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TRW NOTE NO. 68-FMT-711

PROJECT APOLLO

TASK MSC/TRW A-60.1

EARTH-CENTERED ANALYTIC ABORT PROGRAM DOCUMENT - VOLUME I USER'S MANUAL

DECEMBER 5, 1968

Prepared for
MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
NAS 9-4810

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ABSTRACT

This final report is submitted by TRW Systems Group to the NASA Manned Spacecraft Center in partial fulfillment of the documentation requirements of Task MSC/TRW A60.1 for the Mission Trajectory Control Program, contract NAS9-4810. The report describes the Earth-Centered Abort Program.

This earth-centered program uses a conic model to generate the fuel-critical or time-critical trajectory may return to a primary target point, an alternate target point, or to some point without regard to geographical consideration. Discrete solutions, display scans, and optimum abort solutions can be generated by this program.

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NOMENCLATURE

CLA	Contingency landing area
PLA	Planned landing area
A, a	Semimajor axis
A_Z	Azimuth
DV, ΔV	Velocity change required for a maneuver
E, e	Eccentricity
F, f	True anomaly
h	Angular momentum
I	Inclination
k	Hodograph parameter
LON, λ	Longitude
NODE, ω	Longitude of node
P, p	Semilatus rectum
PER	Period of orbit
$\overline{R1}$	Unit vector in direction of angular momentum of preabort orbit
$\overline{R2}$	Unit vector in preabort orbit plane perpendicular to the position vector completing a right-hand coordinate system with $\overline{R1}$ and UNXO
r	Magnitude of position vector
RA	Apogee distance
RP	Perigee distance
RR	Reentry radius
TAR, T_{ar}	Trip time from abort to reentry
T0, T_0	Time of abort
TTP	Time until perigee passage
TZ, T_z	Landing time

NOMENCLATURE (Continued)

$\overline{UNXO}$	Unit vector in the direction of the abort position vector
$U_0, \overline{U_0}$	Preabort velocity
UR	Reentry speed
V	Speed
W, w	Right ascension of perigee
deg	Degree
er	Earth radius
ft	Foot
ft/sec	Feet per second
hr	Hour
n mi	Nautical mile
α	Right ascension
β	Flight-path angle (measured from position vector)
ΔV	Velocity change at abort
$\Delta\alpha$	Change in right ascension
δ	Declination
δ_Z	Latitude of splashpoint
η	Transfer angle
θ_{cr}	Crossrange offset angle
θ_{max}	Maximum allowable rotation of the abort plane
γ_Z	Longitude of splashpoint
μ	Gravitational constant for the earth

See Section 6 for additional variables.

1. INTRODUCTION

The Earth-centered Analytic Abort Program is a computer program to generate conic trajectories that return to earth in any of nine different modes. The package will generate an optimal trajectory (or trajectories) from the specified preabort state vector to earth landing within the framework of the imposed constraints. The constraints considered are maximum inclination of the return trajectory, maximum velocity change at abort (ΔV), maximum reentry speed, minimum and maximum flight time, minimum and maximum landing time, and maximum allowable distance from earth. All solutions generated are two-body trajectories; however, the third-body effect of the moon is considered when computing the corrected flight-path angle and the corrected ΔV, which are output along with the conic values. The conditions at reentry into the atmosphere of the earth are partially specified by a flight-path angle/speed relationship which must be satisfied at the reentry altitude. The preabort motion may be either direct or retrograde; however, all abort orbits are direct. Velocity changes are approximated impulsively. The portion of the trajectory from reentry to landing is simulated either by constant input values or by internally generated values which are functions of the reentry conditions.

The program document is divided into two volumes for the sake of convenience. Volume I contains information on how to run the program, a description of the available abort modes, and general used information. This volume supersedes Reference 4. Volume II contains a brief description of the abort modes, general logic flow for the program and detailed flow charts for the program subroutines.

As the analytic abort program is in a continuing state of development the program capabilities and input/output options are continually being modified. These changes will be reflected by periodic updates to the two volumes of the program document. The final version of the abort program developed for the IBM 7094 computer is the one described in this report; all future updates will apply only to the version of the program used on the UNIVAC 1108 computer.

2. DESCRIPTION OF PROGRAM MODES

2.1 INTRODUCTION

The return-to-earth abort program (earth phase) generates from a specified preabort state vector conic trajectories that satisfy various problem constraints, depending upon the type of abort being performed. Abort trajectories are computed in an optimal manner except for the contingency landing line mode; the parameter being minimized is either transit time, fuel expenditure or the miss distance from a specified site. All abort trajectories except those computed in the extreme fuel critical mode satisfy a target line constraint at the reentry interface; i.e., at a specified altitude above the spherical earth, the reentry speed alone determines the reentry flight-path angle (Figure 1). Hence, for purposes of generating conic trajectories in an arbitrary plane, the problem has one degree of freedom if the reentry constraint is to be satisfied. For the specified site modes and the contingency landing line mode, the independent variable is chosen to be the conic transit time. In the unspecified area modes the solution is a geometrical one. Insight into the nature of the abort problem may be learned from the velocity hodograph. For this reason, a brief description of the use of the velocity hodograph in this problem will be presented. Following this will be a general description of the return to earth abort modes in the program.

2.2 VELOCITY HODOGRAPH

Many aspects of the abort problem become very clear when the special velocity hodograph is introduced. A coordinate system is established in which the radial component of speed is along the ordinate, and the normal component (orthogonal to the radial component) is along the abscissa. If a particular speed at reentry is chosen, the path angle is determined from the target line, which, when coupled with the reentry altitude, determines the energy and angular momentum of a conic. If a preabort altitude is also specified, the velocity components at this altitude may be computed for any particular reentry speed. If this is done for all possible entry speeds, the locus of points in the velocity space

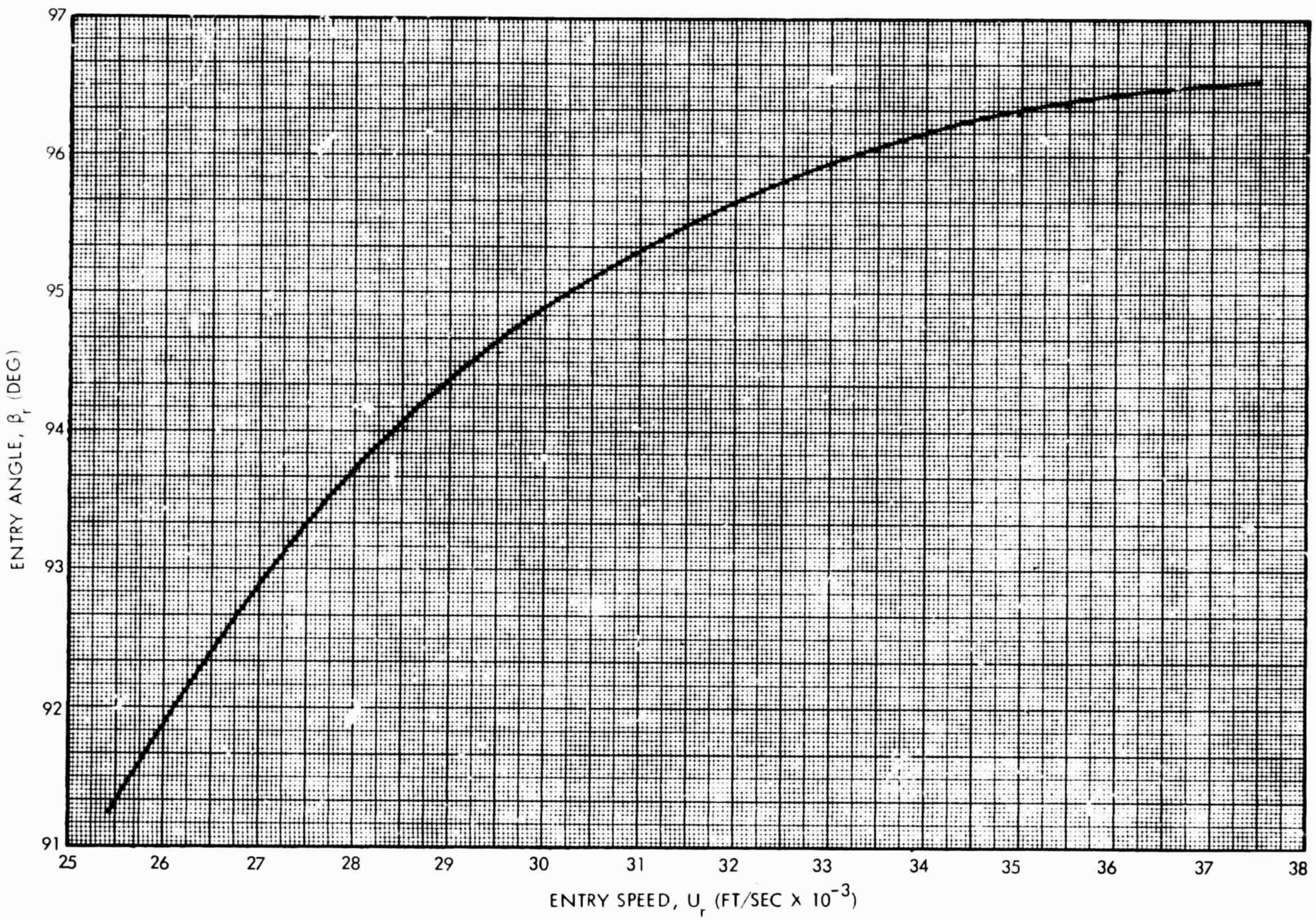

Figure 1. Typical Reentry Target Line for Reentry Altitude of 400, 000 Feet

then determine the velocity vectors that satisfy the target line constraint at reentry. When the reentry path angle is held constant and reentry speed allowed to vary, this locus becomes a hyperbola; for a typical target line, the path angle varies between 91 and 97 degrees; hence, the locus deviates slightly from a true hyperbola. As the abort altitude increases, the figures open, and the intercept on the abscissa moves toward the origin (Figure 2). Also, for any particular altitude as the reentry path angle increases from the minimum to the maximum value, the instantaneous hyperbola becomes more open, and the intercept moves toward the origin. The transit time and, correspondingly, the transfer angle increases monotonically as the radial rate increases from the most negative value through zero to positive values.

With this brief discussion of the hodograph as background, a description of the program modes follows. Unless otherwise noted, all abort trajectories will satisfy the target line at reentry and will have a ΔV less than a specified maximum ΔV, a reentry speed less than a maximum allowed value, and will have trip times that will lie between a minimum and maximum value.

