times at the targets are X48, X58, and X68. Not to be used unless MOPT2 ≠ 0.

MOPT2 — Launch planet number and ephemeris-option indicator.

= 0 Analytical planetary ephemeris is not used.

≠ 0 Analytical planetary ephemeris is used and the specific launch planet is selected as follows: (Continued on next page).

= 1	Mercury	= 14	Icarus (1978)*
2	Venus	15	Eros
3	Earth	16	Geographos (1983)*
4	Mars	17	Encke (1977)*
5	Jupiter	18	Encke (1984)*
6	Saturn	19	Encke (1987)*
7	Uranus	20	Halley
8	Neptune	21	Betulia
9	Pluto	22	Toro (1983)*
10	Ceres	23	Pallas
11	Input Target**	24	Juno
12	D'Arrest (1982)*	25	Vesta
13	Encke (1980)*	26	Astraea

*Year-value indicates apparition for which internal orbital elements are most accurate.

**Input corresponding orbital elements (see CNI, CNIX). None are available for the launch planet.

MOPT2 (cont) = 27 Hebe

28 Iris
29 Flora
30 Achilles
31 Amor
32 Hidalgo
33 Alinda
34 Grigg-Skjellerup (1977)*
35 Kopff
36 Grigg-Skjellerup (1982)*
37 Ganymed
38 Ivar
39 Beira
40 Kepler
41 Giacobini-Zinner (1985)*
42 Borrelly (1987)*
43 Tempel II (1988)*
44 Tempel II (1983)*
45 Tuttle-Giacobini-Kresak
46 Schaumasse
47 Honda-Mrkos-Pajdusakova
48 Giacobini-Zinner (1979)*
49 Icarus (1987)*
50 Toro (1987)*
51 Geographos (1987)*

*Year-value indicates apparition for which internal orbital elements are most accurate.

MOPT3 Planet number of primary-target. Planet selection is the same as for MOPT2. If ephemeris is not used, MOPT3 is used only for retro-stage mass computations.

MOPT4 Array of ten elements, specifying up to ten post-swingby targets. Planet selection is the same as for MOPT2, and a value of zero indicates the absence of a post-swingby target. A negative value in MOPT4(1) selects multiple ballistic swingbys, rather than a set of single swingbys in which case also set MAXHAM = 0. Negative values (in absolute value) produce planet selection the same as for MOPT2. When MOPT4(1) < 0, the remaining elements of MOPT4(i) may be positive or negative. See the section, Swingby Continuation Analysis for details and Sample Case C for an example-case. Should be used only for primary-target flyby missions. Related to T2, MSWING, NSWING and XSWING.

MPOW — Flag used in conjunction with the solar array degradation option. Value of zero results in the optimum orientation of the arrays relative to the sun line. A non-zero value forces the arrays to an orientation yielding the maximum power achievable at that instant. Related to TPOWER.

MPRINT — Indicator for printing the summary-trajectory (final trajectory of a case) as a function of time or for invoking extra printout.

= 0 Small-size block print at thrust switch points only (SWITCH POINT SUMMARY page).

= 1 Same as = 0, except expands to become a standard print-block of parameters for each computed point along the trajectory, including the trajectory extension controlled by the input variable TGO.

= 2 Same as = 0, except each block contains extra lines consisting of target-relative coordinates and target magnitudes.

= 3 Combination of =1 and =2.

MPUNCH — Punched-card and trajectory-tape generation control.

= 0 No special output.

1 Punch final values of independent parameters.

2 In addition, punch selected mission analysis parameters used for graphic documentation or other purposes.

< 0 and > -100 Punch trajectory output used with the ASTEA program. The absolute value of MPUNCH determines the frequency of trajectory points output.

≤ -101 Trajectory tape output used with the ASTEA program. The absolute value less 100 determines the frequency of trajectory points output. Related to NTAPE.

MREAD Card input option (iterator independent variables)

= 0 No special cards input.

1 The independent variables generated by a previous run by the MPUNCH option are input following the NAMELIST case, as discussed in the section, Program Output, of reference [1].

MSWING Array of ten elements, used only when running multiple-target ballistic swingbys, such that MSWING(i) corresponds to MOPT4(i) and selects the type of swingby maneuver desired at the respective swingby target. Used only if MOPT4(1) < 0. The shooting method (MINMX3 iterator) is used, and values of -1, -2, or -3 correspond to a swingby passage distance initial guess of $r_p = \infty$ (i.e., continuous heliocentric velocity). Each element MSWING(i) may have any of the following values:

= - 1 Go* directly for unpowered swingby; if and only if it fails, go for powered swingby having flight time T2(i) = initial guess.

= - 2 Go directly for powered swingby <u>only</u>, having T2(i) = flight time, of post-swingby leg.

= - 3 Go directly for unpowered swingby; then, whether it succeeds or not, go for powered swingby having T2(i) = flight time.

= - 4 Go directly for unpowered swingby, but using initial velocity guess loaded into XSWING(j, i), j = 1, 2, 3, similar to MSWING(i) = - 1.

= - 5 Same as = - 2, except use initial guess as in = - 4.

*"Go for" means "attempt to obtain (solution)".
Related to MOPT4, T2, XSWING, and NSWING.

MTMASS Mission-type selector pertaining to the primary target.

= 0 Flyby mission

1 Orbiter (high-thrust retro-maneuver without velocity loss).

(Continued on next page).

MTMASS (cont)

= 2 Orbiter (high-thrust retro-maneuver with velocity loss).

3 Specified arrival excess speed $v_{\infty n}$.

If $v_{\infty n} = 0$, rendezvous mission

If $v_{\infty n} > 0$, controlled flyby mission

No retro-maneuver in either case.

4 Orbiter (Electric propulsion system performs spiral maneuver. Arrival excess speed $v_{\infty n}$ must be specified as zero).

Other parameters which may be related to MTMASS are DMRETR, CTRET, RPER, RAP, THRET, SPIRET, JPP, and JT.

MUPDAT

Flag indicating whether iterator independent variables at end of one case are to be used as first guesses for next case.

= 0 Use input initial guesses.

1 Use independent variables of previous case as first guesses.

MYEAR

Year of reference date (e.g., 1982). Related to MONTH, MDAY, and HOUR.

NDIST

Identification number of celestial body to be used as the reference for the communication distance and angle measurement printed in the Extremum Point Summary Table. Identification code is the same as for MOPT2.

NHUNG

Maximum number of propulsion-corner-proximity occurrences allowed in a given iteration-sequence. Related to GAP.

NORMAL

Automatic adjoint-variable scaling.

= 0 No action.

1 All Λ and $\dot{\Lambda}$ are scaled such that $\lambda_{\nu o}$ becomes unity.

NPERF — Identification number of end condition that is to be used as the performance index when employing the direct parameter optimization feature (Improve Mode). The identification code is the same as the i in the Yi end condition array.

NPRINT — Print selection flag. Permits selection of amount of printout desired on each case.

- = 0 Print only the case summary.
- 1 Print switching point summary of final trajectory.
- 2 Print MINPUT and case setup.
- 4 Print trajectory summary on each iteration.
- 8 Print partial derivative matrix each iteration.

Combinations of options obtained by summing options desired. If NPRINT > 15, printout consistent with NPRINT = 0 is obtained. If the sign of NPRINT is reversed to negative, the iterator independent and dependent variables additionally are printed for every trajectory which HILTOP generates (including neighboring trajectories).

NSET — Iteration-sequence control array.

NSET(1) — Not used for input.

NSET(2) — Not used for input.

NSET(3) — Maximum number of iterations permitted in attempting to satisfy (point) constraints in satisfy mode. If zero, no upper limit imposed.

NSET(4) — Flag indicating whether (point) constraints are to be satisfied prior to entering improve mode.

- = 0 Satisfy constraints first.
- 1 Proceed immediately to improve mode.

NSET(5) — Maximum number of iterations permitted after entering improve mode. Setting NSET(5) = 1 causes iterator to be bypassed and computes single trajectory to obtain printout.

NSWING	Swingby continuation analysis option indicator. When zero or positive, NSWING is the number of full revolutions which the post-swingby heliocentric trajectory must have, and subroutine ACONIC (not MINMX3) is used to obtain the solution. When negative, NSWING has the same definition as MSWING (which see), and the MINMX3 iterator is used; NSWING must be used when MOPT4(1) $>$ 0, and may be used when MOPT4(1) $<$ 0. If MOPT4(1) $<$ 0 and MSWING(i) = 0, then MSWING(i) will be set to the value of NSWING. Related to MSWING, MOPT4 and T2.
NSWPAR	Iterator independent-variable perturbation-increment control. = 0 No action. 1 Allows the iterator to vary a given independent-variable perturbation Δx whenever a neighboring trajectory is detected which has a different number of thrust switch points than the associated nominal trajectory. Δx is varied until the same number of switch points is achieved.
NTAPE	Specifies the unit-number for the trajectory tape. Pertains to when MPUNCH ≤ -101.
OMI	Ascending node angle (with respect to vernal equinox) of primary-target orbit. Input only when MOPT3 = 11. Related to CNI, ECI, SAI, SOI, TPI, EMUODD, and RADODD. [deg]
OMIX	Array of five elements, the first three of which may be currently used. Ascending node angles of intermediate-target orbits. Input OMIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, SAIX, SOIX, TPIX, EMUODX, and RADODX. [deg]
POWFIX	Launch-vehicle-independent (i.e., no launch vehicle) trajectory option in which the value of POWFIX is the spacecraft's reference power. [kw]

PSIGN	Flag defining the sense of the launch hyperbolic excess velocity relative to the initial primer vector. A value of +1. results in the assignment of the geocentric right ascension of the excess velocity equal to that of the initial primer vector. A value of -1. causes the geocentric right ascension of the excess velocity to be 180 degrees from that of the initial primer.
RADODD	Radius of primary target. Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SAI, SOI, TPI, and EMUODD. [meters]
RADODX	Array of five elements pertaining to the radii of intermediate targets. These inputs are not used at present.
RAP	Apoapse distance of capture orbit about primary target. [planet radii]
REVS	Number of complete revolutions of the ballistic trajectory generated when the associated input MOPT is used. Must be a positive whole number.
RPER	Periapse distance of capture orbit about primary target. [planet radii]
SAI	Semi-major axis of primary-target orbit (must be positive). Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SOI, TPI, EMUODD, and RADODD. [AU]
SAIX	Array of five elements, the first three of which may be currently used. Semi-major axes of intermediate-target orbits (must be positive). Input SAIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, OMIX, SOIX, TPIX, EMUODX, and RADODX. [AU]
SOI	Argument of perihelion of primary-target orbit. Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SAI, TPI, EMUODD, and RADODD. [deg]
SOIX	Array of five elements, the first three of which may be currently used. Arguments of perihelion of intermediate-target orbits. Input SOIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, OMIX, SAIX, TPIX, EMUODX, and RADODX. [deg]

SPIRET — Retro-stage specific impulse (pertaining to the retro-maneuver at the primary target). [sec]

STATE — Array of six elements containing the Cartesian position and velocity components of the primary target. Use only when MOPT2 = 0 and the trigger settings of Y1(2) through Y6(2) are 0 or 1. [AU, AU/tau] (tau = 58.132440991 days)

STEP1 — Thrust-phase computation step size, Δu.

STEP2 — Coast-phase computation step size, $\Delta\beta$.

TCOAST — Array of twenty elements, consisting of the durations of the coast phases corresponding to the coast-phase start-times input in the associated array TOFF. [days]

TDV — Time of occurrence of an impulsive deep space burn, in days from the start of the trajectory, which may be used only if the entire trajectory is ballistic (i.e., electric propulsion is not permitted with this option, nor is a third intermediate target). Iterator independent variables X64, X65, and X66 must be turned on, as these are used as the Δv vector components of the deep space burn in EMOS. Also, set MAXHAM = 0. The following special feature is available regarding a first intermediate-target. If 1.D5 < TDV < 2.D5, then the burn occurs (TDV - 1.D5) days after passage of that target; if TDV > 2.D5, the burn occurs (TDV - 2.D5) days before passage of that target. [days]

TGO — Ballistic trajectory-extension print option. When zero, no action. When positive, TGO = the number of days that the trajectory is to extend ballistically beyond the primary-target when no swingby-continuation is requested, and ballistically beyond the (last) post-swingby target when swingby-continuation is requested (in addition to the post-swingby trajectory segment itself). Any negative value will invoke printout of only the post-swingby trajectory segment or segments when swingby-continuation is requested. Applies also to trajectories with multiple swingbys. [days]

THRET	Retro-stage thrust, used only when MTMASS = 2. [lbs]
TOFF	Array of twenty elements, consisting of the times, in days from the start of the trajectory, at which imposed coast phases are to begin. Times must be in ascending order. Related to TCOAST. [days]
TPI	Time from reference date (MYEAR, etc.) to perihelion passage, for the primary target. Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SAI, SOI, EMUODD, and RADODD. [days]
TPIX	Array of five elements, the first three of which may be currently used. Times from reference date (MYEAR, etc.) to perihelion passages, for the intermediate targets. Input TPIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, OMIX, SAIX, SOIX, EMUODX, and RADODX. [days]
TPOWER	Solar-cell degradation characteristic-time; nuclear electric propulsion radioactive-decay characteristic-time. Related to MPOW. [days]
TSCALE	Iterator dependent-variable tolerance-interval scaling factor; scales all tolerances multiplicatively by the amount TSCALE.
T2	Array of ten elements consisting of initial estimates of swingby-continuation trajectory-segment flight-times, i.e., T2(i) correspond to MOPT4(i). [days]
XANG1	Latitude of the launch site. Used only if LAUNCH is non-zero. Related to XANG2. [deg]
XANG2	Maximum parking orbit inclination, permitted by range safety considerations. Used only if LAUNCH is non-zero. Related to XANG1. [deg]
XSWING	Array of velocity vectors consisting of initial velocity guesses of a given post-swingby trajectory segment. Used only when either NSWING or MSWING has a value of -4 or -5. See especially the description of MSWING = -4. Velocity consists of exactly the same values as found in the V1, V2, V3 locations of the (Continued on next page).

XSWING (cont)	trajectory block print (first block). Related to MSWING, NSWING, MOPT4, and T2. [AU/tau]
X0	Array of seven elements, the first six of which contain the Cartesian position and velocity components of the launch planet. The seventh element is not used for input. Used only when MOPT2 = 0. [AU, AU/tau]

The following describes the iterator independent and dependent variable arrays of the boundary value problem. Input pertaining to the individual independent parameters is contained in the arrays X1 through X70. The independent-parameter arrays have five elements for each variable, as follows (where i = 1, 2, 3, ..., 70):

Xi(1)	Input value of parameter. Must be input regardless of trigger setting. If trigger is on (i.e., Xi(2) = 1), input value is used as initial guess of independent parameter and is varied at each subsequent iteration. If trigger is off, the parameter is not used as an independent parameter and is not changed.
Xi(2)	Trigger indicating whether parameter is to be an independent parameter in boundary value problem. Xi(2) = 0 Not an independent parameter. (Trigger is "off"). 1 Use as independent parameter. (Trigger is "on").
Xi(3)	Maximum change to parameter permitted in a single iteration. Should be a positive quantity. Used only if trigger is on. Units are same as that of the parameter.
Xi(4)	Perturbation increment used to compute partial derivatives by finite differences. Used only if trigger is on. Units are same as that of the parameter.
Xi(5)	Weighting factor. Should be a positive quantity. A value of 1. is generally recommended. The larger the weighting factor, the more the parameter is inhibited from varying. Used only if trigger is on.

The independent variables are as follows:

X1	$\Lambda_o(1)$	Initial primer vector.
X2	$\Lambda_o(2)$	
X3	$\Lambda_o(3)$	
X4	$\dot{\Lambda}_o(1)$	Initial primer derivative.
X5	$\dot{\Lambda}_o(2)$	
X6	$\dot{\Lambda}_o(3)$	
X7	$\lambda_{\nu o}$	Initial mass-ratio adjoint-variable.
X8	λ_τ	Propulsion-time adjoint-variable.
X9		Not used.
X10	δ	Geocentric declination of launch hyperbolic excess velocity. [deg]

There is no conversion from input to internal units for any of the adjoint variables.

X11	Reference thrust acceleration, g. [m/sec^2]
X12	Electric propulsion system jet exhaust speed, c. [m/sec]
X13	Launch hyperbolic excess speed, $v_{\infty o}$. [m/sec]
X14	Hyperbolic excess speed at primary target, $v_{\infty n}$. [m/sec]
X15	Initial time, t_o, measured from the reference date (MYEAR, etc.). [days]
X16	Time at the primary target, t_n, measured from the reference date (MYEAR, etc.). [days]

X17		Launch parking orbit inclination, i. Used only if LAUNCH $\neq 0$. Optimized internally by the program if both X17 and Y17 triggers are off. [deg]
X18	$\dot{x}_o$	Initial spacecraft heliocentric velocity. Not required unless one of the three triggers is on. [AU/tau] (tau = 58.132440991 days)
X19	$\dot{y}_o$	
X20	$\dot{z}_o$	
X21		Constant thrust cone-angle, ϕ. Non-zero value invokes the constant-ϕ constraint. $0 < \phi \leq 180^o$. Zero-value implies that ϕ is optimized along the trajectory (variable ϕ). [deg]

X22 through X29 are currently not used (although some locations following X21 are reserved for additional constant thrust cone-angles).

X30	λ_s	Degradation-time adjoint-variable.

X31 through X40 are currently not used. X41 through X50 pertain to the first intermediate target, X51 through X60 pertain to the second intermediate target, and X61 through X70 pertain to the third intermediate target. The corresponding intermediate-target parameters are ignored if the intermediate target is absent. Subscripts 1, 2, and 3 pertain to the first, second, and third intermediate targets, respectively.

X41	$\Lambda_1(1)$	Primer vector (at start of trajectory segment)
X42	$\Lambda_1(2)$	
X43	$\Lambda_1(3)$	
X44	$\dot{\Lambda}_1(1)$	Primer derivative (at start of trajectory segment)
X45	$\dot{\Lambda}_1(2)$	
X46	$\dot{\Lambda}_1(3)$	

X47 — Encounter speed at first intermediate target, $v_{\infty 1}$. [m/sec]

X48 — Time at the first intermediate target, t_1, measured from the reference date (MYEAR, etc.). [days]

X49 — Sample-mass factor, $k_{samp\ 1}$, for sample-retrieval at first intermediate target.

X50 — Drop-mass factor, $k_{drop\ 1}$, for instrument-package dropoff at first intermediate target.

The independent variables X51 through X60 and X61 through X70 are identical to X41 through X50 except that they pertain to the second and third intermediate targets, respectively. A third intermediate target may not be present when simulating ballistic missions having a deep space burn (See TDV), in which case X64, X65, and X66 are used as follows:

X64	$\Delta\dot{x}$	Deep-space velocity-increment. [AU/tau]
X65	$\Delta\dot{y}$	
X66	$\Delta\dot{z}$	

Inputs pertaining to the individual dependent parameters are contained in the arrays Y1 through Y70. The dependent-parameter arrays have three elements for each variable, as follows (where $i = 1, 2, 3, \ldots, 70$):

Yi(1) — Desired value of the dependent parameter.

Yi(2) — Trigger. If off (i.e., equal to zero), the parameter is ignored and is not considered a dependent parameter. Then the other two inputs pertaining to the parameter need not be input. If trigger is on (i.e., not equal to zero), the parameter is considered to be a dependent parameter or constraint. Certain of the parameters may have

Yi(2) (cont)	up to three non-zero trigger settings. These will be discussed individually below.
Yi(3)	Tolerance of desired value (full interval width).

