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MODIFICATION OF AN IMPULSE-FACTORING ORBITAL-TRANSFER TECHNIQUE TO ACCOUNT FOR ORBIT-DETERMINATION AND MANEUVER-EXECUTION ERRORS

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16. Abstract

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SUMMARY

A method has previously been developed to satisfy terminal rendezvous and intermediate timing constraints for planetary missions involving orbital operations. The method uses impulse factoring in which a two-impulse transfer is divided into three or four impulses which add one or two intermediate orbits. The periods of the intermediate orbits and the number of revolutions in each orbit are varied to satisfy timing constraints. In this paper, techniques are developed to retarget the orbital transfer in the presence of orbit-determination and maneuver-execution errors. Sample results indicate that the nominal transfer can be retargeted with little change in either the magnitude (ΔV) or location of the individual impulses. Additionally, the total ΔV required for the retargeted transfer is little different from that required for the nominal transfer. A digital computer program developed to implement the techniques is described in the appendix.

INTRODUCTION

The objective of one type of planetary mission might be to land a package of instruments at a preselected site on the surface of a planet to study its physical characteristics. The Viking-Mars program is a mission designed to achieve such an objective, and it will be used as an example throughout this paper. To accomplish the goal of surface reconnaissance, the Viking mission plan is to insert a lander-orbiter combination into orbit about Mars. The orbiter engine then makes up to four maneuvers (assumed here to be impulsive) to correct errors made in the Mars-orbit-insertion (MOI) maneuver, position the vehicle to allow reconnaissance of the landing site, and synchronize the spacecraft over the landing site in the proper position to make the deorbit maneuver. The lander then separates from the orbiter, deorbits, and lands while the orbiter maintains a data relay link to Earth. The sequence of orbital maneuvers may be characterized as a time-fixed rendezvous from a specified initial orbit to a final orbit which has a synchronous period P_s, a periapsis radius r_p which does not violate planetary quarantine constraints, and a particular true anomaly f_{PER} directly over the landing site. The value of f_{PER} is defined by a study of the deorbit sequence. The landing-site reconnaissance may be interpreted as an intermediate timing constraint on the rendezvous sequence.

One method of determining the proper sequence of orbital maneuvers is reported in reference 1. In this method, the problem is separated into two parts. First, a two-impulse maneuver is found which transfers from the post-MOI orbit (initial elliptical orbit) to a final orbit which satisfies the geometry constraints $\left(P_s,\ r_p,\text{ and } f_{PER}\text{ over the landing-site latitude } \delta_{PER}\right)$. Then, one or both of the two impulses are factored into two or three collinear parts. For example, for the first impulse,

$$\Delta\overline{V}_1 = q\Delta\overline{V}_1 + (1 - q)\Delta\overline{V}_1$$

By applying the first part of the impulse $\left(q\Delta\overline{V}_1\right)$, waiting one or more revolutions, and then applying the remainder of the impulse $\left((1 - q)\Delta\overline{V}_1\right)$ at the same point, there is no net change in the resulting geometry. However, $q\Delta\overline{V}_1$ places the spacecraft in an intermediate orbit whose period is generally different from those of the two original orbits. This period difference and the number of revolutions in each orbit may be varied to satisfy the timing constraints. If the total number of impulses is limited to four, five different maneuver sequences arise. Two are three-impulse solutions (factor either the first or second impulse), and three are four-impulse solutions (factor each impulse, or factor the first or second impulse twice).

The orbital maneuver sequences determined by the impulse-factoring method do not consider the effects of errors in the determination of the orbital elements nor of errors in the execution of each of the maneuvers. Due to errors in the determination of a spacecraft trajectory from observation data, only an estimate of the actual trajectory is available. A maneuver can be computed based on the estimate of the trajectory, but in reality it is applied to the actual trajectory. Further errors are introduced when the maneuver is applied since the maneuver cannot be executed precisely. One way to study the effects of these error sources is by a Monte Carlo analysis. In this method, the distribution of each error source is assumed. A random sample is obtained from each error distribution and the mission is simulated. By repeatedly simulating the mission with different random samples, statistics may be accumulated which represent the random process. The procedures described in this paper represent a single simulation in such a Monte Carlo analysis.

Only four-impulse transfers from the post-MOI orbit to the final orbit are considered. Since the addition of errors at any point in the sequence of maneuvers invalidates the remainder of the original no-error sequence, the remaining maneuvers must be retargeted from the new orbit to the given final orbit. The rationale for the three-, two-, and one-impulse retargeters is presented in this paper. Sample results are given for retargeting a typical Viking-type mission. The appendix contains a brief description of the digital computer program which has been developed to implement the impulse factoring and retargeting technique.

SYMBOLS

f	true anomaly, deg
f_{PER}	true anomaly of a point in orbit directly over the landing site, deg
F	cost function
G	timing error in final orbit, $t_A - t_D$, hr
i	index defining reconnaissance orbit
I,J,K,L,M	integral revolutions in initial, first factored, transfer, second factored, and final orbits, respectively
k	weighting factor
P	orbital period, hr
P_s	synchronous orbital period, hr
q,r	velocity factors
r_p	periapsis radius, km
t_A	actual time of arrival over landing site, hr
t_D	desired time of arrival over landing site, hr
t_{miss}	target miss time, hr

Δt_f	time from entrance to final orbit to f_{PER}, hr
$\Delta\overline{V}$	vector describing an impulsive velocity change, m/s
ΔV	magnitude of $\Delta\overline{V}$, m/s
ΔV_g	ΔV required for the two-impulse transfer which satisfies the geometry constraints on the final orbit $\Delta V_1 + \Delta V_2$, m/s
δ_{PER}	landing-site latitude, deg

Subscripts:

1,2	refer to the first and second impulses of the geometry solution
f	final orbit

Superscripts:

r,h,n	radial, horizontal, and normal components of ΔV, respectively

ANALYSIS

Nominal Orbital Transfer

After the initial Mars orbit is established, an impulse-factoring technique can be used to find a sequence of four impulsive maneuvers which satisfy the following constraints on the Viking mission:

1. Transfer from the known initial orbit to a final orbit which has the correct period, periapsis radius, and true anomaly over the landing-site latitude.

2. Allow reconnaissance of the landing site on a particular revolution after insertion.

3. Synchronize the spacecraft with the landing site to allow the deorbit maneuver.

The first step of the impulse-factoring technique requires obtaining a "geometry solution" which satisfies the first constraint. This solution consists of two impulses: the first, $\Delta\overline{V}_1$, places the spacecraft into a transfer orbit; the second, $\Delta\overline{V}_2$, places the spacecraft into the geometrically correct final orbit.

In order to satisfy the second and third constraints, the two impulses may be factored such that

$$\left.\begin{aligned} \Delta\overline{V}_1 &= q\Delta\overline{V}_1 + (1 - q)\Delta\overline{V}_1 \\ \Delta\overline{V}_2 &= r\Delta\overline{V}_2 + (1 - r)\Delta\overline{V}_2 \end{aligned}\right\} \tag{1}$$

After I revolutions in the initial orbit the first "factor" of $\Delta\overline{V}_1$, $q\Delta\overline{V}_1$, is applied. This impulse places the spacecraft into an intermediate orbit between the initial and transfer orbits. Then, after J complete revolutions in this intermediate orbit, the spacecraft is placed into the transfer orbit by applying the second factor, $(1 - q)\Delta\overline{V}_1$, at the same point. Similarly, after K revolutions in the transfer orbit $r\Delta\overline{V}_2$ is applied, placing the spacecraft into a second intermediate orbit. After L complete revolutions in the second intermediate orbit the last impulse, $(1 - r)\Delta\overline{V}_2$, places the spacecraft into the final orbit.

Since the intermediate orbits have periods which in general are different from those of the initial, transfer, and final orbits, the time spent in the two intermediate orbits serves to alter the timing of the geometry solution. By selecting proper values for q, r, I, J, K, and L, the reconnaissance and rendezvous constraints can be satisfied.

Two other four-impulse schemes are

$$\left.\begin{aligned} \Delta\overline{V}_1 &= q\Delta\overline{V}_1 + r(1 - q)\Delta\overline{V}_1 + (1 - r)(1 - q)\Delta\overline{V}_1 \\ \Delta\overline{V}_2 &= \Delta\overline{V}_2 \end{aligned}\right\} \tag{2}$$

where $\Delta\overline{V}_1$ is factored twice and $\Delta\overline{V}_2$ is applied in full; and

$$\left.\begin{aligned} \Delta\overline{V}_1 &= \Delta\overline{V}_1 \\ \Delta\overline{V}_2 &= q\Delta\overline{V}_2 + r(1 - q)\Delta\overline{V}_2 + (1 - r)(1 - q)\Delta\overline{V}_2 \end{aligned}\right\} \tag{3}$$

where $\Delta\overline{V}_1$ is applied in full and $\Delta\overline{V}_2$ is factored twice.

Two three-impulse schemes are

$$\left.\begin{aligned} \Delta\overline{V}_1 &= q\Delta\overline{V}_1 + (1 - q)\Delta\overline{V}_1 \\ \Delta\overline{V}_2 &= \Delta\overline{V}_2 \end{aligned}\right\} \tag{4}$$

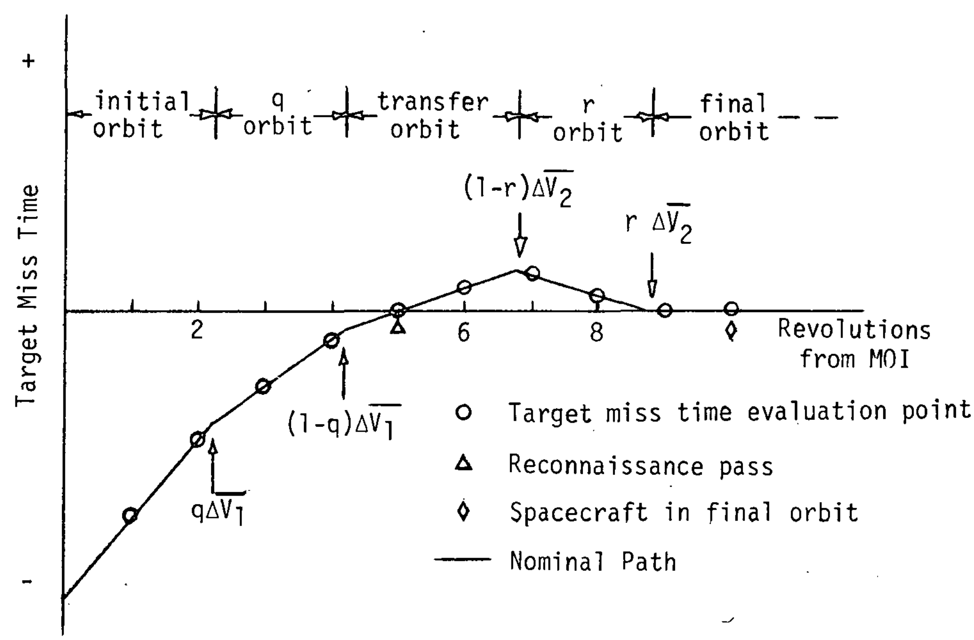
where $\Delta\overline{V}_1$ is factored once and $\Delta\overline{V}_2$ is applied in full; and

$$\left.\begin{aligned}\Delta\overline{V}_1 &= \Delta\overline{V}_1 \\ \Delta\overline{V}_2 &= q\Delta\overline{V}_2 + (1 - q)\Delta\overline{V}_2\end{aligned}\right\} \tag{5}$$

where $\Delta\overline{V}_1$ is applied in full and $\Delta\overline{V}_2$ is factored once.