2.3 TIME CRITICAL, UNSPECIFIED AREA

This mode generates the abort trajectory that returns to earth in the minimum time and meets the problem constraints. The program has the capability of generating solutions in this mode in two different ways. In the first method the trajectory is produced by finding the intersections of the hyperbola for the altitude of interest with a circle of radius maximum ΔV about the preabort velocity vector (the initial hyperbola being generated by arbitrarily selecting a value of reentry-path angle). The intersection with the most negative radial rate is the minimum time solution for posigrade returns (Figure 3). This point provides the postabort velocity vector; the associated orbital parameter and the reentry condition may now be calculated. From the speed at reentry, the reentry-path angle satisfying the target line constraint is computed. If this value of β_r is different from the value assumed to generate the hyperbola, then the new β_r is used to compute a new hyperbola and the calculations are repeated. This procedure is repeated until the path angle of reentry is converged. If this solution satisfies the reentry speed

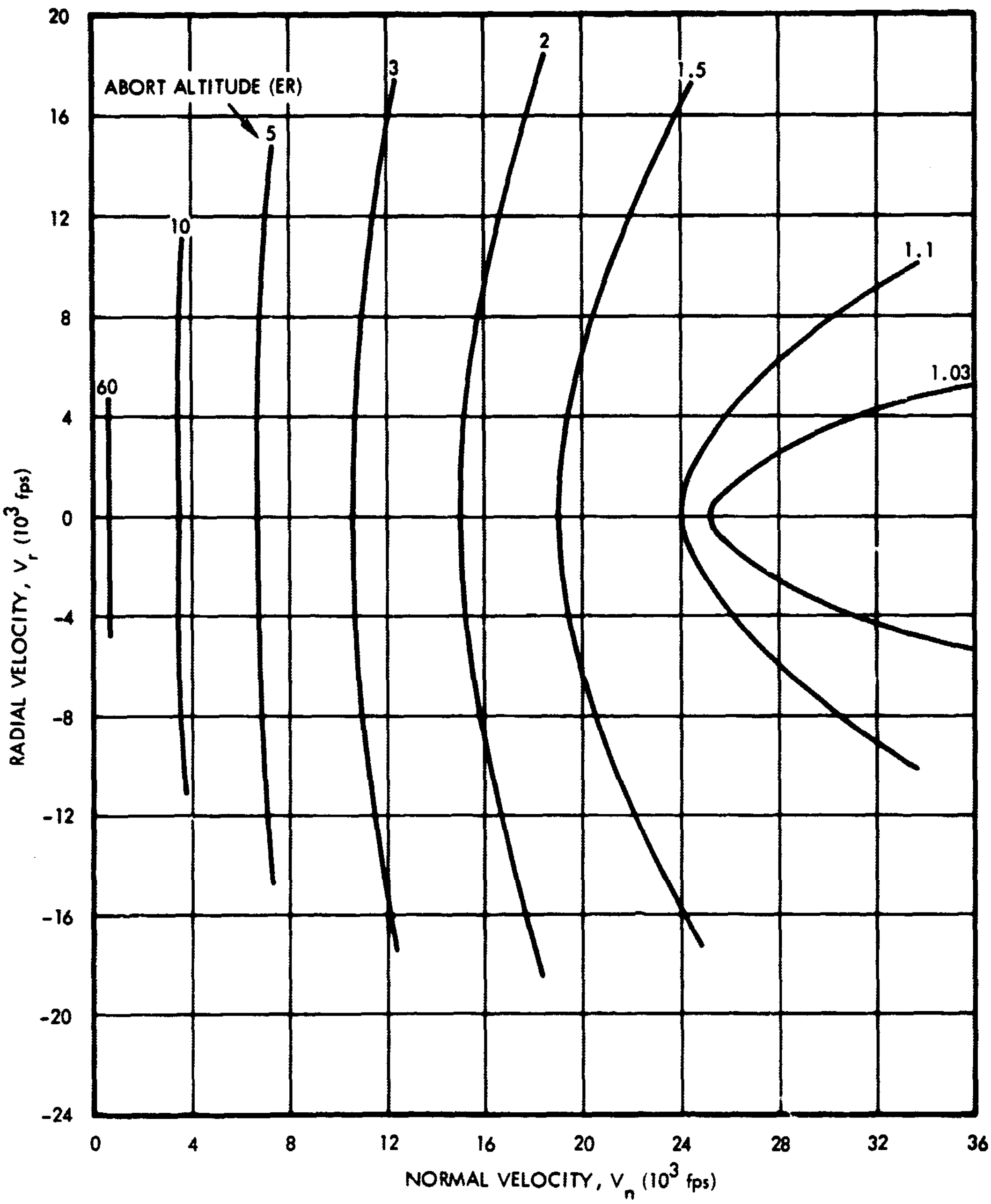

Figure 2. Velocity Hodograph for Target Line Constraint

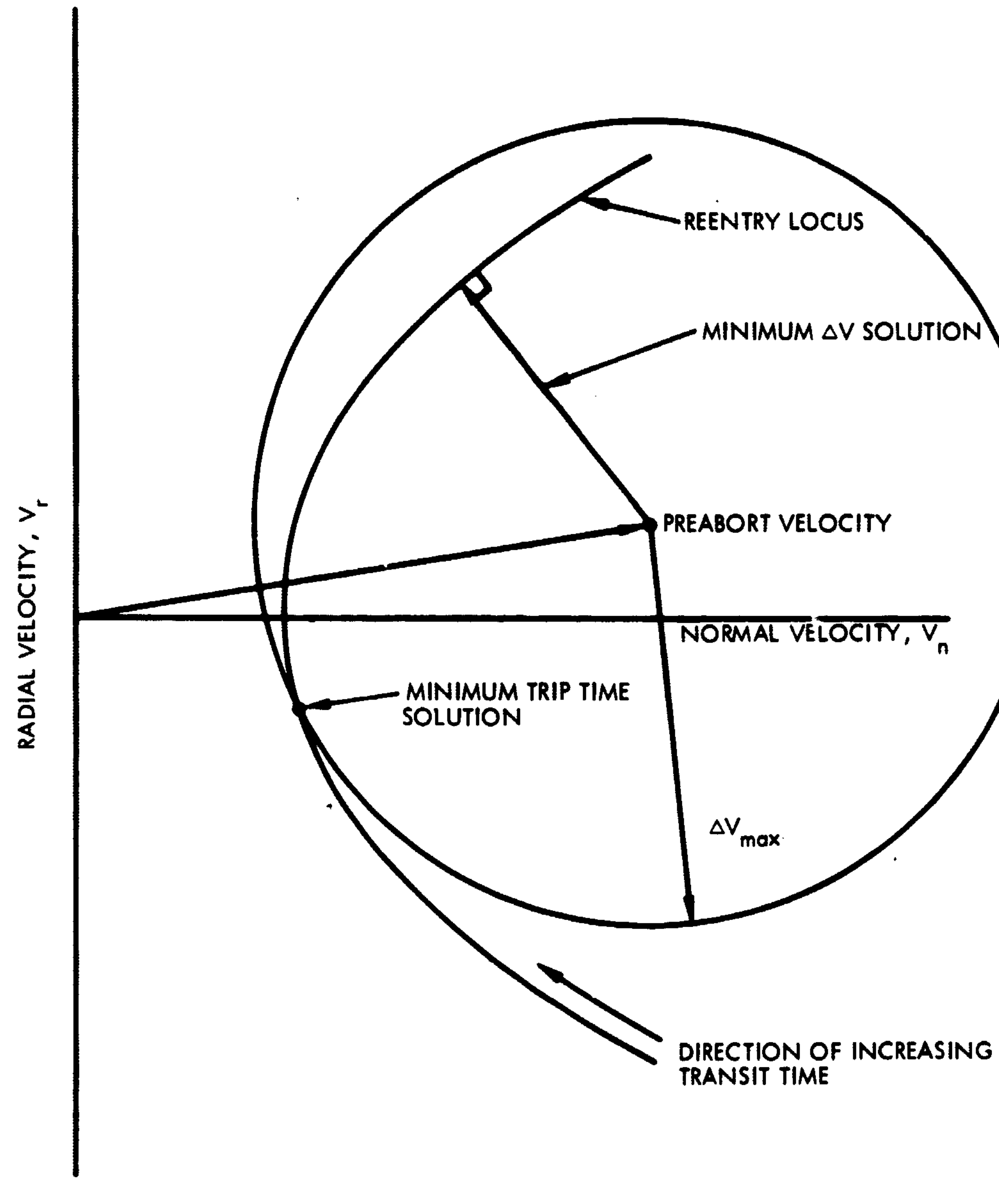

Figure 3. Velocity Hodograph for Abort Geometry

constraint, it is accepted as the desired solution. Otherwise, the minimum time trajectory is generated with the maximum allowable reentry speed. The trip time for this trajectory is tested against the minimum time allowable, and if it is less than the minimum, a new trajectory is constructed with a trip time equal to the smallest allowable value.

The alternate computation of the minimum time trajectory is initialized by computing the maximum entry speed trajectory with a negative radial rate. If the transit time and ΔV required are within the program limits, this solution is accepted. If the minimum trip time constraint is violated, a trajectory is generated with the minimum allowable time, and if all constraints are met, this trajectory is accepted. If ΔV is still violated, the minimum time trajectory is stored as the lower limit on time, and the program generates the fuel minimum solution. The time for this solution is used as an upper limit on trip time, if the ΔV required is less than the maximum allowed. If the maximum ΔV is violated, there is no acceptable solution. The situation consists of two limiting values of transit time requiring ΔV's on opposite sides of the maximum ΔV; hence, somewhere between the two, the minimum time solution exists requiring the exact maximum ΔV. The next step is to generate trajectories with times intermediate to the limiting values; at each step the minimum or maximum trip time is reset depending on whether ΔV is greater than or less than maximum ΔV, respectively. This iterative process continues until a solution is formed, or until the transit time limits become equal.

In both schemes the landing site is computed after the trajectory has been calculated. All solutions are in the preabort plane unless the inclination constraint is violated; in which case the return plane is rotated in a fuel optimal manner until the inclination is equal to the maximum allowable.

2.4 FUEL CRITICAL, UNSPECIFIED AREA

The abort orbit that requires the minimum velocity change is generated in a manner analogous to the first minimum time solution. The postabort velocity vector is determined by computing the line from the preabort velocity vector normal to the appropriate hyperbola. The intersection of this line with the hyperbola defines the postabort velocity vector for the minimum ΔV maneuver (Figure 3). Again, a recursive computation is needed to satisfy the reentry constraint. When this computation has converged, additional orbital and reentry parameters are calculated, and the reentry speed is tested against the maximum speed allowable. If this constraint is violated, a new trajectory is generated which is characterized by the maximum allowable reentry speed, which then becomes the desired fuel critical solution. After the appropriate trajectory has been selected, the trip time is tested against the minimum and maximum allowable values. If either is violated, a new trajectory is constructed whose trip time is equal to the offended constraint. Maximum ΔV is not considered in this mode. If the extreme fuel critical solution is being sought, the ΔV needed for the nominal fuel critical trajectory is tested against the maximum allowable ΔV. If the required ΔV is excessive, the reentry constraint is relaxed in order to attempt to satisfy the maximum ΔV constraint. The reentry-path angle is allowed to vary from 90 to 110 degrees; within this range a trajectory is sought that requires maximum ΔV. If the constraint is not satisfied after varying the reentry-path angle through this range, then a trajectory is generated using the limiting value of path angle which requires the least ΔV. The landing site for the minimum fuel solution is now computed. For the extreme fuel critical unspecified area, the trip time constraints are not considered.