It should be noted that the transversality conditions, which comprise some of the parameters, are developed under the assumption that all constraints are of the point constraint type. Therefore, the satisfy-mode is sufficient in solving any optimization problems for which a complete set of transversality conditions is available.

The dependent-parameter arrays are as given below. T(x) represents "the transversality condition associated with x" and the function T(x) will have different values depending upon the constraints imposed on the problem. See NOMENCLATURE of reference [1] for definition of symbols and subscripts.

	Trigger 1		Trigger 2		Trigger 3	
Y1	Δx_n [AU]	a [AU]	Solar distance* [AU]		$T(\sigma)$	NERVA
Y2	Δy_n [AU]	e	$T(\theta_t)$*		$T(\theta_t)$	NERVA
Y3	Δz_n [AU]	i [deg]			$T(t_n)$	NERVA
Y4	$\Delta \dot{x}_n$ [AU/tau]	$T(\Omega)$	$T(\dot{x}_n)$	optimal flyby	$T(\xi)$	NERVA
Y5	$\Delta \dot{y}_n$ [AU/tau]	$T(\omega)$	$T(\dot{y}_n)$	optimal flyby	$v_{\infty o}$	NERVA
Y6	$\Delta \dot{z}_n$ [AU/tau]	T(f)	$T(\dot{z}_n)$	optimal flyby	$T(\lambda)$	

*Applicable only for two-dimensional motion in the xy plane. Also requires that MOPT2 = 0.

Under Trigger 1 above, the first set of conditions applies to ordinary targeting conditions for position and velocity, and also to extra-ecliptic conditions to be satisfied when IOUT = 1; the second set of conditions applies to extra-ecliptic missions when IOUT = 2. $T(\Omega)$, $T(\omega)$, and T(f) are symbols for the transversality conditions yielding optimum final node angle, argument of perihelion, and true anomaly, respectively.

	Trigger 1	Trigger 2	Trigger 3
Y7	ν_n	$\lambda_{\nu n}$	m_{net} [kg]
Y8	$T(\tau)$	τ [days]	
Y9	Currently not used.		
Y10	$T(\delta)$	δ [deg]	Used only if LAUNCH $\neq 0$.
Y11	$T(g)$	g [m/sec^2]	p_{ref} [kw]
Y12	$T(c)$	c [m/sec]	
Y13	$T(v_{\infty o})$	$v_{\infty o}$ [m/sec]	
Y14	$T(v_{\infty n})$	$v_{\infty n}$ [m/sec]	extra-ecliptic inclination [deg]
Y15	$T(t_o)$	t_o [days]	
Y16	$T(t_n)$	t_n [days]	$t_n - t_o$ [days]*

*Time transversality with flight time fixed is assigned to Y15 under trigger 1.

Y17	$T(i)$	i [deg], where i = parking orbit inclination.	Used only if LAUNCH $\neq 0$.
Y18	$T(\dot{x}_o)$	$\dot{x}_o$ [AU/tau]	
Y19	$T(\dot{y}_o)$	$\dot{y}_o$ [AU/tau]	
Y20	$T(\dot{z}_o)$	$\dot{z}_o$ [AU/tau]	
Y21	$T(\phi)$	ϕ [deg] for ϕ = constant with time.	

Y22 through Y29 are currently not used.

	Trigger 1	Trigger 2	
Y30	$T(s)$	s [days]	(Degradation time)

Y31 through Y40 are currently not used. Y41 through Y50 pertain to the first intermediate target.

	Trigger 1	Trigger 2	
Y41	Δx_1 [AU]		
Y42	Δy_1 [AU]		
Y43	Δz_1 [AU]		
Y44	$\Delta \dot{x}_1$ [AU/tau] ;	$T(\dot{x}_1)$	optimal flyby
Y45	$\Delta \dot{y}_1$ [AU/tau] ;	$T(\dot{y}_1)$	optimal flyby
Y46	$\Delta \dot{z}_1$ [AU/tau] ;	$T(\dot{z}_1)$	optimal flyby
Y47		$v_{\infty 1}$ [m/sec]	
Y48	$T(t_1)$	t_1 [days]	
Y49	$m_{samp\ 1}$ [kg]		
Y50	$m_{drop\ 1}$ [kg]		

Y51 through Y60 and Y61 through Y70 are identical to Y41 through Y50 except that they pertain to the second and third intermediate targets, respectively.

C. DEFAULT VALUES OF INPUT PARAMETERS

The following is a complete, alphabetical list of the default values of program input quantities having non-zero default values, except for the iterator arrays. All other inputs are zeroed. The default values of the iterator arrays Xi(1), Xi(2), Yi(1), and Yi(2), for i = 1, 2, 3, ..., 70, are zero, and the default values of Xi(3) through Xi(5) and Yi(3) for the same range of i are listed in the listing of program inputs of Sample Case C.

ALPHAA	15.	NSET(3)	300
ALPHAT	15.	NSET(5)	300
AN	1.5	NSWPAR	1
AR	1.	NTAPE	17
BI	.76	POWFIX	-1.
CTANK	.03	PSIGN	1.
CTRET	1/9	RADODD	1.
DI	13.	RAP	38.
GAMMAX	1.	RPER	2.
GAP	.0001	SAI	1.
HOUR	12.	SPIRET	300.
IRK	1	STATE(1)	1.
IRL	1	STATE(5)	1.
ITF	3	STEP1	.03125
MAXHAM	5	STEP2	.125
MDAY	1	TDV	-1.
MODE	4	TGO	-1.
MONTH	1	THRET	400.
MOPT3	10	TOFF	20*-1.
MUPDAT	1	TPOWER	10.**30
MYEAR	1975	TSCALE	1.
NDIST	3	T2(i)	50*i
NHUNG	25	X0(1)	1.
NPRINT	7	X0(5)	1.0000015

IV. SAMPLE PROBLEMS AND RESULTS

Three sample cases have been selected for presentation in the following pages. Each case was selected to display the use of one or more new features that have been added to the program. The first case is an extra-ecliptic mission that exhibits the effects of high launch asymptote declinations on launch vehicle performance and the low thrust trajectory. This case also displays the housekeeping power option that was recently added to the program. The second case is a comet rendezvous mission which includes the effects of solar array degradation due to radiation effects. The third and final case displays the HILTOP's powerful capability for ballistic mission design and optimization. The specific mission chosen is a cometary flyby past Giacobini-Zinner followed by a deep space burn 10 days after passage, a return to and swingby of Earth (unpowered), a second swingby of Earth (powered), and finally encountering the comet Borrelly nearly 1023 days from launch. The tremendous flexibility for creating imaginative, multi-target mission profiles is demonstrated in this example.

A. EXTRA ECLIPTIC MISSION

The objective of this mission is to place maximum payload in a circular orbit of 1.001 AU radius inclined 45 degrees to the ecliptic. The mission is $2\frac{1}{2}$ years (912.5 days) in duration and departs from Earth parking orbit on April 21, 1979. The solution given in this example is contained in the class of six-burn solutions which, for the mission duration assumed, tends to restrain the trajectory from deviating far from the nominal 1 AU solar distance. The specific case chosen uses the Titan III E/Centaur launch vehicle. The reference power (the power delivered to the power conditioners at 1 AU) is 20.35 kw and the specific impulse of the thrusters is 3000 seconds. The launch excess speed is optimized. The extra-ecliptic end conditions are invoked by setting IOUT = 1 and defining the desired values for AR, AE and AAI, the radius, eccentricity and inclination, respectively.

This case exhibits the use of several optional features of the program. A total of 0.65 kw of power developed by the solar arrays is reserved for housekeeping (non-propulsive) uses. This option is triggered with the input DPOW which is the ratio of housekeeping power to reference power. The power delivered to the power conditioners at distances below 1 AU is not permitted to exceed that delivered at 1 AU. This constraint is invoked by setting MODE equal to 5 and GAMMAX (the maximum permissible value of the power factor γ) equal to 1. The effects of launch asymptote declination are included in the launch vehicle performance model by setting LAUNCH equal to 1. The equatorial inclination of the launch parking orbit is limited to a maximum of 36 degrees through the input parameter XANG2. Since the geocentric declination of the launch asymptote for extra ecliptic missions is usually much greater than this inclination limit, the solution will include a non-coplanar injection maneuver from the launch parking orbit. The declination of the launch asymptote is optimized. Finally, the option of inputting the coefficients of the power profile is illustrated. The inputs for this case are listed on the next page.

It should be noted that the choice of final orbit radius of 1.001 AU rather than 1.0 AU was made to alleviate numerical difficulties arising as a result of the corner in the power curve at 1 AU. Neighboring trajectories terminating on opposite sides of the corner point tend to possess different partial derivatives (i.e., they will behave differently when subjected to the same perturbation). Consequently, if the final desired distance is exactly the point of the discontinuity, one might expect convergence retardation when the end conditions are nearly satisfied.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X7=1.D0,X10(2)=1.D0,X11(2)=1.D0,X12=2.94199D4
X13(2)=1.D0,X15=3.10370D1,X16=9.43537D2
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=1.D0,Y5(2)=1.D0,Y6(2)=1.D0
Y10(2)=1.D0,Y11=20.35D0,3.D0,Y13(2)=1.D0
LAUNCH=1,MBOOST=15,MTMASS=3,MODE=5
MOPT2=3,MOPT3=0,MYEAR=1979,MONTH=3,MDAY=21
BI=.63D0,DI=0.D0,CTANK=.035D0,GAMMAX=1.D0,DPOW=3.194103194103D-2
IOUT=1,AAI=45.D0,AR=1.001D0,XANG1=28.5D0,XANG2=36.D0
ASOL=1.4382D0,0.D0,-.2235D0,0.D0,-.2147D0
 X1=-1.849269016836D-02, X2=-3.444545869687D-01, X3=-5.292894680826D 00
 X4= 7.283860051662D-01, X5= 6.489958277263D-01, X6=-3.277641804973D-01
X10=-3.809150729556D 01,X11= 2.790574061256D-04,X13= 5.328606534645D 03
&END
```

CASE 1 TIME TO GO CPU 59, I/O 43 SEC

MINIMUM DENSITY = 0.0 MAXIMUM OPOWD = 1.4382000000000000D 00

PROGRAM INPUTS

X 1 =	-1.8492690168360000D-02,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 =	-3.4445458696870000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 =	-5.2928946808260000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 =	7.2838600516620000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 =	6.4839582772630000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 =	-3.2776418049730000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 =	1.0000000000000000D 00,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 =	-3.8091507295560000D 01,	1.0000000000000000D 00,	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 =	2.7905740612559999D-04,	1.0000000000000000D 00,	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 =	2.9419950000000000D 04,	0.0 ,	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 =	5.3286065346449999D 03,	1.0000000000000000D 00,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 =	3.1037000000000000D 01,	0.0 ,	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 =	9.4353700000000000D 02,	0.0 ,	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 =	0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 =	0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 =	0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,

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X59 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X60 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X61 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X62 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X63 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X64 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X65 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X66 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X67 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00.
X68 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00.
X69 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
X70 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00.
Y 1 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 2 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 3 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 4 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 5 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 6 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 7 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y 8 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y 9 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y10 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y11 =	2.0350000000000000D 01,	3.0000000000000000D 00,	9.9999999999999999D-05,		
Y12 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y13 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y14 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y15 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y16 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y17 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y18 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y19 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y20 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y21 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y22 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y23 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y24 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y25 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y26 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y27 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y28 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y29 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y30 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y31 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y32 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y33 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y34 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y35 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y36 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y37 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y38 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y39 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y40 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y41 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y42 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y43 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y44 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y45 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y46 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y47 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y48 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y49 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y50 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y51 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y52 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y53 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y54 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		

```
Y55 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y56 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y57 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y58 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y59 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y60 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y61 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y62 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y63 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y64 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y65 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y66 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y67 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y68 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y69 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
Y70 =  0.0                 ,  0.0               ,  9.999999999999999D-05,
&OUTPUT                                           ,ALPHAA=  15.0000000000000    ,ALPHAT=  15.0000000000000    ,ALTITU=
AAI=  45.0000000000000    ,AE= 0.0
 0.0               ,AN=  1.50000000000000    ,AR=  1.00100000000000    ,ASOL=  1.63820000000000    , 0.0               ,
-0.223500000000000   , 0.0               ,-0.214700000000000    ,BI= 0.630000000000000    ,B1= 0.0              ,B2=
 0.0               ,B3= 0.0               ,CNI= 0.0               ,CNIX= 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               ,CSTR= 0.0               ,CTANK= 0.3499999999999999D-01,
CTRET= 0.111111111111111   ,DI= 0.0               ,DMRETR= 0.0               ,DPOW= 0.3194103194102999D-01,ECI=
 0.0               ,ECIX= 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               ,EI= 0.0               ,EMUODD= 0.0               ,EMJODX= 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               ,GAMMAX=  1.00000000000000    ,GAP=
 0.9999999999999999D-04,HOUR=  12.0000000000000    ,OMI= 0.0               ,OMIX= 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               ,POWFIX= -1.00000000000000    ,
PSIGN=  1.00000000000000    ,RADODD=  1.00000000000000    ,RADODX= 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               ,RAP=  38.0000000000000    ,REVS= 0.0               ,
RPER=  2.00000000000000    ,SAI=  1.00000000000000    ,SAIX= 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               ,SOI= 0.0               ,SOIX= 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               ,SPIRET=  300.000000000000    ,
STATE=  1.00000000000000    , 0.0               , 0.0               , 0.0               , 1.00000000000000    ,
 0.0               ,STEP1= 0.3125000000000000D-01,STEP2= 0.125000000000000    ,TCOAST= 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               ,TDV= -1.00000000000000    ,TGO=
 -1.00000000000000    ,THRET=  400.000000000000    ,TOFF= -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    ,TPI= 0.0               ,TPIX= 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               ,TPOWER= 0.1000000000000000D 31,TSCALE=
  1.00000000000000    ,T2=  50.0000000000000    ,  100.000000000000    ,  150.000000000000    ,  200.000000000000    ,
  250.000000000000    ,  300.000000000000    ,  350.000000000000    ,  400.000000000000    ,  450.000000000000    ,
  500.000000000000    ,XANG1=  28.5000000000000    ,XANG2=  36.0000000000000    ,XSWING= 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               , 0.0               ,
 0.0               , 0.0               , 0.0               , 0.0               ,X0=  1.00000000000000    ,
 0.0               , 0.0               , 0.0               ,  1.00000150000000    , 0.0               ,
 0.0               ,IBAL=           0,INTPR=          0,IOJT=           1,IRK=            1,IRL=            1,IROT=           0,ISPIN=
          0,ITF=            3,ITPRNT=         0,JPP=            0,JPRINT=         0,JT=             0,KPART=          0,LAUNCH=
          1,LOADX=          0,MAXHAM=         5,MBOOST=        15,MDAY=          21,MODE=           5,MONTH=          3,MOPT=
          0,MOPTX=          0,         0,         0,         0,MOPT2=          3,MOPT3=          0,MOPT4=          0,
          0,         0,         0,         0,         0,         0,         0,         0,MPOW=           0,
MPRINT=        0,MPUNCH=         0,MREAD=          0,MSWING=         0,         0,         0,         0,         0,
          0,         0,         0,         0,MTMASS=         3,MUPDAT=         1,MYEAR=       1979,NDIST=
          3,NHUNG=         25,NORMAL=          0,NPERF=          0,NPRINT=         7,NSET=           0,         0,       300,
          0,       300,NSWING=          0,NSWPAR=         1,NTAPE=         17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	-1.8492690168360000D-02	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	-3.4445458696870000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-5.2928946808260000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	7.2838600516620000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	6.4899582772630000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	-3.2776418049730000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	10	-3.8091507295560000D 01	9.0000000000000000D 01	9.9999999999999990D-07	1.0000000000000000D 00
8	11	2.7905740612559990D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
9	13	5.3286065346449990D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	10	0.0	9.9999999999999990D-05
8	11	2.0350000000000000D 01	9.9999999999999990D-05
9	13	0.0	9.9999999999999990D-05

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---------- NOMINAL TRAJECTORY  1 (TOTAL    1) ---------- INHIBITOR IS    5.8208D-11 -----------------------------------------------------
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                                                  INDEPENDENT PARAMETERS
  1,PRIM1(-1.8492690D-02)   2,PRIM2(-3.4445459D-01)   3,PRIM3(-5.2928947D 00)   4,PDOT1( 7.2838601D-01)   5,PDOT2( 6.4899583D-01)
  6,PDOT3(-3.2776418D-01)  10,DECLN(-3.8091507D 01)  11,ACCEL( 2.7905741D-04)  13,VINF1( 5.3286065D 03)
                                                  DEPENDENT PARAMETERS
  1,DELTA X( 1.36734D-02)   2,DELTA Y(-2.04257D-02)   3,DELTA Z( 2.52203D-02)   4,DELT XD( 1.62397D-02)   5,DELT YD(-2.40807D-02)
  6,DELT ZD( 2.57904D-02)  10,T,DECLN( 1.75024D-09)  11, POWER ( 2.03500D 01)  13,T,VINF1(-3.71296D-09)
THRUST SWITCHING TIMES (DAYS)          0.0      ON        80.374   OFF      103.276   ON        218.909   OFF     247.259   ON        399.777   OFF
   439.175   ON       567.999   OFF      618.895   ON      749.493   OFF      809.322   ON       912.500   ON
                                              ELECTRIC PROPULSION PARAMETERS
     POWER                EFFICIENCY            PROP TIME                J                 PROP TIME RATIO          AVE ACCEL
     20.3499999990          0.6300000000         712.1252770929       11.3661826370          0.7804112626          0.0004309116
                                                  MASS COMPONENT BREAKDOWN
     INITIAL              PROPULSION            PROPELLANT            TANKAGE              STRUCTURE               PAYLOAD
   3123.1976935923        620.2499999709        1813.3820629241       63.4683722023          0.0                   626.0972584950

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---------- NOMINAL TRAJECTORY  2 (TOTAL    4) ---------- INHIBITOR IS    1.8190D-12 -----------------------------------------------------
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                                                  INDEPENDENT PARAMETERS
  1,PRIM1(-9.0058542D-03)   2,PRIM2(-3.5175913D-01)   3,PRIM3(-5.2008632D 00)   4,PDOT1( 6.9910970D-01)   5,PDOT2( 6.2888718D-01)
  6,PDOT3(-3.3398207D-01)  10,DECLN(-3.7843959D 01)  11,ACCEL( 2.6655743D-04)  13,VINF1( 5.1101377D 03)
                                                  DEPENDENT PARAMETERS
  1,DELTA X(-1.06725D-05)   2,DELTA Y(-9.99850D-04)   3,DELTA Z(-2.51111D-03)   4,DELT XD( 1.14983D-03)   5,DELT YD(-7.22438D-04)
  6,DELT ZD( 2.13528D-03)  10,T,DECLN( 2.70967D-03)  11, POWER ( 2.03067D 01)  13,T,VINF1(-1.69061D-03)
THRUST SWITCHING TIMES (DAYS)          0.0      ON        80.395   OFF      103.651   ON        219.584   OFF     247.918   ON        400.527   OFF
   439.396   ON       566.714   OFF      616.029   ON      747.829   OFF      804.878   ON       912.500   ON
                                              ELECTRIC PROPULSION PARAMETERS
     POWER                EFFICIENCY            PROP TIME                J                 PROP TIME RATIO          AVE ACCEL
     20.3066573251          0.6300000000         715.6762058950        9.8909155678          0.7843026914          0.0004008460
                                                  MASS COMPONENT BREAKDOWN
     INITIAL              PROPULSION            PROPELLANT            TANKAGE              STRUCTURE               PAYLOAD
   3262.5709661616        618.9289536062        1819.7281211922       63.5904842417          0.0                   760.2234071214

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---------- NOMINAL TRAJECTORY  3 (TOTAL    7) ---------- INHIBITOR IS    5.6843D-14 -----------------------------------------------------
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                                                  INDEPENDENT PARAMETERS
  1,PRIM1( 2.2736015D-03)   2,PRIM2(-3.7436282D-01)   3,PRIM3(-5.1922367D 00)   4,PDOT1( 7.0903573D-01)   5,PDOT2( 6.3603250D-01)
  6,PDOT3(-3.2226660D-01)  10,DECLN(-3.7854840D 01)  11,ACCEL( 2.6660044D-04)  13,VINF1( 5.0985903D 03)
                                                  DEPENDENT PARAMETERS
  1,DELTA X( 9.71723D-04)   2,DELTA Y(-4.33226D-04)   3,DELTA Z(-1.01801D-03)   4,DELT XD(-5.13886D-04)   5,DELT YD( 4.32699D-05)
  6,DELT ZD( 3.84511D-04)  10,T,DECLN(-3.74522D-05)  11, POWER ( 2.03500D 01)  13,T,VINF1( 3.24076D-05)
THRUST SWITCHING TIMES (DAYS)          0.0      ON        80.299   OFF      103.546   ON        220.043   OFF     248.369   ON        400.927   OFF
   439.925   ON       568.200   OFF      617.759   ON      749.422   OFF      806.781   ON       912.500   ON
                                              ELECTRIC PROPULSION PARAMETERS
     POWER                EFFICIENCY            PROP TIME                J                 PROP TIME RATIO          AVE ACCEL
     20.3499746867          0.6300000000         715.0113506695        9.8704819992          0.7835740829          0.0004006508
                                                  MASS COMPONENT BREAKDOWN
     INITIAL              PROPULSION            PROPELLANT            TANKAGE              STRUCTURE               PAYLOAD
   3269.1258074603        620.2492284722        1821.6164813205       63.7565768462          0.0                   763.5035208214

THIS CASE IS CONVERGED.