The technique for selecting an optimum set of values for q, r, I, J, K, and L for each of the factoring solutions is the subject of reference 2. There are many possibilities which must be investigated, but for the present paper it is assumed that an optimum set has been found. This set determines the nominal four-impulse transfer maneuver to which orbit-determination and maneuver-execution errors are applied.

One way to display the sequence of maneuvers is illustrated in sketch (a). Target miss time is plotted versus revolutions from MOI. The target miss time is evaluated



Sketch (a). - Nominal targeting sequence.

once each orbit as the spacecraft crosses the landing-site latitude. It is the time required for the landing site to rotate to a point directly beneath the plane of the orbit. As an aid to visualizing the maneuver sequence, the target-miss-time evaluation points are connected by straight lines. As the periods of the orbits change with each impulse, the slope of the connecting line is changed. For the Viking mission, zero slope represents a synchronous period while positive and negative slopes represent super-synchronous and sub-synchronous periods, respectively. The target miss time must be zero both for the reconnaissance pass and when the spacecraft reaches the final orbit. The final orbit should have a synchronous period. By varying the factors and the number of revolutions in each orbit, the timing constraints can be satisfied.

The Overall Retargeting Technique

Although a nominal orbital transfer (here restricted to four impulses) has been established, the problem is not yet solved. Since the nominal four-impulse transfer cannot be performed perfectly because of orbit-determination and maneuver-execution errors, a method must be developed to retarget the individual impulses to correct the final target parameters within acceptable tolerances. The parameters which must be controlled on the final orbit for the Viking mission are periapsis altitude, period, target miss time, and f_{PER} over the landing-site latitude. A lower bound is placed on the periapsis altitude to satisfy the Mars quarantine constraint. The errors in the final-orbit period and target miss time are constrained since the spacecraft is required to be in a synchronous orbit directly over the landing site. The purpose of this requirement on the Viking mission is to allow the lander to deorbit to the landing site while the orbiter maintains a communications link with the Earth-based tracking stations.

The overall technique for determining the effect of maneuver-execution and orbit-determination errors on the impulse sequence and final target parameters is as follows:

1. Generate a nominal four-impulse transfer from the actual initial orbit to the final orbit using the impulse-factoring technique to satisfy all constraints. The result is a sequence of four impulses applied at particular points in each orbit.

2. Perturb the actual initial orbit with orbit-determination errors, obtaining an estimate of the initial orbit.

3. Retarget the predicted four-impulse transfer from the estimated initial orbit to the known final orbit in order to remove accumulated errors.

4. Add execution errors to the first impulse of the retargeted four-impulse solution and apply this first impulse to the actual initial orbit. This step results in an actual second orbit.

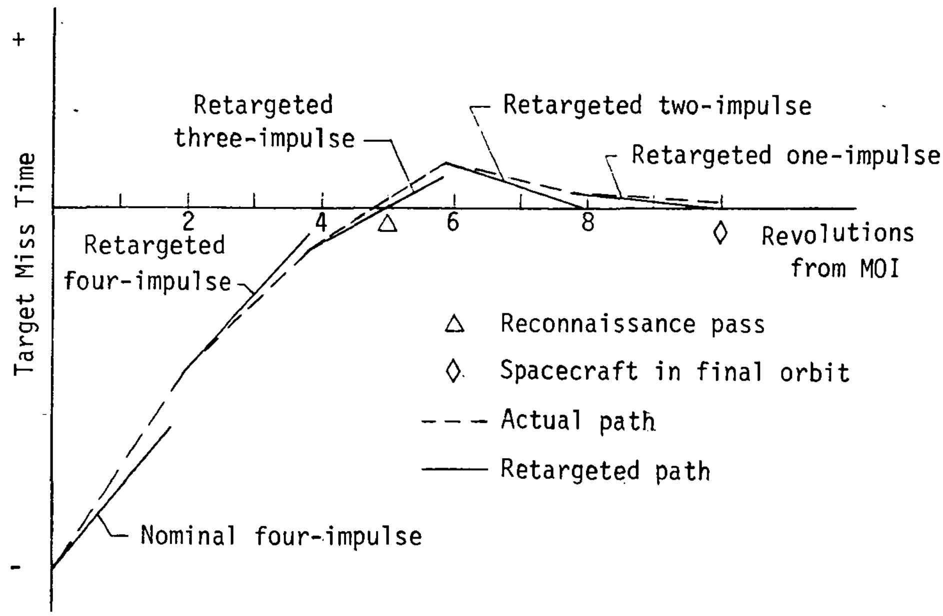
5. Add orbit-determination errors to the actual second orbit, obtaining an estimate of the second orbit.

6. Using the estimated second orbit as an initial orbit, retarget a three-impulse transfer to the known final orbit in order to remove accumulated errors.

7. Repeat steps 4, 5, and 6 by applying errors to the first maneuver and first orbit in each sequence, thus retargeting two- and one-impulse transfers. The imperfect orbital transfers result in errors in the final orbit which cannot be removed completely. By

keeping track of the actual location, magnitude, and direction of each of the four applied maneuvers, the errors in the final-target conditions can be calculated. If the errors are within acceptable tolerances for a wide range of sample cases, the retargeting strategy is successful.

A typical retargeting sequence is illustrated in sketch (b). For clarity, target miss times versus revolutions from MOI are plotted as straight lines. The solid lines indicate



Sketch (b). - Typical retargeting sequence.

the intended variation in target miss time as each impulse is retargeted. The dashed line traces the actual target miss time throughout the sequence. The difference between the dotted and solid lines represents the period error of each orbit due to maneuver-execution and orbit-determination errors.

The following sections present one way of formulating each of the retargeting methods.

<u>Four-impulse retargeting</u>. - The four-impulse retargeting is a simple modification of the original four-impulse problem. Orbit-determination errors are added to the actual initial orbit to yield an estimate of the orbital elements. A new four-impulse sequence is generated based on the estimated initial orbit. Then, the first impulse of the new sequence is perturbed with execution errors and applied to the actual initial orbit to yield an actual second orbit.

<u>Three-impulse retargeting</u>. - The three-impulse retargeting is formulated as a modification to the three-impulse transfers (eqs. (4) and (5)). The initial orbit is taken

to be the actual second orbit that results from applying the first impulse of the retargeted four-impulse transfer with execution errors imposed. An estimate of this actual orbit is obtained by adding orbit-determination errors. A small timing error is allowed in the equations for the reconnaissance condition to account for accumulated errors at the time of landing-site reconnaissance. The ΔV required for the three-impulse retargeted transfer is minimized by the adaptive creeping algorithm discussed in reference 3. The velocity factor is adjusted to remove errors in the final target parameters.

Two-impulse retargeting. - The two-impulse retargeting requires a formulation different from those previously used. The actual second orbit of the retargeted three-impulse transfer is used as the initial orbit for this portion of the trim strategy. An estimate of the initial orbit is found by adding orbit-determination errors. Since two impulses are required to transfer from this estimated initial orbit to the given final orbit, the impulse factoring technique can no longer be used. The only timing constraint which must be satisfied is the target miss time in the final orbit since the reconnaissance pass has been made on a previous orbit. A penalty-function approach is used to satisfy the final timing constraint. In this approach, the original cost function ΔV_g is augmented by a weighted function of the equality constraint to be satisfied. The augmented function F is then successively minimized with increasing weights to drive the equality constraint to its desired value. That is, F is minimized where

$$F = \Delta V_g + kG^2$$

It is desired to drive G to within some acceptable tolerance. By choosing a sufficiently large k and minimizing F, the timing constraint G will be satisfied at the expense of ΔV_g. Thus, the retargeted two-impulse transfer satisfies all constraints on the final orbit.

One-impulse retargeting. - For the one-impulse retargeting, the initial orbit is taken to be the second actual orbit of the retargeted two-impulse transfer. An estimate of this initial orbit is obtained by adding orbit-determination errors. Since only one impulse remains for the transfer to the desired final orbit, not all of the elements of the final orbit can be controlled simultaneously. Thus, a tradeoff must be made between the final timing error and the period error in the final orbit to keep both parameters within acceptable tolerances. The method used to target the final impulse is as follows:

1. Given the estimated elements of the fourth orbit and the desired final orbit along with the number of revolutions in each, a final target miss time t_{miss} may be computed.

2. The miss time is nominally corrected to zero by targeting to an asynchronous final period:

$$P_f = P_s - \frac{t_{miss}}{M + \frac{\Delta t_f}{P_s}}$$

The new period of the final orbit has the effect of apportioning the timing error over M^+ revolutions.

3. Given the new final period, a new semimajor axis of the final orbit is calculated.

4. By holding the eccentricity of the final orbit and true anomaly into the final orbit constant, a one-impulse transfer can be computed to target to the new semimajor axis on the final orbit (essentially the second impulse of the two-impulse transfer described in ref. 1). Since the true anomaly is held constant, Δt_f will change and a new computed t_{miss} will not necessarily be zero. If t_{miss} is not within bounds, the entire procedure can be repeated from step 2 above using the new Δt_f. Since there is no flexibility in the one-impulse transfer, ΔV cannot be minimized.