2.5 FUEL CRITICAL, SPECIFIED SITE

This logic is designed to generate the minimum fuel trajectories that impact a specified distance from a desired landing location. As the site may be available several times, a scan is performed over the allowed range of trip times. The utility of the miss distance as a parameter may be seen in Figure 4. If the landing site is located at +3 degrees latitude and +120 degrees longitude, the site is just outside the maximum ΔV contour and is unavailable for a zero miss solution. If a 50-nautical mile miss is acceptable, this trajectory may be generated with a ΔV of approximately 15,000 feet per second. However, if a 300-nautical mile miss is acceptable, the required ΔV drops to approximately 5000 feet per second. Therefore, a small change in the miss distance may significantly reduce the ΔV required. For each transit time considered, the abort trajectory is computed so as to minimize the distance from the impact point to the

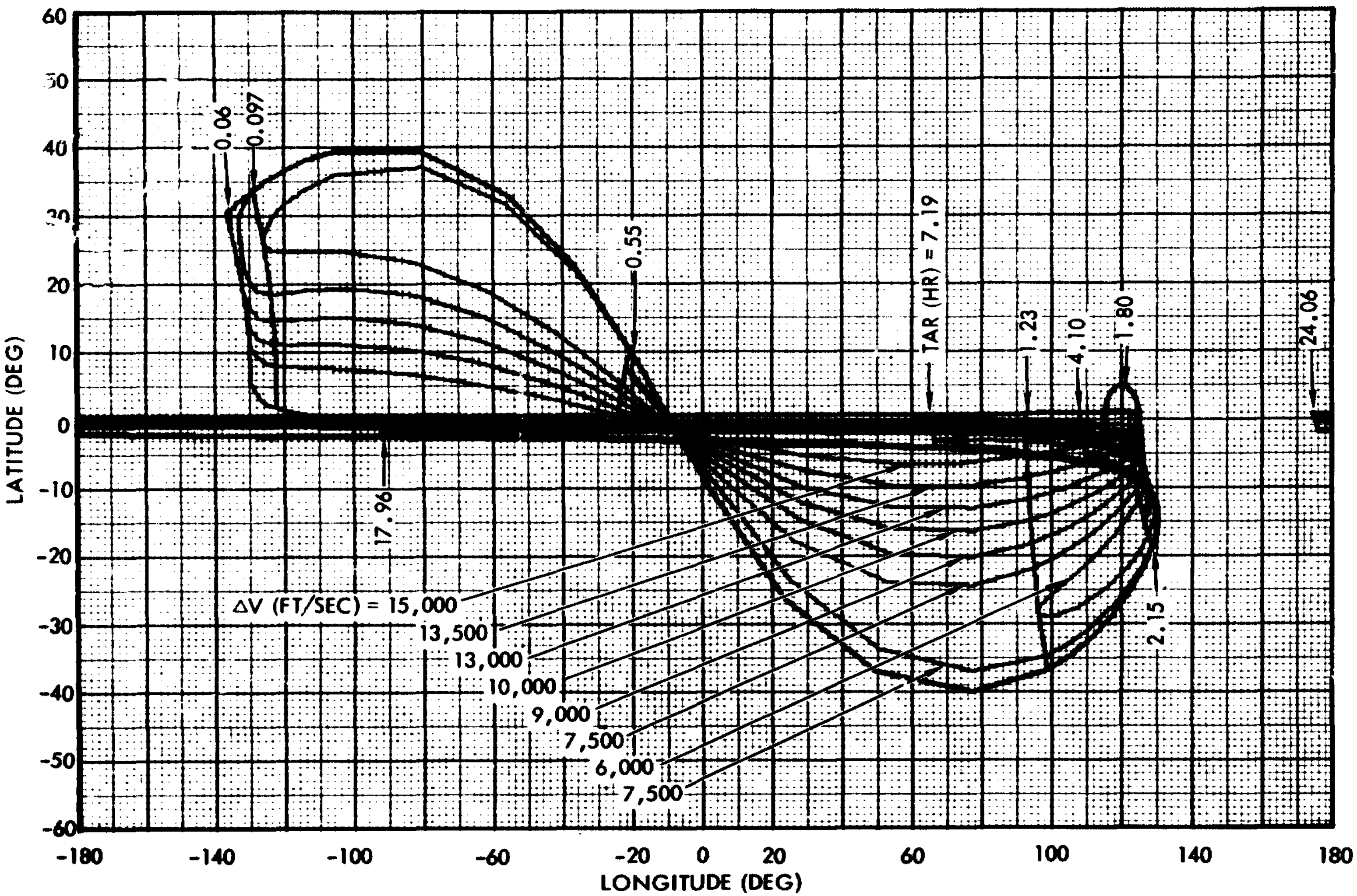

Figure 4. Accessibility Contour Plot for Typical Near Earth Orbit

desired landing site. This situation is achieved by computing the azimuth of a plane passing through the landing site along with azimuths of return trajectory planes characterized by the inclination or maximum ΔV constraint. The azimuth of the return trajectory is set equal to that of the plane passing through the landing site unless this azimuth violates that of one of the constraints. In that case, the return orbit is computed in the plane of the limiting constraint. In this manner, the miss distance is minimized for each transit time considered. The search is inaugurated at the minimum trip time trajectory, and trip time is advanced until the miss distance becomes equal to the allowable miss distance. At this point a fine scan is performed; for each transit time in the scan, a rotation is performed to generate the minimum fuel solution that impacts a specified distance from the site. However, if the inplane solution lands within the allowed miss distance, no rotation is performed. In this manner, the trip time and ΔV required for the fuel-critical solutions that impact within a particular distance for the specified site are generated. At the end of the scan, the search is reinitiated to determine the next time the site is available; at which time, the scan is repeated. This procedure continues until the maximum allowable trip time or the maximum allowable ΔV constraint is violated. If the conditions from reentry to landing are functions of the state at reentry, the azimuth selection and miss distance computation are somewhat altered; however, the basic scheme for trajectory generation remains the same. This logic is used in the program in the PLA tradeoff mode (mode 4) which not only generates the required ΔV, the landing time, and the miss distance for solutions but also has the capability of handling up to eight miss distances simultaneously. Mode 6 generates more detailed information about the trajectory but accomodates only one miss distance at a time.

2.6 MINIMUM MISS, SPECIFIED SITE

The above scheme is also used to generate the minimum miss solution to a desired landing site. The logic operates as before with the plane of the return trajectory selected to minimize the miss distance for each transit time. Since the landing site may be available several times during the allowed range of trip times, the program examines all local minima in miss distance and selects the smallest miss distance. If it is possible to achieve a zero miss over a range of abort times, the program uses the additional degree of freedom to minimize the landing time.

2.7 WATER LANDING SOLUTIONS

This logic is designed to produce trajectories that land on or are within the boundaries of the water landing area (WLA). The WLA is defined by lines on the surface of the earth, each line consisting of connected discrete points whose coordinates are specified by latitude-longitude pairs. These closed boundaries roughly define the major oceans of the earth and are contained within the program logic. The time-critical WLA solution is generated by first construction the time-critical solution as in the TCUA mode. If this solution lands within the WLA, it is accepted as the desired solution. If not, trip time is advanced until the trajectory impacts within the WLA. The minimum fuel WLA trajectory is generated by first determining the impact point of the fuel-critical unspecified area solution. If the solution is within the WLA, it is accepted. If not, a search is instigated which varies trip time in such a way as to generate the minimum fuel trajectory that lands within the desired area.

2.8 CONTINGENCY LANDING AREA

This logic generates all trajectories that impact on contingency lines which are established on the surface of the earth. These lines are produced by connecting points on the surface of the earth which are defined by their latitude and longitude. As for the time critical unspecified area, solutions in this mode may be generated in two distinct ways. In the first manner, a table of impact points is defined by advancing transit time until either the maximum time constraint or maximum ΔV constraint is violated or until 40 impact points have been generated. These trajectories are computed in the plane of preabort motion unless the inclination constraint is violated. If the inclination constraint is violated, the plane is rotated in a fuel minimum manner to satisfy this constraint. Once the points have been generated, the first pair is joined by a straight line, and a check is made to determine if this line possibly intersects a contingency line. If so, the logic establishes a miss distance defined to be the longitude difference between the impact point and the contingency line, measured along the parallel of latitude of the impact point. Trajectories are then generated which attempt to drive the miss distance to zero; when this is done, and if the impact point is within the latitude limits of the contingency line, an acceptable solution has been generated. If not the logic repeats the procedure with the next pair of points and continues to do so until all pairs have been examined. The 40-point limit occasionally prevents the full range of transit times from being searched; however, this mode can handle up to eight contingency lines per case.

The second manner is similar, but instead of generating a table of impact points, the logic starts from the minimum time solutions and attempts to drive the miss distance to zero. As the line may be available several times during the allowable trip time range, once an acceptable solution is found, it is stored, and transit time is advanced to seek further solutions. The process is terminated when either maximum ΔV or maximum transit time is violated. This option will handle only one line at a time; however, the full spectrum of transit times will be examined. The contingency lines must not be defined to be double valued with respect to latitude = f(longitude).

2.9 ABORT STATE VECTOR PROPAGATION

The program is capable of computing aborts from any point on the preabort trajectory by numerical integration. Using this capability of the program, a single state vector from the preabort trajectory may be input and abort trajectories found for a series of equally spaced abort points. The spacing may be either in time or true anomaly. A third method of spacing abort points on the preabort orbit uses an algorithm, developed by IBM for the RTCC version of this program, which attempts a more uniform spacing of abort points about the orbit for all eccentricities than afforded by either time or true anomaly alone. For high eccentricities, equal time advance tends to cluster abort states about apogee and spread them near perigee; whereas, the converse is true for true anomaly advances. The algorithm attempts a compromise between the two and, hence, does not produce a uniform change either in time or true anomaly.

This part of the program logic propagates the input state vector along the preabort trajectory using a numerical integration routine and sets up an array of abort state vectors. The following input information is required by the logic which produces the array:

a) A reference state vector and time which is on the preabort trajectory

b) The time or true anomaly from reference time to the first point in the array

c) The time or true anomaly from the first point to the end of the array

d) The number of points in the array

After the array state vectors and times have been constructed, the abort solution is found for each abort time in the array.

2.10 OPTIMUM ABORT TIME

If the abort time which minimizes required ΔV or miss distance in a given time interval is being sought, an array of abort state vectors and times is constructed as described in the previous paragraph, and a search performed to find the optimum time to abort. This search is performed by finding the abort solution for each point in the array successively. When a solution is found which is better than its adjacent solutions (i.e, requires less abort ΔV), the local minimum is found by analytically propagating the abort state and searching the region. If the problem is fuel critical and all local minima have been found, the time corresponding to the minimum for the entire interval is selected as the optimum abort time. The exact state vector is found at this time by numerical integration, and the abort solution for the optimum abort time is determined.

2.11 TRADEOFF DISPLAY SCAN

Modes 4 and 10 are capable of producing an ordered set of solutions which reflect the functional relationship (tradeoff) of abort ΔV to abort time, landing time, and miss distance (mode 4 only). Mode 4 produces these data for primary landing areas, while mode 10 generates it for contingency landing areas. The logic here differs from the logic in

Sections 2.3 and 2.6 in only one respect - the time of abort is an additional variable which is allowed to operate in the problem. The data for each abort time are sorted and compared to previously generated abort time data. If there are several solutions which have the same landing time for a fixed miss distance, the one which requires the least ΔV is selected for output.

2.12 PROGRAM LIMITATIONS

All trajectories and computations in the analytic return-to-earth abort program are based upon conic two body motion, with two exceptions:

a) Preabort state vectors are computed by a numerically integrating program which accounts for lunisolar perturbations, higher order terms in the geopotential, atmospheric drag, etc.

b) After an abort trajectory meeting all problem constraints has been determined, a calibration routine is used to partially account for lunar perturbations on the conic orbit. This routine outputs a postabort velocity vector which compensates for the lunar perturbing force and at the same time yields a conic that returns to the same reentry state as the uncalibrated orbit. The correction is made in the same plane as the postabort conic, i.e. the out-of-plane component of the disturbing force is neglected.