     8 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND    3 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.
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CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			**START OF TRAJECTORY, THRUST ON**				
0.0	8.98977775D-01	1.21180874D-01	9.22842759D 00	3.08348545D 01	1.80000000D 02	1.00498235D 00	0.0
-8.62926339D-01	-5.15119079D-01	0.0	4.96430685D-01	-7.80199267D-01	-1.50185951D-01	1.00000000D 00	4.46544954D-02
1.43302209D-03	-3.71273470D-01	-5.19222332D 00	7.08559116D-01	6.35286348D-01	-3.26439161D-01	1.00000000D 00	9.49111444D-02
0.0	0.0	0.0	8.60527166D 01	1.71366591D 01	9.41156981D-01	9.93095163D-01	4.19307526D 00
-7.70840302D 01	8.06481424D 01	8.79184672D 01	0.0	-1.49165146D 02	-1.61208637D 00	9.36851858D-01	0.0
			SWITCH THRUST OFF				
8.03383162D 01	9.24015325D-01	1.03022217D-01	1.19678031D 01	4.06593345D 01	2.52732848D 02	8.89443736D-01	8.23696730D 01
3.41100615D-01	-8.02334532D-01	-1.76124469D-01	9.42332071D-01	5.25634816D-01	-4.56244954D-02	9.37112533D-01	4.79824670D-02
3.97728374D-01	-4.69486344D-02	-1.11930619D 00	-4.70177337D-02	-6.32061682D-01	5.36711351D 00	1.25303011D 00	9.49111521D-02
-3.87479887D 00	-7.30163733D-02	0.0	9.74079507D 01	1.51105162D 01	9.56142362D-01	1.00000000D 00	-3.99680289D-15
-6.04197599D 01	4.47840023D 01	6.94899910D 01	-1.14209389D 01	-6.69679493D 01	-5.51206966D 00	1.07998300D 00	8.03383162D 01
			SWITCH THRUST ON				
1.03587476D 02	9.24015325D-01	1.03022217D-01	1.19678031D 01	4.05593345D 01	2.81687783D 02	8.52502666D-01	1.11324607D 02
6.63125730D-01	-5.07008397D-01	-1.73111372D-01	6.28717706D-01	9.29830855D-01	6.25834478D-02	9.37112533D-01	4.79824670D-02
4.07327513D-01	-3.99412178D-01	1.04297296D 00	1.31127036D-01	-1.05012549D 00	5.22760591D 00	1.25303011D 00	9.49111521D-02
-3.87479887D 00	-7.30163733D-02	0.0	9.04770078D 01	1.74834324D 02	9.56142362D-01	1.00000000D 00	-1.33226763D-15
7.32179111D 01	-3.52154795D 00	7.32505352D 01	-1.17161055D 01	-3.74005722D 01	-3.91080390D 00	1.12418886D 00	8.03383162D 01
			SWITCH THRUST OFF				
2.20047131D 02	9.26812233D-01	9.30891521D-02	1.57548141D 01	4.10752060D 01	7.03114536D 01	9.29508201D-01	2.60280593D 02
-3.17352054D-01	8.40718021D-01	2.37626552D-01	-9.84539957D-01	-2.99723195D-01	1.18969743D-01	8.45914448D-01	5.31554595D-02
-2.43332572D-01	-6.42014437D-01	1.19757838D 00	-8.53083278D-01	4.97309569D-01	-4.74623336D 00	1.61188302D 00	9.49111675D-02
-8.08440714D 00	-2.04809354D-01	0.0	8.92745773D 01	1.62097586D 02	9.58530572D-01	1.00000000D 00	-1.75415238D-14
6.39873057D 01	1.08435053D 02	9.79719829D 01	1.48119626D 01	1.10680388D 02	5.33875555D 00	1.03571631D 00	1.96797972D 02
			SWITCH THRUST ON				
2.48414939D 02	9.26812233D-01	9.30891521D-02	1.57548141D 01	4.10752060D 01	9.98993508D 01	9.72918798D-01	2.89868490D 02
-7.32170229D-01	5.85470285D-01	2.60235064D-01	-6.83124837D-01	-7.13729664D-01	-2.51642405D-02	8.45914448D-01	5.31554595D-02
-5.74162417D-01	-3.78433842D-01	-1.19695974D 00	-4.74087039D-01	5.85741621D-01	-4.83344864D 00	1.61188302D 00	9.49111675D-02
-8.08440714D 00	-2.04809354D-01	0.0	8.59477730D 01	3.68564479D 01	9.58530572D-01	1.00000000D 00	2.88657986D-15
-5.84964179D 01	9.92381776D 01	9.48121931D 01	1.55142903D 01	1.41352882D 02	4.51838882D 00	9.88282761D-01	1.96797972D 02

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
			SWITCH THRUST OFF				
4.01007063D 02	9.92879243D-01	4.02155666D-02	2.21269693D 01	3.93188421D 01	2.47986770D 02	9.75885413D-01	4.36104098D 02
2.48074136D-01	-8.80159405D-01	-3.40779965D-01	9.46754478D-01	3.59787121D-01	-1.31060568D-01	7.27681725D-01	6.17920853D-02
2.35527599D-01	2.13550188D-01	-1.69256092D 00	4.52371528D-01	-1.13072380D 00	4.56849831D 00	2.33764139D 00	9.49111744D-02
-1.55912236D 01	-4.38696216D-01	0.0	9.62761537D 01	9.56648768D 00	9.95627173D-01	1.00000000D 00	-2.22044605D-16
-6.60531536D 01	4.90300110D 01	7.45660917D 01	-2.04384401D 01	-7.42594368D 01	-2.08584300D 00	1.02090603D 00	3.49390095D 02
			SWITCH THRUST ON				
4.39995224D 02	9.92879243D-01	4.02155666D-02	2.21269693D 01	3.93188421D 01	2.89061430D 02	9.56648104D-01	4.77178758D 02
7.72434893D-01	-4.50032489D-01	-3.40574061D-01	5.47287023D-01	8.75159484D-01	1.34290227D-01	7.27681725D-01	6.17920853D-02
6.06462603D-01	-7.88401037D-01	1.40586852D 00	6.78391350D-01	-1.64098079D 00	4.29290007D 00	2.33764139D 00	9.49111744D-02
-1.55912236D 01	-4.38696216D-01	0.0	1.00617913D 02	1.82708336D 02	9.95627173D-01	1.00000000D 00	-1.42108547D-14
7.68214783D 01	-2.34991726D 01	7.79316696D 01	-2.08552147D 01	-3.02257379D 01	-9.69142906D-01	1.04089436D 00	3.49390095D 02
			SWITCH THRUST OFF				
5.68192252D 02	9.88050953D-01	2.60924695D-02	2.85385054D 01	3.92753538D 01	6.34800786D 01	9.91545574D-01	6.11386147D 02
-1.50680764D-01	8.83626362D-01	4.23865999D-01	-9.46930481D-01	-2.40255093D-01	2.24854678D-01	6.27292252D-01	7.16810563D-02
2.74751786D-01	-8.12647077D-01	1.79678239D 00	-1.20802370D 00	1.53921638D 00	-3.87447795D 00	3.13515823D 00	9.49111739D-02
-2.14980782D 01	-7.14745724D-01	0.0	7.88119551D 01	1.82664597D 02	9.93669095D-01	1.00000000D 00	-1.99840144D-15
8.02170366D 01	8.96381090D 01	8.99385092D 01	2.53077453D 01	9.96773020D 01	1.48136430D 00	1.00247667D 00	4.77587122D 02
			SWITCH THRUST ON				
6.17787734D 02	9.88050953D-01	2.60924695D-02	2.85385064D 01	3.92753538D 01	1.11915500D 02	1.00964716D 00	6.59821569D 02
-8.12635205D-01	3.98440091D-01	4.47500736D-01	-5.13813741D-01	-8.22276169D-01	-1.69274393D-01	6.27292252D-01	7.07254966D-02
-7.59651492D-01	6.68759640D-01	-1.71464309D 00	-1.11335732D 00	1.73741786D 00	-3.83105002D 00	3.13515823D 00	9.49111739D-02
-2.14980782D 01	-7.14745724D-01	0.0	7.33252181D 01	3.48989604D 00	9.93669095D-01	9.86669286D-01	0.0
-8.49679201D 01	4.86568434D 01	8.66783836D 01	2.63098225D 01	1.53881000D 02	8.16706132D-01	9.84274595D-01	4.77587122D 02
			SWITCH THRUST OFF				
7.49620995D 02	1.00804875D 00	1.32228657D-02	3.66979141D 01	3.85848967D 01	2.39910774D 02	9.98897052D-01	7.86976106D 02
4.07334674D-02	-8.54029807D-01	-5.16497041D-01	9.31329097D-01	2.34806476D-01	-2.96115285D-01	5.25445504D-01	8.55749471D-02
-6.46199962D-01	8.69900643D-01	-2.03255295D 00	1.22009578D 00	-1.96700217D 00	3.54878452D 00	4.32996125D 00	9.49111731D-02
-2.83589344D 01	-1.09577048D 00	0.0	1.07234215D 02	3.47675472D 02	1.00392853D 00	1.00000000D 00	-1.33226763D-15
-8.13025878D 01	3.62548364D 01	8.29959259D 01	-3.11357392D 01	-8.72693126D 01	-5.50853847D-01	1.00508349D 00	6.09420384D 02

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANG_E	VMAG	PROP TIME

SWITCH THRUST ON

8.069674900 02	1.008048750 00	1.32228657D-02	3.66979141D 01	3.85848967D 01	2.97121540D 02	9.94917420D-01	8.44186872D 02
7.97354840D-01	-2.72125911D-01	-5.29181842D-01	4.73837759D-01	8.47807930D-01	2.73680582D-01	5.25445504D-01	8.55749471D-02
7.83561757D-01	-1.42943432D 00	1.62736643D 00	1.50229447D 00	-2.19533704D 00	3.28679233D 00	4.32996125D 00	9.49111731D-02
-2.83589344D 01	-1.09577048D 00	0.0	1.13591407D 02	1.95687279D 02	1.00392853D 00	1.00000000D 00	-2.22044605D-16
7.94695982D 01	-6.86334532D 01	8.61821641D 01	-3.21329183D 01	-1.39440461D 01	1.30096642D-01	1.00905975D 00	6.09420384D 02

INPUT TARGET

END OF TRAJECTORY, THRUST ON

9.12500000D 02	1.00106538D 00	9.48292938D-05	4.49997836D 01	3.67623759D 01	4.27871776D 01	1.00097463D 00	9.48261908D 02
3.00751309D-01	8.24828464D-01	4.80787750D-01	-8.54397579D-01	9.15870555D-03	5.18688355D-01	4.42847453D-01	1.01398543D-01
1.21941148D 00	-1.87446810D 00	2.72866300D 00	-1.26430491D 00	1.82050334D 00	-2.36961053D 00	5.78219673D 00	9.49111759D-02
-3.47077081D 01	-1.51236697D 00	0.0	7.32087472D 01	2.02139546D 02	1.00053254D 00	9.98645954D-01	9.35519994D-01
8.38124147D 01	6.96227992D 01	8.78491690D 01	2.87062738D 01	6.99669886D 01	-1.59493295D-03	9.99558345D-01	7.14952894D 02

CASE 1

ITERATOR SUMMARY

INDEPENDENT PARAMETERS

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 1,PRIM1( 1.4330221D-03)  2,PRIM2(-3.7127347D-01)  3,PRIM3(-5.1922233D 00)  4,PDOT1( 7.0855915D-01)  5,PDOT2( 6.3528635D-01)
 6,PDOT3(-3.2643916D-01)  7,LMASS( 1.0000000D 00)  8, LTAJ( 0.0           )  9,     ( 0.0           ) 10,DECLN(-3.7853674D 01)
11,ACCEL( 2.6664805D-04) 12,V JET( 2.9419950D 04) 13,VINF1( 5.0995285D 03) 14,VINF2( 0.0           ) 15,TIME1( 3.1037000D 01)
16,TIME2( 9.4353700D 02) 17,IPARK( 0.0           ) 18,VELO1( 0.0           ) 19,VELO2( 0.0           ) 20,VELO3( 0.0           )
21,THET1( 0.0           ) 22,THET2( 0.0           ) 23,THET3( 0.0           ) 24,THET4( 0.0           ) 25,THET5( 0.0           )
26,THET6( 0.0           ) 27,THET7( 0.0           ) 28,THET8( 0.0           ) 29,THET9( 0.0           ) 30,LDEGR( 0.0           )
31, PHI1( 0.0           ) 32, PHI2( 0.0           ) 33, PHI3( 0.0           ) 34, PHI4( 0.0           ) 35, PHI5( 0.0           )
36, PHI6( 0.0           ) 37, PHI7( 0.0           ) 38, PHI8( 0.0           ) 39, PHI9( 0.0           ) 40,PHI10( 0.0           )
41,PR1-A( 0.0           ) 42,PR2-A( 0.0           ) 43,PR3-A( 0.0           ) 44,PD1-A( 0.0           ) 45,PD2-A( 0.0           )
46,PD3-A( 0.0           ) 47,VINFA( 0.0           ) 48,TIMEA( 0.0           ) 49,KSAMP( 0.0           ) 50,KDROP( 0.0           )
51,PR1-B( 0.0           ) 52,PR2-B( 0.0           ) 53,PR3-B( 0.0           ) 54,PD1-B( 0.0           ) 55,PD2-B( 0.0           )
56,PD3-B( 0.0           ) 57,VINFB( 0.0           ) 58,TIMEB( 0.0           ) 59,KSAMP( 0.0           ) 60,KDROP( 0.0           )
61,PR1-C( 0.0           ) 62,PR2-C( 0.0           ) 63,PR3-C( 0.0           ) 64,PD1-C( 0.0           ) 65,PD2-C( 0.0           )
66,PD3-C( 0.0           ) 67,VINFC( 0.0           ) 68,TIMEC( 0.0           ) 69,KSAMP( 0.0           ) 70,KDROP( 0.0           )
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DEPENDENT PARAMETERS

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 1,DELTA X( 3.62559D-05)  2,DELTA Y(-1.85804D-05)  3,DELTA Z(-4.36244D-05)  4,DELT XD(-4.20018D-05)  5,DELT YD( 2.21776D-05)
 6,DELT ZD( 4.21362D-05)  7.       ( 0.0        )  8.       ( 0.0        )  9.       ( 0.0        ) 10,T,DECLN( 5.77598D-07)
11, POWER ( 2.03500D 01) 12.       ( 0.0        ) 13,T,VINF1(-1.61358D-06) 14.       ( 0.0        ) 15.       ( 0.0        )
16.       ( 0.0        ) 17.       ( 0.0        ) 18.       ( 0.0        ) 19.       ( 0.0        ) 20.       ( 0.0        )
21.       ( 0.0        ) 22.       ( 0.0        ) 23.       ( 0.0        ) 24.       ( 0.0        ) 25.       ( 0.0        )
26.       ( 0.0        ) 27.       ( 0.0        ) 28.       ( 0.0        ) 29.       ( 0.0        ) 30.       ( 0.0        )
31.       ( 0.0        ) 32.       ( 0.0        ) 33.       ( 0.0        ) 34.       ( 0.0        ) 35.       ( 0.0        )
36.       ( 0.0        ) 37.       ( 0.0        ) 38.       ( 0.0        ) 39.       ( 0.0        ) 40.       ( 0.0        )
41.       ( 0.0        ) 42.       ( 0.0        ) 43.       ( 0.0        ) 44.       ( 0.0        ) 45.       ( 0.0        )
46.       ( 0.0        ) 47.       ( 0.0        ) 48.       ( 0.0        ) 49.       ( 0.0        ) 50.       ( 0.0        )
51.       ( 0.0        ) 52.       ( 0.0        ) 53.       ( 0.0        ) 54.       ( 0.0        ) 55.       ( 0.0        )
56.       ( 0.0        ) 57.       ( 0.0        ) 58.       ( 0.0        ) 59.       ( 0.0        ) 60.       ( 0.0        )
61.       ( 0.0        ) 62.       ( 0.0        ) 63.       ( 0.0        ) 64.       ( 0.0        ) 65.       ( 0.0        )
66.       ( 0.0        ) 67.       ( 0.0        ) 68.       ( 0.0        ) 69.       ( 0.0        ) 70.       ( 0.0        )
```