Application of Orbit-Determination and Maneuver-Execution Errors

Each of the retargeting methods discussed in the previous sections is applied to an initial orbit which has been corrupted by orbit-determination errors. The errors are obtained by sampling from one of two multivariate distributions which are represented by satellite-knowledge covariance matrices. The errors are in the classical orbital elements (semimajor axis, eccentricity, inclination, argument of periapsis, right ascension of the ascending node, and time of periapsis passage). One covariance matrix is valid at apoapsis and the other is valid at periapsis. The estimated true anomaly for the next maneuver determines which matrix is to be used. That is, if the maneuver true anomaly is between -90° and 90° the periapsis covariance matrix is used; otherwise, the apoapsis matrix is used. These matrices are input to the program described in the appendix.

After retargeting methods are applied, the estimated sequence of maneuvers is known. However, before the next impulse is applied maneuver-execution errors are added. The following errors (assumed independent) are considered: accelerometer bias, accelerometer calibration, ignition timing error, and errors in two pointing angles (right ascension and declination of the fixed thrust vector) for each of the four trim maneuvers. These errors have the effect of perturbing the elements of the succeeding orbit in the maneuver sequence. The standard deviation of each error source is input to the program described in the appendix. The orbit-determination and maneuver-execution errors used for the following sample results are representative of those expected for the Viking mission.

SAMPLE RESULTS

The computer program developed to implement the retargeting techniques is described in the appendix. Figures 1 and 2 are a listing and flow chart of the main program. The subroutines required are also described in the appendix. A sample Viking case was computed to illustrate the retargeting techniques described herein.

Input for this case is shown in figure 3 and described in the appendix. The actual initial orbit is taken from the output of a program described in reference 4. On the final orbit, f_{PER} is -10.6^{o}, the target latitude is 12.182^{o}, and the final orbital period is synchronous (24.623 hr). Most of the remaining input is program related and does not change from case to case (see the appendix). The nominal four-impulse maneuver sequence from the actual initial orbit to the required final orbit is given in figure 4. In figure 5, the actual initial orbit has been perturbed by orbit-determination errors and the sequence has been retargeted to the required final orbit. In figure 6, the second orbit of figure 5 has been perturbed by orbit-determination and maneuver-execution errors and retargeted to the required final orbit. In figure 7, errors have been added to the second orbit of figure 6 and the maneuvers retargeted. In figure 8, errors have been added to the second orbit of figure 7. Here, however, a slightly asynchronous orbit of 24.62355 hours is required in order to minimize the final timing error. The following table summarizes the retargeted maneuvers:

Maneuver	Impulses								Timing error, hr
	First		Second		Third		Fourth		
	f, deg	ΔV, m/s	f, deg	ΔV, m/s	f, deg	ΔV, m/s	f, deg	ΔV, m/s	
Nominal four-impulse	110.4	35.3	112.7	4.4	113.0	7.7	-152.4	11.1	-0.005
Retargeted four-impulse	109.6	35.6	111.9	5.2	112.2	6.9	-156.6	10.7	-0.006
Retargeted three-impulse			109.2	3.9	109.4	8.0	-147.7	11.8	-0.0005
Retargeted two-impulse					110.3	7.9	-148.0	12.5	0.0
Retargeted one-impulse							-148.0	11.5	0.004

The small changes in the retargeted controls for this sample case demonstrate the stability of the nominal maneuver sequence in the presence of orbit-determination and maneuver-execution errors. The summary of actual end conditions in figure 8 shows that the error in the final orbital period is 7 seconds, the error in final periapsis radius is 0.75 km, and the actual final timing error is -5.3 seconds. All of these errors are well within acceptable tolerances. The actual total ΔV required for the trim is 58.5 m/s as opposed to a nominal total ΔV of 58.4 m/s, indicating that no appreciable penalty is encountered to correct orbit-determination and maneuver-execution errors for the sample case. Experience has indicated similar behavior for a wide range of maneuver sequences.

CONCLUDING REMARKS

A method has been presented to retarget an impulse-factoring orbital transfer to account for orbit-determination and maneuver-execution errors. Sample results indicate that the errors can be eliminated at small cost in velocity change by the retargeting techniques developed here. Additionally, the original solution for the sample case is quite stable in the presence of errors since the retargeted solutions are close to the nominal both in magnitude and location of the impulses. A digital computer program has been developed at the Langley Research Center to implement the impulse-factoring and retargeting techniques.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., February 4, 1974.

APPENDIX

PROGRAM DESCRIPTION

General

A digital computer program has been developed to implement the impulse-factoring and impulse-retargeting technique described in the text. The program is coded in FORTRAN for the CDC 6600 computer. All of the subroutines required for MITOP (Multiple Impulse Transfer Optimization Program) are stored on the Langley Research Center data cell. The core storage required is about 70 K octal locations. Running time per case ranges from 1 to 10 sec of CPU time depending on the types of options exercised. Almost all data transfer is through two common arrays (C and IC) for floating point and integer variables. The contents of these arrays are described in tables I and II. Data associated with applying and accumulating errors for the retargeting cases are transferred through labeled COMMON TXERR described in table III. The following sections describe the main program, the primary-level subroutines, the input, and the output options.

Main Program

A listing of the main program for MITOP is presented in figure 1. A schematic flow chart of the main program logic is given in figure 2. The main program is simply an executive routine to handle input, output, data transfer, and scheduling between the primary-level subroutines. The modular construction of the MITOP-logic flow facilitates modifications to the program without disturbing the underlying subroutines.

Primary-Level Subroutines

The primary-level subroutines are those called by the main program. These special purpose subroutines in turn call the other subroutines listed on the data cell. The following is a brief description of each of the primary subroutines:

INITIAL This subroutine is called to initialize inputs or various parameters which need to be calculated only once in a run. It is called with a single integer argument (I):

- I = 0 Standard or "canned" inputs are stored (see tables I and II).
- I = 1 Calculates parameters which remain constant for a single case.
- I = 2 Calculates parameters which remain constant for a single Monte Carlo sample (this option is called from the other primary-level subroutines).

STATX

This subroutine calculates the mean and standard deviation of parameters of interest which are input in a vector. The first call initializes various storage locations and subsequent calls accumulate statistics. It is called only in the Monte Carlo mode.

RITE

This subroutine contains the various output options which are chosen by a single integer argument. The options are described in the output section.

ERRORS

This subroutine adds errors due to maneuver execution and orbit determination to the initial orbit involved in the current retargeting. It is called with a single integer argument which denotes the number of the maneuver being performed. The first call is with a zero to add orbit-determination errors to the initial orbit. This subroutine calls SAMPLE which generates the errors in orbital elements by sampling from covariance matrices which are input. In addition, SAMPLE keeps track of the actual performed maneuvers and computes the errors in the actual final target parameters.

BURN 4, BURN 3, BURN 2, BURN 1

These subroutines generate the optimal four-, three-, two-, and one-impulse transfers, given an initial orbit and the final target parameters. The BURN 4 subroutine is called twice. The first call is to generate a nominal four-impulse control history. The second call of BURN 4 (only in the retargeting option) is made after errors have been added to the initial orbit. A new four-impulse control history is calculated based on the perturbed initial orbit. (The same technique is used for BURN 3, BURN 2, and BURN 1.) These subroutines call several other special purpose subroutines. MODEL is the function evaluation routine which calculates the two-impulse geometry transfer (GEOM), and depending upon the mode, satisfies the timing constraints (TRIM) on every iteration, or for only the geometry minimum transfer. GPOP is the function minimization routine which uses an algorithm due to Rosenbrock (ref. 3). GUESS discretizes the independent-variable space to provide a good first guess for GPOP. RANGE determines if the reconnaissance constraints are satisfied and MISS determines if the final timing constraint is satisfied.

STATOUT This subroutine computes and outputs statistics on variables of interest. It is called only in the Monte Carlo mode. The output consists of mean and standard deviation of each parameter, the covariance matrix which indicates the degree of correlation between parameters, and histograms which indicate the distribution of selected parameters.

Input

The primary method of input to MITOP is by the NAMELIST identified as CASE. Selected variables from the C- and IC-arrays and from the TXERR COMMON are input by name. Any other required input may be made directly to the arrays. A sample input is shown in figure 3. The input variables are equivalent to locations in the C- and IC-arrays as described in tables I and II. If only a single case is run, set NMC = 1 and input the initial orbit in AO. If a Monte Carlo case is run, the individual samples are input by a tape (identified as TAPE 10) which contains many post-MOI orbits from program VEAMCOP (ref. 4). The tape is read as follows:

First record	Total number of samples on tape (NOMC).
Second record	Five elements of the nominal initial orbit (ANOM).
Third and subsequent records	Five elements of the current sample initial orbit (AO), true anomaly of cutoff of the MOI maneuver (FBO), initial time bias (TBIAS), and the MOI ΔV (DVMOI).

Multiple cases may be run with little effort. Only variables which change between cases must be input.

Output

There are several output options available in MITOP. The output is controlled by subroutine RITE which is called at various points in the program. The subroutine has a single integer argument which controls the type of print at each call. Four input locations – IC(7 to 10) – are available to store the integer control key. Each location controls the output option chosen as follows:

IC(7)	After nominal four-impulse targeting.
IC(8)	Prior to each retargeting.
IC(9)	After each retargeting.
IC(10)	After each Monte Carlo sample.

Each output control key may take values of 0 to 10. The various values produce the following output:

0	No output.
1	Comprehensive output (explained below).
2	Minimal output consisting of one line (explained below).
3	Output the contents of the C- and IC-arrays.
4	Error summary at end of Monte Carlo sample (explained below).
5	1 + 3.
6	1 + 4.
7	2 + 3.
8	2 + 4.
9	1 + 3 + 4.
10	Available for user-supplied output.

Comprehensive output. - An example of the comprehensive output mode is given in figure 4. The labels are described as follows:

ORBIT NUMBER	1 to 5 refer to initial orbit through final orbit.
A	semimajor axis.

E	eccentricity.
I	inclination.
W	argument of periapsis.
O	right ascension of ascending node.
F-IN	true anomaly of entrance to orbit.
F-OUT	true anomaly of exit from orbit.
P	semilatus rectum.
HP	periapsis altitude.
HA	apoapsis altitude.
PERIOD	period.
DELT	time from F-IN to F-OUT.
PER LAT	latitude directly beneath f_{PER} (sub-PER point).
RADIUS-IN	magnitude of orbital radius at F-IN.
RADIUS-OUT	magnitude of orbital radius at F-OUT.
R-OUT	X-, Y-, and Z-components of orbital radius at F-OUT.
V-OUT	components of orbital velocity at F-OUT.
DV	components of ΔV required to transfer between successive orbits.
TIME/ORBIT	total time spent on each orbit.