Apart from limitations incurred in the model chosen, there will be inaccuracies and discrepancies caused by the program due to tolerances and numerical computations. Two parameters are output to indicate program inaccuracies:

a) The quantity DBETAR is the path angle difference between the output reentry path angle and the path angle on the target line corresponding to the output reentry speed. Iterative loops are used in the program to satisfy the target line constraint; in all loops the convergence tolerance on reentry path angle is 0.0001 radians.

b) The output DLTAR, which is the time difference between the output trip time (TAR) and a conic trip time computed from reentry speed. This discrepancy is introduced by a curvefit relation which gives the transfer angle (and hence other conic parameters) as a function of transfer time and is integral to the way in which the program constructs trajectories.

Program tolerances and iteration limits, which determine how well problem constraints are satisfied, are listed below for the various types of solutions:

a) Mode 1 - Time Critical Unspecified Area

1) $|\Delta V - \Delta V_{max}| < 0.001$ er/hr

2) $T_{armin} \leq T_{ar} \leq T_{armax}$

3) $UR \leq UR_{max}$

4) Iteration limit of 25 passes or the difference in the iteration limits becomes $< 10^{-5}$.

b) Modes 2 and 3 - Fuel Critical Unspecified Area

1) $UR \leq UR_{max}$

2) $T_{armin} \leq T_{ar} \leq T_{armax}$ (mode 2 only)

3) $|\Delta V - \Delta V_{max}| < 0.0003$ er/hr (Mode 3 only)

c) Modes 4, 6, 7 - Specified Site

1) $UR \leq UR_{max}$

2) $T_{armin} \leq T_{ar} \leq T_{armax}$

3) $\Delta V \leq \Delta V_{max} + 0.0009$ er/hr $\approx \Delta V_{max} + 5$ ft/sec

4) Miss distance ≤ 0.0001 er or 0.34 n mi if MDM $\neq 0$.
≤ 0.0002 er if MDM = 0.

d) Mode 10 - Contingency Landing Line

1) $UR \leq UR_{max}$

2) $T_{armin} \leq T_{ar} \leq T_{armax}$

3) $\Delta V \leq \Delta V_{max}$

4) Miss Distance $\leq 0.01^{\circ}$ or 0.6 miles

The miss distance constraint is frequently violated in generating aborts. This is due to the approximate way in which the portion of the trajectory from reentry to landing is simulated. A more complete discussion of this problem and its associated errors is given in Reference 3.

3. INPUT DESCRIPTION

3.1 INPUT FORMAT

An attempt has been made to retain program flexibility while making the input requirements as simple as possible. This was done by grouping the types of cases to be controlled by a single input and setting many of the control flags internally to their normal value. These control flags may be overridden by inputting the desired value. If no value is input, the preset value is used. A list of the preset values is given later. The information presented here will demonstrate much of the program flexibility and should provide sufficient detail to permit the actual running of the program.

In the program, all input information is printed on the first pages of each case. The symbols and method for inputting are explained below. Provision has been made for a heading card which must be input in front of each case of the run. If no heading is desired, a blank card must be included as the first data card. There are 54 spaces available for this heading, and any alphanumeric information may be input. For purposes of centering the print, the 27th space will be printed in the center of the page.

To facilitate the stacking of many cases for each computer run, the program uses the NAMELIST form of input. All inputs are grouped under one name, and the entire block is called at once. The NAMELIST in the program is called /INPUTS/, and several rules must be obeyed when inputting. Of the 80 columns available on a coding form, only columns 2-80 may be used; column 1 is always ignored by the computer. The second card for each case must have a $ in column 2, followed immediately by the name INPUTS. The next card starts the data for the input quantities included in the case. Any combination of data items may be used. Data items must be separated by commas; however, use of a comma following the last item is optional. If more than one line is needed for input data, the last item of each except the last line must be a constant followed by a comma. A data item must not be broken between between two lines. The end of each case is signaled by a $ after the last data item.

Data items may take the following form:

a) Variable name = constant, where the variable name may be a vector element name or a scalar variable name (e.g., XOI (3) = 1834.69, IRMAXI = 40.,)

b) Vector name = set of constants (separated by commas), where the number of constants must be equal to the number of elements in the array (e.g., XOI = 22575.2, 4313.7711, - 1834.69).

The order of the data items within a NAMELIST block is irrelevant; and if a quantity is not required, no input is necessary. If a quantity is unchanged from the previous case, no further input is required. When stacking cases, after the first case only the quantities to be changed need be input, enabling many different cases to be easily included in the same computer run. A sample case is shown in Figure 5.

3.2 INPUT DEFINITIONS

All input to the program are contained in the same NAMELIST/ INPUTS/. Each input has two distinct FORTRAN names, one corresponding to the name given in NAMELIST, and the other name used throughout the program. This dual identity is necessary since the input/output units may be different from the internal units. Thus, a quantity is read into the program using the NAMELIST name, and is then immediately transformed to the program name. Under the program name all quantities will be converted, if necessary, to internal units which are earth radii, earth radii/ hour, hours, and radians. When this case is complete, the succeeding case may use the original unconverted NAMELIST quantity without the necessity of specifically including it in the input, and without the danger of it undergoing another unit conversion.

The following discussion employs the input NAMELIST name of the input.

A completely defined case will consist of all the basic input requirements, input data for one of the modes of operation, and any program options desired.

Name	Required Input	Assigned Value if Not Input	Description
X0I	X	--	The epoch position vector. This may be input in any of three coordinate systems or three systems of units which are specified by the input flags ISYSI and IPOSI. If these flags are not input, the program assumes the position vector is given in units of nautical miles and expressed in a geocentric, equatorial, Cartesian coordinate system. The X-axis is towards the intersection of the mean equator and equinox for the nearest beginning of a Besselian year, the Z-axis is along the earth's axis of rotation, and the Y-axis completes a right-handed set.
U0I	X	--	The epoch velocity vector. The coordinate system in which the vector is expressed is defined by ISYSI, and the units of velocity are defined by the flags IVELI(1) and IVELI (2). If these flags are not input, the same coordinate system defined for position is used and the input units are taken to be feet per second.
YEARI MONTHI DAYI HOURI MINI SECI	X	--	Time associated with the epoch state vector.

Name	Required Input	Assigned Value if Not Input	Description
ISYSI		1	This flag specifies the coordinate system in which the input state vector is expressed. If input as 1, or if not input, the mean earth equatorial coordinate system is used. If input as 2, this indicates the epoch state vector is expressed in polar coordinates. In this case, the first number of X0I is the magnitude of the position vector (r), the second is the right ascension (α), and the third is the declination (δ). The first input for the velocity vector is the magnitude of the velocity (V), the second is the flight-path angle (β), (measured from the position vector), and the third input is the azimuth (AZ). If the flag is input as 3, the input state vector is expressed with respect to earth-moon plane coordinates, with the X-axis now along the earth-moon line, the Z-axis normal to the earth-moon plane, the Y-axis completing the right-handed set. The origin is still at the center of the earth.
IPOSI		1	This flag specifies the units of input position vector X0I. When 1 is input, the units are nautical miles; when 2 is input, units are earth radii; when 3 is input, the units are kilometers; when 4 is input, the units are feet.

Name	Required Input	Assigned Value if Not Input	Description
IVELI(1) IVELI(2)		1 1	These two flags specify the units of the input velocity vector U0I; IVELI(1) specifying the length unit and IVELI(2), the time unit. IVELI(1) = 1 implies feet, IVELI(1) = 2 implies Earth radii. IVELI(1) = 3 implies rautical miles. IVELI(1) = 4 implies kilometers. If IVELI(2) = 1, the time unit is seconds, and it IVELI(2) = 2, the time unit is hours. Thus, IVELI (1) = 4 and IVELI(2) = 2 means the velocity was input as kilometers per hour.
IDEGI		1	This specifies the units for all angular inputs. IDEGI = 1 means the angles are in degrees. IDEGI = 2 means the angles are in radians.
LINESI(J) J = 1, . . . , 5		LINESI(1) = 1 LINESI(J) = 0 J = 2, . . . , 5	This flag indicates which lines of additional print are desired in the solution output. The parameters obtained in each line are indicated in the output list. Each line desired is printed out twice, one for the preabort state vector and one for the reentry state vector. For each line of output desired, set input LINESI(J) = 1, where J is the number of the output line desired. Thus if lines 2 and 5 are the only additional outputs of interest, set LINEI(2) = 1, LINEI(5) = 1, and the others need not be input or may be input as 0.

Name	Required Input	Assigned Value if Not Input	Description
IADVI		2	This flag determines whether or not the input state vector is to be advanced and if abort time is to be used as a degree of freedom for optimization. If IADVI = 2, a table of preabort state vectors will be generated in a manner specified by following seven input quantities. Aborts will then be generated from these preabort state vectors. If no advance is desired, IADVI should be input as 2 along with DTAI = 0 and DTMAXI = 0. (Note that these are the preset values of these variables, hence no inputs are really needed.) IADVI = 1 is used differently in different modes. Basically, it indicates whether or not to use abort time as a degree of freedom for minimizing some parameter. If optimization is desired, the program generates state vectors intermediate to those indicated in the preabort table in order to achieve the optimization. The option is available for modes 6, 7, 8, and 9. For modes 2 and 3, if IADVI = 1, the program integrates the preabort orbit to apogee and then computes the fuel minimum trajectory. If the input state vector is post apogee, the desired interval is divided into ten equal increments and fuel critical solutions computed at these points. IADVI = 1 is not used in modes 1, 4, and 10.

Name	Required Input	Assigned Values if Not Input	Description
LETSGI		1	This flag and the following six flags specify the number of preabort state vectors to be used and the manner in which they are to be generated. All integration in determining the preabort state vectors includes effects of earth oblateness, lunisolar perturbation, and n-body effects. Flag LETSGI determines manner in which a state vector is to be propagated. LETSGI = 1 indicates time advance, LETSGI = 2 means true anomaly advance, LETSGI = 3 uses an algorithm to group state vectors around points on the preabort orbit which are of special interest.
DTAI DTMAXI TJUMPI		0. 0. 1.	If LETSGI is input as 1, these inputs specify the number and time of the preabort state vector. DTAI is time interval after input epoch time at which first abort is to take place DTMAXI is time interval from first abort until last abort, and TJUMPI is time increment between state vectors. Up to 40 state vectors may be run per case. Hence, ratio of DTMAXI to TJUMPI may be no greater than 39. All intervals are input in units of hours.
DETAII DEMAXI JUMPI		0. 360. 40	If LETSGI = 2, these flags specify the advance on true anomaly. DEMAXI is maximum number of degrees through which a state vector is to be advanced. DETAII is

Name	Required Input	Assigned Value if Not Input	Description
			number of degrees after initial time that abort is to start. JUMPI is number of state vectors to be generated. These are input in degrees. Again, no more than 40 state vectors may be generated. If LETSGI = 3, then a combination of JUMP, specifying number of state vectors to be generated, DTAI, the time interval after input epoch time at which first abort is to take place, and DTMAXI, time interval from first abort until last abort. If DTMAXI is larger than period of the orbit, then JUMP number of state vectors will be generated for one period of orbit.
LPLOTI		0	This is flag for printer plot in mode 4 and the 4020 plot in modes 4 and 10. A nonzero value is input if plot is desired. If a 4020 plot is desired, unit B8 must be saved. LPLOTI = 3 will cause cards that can be used as input to the CalComp plot program HU017A to be punched out.
LSTCSE		0	This flag is set to 1 to indicate to 4020 plotter which is last case to be plotted.
URMAXI		36,329.406 ft/sec	Maximum allowable speed at reentry, expressed in inertial speed and input in feet per second.