```
THRUST SWITCHING TIMES (DAYS)      0.0    ON     80.338  OFF    103.587  ON     220.047  OFF    248.415  ON    401.007  OFF
   439.995  ON     568.192  OFF    617.788  ON    749.621  OFF    806.967  ON     912.500  ON
```

ELECTRIC PROPULSION PARAMETERS

POWER	EFFICIENCY	PROP TIME	J	PROP TIME RATIO	AVE ACCEL
20.3499990796	0.6300000000	714.9528938345	9.8696171166	0.7835100206	0.0004006926

MASS COMPONENT BREAKDOWN

INITIAL	PROPULSION	PROPELLANT	TANKAGE	STRUCTURE	PAYLOAD
3268.5460092059	620.2499719473	1821.0787330785	63.7377556577	0.0	763.4795485224

SWITCH-COUNT HISTORY   ALL 12

422 THRUST COMPUTE STEPS.   32 COAST COMPUTE STEPS

LAUNCH ASYMPTOTE OFFSET FROM PRIMER = -32.786 DEGREES.

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC		SOLAR		COMMUNICATION				SWITCH				THRUST ANGLES				INPUT		ARRAY
		LONGITUDE		DISTANCE		ANGLE		DISTANCE		FUNCTION		PSI		THETA		PHI		POWER		ANGLE
0	0.0	0.0		1.005		75.7		0.0	ON	4.19D 00		-77.1		80.5		87.9		20.2	ON	0.0
4	1.065	1.0		1.004		75.3		0.00	MAX	4.19D 00		-77.1		80.5		87.9		20.2		0.0
5	8.379	7.6	*	1.000		72.6		0.03		4.15D 00		-77.2		79.6		87.7		20.3		0.0
4	8.428	7.7		1.000		72.5		0.03		4.15D 00	MIN	-77.2		79.5		87.7	MAX	20.3		0.7
4	80.338	82.2		0.889		52.3		0.24	OFF	-4.00D-15		-60.4		44.8		69.5		20.3		37.7
6	91.933	96.6		0.870		51.4		0.28	MIN	-7.45D-01		*****		******		*****		0.0		90.0
7	99.677	106.6		0.858	MIN	51.3		0.31		-3.23D-01		*****		******		*****		0.0		90.0
5	103.587	111.8		0.853		51.3		0.32	ON	-1.33D-15		73.2		-3.5		73.3		20.3		43.4
4	136.984	156.9	MIN	0.830		54.2		0.45		2.39D 00		85.4		-80.5		89.2		20.3		46.5
4	159.653	186.8		0.840		57.0		0.55	MAX	2.93D 00		87.2		-133.4		91.9		20.3		45.1
5	165.388	194.2		0.846		57.6		0.57		2.90D 00	MAX	87.3		-154.1		92.4		20.3		44.4
4	220.047	259.8		0.930		62.3		0.78	OFF	-1.75D-14		64.0		108.4		98.0		20.3		30.2
8	234.249	275.5		0.952		63.3		0.81	MIN	-7.08D-01		*****		******		*****		0.0		90.0
5	248.415	290.5		0.973		64.5		0.82	ON	2.39D-15		-58.5		99.2		94.8		20.3		18.8
4	257.189	299.5		0.984		65.3	MAX	0.82		6.50D-01		-68.1		97.2		92.7		20.3		14.5
4	272.871	314.9	*	1.000		66.7		0.82		1.74D 00		-74.7		93.7		91.0		20.3		0.0
5	315.465	353.8		1.019		70.4		0.74		3.47D 00	MIN	-78.1		84.3		88.8		19.9		0.0
4	316.969	355.2	MAX	1.019		70.5		0.74		3.49D 00		-78.1		84.0		88.8	MIN	19.8		0.0
5	325.138	362.3		1.018		70.9		0.72	MAX	3.53D 00		-78.0		82.1		88.4		19.8		0.0
4	335.882	371.8		1.016	MAX	71.1		0.70		3.45D 00		-77.7		79.5		87.8		19.9		0.0
4	356.876	390.7		1.006		70.3	MIN	0.69		2.84D 00		-76.5		73.6		86.2		20.2		0.0
3	366.544	399.8	*	1.000		69.5		0.59		2.33D 00		-75.6		70.3		85.2		20.3		0.0
6	401.007	434.9		0.976		65.2		0.75	OFF	-2.22D-16		-66.1		49.0		74.6		20.3		17.8
6	420.432	456.6		0.965		62.8		0.80	MIN	-1.24D 00		*****		******		*****		0.0		90.0
5	439.995	478.9		0.957		61.1		0.84	ON	-1.42D-14		76.8		-23.5		77.9		20.3		23.8
4	461.762	503.1	MIN	0.953		60.2		0.87		1.52D 00		83.1		-60.5		86.6		20.3		24.6
4	467.030	508.7		0.954	MIN	60.2		0.87		1.31D 00		83.9		-67.2		87.6		20.3		24.6
5	476.946	518.9		0.955		60.3	MAX	0.87		2.27D 00		84.9		-78.6		89.0		20.3		24.3
4	503.064	544.6		0.962		61.2		0.87	MAX	2.79D 00		87.6		-115.0		91.0		20.3		22.2
6	509.882	551.0		0.965		61.5	MIN	0.87		2.75D 00		88.1		-133.9		91.3		20.3		21.4
5	518.520	559.2		0.969		61.8		0.87		2.51D 00	MAX	88.5		-172.2		91.5		20.3		20.3
4	529.847	570.1		0.974		62.1		0.87		2.26D 00		87.8		139.0	MAX	91.6		20.3		18.5
4	544.170	584.0		0.980	MAX	62.3		0.89		1.53D 00		86.0		111.0		91.4		20.3		16.0
4	568.192	608.8		0.992		61.9		0.94	OFF	-2.00D-15		80.2		89.6		89.9		20.3		10.5
5	588.100	630.6	*	1.000		61.3		0.97		-1.51D 00		*****		******		*****		0.0		90.0
6	593.002	636.1		1.002		61.2		0.98	MIN	-1.72D 00		*****		******		*****		0.0		90.0
5	604.245	648.5		1.006	MIN	61.1		0.99		-1.04D 00		*****		******		*****		0.0		90.0
5	613.892	658.9		1.009		61.2	MAX	1.00		-2.92D-01		*****		******		*****		0.0		90.0
6	617.788	663.0		1.010		61.3		1.00	ON	0.0		-85.0		48.7		86.7		20.1		0.0
5	633.894	679.4		1.013		62.1		0.98		1.10D 00		-87.1	MIN	42.5		87.9		20.0		0.0
5	651.984	696.2		1.015		63.6		0.94		2.04D 00	MIN	-87.6		48.8		88.4		19.9		0.0
4	658.478	701.9	MAX	1.015		64.3		0.92		2.28D 00		-87.5		52.6		88.5	MIN	19.9		0.0
4	668.726	710.5		1.014		65.4		0.88		2.56D 00		-87.4		57.8	MAX	88.6		19.9		0.0
6	683.476	722.6		1.013		66.8		0.83	MAX	2.71D 00		-86.8		62.1		88.5		20.0		0.0
7	692.955	730.2		1.011		67.4		0.81		2.65D 00		-86.3	MAX	62.8		88.3		20.0		0.0
4	704.384	739.6		1.009	MAX	67.7		0.79		2.41D 00		-85.6		61.9		87.9		20.1		0.0
6	711.876	745.9		1.007		67.6	MIN	0.78		2.15D 00		-85.1		60.3		87.6		20.1		0.0
4	743.566	775.5	*	1.000		64.5		0.85		4.29D-01		-82.3		42.9		84.3		20.3		0.0
4	749.621	781.9		0.999		63.6		0.87	OFF	-1.33D-15		-81.3		36.3		83.0		20.3		3.8
6	778.265	815.8		0.995		59.6		0.99	MIN	-2.00D 00		*****		******		*****		0.0		90.0
5	796.948	838.7	MIN	0.995		58.1		1.03		-7.51D-01		*****		******		*****		0.0		90.0
6	806.967	850.3		0.995		57.8		1.04	ON	-2.22D-16		79.5		-68.6		86.2		20.3		8.2
5	809.171	852.8		0.995	MIN	57.8		1.04		1.57D-01		80.1		-70.6		86.7		20.3		8.1
4	810.095	853.8		0.995		57.8	MAX	1.04		2.22D-01		80.3		-71.4		86.9		20.3		8.0
4	857.824	896.6		1.000		62.1		0.92		2.29D 00		88.4		-116.9	MAX	90.7		20.3		2.3
5	863.133	900.6	*	1.000		62.8		0.90		2.33D 00		89.1		-136.6		90.7		20.3		0.0
4	866.463	903.1		1.000		63.3		0.89	MAX	2.34D 00		89.4		-165.0		90.6		20.3		0.0
5	868.262	904.4		1.000		63.5		0.88		2.34D 00	MAX	89.4		171.9		90.6		20.3		0.0
6	895.587	924.9		1.001		65.7	MIN	0.82		1.75D 00		86.2		81.6		89.5		20.3		0.0
5	896.651	925.8	MAX	1.001		65.7		0.83		1.71D 00		86.1		80.8		89.4	MIN	20.3		0.0
4	898.104	926.9		1.001	MAX	65.7		0.83		1.55D 00		85.9		79.8		89.3		20.3		0.0
5	912.500	939.1		1.001		65.1		0.85	ON	9.35D-01		83.8		69.6		87.8		20.3	ON	0.0

ORIGINAL PAGE IS OF POOR QUALITY

MISSION SCHEDULE

APRIL 21, 1979 1.2888000D 01 G.M.T.
2443985.0370 00 JULIAN DATE

DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-8.6292634D-01	-5.1511908D-01	0.0	4.9631842D-01	-8.6241113D-01	0.0	1.0049824D 00	0.0	-149.165
S/C	-8.6292634D-01	-5.1511908D-01	0.0	4.9543063D-01	-7.8019927D-01	-1.5018595D-01	1.0049824D 00	0.0	-149.165

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

OUT OF ECLIPTIC MISSION FINAL INCLINATION = 44.9998 DEG

LAUNCH VEHICLE IS TITAN III E/CENTAUR (COEFFICIENTS = 157238.9500 3480.2038 1753.6965)

LD = APR 21, 1979, 12.8880 HOURS GMT
JULIAN DATE 43985.0370

AD = OCT 20, 1981, 0.8880 HOURS GMT
JULIAN DATE 44897.5370

FLIGHT TIME = 912.5000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.0000	0.0350	0.0	0.63000	0.0	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
3268.5460	620.2500	1821.0797	63.7378	0.0	763.4795

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
20.3500	0.6500	20.3224	0.871551	2.6664830-04	3000.000	0.63000	1.0000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
1.0189599	0.8296067	20.349999	0.87155141	714.95289	710.01587	948.26191

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-37.8537	36.0000 AT LIMIT	5099.62849	26.006211	0.0	0.0

B. COMET RENDEZVOUS MISSION

The objective of this mission is to deliver maximum payload to the comet Tempel II, rendezvousing at perihelion of the comet's path in the 1988 apparition. For the case shown, the arrival date is fixed at September 16, 1988; the launch date and launch excess speed are optimized to yield maximum payload for the nominally 4-year class of solutions. The launch vehicle assumed is the Titan III E/Centaur. The electric propulsion system parameters are representative of projections of the SERT III spacecraft. Specifically, the reference power is 8.671 kw, the specific impulse is 2900 seconds, the efficiency is 0.63376 and the specific propulsion system mass (arrays plus power conditioning and thruster subsystem) is 30.285 kg/kw.

This example illustrates the use of the solar array degradation option. This option is invoked by setting the characteristic degradation time TPOWER to a value less than 10^{10}. In this case, it is set to 7121 days which means that if the arrays were situated at 1 AU and oriented normal to the sun line for this amount of time, the power developed by the array would degrade to 1/e of its initial power output. The input MPOW = 1 forces the arrays to be oriented normal to the sun line throughout the mission. Setting the triggers X30(2) and Y30(2) to 1 results in the optimal adjustment of the trajectory to accomodate the degradation. The complete set of inputs for this case follows and the resultant program output begins on the next page.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X11(2)=1.D0,X13(2)=1.D0,X15(2)=1.D0,X7=1.D0
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=1.D0,Y5(2)=1.D0,Y6(2)=1.D0
Y13(2)=1.D0,Y15(2)=1.D0,ALPHAT=15.285D0,MBOOST=15,MTMASS=3
MOPT2=3,MOPT3=43,MYEAR=1988,MONTH=9,MDAY=16,HOUR=17.22D0
X12=2.8439285D4,BI=.63376D0,DI=0.D0,CTANK=.1D0,Y11=8.671D0,3.D0,1.D-3
TPOWER=7121.D0,MPOW=1,X30(2)=1.D0,Y30(2)=1.D0
 X1= 5.072998588224D 00, X2= 3.350183672126D 00, X3=-2.159808142389D 00
 X4=-2.069314933312D 00, X5= 4.565247741305D 00, X6= 3.317322088503D-01
X11= 1.647979654151D-04,X13= 6.718039798493D 03,X15=-1.517625284470D 03
X30=-4.657406222646D-03 &END
```

CASE 1 TIME TO GO CPU 59, I/O 43 SEC

PROGRAM INPUTS

X 1 =	5.072998588224000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 2 =	3.350183672126000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 3 =	-2.159808142389000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 4 =	-2.069314933120000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 5 =	4.565247741305000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 6 =	3.317322088503000D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 7 =	1.000000000000000D 00,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X 8 =	0.0 ,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X 9 =	0.0 ,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X10 =	0.0 ,	0.0 ,	9.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X11 =	1.647979654151000D-04,	1.000000000000000D 00,	9.999999999999999D-04,	1.000000000000000D-11,	1.000000000000000D 00,
X12 =	2.843928500000000D 04,	0.0 ,	2.000000000000000D 03,	9.999999999999999D-04,	1.000000000000000D 00,
X13 =	6.718039798492999D 03,	1.000000000000000D 00,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X14 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-04,	1.000000000000000D 00,
X15 =	-1.517625284470000D 03,	1.000000000000000D 00,	8.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X16 =	0.0 ,	0.0 ,	1.000000000000000D 02,	9.999999999999999D-07,	1.000000000000000D 00,
X17 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X18 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X19 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X20 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X21 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X22 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X23 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X24 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X25 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X26 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X27 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X28 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X29 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X30 =	-4.657406222645999D-03,	1.000000000000000D 00,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X31 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X32 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X33 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X34 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X35 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X36 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X37 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X38 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X39 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X40 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X41 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X42 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X43 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X44 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X45 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X46 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X47 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X48 =	0.0 ,	0.0 ,	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X49 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X50 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X51 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X52 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X53 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X54 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X55 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X56 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X57 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X58 =	0.0 ,	0.0 ,	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X59 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X60 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,

X61 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X62 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X63 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X64 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X65 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X66 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X67 =	0.0	0.0	5.000000000000000D 02	9.999999999999999D-05	1.000000000000000D 00
X68 =	0.0	0.0	5.000000000000000D 01	9.999999999999999D-07	1.000000000000000D 00
X69 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X70 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
Y 1 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y 2 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y 3 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y 4 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y 5 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y 6 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y 7 =	0.0	0.0	9.999999999999999D-05		
Y 8 =	0.0	0.0	9.999999999999999D-05		
Y 9 =	0.0	0.0	9.999999999999999D-05		
Y10 =	0.0	0.0	9.999999999999999D-05		
Y11 =	8.671000000000000D 00	3.000000000000000D 00	9.999999999999999D-04		
Y12 =	0.0	0.0	9.999999999999999D-05		
Y13 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y14 =	0.0	0.0	9.999999999999999D-05		
Y15 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y16 =	0.0	0.0	9.999999999999999D-05		
Y17 =	0.0	0.0	9.999999999999999D-05		
Y18 =	0.0	0.0	9.999999999999999D-05		
Y19 =	0.0	0.0	9.999999999999999D-05		
Y20 =	0.0	0.0	9.999999999999999D-05		
Y21 =	0.0	0.0	9.999999999999999D-05		
Y22 =	0.0	0.0	9.999999999999999D-05		
Y23 =	0.0	0.0	9.999999999999999D-05		
Y24 =	0.0	0.0	9.999999999999999D-05		
Y25 =	0.0	0.0	9.999999999999999D-05		
Y26 =	0.0	0.0	9.999999999999999D-05		
Y27 =	0.0	0.0	9.999999999999999D-05		
Y28 =	0.0	0.0	9.999999999999999D-05		
Y29 =	0.0	0.0	9.999999999999999D-05		
Y30 =	0.0	1.000000000000000D 00	9.999999999999999D-05		
Y31 =	0.0	0.0	9.999999999999999D-05		
Y32 =	0.0	0.0	9.999999999999999D-05		
Y33 =	0.0	0.0	9.999999999999999D-05		
Y34 =	0.0	0.0	9.999999999999999D-05		
Y35 =	0.0	0.0	9.999999999999999D-05		
Y36 =	0.0	0.0	9.999999999999999D-05		
Y37 =	0.0	0.0	9.999999999999999D-05		
Y38 =	0.0	0.0	9.999999999999999D-05		
Y39 =	0.0	0.0	9.999999999999999D-05		
Y40 =	0.0	0.0	9.999999999999999D-05		
Y41 =	0.0	0.0	9.999999999999999D-05		
Y42 =	0.0	0.0	9.999999999999999D-05		
Y43 =	0.0	0.0	9.999999999999999D-05		
Y44 =	0.0	0.0	9.999999999999999D-05		
Y45 =	0.0	0.0	9.999999999999999D-05		
Y46 =	0.0	0.0	9.999999999999999D-05		
Y47 =	0.0	0.0	9.999999999999999D-05		
Y48 =	0.0	0.0	9.999999999999999D-05		
Y49 =	0.0	0.0	9.999999999999999D-05		
Y50 =	0.0	0.0	9.999999999999999D-05		
Y51 =	0.0	0.0	9.999999999999999D-05		
Y52 =	0.0	0.0	9.999999999999999D-05		
Y53 =	0.0	0.0	9.999999999999999D-05		
Y54 =	0.0	0.0	9.999999999999999D-05		
Y55 =	0.0	0.0	9.999999999999999D-05		
Y56 =	0.0	0.0	9.999999999999999D-05		

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Y57 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y58 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y59 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y60 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y61 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y62 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y63 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y64 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y65 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y66 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y67 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y68 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y69 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
Y70 =  0.0                    ,   0.0                    ,   9.9999999999999990D-05,
&OUTPUT
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 0.0                ,AN=  1.50000000000000    ,AR=  1.00000000000000    ,ASOL= 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                ,B1= 0.633760000000000    ,B1= 0.0                ,B2=
 0.0                ,B3= 0.0                ,CNI= 0.0                ,CNIX= 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                ,CSTR= 0.0                ,CTANK= 0.100000000000000D 00,
CTRET= 0.111111111111111    ,DI= 0.0                ,DMRETR= 0.0                ,DPOW= 0.0                ,ECI=
 0.0                ,ECIX= 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                ,EI= 0.0                ,EMUODD= 0.0                ,EMUODX= 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                ,GAMMAX=  1.00000000000000    ,GAP=
 0.9999999999999999D-04,HOUR=  17.2200000000000    ,OMI= 0.0                ,OMIX= 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                ,POWFIX= -1.00000000000000    ,
PSIGN=  1.00000000000000    ,RADODD=  1.00000000000000    ,RADODX= 0.0                , 0.0                ,
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RPER=  2.00000000000000    ,SAI=  1.00000000000000    ,SAIX= 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                ,SOI= 0.0                ,SOIX= 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                ,SPIRET=  300.000000000000    ,
STATE=  1.00000000000000    , 0.0                , 0.0                , 0.0                ,  1.00000000000000    ,
 0.0                ,STEP1= 0.312500000000000D-01,STEP2= 3.12500000000000    ,TCOAST= 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                ,TDV= -1.00000000000000    ,TGO=
 -1.00000000000000    ,THRET=  400.000000000000    ,TOFF= -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000    , -1.00000000000000    ,TPI= 0.0                ,TPIX= 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                ,TPOWER=  7121.00000000000    ,TSCALE=
  1.00000000000000    ,T2=  50.0000000000000    ,  100.000000000000    ,  150.000000000000    ,  200.000000000000    ,
  250.000000000000    ,  300.000000000000    ,  350.000000000000    ,  400.000000000000    ,  450.000000000000    ,
  500.000000000000    ,XANG1= 0.0                ,XANG2=  32.5000000000000    ,XSWING= 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                , 0.0                ,
 0.0                , 0.0                , 0.0                , 0.0                ,X0=  1.00000000000000    ,
 0.0                , 0.0                , 0.0                ,  1.00000150000000    , 0.0                ,
 0.0                ,IBAL=            0,INTPR=            0,IOUT=            0,IRK=            1,IRL=            1,IROT=            0,ISPIN=
           0,ITF=            3,ITPRNT=            0,JPP=            0,JPRINT=            0,JT=            0,KPART=            0,LAUNCH=
           0,LOADX=            0,MAXHAM=            5,MBOOST=           15,MDAY=           16,MODE=            4,MONTH=            9,MOPT=
           0,MOPTX=            0,            0,            0,            0,            0,MOPT2=            3,MOPT3=           43,MOPT4=            0,
           0,            0,            0,            0,            0,            0,            0,            0,            0,MPOW=            1,
MPRINT=            0,MPUNCH=            0,MREAD=            0,MSWING=            0,            0,            0,            0,            0,
           0,            0,            0,            0,MTMASS=            3,MUPDAT=            1,MYEAR=         1988,NDIST=
           3,NHUNG=           25,NORMAL=            0,NPERF=            0,NPRINT=            7,NSET=            0,            0,          300,
           0,          300,NSWING=            0,NSWPAR=            1,NTAPE=           17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	5.0729985882240000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	3.3501836721260000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-2.1598081423890000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	-2.0693149333120000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	4.5652477413050000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	3.3173220885030000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	11	1.6479796541510000D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
8	13	6.7180397984929990D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00
9	15	-1.5176252844700000D 03	8.0000000000000000D 00	9.9999999999999990D-07	1.0000000000000000D 00
10	30	-4.6574062226459990D-03	1.0000000000000000D 01	9.9999999999999990D-05	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	11	8.6710000000000000D 00	9.9999999999999990D-04
8	13	0.0	9.9999999999999990D-05
9	15	0.0	9.9999999999999990D-05
10	30	0.0	9.9999999999999990D-05