CUM TIME OUT	cumulative time from F-IN on the initial orbit to F-OUT on each orbit.
REVS/ORBIT	number of revolutions on each orbit.
CUM REV TO FOUT	cumulative revolutions to F-OUT on each orbit.
DELTA V	magnitude of each maneuver.
MOI DV	Mars-orbit-insertion ΔV.
TOTAL DELTA V	sum of all maneuvers.
RECONNAISSANCE (OCCURS ON ORBIT i)	the reconnaissance pass occurs on the orbit identified by orbit number i.

The following reconnaissance-pass variables are labeled at three times (closest slant range approach to the target, spacecraft at f_{PER}, and the spacecraft directly over the target latitude):

REV	revolution from F-IN on the initial orbit.
T. A.	true anomaly.
PHOTO TIME	time from F-IN on the initial orbit.
TARGET RA	right ascension of target at PHOTO TIME.
SUB S/C DEC and RA	declination and right ascension of the spacecraft.
TIME TO IMPULSE, LAST and NEXT	time between the last impulse and PHOTO TIME and between PHOTO TIME and next impulse.
LOOK ANGLE	angle at target between spacecraft and local vertical.
RANGE	slant range between spacecraft and target.
CENT-ANG	central angle between spacecraft and target.

The following variables refer to the final orbital alinement.

TARGET DEC and RA	declination and right ascension of target when the spacecraft is at f_{PER}.
SUB-PER DEC and RA	declination and right ascension of sub-PER point.
ANGULAR MISS	central angle between target and spacecraft at f_{PER}.
MISS TIME AT PER	timing error between target and spacecraft at f_{PER}.

Minimal output. - The minimal output consists of a single line of numbers which are listed from left to right as follows:

1	Monte Carlo sample number.
2,3,4,5	integer revolutions on each orbit.
6	type of trim solution.
7,8	q and r factors applied to ΔV.
9	ΔV required to satisfy geometry constraints, km/s.
10	ΔV required for total trim, km/s.
11	true anomaly out of the initial orbit (F-OUT), deg.
12,13,14	components of ΔV_1, km/s.
15	true anomaly into the final orbit (F-IN), deg.
16	slant range at reconnaissance, km.
17	final miss time, hr.
18	MOI ΔV, km/s.

Error summary at end of Monte Carlo sample. - This output option consists of the following variables which summarize the actual end conditions for each sample:

FINAL ORBIT	a, e, i, ω, Ω, F-IN, F-OUT on the final orbit.
PDF	period of final orbit, hr.
DPDF	difference between actual and desired PDF, s.
HPF	periapsis altitude of final orbit, km.
DHPF	difference between actual and desired HPF, km.
JDLAND	actual Julian date when spacecraft reaches f_{PER} in final orbit, days.
TBIASF	timing error in the final orbit, s.
DVTRMA	actual ΔV required for trim maneuvers, km/s.

In addition to the above print options, the following is output at the end of a Monte Carlo case:

(1) A summary of each sample consisting of case number; ΔV_{MOI}; ΔV_{TRIM}; ΔV_{TOTAL}; and period, periapsis-altitude, and timing errors in the final orbit.

(2) The means and covariance matrix of ΔV_{MOI}; $\Delta V_{GEOMETRY}$; ΔV_{TRIM}; ΔV_{TOTAL}; and period, periapsis-altitude, and timing errors.

(3) Histograms of ΔV_{MOI}; ΔV_{TRIM}; ΔV_{TOTAL}; and period, periapsis-altitude, and timing errors.

(4) A listing of the summary statistics ordered on ΔV_{TOTAL}.

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1. Kibler, James F.; Green, Richard N.; and Young, George R.: Orbital Trim by Velocity Factoring With Applications to the Viking Mission. Proceedings of the National Space Meeting of the Institute of Navigation, Inst. Navigation, Mar. 1972, pp. 20-27.
2. Green, Richard N.; Kibler, James F.; and Young, George R.: Time-Fixed Rendezvous by Impulse Factoring With an Intermediate Timing Constraint. NASA TR R-422, 1974.
3. Rosenbrock, H. H.: An Automatic Method for Finding the Greatest or Least Value of a Function. Comput. J., vol. 3, 1960/1961, pp. 175-184.
4. Green, Richard N.; Hoffman, Lawrence H.; and Young, George R.: A Monte Carlo Error Analysis Program for Near-Mars, Finite-Burn, Orbital Transfer Maneuvers. NASA TN D-6598, 1972.

TABLE I. - DESCRIPTION OF ELEMENTS IN C-ARRAY

Location	Variable name	Stored value	Description
1	U	42 828.4	Gravitational constant for Mars, km^3/s^2.
2	RS	3393.4	Radius of Mars, km.
3	DR	$2\pi/360$	Degrees to radians conversion factor.
4	RD	$360/2\pi$	Radians to degrees conversion factor.
5	RHOMAX	2000.0	Maximum acceptable slant range from the landing site to the spacecraft at reconnaissance, km.
6	SCONV		No longer used.
7	CONV		No longer used.
8	TLAT	-30.0	Target latitude, deg.
9	STLAT		Sine of target latitude.
10	CTLAT		Cosine of target latitude.
11 to 15	STEPLIM		No longer used.
16 to 20	STEPPAR		No longer used.
21 to 25	XIPLOW	0, 0, 0.03, 0, 0	Lower bounds on independent variables (F-OUT, ΔV_1^r, ΔV_1^h, ΔV_1^n, F-IN) for discretization routine (GUESS).
26 to 30	XIPSTEP	15.0, 0, 0.01, 0, 15.0	Step sizes for independent variables (above) for subroutine GUESS, km/s and deg.
	For the following, O refers to initial, T refers to transfer, and F refers to the final orbits, respectively.		
31, 61, 91	AO, AT, AF		Semimajor axis, km.
32, 62, 92	EO, ET, EF		Eccentricity.
33, 63, 93	XIO, XIT, XIF		Inclination, deg.

TABLE I. - DESCRIPTION OF ELEMENTS IN C-ARRAY – Continued

Location	Variable name	Stored value	Description
34, 64, 94	WO, WT, WF		Argument of periapsis, deg.
35, 65, 95	OO, OT, OF		Right ascension of the ascending node, deg.
36, 66, 96	FOIN, FTIN, FFIN	0, -, -	True anomaly of entrance to the orbit, deg.
37, 67, 97	FOOUT, FTOUT, FFOUT	-, -, -10.6	True anomaly of exit from the orbit - FFOUT is defined to be f_{PER}, deg.
38, 68, 98	SIO, SIT, SIF		Sine of inclination.
39, 69, 99	CIO, CIT, CIF		Cosine of inclination.
40, 70, 100	SWO, SWT, SWF		Sine of little omega.
41, 71, 101	CWO, CWT, CWF		Cosine of little omega.
42, 72, 102	SOO, SOT, SOF		Sine of capital omega.
43, 73, 103	COO, COT, COF		Cosine of capital omega.
44, 74, 104	SFOIN, SFTIN, SFFIN		Sine of true anomaly of entrance.
45, 75, 105	CFOIN, CFTIN, CFFIN		Cosine of true anomaly of entrance.
46, 76, 106	SFOOUT, SFTOUT, SFFOUT		Sine of true anomaly of exit.
47, 77, 107	CFOOUT, CFTOUT, CFFOUT		Cosine of true anomaly of exit.
48, 78, 108	SLRO, SLRT, SLRF		Semilatus rectum, km.
49, 79, 109	PO, PT, PF	-, -, 24.623	Period, hr.
50, 80, 110	DELFO, DELFT, DELFF		Change in true anomaly from entrance to exit, deg.
51, 81, 111	DELTO, DELTT, DELTF		Time from entrance to exit, hr.
52, 82, 112	HAO, HAT, HAF		Apoapsis altitude, km.

TABLE I. - DESCRIPTION OF ELEMENTS IN C-ARRAY - Continued

Location	Variable name	Stored value	Description
53, 83, 113	HPO, HPT, HPF	-, -, 1500.0	Periapsis altitude, km.
54, 84, 114	TBO, TBT, TBF		Time bias, hr.
55, 85, 115	RAOP, RATP, RAFP		Right ascension of the reconnaissance point, deg.
56, 86, 116	FOP, FTP, FFP		True anomaly of the reconnaissance point, deg.
57, 87, 117	TFOIN, TFTIN, TFFIN		Time of entrance to orbit referenced to periapsis, hr.
58, 88, 118	TFOOUT, TFTOUT, TFFOUT		Time of exit from orbit referenced to periapsis, hr.
59, 89, 119	TFOP, TFTP, TFFP		Time of reconnaissance point referenced to periapsis. hr.
60, 90, 120			Not used.
For the following, Q refers to the first factored orbit (q-orbit) and R refers to the second factored orbit (r-orbit).			
121, 141	AQ, AR		Semimajor axis, km.
122, 142	EQ, ER		Eccentricity.
123, 143	XIQ, XIR		Inclination, deg.
124, 144	WQ, WR		Argument of periapsis, deg.
125, 145	OQ, OR		Right ascension of ascending node, deg.
126, 146	FQ, FR		True anomaly of maneuver point, deg.
127, 147	SIQ, SIR		Sine of inclination.
128, 148	CIQ, CIR		Cosine of inclination.
129, 149	SWQ, SWR		Sine of little omega.
130, 150	CWQ, CWR		Cosine of little omega.
131, 151	SOQ, SOR		Sine of capital omega.
132, 152	COQ, COR		Cosine of capital omega.