Name	Required Input	Assigned Value if Not Input	Description
IRMAXI		40 deg	This specifies maximum inclination of abort trajectories and is input in degrees.
TARMAXI		180 hr or internally calculated value	This is maximum allowable trip time from abort to reentry in units of hours. This time may be no greater than 180 hours and program calculates the maximum possible trip time from the state vector and maximum reentry speed specified and sets the maximum allowable trip time to smaller of calculated and input values.
TARMNI		0.3333 hr	Minimum acceptable trip time from abort to reentry (hr)
TZMAXI		1000 hr	The maximum landing time, measured from 0 hours on the day of abort and expressed in hours. This input serves another function in that, if it is input $\leq 10,000$ hours, then the ΔV difference between the conic and precision trajectory will be less than 100 feet per second. If input $> 10,000$ hours, the program ignores the 100 feet per second ΔV error constraint. This constraint is not used in modes 2 and 3.
TZMINI		0	The minimum permissible time of landing. This quantity is measured the same as TZMAXI.

Name	Required Input	Assigned Value if Not Input	Description
RMAXI		60 er	Maximum allowable distance from earth for the abort trajectory. If the input position vector is more than 60 er out, the program immediately advances to the next abort state vector.
DVMAXI		10,000 ft/sec	The maximum allowable velocity change, in units of feet per second.
HRI		400,000 ft	The reentry altitude, in feet.
ICRNGI		1	Input flag indicating the manner in which the phase of the trajectory from reentry to landing is to be simulated. The reentry transfer angle, time from reentry to landing and crossrange distance are calculated as a function of the reentry conditions if ICRNGI is non-zero. ICRNGI = 1 uses the constant G equations and the MSFN target line. ICRNGI = 2 specifies using the G&N mode for these calculations. ICRNGI = 3 uses the constant G equations and the contingency target line. If ICRNGI is input as 0, the reentry simulation parameters may be specified through the following three inputs, which are constant throughout the case.
ETARZI		33 deg	Transfer angle from reentry to landing, in degrees. This and the two following parameters are used only if ICRNGI = 0.

Name	Required Input	Assigned Value if Not Input	Description
TRZI		0.17 hr	Time from reentry to landing (hr)
THCRI		0	Crossrange angle (deg)
KKMAXI		5 - Mode 4 1 - Mode 6	This specifies the number of miss distances to be investigated in mode 4. For mode 4, up to 8 miss distances may be input. KKMAX is always set to 1 for mode 6.
MDSPI(J)		MDSPI(1) = 400 MDSPI(2) = 300 MDSPI(3) = 200 MDSPI(4) = 100 MDSPI(5) - 0	Values for the miss distances to be used in mode 4. These values are input in nautical miles.
DELZI LAMZI		0. 0.	Latitude and longitude, respectively, of the desired landing site. Required input for the PLA modes, input in degrees. North latitude is input positive, and south latitude is input negative. Longitude may be input positive east or negative west from the Greenwich Meridian.
ITSFGI		0	Flag for third body calibration. If ITSFGI = 0, small correction package is used; if ITSFGI = 1, large package is used. ITSFGI > 1 routine print is generated in the large package.
RFLAGI		0	Flag indicating routine print desired. If set to 0, no routine printout is obtained; if set to 2, then limited amount of print is output. If set to 1, print is obtained from most major subroutines.

Name	Required Input	Assigned Value if Not Input	Description
			RFLAGI = 2 gives sufficient output to follow trajectory computations and selection of optimal solutions.
LMAXPI(J) J = 1, ..., 8		2, 4, 4, 2, 4	This quantity is used only for mode 10 cases and indicates number of points that are being input to describe desired contingency lines. The following inputs specify values of the points themselves. If less than 8 contingency lines are input, then there must be zero at the end of this input to indicate last value of array.
CL1, CL2, ..., CL8		CL1 = 40., 195., -40., 195., CL2 = 40., 225., 21., 238., -11., 271., -40., 277., CL3 = 40., 330., 10., 330., -5., 335., -40., 335., CL4 = 15., 65., -40., 65., CL5 = 40., 150., 10., 150., -15., 170., -40., 170.,	CL1 consists of the latitude-longitude pairs describing the first contingency line, similarly for CL2 through CL8. The points specifying any particular line are to be input in order of decreasing latitude. Thus, if LMAXPI(1) = 3, first conting ncy line will be specified by three points. These points are input under CL1 as δ_1, λ_1, δ_2, λ_2, δ_3, λ_3, where δ and λ are latitude and longitude of points and $\delta_1 \geq \delta_2 \geq \delta_3$.
IBRFGI		1	Flag specifying if fixed or variable flight-path angle is to be used = 0 Fixed = 1 Variable
BETARI		96 deg	Specifies the fixed flight-path angle to be used if flag IBRFGI = 0.
MODEI	X		Specifies type of case to be run. (See program description.)

Name	Required Input	Assigned Value if Not Input	Description
IRTCCI		0	Flag used to indicate if RTCC's version of the mode 3 and mode 10 logic is to be used, or if regular logic is to be used. IRTCCI = 0 Regular logic IRTCCI = 1 RTCC logic
IMANUI		0	Flag specifies output units for maneuver description IMANUI = 0 output maneuver description in units of nautical miles and ft/sec, = 1 output maneuver description in same units as the case was input.
MVALI ETASWI		1.5 0.	Values used to alter the distribution of state vectors in the algorithm advance.
RRBI		0.	A bias to be added on to the down range distance computed in the cross range logic in nautical miles.
L2DI		.25	Lift to drag coefficient used in computing the down range and the cross range.
MDMI		0	Maximum allowable miss distance from the input landing site input in nautical miles.

Figure 5 presents sample input data to illustrate some of the input requirements discussed above.

```
CASE 32 TABLE A-5(A)
$INPUTS
 XOI    =100000.       ,0.                            ,0.                  ,
 UOI    =0.            ,1250.                         ,450.                ,
 YEARI  =1967.         ,DAYI   =1.                    ,HOURI  =0.          ,MONTHI=12,
 ETARZI=33.            ,THCRI  =0.                    ,TRZI   =.17         ,
 DTAI   =0.            ,DTMAXI=0.                     ,
 DETAII=0.             ,DEMAXI=0.                     ,
 DELZI  =0.            ,LAMZI  =0.                    ,
 TARMXI=180.           ,TARMNI=.33                    ,
 TZMAXI=100.           ,TZMINI=.33                    ,
 MDMI   =0.            ,DVMAXI=10000.                 ,
 URMAXI=36320.406      ,BETARI=96.                    ,
 ISYSI  =1             ,IVELI  =1,1                   ,LINESI=1,1,1,1,1,
 LETSGI=1              ,JUMPI  =1.                    ,TJUMPI=1.           ,
 IPOSI  =1             ,IDEGI  =1                     ,IADVI  =2           ,
 KKMAXI=5              ,MODEI  =1                     ,ICRNGI=2            ,
 IRTCCI=0              ,
 MDSPI  =400.,300.,200.,100.,0.,
$
CASE 1 TABLE A-7
$INPUTS
 XOI    =-4645.5012    ,1429.3974                     ,1131.8791           ,
 UOI    =-9214.6008    ,-15070.815                    ,-9134.1282          ,
 YEARI  =1968.         ,DAYI   =6.                    ,HOURI  =22.082365   ,MONTHI=5.,
 ETARZI=33.            ,THCRI  =0.                    ,TRZI   =.17         ,
 DTAI   =0.            ,DTMAXI=3.4                    ,
 DETAII=0.             ,DEMAXI=0.                     ,
 DELZI  =22.           ,LAMZI  =202.                  ,
 TARMXI=180.           ,TARMNI=.33                    ,
 TZMAXI=140.           ,TZMINI=0.                     ,
 MDMI   =0.            ,DVMAXI=10000.                 ,
 URMAXI=36323.         ,BETARI=96.                    ,
 ISYSI  =1             ,IVELI  =1,1                   ,LINESI=1,1,1,1,1,
 LETSGI=3              ,JUMPI  =40.                   ,TJUMPI=0.           ,
 IPOSI  =1             ,IDEGI  =1                     ,IADVI  =2           ,
 KKMAXI=5              ,MODEI  =4                     ,ICRNGI=2            ,
 IRTCCI=0              ,
   LPLOTI = 1 ,
 MDSPI  =400.,300.,200.,100.,0.,
$
CASE 175 TABLE A-3(A)
$INPUTS
 XOI    =233.4735      ,4250.0448                     ,2687.6652           ,
 UOI    =-23195.435    ,12060.729                     ,8810.793            ,
 YEARI  =1968.         ,DAYI   =6.                    ,HOURI  =21.632366   ,MONTHI=5.,
 ETARZI=33.            ,THCRI  =0.                    ,TRZI   =.17         ,
 DTAI   =0.            ,DTMAXI=0.                     ,
 DETAII=0.             ,DEMAXI=0.                     ,
 DELZI  =2.            ,LAMZI  =124.                  ,
 TARMXI=180.           ,TARMNI=.33                    ,
 TZMAXI=45.802366      ,TZMINI=22.132366              ,
 MDMI   =300.          ,DVMAXI=10000.                 ,
 URMAXI=36323          ,BETARI=96.                    ,
 ISYSI  =1             ,IVELI  =1,1                   ,LINESI=1,1,1,1,1,
 LETSGI=1              ,JUMPI  =1.                    ,TJUMPI=0.           ,
 IPOSI  =1             ,IDEGI  =1                     ,IADVI  =2           ,
 KKMAXI=5              ,MODEI  =6                     ,ICRNGI=2            ,
 IRTCCI=0              ,
 MDSPI  =400.,300.,200.,100.,0.,
$
CASE 28 TABLE A-4
$INPUTS
XOI=672.6378,3668.7858,2296.6383,
UOI=-23086,881,9768.2235,7334,7017,
YEARI=1968.,MONTHI=5.,DAYI=6.,HOURI=21.607366,
LINESI=1,1,1,1,1,MODEI=10,ICRNGI=2,IRTCCI=1,
IADVI=2,LETSGI=1,DTAI=0.,DTMAXI=0.,TJUMPI=0.,
TZMAXI=45.777366,TZMINI=22.107366,
URMAXI=36323.,LMAXPI=2,0,
CLI=3.,160.,-46,5,60.,
$
```

Figure 5. Sample Inputs

4. OUTPUT DESCRIPTION

The return to earth abort program is designed to output standard blocks of data for each solution generated and is capable of generating additional information at the user's request. At the beginning of each case, the program repeats the user's inputs - initial state vector, constraints, number of state vectors to be run, etc. Then for each solution generated there results the following three groups of information:

a) A description of the preabort state vector

b) A description of the abort maneuver

c) A description of the reentry state vector

The first and third blocks have the same format and will be discussed jointly. The first line gives the position and velocity vector expressed in geocentric, equatorial, Cartesian coordinates. This line is standard output. The additional four lines are optional and may be output in any combination through the input LINESI(J). Line 2 of the block gives the state vector in polar coordinates, i.e., radial distance, right ascension, declination, speed, flight path angle and azimuth. The third line expresses the state vector in Cartesian moon plane coordinates. The coordinate system is one whose X-axis is along the earth-moon line, the Z-axis is parallel with the direction of the moon's orbital angular momentum vector and the Y-axis completes the right handed system. Line 4 gives the orbital elements for the preabort or postabort orbit - semi-major axis (A), eccentricity (E), inclination (I), longitude of node (NODE), right ascension of perigee (W) and true anomaly (F). The last line gives some additional parameters associated with the state vector. This line gives the longitude (LON), apogee distance (RA), perigee distance (RP), period of the orbit (PER), time until perigee passage (TTP) and the semilatus rectum (P). The units for all output quantities will be the same as the units of the input state vector.

