NASA TECHNICAL MEMORANDUM

NASA TM X-53434

April 12, 1966

NASA TM X-53434

ANALYSIS OF AN INTERPLANETARY TRAJECTORY TARGETING TECHNIQUE WITH APPLICATION TO A 1975 VENUS FLYBY MISSION

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ABSTRACT

A trajectory technique is discussed that, when systematically applied, enables the trajectory analyst to obtain a continuous, free-flight integrated trajectory from planet A to a desired target planet C via some intermediate target planet B. Basically, the scheme defines targeting parameters at the intermediate planet B in terms of the desired values at planet C. This allows an actual search between planets A and B, while, in reality, a targeting at planet C is taking place. An application of this targeting technique to a Venus flyby trajectory, i.e., A = Earth, B = Venus, C = Earth, is described in this report.

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SUMMARY

A trajectory technique is discussed that, when systematically applied, enables the trajectory analyst to obtain a continuous, free-flight integrated trajectory from planet A to a desired target planet C via some intermediate target planet B. Basically, the scheme defines targeting parameters at the intermediate planet B in terms of the desired values at planet C. This allows an actual search between planets A and B, while, in reality, a targeting at planet C is taking place. An application of this targeting technique to a Venus flyby trajectory, i.e., A = Earth, B = Venus, C = Earth, is described in this report.

I. INTRODUCTION

The interplanetary trajectories of interest here are the flyby and swingby type trajectories. These trajectories, in general, depart from planet A, pass close by and are perturbed by an intermediate planet B, and arrive at a target planet C. The JPL Space Trajectories Program* uses a linear search routine, but a linear search between planets A and C is not practical because of the perturbation of the trajectory by planet B. Hand perturbations of the independent parameters at planet A are ineffective in adjusting target parameters at C. The targeting technique presented here will allow target parameters at planet B to be defined such that a targeting at C will occur. This allows the use of the present JPL linear search routine to be used for targeting at planet B.

The targeting technique is applied to the 1975 Venus conjunction flyby mission where A = Earth, B = Venus, and C = Earth.

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* This JPL computer program is a high accuracy program employing either Encke's or Cowell's method of integration as desired. It uses precision ephemerides as described by JPL Technical Release No. 34-239 and an oblate earth potential function containing the second, third, and fourth spherical harmonics. Gravitational effects of Sun, Venus, Earth, Moon, Mars, and Jupiter are considered. This program is described in detail in JPL Technical Report No. 32-223.

II. TARGETING TECHNIQUE

Flyby or swingby interplanetary trajectories depart from planet A*, pass close by an intermediate planet B*, and arrive at a target planet C*. If A = C, the trajectory is called a B flyby trajectory, and if A ≠ C, the trajectory is called a B swingby trajectory. Figure 1 shows a typical Venus flyby trajectory where A = Earth, B = Venus, and C = Earth.

Knowing the relation between the planets of interest (dates, heliocentric longitude, etc.) and the approximate trip times from A to B and B to C, we can easily find the flyby or swingby trajectories by two-body approximating conic programs [6, 7]. Using the conic program, we determine the flyby or swingby trajectories by analyzing groups of A to B trajectories and B to C trajectories. The conditions necessary at B to insure a flyby or swingby trajectory are as follows: (1) the time of arrival at B from the A to B trajectory must equal the depart time for the B to C trajectory and (2) the arrival hyperbolic excess velocity magnitude from the A to B trajectory at B must equal the depart hyperbolic excess velocity magnitude for the B to C trajectory. With these conditions met, the angle between the arrival hyperbolic excess velocity vector and the depart hyperbolic excess velocity vector, which is the bend angle, determines the radius of closest approach (RCA) at B. With conditions (1) and (2) met at B, the trajectory from A to B is said to be merged with the trajectory from B to C, thus yielding a flyby or swingby trajectory. Reference 6 describes a program which has the above conditions automated, and the selection of RCA is left for the analyst. Venus swingby trajectory opportunities with respect to Earth-Mars and Mars-Earth trajectories can be found in References 2 and 9 and flyby trajectories to Mars and Venus can be found by using References 8 and 10.

Two-body approximating conic trajectories are good for preliminary analysis. However, for detail mission analysis where communication distances, communication angles, tracking requirements, and point by point time histories are needed, a precision integrated trajectory becomes necessary. Here, in particular, the nominal or reference free flight trajectory is of importance.

The JPL Space Trajectory Program [3, 5] is used to determine the integrated flyby or swingby trajectory. As presently used, the JPL program employs a targeting method which provides the capability of finding A to B type trajectories. To clarify terminology, the JPL targeting method will be discussed briefly.

* A, B, and C are used to refer to planet A, planet B, and planet C, respectively.

The JPL trajectory targeting method is the N x N Newton-Raphson scheme as defined in Reference 5. In this scheme, a nominal trajectory to B, usually using conditions from approximating conic trajectories, is made to establish a column matrix of miss components, $\bar{P}$. The N^2 partials are obtained by N perturbed trajectories and differencing. Having obtained a matrix M of partials, the search routine solves the equation

$$M \triangle \bar{X} = \bar{P} \qquad (1)$$

to obtain incremental conditions, as represented by the column matrix $\triangle X$, at A to null the miss components at B. The partials found by differencing are used for three iterations and then are recomputed. This procedure is repeated until the miss components are driven to zero or within some convergence tolerance.

The miss components are the differences between the desired dependent variables at B and the values obtained in the nominal trajectory. The dependent variables are usually the two components of the impact parameter $\bar{B}$ and the time of flight, T_F, from A to B or hyperbolic excess velocity, V_H, on arrival at B. The two components of the impact parameter $\bar{B}$ are known as the JPL targeting system [5] or the $\bar{B}\cdot\hat{T}$, $\bar{B}\cdot\hat{R}$ system.

The $\bar{B}\cdot\hat{T}$, $\bar{B}\cdot\hat{R}$ target system as used in the JPL Space Trajectory Program [3] will be described. In Figures 2 and 3, $\hat{S}$ is a unit vector parallel to the incoming asymptote referenced to the center of target or planet of interest, $\hat{T}$ is a unit vector parallel to or lying in the plane of interest (ecliptic plane, earth's equatorial plane, etc.) and perpendicular to $\hat{S}$, and $\hat{R}$ completes the orthogonal system $\hat{R}$, $\hat{S}$, and $\hat{T}$. The vector $\bar{B}$ lies in the $\hat{R}$ - $\hat{T}$ plane and perpendicular to the approach asymptote (see Figures 2 and 4). $\bar{B}$ has the magnitude of the semi-major axis, b, of the approach hyperbola. In Figure 5, looking at the $\hat{R}$ - $\hat{T}$ plane, we see that $\bar{B}\cdot\hat{R}$ and and $\bar{B}\cdot\hat{T}$ are the projections of $\bar{B}$ on $\hat{R}$ and $\hat{T}$, respectively.