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---------- NOMINAL TRAJECTORY  1 (TOTAL    1) ---------- INHIBITOR IS   5.8208D-11 -------------------------------------------
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                                                INDEPENDENT PARAMETERS
  1,PRIM1( 5.0729986D 00)   2,PRIM2( 3.3501837D 00)   3,PRIM3(-2.1598081D 00)   4,PDOT1(-2.0693149D 00)   5,PDOT2( 4.5652477D 00)
  6,PDOT3( 3.3173221D-01)  11,ACCEL( 1.6479797D-04)  13,VINF1( 6.7180398D 03)  15,TIME1(-1.5176253D 03)  30,LDEGR(-4.6574062D-03)
                                                 DEPENDENT PARAMETERS
  1,DELTA X(-8.88898D-02)   2,DELTA Y( 3.21013D-01)   3,DELTA Z(-1.56897D-03)   4,DELT XD(-1.14063D-01)   5,DELT YD( 2.32885D-01)
  6,DELT ZD( 5.61628D-03)  11, POWER ( 8.67100D 00)  13,T,VINF1(-4.41645D-02)  15,T,TIME1( 3.36196D-06)  30,T,DEGRD( 2.32504D-03)
THRUST SWITCHING TIMES (DAYS)          0.0     ON     1517.625  ON
                                             ELECTRIC PROPULSION PARAMETERS
      POWER               EFFICIENCY           PROP TIME                J                PROP TIME RATIO        AVE ACCEL
       8.6710000109         0.6337600000       1517.6252844700      1.0915980627        1.0000000000         0.0001829860
                                                MASS COMPONENT BREAKDOWN
      INITIAL             PROPULSION           PROPELLANT           TANKAGE              STRUCTURE              PAYLOAD
   2345.0574592971       262.6012353301       443.0100468725       44.3010046873        0.0                 1595.1451724072

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---------- NOMINAL TRAJECTORY  2 (TOTAL    6) ---------- INHIBITOR IS   5.9605D-08 -------------------------------------------
------------------------------------------------------------------------------------------------------------------------------
                                                INDEPENDENT PARAMETERS
  1,PRIM1( 5.3132693D 00)   2,PRIM2( 3.3270277D 00)   3,PRIM3(-2.1717152D 00)   4,PDOT1(-2.0698180D 00)   5,PDOT2( 4.7839810D 00)
  6,PDOT3( 3.1881327D-01)  11,ACCEL( 1.6287355D-04)  13,VINF1( 6.6779946D 03)  15,TIME1(-1.5192051D 03)  30,LDEGR(-2.8739127D-03)
                                                 DEPENDENT PARAMETERS
  1,DELTA X( 2.52805D-01)   2,DELTA Y( 3.10551D-02)   3,DELTA Z(-3.77541D-02)   4,DELT XD(-4.17647D-02)   5,DELT YD(-1.35767D-03)
  6,DELT ZD( 4.36855D-02)  11, POWER ( 8.65952D 00)  13,T,VINF1(-7.25369D-02)  15,T,TIME1( 4.72439D-03)  30,T,DEGRD( 3.86791D-03)
THRUST SWITCHING TIMES (DAYS)          0.0     ON     1519.205  ON
                                             ELECTRIC PROPULSION PARAMETERS
      POWER               EFFICIENCY           PROP TIME                J                PROP TIME RATIO        AVE ACCEL
       8.6595241412         0.6337600000       1519.2050826052      1.0241766936        1.0000000000         0.0001799814
                                                MASS COMPONENT BREAKDOWN
      INITIAL             PROPULSION           PROPELLANT           TANKAGE              STRUCTURE              PAYLOAD
   2369.6249929452       262.2536886154       429.0728049393       42.9072804939        0.0                 1635.3912188969

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---------- NOMINAL TRAJECTORY  3 (TOTAL   16) ---------- INHIBITOR IS   3.9063D-03 -------------------------------------------
------------------------------------------------------------------------------------------------------------------------------
                                                INDEPENDENT PARAMETERS
  1,PRIM1( 5.3133875D 00)   2,PRIM2( 3.3268842D 00)   3,PRIM3(-2.1717072D 00)   4,PDOT1(-2.0695322D 00)   5,PDOT2( 4.7840736D 00)
  6,PDOT3( 3.1878921D-01)  11,ACCEL( 1.6099008D-04)  13,VINF1( 6.7247596D 03)  15,TIME1(-1.5170481D 03)  30,LDEGR(-3.1763748D-03)
                                                 DEPENDENT PARAMETERS
  1,DELTA X(-7.41178D-04)   2,DELTA Y( 8.36556D-02)   3,DELTA Z(-1.09468D-02)   4,DELT XD(-5.15364D-02)   5,DELT YD( 4.91521D-02)
  6,DELT ZD( 8.26291D-03)  11, POWER ( 8.45577D 00)  13,T,VINF1(-2.37939D-02)  15,T,TIME1( 1.66400D-03)  30,T,DEGRD( 1.44320D-03)
THRUST SWITCHING TIMES (DAYS)          0.0     ON     1206.867  OFF    1375.891  ON     1519.048  ON
                                             ELECTRIC PROPULSION PARAMETERS
      POWER               EFFICIENCY           PROP TIME                J                PROP TIME RATIO        AVE ACCEL
       8.4557672000         0.6337600000       1350.0244116041      0.8691215491        0.8887305043         0.0001756068
                                                MASS COMPONENT BREAKDOWN
      INITIAL             PROPULSION           PROPELLANT           TANKAGE              STRUCTURE              PAYLOAD
   2340.9387961429       256.0829096522       373.4807477299       37.3480747730        0.0                 1674.0270639878
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---------- NOMINAL TRAJECTORY  4 (TOTAL  19) ---------- INHIBITOR IS   1.52590-05 ----------
                                        INDEPENDENT PARAMETERS
 1.PRIM1( 5.31320200 00)   2.PRIM2( 3.3269287D 00)   3.PRIM3(-2.1715769D 00)   4.PDOT1(-2.0689020D 00)   5.PDOT2( 4.7827008D 00)
 6.PDOT3( 3.18897250-01)  11.ACCEL( 1.62587400-04)  13.VINF1( 6.71318350 03)  15.TIME1(-1.51910230 03)  30.LDEGR(-6.19774630-03)
                                        DEPENDENT PARAMETERS
 1.DELTA X(-5.60128D-03)   2.DELTA Y(-1.72518D-02)   3.DELTA Z( 2.42312D-04)   4.DELT XD(-1.73773D-03)   5.DELT YD(-1.22757D-02)
 6.DELT ZD( 8.54559D-03)  11. POWER ( 8.56555D 00)  13.T.VINF1(-2.85065D-02)  15.T.TIME1( 4.81076D-04)  30.T.DEGRD(-1.46812D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1236.139  OFF   1372.865  ON    1519.102  ON
                                   ELECTRIC PROPULSION PARAMETERS
    POWER              EFFICIENCY          PROP TIME            J                PROP TIME RATIO        AVE ACCEL
  8.5655498465        0.6337600000     1382.3770869819     0.8952147629         0.9099960737        0.0001776305
                                      MASS COMPONENT BREAKDOWN
    INITIAL             PROPULSION          PROPELLANT          TANKAGE            STRUCTURE           PAYLOAD
 2348.0346249507     259.4076771027     380.8594236109     38.0859423611         0.0              1669.6815818760

---------- NOMINAL TRAJECTORY  5 (TOTAL  22) ---------- INHIBITOR IS   5.9605D-08 ----------
                                        INDEPENDENT PARAMETERS
 1.PRIM1( 5.2191362D 00)   2.PRIM2( 3.2734061D 00)   3.PRIM3(-2.1659385D 00)   4.PDOT1(-2.0287369D 00)   5.PDOT2( 4.6843639D 00)
 6.PDOT3( 3.0652065D-01)  11.ACCEL( 1.6373773D-04)  13.VINF1( 6.71453760 03)  15.TIME1(-1.5190635D 03)  30.LDEGR(-7.2061816D-03)
                                        DEPENDENT PARAMETERS
 1.DELTA X( 1.33510D-03)   2.DELTA Y( 2.14569D-03)   3.DELTA Z(-2.39479D-03)   4.DELT XD(-3.35654D-03)   5.DELT YD(-1.53897D-03)
 6.DELT ZD( 3.88323D-03)  11. POWER ( 8.62288D 00)  13.T.VINF1(-1.21597D-02)  15.T.TIME1( 4.41532D-04)  30.T.DEGRD(-2.53145D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1232.409  OFF   1374.451  ON    1519.064  ON
                                   ELECTRIC PROPULSION PARAMETERS
    POWER              EFFICIENCY          PROP TIME            J                PROP TIME RATIO        AVE ACCEL
  8.6228773519        0.6337600000     1377.0217396572     0.9071750874         0.9064938549        0.0001789778
                                      MASS COMPONENT BREAKDOWN
    INITIAL             PROPULSION          PROPELLANT          TANKAGE            STRUCTURE           PAYLOAD
 2347.1431552637     261.1438406008     382.7034428903     38.2703442890         0.0              1665.0255274835

---------- NOMINAL TRAJECTORY  6 (TOTAL  27) ---------- INHIBITOR IS   7.4506D-09 ----------
                                        INDEPENDENT PARAMETERS
 1.PRIM1( 5.1599153D 00)   2.PRIM2( 3.2549972D 00)   3.PRIM3(-2.1596535D 00)   4.PDOT1(-2.0104620D 00)   5.PDOT2( 4.6285800D 00)
 6.PDOT3( 2.8988390D-01)  11.ACCEL( 1.6440323D-04)  13.VINF1( 6.7141174D 03)  15.TIME1(-1.5189516D 03)  30.LDEGR(-5.9051982D-03)
                                        DEPENDENT PARAMETERS
 1.DELTA X( 7.45271D-04)   2.DELTA Y(-6.39267D-04)   3.DELTA Z(-1.51192D-03)   4.DELT XD(-7.33083D-04)   5.DELT YD(-3.71706D-03)
 6.DELT ZD( 1.70128D-03)  11. POWER ( 8.65910D 00)  13.T.VINF1(-3.47048D-03)  15.T.TIME1(-1.05360D-05)  30.T.DEGRD(-1.24976D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1237.403  OFF   1369.671  ON    1518.952  ON
                                   ELECTRIC PROPULSION PARAMETERS
    POWER              EFFICIENCY          PROP TIME            J                PROP TIME RATIO        AVE ACCEL
  8.6591006747        0.6337600000     1386.6839462631     0.9231469282         0.9129217404        0.0001799027
                                      MASS COMPONENT BREAKDOWN
    INITIAL             PROPULSION          PROPELLANT          TANKAGE            STRUCTURE           PAYLOAD
 2347.4620903736     262.2408639344     387.0564540193     38.7066454019         0.0              1659.4481270183
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---------- NOMINAL TRAJECTORY  7 (TOTAL  32) ---------- INHIBITOR IS   1.4901D-08 ------------------------------------------------
                                                    INDEPENDENT PARAMETERS
 1,PRIM1( 5.1336404D 00)   2,PRIM2( 3.2629313D 00)   3,PRIM3(-2.1557714D 00)   4,PDOT1(-2.0141728D 00)   5,PDOT2( 4.6048409D 00)
 6,PDOT3( 2.8387868D-01)  11,ACCEL( 1.6460417D-04)  13,VINF1( 6.7137432D 03)  15,TIME1(-1.5187710D 03)  30,LDEGR(-5.1412997D-03)
                                                    DEPENDENT PARAMETERS
 1,DELTA X( 2.35927D-04)   2,DELTA Y(-1.07608D-04)   3,DELTA Z(-5.52100D-04)   4,DELT XD(-3.29142D-04)   5,DELT YD(-3.09067D-03)
 6,DELT ZD( 7.41430D-04)  11, POWER ( 8.67053D 00)  13,T,VINF1(-6.54911D-04)  15,T,TIME1(-2.23381D-04)  30,T,DEGRD(-4.99774D-04)
THRUST SWITCHING TIMES (DAYS)          0.0      ON      1239.035   OFF    1368.048   ON     1518.771   ON
                                               ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME                J                 PROP TIME RATIO        AVE ACCEL
      8.6705313436        0.6337600000      1389.7585967565        0.9280672161          0.9150547169         0.0001801835
                                                 MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT           TANKAGE              STRUCTURE            PAYLOAD
   2347.6914743591     262.5870417409       388.4296679449       38.8429667945           0.0              1657.8317978787

---------- NOMINAL TRAJECTORY  8 (TOTAL  36) ---------- INHIBITOR IS   3.7253D-09 ------------------------------------------------
                                                    INDEPENDENT PARAMETERS
 1,PRIM1( 5.1088483D 00)   2,PRIM2( 3.2963260D 00)   3,PRIM3(-2.1550970D 00)   4,PDOT1(-2.0358208D 00)   5,PDOT2( 4.5872536D 00)
 6,PDOT3( 2.9845884D-01)  11,ACCEL( 1.6467645D-04)  13,VINF1( 6.7147767D 03)  15,TIME1(-1.5184032D 03)  30,LDEGR(-4.8228501D-03)
                                                    DEPENDENT PARAMETERS
 1,DELTA X( 2.39729D-04)   2,DELTA Y(-1.27285D-04)   3,DELTA Z(-8.13075D-05)   4,DELT XD(-1.09389D-04)   5,DELT YD(-1.96172D-03)
 6,DELT ZD( 4.01517D-04)  11, POWER ( 8.67200D 00)  13,T,VINF1(-1.39191D-04)  15,T,TIME1(-1.48701D-04)  30,T,DEGRD(-1.80187D-04)
THRUST SWITCHING TIMES (DAYS)          0.0      ON      1238.824   OFF    1363.853   ON     1518.433   ON
                                               ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME                J                 PROP TIME RATIO        AVE ACCEL
      8.6719973228        0.6337600000      1393.3738931869        0.9324505011          0.9176574035         0.0001803267
                                                 MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT           TANKAGE              STRUCTURE            PAYLOAD
   2347.0578738041     262.6314389198       389.7150553728       38.9715055373           0.0              1655.7398739742

---------- NOMINAL TRAJECTORY  9 (TOTAL  39) ---------- INHIBITOR IS   1.1642D-10 ------------------------------------------------
                                                    INDEPENDENT PARAMETERS
 1,PRIM1( 5.0760147D 00)   2,PRIM2( 3.3463430D 00)   3,PRIM3(-2.1582755D 00)   4,PDOT1(-2.0671646D 00)   5,PDOT2( 4.5669170D 00)
 6,PDOT3( 3.2898985D-01)  11,ACCEL( 1.6477406D-04)  13,VINF1( 6.7174628D 03)  15,TIME1(-1.5178833D 03)  30,LDEGR(-4.6613107D-03)
                                                    DEPENDENT PARAMETERS
 1,DELTA X( 4.84058D-04)   2,DELTA Y(-9.14775D-04)   3,DELTA Z(-1.93914D-05)   4,DELT XD( 2.53154D-04)   5,DELT YD(-7.39846D-04)
 6,DELT ZD( 1.52396D-04)  11, POWER ( 8.67105D 00)  13,T,VINF1(-1.48676D-04)  15,T,TIME1( 9.64158D-06)  30,T,DEGRD(-3.70422D-06)
THRUST SWITCHING TIMES (DAYS)          0.0      ON      1237.601   OFF    1356.688   ON     1517.883   ON
                                               ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME                J                 PROP TIME RATIO        AVE ACCEL
      8.6710499330        0.6337600000      1398.7961204684        0.9390740281          0.9215439260         0.0001805308
                                                 MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT           TANKAGE              STRUCTURE            PAYLOAD
   2345.4111595641     262.6027472223       391.5490838753       39.1549083875           0.0              1652.1044200790
THIS CASE IS CONVERGED.