The maneuver description is standard output for each solution generated and consists of the following parameters:

1)	TAZ	Flight time from abort to landing (hr)
2)	TZ	Time of landing measured from zero hours on the abort day (hr)
3)	DV	Velocity change required to achieve postabort orbit (fps)
4)	DGAM	Change in the flight-path angle (deg)
5)	DELV	Difference in the magnitudes of pre-abort and postabort velocity vectors (fps)
6)	SW6	Flag indicating direction of motion of the landing point with increasing trip time. If SW6 = 0, motion of the splashpoint is easterly. If SW6 = 1, splashpoint is moving westerly. If SW6 = -1 the calculation of SW6 was not valid
7)	MD	Distance that actual landing point missed the desired landing site (n mi)
8)	ETARS	Transfer angle from abort to reentry (deg)
9)	DVC	Required velocity change, calibrated to include lunar third-body effect (fps)
10)	DGAMC	Corrected change in flight-path angle (deg)
11)	DELVC	Corrected DELV (fps)
12)	DAZ	Azimuth change from the preabort velocity vector to the postabort velocity vector
13)	DR	Downrange inplane distance from reentry to landing (n mi)
14)	CR	Crossrange distance, measured normal to reentry groundtrack (n mi)
15)	TRZ	Time from reentry to landing

16)	DELTA	Latitude of landing site
17)	LAMDA	Longitude of landing site
18)	DBETAR	Difference in reentry flight-path angle between the actual value at reentry and value on target line for same reentry speed (deg)
19)	DVX, DVY, DVZ	Cartesian components of DV vector, in feet per second
20)	BETADV	Flight-path angle of DV vector (deg)
21)	AZDV	Azimuth of the DV vector (deg)
22)	F	True anomaly on the postabort trajectory, (deg)
23	VAX, VAY, VAZ	Cartesian components of postabort velocity vector (fps)
24)	TAR	Time from abort to reentry (hr)
25)	BETA	Flight-path angle at reentry
26)	BETAC	Flight-path angle at reentry baised on the corrected postabort velocity
27)	VV2X, VV2Y, VV2Z	Postabort velocity vector corrected by calibration package
28)	AZCV	Azimuth of the postabort velocity vector
29)	DLTAR	The difference between the trip time returned by the program and the value baised on the comic elements
30)	VA	Postabort uncorrected velocity magnitude

The above output format is used for all modes except mode 4. The mode 4 output consists of an ordered list of solutions where each solution is described by abort time T0, landing time TZ, and the required velocity change DV (sample output is given on pages 4-5 through 4-9). The solutions are output in groups, each containing the same abort time and nearly the same landing time with the number in each group being the number of miss distances being investigated. The first solution of the group corresponds to the largest miss distance allowed and will be characterized by the smallest DV. If acceptable solutions cannot be generated for all miss distances, then the inaccessible miss distances are indicated by setting T0 = TZ = 0 and DV = 5812.70498. The solutions are ordered by collecting all groups that belong to the same family, i.e., all having nearly the same landing time, TZ. Within each family the groups are printed out in order of increasing abort time, T0. If desired, the program will produce a digital plot of DV versus T0 for the solutions generated. Along with the abort time there is given the quantity INO, which is the number of solutions plotted for this abort time; and the landing time for the solution with the largest miss distance is output at the top of the plot. Each family of solutions, characterized by having nearly the same landing time, is displayed on a separate plot. DV is not plotted continuously but has a granularity of 100 feet per second. Hence, each point is output as a + or -; the plus resulting if the actual DV is less than 50 feet per second greater than the plotted value, and the minus if DV is less than 50 feet per second less than the plotted value. Thus, for example, if DV were 8749, the program would plot a + at 8700, but if the DV were 8751, the program outputs a - at 8800. If the number of points plotted differs from INO, then some of the solution had DV's within 100 feet per second of one another. All such solutions will be characterized by one point of the plot.

```
                              CASE NUMBER  2

                    CASE 32 TABLE A-5(A)

                         ABORT DATE     12/ 1./1967.
                         ABORT TIME       0.         HOURS

     X                Y               Z               XDOT            YDOT            ZDOT
      29.C365644        0.              C.              0.              0.2150462       0.0774166

     X                Y               Z               XDOT            YDOT            ZDOT
 1J0000.0C00000         0.              C.              0.           1250.0000000     450.0000000

     URMAX            IRMAX           DVMAX           BETAR           THCR            ETARZ
  36329.4C57617        40.000C000   10000.000000C     96.00C0000      0.              33.0000000

     TARMAX           TARMIN          TRZ             TZMAX           TZMIN           MDM
     180.000000C        0.33C0000       C.1700000     100.0000000      0.3300000       0.

     DELZ             LAMZ            HR              DTA             DTMAX           TJUMP
       0.               0.          400000.0000000      0.              0.              1.0000000

     JD               DETAII          DEMAXI          JUMPI           LETSGI          LSTCSE
 2439825.5000000        0.              0.              1               1              0

     RFLAG            IBRFGI          IADV            MODE            ITSFGI          ICRNGI
      0                1               2               1               0              2

     IPOSI            IVELI           ISYSI           IDEGI                  LINESI
      1           1        1           1               1               1       1       1       1       1

     MVALI             ETASWI          IRTCCI          IMANUI          LPLOTI
       1.5000000        0.              0               0              C
                                   STATE VECTOR NO.   1
XO=   0.99999999E 05   0.               0.              0.99999999E 05
UO=   0.               0.12500000E 04   0.44999999E 03  0.13285330E 04
T1=   0.
MU/H =      17438.03466797 E*MU/H =      16109.50158691
A =     5.19800746E 04 E =     9.23814058E-01 W =     1.80000000E 02
```

PRE-ABORT DESCRIPTION

TIME OF ABORT IS 0. HOURS

X	Y	Z	XDOT	YDOT	ZDOT
99999.9980469	0.	0.	0.	1249.9999390	449.9999809
RMAG	ALPHA	DELTA	VMAG	BETA	AZ
99999.99804688	[illegible]	0.	1328.53295898	90.00000000	70.20112324
XM	YM	ZM	XMDOT	YMDOT	ZMDOT
-51979.6567383	85328.5039063	4142.5477905	-1126.9850922	-677.2923965	-190.2088661
A	E	I	NODE	W	F
51980.0751953	0.9238141	19.7988777	0.	-180.0000000	180.0000000
LON	RA	RP	PER	TTP	P
290.8410301	99999.9990234	3960.1505432	82.5702887	41.2933097	7618.5935669

MANEUVER DESCRIPTION

TAZ	TZ	DV	DGAM	DELV	SW6
17.5339155	17.5339155	6689.4061279	-79.2703943	5479.6235352	1
MD	ETARS	DVC	DGAMC	DELVC	DAZ
9056.2873535	145.9052124	6689.4060669	-79.2703943	5479.6234741	0.
DR	CR	NIGHT	DELTA	LAMDA	DBETAR
2164.6552429	-25.5611846	10.3520769	-0.2494086	-150.9391022	-0.0000162
DVX	DVY	DVZ	BETADV	AZDV	F
-6689.1277466	-57.4214201	-20.6717169	179.4772606	-109.7988806	-158.5331001
VAX	VAY	VAZ	TAR	BETA	BETAC
-6689.1277466	1192.5785217	429.3282623	17.3314116	169.2703915	169.2703934
VV2X	VV2Y	VV2Z	AZCV	DLTAR	VA

-6689.1276855	1192.5785065	429.3282585	70.2011242	-0.0032907	6808.1565552

REENTRY DESCRIPTION

X	Y	Z	XDOT	YDOT	ZDOT
-2906.4762268	1851.1458893	666.4125137	-16934.9184570	-30245.8488770	-10888.5053711
RMAG	ALPHA	DELTA	VMAG	BETA	AZ
3509.76507568	147.50678062	10.94542074	36334.03906250	96.31402397	106.60037518
XM	YM	ZM	XMDOT	YMDOT	ZMDOT
-812.9654694	-3390.6165771	-401.5677795	35789.1977539	-4906.8263550	3901.1134033
A	E	I	NODE	W	F
-68785258.0000000	1.0000252	19.7988777	-0.	-201.4668941	-12.6278919
LON	RA	RP	PER	TTP	P
177.6648922	-68786124.0000000	3466.4830933	0.	0.0282766	6932.9661865

*****EXECUTION TIME = 16.7000 SEC.

```
                              CASE NUMBER  2

                    CASE 1 TABLE A-7

                         ABORT DATE      5/ 6./1968.
                         ABORT TIME      22.08236500 HOURS

     X              Y              Z              XDOT           YDOT           ZDOT
   -1.3488939       .4150479       .3286588      -1.5852517     -2.5927369     -1.5714075

     X              Y              Z              XDOT           YDOT           ZDOT
 -4645.5012000   1429.3974000   1131.8791000   -9214.6007000  -15070.8149000  -9134.1282000

   UPMAX          TPMAX          DVMAX          BETAR          THCP           ETARZ
 36323.0000000    40.0000000   10000.0000000    56.0000000      .0000000      33.0000000

   TARMAX         TARMIN         TSF            TZMAX          TZMIN          WOM
  180.0000000      .3300000       .1700000     139.9999900      .0000000       .0000000

   DELZ           LAMZ           HR             DTA            DTMAX          TJUMP
   22.0000000    202.0000000  400000.0000000     .0000000      3.4000000       .0000000

     JD           DETAII         DEMAXI         JUMPI          LETSGI         LSTCSE
 2439982.4000000    .0000000      .0000000      40             3              0

   PFLAG          ISAEGI         IADV           MODE           ITSFGI         ICRNGI
    0              1              2              4              0              2

   IPOSI          IVALI          ISYSI          IDEGI                 LINESI
    1        1     1              1              1              1      1      1      1      1

   HVALI          ETASMI         IRTCCI         IMANUI         LPLOTI
    1.5000000      .0000000      0              0              1

 MDSP( 1) = 400.000000

 MDSP( 2) = 300.000000

 MDSP( 3) = 200.000000
 MDSP( 4) = 100.000000

 MDSP( 5) =    .000000
                                       STATE VECTOR NO.   1
  X0=      .20449397+04    .26767914+04    .16068545+04    .37321540+04
  U0=    -.29334820+05    .14059713+05    .98680495+04    .26618768+05
  T1=      .23500237+02

 MU/H =      23489.0160000 E*MU/H =     4337.1696000
 A=      4.34715850+03 E =     1.84646710-01 W =     4.73621050+01
```