Injection conditions at A are usually referred to as the independent variables for the search procedure. These independent variables as used here are (1) T_L, launch time of day which, in conjunction with a specified earth launch azimuth, establishes a specific departure orbit, (2) T_{CO}, the departure point or coasting time in the specified earth orbit, and (3) T_{BU}, the thrusting time of the earth escape maneuver.

Now using the independent variables T_L, T_{CO}, T_{BU} and the dependent variables $\bar{B}\cdot\hat{T}$, $\bar{B}\cdot\hat{R}$, V_H, the elements in equation (1) become

$$
M = \begin{bmatrix} \frac{\partial \bar{B}\cdot\hat{T}}{\partial T_L} & \frac{\partial \bar{B}\cdot\hat{T}}{\partial T_{CO}} & \frac{\partial \bar{B}\cdot\hat{T}}{\partial T_{BU}} \\ \frac{\partial \bar{B}\cdot\hat{R}}{\partial T_L} & \frac{\partial \bar{B}\cdot\hat{R}}{\partial T_{CO}} & \frac{\partial \bar{B}\cdot\hat{R}}{\partial T_{BU}} \\ \frac{\partial V_H}{\partial T_L} & \frac{\partial V_H}{\partial T_{CO}} & \frac{\partial V_H}{\partial T_{BU}} \end{bmatrix} \tag{2}
$$

$$
\Delta\bar{X} = \begin{bmatrix} \Delta T_L \\ \Delta T_{CO} \\ \Delta T_{BU} \end{bmatrix} \quad \text{at planet A} \tag{3}
$$

$$
\bar{P} = \begin{bmatrix} \Delta\bar{B}\cdot\hat{T} \\ \Delta\bar{B}\cdot\hat{R} \\ \Delta V_H \end{bmatrix} \quad \text{at planet B} \tag{4}
$$

The procedure for obtaining these values is as described above.

Since the flyby or swingby trajectory is hyperbolic about B, the set of dependent variables above are linear for reasonable perturbations of the independent variables. This linearity arises from the fact that, with small perturbations of the independent variables at A, the hyperbolic excess velocity vector is translated and not rotated at planet B [5].

After finding the desired conditions at planet B, as specified from the approximating conic conditions, the trajectory is allowed to continue by B, and its relationship to planet C is observed. From Reference 10 and from experience in obtaining flyby trajectories, the first try usually has a large RCA at C (approximately 6×10^6 km for Venus flyby and Mars flyby trajectories where C = Earth). Attempts to move the conditions at B to reduce the RCA at C by using various curve-fitting schemes and manual perturbations of independent variables at A yield trajectories which return to C with first order of magnitude improvements (3×10^5 km for Venus flyby and Mars flyby trajectories where C = Earth).

Reference 4 has shown that the effects at C from errors occurring in hyperbolic excess velocity (V_H), right ascension (α) and declination (δ) of the incoming asymptote, and time of flight from A to B (T_{A-B}) at B are small in comparison to errors in the impact parameter components ($\bar{B}\cdot\hat{T}$ and $\bar{B}\cdot\hat{R}$) at B. Targeting at C from flyby or swingby conditions at B will be described in terms of the impact parameter components at B and C. The effects of small perturbations in the impact parameter components at B on the impact parameter component at C must be found and used in a manner to obtain desired changes at B to null the errors in the impact parameter components at C, thus targeting the trajectory at C. From Reference 4, the variation in impact parameter components at B and their effects on target parameters at C are given by the R matrix:

$$R = \begin{bmatrix} \dfrac{\partial \bar{B}\cdot\hat{T}_C}{\partial \bar{B}\cdot\hat{T}_B} & \dfrac{\partial \bar{B}\cdot\hat{T}_C}{\partial \bar{B}\cdot\hat{R}_B} \\[2ex] \dfrac{\partial \bar{B}\cdot\hat{R}_C}{\partial \bar{B}\cdot\hat{T}_B} & \dfrac{\partial \bar{B}\cdot\hat{R}_C}{\partial \bar{B}\cdot\hat{R}_B} \end{bmatrix}^{**} \tag{5}$$

By knowing the R matrix, changes in impact parameter components at B produce associated changes in impact parameter components at C.

$$\begin{bmatrix} \Delta\bar{B}\cdot\hat{T}_C \\ \Delta\bar{B}\cdot\hat{R}_C \end{bmatrix} = R \begin{bmatrix} \Delta\bar{B}\cdot\hat{T}_B \\ \Delta\bar{B}\cdot\hat{R}_B \end{bmatrix} \tag{6}$$

** Subscripts B and C indicate planet B and C, respectively.

However, the desired conditions at C are known and the conditions at B are desired in order to target the flyby or swingby trajectory at B.

$$\begin{bmatrix} \Delta\bar{B}\cdot\hat{T}_B \\ \\ \Delta\bar{B}\cdot\hat{R}_B \end{bmatrix} = R^{-1} \begin{bmatrix} \Delta\bar{B}\cdot\hat{T}_C \\ \\ \Delta\bar{B}\cdot\hat{R}_C \end{bmatrix} \tag{7}$$

Using equations (7) and (1), and the R matrix, we can find the desired changes in impact parameter components at C, and finally the needed changes in impact components at B. The process for finding the "best" trajectory is an iterative process. "Best" is used to mean (1) convergence to the desired conditions at C or (2) that the desired changes at B fall within a convergence tolerance.

Figure 6 shows a simplified logic flow diagram of the above procedure for obtaining targeting at C using the JPL Space Trajectory Program.

In the next section, the targeting technique is used to obtain a flyby trajectory where A = Earth, B = Venus and C = Earth. Only the targeting technique from B to C will be discussed in detail, since adequate documentation of the JPL targeting method is found in References 3, 5, and 10.

III. VENUS FLYBY TRAJECTORY

In phase I of the Manned Venus/Mars Flyby Study [10], minimum weight in earth-orbit missions for various Venus conjunctions are presented. The minimum weight in Earth orbit mission for the 1975 Venus conjunction was selected from Reference 10 to illustrate the targeting technique where A = Earth, B = Venus, and C = Earth and to provide a reference trajectory for phase II of the Manned Venus/Mars Flyby Study for the 1975 Venus conjunction.