   40 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND   9 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.
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ORIGINAL PAGE IS POOR QUALITY

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
S	LS	DENSITY	DPOWR	DPOWD	DEGRAD	CHI	CHI REF

EARTH

START OF TRAJECTORY, THRUST ON

0.0	1.88051647D 00	4.59968606D-01	3.61057023D 00	1.19246544D 02	1.80000000D 02	1.01599843D 00	0.0
4.96384945D-01	-8.86484515D-01	0.0	1.03372294D 00	6.02045556D-01	-7.54731520D-02	1.00000000D 00	2.72282147D-02
5.07390960D 00	3.34883875D 00	-2.15881492D 00	-2.06852277D 00	4.56573081D 00	3.31035699D-01	1.00000000D 00	-1.37300066D-02
0.0	0.0	0.0	7.63106077D 01	6.67251942D 01	1.21764260D 00	9.79862918D-01	5.23836841D 00
-1.59489053D 01	9.40953232D 01	9.39374288D 01	0.0	-6.07534559D 01	-9.68272173D-01	1.19864013D 00	0.0
0.0	-4.65592672D-03	9.68754933D-01	-1.24543143D 00	6.53083836D-01	1.00000000D 00	0.0	0.0

SWITCH THRUST OFF

1.23683102D 03	2.67049672D 00	4.90630378D-01	1.08825737D 01	1.25632040D 02	6.67674540D 01	2.73670624D 00	2.52946051D 02
-2.63611211D 00	-5.61296528D-01	4.74784359D-01	3.96566436D-01	-4.46020316D-01	-1.20115403D-02	8.71352371D-01	6.08287311D-03
3.75307033D-01	-1.41086288D 00	7.03135538D-01	1.92992332D-01	1.80125840D-01	-9.05853695D-01	1.77017914D 00	-1.37301267D-02
-1.95211637D 01	-1.88467069D-01	0.0	8.09210446D 01	1.30145263D 02	1.42395914D 00	1.90743054D-01	-1.27051147D-14
2.14624934D 01	8.81060683D 01	8.82374416D 01	9.99065272D 00	-1.67979755D 02	-2.93507184D 01	5.96945006D-01	1.23683102D 03
1.97788487D 02	-2.27625848D-04	1.33519174D-01	-1.27813690D-01	1.30988114D 00	9.72606808D-01	9.00000000D 01	9.00000000D 01

SWITCH THRUST ON

1.35715295D 03	2.67049672D 00	4.90630378D-01	1.08825737D 01	1.25632040D 02	9.63835672D 01	2.06764574D 00	2.82562264D 02
-1.50614591D 00	-1.36241789D 00	3.87944452D-01	7.10632057D-01	-2.85511823D-01	-7.90536006D-02	8.71352371D-01	1.00425665D-02
7.14174926D-01	-8.62338171D-01	-1.17179606D 00	1.30527923D-01	3.72514782D-01	-8.54746384D-01	1.77017914D 00	-1.37301267D-02
-1.95211637D 01	-1.88467069D-01	0.0	7.29375879D 01	5.70636244D 01	1.42395914D 00	3.14908724D-01	-8.23993651D-17
-4.44996537D 01	9.85505580D 01	9.60875600D 01	1.08142825D 01	-1.37868379D 02	-2.65512448D 01	7.69949037D-01	1.23683102D 03
1.97788487D 02	-2.27625848D-04	2.33909434D-01	-2.64923277D-01	1.17089652D 00	9.72606808D-01	0.0	0.0

TEMPEL II(1988)

END OF TRAJECTORY, THRUST ON

1.51785637D 03	3.03673004D 00	5.44431648D-01	1.24316650D 01	1.19118131D 02	1.91041078D 02	1.38343810D 00	3.70829354D 02
8.86771280D-01	-1.06032284D 00	-5.70362666D-02	7.86262148D-01	6.69570707D-01	-2.23246432D-01	8.33184679D-01	2.02263078D-02
6.32371134D-01	9.39816712D-01	-2.18494377D 00	-4.08075153D-01	8.72622840D-01	5.18177314D-01	1.88473916D 00	-1.37301441D-02
-2.05246983D 01	-2.61343285D-01	0.0	7.95785650D 01	2.02254602D 01	1.45172008D 00	6.06462629D-01	8.16486183D-01
-5.11364286D 01	9.83736007D 01	9.52427968D 01	-2.36285515D 00	-5.00935201D 01	2.63376380D-04	1.05658510D 00	1.39753444D 03
2.59774436D 02	2.21148515D-08	5.22493074D-01	-5.79867479D-01	9.00064153D-01	9.64177329D-01	0.0	0.0

CASE 1

ITERATOR SUMMARY

INDEPENDENT PARAMETERS

1.PRIM1(5.0739096D 00)	2.PRIM2(3.3488387D 00)	3.PRIM3(-2.1588149D 00)	4.PDOT1(-2.0685228D 00)	5.PDOT2(4.5657308D 00)
6.PDOT3(3.3103570D-01)	7.LMASS(1.0000000D 00)	8. LTAU(0.0)	9. (0.0)	10.DECLN(0.0)
11.ACCEL(1.6478510D-04)	12.V JET(2.8439285D 04)	13.VINF1(6.7177410D 03)	14.VINF2(0.0)	15.TIME1(-1.5178564D 03)
16.TIME2(0.0)	17.IPARK(0.0)	18.VELO1(0.0)	19.VELO2(0.0)	20.VELO3(0.0)
21.THET1(0.0)	22.THET2(0.0)	23.THET3(0.0)	24.THET4(0.0)	25.THET5(0.0)
26.THET6(0.0)	27.THET7(0.0)	28.THET8(0.0)	29.THET9(0.0)	30.LDEGR(-4.6559267D-03)
31. PHI1(0.0)	32. PHI2(0.0)	33. PHI3(0.0)	34. PHI4(0.0)	35. PHI5(0.0)
36. PHI6(0.0)	37. PHI7(0.0)	38. PHI8(0.0)	39. PHI9(0.0)	40.PHI10(0.0)
41.PR1-A(0.0)	42.PR2-A(0.0)	43.PR3-A(0.0)	44.PD1-A(0.0)	45.PD2-A(0.0)
46.PD3-A(0.0)	47.VINFA(0.0)	48.TIMEA(0.0)	49.KSAMP(0.0)	50.KDROP(0.0)
51.PR1-B(0.0)	52.PR2-B(0.0)	53.PR3-B(0.0)	54.PD1-B(0.0)	55.PD2-B(0.0)
56.PD3-B(0.0)	57.VINFB(0.0)	58.TIMEB(0.0)	59.KSAMP(0.0)	60.KDROP(0.0)
61.PR1-C(0.0)	62.PR2-C(0.0)	63.PR3-C(0.0)	64.PD1-C(0.0)	65.PD2-C(0.0)
66.PD3-C(0.0)	67.VINFC(0.0)	68.TIMEC(0.0)	69.KSAMP(0.0)	70.KDROP(0.0)

DEPENDENT PARAMETERS

1.DELTA X(4.65245D-06)	2.DELTA Y(-8.98292D-06)	3.DELTA Z(-6.49573D-07)	4.DELT XD(2.39851D-06)	5.DELT YD(-6.47139D-06)
6.DELT ZD(1.01292D-06)	7. (0.0)	8. (0.0)	9. (0.0)	10. (0.0)
11. POWER (8.67100D 00)	12. (0.0)	13.T.VINF1(-1.06427D-06)	14. (0.0)	15.T.TIME1(7.73449D-08)
16. (0.0)	17. (0.0)	18. (0.0)	19. (0.0)	20. (0.0)
21. (0.0)	22. (0.0)	23. (0.0)	24. (0.0)	25. (0.0)
26. (0.0)	27. (0.0)	28. (0.0)	29. (0.0)	30.T.DEGRD(2.21149D-08)
31. (0.0)	32. (0.0)	33. (0.0)	34. (0.0)	35. (0.0)
36. (0.0)	37. (0.0)	38. (0.0)	39. (0.0)	40. (0.0)
41. (0.0)	42. (0.0)	43. (0.0)	44. (0.0)	45. (0.0)
46. (0.0)	47. (0.0)	48. (0.0)	49. (0.0)	50. (0.0)
51. (0.0)	52. (0.0)	53. (0.0)	54. (0.0)	55. (0.0)
56. (0.0)	57. (0.0)	58. (0.0)	59. (0.0)	60. (0.0)
61. (0.0)	62. (0.0)	63. (0.0)	64. (0.0)	65. (0.0)
66. (0.0)	67. (0.0)	68. (0.0)	69. (0.0)	70. (0.0)

THRUST SWITCHING TIMES (DAYS) 0.0 ON 1236.831 OFF 1357.153 ON 1517.856 ON

ELECTRIC PROPULSION PARAMETERS

POWER	EFFICIENCY	PROP TIME	J	PROP TIME RATIO	AVE ACCEL
8.6710000072	0.6337600000	1397.5344446940	0.9382774144	0.9207290424	0.0001805291

MASS COMPONENT BREAKDOWN

INITIAL	PROPULSION	PROPELLANT	TANKAGE	STRUCTURE	PAYLOAD
2345.2405989059	262.6012352180	391.2220623059	39.1222062306	0.0	1652.2950951515

SWITCH-COUNT HISTORY 2.2.4.4.4.4.4.4.4/

204 THRUST COMPUTE STEPS. 7 COAST COMPUTE STEPS

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION		THRUST ANGLES PSI		THRUST ANGLES THETA		THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		1.016		86.1		0.0	ON	5.24D 00		-15.9		94.1		93.9		8.5	ON	0.0
4	1.834	2.1		1.016		87.7		0.01		5.25D 00		-15.8		93.4		93.3	MAX	8.5		0.0
4	2.644	3.1	MIN	1.016		88.4		0.01		5.25D 00		-15.7		93.1		93.0		8.5		0.0
4	13.958	16.2		1.024		98.7		0.05	MAX	5.30D 00		-14.4		88.8		88.9		8.4		0.0
5	83.425	80.3		1.364	MAX	166.0		0.38		4.45D 00		-0.4		69.7		69.7		5.5		0.0
4	152.250	114.2		1.867		115.4		1.22		3.83D 00		19.1		62.8	MIN	64.5		3.3		0.0
5	173.169	121.2		2.016		101.0		1.58	MIN	3.30D 00		24.6		62.0		64.8		2.9		0.0
4	226.549	135.4		2.372		67.2		2.57		3.94D 00		36.5	MIN	61.3		67.3		2.2		0.0
5	339.725	155.6		2.992	MIN	0.9		4.01		4.56D 00		51.5		63.0		73.6		1.4		0.0
7	367.048	159.4		3.115		16.9	MAX	4.07		4.70D 00		53.6		63.7		74.8		1.3		0.0
7	539.712	178.8		3.679		171.8	MIN	2.70		5.18D 00		61.0		68.7		79.9		1.0		0.0
5	546.123	179.4		3.694	MAX	178.3		2.71		5.18D 00		61.1		68.9		80.0		0.9		0.0
4	555.805	180.3		3.714		167.8		2.75	MAX	5.18D 00		61.3		69.2		80.2		0.9		0.0
4	714.156	194.5		3.913		24.1		4.82		4.85D 00	MAX	62.7		73.5		82.5		0.8		0.0
5	748.378	197.5		3.922		2.8	MAX	4.93		4.59D 00		62.7		74.3		82.9		0.8		0.0
5	748.744	197.5		3.922	MIN	2.8		4.93		4.59D 00		62.7		74.3		82.9		0.8		0.0
4	757.403	198.3	MAX	3.922		6.6		4.93		4.55D 00		62.6		74.5		83.0		0.8		0.0
5	759.248	198.4		3,922		7.8		4.92		4.54D 00		62.6		74.6		83.0	MIN	0.8		0.0
5	946.761	215.3		3.742	MAX	172.0		2.76		3.23D 00		59.7		78.9		84.4		0.9		0.0
5	953.421	216.0		3.729		168.6	MIN	2.75		3.17D 00		59.5		79.0		84.5		0.9		0.0
4	1131.643	236.1		3.207		17.6	MAX	4.16		1.13D 00		47.6		83.6		85.7		1.2		0.0
4	1157.452	239.7		3.103	MIN	6.7		4.10		8.55D-01		43.7		84.5		86.1		1.3		0.0
4	1236.831	252.8		2.737		50.4		3.25	OFF	-1.27D-14		21.5		88.1		88.2		1.7		0.0
5	1296.317	265.5		2.420		89.3		2.22	MIN	-2.87D-01		*****		******		*****		0.0		90.0
7	1357.153	282.9		2.068		134.8		1.24	ON	-8.24D-17		-44.5		98.6		96.1		2.7		0.0
5	1394.950	297.1		1.845	MAX	158.0		0.87		3.37D-01		-54.7		102.7		97.3		3.3		0.0
6	1432.834	315.0		1.636		133.2	MIN	0.76		6.55D-01		-58.8		105.2		97.8		4.0		0.0
5	1441.845	319.9		1.591		125.7		0.77		7.17D-01		-59.1		105.4	MAX	97.8		4.2		0.0
4	1444.313	321.3		1.579		123.8		0.77		7.33D-01		-59.1	MAX	105.4		97.8		4.3		0.0
4	1446.468	322.6		1.569		122.1		0.77		7.45D-01	MIN	-59.1		105.4		97.8		4.3		0.0
4	1489.227	350.0		1.417		97.8		0.86	MAX	8.79D-01		-56.3		102.6		96.9		5.1		0.0
4	1517.072	370.1		1.383		89.4		0.96		8.20D-01		-51.3		98.5		95.3	MAX	5.3		0.0
3	1517.855	370.7	MIN	1.383		89.2		0.96		8.15D-01		-51.1		98.4		95.2		5.3		0.0
4	1517.856	370.7		1.383		89.2		0.96	ON	8.15D-01		-51.1		98.4		95.2		5.3	ON	0.0

MISSION SCHEDULE

JULY 21, 1984 2.0667050 3D 01 G.M.T.
2445903.361D 00 JULIAN DATE — DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	4.96384940D-01	-8.86484510D-01	0.0	8.56335750D-01	4.84968630D-01	0.0	1.01599840 00	0.0	-60.753
S/C	4.96384940D-01	-8.86484510D-01	0.0	1.03372290 00	6.02045560D-01	-7.54731520D-02	1.01599840 00	0.0	-60.753

SEPTEMBR 16, 1988 1.72200000D 01 G.M.T.
2447421.218D 00 JULIAN DATE — ARRIVE AT TEMPEL II(1988)

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	8.86766630-01	-1.06031390 00	-5.70356170-02	7.86259750-01	6.69577180-01	-2.23247440-01	1.38342820 00	-2.363	-50.093
S/C	8.86771280-01	-1.06032280 00	-5.70362670-02	7.86252150-01	6.69570710-01	-2.23246430-01	1.38343810 00	-2.363	-50.094

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND TEMPEL II(1988) IS 10.9158 DEGREES.

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

EARTH TO TEMPEL II(1988) WITH FIXED ARRIVAL EXCESS SPEED

ARRIVAL AT TEMPEL II(1988) PERIHELION

LAUNCH VEHICLE IS TITAN III E/CENTAUR (COEFFICIENTS = 167238.9500 3480.2038 1753.6965)

LD = JUL 21, 1984, 20.6671 HOURS GMT
JULIAN DATE 45903.3611

AD = SEP 16, 1988, 17.2200 HOURS GMT
JULIAN DATE 47421.2175

FLIGHT TIME = 1517.8564 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.2850	0.1000	0.0	0.63376	0.0	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
2345.2406	262.6012	391.2221	39.1222	0.0	1652.2951

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
8.6710	0.0	5.2586	0.386461	1.647851D-04	2900.000	0.63376	7.1210000D 03 CONSTRAINED MAX

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
3.9221510	1.0155371	8.498784	0.37878516	1397.53444	259.77444	370.82935

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-5.7634	28.5000	6717.74104	45.128045	0.20776	0.000000

C. MULTIPLE BALLISTIC SWINGBY MISSION

This computer run demonstrates how the program may be effectively used in the investigation of all-ballistic missions (with electric propulsion absent).

In general, trajectories are forced to be all-ballistic by setting the propulsion-time adjoint variable X8 to a "large" negative number (X8 = - 1.D3) with respect to the mass ratio adjoint variable X7 = 1.D0. These settings (together with the reference thrust acceleration X11 = 1.D-4, jet exhaust speed X12 = 1.D0, and non-zero primer vector components X2 = .1D0 at the launch planet and X42 = .1D0 at the first intermediate-target) guarantee that the electric propulsion thrust switch-function will be maintained negative, yielding ballistic flight at all times. The electric propulsion specific masses ALPHAA and ALPHAT are also set to zero, so that the net spacecraft mass equals the launch vehicle payload.

The particular ballistic mission simulation demonstrated here involves a March 6, 1985 launch of a 1,635 kg payload by an Atlas/Centaur launch vehicle (using the launch vehicle selection default-value of MBOOST = 0; actually, changing MBOOST alters the payload mass computation but not the C_3 or the trajectory).

The primary target is the Earth, specified by MOPT3 = 3, and there is one intermediate target, the comet Giacobini-Zinner, specified by MOPTX = 41. The launch occurs fifteen days before (X15 = - 15.D0) the reference date (MYEAR = 1985, MONTH = 3, MDAY = 21), and the spacecraft passes Giacobini-Zinner 174.22 days (X48) after the reference date and arrives back at Earth 353 days (X16) after the reference date.

Ten days after passing Giacobini-Zinner a deep-space burn (of 188.9 m/sec) makes possible the re-targeting to Earth. This is accomplished by inputting TDV = 1.00010D5 together with X64(2), X65(2), and X66(2) = 1.D0.

The deep space burn velocity-increment (X64, X65, X66) initial guess is the zero vector, by default. The deep-space burn could just have well occurred before arriving at Giacobini-Zinner (e.g., TDV = 2.00005D5). The iteration sequence consists of a 6x6 hunt, with the independent variables being the initial heliocentric velocity at Earth (X18, X19, X20) and the deep-space burn velocity increment (X64, X65, X66), and the dependent variables being the position targeting at Giacobini-Zinner (Y41, Y42, Y43) and at Earth (Y1, Y2, Y3). The setting MAXHAM = 0 is made to avoid an unwarranted BAD HAMILTONIAN warning message due to the presence of the deep-space burn.

The detailed printout of the iteration sequence is omitted by setting NPRINT = 3 (compared to the default value NPRINT = 7), and three extra lines are added to each print-block by setting MPRINT = 2.

Finally, the multiple ballistic swingby option is invoked by means of MOPT4 = -3, 42, which directs the spacecraft to swingby the primary target (Earth) in such a manner as to re-target to Earth (MOPT4(1) = -3), and then, at the second Earth passage, to again swingby in such a manner as to target to the comet Borrelly (MOPT4(2) = 42). Furthermore, the first Earth swingby is specified as unpowered (MSWING(1) = -1) having T2(1) = 480 days as the initial guess of the Earth-to-Earth transfer time, and the second Earth swingby is specified to be powered (MSWING(2) = -5) with a specified transfer time from Earth to Borrelly (T2(2) = 127 days) and using the input Earth-departure heliocentric velocity initial-guess XSWING(1,2) = .62D0, .91D0, 0.D0. Both swingby iterations converged, and the powered-swingby incremental speed turned out to be -13.7 m/sec, the minus sign denoting a braking burn. The default value of TGO = - 1.D0 resulted in the printout of several pages describing the trajectory segments following the time of primary target passage.

It should be noted that the trajectory simulation would have terminated at the primary target (first Earth encounter) if MOPT4(1) were zero, and would have terminated at the second Earth encounter had MOPT4(2) been zero. The mission, as simulated, thus consists initially of a comet-flyby, followed by a second comet-flyby making use of a double Earth-swingby to reach the second comet.