TO =	2.35002370+01	T7 =	4.58900250+01	DV =	8.17177340+03
TO =	2.35002370+01	T7 =	4.60078250+01	DV =	8.17678740+03
TO =	2.35002370+01	T7 =	4.61256240+01	DV =	8.18297390+03
TO =	2.35002370+01	T7 =	4.62669820+01	DV =	8.18979700+03
TO =	2.35002370+01	T7 =	4.63344760+01	DV =	8.57287900+03
TO =	2.35002370+01	T7 =	6.98712920+01	DV =	8.79108540+03
TO =	2.35002370+01	T7 =	7.00496730+01	DV =	8.79311300+03
TO =	2.35002370+01	T7 =	7.01068880+01	DV =	8.79416200+03
TO =	2.35002370+01	T7 =	7.02482450+01	DV =	8.79640500+03
TO =	2.35002370+01	T7 =	7.03312300+01	DV =	8.94677450+03
TO =	2.35002370+01	T7 =	9.38239980+01	DV =	9.02782530+03
TO =	2.35002370+01	T7 =	9.39417960+01	DV =	9.02937890+03
TO =	2.35002370+01	T7 =	9.40595940+01	DV =	9.02992600+03
TO =	2.35002370+01	T7 =	9.42009520+01	DV =	9.03055150+03
TO =	2.35002370+01	T7 =	9.42885280+01	DV =	9.11905540+03
TO =	2.35002370+01	T7 =	1.17995211+02	DV =	9.15780640+03
TO =	2.35002370+01	T7 =	1.17995211+02	DV =	9.15780640+03
TO =	2.35002370+01	T7 =	1.18003085+02	DV =	9.15865070+03
TO =	2.35002370+01	T7 =	1.18144442+02	DV =	9.15907650+03
TO =	2.35002370+01	T7 =	1.18235227+02	DV =	9.21999920+03

5. NOTES

The program has numerous internal error messages and comments. A list of the important messages and their significance is now given:

1)	EPHEMERIS ERROR	Error was made in generating moon's position. Program advances to next case.
2)	TARMAX LT. TARMIN	Maximum trip time is less than minimum trip time. Program advances to next state vector.
3)	NO SOLUTION FOUND FOR DVMAX READ IN NEXT CASE	No acceptable solution for minimum trip time trajectory. Next state vector is now read in.
4)	MIN TIME GT TARMAX	Minimum trip time solution exceeds maximum allowable trip time. Program advances to next state vector.
5)	MISS DISTANCE ITERATION COUNT EXCEEDED. READ IN NEW STATE VECTOR	Error message from PLA modes in searching for solutions. Program generates a variable number of trajectories in searching for solutions, depending upon maximum trip time but which is no less than 1000 passes per state vector. If error message is obtained, state vector will be rerun with a limited amount of output as an aid in determining the error. Program then advances to next state vector.
6)	SOLUTION NEAR PARABOLIC GO TO DROOTS	Message is printed in generation of minimum trip time trajectory and merely indicates manner in which the trajectory is generated.
7)	RETURN WITH MAXIMUM REENTRY VELOCITY. GO BACK FOR SECOND ROOT	Indicates that minimum trip time trajectory is limited by maximum allowable reentry speed.

8)	NO SOLUTION IN DVMAXQ. INSUFFICIENT DV TO PERMIT SAFE REENTRY	Message is returned during search for minimum trip time trajectory and indicates there were no solutions to the time-critical quartic. Program then advances to next state vector.
9)	INSUFFICIENT DV TO PERMIT REENTRY IN DESIRED DIRECTION	If preabort motion is retrograde and there is not sufficient fuel to achieve a direct return orbit, this message is printed. Program then advances to the next state vector.
10)	INSUFFICIENT DV TO PREVENT EXCESSIVE REENTRY VELOCITY	If all solutions for minimum time trajectory exceed maximum allowable reentry speed, this message is printed and program advances to next state vector.
11)	ABORT TRAJECTORY IS OUTBOUND LEG OF HYPERBOLA, NO RETURN TO EARTH	Message indicates that error was made in generating the minimum time return-to-earth trajectory. Program continues to seek the minimum trip time solution.
12)	NO CONVERGENCE IN BETA LOOP ETCUA	If iterative loop to satisfy the reentry conditions does not converge after 40 passes, this error message results. Program then calls subroutine TMIN which returns minimum trip time.
13)	APOGEE OF ABORT TRAJECTORY EXCEEDS RMAX LIMIT	Program continues as before.
14)	ABSOLUTE MINIMUM DV GIVES ABORT ON OUTBOUND LEG OF HYPERBOLA. RETURN INSTEAD WITH MAXIMUM PERMISSIBLE REENTRY VELOCITY	Message is generated as program seeks a fuel-critical solution and indicates that the smallest ΔV solution corresponds to motion on the outward bound leg of a hyperbola. The program now picks reentry speed as the smaller of URMAX or the speed achieved falling from an altitude RMAX. This solution is then the fuel-critical solution.

15)	ABSOLUTE MINIMUM DV ABORT EXCEEDS REENTRY VELOCITY LIMITS. RETURN WITH MAXIMUM REENTRY VELOCITY	Fuel-critical solution will be determined by the maximum allowable reentry speed.
16)	RUBR GIVES ABORT TRAJECTORY ON OUTBOUND LEG OF HYPERBOLA NO RETURN TO EARTH	The program has generated a trajectory that does not return to earth. Program continues as before.
17)	P NEGATIVE	Error message from subroutine VELCOM indicating that parameter of the ellipse was computed negative. The program then recomputes p using a limiting value of reentry speed. If p is again negative, program prints following messages.
18)	VELCOM - P NEGATIVE	Subroutine now returns without computing other conic parameters.
19)	NO CONVERGENCE IN BETAR LOOP. READ IN NEXT CASE	If iterative loop to satisfy reentry conditions does not converge after a total of 40 passes, this message is printed. The program then continues with values generated on the last iteration.
20)	NO SOLUTION WAS FOUND FOR SEARCH STATE VECTORS	This message indicates program was unable to generate desired preabort state vector.
21)	XOMAG EXCEEDS CONSTRAINT LIMITS XOMAG =	If the abort radius is larger than 60 e.r. or smaller than 1.025 e.r., the attitude constraints are violated and the search is terminated.
22)	NO SOLUTION IN VELCOM	No solution could be found in VELCOM after 100 iterations.
23)	X1 OUT OF INTERPOLATION RANGE	The value of reentry speed that has been selected is outside the range defined for the reentry target line.
24)	X AND/OR TAR ARE OUTSIDE THE RANGE OF ETAARF	The value of abort attitude and/or trip time that is used in the polynomial array fits in subroutine ETAARF in outside the validity range for this routine.

25)	NO CONVERGENCE IN CLA LOGIC. GO TO NEXT STATE VECTOR	The RTCC logic for generating solutions to a CLA has failed to converge after 500 passes. The program advances to the next state vector.

6. VARIABLES AND CONSTANTS USED THROUGHOUT THE PROGRAM

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	COMP	AA	1	AA	rad	Coefficient used to correct transfer angle
	COMP	ALPAG	1	α_g	rad	Right ascension of Greenwich at epoch plus a bias
	CINPUT	ALPAO	1	α_o	rad	Right ascension of abort position at epoch
	COMP	ALPAZ	1	α_z	rad	Right ascension of the desired landing site
	FLAGS	ALPGO	1	α_{go}	rad	Right ascension of Greenwich at epoch
	COMP	ALPHA	1	α	rad	Right ascension of the impact point
	MN2MN4	AMDS	1	AMDS	rad	Maximum acceptable miss for mode 7
	FLAGS	AM1	1	AM1	rad	Azimuth of the north inclination constraint
	MODE10	ANG	1	ANG	rad	Value used to compute SW6
	FLAGS	AZ	1	A_z	rad	Azimuth
	COMP	A	1	A	er	Semimajor axis
	COMP	BB	1	BB	rad/hr	Coefficient used to correct transfer angle

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	COMP	BETAA	1	β_a	rad	Postabort flight-path angle
	INPTT	BETAR	1	β_r	rad	Flight-path angle at reentry
	U	BETAOP	1	β_{op}	rad	Preabort flight-path angle
	FG	BRANCH	1	BRANCH		Mode 4 flag
	TABLE	BRTABL	32	β_{rtabl}	rad	Table used to interpolate for flight-path angle
	SERCH	CENT	1	CENT		Flag used in integration package
	MODE10	CNM	1	CNM		Subscript used in control
	MODE10	CNT	1	CNT		Subscript used in control
	MODE10	CN	1	CN		Contingency line number
	COMP	CRTN	1	CRTN	rad	Correction to transfer angle
	PIE	C2PI	1	2π		Constant = 6. 28318531
	INPTT	DAY	1	DAY	days	Day of abort
	INPTT	DBETR	1	$D\beta_r$	rad	Flight-path angle increment
	ETAARO	DDT	1	DDT	hr	Time increment
	CONTLN	DELPP	8, 5	δ''	deg	Latitude of points defining contingency lines

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	MODE10	DELP	40	δ'	rad	Latitude differences between impact point and contingency line
	COMP	DELTA	1	δ_a	rad	Latitude of the impact point
	MN2MN4	DELTLS	1	δ_s	deg	Saved value of impact latitude
	CINPUT	DELTO	1	δ_o	rad	Declination of abort position
	MODE10	DELT	1	ΔT	hr	Time increment
	INPTT	DELZ	1	δ_z	rad	Latitude of the desired landing site
	ADV	DEMAX	1	$\Delta_{\eta\,max}$	rad	Maximum angle true anomaly is to be advanced
		DETAIN	1	$\Delta_{\eta\,in}$	rad	Delay in true anomaly for first abort
	CRANGE	DLTRZF	1	ΔT_{rzf}	hr	Difference in input and calculated values of trip time from reentry to landing
	PIE	DPR	1	DPR	deg/rad	Constant = 57.2957795
	SERCH	DTA	1	ΔT_a	hr	Time delay after input that abort is to start
	INPTT	DTHETA	1	D_θ	rad	Azimuth change increment
	INPTT	DTMAX	1	ΔT_{max}	hr	Amount of time state vector is to be advanced

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	COMP	DVBAR	3	$\overline{DV}$	er/hr	Velocity vector change
	U	DVIMAX	1	DV_{imax}	er/hr	Maximum allowable velocity change
	INPTT	DVMAX	1	DV_{max}	er/hr	Maximum allowable velocity change
	DVP	DVP	1	DVP	er/hr	Past value of change in velocity
	DVP	DVSP	8	DVSP	er/hr	Stored velocity changes for Mode 4
	CALC	DVS	1	ΔV_s	er/hr	Change in velocity
	MODE10	EARPS	1	η_{rps}	rad	Past value of transfer angle
	SERCH	ENCORE	1	ENCORE		Flag used in integration package
	FLAGS	ENDI	1	ENDI		End of case flag
	SERCH	END	1	END		End of state vector flag
	SERCH	EPSI	1	EPSI		Flag used in integration package
	ETARRO	ETAARO	1	η_{aro}	rad	Initial value for trans [illegible] angle
	CALC	ETAARS	1	η_{ars}	rad	Transfer angle from abort to reentry
	CRANGE	ETARZP	1	η_{rzp}	rad	Transfer angle from reentry to landing