Using the two-body conic program to establish a preliminary trajectory, a trajectory having the characteristics given in Table 1 was chosen. This is a free flight trajectory which departs Earth (A) on June 7, 1975, passes Venus (B) on October 2, 1975, and returns to Earth (C) on June 7, 1976, for a total trip time of 366.4 days. A typical 1975 Venus trajectory is shown in Figure 1.

The conic arrival and depart conditions at Venus were used to establish the $\bar{B}\cdot\hat{T}^*_{♀}$, $\bar{B}\cdot\hat{R}_{♀}$ and $V_{H_{♀}}$ for the initial dependent search parameters. The JPL trajectory targeting method was used with the independent search parameters, T_L, T_{CO}, and T_{BU}. A converged trajectory from Earth was obtained. This trajectory was allowed to continue past Venus and to return toward the Earth. The RCA at Earth return was 5,696,092 km. Conditions on this first pass trajectory are given in Table 2, Column 1.

The perturbed trajectories were found using the same procedure as discussed above and are tabulated in Table 2, Columns 2 and 3. With these conditions, the R matrix was computed and is tabulated in Table 2B as First R Matrix. Using this R matrix and equation (7) of Section II, the $\Delta\bar{B}\cdot\hat{T}_{♀}$ and $\Delta\bar{B}\cdot\hat{R}_{♀}$ were calculated and are shown in Table 2, Column 4. (Note: Desired $\bar{B}\cdot\hat{T}_{\oplus}$ = 13430 km and $\bar{B}\cdot\hat{R}_{\oplus}$ = 50 km.) With a new $\bar{B}\cdot\hat{T}_{♀}$ and $\bar{B}\cdot\hat{R}_{♀}$, a trajectory was found as shown in Table 2, Column 5 where the RCA at Earth is 687,691 km. This procedure continued for two more iterations as seen in Table 2. A new R matrix was then calculated (Table 2B, Second R Matrix) and used for one iteration (Table 2A, Column 5). This trajectory, Table 2A, Column 5, yielded a $\Delta\bar{B}\cdot\hat{T}_{♀}$ and $\Delta\bar{B}\cdot\hat{R}_{♀}$, Table 2A, Column 6, less than the convergence tolerance of 1.5 km used in the JPL Space Trajectories Program [3]. The "best" trajectory was then printed in detail.

The conic trajectory and integrated trajectory are compared in Table 1. The hyperbolic excess velocities leaving Earth, arriving and departing Venus, and arriving Earth are in close agreement. This agreement confirms that conic approximation assumptions used in calculating weight in Earth orbit of Reference 10 are valid.

For purposes of communication between the spacecraft and Earth, for the 1975 Venus flyby trajectory, Figures 7, 8, and 9 show the pertinent communication angle and distances from Earth and Venus. A maximum distance from Earth of 117,360,440 km occurs 190 days after injection.

Table 3 is a tabulation of the thrusting trajectory for the Earth escape maneuver. The initial weight is based on Reference 10 where two J-2 engines are used in the Earth escape stage for the minimum weight Venus mission during the 1975 conjunction. Thrusting is along the vehicle's longitudinal axis and in the plane of motion. This trajectory starts from a 485 km orbit on June 7, 1975 at 6 hours, 49 minutes, and 27.591 seconds past midnight, GMT. The 485 km Earth orbit was chosen

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* $\hat{T}$ is referenced to Earth equatorial plane. Subscripts ♀ and ⊕ refer to Venus and Earth, respectively.

for its rendezvous and lifetime characteristics, both of which are important for manned missions involving earth orbital operation. Figure 10 illustrates the coordinate systems used in the trajectory tabulations.

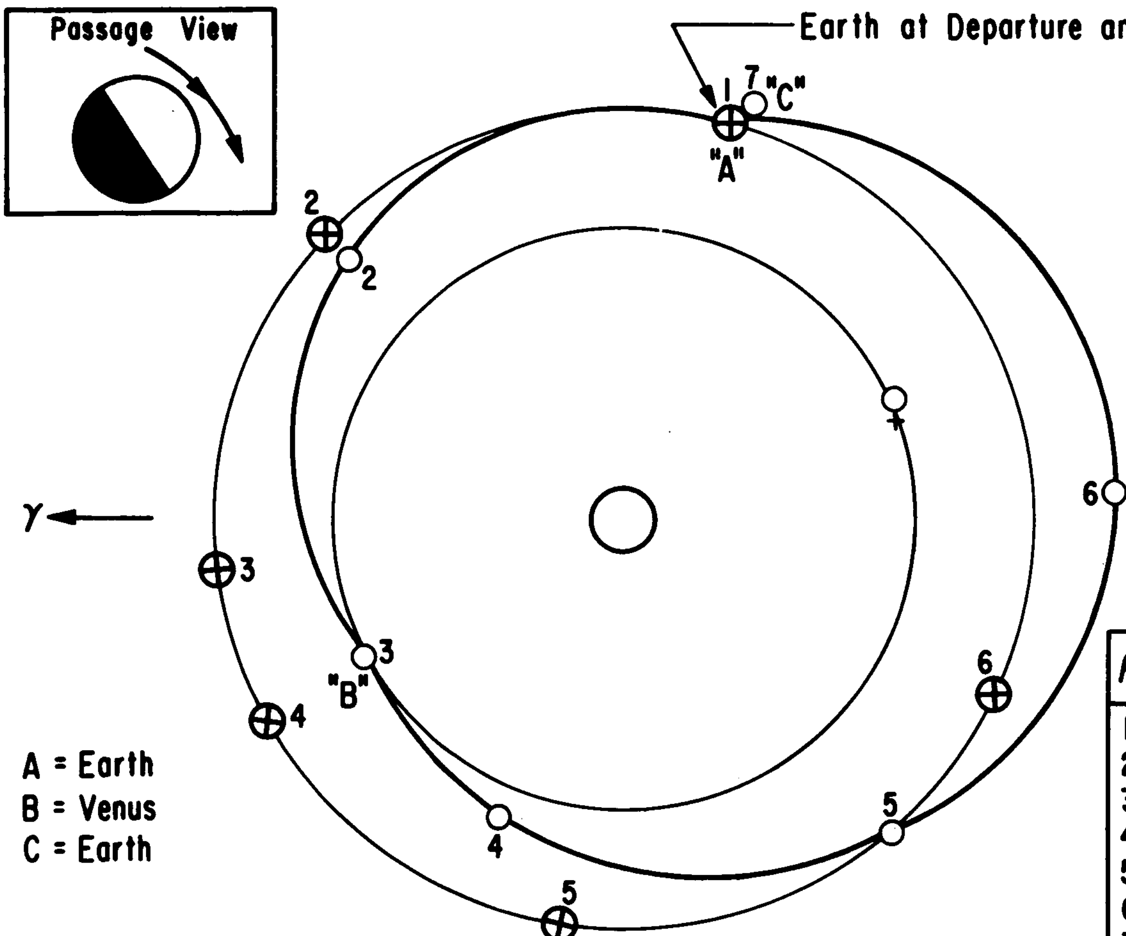
Table 4 is a listing of various trajectory parameters for the Venus flyby trajectory. The trajectory is tabulated in five phases: (1) Earth Depart, (2) Heliocentric Earth-Venus, (3) Aphrodiocentric, (4) Heliocentric Venus-Earth, and (5) Earth Return. After a thrusting period of 393.6 seconds (Table 3), the spacecraft reaches mission injection on June 7, 1965, at 6 hours, 56 minutes, and 1.192 seconds, GMT, with a hyperbolic excess velocity of .1091 EMOS. The time from injection to pericenter passage at Venus is 116 days, 0 hours, 34 minutes, and 29.06 seconds.