TABLE I. - DESCRIPTION OF ELEMENTS IN C-ARRAY – Continued

Location	Variable name	Stored value	Description
133, 153	SFQ, SFR		Sine of maneuver true anomaly.
134, 154	CFQ, CFR		Cosine of maneuver true anomaly.
135, 155	PQ, PR		Period, hr.
136, 156	HAQ, HAR		Apoapsis altitude, km.
137, 157	HPQ, HPR		Periapsis altitude, km.
138, 158	QV, RV		Factors associated with splitting ΔV.
139, 159	QP, RP		Factors associated with splitting the change in period between orbits.
140, 160			Not used.
161	DV1		ΔV_1 Magnitude of the first maneuver of the two-impulse transfer which satisfies all geometry constraints, km/s.
162	DV2		ΔV_2 Magnitude of the second maneuver, km/s.
163	DVGEOM		ΔV_g Sum of $\Delta V_1 + \Delta V_2$, km/s.
164	DVTRIM		Total ΔV required to satisfy geometry and timing constraints, km/s.
165, 166, 167	DV1R, DV1H, DV1N		Radial, horizontal, and normal components of ΔV_1, km/s.
168, 169, 170	H2X, H2Y, H2Z		X-, Y-, and Z-components of the angular momentum vector associated with the second orbit, km^2/s.

TABLE I. - DESCRIPTION OF ELEMENTS IN C-ARRAY – Continued

Location	Variable name	Stored value	Description
171, 172, 173	PX, PY, PZ		X-, Y-, and Z-components of a unit vector pointing toward PER on the final orbit.
174 to 182	RXYZ		3×3 array containing the coefficients for a coordinate transformation from the PQW to the XYZ system.
183	RATO		Right ascension of the landing site when the spacecraft is at periapsis on the initial orbit, deg.
184	ANGRAT	360.0/24.623	Angular rotation rate of Mars, deg/hr.
185	SH	1.0/3600.0	Seconds to hours conversion factor.
186	PMISS	0.5	Maximum acceptable miss time at reconnaissance, hr.
187	TMIN	0.5	Minimum time between reconnaissance and the closest maneuver, hr.
188	TBIAS		Time required for the landing site to rotate from its position when the spacecraft is at periapsis on the initial orbit to a point beneath the sub-PER right ascension, hr.
189	DELPTO		Difference in period from the initial to the transfer orbit PT-PO, hr.
190	DELPFT		Difference in period from the transfer to the final orbit PF-PT, hr.
191 to 195	STEPITR	5.0, 0.003, 0.003, 0.003, 5.0	Initial step sizes in the independent variables (above) for the minimization routine, deg, km/s.

TABLE I. - DESCRIPTION OF ELEMENTS IN C-ARRAY - Concluded

Location	Variable name	Stored value	Description
196	DVMOI		ΔV required for the Mars orbit insertion maneuver, km/s.
197	RHOMISS		Slant range at the reconnaissance point, km.
198	RAMISS		Difference in right ascension between the loading site and the spacecraft at reconnaissance, deg.
199			Not used.
200	TMISS		Miss time in final orbit, hr.

TABLE II. - DESCRIPTION OF ELEMENTS IN IC-ARRAY

Location	Variable name	Stored value	Description
1	NMC	25	Number of Monte Carlo samples. (If set to 1, only a single case is run. If >1, sample input is by tape.)
2	IPHOTO	8	Revolution on which reconnaissance takes place.
3 to 6	IMIN, JMIN, KMIN, LMIN	1, 2, 1, 2	Minimum number of revolutions on the initial, first-factored, transfer, and second-factored orbits, respectively.
7 to 10		0, 0, 0, 4	Write keys which may take values from 0 to 9 (explained in output section).
11		1	Retargeting control key: if 0 no retargeting; if 1 retarget each impulse.
12 to 15	IBEST, JBEST, KBEST, LBEST		Distribution of revolutions in each orbit for the most favorable total trim.
16	KKGEOM		Not used.
17	KEYBEST		Best type of trim solution.
18	MODE	1	Cost function to be minimized: if 1 minimize ΔV_g; if 2 minimize $\Delta V_{TOTAL} = \Delta V_g$ + penalty due to timing; if 3 minimize $\Delta V_g + KG^2$.
19	IMC	1	Number of the current Monte Carlo sample.
20	NREV	19	Periapsis passage on which transfer must be complete.
21 to 25	NSTEP	24, 1, 2, 1, 24	Number of steps in each independent variable for subroutine GUESS.
26	ISUM		Number of integer revolutions in trim solution.
27	ITR	2500	Number of iterations for subroutine GPOP.

TABLE II. - DESCRIPTION OF ELEMENTS IN IC-ARRAY – Concluded

Location	Variable name	Stored value	Description
28	ITRIM	0	Key to choose factoring method: if 0 factor periods; if 1 factor ΔV.
29	IHALF	0	Key to choose $1\frac{1}{2}$ minimum revolutions on each orbit: if 0 no constraint; if 1 at least $1\frac{1}{2}$ revolutions on initial and transfer orbits.
30			Not used.
31 to 36	IKEY1 to IKEY6	1, 1, 1, 1, 1, 1	Keys to choose types of trim solutions: if 0 skip solution; if 1 test solution.
37 to 49			Not used.
50	MBEST	2	Number of integer revolutions on final orbit.

TABLE III. - DESCRIPTION OF VARIABLES IN TXERR

Variable	Dimensions	Description
TJDCA	1	Julian date of periapsis passage on nominal approach hyperbola.
KNSAT	1	Satellite knowledge flag: 0, use covariance of errors; 1, perfect knowledge.
VCAL	1	Calibrated value of velocity counting accelerometer.
IOSIG	1	Special flag to indicate use of 1-sigma level satellite orbit determination and maneuver-execution errors: 0, off; 1, on.
SATKN	$6 \times 6 \times 2$	6×6 satellite-knowledge covariance matrices valid at periapsis, SATKN(i,j,1), and apoapsis, SATKN(i,j,2). These matrices represent errors in the classical orbital elements, a, e, i, ω, Ω, t_p.
OTCONT	11	Standard deviations of trim control parameters and spacecraft parameters σ_{δ_r}, σ_ϵ, $\sigma_{t_{IGN}}$, σ_{α_1}, σ_{δ_1}, σ_{α_2}, σ_{δ_2}, σ_{α_3}, σ_{δ_3}, σ_{α_4}, σ_{δ_4}. δ_r is accelerometer bias; ϵ is accelerometer calibration error; t_{IGN} is ignition timing error; α and δ are pointing angle errors for each of a possible four trims.
TKACT	7×5	Array of values of classical orbital elements (a, e, i, ω, Ω, F-IN, F-OUT) for each of five possible actual ellipses (Post-MOI, Post-OT1,. . . POST-OT4).
PDA	5	Period of each of the five actual ellipses mentioned above.

TABLE III. - DESCRIPTION OF VARIABLES IN TXERR - Concluded

Variable	Dimensions	Description
TJDPNA	6	Julian date of initial periapsis passage for each of the five actual ellipses and the Julian date of periapsis passage on the orbit following the orbit maneuver.
HPF	1	Periapsis altitude of the actual final orbit.
DVTRMA	1	Total actual ΔV.
DTAUF	1	Difference between actual final period and synchronous.
DHPF	1	Difference between actual final periapsis altitude and 1500 km.
TBIASF	1	Error in terms of Mars rotation time between the sublongitude of the PER point and the desired landing site.

```
      PROGRAM MITOP     (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)
      DIMENSION AO(5),XIPLOW(5),XIPSTEP(5),NSTEP(5),XMEAN(7),XCOV(7,7),
     .XIN(7),ANOM(8),XIP(5),STEP(5),SAVE(6,100),KEYOPT(6)
     $,CSAVE(200),ICSAVE(50)
      COMMON C(200),IC(50)
      COMMON/TXERR/TJDCA,KNSAT,VCAL, IOSIG,SATKN(6,6,2),OTCONT(11),
     .TKACT(7,5),PDA(5),TJDPNA(6),HPF,DVTRMA,DTAUF,DHPF,TBIASF
      NAMELIST/CASE/AO,PER,TLAT,TBIAS,DVMOI,TMIN,NREV,IPHOTO,IMIN,JMIN,
     *KMIN,LMIN,NMC,KEYW1,KEYW2,CONV,XIPLOW,XIPSTEP,NSTEP,MODE,ITR,IHALF
     *,KEYOPT,C,IC
     .,TJDCA,KNSAT,IOSIG,SATKN,OTCONT,VCAL
      EQUIVALENCE (AO(1),C(31)),(PER,C(97)),(TLAT,C(8)),(TBIAS,C(188)),(
     *DVMOI,C(196)),(TMIN,C(187)),(NREV,IC(20)),(IPHOTO,IC(2)),(IMIN,IC(
     *3)),(JMIN,IC(4)),(KMIN,IC(5)),(LMIN,IC(6)),(NMC,IC(1)),(KEYW1,IC(7
     *)),(KEYW2,IC(8)),(CONV,C(7)),(XIPLOW(1),C(21)),(XIPSTEP(1),C(26)),
     *(NSTEP(1),IC(21)),(ITR,IC(27)),(IMC,IC(19)),(MODE,IC(18)),(FOOUT,C
     *(37)),(DV1R,C(165)),(DV1H,C(166)),(DV1N,C(167)),(FFIN,C(96)),(DVGE
     *OM,C(163)),(DVTRIM,C(164)),(ITRIM,IC(28)),(IHALF,IC(29)),(KEYOPT(1
     *),IC(31))
      CALL INITIAL(0)
      MBEST=IC(50)=2
    1 CONTINUE
      READ(5,CASE) $ IF(EOF,5) 2,3
    2 STOP
    3 CONTINUE
      IC(9)=2
      IC(9)=1
      WRITE(6,CASE)
      CALL INITIAL(1)
      DO 160 I=1,200
  160 CSAVE(I)=C(I)
      DO 161 I=1,50
  161 ICSAVE(I)=IC(I)
      IF(NMC.EQ.1) GO TO 5
      CALL STATX(1,7,XMEAN,XCOV,XIN)
      REWIND 10
      READ(10) NOMC $ IF(NOMC.LT.NMC) NMC=NOMC
      WRITE(6,101) NOMC
  101 FORMAT(I7)
      READ(10) ANOM
      WRITE(6,102) ANOM
  102 FORMAT(8E16.8)
      DO 1000 JMC=1,NMC
      DO 162 I=1,200
  162 C(I)=CSAVE(I)
      DO 163 I=1,50
  163 IC(I)=ICSAVE(I)
      READ(10) AO,FRO,TBIAS,DVMOI
      IMC=JMC
      CALL BURN4
      DVTRMA=DVTRIM
      DTAUF=0.0
      DHPF=0.0
      TBIASF=0.0
      CALL RITE(IC(7))
      IF(IC(11).EQ.0)GO TO 10
      CALL ERRORS(0)
      IC(27)=250
      CALL BURN4
      CALL ERRORS(1)
      CALL BURN3
      CALL ERRORS(2)
      CALL BURN2
      CALL ERRORS(3)
      CALL BURN1
      CALL ERRORS(4)
      CALL RITE(IC(10))
   10 CONTINUE
      XIN(1)=DVMOI
      XIN(2)=DVGEOM
      XIN(3)=DVTRMA
      XIN(4)=DVMOI+DVTRMA
      XIN(5)=DTAUF
      XIN(6)=DHPF
      XIN(7)=TBIASF
      SAVE(1,IMC)=DVMOI
      DO 200 I=2,6
      SAVE(I,IMC)=XIN(I+1)
200   CONTINUE
       CALL STATX(2,7,XMEAN,XCOV,XIN)
1000  CONTINUE
      CALL STATOUT(XMEAN,XCOV,XIN,SAVE)
      GO TO 1
    5 CONTINUE
      DVMOI=0.
      CALL BURN4
      CALL RITE(IC(7))
      IF(IC(11).EQ.0)GO TO 20
      CALL ERRORS(0)
      CALL BURN4
      CALL ERRORS(1)
      CALL BURN3
      CALL ERRORS(2)
      CALL BURN2
      CALL ERRORS(3)
      CALL BURN1
      CALL ERRORS(4)
      CALL RITE(IC(10))
   20 CONTINUE
      GO TO 1
      END
```

Figure 1. - Listing of main program.