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	INPTT	ETARZ	1	η_z	rad	Transfer angle from reentry to landing
	COMP	E	1	e		Eccentricity
	CONSTS	FTPER	1	FTPER	ft/er	Constant = 20925738.2
	SERCH	HMIN	1	H_{min}		Flag used in integration package
	INPTT	HOUR	1	HOUR	hrs	Hour of abort
	MN2MN4	IADVFG	1	IADVFG		Flag indicating type of advance
	INPTT	IADV	1	IADV		Advance flag
	IBFLG	IBRFLG	1	IBRFLG		Fixed flight-path angle flag
	ICLFG	ICLFG	1	ICLFG		Number of contingency lines to be run
	CRANGE	ICRNGG	1	ICRNGG		Crossrange logic flag
	IERR	IERR	1	IERR		Error flag from JPLEPH
	TABLE	IMAX	1	I_{max}		Number of cells in interpolation tables
	INPTT	IRMAX	1	IR_{max}	rad	Maximum allowable inclination postabort
	MN2MN4	IRP	1	IRP	rad	Inclination
	Q	IRTCC	1	IRTCC		RTCC logic flag

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	Q	ITSFLG	1	ITSFLG		Velocity correction package
	WLSCON	IWATFG	1	IWATFG		Flag indicating impact area =0 water =1 land mass =2 land mass
	CINPUT	JD	1	JD	yr	Julian date
	SERCH	JSAVE		JSAVE		Number of the state vector being generated
	MODE10	JSTAVC	1	JSTAVC		State vector counter
	SERCH	JUMP	1	JUMP		Number of state vectors to be generated
	KASE	KASE	1	KASE		Case number
	TZMXMN	KKMAX	1	KKMAX		Number of miss distances being run in mode 4
	TZMXMN	KK	1	KK		Indicates which miss distance is being run
	WLSCON	KMAX	1	KMAX		Number of lines defining land and water masses
	SERCH	KRIT	1	KRIT		Flag used in integration package
	COMP	K	1	K		Solution counter
	CO[illegible]	[illegible]A	1	λ	rad	Longitude of the impact point

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	MN2MN4	LAMDAS	1	λ_s	deg	Saved value of impact longitude
	CONTLN	LAMPP	8, 5	λ''	deg	Longitude of points defining contingency lines
	MODF10	LAMP	40	λ'	rad	Longitude differences between impact point and contingency line
	INPTT	LAMZ	1	λ_z	rad	Longitude of the desired landing site
	SERCH	LETSGO	1	LETSGO		Flag indicating type of advance
	CONTLN	LMAXP	8	LMAXP		Array containing number of points describing each contingency line
	WLSCON	LMAX	6	LMAX		Array containing number of points in lines defining land and water masses
	LPLOT	LPLOT	1	LPLOT		Flag indicating plot data output is desired
	COMP	L	1	L		Contingency line counter
	DVP	MDKK	8	MD(KK)	rad	Stored values of miss distance for mode 4
	DVP	MDMKK	8	MDM(KK)	rad	Stored values of miss distance for mode 4
	MN2MN4	MDMM	1	MDMM	rad	Miss distance

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	INPTT	MDM	1	MDM	rad	Maximum allowable miss distance
	MODE10	MDP	1	MDP	rad	Past value of miss distance
	MODE10	MD10FG	1	MD10FG		Solution flag for mode 10 case
	MODE3	MD3FG	1	MD3FG		Mode 3 solution flag
	TZMXMN	MDSP	8	MDSP	rad	Miss distances being run in mode 4
	MN2MN4	MDS	1	MDS	rad	Saved value of miss distance
	TMINF	MINTFG	1	MINTFG		Flag indicating type of solution from EFCUA
	INPTT	MIN	1	MIN	mins	Minute of abort
	INPTT	MODE	1	MODE		Type of case being run
	INPTT	MONTH	1	MONTH		Month of abort
	FLAGS	M7FG	1	M7FG		Mode 7 solution flag
	CONSTS	MUE	1	μ_e	er3/hr2	Gravitational constant of the earth = 19.909416
	MODE10	M	1	M		Subscript used in CONTL
	MN2MN4	NANOM	1	NANOM		Flag used to repeat a state vector for purpose of obtaining debug print

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	CONSTS	NMPER	1	NMPER	n mi/er	Constant = 3443.93359
	CONSTS	OMGE	1	ω_e	rad/hr	Earth's rotational rate = .262516144
	OUTPUT	OUTPT	25	OUTPT		Contains the output conversion factors
	FLAGS	PARP1		PARP1	rad	Value of miss distance
	FLAGS	PARP	1	PARP	rad	Past value of difference in past and present value of miss distance
	WLSCON	PASS	1	PASS		Flag used in water landing logic
	PFLAG	PFLAG	1	PFLAG		Routine print flag
	COMP	PHIZ	1	ϕ_z	rad	Transfer angle from abort to desired landing
	COMP	PHI		ϕ	rad	Transfer angle from abort to impact
	PIE	PI02	1	$\pi/2$	rad	Constant = 1.57079633
	PIE	PI	1	π		Constant = 3.14159265
	COMP	P	1	P		Semilatus rectum
	CALC	QA	1	Q_α		Apogee passage flag, =0 postapogee =1 preapogee

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	CALC	QE	1	Q_e		Postabort motion flag; Q_e = 0 motion is direct Q_e = 1 motion is retrograde
	CALC	QO	1	Q_o		Preabort motion
	Q	Q	1	Q	hr	Time increment used in PLA scans across miss distance contour
	SERCH	REGION	1	REGION		Flag used in integration package package
	CONSTS	RE	1	RE	er	Radius of the earth = 1.0
	RFLAG	RFLAG	1	RFLAG		Routine print flag
	CRANGE	RIR	1	i	rad	Inclination
	INPTT	RMAX	1	R_{max}	er	Maximum allowable radius from the earth
	CINPUT	RR	1	RR	er	Reentry radius
	COMP	R1	3	$\overline{R1}$		Preabort angular momentum unit vector
	COMP	R2	3	$\overline{R2}$		Completes coordinate system with UNXO and R1
	SERCH	SCAN	1	SCAN		Flag used in integration package
	CONSTS	SCPHR	1	SCPHR	sec/hr	Constant = 3600.00000
	COMP	SDV	1	SDV	er/hr	Stored value of DVMAX

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	INPTT	SEC	1	SEC	SEC	Second of abort
	MN2MN4	SEEK	1	SEEK		Search flag
	FLAGS	SOL	1	SOL		Solution flag
	SERCH	STAVEC	41, 7	STAVEC	er, er/ hr, hr	State vectors generated in the integration package
	SERCH	STAVEX	7, 7	STAVEX	er, er/ hr	Contains the optimum state vector generated
	FLAGS	SW1	1	SW1		Initial pass flag
	FLAGS	SW2	1	SW2		Search flag used in PLA cases
	FLAGS	SW3	1	SW3		Flag used in water landing logic
	FLAGS	SW4	1	SW4		Initial pass flag
	MODE10	SW5	1	SW5		Flag used in contingency landing logic
	MODE10	SW6	1	SW6		Flag indicating direction of impact point
	INPTT	TARMAX	1	Tarmax	hr	Maximum allowable trip time
	INPTT	TARMIN	1	Tarmin	hr	Minimum input allowable trip time
	COMP	TARPRM	1	Tarprm	hr	Minimum calculated allowable trip time
	MODE10	TARPS	1	Tarps	hr	Past value of trip time

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	COMP	TARO	1	TARO	hr	Initial time
	CALC	TARS	1	Tars	hr	Saved value for trip time
	FLAGS	TEST	1	TEST		Search flag
	CRANGE	THCR	1	θ_{cr}	rad	Crossrange offset angle
	COMP	THETA	1	θ	rad	Change in azimuth
	COMP	THMDP	1	θ_{mdp}	rad	Azimuth change to the south inclination constraint
	COMP	THMD	1	θ_{md}	rad	Azimuth change to the most constraining of the inclination or DVMAX constraints to the south
	COMP	THMUP	1	θ_{mup}	rad	Azimuth change to the north inclination constraint
	COMP	THMU	1	θ_{mu}	rad	Azimuth change to the most constraining of the inclination or DVMAX constraints to the north
	COMP	THXX	1	θ_{mx}	rad	Maximum change in azimuth
	TZMXMN	THO	1	θ_o	rad	Initial value for azimuth change
	COMP	THZ	1	θ_z	rad	Azimuth change to the desired landing site
	SERCH	TJUMPN	1	TJUMPN	hr	Time step used in generating state vectors

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	SERCH	TJUMP	1	TJUMP	hr	Time step used in generating state vector
	TMT	TMT	1	TMT	hr	Minimum trip time
	Q	TRPM	1	Trpm	hr	Minimum trip time based on reentry velocity of 37,500 feet per second
	INPTT	TRZ	1	Trz	hr	Time from reentry to landing
	DVP	TOP	8	Top	hr	Stored times of abort for Mode 4
	CINPUT	TO	1	To	hr	Time of abort
	SERCH	T1	1	T1	hr	Time associated with output state vector from integration package
	TZMXMN	TZMAX	1	Tzmax	hr	Maximum total trip time
	TZMXMN	TZMIN	1	Tzmin	hr	Minimum total trip time
	DVP	TZP	8	Tzp	hr	Stored times of landing for mode 4
	COMP	TZ	1	Tz	hr	Time of landing
	COMP	UA	1	UA	er/hr	Postabort speed
	CINPUT	UNUO	3	$\hat{U}_o$	er/hr	Unit vector in direction of pre-abort velocity vector
	CINPUT	UNXO	3	$\hat{X}_o$	er	Abort position unit vector

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	INPTT	URMAX	1	UR_{max}	er/hr	Maximum allowable reentry speed
	CALC	URS	1	UR_s	er/hr	Speed at reentry
	TABLE	URTABL	32	URTABL	er/hr	Table used to interpolate for flight-path angle
	CINPUT	UOMAG	1	$\lvert\overline{U}_o\rvert$	er/hr	Preabort velocity magnitude
	U	UOPBAR	3	$\overline{UOP}$	er/hr	Preabort velocity vector
	INPTT	UO	3	$\overline{U}_o$	er/hr	Preabort velocity vector
	INPT	VABAR	3	$\overline{VA}$	er/hr	Postabort velocity vector
	COMP	VAR	1	VAR	er/hr	Radial component of postabort velocity
	COMP	VAT	1	VAT	er/hr	Tangential component of postabort velocity
	COMP	VR	1	VR	er/hr	Reentry speed
	FLAGS	VOR	1	VOR	er/hr	Radial component of preabort velocity
	COMP	VOT	1	VOT	er/hr	Tangential component of preabort velocity
	WLSCON	WLN	6, 20	WLN	deg	Longitude of points defining water and land masses

I/O	Named Common	Symbolic Name	Prog. Dim.	Math Symbol	Data Units	Definitions
	WLSCON	WLT	6, 20	WLT	deg	Latitude of points defining water and land masses
	XMONTH	XMON	12	XMON		Array containing the names of the months
	CINPUT	XOMAG	1	$\lvert\overline{X}o\rvert$	er	Abort position magnitude
	INPTT	XO	3	$\overline{X}_o$	er	Abort position vector
	CINPUT	X	3	$\overline{X}$	er	Unit vector (1, 0, 0)
	INPTT	YEAR	1	YEAR	yr	Year of abort
	CINPUT	Y	3	$\overline{Y}$	er	Unit vector (0, 1, 0)
	CINPUT	Z	3	$\overline{Z}$	er	Unit vector (0, 0, 1)

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4. D. R. Davis et al, "Users Manual for the Earth-Centered Analytic Abort Program," TRW Note No. 67-FMT-589, Task MSC/TRW A60.1, 20 December 1967.