The trajectory passes Venus with an RCA of 6354.2 km on October 1, 1975, at 7 hours, 30 minutes, and 30.252 seconds, GMT, and returns to a geocentric radius of 9717.2 km with a hyperbolic excess velocity of .2544 EMOS on June 7, 1976 at 4 hours, 58 minutes, and 27.824 seconds, GMT. A total mission trip time of 365 days, 22 hours, 2 minutes, and 26.6 seconds is required.

CONCLUSIONS

The targeting technique presented here provides a means whereby accurate integrated reference trajectories for flyby or swingby missions can be obtained. For the Venus swingby illustration , the RCA on arrival at Earth was improved by an order of magnitude over that obtained using previous techniques.

IBM 7094 computer time for obtaining the Venus trajectory using this targeting technique was approximately 4.1 hours. The R matrix and increment values were calculated by hand. This, however, reduced computation time by a factor of four over that required for previous techniques. Therefore, the targeting method described in this report allows one to obtain a more desirable trajectory with a considerable reduction in the amount of computer time.



$\rho \triangleq$ Earth - Probe Distance in A.U.

ρ	Date	Communication Distance
1	5-7-75	——
2	8-6-75	.117
3	10-1-75	.422
4	10-25-75	.606
5	12-14-75	.784
6	2-22-76	.570
7	5-7-76	——