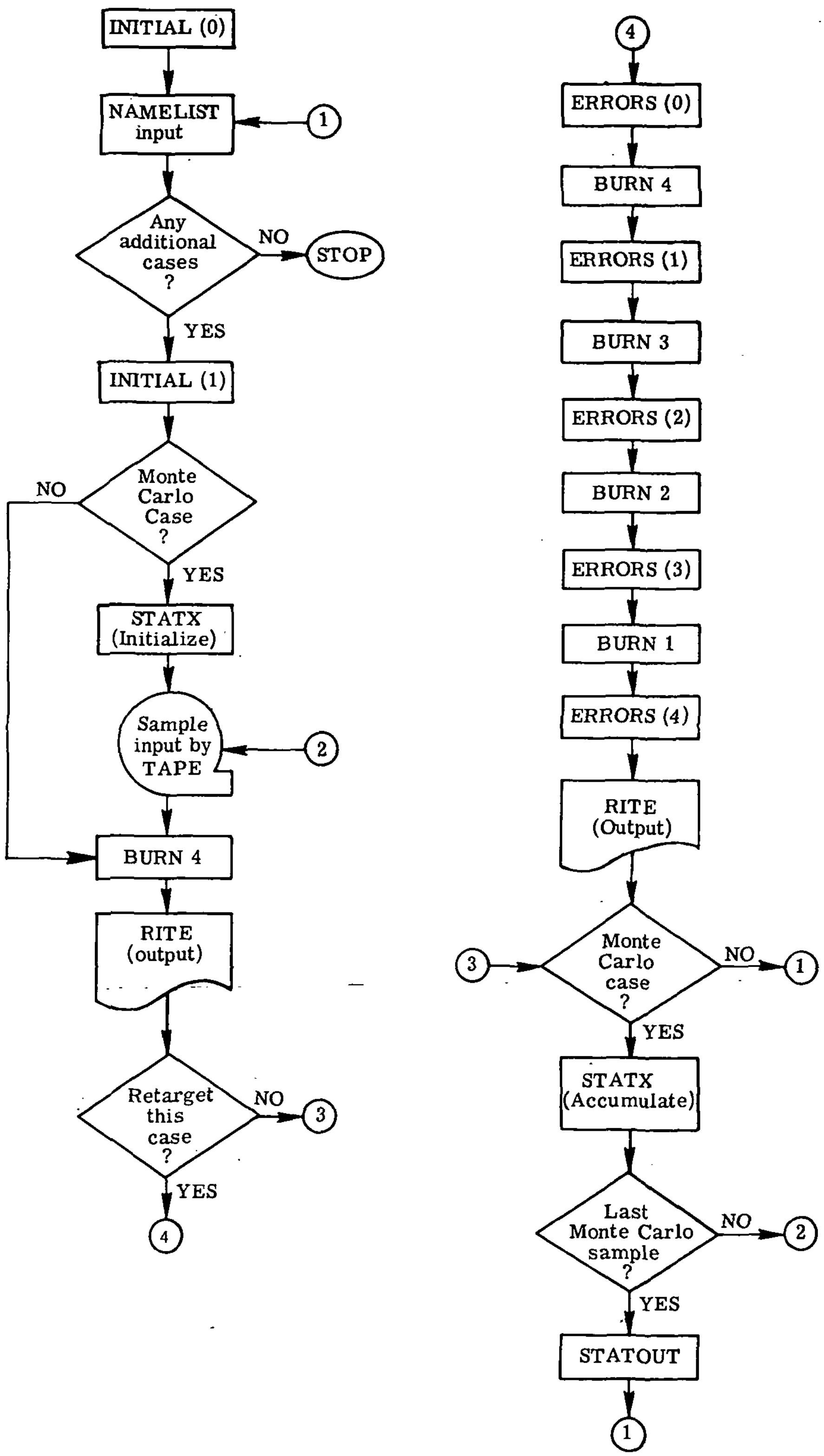

Figure 2. - Flow chart of main program.

```
$CASE
AO       =  0.2406617E+05,  0.800566E+00,  0.339698E+02,  0.327894E+02,
            0.1002376E+03,
PER      = -0.106E+02,
TLAT     =  0.121824287E+02,
TBIAS    =  0.7816E+01,
DVMOI    = I,
TMIN     =  0.5E+00,
NREV     =  9,
IPHOTO   =  5,
IMIN     =  1,
JMIN     =  2,
KMIN     =  1,
LMIN     =  2,
NMC      =  10,
KEYW1    =  0,
KEYW2    =  0,
CONV     =  0.1E-05,
XIPLOW   = -0.45E+02,  0.0, -0.3E-01,  0.0,  0.135E+03,
XIPSTEP  =  0.5E+01,  0.0,  0.1E-01,  0.0,  0.5E+01,
NSTEP    =  19,  1,  3,  1,  19,
MODE     =  2,
ITR      =  700,
IHALF    =  1,
KEYOPT   =  0,  0,  0,  1,  1,  1,
C        =  0.428284E+05,  0.33934E+04,  0.17453292519943E-01,
            0.57295779513082E+02,  0.2E+04,  0.1E-02,  0.1E-05,
            0.121824287E+02, I, I,  0.5E+01,  0.5E-02,  0.5E-02,  0.5E-02,
            0.5E+01,  0.1E-01,  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-01,
           -0.45E+02,  0.0, -0.3E-01,  0.0,  0.135E+03,  0.5E+01,  0.0,
            0.1E-01,  0.0,  0.5E+01,  0.2406617E+05,  0.800566E+00,
            0.339698E+02,  0.327894E+02,  0.1002376E+03,  0.0, I, I, I, I, I, I,
           I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I,
           I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I,
           I, I, I, I, I, I, I, I, -0.106E+02, I, I, I, I, I, I, I, I, I, I, I,
            0.24623E+02, I, I, I,  0.15E+04, I, I, I, I, I, I, I, I, I, I, I, 1,
           I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I,
           I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I, I,
           I, I, I, I, I, I, I, I, I, I, I, I, 1,  0.27777777777778E-03,  0.0,
            0.5E+00,  0.7816E+01, I, I,  0.5E+01,  0.3E-02,  0.3E-02,  0.3E-02,
            0.5E+01, I, I, I, I, I,
IC       =  10,  5,  1,  2,  1,  2,  0,  0,  1,  4,  1,  287948901175024415,
            287948901175024416,  287948901175024417,  287948901175024418,
            287948901175024419,  287948901175024420,  2,  1,  9,  19,  1,  3,
            1,  19,  287948901175024429,  700,  0,  1,  287948901175024433,  0,
            0,  0,  1,  1,  1,  287948901175024440,  287948901175024441,
            287948901175024442,  287948901175024443,  287948901175024444,
            287948901175024445,  287948901175024446,  287948901175024447,
            287948901175024448,  287948901175024449,  287948901175024450,
            287948901175024451,  287948901175024452,  2,
TJDCA    =  0.24429525E+07,
KNSAT    =  0,
IOSIG    =  0,
SATKN    =  0.178062336E+03,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.1565001E-07,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.95481E-03,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.363609E-02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.103684E-02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.1540081E+01,
            0.2982529E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.63001E-09,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.2304E-02,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.494209E-02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.109561E-02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.132641289E+03,
OTCONT   =  0.23E-01,  0.3E-04,  0.0,  0.45E+00,  0.45E+00,  0.45E+00,
            0.45E+00,  0.45E+00,  0.45E+00,  0.45E+00,  0.45E+00,
VCAL     =  0.3E-01,
$END
```

Figure 3. - Sample input. Note: Tape input overrides the values for AO, TBIAS, and DVMOI.