The inputs for this computer run are listed below, and the resulting program output is displayed on the following pages.

```
&MINPUT X7=1.D0,X2=.1D0,X42=.1D0,X8=-1.D3,ALPHAA=0.D0,ALPHAT=0.D0
X64(2)=1.D0,X65(2)=1.D0,X66(2)=1.D0,X18(2)=1.D0,X19(2)=1.D0,X20(2)=1.D0
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y41(2)=1.D0,Y42(2)=1.D0,Y43(2)=1.D0
MYEAR=1985,MONTH=3,MDAY=21,MOPT2=3,MOPT3=3,MOPTX=41,X11=1.D-4,X12=1.D0
TDV=1.00010D5,X15=-15.D0,X16=353.D0,X48=174.22D0
X18=-8.3276D-2,X19=-1.00340D0,X20=-2.0143D-3
T2=480.D0,127.D0,XSWING(1,2)=.62D0,.91D0,0.D0
MOPT4=-3,42,MSWING=-1,-5,MPRINT=2,MAXHAM=0,NPRINT=3 &END
```

CASE 1 TIME TO GO CPU 59, I/O 43 SEC

PROGRAM INPUTS

X 1 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 =	1.0000000000000000D-01,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 =	1.0000000000000000D 00,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 =	-1.0000000000000000D 03,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 =	0.0 ,	0.0 ,	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 =	9.9999999999999999D-05,	0.0 ,	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 =	1.0000000000000000D 00,	0.0 ,	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 =	-1.5000000000000000D 01,	0.0 ,	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 =	3.5300000000000000D 02,	0.0 ,	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 =	-8.3276000000000000D-02,	1.0000000000000000D 00,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 =	-1.0034000000000000D 00,	1.0000000000000000D 00,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 =	-2.0143000000000000D-03,	1.0000000000000000D 00,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 =	1.0000000000000000D-01,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 =	1.7422000000000000D 02,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X59 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X60 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,

X61 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X62 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X63 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X64 =	0.0	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X65 =	0.0	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X66 =	0.0	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X67 =	0.0	0.0	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X68 =	0.0	0.0	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X69 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X70 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
Y 1 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y 2 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y 3 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y 4 =	0.0	0.0	9.999999999999999D-05,		
Y 5 =	0.0	0.0	9.999999999999999D-05,		
Y 6 =	0.0	0.0	9.999999999999999D-05,		
Y 7 =	0.0	0.0	9.999999999999999D-05,		
Y 8 =	0.0	0.0	9.999999999999999D-05,		
Y 9 =	0.0	0.0	9.999999999999999D-05,		
Y10 =	0.0	0.0	9.999999999999999D-05,		
Y11 =	0.0	0.0	9.999999999999999D-05,		
Y12 =	0.0	0.0	9.999999999999999D-05,		
Y13 =	0.0	0.0	9.999999999999999D-05,		
Y14 =	0.0	0.0	9.999999999999999D-05,		
Y15 =	0.0	0.0	9.999999999999999D-05,		
Y16 =	0.0	0.0	9.999999999999999D-05,		
Y17 =	0.0	0.0	9.999999999999999D-05,		
Y18 =	0.0	0.0	9.999999999999999D-05,		
Y19 =	0.0	0.0	9.999999999999999D-05,		
Y20 =	0.0	0.0	9.999999999999999D-05,		
Y21 =	0.0	0.0	9.999999999999999D-05,		
Y22 =	0.0	0.0	9.999999999999999D-05,		
Y23 =	0.0	0.0	9.999999999999999D-05,		
Y24 =	0.0	0.0	9.999999999999999D-05,		
Y25 =	0.0	0.0	9.999999999999999D-05,		
Y26 =	0.0	0.0	9.999999999999999D-05,		
Y27 =	0.0	0.0	9.999999999999999D-05,		
Y28 =	0.0	0.0	9.999999999999999D-05,		
Y29 =	0.0	0.0	9.999999999999999D-05,		
Y30 =	0.0	0.0	9.999999999999999D-05,		
Y31 =	0.0	0.0	9.999999999999999D-05,		
Y32 =	0.0	0.0	9.999999999999999D-05,		
Y33 =	0.0	0.0	9.999999999999999D-05,		
Y34 =	0.0	0.0	9.999999999999999D-05,		
Y35 =	0.0	0.0	9.999999999999999D-05,		
Y36 =	0.0	0.0	9.999999999999999D-05,		
Y37 =	0.0	0.0	9.999999999999999D-05,		
Y38 =	0.0	0.0	9.999999999999999D-05,		
Y39 =	0.0	0.0	9.999999999999999D-05,		
Y40 =	0.0	0.0	9.999999999999999D-05,		
Y41 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y42 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y43 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y44 =	0.0	0.0	9.999999999999999D-05,		
Y45 =	0.0	0.0	9.999999999999999D-05,		
Y45 =	0.0	0.0	9.999999999999999D-05,		
Y47 =	0.0	0.0	9.999999999999999D-05,		
Y48 =	0.0	0.0	9.999999999999999D-05,		
Y49 =	0.0	0.0	9.999999999999999D-05,		
Y50 =	0.0	0.0	9.999999999999999D-05,		
Y51 =	0.0	0.0	9.999999999999999D-05,		
Y52 =	0.0	0.0	9.999999999999999D-05,		
Y53 =	0.0	0.0	9.999999999999999D-05,		
Y54 =	0.0	0.0	9.999999999999999D-05,		
Y55 =	0.0	0.0	9.999999999999999D-05,		
Y56 =	0.0	0.0	9.999999999999999D-05,		

```
Y57 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y58 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y59 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y60 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y61 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y62 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y63 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y64 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y65 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y66 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y67 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y68 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y69 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
Y70 =  0.0                 ,  0.0                ,  9.9999999999999990-05,
&OUTPUT
AAI= 0.0               ,AE= 0.0               ,ALPHAA= 0.0               ,ALPHAT= 0.0               ,ALTITU=
 0.0                   ,AN=  1.50000000000000    ,AR=  1.00000000000000    ,ASOL= 0.0              , 0.0                ,
 0.0                   , 0.0                   , 0.0                   ,BI= 0.760000000000000    ,BI= 0.0               ,B2=
 0.0                   ,B3= 0.0                ,CNI= 0.0               ,CNIX=  31.8737400000000   , 0.0                ,
 0.0                   , 0.0                   , 0.0                   ,CSTR= 0.0                 ,CTANK= 0.29999999999999990-01,
CTRET= 0.111111111111111   ,DI=  13.0000000000000    ,DMRETR= 0.0          ,DPOW= 0.0               ,ECI=
 0.0                   ,ECIX= 0.707553500000000   , 0.0                   , 0.0                , 0.0                ,
 0.0                   ,EI= 0.0                ,EMUDDD= 0.0            ,EMUDDX= 0.0              ,
 0.0                   , 0.0                   , 0.0                   , 0.0                ,GAMMAX=  1.00000000000000    ,GAP=
0.99999999999999990-04,HOUR=  12.0000000000000    ,OMI= 0.0          ,OMIX=  195.207380000000   ,
 0.0                   , 0.0                   , 0.0                   , 0.0                ,POWFIX= -1.00000000000000    ,
PSIGN=  1.00000000000000    ,RADDDD=  1.00000000000000    ,RADDDX=  1.00000000000000    , 0.0               ,
 0.0                   , 0.0                   , 0.0                   ,RAP=  38.0000000000000    ,REVS= 0.0               ,
RPER=  2.00000000000000    ,SAI=  1.00000000000000    ,SAIX=  3.51601400000000    , 0.0             ,
 0.0                   , 0.0                   , 0.0                   ,SDI= 0.0               ,SDIX=  172.482230000000   ,
 0.0                   , 0.0                   , 0.0                   , 0.0                ,SPIRET=  300.000000000000   ,
STATE=  1.00000000000000    , 0.0                 , 0.0                 , 0.0                ,  1.00000000000000   ,
 0.0                   ,STEP1= 0.31250000000000000-01,STEP2= 0.125000000000000    ,TCOAST= 0.0          ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                ,TDV=  100010.000000000    ,TGO=
 -1.00000000000000     ,THRET=  400.000000000000    ,TOFF= -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000     , -1.00000000000000     , -1.00000000000000     , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000     , -1.00000000000000     , -1.00000000000000     , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000     , -1.00000000000000     , -1.00000000000000     , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000     , -1.00000000000000     ,TPI= 0.0              ,TPIX=  168.195833333332    , 0.0          ,
 0.0                   , 0.0                   , 0.0                   ,TPOWER= 0.10000000000000000 31,TSCALE=
  1.00000000000000     ,T2=  480.000000000000    ,  127.000000000000    ,  150.000000000000    ,  200.000000000000   ,
  250.000000000000     ,  300.000000000000     ,  350.000000000000     ,  400.000000000000    ,  450.000000000000   ,
  500.000000000000     ,XANG1= 0.0             ,XANG2= 0.0             ,XSWING= 0.0          ,
 0.0                   , 0.0                   , 0.620000000000000     , 0.910000000000000    , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                , 0.0                ,
 0.0                   , 0.0                   , 0.0                   , 0.0                ,X0=  1.00000000000000    ,
 0.0                   , 0.0                   , 0.0                   ,  1.00001500000000   , 0.0                ,
 0.0                   ,IBAL=          0,INTPR=           0,IOUT=           0,IRK=           1,IRL=           1,IROT=           0,ISPIN=
        0,ITF=          3,ITPRNT=          0,JPP=          0,JPRINT=          0,JT=          0,KPART=          0,LAUNCH=
        0,LOADX=          0,MAXHAM=          0,MBOOST=          0,MDAY=         21,MODE=          4,MONTH=          3,MOPT=
        0,MOPTX=         41,          0,          0,          0,          0,MOPT2=          3,MOPT3=          3,MOPT4=         -3,
       42,          0,          0,          0,          0,          0,          0,          0,MPOW=          0,
MPRINT=          2,MPUNCH=          0,MREAD=          0,MSWING=         -1,         -5,          0,          0,          0,
        0,          0,          0,          0,          0,MTMASS=          0,MUPDAT=          1,MYEAR=       1985,NDIST=
        3,NHUNG=         25,NORMAL=          0,NPERF=          0,NPRINT=          3,NSET=          0,          0,        300,
        0,        300,NSWING=          0,NSWPAR=          1,NTAPE=         17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	18	-8.3276000000000000D-02	1.0000000000000000D 00	9.9999999999999990D-05	1.0000000000000000D 00
2	19	-1.0034000000000000D 00	1.0000000000000000D 00	9.9999999999999990D-05	1.0000000000000000D 00
3	20	-2.0143000000000000D-03	1.0000000000000000D 00	9.9999999999999990D-05	1.0000000000000000D 00
4	64	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	65	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	66	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	41	0.0	9.9999999999999990D-05
5	42	0.0	9.9999999999999990D-05
6	43	0.0	9.9999999999999990D-05

THIS CASE IS CONVERGED.

8 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 3 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
R1 REL	R2 REL	R3 REL	V1 REL	V2 REL	V3 REL	RMAG REL	VMAG REL
S/C NUC MAG	S/C TOT MAG	GEO NUC MAG	GEO TOT MAG	ANG(V,R)	ANG(V,XY)		
R1 REL ECL	R2 REL ECL	R3 REL ECL	V1 REL ECL	V2 REL ECL	V3 REL ECL	RMAG ECL	VMAG ECL

EARTH — START OF TRAJECTORY, THRUST OFF

0.0	9.96643137D-01	9.87735807D-02	1.01229330D-01	3.45870942D 02	1.80000000D 02	9.92238982D-01	0.0
-9.62222104D-01	2.42212345D-01	0.0	-1.48125469D-01	-9.95153753D-01	-1.76892321D-03	1.00000000D 00	1.70303186D-02
0.0	1.00000000D-01	0.0	0.0	0.0	0.0	1.00000000D 00	-2.47940469D-02
0.0	0.0	0.0	9.67331739D 01	2.82491762D 02	9.93438306D-01	1.00991974D 00	-8.85036241D 04
-9.81671658D-02	-7.58709206D 01	7.58709418D 01	0.0	1.65870942D 02	-5.66291334D 00	1.00611892D 00	0.0
-3.49582889D 08	-1.42900098D 08	3.84025044D 07	4.08434740D 01	-1.50175577D 01	-1.45372304D 01	3.79609518D 08	4.58807963D 01
1.91253369D 01	1.89370829D 01	1.91253369D 01	1.89370829D 01	2.71005439D 01	-1.84724012D 01		
-3.79705824D 07	3.39819832D 08	-1.64876024D 08	-2.41704518D 01	-3.89301082D 01	2.29856657D 00	3.79609518D 08	4.58807963D 01

GIACOB-ZIN(1985) — END OF TRAJECTORY SEGMENT 1, THRUST OFF

1.89220000D 02	9.96643137D-01	9.87735807D-02	1.01229530D-01	3.45870942D 02	2.92569026D 01	1.03183011D 00	2.09256903D 02
9.96072788D-01	2.69279731D-01	8.90960221D-04	-1.65104405D-01	9.52719015D-01	1.55112643D-03	1.00000000D 00	1.61945216D-02
8.90534139D-02	5.19545571D-02	2.91500507D-04	7.03097557D-02	-5.99105494D-02	-1.24999359D-04	1.00000000D 00	-2.47940469D-02
0.0	0.0	0.0	9.01062897D 01	7.62730611D 01	9.93438306D-01	9.60355902D-01	-9.15340905D 04
9.11813763D-02	1.51319843D 01	1.51322526D 01	4.94735194D-02	1.51278063D 01	5.29627289D 00	9.66920588D-01	0.0
-1.63493260D 01	-2.38745810D 01	-1.40731107D 01	6.03322532D-01	-1.39200454D 01	1.51802097D 01	3.21768321D 01	2.06051069D 01
-1.69850237D 01	-1.82688858D 01	1.51106013D 01	1.33954481D 01	8.83221259D 01	4.74528177D 01		
-8.55279570D 00	-3.10126809D 01	6.41739067D-01	1.55860006D 00	-3.52045428D 00	2.02422231D 01	3.21768321D 01	2.06051069D 01

GIACOB-ZIN(1985) — START OF TRAJECTORY SEGMENT 2, THRUST OFF

1.89220000D 02	9.96643137D-01	9.87735807D-02	1.01229530D-01	3.45870942D 02	2.92569026D 01	1.03183011D 00	2.09256903D 02
9.96072788D-01	2.69279731D-01	8.90960221D-04	-1.65104405D-01	9.52719015D-01	1.56112643D-03	1.00000000D 00	1.61945216D-02
8.90534139D-02	5.19545571D-02	2.91500507D-04	7.03097557D-02	-5.99105494D-02	-1.24999359D-04	1.00000000D 00	-2.47940469D-02
0.0	0.0	0.0	9.01062897D 01	7.52730611D 01	9.93438306D-01	9.60355902D-01	-9.15340905D 04
9.11813763D-02	1.51319843D 01	1.51322526D 01	4.94735194D-02	1.51278063D 01	5.29627289D 00	9.66920588D-01	0.0
-1.20874445D 07	6.81851853D 07	1.33286758D 05	-9.82665934D 00	-2.68677323D 00	4.64980206D-02	6.92484193D 07	1.01874501D 01
1.57399077D 01	1.33414852D 01	-1.00000000D 30	-1.00000000D 30	1.64705936D 02	2.61512895D-01		
1.24923929D 06	6.92370220D 07	1.33286758D 05	-1.01599126D 01	-7.47097032D-01	4.64980206D-02	6.92484193D 07	1.01874501D 01

DEEP SPACE BURN 188.9 METERS/SECOND AT 199.22 DAYS

EARTH — END OF TRAJECTORY, THRUST OFF

3.68000000D 02	9.98616572D-01	1.03484708D-01	1.07925514D-01	3.48629200D 02	1.79998265D 02	9.92956978D-01	3.62756518D 02
-9.73461071D-01	1.95798630D-01	5.66445051D-08	-9.54343053D-02	-1.00184298D 00	-1.88553052D-03	1.00000000D 00	1.70147744D-02
4.42397226D-02	5.72647197D-01	9.08642764D-04	-4.71642417D-01	9.01774272D-02	-1.06553100D-05	1.00000000D 00	-2.52050791D-02
0.0	0.0	0.0	9.61297040D 01	2.82703697D 02	9.93942806D-01	1.00899794D 00	-8.85567936D 04
-1.64883689D-02	-8.30450704D 01	8.30450707D 01	3.26851127D-06	1.69627465D 02	-5.93102027D 00	1.00637995D 00	0.0
9.37043785D 02	-4.49482319D 03	8.47396132D 00	-3.55105422D 00	-1.77653929D-01	-5.61603693D-02	4.59146582D 03	3.55593883D 00
-4.52697209D 00	-7.58024821D 00	-1.00000000D 30	-1.00000000D 30	1.76996516D 02	-9.04932867D-01		
-3.24620058D 01	4.59134325D 03	8.47396132D 00	3.51637918D 00	-5.25950998D-01	-5.61603693D-02	4.59146582D 03	3.55593883D 00

CASE 1

ITERATOR SUMMARY

INDEPENDENT PARAMETERS

1.PRIM1(0.0)	2.PRIM2(1.0000000D-01)	3.PRIM3(0.0)	4.PDOT1(0.0)	5.PDOT2(0.0)
6.PDOT3(0.0)	7.LMASS(1.0000000D 00)	8. LTAJ(-1.0000000D 03)	9. (0.0)	10.DECLN(0.0)
11.ACCEL(1.0000000D-04)	12.V JET(1.0000000D 00)	13.VINF1(0.0)	14.VINF2(0.0)	15.TIME1(-1.5000000D 01)
16.TIME2(3.5300000D 02)	17.IPARK(0.0)	18.VEL01(-1.4812547D-01)	19.VEL02(-9.9515375D-01)	20.VEL03(-1.7689232D-03)
21.THET1(0.0)	22.THET2(0.0)	23.THET3(0.0)	24.THET4(0.0)	25.THET5(0.0)
26.THET6(0.0)	27.THET7(0.0)	28.THET8(0.0)	29.THET9(0.0)	30.LDEGR(0.0)
31. PHI1(0.0)	32. PHI2(0.0)	33. PHI3(0.0)	34. PHI4(0.0)	35. PHI5(0.0)
36. PHI6(0.0)	37. PHI7(0.0)	38. PHI8(0.0)	39. PHI9(0.0)	40.PHI10(0.0)
41.PR1-A(8.9053414D-02)	42.PR2-A(5.1954557D-02)	43.PR3-A(2.9150051D-04)	44.PD1-A(7.0309756D-02)	45.PD2-A(-5.9910549D-02)
46.PD3-A(-1.2499936D-04)	47.VINFA(0.0)	48.TIMEA(1.7422000D 02)	49.KSAMP(0.0)	50.KDROP(0.0)
51.PR1-B(0.0)	52.PR2-B(0.0)	53.PR3-B(0.0)	54.PD1-B(0.0)	55.PD2-B(0.0)
56.PD3-B(0.0)	57.VINFB(0.0)	58.TIMEB(0.0)	59.KSAMP(0.0)	60.KDROP(0.0)
61.PR1-C(0.0)	62.PR2-C(0.0)	63.PR3-C(0.0)	64.PD1-C(5.5704329D-03)	65.PD2-C(3.0309412D-03)
66.PD3-C(1.4643332D-04)	67.VINFC(0.0)	68.TIMEC(0.0)	69.KSAMP(0.0)	70.KDROP(0.0)

DEPENDENT PARAMETERS

1.DELTA X(-2.16993D-07)	2.DELTA Y(3.06910D-05)	3.DELTA Z(5.66445D-08)	4. (0.0)	5. (0.0)
6. (0.0)	7. (0.0)	8. (0.0)	9. (0.0)	10. (0.0)
11. (0.0)	12. (0.0)	13. (0.0)	14. (0.0)	15. (0.0)
16. (0.0)	17. (0.0)	18. (0.0)	19. (0.0)	20. (0.0)
21. (0.0)	22. (0.0)	23. (0.0)	24. (0.0)	25. (0.0)
26. (0.0)	27. (0.0)	28. (0.0)	29. (0.0)	30. (0.0)
31. (0.0)	32. (0.0)	33. (0.0)	34. (0.0)	35. (0.0)
36. (0.0)	37. (0.0)	38. (0.0)	39. (0.0)	40. (0.0)
41.DEL X A(-5.71715D-08)	42.DEL Y A(-2.07305D-07)	43.DEL Z A(4.28973D-09)	44. (0.0)	45. (0.0)
46. (0.0)	47. (0.0)	48. (0.0)	49. (0.0)	50. (0.0)
51. (0.0)	52. (0.0)	53. (0.0)	54. (0.0)	55. (0.0)
56. (0.0)	57. (0.0)	58. (0.0)	59. (0.0)	60. (0.0)
61. (0.0)	62. (0.0)	63. (0.0)	64. (0.0)	65. (0.0)
66. (0.0)	67. (0.0)	68. (0.0)	69. (0.0)	70. (0.0)

THRUST SWITCHING TIMES (DAYS) 0.0 OFF 189.220 VISIT 199.220 ON 368.000 OFF

ELECTRIC PROPULSION PARAMETERS

POWER	EFFICIENCY	PROP TIME	J	PROP TIME RATIO	AVE ACCEL
18175.6839354431	0.0000000045	0.0	0.0	0.0	0.0001000000

MASS COMPONENT BREAKDOWN

INITIAL	PROPULSION	PROPELLANT	TANKAGE	STRUCTURE	PAYLOAD
1634.7360602603	0.0	0.0	0.0	0.0	1634.7360602603

SWITCH-COUNT HISTORY ALL 5

0 THRUST COMPUTE STEPS. 52 COAST COMPUTE STEPS

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE	COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992	3.4		0.0	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0
4	82.559	93.1	MIN	0.898	54.6		0.23		-8.19D 04	*****	******	*****	0.0		90.0
5	179.513	200.2		1.016	77.6	MAX	0.47		-9.03D 04	*****	******	*****	0.0		90.0
4	189.220	209.3		1.032	79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
0	189.220	209.3		1.032	79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
4	199.220	218.3		1.047	82.5		0.45	OFF	-9.27D 04	*****	******	*****	0.0		90.0
4	267.702	275.6	MAX	1.102	106.2		0.29		-9.72D 04	*****	******	*****	0.0		90.0
4	368.000	362.8		0.993	101.8		0.00	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0

CASE 1

MISSION SCHEDULE

MARCH 6, 1985 1.200000000 01 G.M.T.
2446131.0000 00 JULIAN DATE — DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-9.6222210D-01	2.4221234D-01	0.0	-2.6045055D-01	-9.7355492D-01	0.0	9.9223898D-01	0.0	165.871
S/C	-9.6222210D-01	2.4221234D-01	0.0	-1.4812547D-01	-9.9515375D-01	-1.7689232D-03	9.9223898D-01	0.0	165.871

SEPTEMBR 11, 1985 1.728000000 01 G.M.T.
2446320.2200 00 JULIAN DATE — PASS GIACOB-ZIN(1985) AT 20.605 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	9.9607285D-01	2.6927994D-01	8.9095593D-04	-2.1743291D-01	1.0709149D 00	-6.7805209D-01	1.0318302D 00	0.049	15.128
S/C	9.9607279D-01	2.6927973D-01	8.9096022D-04	-1.6510441D-01	9.5271901D-01	1.5611264D-03	1.0318301D 00	0.049	15.128

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND GIACOB-ZIN(1985) IS 209.2569 DEGREES.

MARCH 9, 1986 1.200000000 01 G.M.T.
2446499.0000 00 JULIAN DATE — PASS EARTH AT 3.556 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-9.7346085D-01	1.9576794D-01	0.0	-2.1349335D-01	-9.8418468D-01	0.0	9.9295071D-01	0.0	168.629
S/C	-9.7346107D-01	1.9579863D-01	5.6644505D-08	-9.5434305D-02	-1.0018430D 00	-1.8355305D-03	9.9295698D-01	0.000	168.627

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND EARTH IS 2.7583 DEGREES.

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

EARTH TO EARTH FLYBY

WITH VISITATION OF GIACOB-ZIN(1985)

LAUNCH VEHICLE IS ATLAS(SLV3X)/CENTAUR (COEFFICIENTS = 77360.1300 3652.7918 1653.7180)

LD = MAR 6, 1985, 12.0000 HOURS GMT
JULIAN DATE 46131.0000

AD = MAR 9, 1986, 12.0000 HOURS GMT
JULIAN DATE 46499.0000

FLIGHT TIME = 368.0000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
0.0	0.0	0.0300	0.0	0.76000	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
1634.7361	0.0	0.0	0.0	0.0	1634.7361

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
18175.6839	0.0	18339.2277	0.163474	1.0000000D-04	0.102	0.00000	1.00000000 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
1.1019581	0.8982011	0.0	0.0	0.0	0.0	362.75652

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-5.1246	28.5000	3407.29049	11.609629	3555.93883	12.644701

SWINGBY CONTINUATION ANALYSIS

THIS CASE IS CONVERGED.

11 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 4 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

EARTH SWINGBY CONTINUATION TO EARTH

PASS DIST (RADII)	SPEED (M/SEC)	INCLIN (DEG)	NODE (DEG)	ARG PER (DEG)	LEG TIME (DAYS)	MISSION TIME (DAYS)	ARR VINF (M/SEC)
60.0441	3837.49	162.1881	185.7729	108.232	527.95	895.95	3557.35