FIG. I. TYPICAL VENUS FLYBY MISSION PROFILE FOR 1975 CONJUNCTION

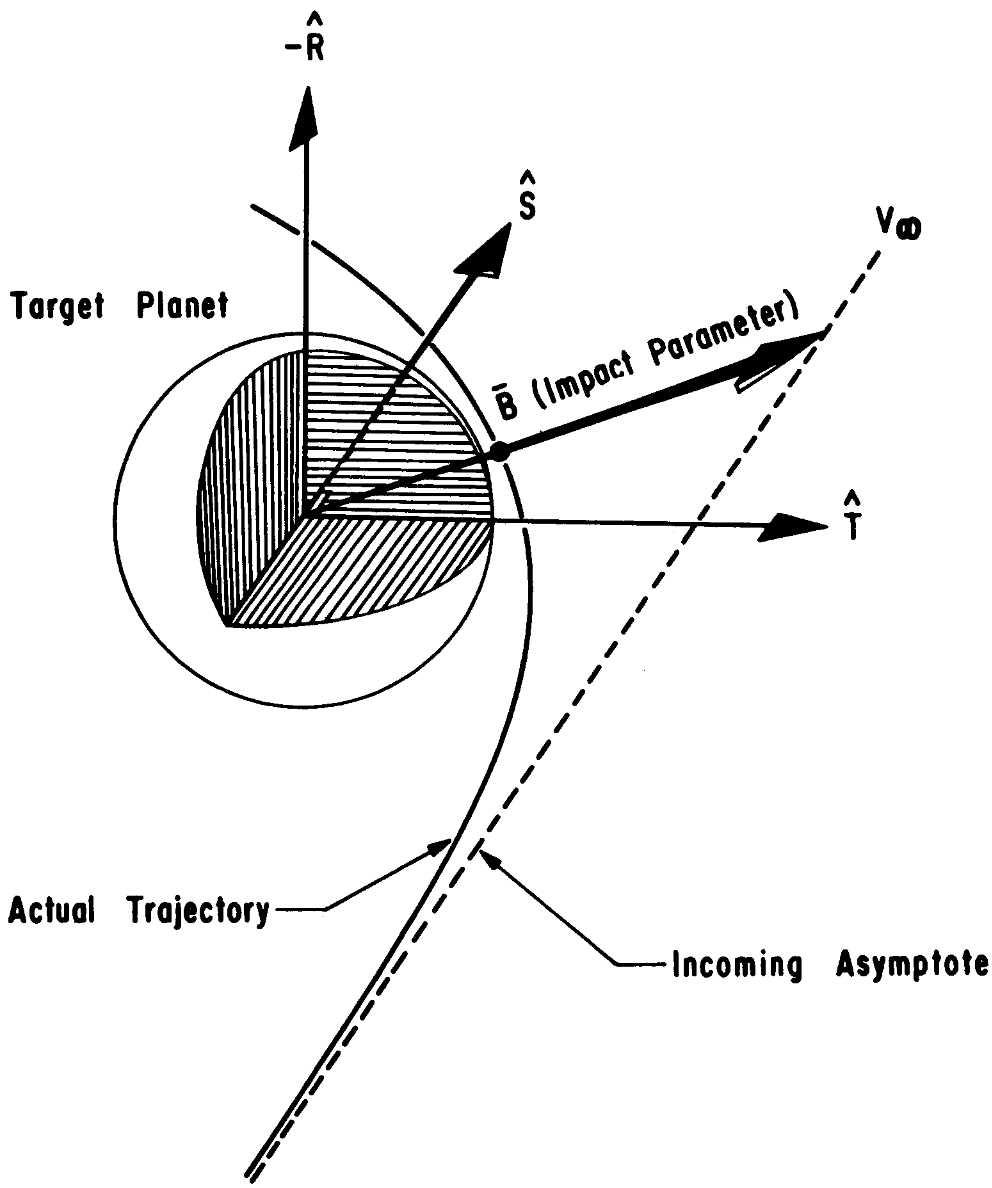


FIG. 2. TARGET SYSTEM RELATIONS

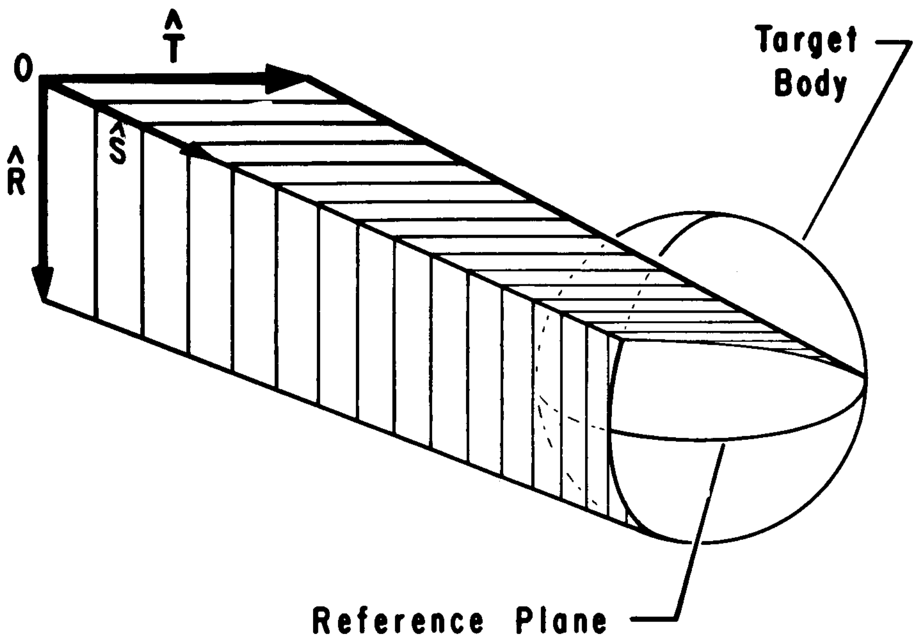