ORBIT NUMBER	1	2	3	4	5
PARAMETERS					
A,KM	2.21514281E+04	2.07335332E+04	2.05725814E+04	2.02959531E+04	2.04277099E+04
E	7.74369722E-01	7.66492786E-01	7.65608536E-01	7.64097732E-01	7.60452835E-01
I,DEG	3.33147645E+01	3.28273217E+01	3.27660351E+01	3.26574991E+01	3.29595516E+01
W,DEG	3.85390913E+01	3.57713743E+01	3.54275891E+01	3.48210955E+01	3.34226681E+01
O,DEG	1.04815176E+02	1.05358880E+02	1.05428446E+02	1.05552322E+02	1.06601094E+02
F-IN,DEG	0.	1.12673280E+02	1.12958588E+02	1.13460853E+02	2.08144857E+02
F-OUT,DEG	1.10361190E+02	1.12673280E+02	1.12958588E+02	-1.52372082E+02	-1.06000000E+01
P,KM	8.86835821E+03	8.55235042E+03	8.51383050E+03	8.44625540E+03	8.61459990E+03
HP,KM	1.60463288E+03	1.44802958E+03	1.42863746E+03	1.39446138E+03	1.50000000E+03
HA,KM	3.59114234E+04	3.32322368E+04	3.29297253E+04	3.24106449E+04	3.25686198E+04
PERIOD,HR	2.78044327E+01	2.51780109E+01	2.48854000E+01	2.43851606E+01	2.46230000E+01
DELT,HR	1.41055279E+00	0.	0.	1.81090632E+01	4.79824779E+00
PER LAT,DEG	1.49120503E+01	1.33308490E+01	1.31351118E+01	1.27902300E+01	1.21824287E+01
RADIUS-IN,KM	4.99803288E+03	1.21389898E+04	1.21389898E+04	1.21389898E+04	2.61472580E+04
RADIUS-OUT,KM	1.21389898E+04	1.21389898E+04	1.21389898E+04	2.61472580E+04	4.92973868E+03
R-OUT,KM X-COMP	-2.40772358E+03	-2.40772358E+03	-2.40772358E+03	2.20453528E+04	-2.83571206E+03
Y-COMP	-1.13885106E+04	-1.13885106E+04	-1.13885106E+04	-6.41833383E+03	3.89600309E+03
Z-COMP	3.44380129E+03	3.44380129E+03	3.44380129E+03	-1.25094569E+04	1.04029828E+03
V-OUT, X-COMP	1.00622269E+00	9.93236240E-01	9.91631974E-01	-5.72747180E-01	-2.27649731E+00
KM/SEC Y-COMP	-2.00473116E+00	-1.98145068E+00	-1.97857475E+00	8.93103200E-01	-2.55575120E+00
Z-COMP	-3.02437143E-01	-2.79308440E-01	-2.76451263E-01	2.00178470E-01	1.88802482E+00
DV,M/SEC X-COMP	-1.29864498E+01	-1.60426598E+00	-2.82587967E+00	-4.92154961E+00	
Y-COMP	2.32804813E+01	2.87592719E+00	5.06588328E+00	6.14690678E+00	
Z-COMP	2.31287023E+01	2.85717734E+00	5.03285583E+00	-7.81758336E+00	
TIME/ORBIT,HR	5.70194182E+01	5.03560218E+01	7.46561999E+01	4.24942238E+01	5.40442478E+01
CUM TIME OUT,DA	2.37580909E+00	4.47397667E+00	7.58465167E+00	9.35524433E+00	1.16070880E+01
REVS/ORBIT	2.05073122E+00	2.00000000E+00	3.00000000E+00	1.74262637E+00	2.19486853E+00
CUM REV TO FOUT	2.05073122E+00	4.05073122E+00	7.05073122E+00	8.79335759E+00	1.09882261E+01
DELTA V,M/SEC	3.52925709E+01	4.35982671E+00	7.67974004E+00	1.10959778E+01	5.84281154E+01
MOI DV,KM/SEC	1.011476				
TOTAL DELTA V,KM/SEC	1.069904				

RECONNAISSANCE(OCCURS ON ORBIT 3)

	REV	T.A. DEG	PHOTO TIME HRS	PHOTO TIME DAYS	TARGET RA,DEG	SUB S/C DEC,DEG	SUB S/C RA,DEG	TIME TO IMPULSE LAST,HR	TIME TO IMPULSE NEXT,HR	LOOK ANGLE DEG	RANGE KM	CENT-ANG DEG
CLOSEST APPROACH	4.991	-10.282	130.777	5.449	125.171	13.295	126.968	23.402	51.254	6.875	1469.831	2.077
S/C AT PER	4.991	-10.600	130.775	5.449	125.143	13.135	126.686	23.400	51.256	5.897	1470.016	1.782
S/C OVER T-LAT	4.991	-12.478	130.764	5.449	124.978	12.182	125.027	23.389	51.267	.157	1478.546	.048

FINAL ORBIT ALIGNMENT

TARGET DEC,DEG 12.182 TARGET RA,DEG 125.971 SUB-PER DEC,DEG 12.182 SUB-PER RA,DEG 126.049

ANGULAR MISS,DEG -7.805E-02 MISS TIME AT PER,HR -5.338E-03

Figure 4. - Nominal 4-impulse transfer.

ORBIT NUMBER	1	2	3	4	5
PARAMETERS					
A,KM	2.21487644E+04	2.07428688E+04	2.05556353E+04	2.03120754E+04	2.04277099E+04
E	7.74385598E-01	7.66670246E-01	7.65656462E-01	7.64346260E-01	7.60452835E-01
I,DEG	3.32884057E+01	3.27847030E+01	3.27103070E+01	3.26106281E+01	3.29779258E+01
W,DEG	3.85256407E+01	3.57223683E+01	3.53132854E+01	3.47672014E+01	3.34107506E+01
O,DEG	1.04853064E+02	1.05433329E+02	1.05520645E+02	1.05638303E+02	1.06712189E+02
F-IN,DEG	0.	1.11903622E+02	1.12239266E+02	1.12686296E+02	2.03866958E+02
F-OUT,DEG	1.09586805E+02	1.11903622E+02	1.12239266E+02	-1.56586750E+02	-1.06000000E+01
P,KM	8.86674720E+03	8.55055765E+03	8.50530895E+03	8.44524898E+03	8.61459990E+03
HP,KM	1.60368023E+03	1.44652849E+03	1.42368029E+03	1.39321653E+03	1.50000000E+03
HA,KM	3.59070486E+04	3.32524092E+04	3.29007903E+04	3.24441343E+04	3.25686198E+04
PERIOD,HR	2.77994177E+01	2.51950181E+01	2.48546584E+01	2.44142222E+01	2.46230000E+01
DELT,HR	1.38216098E+00	0.	0.	1.73684026E+01	5.59837540E+00
PER LAT,DEG	1.48946195E+01	1.32905086E+01	1.30573203E+01	1.27464604E+01	1.21824287E+01
RADIUS-IN,KM	4.99708023E+03	1.19756313E+04	1.19756313E+04	1.19756313E+04	2.82839622E+04
RADIUS-OUT,KM	1.19756313E+04	1.19756313E+04	1.19756313E+04	2.82839622E+04	4.92973868E+03
R-OUT,KM X-COMP	-2.50490425E+03	-2.50490425E+03	-2.50490425E+03	2.35149602E+04	-2.84229637E+03
Y-COMP	-1.11841592E+04	-1.11841592E+04	-1.11841592E+04	-8.90340101E+03	3.89120217E+03
Z-COMP	3.47214387E+03	3.47214387E+03	3.47214387E+03	-1.29521664E+04	1.04029828E+03
V-OUT, X-COMP	1.00132624E+00	9.88403879E-01	9.86528745E-01	-4.35077728E-01	-2.27146558E+00
KM/SEC Y-COMP	-2.03228011E+00	-2.00958863E+00	-2.00629592E+00	8.46006106E-01	-2.55938519E+00
Z-COMP	-2.93436534E-01	-2.69210089E-01	-2.65694643E-01	1.22148199E-01	1.88916212E+00
DV,M/SEC X-COMP	-1.29223578E+01	-1.87513440E+00	-2.49925574E+00	-4.64969358E+00	
Y-COMP	2.26914821E+01	3.29271015E+00	4.38865863E+00	5.72115216E+00	
Z-COMP	2.42264453E+01	3.51544522E+00	4.68552903E+00	-7.80116873E+00	
TIME/ORBIT,HR	5.69809963E+01	5.03900361E+01	7.45639751E+01	4.17826248E+01	5.48443754E+01
CUM TIME OUT,DA	2.37420818E+00	4.47379302E+00	7.58062532E+00	9.32156801E+00	1.16067503E+01
REVS/ORBIT	2.04971906E+00	2.00000000E+00	3.00000000E+00	1.71140512E+00	2.22736366E+00
CUM REV TO FOUT	2.04971906E+00	4.04971906E+00	7.04971906E+00	8.76112418E+00	1.09884878E+01
DELTA V,M/SEC	3.56203782E+01	5.16879330E+00	6.88917891E+00	1.07335673E+01	5.84119176E+01
MOI DV,KM/SEC	1.011476				
TOTAL DELTA V,KM/SEC	1.069888				

RECONNAISSANCE(OCCURS ON ORBIT 3)

	REV	T.A. DEG	PHOTO TIME HRS	PHOTO TIME DAYS	TARGET RA,DEG	SUB S/C DEC,DEG	SUB S/C RA,DEG	TIME TO IMPULSE LAST,HR	TIME TO IMPULSE NEXT,HR	LOOK ANGLE DEG	RANGE KM	CENT-ANG DEG
CLOSEST APPROACH	4.991	-10.246	130.771	5.449	125.285	13.236	127.003	23.400	51.164	6.571	1463.946	1.979
S/C AT PER	4.991	-10.600	130.769	5.449	125.254	13.057	126.689	23.398	51.166	5.479	1464.268	1.651
S/C OVER T-LAT	4.991	-12.327	130.759	5.448	125.103	12.182	125.163	23.388	51.176	.193	1472.335	.058

FINAL ORBIT ALIGNMENT
TARGET DEC,DEG 12.182 TARGET RA,DEG 126.057 SUB-PER DEC,DEG 12.182 SUB-PER RA,DEG 126.146
ANGULAR MISS,DEG -8.902E-02 MISS TIME AT PER,HR -6.088E-03

Figure 5. - Retargeted 4-impulse transfer.