```
ARRIVAL   V00 = 1.18059057D-01 -1.76583002D-02 -1.88553052D-03    MAG = 1.19387235D-01   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = 1.14058254D-01 -3.52707853D-02  5.00585992D-07    MAG = 1.19387242D-01   (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL   V00 = 9.88875047D-01 -1.47907774D-01 -1.57934014D-02    MAG = 1.00000000D 00   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = 9.55363839D-01 -2.95431779D-01  4.19296052D-05    MAG = 1.00000000D 00   (ECLIPTIC REFERENCE SYSTEM)
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HELIOCENTRIC APPROACH ANGLE = 177.0, DEPART ANGLE = 174.2, BEND ANGLE = 8.7 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC = -6.0 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED = 0.0 METERS/SECOND. BEND ANGLE = 8.7 DEGREES. (PLANETOCENTRIC)

POWERED SWINGBY ANALYSIS ONLY. FOR FIXED SWINGBY LEG FLIGHT TIME 127.0 DAYS.

THIS CASE IS CONVERGED.

5 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 2 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

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ARRIVAL   V00 = 1.05096419D-01 -5.67395634D-02 -4.65529660D-07    MAG = 1.19434649D-01   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = 8.32614016D-02  8.24040653D-02 -1.79817708D-02    MAG = 1.18516814D-01   (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL   V00 = 8.79949161D-01 -4.75067862D-01 -3.89777727D-05    MAG = 1.00000000D 00   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = 7.02528184D-01  6.95294303D-01 -1.51723374D-01    MAG = 1.00000000D 00   (ECLIPTIC REFERENCE SYSTEM)
```

HELIOCENTRIC APPROACH ANGLE = 5.7, DEPART ANGLE = 78.9, BEND ANGLE = 73.3 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC = 9.1 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED = -13.7 METERS/SECOND. BEND ANGLE = 73.3 DEGREES. (PLANETOCENTRIC)

EARTH SWINGBY CONTINUATION TO BORRELLY(1987)

PASS DIST (RADII)	SPEED (M/SEC)	INCLIN (DEG)	NODE (DEG)	ARG PER (DEG)	LEG TIME (DAYS)	MISSION TIME (DAYS)	ARR VINF (M/SEC)
3.3636	7057.96	15.9836	15.8632	263.592	127.00	1022.95	17349.74

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO EARTH

FOR SOLUTION HAVING 60.04 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
R1 REL	R2 REL	R3 REL	V1 REL	V2 REL	V3 REL	RMAG REL	VMAG REL
S/C NUC MAG	S/C TOT MAG	GEO NUC MAG	GEO TOT MAG	ANG(V,R)	ANG(V,XY)		
R1 REL ECL	R2 REL ECL	R3 REL ECL	V1 REL ECL	V2 REL ECL	V3 REL ECL	RMAG ECL	VMAG ECL

EARTH

START OF TRAJECTORY SEGMENT 3, THRUST OFF

3.68000000D 02	1.03625958D 00	1.09300439D-01	2.86571131D-05	1.79999991D 02	3.48627474D 02	9.92956978D-01	3.62756518D 02
-9.73461071D-01	1.95798630D-01	5.66445051D-08	-9.94351089D-02	-1.01945546D 00	5.00585992D-07	1.00000000D 00	1.70147744D-02
4.42397226D-02	5.72647197D-01	9.08642764D-04	-4.71642417D-01	9.01774272D-02	-1.06553100D-05	1.00000000D 00	-2.55037591D-02
0.0	0.0	0.0	9.61297040D 01	2.82703697D 02	1.01186946D 00	1.00899794D 00	-3.56615874D 04
9.06712656D-02	-8.30450619D 01	8.30450707D 01	3.26851127D-06	1.68627465D 02	-5.80167143D 00	1.02429331D 00	0.0
9.37043785D 02	-4.49482319D 03	8.47396132D 00	-3.53765587D 00	3.60129800D-01	1.49099120D-05	4.59146582D 03	3.55593905D 00
-4.52697209D 00	-7.58024821D 00	-1.00000000D 30	-1.00000000D 30	1.74187371D 02	2.40238942D-04		
-3.24620058D 01	4.59134325D 03	8.47396132D 00	3.39721558D 00	-1.05053740D 00	1.49099120D-05	4.59146582D 03	3.55593905D 00

EARTH

END OF TRAJECTORY, THRUST OFF

8.95945897D 02	1.03625958D 00	1.09300439D-01	2.86571131D-05	1.79999991D 02	1.45934513D 02	1.01205077D 00	8.80063558D 02
8.38380643D-01	-5.66890347D-01	1.40795398D-07	6.49008911D-01	7.68090940D-01	-4.65529660D-07	1.00000000D 00	1.66065959D-02
-5.76592725D-01	-7.09802000D-01	-8.22036755D-04	8.09433294D-01	-5.48973269D-01	-5.16342137D-04	1.00000000D 00	-2.55037591D-02
0.0	0.0	0.0	7.94284059D 01	2.60568839D 02	1.01186946D 00	9.84792437D-01	-3.58057058D 04
-5.15304272D-02	-9.50224599D 01	9.50224579D 01	7.97092623D-06	-3.40654957D 01	6.13109852D 00	1.00557260D 00	0.0
3.76962632D 01	-7.02304520D 00	2.10628507D 01	3.53975136D 00	3.53421754D-01	-1.38657621D-05	4.37490012D 01	3.55735106D 00
-1.31587261D 01	-1.76437918D 01	-1.00000000D 30	-1.00000000D 30	5.70172444D 00	-2.23325187D-04		
2.72936130D 01	-2.69330673D 01	2.10628507D 01	3.13028809D 00	-1.68998317D 00	-1.38657621D-05	4.37490012D 01	3.55735106D 00

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		3.4		0.0	OFF	-8.85D 04	*****	******	*****	0.0	ON	90.0
4	82.559	93.1	MIN	0.898		54.6		0.23		-8.19D 04	*****	******	*****	0.0		90.0
5	179.513	200.2		1.016		77.6	MAX	0.47		-9.03D 04	*****	******	*****	0.0		90.0
4	189.220	209.3		1.032		79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
0	189.220	209.3		1.032		79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
4	199.220	218.3		1.047		82.5		0.45	OFF	-9.27D 04	*****	******	*****	0.0		90.0
4	267.702	275.6	MAX	1.102		106.2		0.29		-9.72D 04	*****	******	*****	0.0		90.0
4	368.000	362.8		0.993		101.8		0.00	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0
0	368.000	362.8		0.993		101.8		0.00	OFF	-3.57D 04	*****	******	*****	0.0		90.0
4	368.005	362.8		0.993		84.2	MIN	0.00		-3.57D 04	*****	******	*****	0.0		90.0
4	434.075	436.2	MIN	0.923		54.6		0.17		-3.52D 04	*****	******	*****	0.0		90.0
5	521.214	530.2		1.032		83.4	MAX	0.34		-3.50D 04	*****	******	*****	0.0		90.0
4	626.726	616.2	MAX	1.150		169.8		0.16		-3.59D 04	*****	******	*****	0.0		90.0
9	632.049	620.2		1.149		179.5	MIN	0.16		-3.59D 04	*****	******	*****	0.0		90.0
7	632.345	620.4		1.149	MAX	180.0		0.16		-3.59D 04	*****	******	*****	0.0		90.0
5	742.568	712.1		1.012		82.8	MAX	0.35		-3.53D 04	*****	******	*****	0.0		90.0
4	819.377	796.2	MIN	0.923		57.9		0.20		-3.52D 04	*****	******	*****	0.0		90.0
3	895.946	880.1		1.012		92.6	MIN	0.00		-3.58D 04	*****	******	*****	0.0		90.0
4	895.946	880.1		1.012		149.5		0.00	OFF	-3.59D 04	*****	******	*****	0.0	ON	90.0

AUGUST 19, 1987 1.07015188D 01 G.M.T.
2447026.946D 00 JULIAN DATE

PASS EARTH AT 3.557 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	8.38380460D-01	-5.66890170D-01	0.0	5.43912490D-01	8.24830500D-01	0.0	1.01205050 00	0.0	-34.065
S/C	8.38380640D-01	-5.66890350D-01	1.40795400D-07	6.49008910D-01	7.68090940D-01	-4.65529660-07	1.01205080 00	0.000	-34.065

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND EARTH IS 160.0636 DEGREES.

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO BORRELLY(1987)

FOR SOLUTION HAVING 3.36 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
R1 REL	R2 REL	R3 REL	V1 REL	V2 REL	V3 REL	RMAG REL	VMAG REL
S/C NUC MAG	S/C TOT MAG	GEO NUC MAG	GEO TOT MAG	ANG(V,R)	ANG(V,XY)		
R1 REL ECL	R2 REL ECL	R3 REL ECL	V1 REL ECL	V2 REL ECL	V3 REL ECL	RMAG ECL	VMAG ECL

EARTH — START OF TRAJECTORY SEGMENT 4, THRUST OFF

8.95945897D 02	1.31675896D 00	2.31624927D-01	9.34109222D-01	1.45934993D 02	1.79999511D 02	1.01205077D 00	8.80063558D 02
8.38380643D-01	-5.66890347D-01	1.40795398D-07	6.27173894D-01	9.07234569D-01	-1.79817708D-02	1.00000000D 00	1.66065959D-02
-5.76592725D-01	-7.09802000D-01	-8.22036755D-04	8.09433294D-01	-5.48973269D-01	-5.16342137D-04	1.00000000D 00	6.85470793D-02
0.0	0.0	0.0	7.94284059D 01	2.60568839D 02	1.11629508D 00	9.84792437D-01	-3.58057058D 04
-9.82025299D-01	-9.50231976D 01	9.50224579D 01	7.97092523D-06	-3.40654957D 01	5.90643552D-01	1.10306165D 00	0.0
-1.69367987D 08	-6.70264746D 07	7.21319315D 07	2.63030952D 01	5.91323267D 00	5.18989117D 00	1.95910895D 08	2.74545826D 01
1.73856513D 01	1.69804738D 01	1.73856509D 01	1.69804739D 01	1.66528869D 01	1.08965033D 01		
-1.19806972D 08	-6.18246515D 07	1.42144577D 08	2.60083123D 01	3.05278047D 00	-8.24635270D 00	1.95910895D 08	2.74545826D 01

BORRELLY(1987) — END OF TRAJECTORY, THRUST OFF

1.02294590D 03	1.31675896D 00	2.31624927D-01	9.34109222D-01	1.45934993D 02	2.87810226D 02	1.35864643D 00	9.87874273D 02
3.80201236D-01	1.30419417D 00	-2.10878993D-02	-7.34535522D-01	4.16015951D-01	1.08930260D-03	1.00000000D 00	1.09073500D-02
8.11785347D-01	-4.19648936D-01	4.26549064D-03	2.10373153D-01	4.35492117D-01	5.25235184D-03	1.00000000D 00	6.85470793D-02
0.0	0.0	0.0	1.03022842D 02	2.62522979D 02	1.11629508D 00	6.46819844D-01	-3.89521325D 04
3.76840308D-01	-1.01086943D 02	1.01086701D 02	-8.89338181D-01	7.37474369D 01	1.32703596D 01	8.44164020D-01	0.0
4.86518811D 00	-9.59694915D 00	-2.09227858D 00	4.70047212D 00	-1.13557788D 01	-1.22460387D 01	1.09612553D 01	1.73497439D 01
-1.70193101D 01	-2.00098098D 01	1.48530167D 01	1.42706208D 01	7.42807077D 01	-4.48969591D 01		
8.27254589D 00	2.54795529D 00	-6.72473244D 00	4.72217933D 00	3.25534561D 00	-1.63742896D 01	1.09612553D 01	1.73497439D 01

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE	SOLAR DISTANCE	COMMUNICATION ANGLE	COMMUNICATION DISTANCE	SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER	ARRAY ANGLE
0	0.0	0.0	0.992	3.4	0.0	OFF -8.85D 04	*****	******	*****	0.0	ON 90.0
4	82.559	93.1 MIN	0.898	54.6	0.23	-8.19D 04	*****	******	*****	0.0	90.0
5	179.513	200.2	1.016	77.6 MAX	0.47	-9.03D 04	*****	******	*****	0.0	90.0
4	189.220	209.3	1.032	79.9	0.46	OFF -9.15D 04	*****	******	*****	0.0	90.0
0	189.220	209.3	1.032	79.9	0.46	OFF -9.15D 04	*****	******	*****	0.0	90.0
4	199.220	218.3	1.047	82.5	0.45	OFF -9.27D 04	*****	******	*****	0.0	90.0
4	267.702	275.6 MAX	1.102	106.2	0.29	-9.72D 04	*****	******	*****	0.0	90.0
4	368.000	362.8	0.993	101.8	0.00	OFF -8.35D 04	*****	******	*****	0.0	ON 90.0
0	368.000	362.8	0.993	101.8	0.00	OFF -3.57D 04	*****	******	*****	0.0	90.0
4	368.005	362.8	0.993	84.2 MIN	0.00	-3.57D 04	*****	******	*****	0.0	90.0
4	434.075	436.2 MIN	0.923	54.6	0.17	-3.52D 04	*****	******	*****	0.0	90.0
5	521.214	530.2	1.032	83.4 MAX	0.34	-3.50D 04	*****	******	*****	0.0	90.0
4	626.726	616.2 MAX	1.150	169.8	0.16	-3.59D 04	*****	******	*****	0.0	90.0
9	632.049	620.2	1.149	179.5 MIN	0.16	-3.59D 04	*****	******	*****	0.0	90.0
7	632.345	620.4	1.149 MAX	180.0	0.16	-3.59D 04	*****	******	*****	0.0	90.0
5	742.568	712.1	1.012	82.8 MAX	0.35	-3.58D 04	*****	******	*****	0.0	90.0
4	819.377	796.2 MIN	0.923	57.9	0.20	-3.52D 04	*****	******	*****	0.0	90.0
3	895.946	880.1	1.012	92.6 MIN	0.00	-3.58D 04	*****	******	*****	0.0	90.0
4	895.946	880.1	1.012	149.5	0.00	OFF -3.58D 04	*****	******	*****	0.0	ON 90.0
0	895.946	880.1	1.012	149.5	0.00	OFF -3.58D 04	*****	******	*****	0.0	90.0
7	895.946	880.1	1.012	151.1 MIN	0.00	-3.58D 04	*****	******	*****	0.0	90.0
8	963.191	945.8	1.150 MAX	173.7	0.16	-3.59D 04	*****	******	*****	0.0	90.0
4	1022.946	987.9	1.359	125.6	0.53	OFF -3.93D 04	*****	******	*****	0.0	ON 90.0

DECEMBER 24, 1987 1.07015168D 01 G.M.T.
2447153.946D 00 JULIAN DATE

PASS BORRELLY(1987) AT 17.350 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	3.80201180D-01	1.30419420D 00	-2.10878540D-02	-8.93078160D-01	3.05720850D-01	5.50840370D-01	1.35864640D 00	-0.889	73.747
S/C	3.80201240D-01	1.30419420D 00	-2.10878990D-02	-7.34535520D-01	4.16015950D-01	1.08930260D-03	1.35864640D 00	-0.889	73.747

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND BORRELLY(1987) IS 267.8768 DEGREES.

V. REFERENCES

[1] F.I. Mann, J.L. Horsewood and P.F. Flanagan, "HILTOP, Heliocentric Interplanetary Low Thrust Trajectory Optimization Program," AMA, Inc. Report No. 73-1, January 1973.

[2] F.I. Mann and J.L. Horsewood, "Selected Solar Electric Propulsion and Ballistic Missions Studies," NASA CR-132753, January 1973.

[3] J. L. Horsewood, F.I. Mann and K.B. Brice, "The Generation and Interpretation of Electric Propulsion Mission Analysis Data," AMA, Inc. Report No. 73-38, August 1973.

[4] Jerry L. Horsewood and F.I. Mann, "The Optimization of Low Thrust Heliocentric Trajectories with Large Launch Asymptote Declinations," AIAA Paper No. 74-803, Presented at the AIAA Mechanics and Control of Flight Conference, Anaheim, California, August 5-9, 1974.

[5] "Launch Vehicles Estimating Factors," NASA Office of Space Science, 1973 Edition.

[6] P. Gunther, "Asymptotically Optimum Two-Impulse Transfer from Lunar Orbit," <u>AIAA Journal</u>, Vol. 4, No. 2, pp. 346-349, February 1966.