FIG. 3. $\hat{R}, \hat{S}, \hat{T}$ TARGET COORDINATE SYSTEM

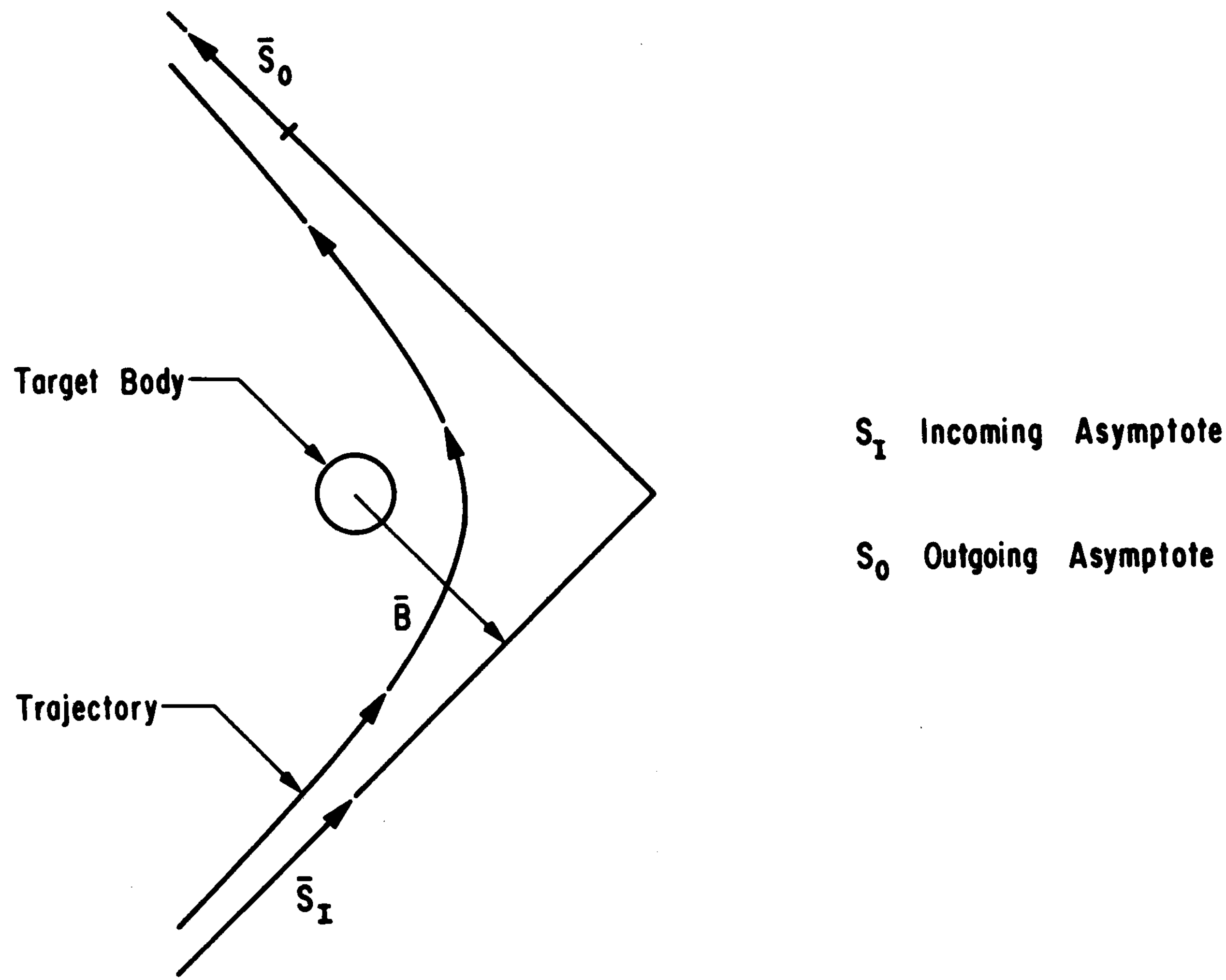
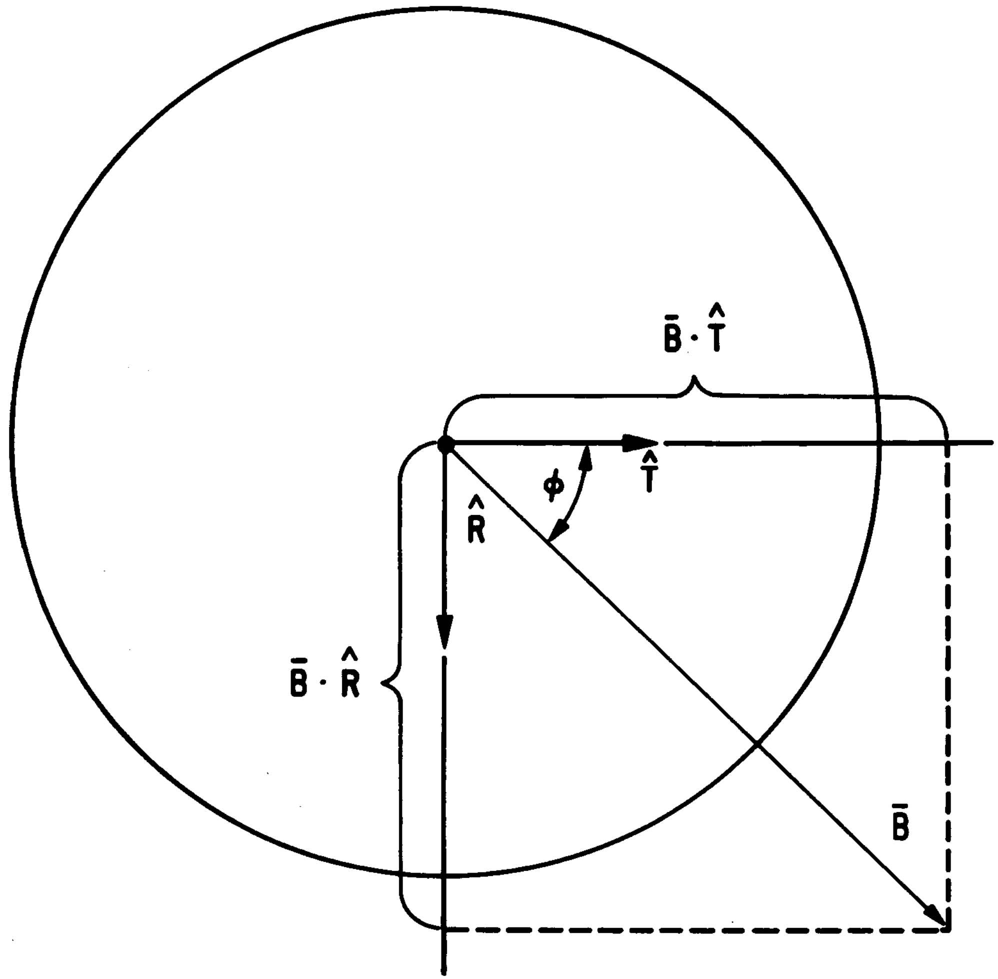