ORBIT NUMBER	1	2	3	4	5
PARAMETERS					
A,KM	2.07310046E+04	2.05826900E+04	2.02824971E+04	2.04277099E+04	
E	7.66521195E-01	7.65616751E-01	7.63787832E-01	7.60452835E-01	
I,DEG	3.28459431E+01	3.27972184E+01	3.26956104E+01	3.29466215E+01	
W,DEG	3.58380761E+01	3.55349764E+01	3.49047656E+01	3.34310638E+01	
O,DEG	1.05403668E+02	1.05466700E+02	1.05598815E+02	1.06674704E+02	
F-IN,DEG	1.12435779E+02	1.09400770E+02	1.09919862E+02	2.12828557E+02	
F-OUT,DEG	1.09150640E+02	1.09400770E+02	-1.47740993E+02	-1.06000000E+01	
P,KM	8.55040451E+03	8.51775499E+03	8.45025920E+03	8.61459990E+03	
HP,KM	1.44685017E+03	1.43083775E+03	1.39757261E+03	1.50000000E+03	
HA,KM	3.32283589E+04	3.29477423E+04	3.23806217E+04	3.25686198E+04	
PERIOD,HR	2.51734050E+01	2.49037439E+01	2.43609139E+01	2.46230000E+01	
DELT,HR	2.50584799E+01	0.	1.89469075E+01	4.05904957E+00	
PER LAT,DEG	1.33713312E+01	1.32006114E+01	1.28459847E+01	1.21824287E+01	
RADIUS-IN,KM	1.20860780E+04	1.14227687E+04	1.14227687E+04	2.38635448E+04	
RADIUS-OUT,KM	1.14227687E+04	1.14227687E+04	2.38635448E+04	4.92973868E+03	
R-OUT,KM X-COMP	-2.82312898E+03	-2.82312898E+03	2.03170112E+04	-2.84139476E+03	
Y-COMP	-1.04821011E+04	-1.04821011E+04	-3.94340401E+03	3.89186058E+03	
Z-COMP	3.55459492E+03	3.55459492E+03	-1.18801259E+04	1.04029828E+03	
V-OUT, X-COMP	9.66131806E-01	9.64745483E-01	-7.28168660E-01	-2.27326220E+00	
KM/SEC Y-COMP	-2.10758120E+00	-2.10496394E+00	9.29325598E-01	-2.55921969E+00	
Z-COMP	-2.39911912E-01	-2.37430723E-01	2.89779018E-01	1.88722428E+00	
DV,M/SEC X-COMP	-1.38632293E+00	-2.87687688E+00	-5.35711817E+00		
Y-COMP	2.61725906E+00	5.43129738E+00	6.42037642E+00		
Z-COMP	2.48118873E+00	5.14892622E+00	-8.39411877E+00		
TIME/ORBIT,HR	5.02318849E+01	7.47112318E+01	4.33078214E+01	5.33050496E+01	
CUM TIME OUT,DA	2.09299520E+00	5.20596319E+00	7.01045575E+00	9.23149948E+00	
REVS/ORBIT	1.99543466E+00	3.00000000E+00	1.77775848E+00	2.16484789E+00	
CUM REV TO FOUT	1.99543466E+00	4.99543466E+00	6.77319314E+00	8.93804103E+00	
DELTA V,M/SEC	3.86370726E+00	8.01790827E+00	1.18482563E+01	2.37298719E+01	
MOI DV,KM/SEC	1.011476				
TOTAL DELTA V,KM/SEC	1.035206				

RECONNAISSANCE(OCCURS ON ORBIT 2)

	REV	T.A. DEG	PHOTO TIME HRS	PHOTO TIME DAYS	TARGET RA,DEG	SUB S/C DEC,DEG	SUB S/C RA,DEG	TIME TO IMPULSE LAST,HR	TIME TO IMPULSE NEXT,HR	LOOK ANGLE DEG	RANGE KM	CENT-ANG DEG
CLOSEST APPROACH	2.941	-10.246	73.777	3.074	125.521	13.379	127.127	23.545	51.166	6.521	1471.074	1.971
S/C AT PER	2.941	-10.600	73.775	3.074	125.490	13.201	126.813	23.543	51.169	5.437	1471.422	1.644
S/C OVER T-LAT	2.940	-12.606	73.763	3.073	125.314	12.182	125.041	23.531	51.181	.878	1481.922	.267

FINAL ORBIT ALIGNMENT

TARGET DEC,DEG 12.182 TARGET RA,DEG 126.125 SUB-PER DEC,DEG 12.182 SUB-PER RA,DEG 126.133

ANGULAR MISS,DEG -7.729E-03 MISS TIME AT PER,HR -5.287E-04

Figure 6. - Retargeted 3-impulse transfer.

```
 ORBIT NUMBER                    1                   2                   3                   4                   5
PARAMETERS
   A,KM               2.05854748E+04      2.02863344E+04      2.04277099E+04
   E                  7.65610337E-01      7.63804408E-01      7.60452835E-01
   I,DEG              3.28867199E+01      3.27869751E+01      3.30656241E+01
   W,DEG              3.55228707E+01      3.49047656E+01      3.33540794E+01
   O,DEG              1.05423209E+02      1.05548553E+02      1.06723250E+02
   F-IN,DEG           1.09694772E+02      1.10776945E+02      2.12577232E+02
   F-OUT,DEG          1.10258643E+02     -1.47981922E+02     -1.06000000E+01
   P,KM               8.51910962E+03      8.45134423E+03      8.61459990E+03
   HP,KM              1.43162251E+03      1.39814276E+03      1.50000000E+03
   HA,KM              3.29525271E+04      3.23877259E+04      3.25686198E+04
   PERIOD,HR          2.49087983E+01      2.43678275E+01      2.46230000E+01
   DELT,HR            1.90484864E-02      1.88885787E+01      4.09535511E+00
   PER LAT,DEG        1.32270527E+01      1.28784290E+01      1.21824287E+01
   RADIUS-IN,KM       1.14815559E+04      1.15921890E+04      2.39832780E+04
   RADIUS-OUT,KM      1.15921890E+04      2.39832780E+04      4.92973868E+03
   R-OUT,KM X-COMP   -2.72780484E+03      2.03901341E+04     -2.83845588E+03
            Y-COMP   -1.06962168E+04     -4.08453848E+03      3.89400452E+03
            Z-COMP    3.53961483E+03     -1.19480793E+04      1.04029828E+03
   V-OUT,   X-COMP    9.70459120E-01     -7.18830554E-01     -2.27061301E+00
     KM/SEC Y-COMP   -2.07492775E+00      9.28408123E-01     -2.55613054E+00
            Z-COMP   -2.48094501E-01      2.85776418E-01      1.89458575E+00
   DV,M/SEC X-COMP   -2.74292527E+00     -5.61641234E+00
            Y-COMP    5.54205743E+00      6.26228466E+00
            Z-COMP    4.87427144E+00     -9.17907387E+00
   TIME/ORBIT,HR      7.47454433E+01      4.32564062E+01      5.33413551E+01
   CUM TIME OUT,DA    3.11439347E+00      4.91674373E+00      7.13930019E+00
   REVS/ORBIT         3.00076473E+00      1.77514414E+00      2.16632235E+00
   CUM REV TO FOUT    3.00076473E+00      4.77590887E+00      6.94223122E+00
   DELTA V,M/SEC      7.87378953E+00      1.24505299E+01      2.03243194E+01
   MOI DV,KM/SEC      1.011476
   TOTAL DELTA V,KM/SEC 1.031801

   RECONNAISSANCE(OCCURS ON ORBIT 1)
                      REV     T.A.     PHOTO TIME     TARGET       SUB S/C       TIME TO IMPULSE  LOOK ANGLE   RANGE     CENT-ANG
                               DEG     HRS    DAYS    RA,DEG    DEC,DEG RA,DEG   LAST,HR NEXT,HR     DEG        KM         DEG
     CLOSEST APPROACH .945  -10.470   23.538  .981   125.113   13.293 126.854   23.538 51.207      6.707   1473.748     2.029
     S/C AT PER       .945  -10.600   23.538  .981   125.101   13.227 126.739   23.538 51.208      6.308   1473.816     1.909
     S/C OVER T-LAT   .944  -12.653   23.525  .980   124.921   12.182 124.928   23.525 51.220       .022   1482.973      .007

   FINAL ORBIT ALIGNMENT
        TARGET DEC,DEG   12.182     TARGET RA,DEG   126.089     SUB-PER DEC,DEG  12.182     SUB-PER RA,DEG   126.089
        ANGULAR MISS,DEG  2.183E-09     MISS TIME AT PER,HR  1.493E-10
```

Figure 7. - Retargeted 2-impulse transfer.

```
ORBIT NUMBER                     1                 2                 3                 4                 5
PARAMETERS
   A,KM                    2.02833773E+04    2.04280145E+04
   E                       7.63742841E-01    7.60452835E-01
   I,DEG                   3.27136567E+01    3.29579249E+01
   W,DEG                   3.48548217E+01    3.34237239E+01
   O,DEG                   1.05549181E+02    1.06581985E+02
   F-IN,DEG                1.10608777E+02   -1.47422768E+02
   F-OUT,DEG              -1.47986066E+02   -1.06000000E+01
   P,KM                    8.45201988E+03    8.61472837E+03
   HP,KM                   1.39869309E+03    1.50007297E+03
   HA,KM                   3.23812615E+04    3.25691561E+04
   PERIOD,HR               2.43624996E+01    2.46235508E+01
   DELT,HR                 1.88882257E+01    4.09544666E+00
   PER LAT,DEG             1.28271601E+01    1.21824287E+01
   RADIUS-IN,KM            1.15595200E+04    2.39836356E+04
   RADIUS-OUT,KM           2.39836356E+04    4.92981220E+03
   R-OUT,KM X-COMP         2.04035792E+04   -2.83454040E+03
            Y-COMP        -4.10234784E+03    3.89694447E+03
            Z-COMP        -1.19197096E+04    1.04031379E+03
   V-OUT,   X-COMP        -7.18309418E-01   -2.27733904E+00
     KM/SEC Y-COMP         9.28995854E-01   -2.55504143E+00
            Z-COMP         2.84542453E-01    1.88791003E+00
   DV,M/SEC X-COMP        -5.22543772E+00
            Y-COMP         6.39020989E+00
            Z-COMP        -8.01668743E+00
   TIME/ORBIT,HR           4.32507253E+01    5.33425482E+01
   CUM TIME OUT,DA         1.80211356E+00    4.02471973E+00
   REVS/ORBIT              1.77529917E+00    2.16632234E+00
   CUM REV TO FOUT         1.77529917E+00    3.94162151E+00
   DELTA V,M/SEC           1.15068353E+01    1.15068353E+01
   MOI DV,KM/SEC           1.011476
   TOTAL DELTA V,KM/SEC 1.022983

   FINAL ORBIT ALIGNMENT
        TARGET DEC,DEG  12.182     TARGET RA,DEG  126.084     SUB-PER DEC,DEG  12.182     SUB-PER RA,DEG  126.031
        ANGULAR MISS,DEG  5.305E-02     MISS TIME AT PER,HR  3.628E-03


   .....ACTUAL END CONDITIONS

   FINAL ORBIT =     2.042878E+04   7.604284E-01   3.289859E+01   3.340541E+01   1.066115E+02   2.125870E+02   -1.060000E+01

      PDF =        2.46249377E+01      DPDF-SEC =      6.97557497E+00
      HPF =        1.50075525E+03          DHPF =      7.55250675E-01
   JDLAND =    2.4429641067794E+06   TBIASF-SEC =     -5.27715324E+00     DVTRMA =       5.85431525E-02
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Figure 8. - Retargeted 1-impulse transfer and summary of actual end conditions.

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