FIG. 4. $\bar{B}$ IMPACT PARAMETER



$$\bar{B} \cdot \hat{T} = |\bar{B}|\ |\hat{T}| \cos \phi$$

$$\bar{B} \cdot \hat{R} = |\bar{B}|\ |\hat{R}| \sin \phi$$

FIG. 5. $\bar{B} \cdot \hat{T}$ AND $\bar{B} \cdot \hat{R}$ IN THE $\hat{R}-\hat{T}$ PLANE

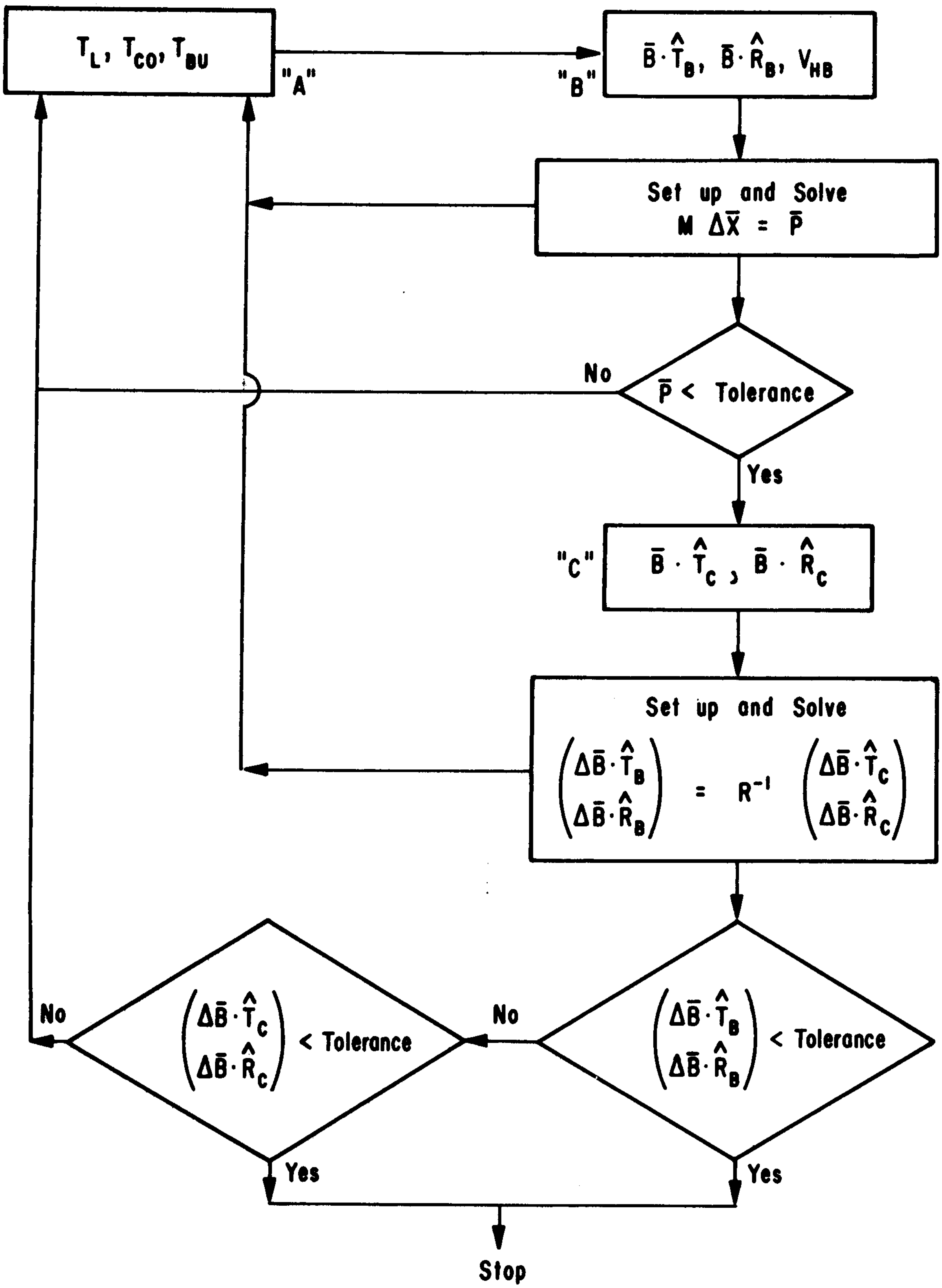


FIG. 6. SIMPLIFIED LOGIC DIAGRAM FOR TARGETING AT C

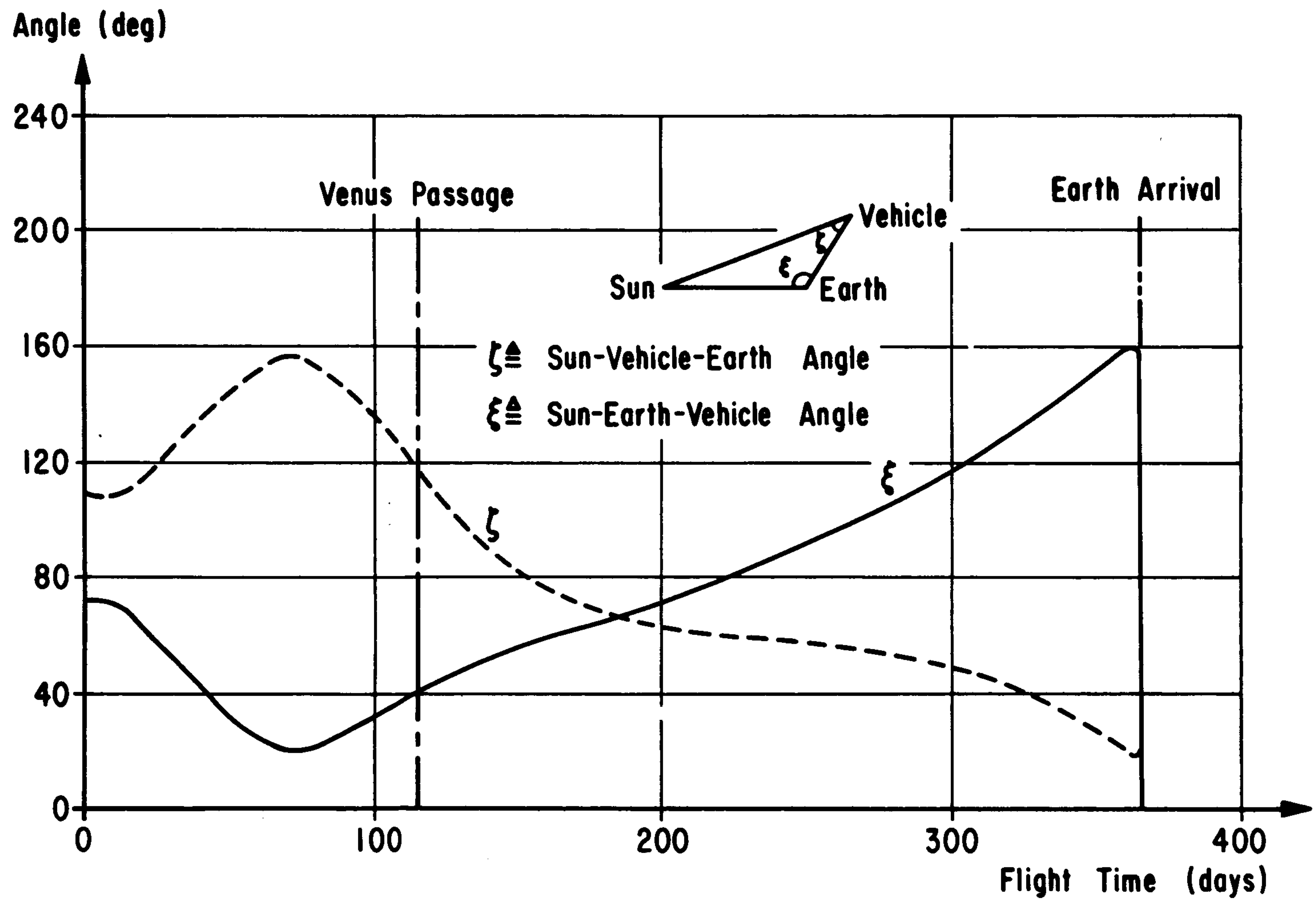


FIG. 7. VENUS FLYBY MISSION 1975 CONJUNCTION SUN-VEHICLE-EARTH ANGLE AND SUN-EARTH-VEHICLE ANGLE VERSUS FLIGHT TIME

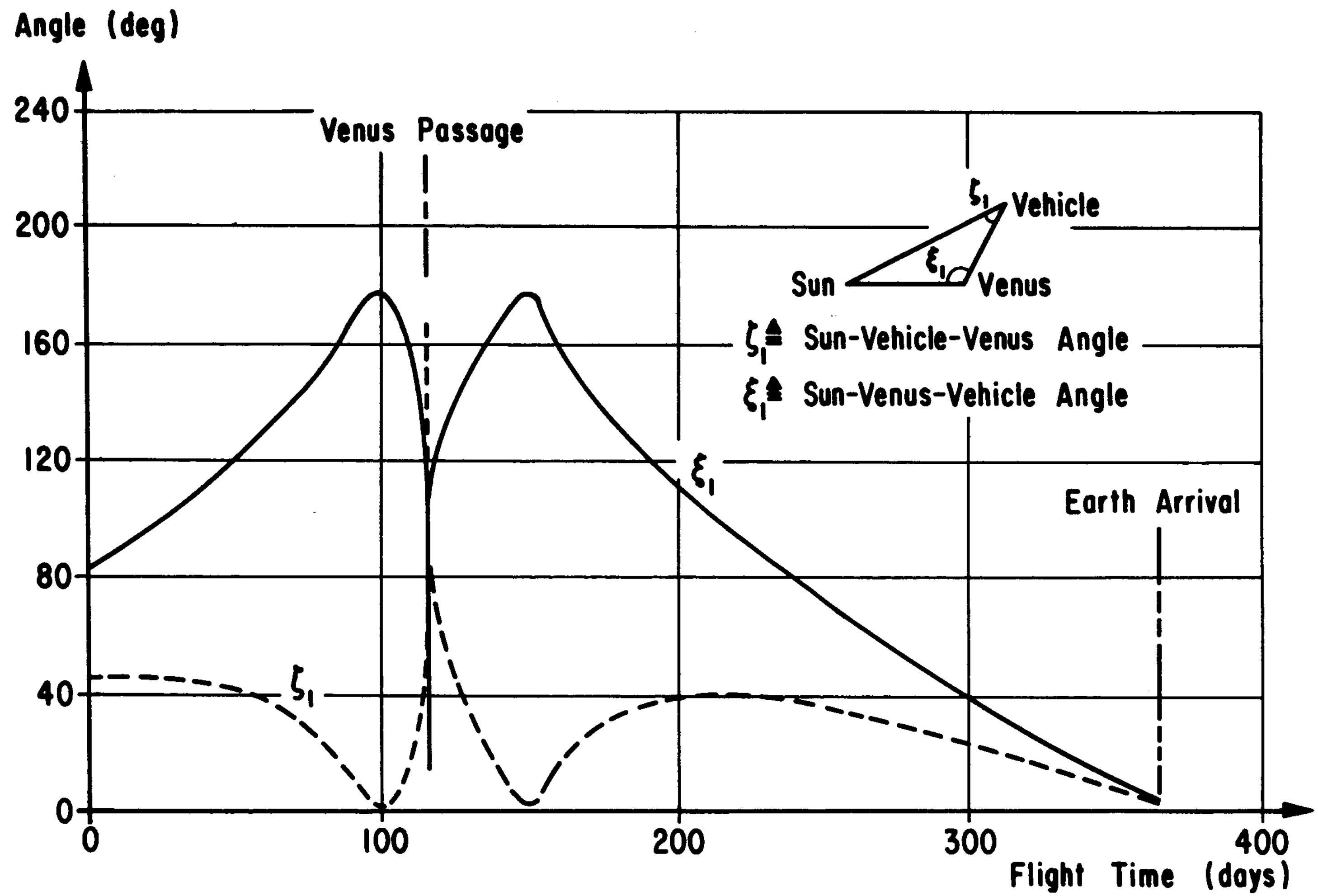


FIG. 8. VENUS FLYBY MISSION 1975 CONJUNCTION SUN-VEHICLE-VENUS ANGLE AND SUN-VENUS-VEHICLE ANGLE VERSUS FLIGHT TIME

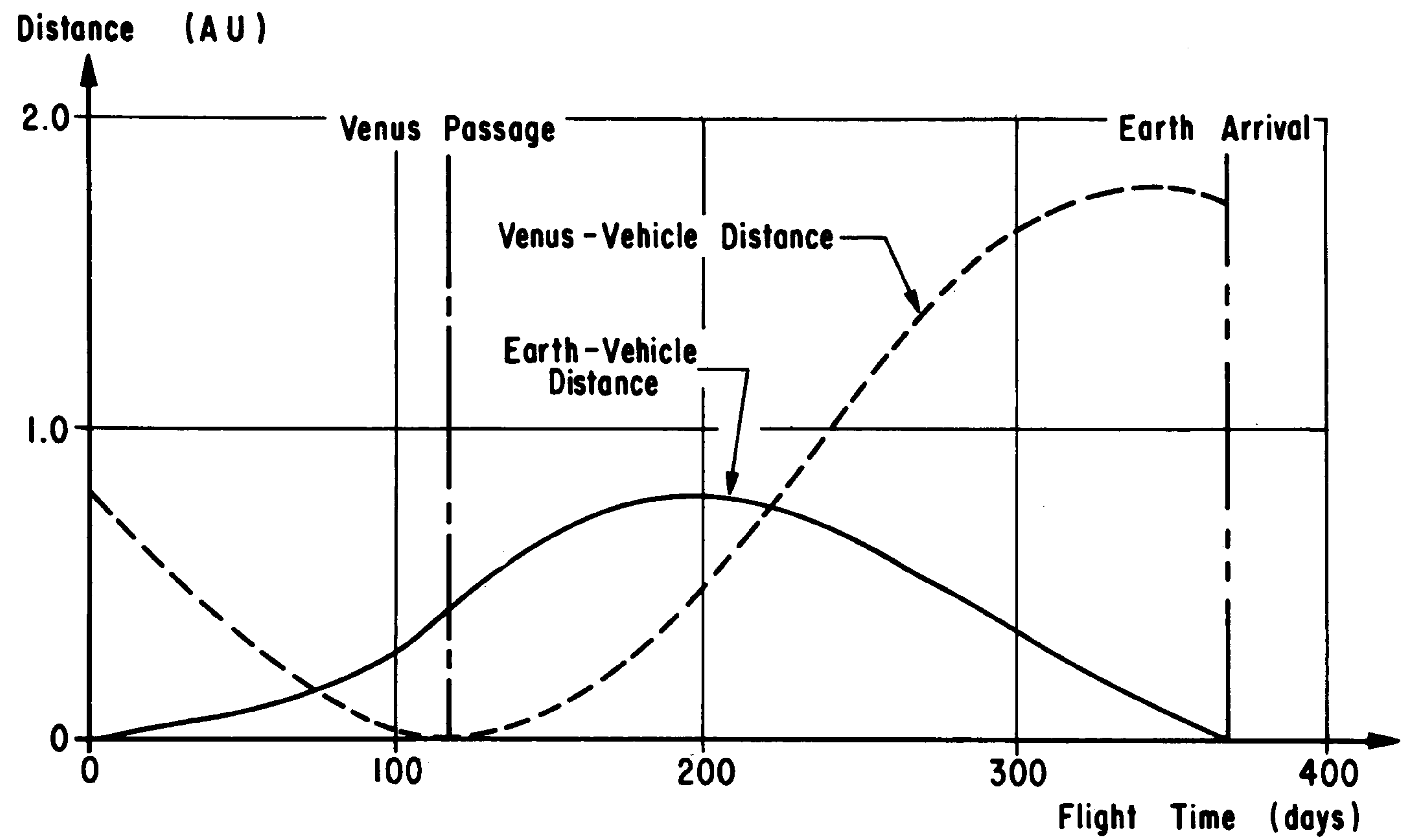


FIG. 9. VENUS FLYBY MISSION 1975 CONJUNCTION EARTH-VEHICLE DISTANCE AND VENUS-VEHICLE DISTANCE VERSUS FLIGHT TIME

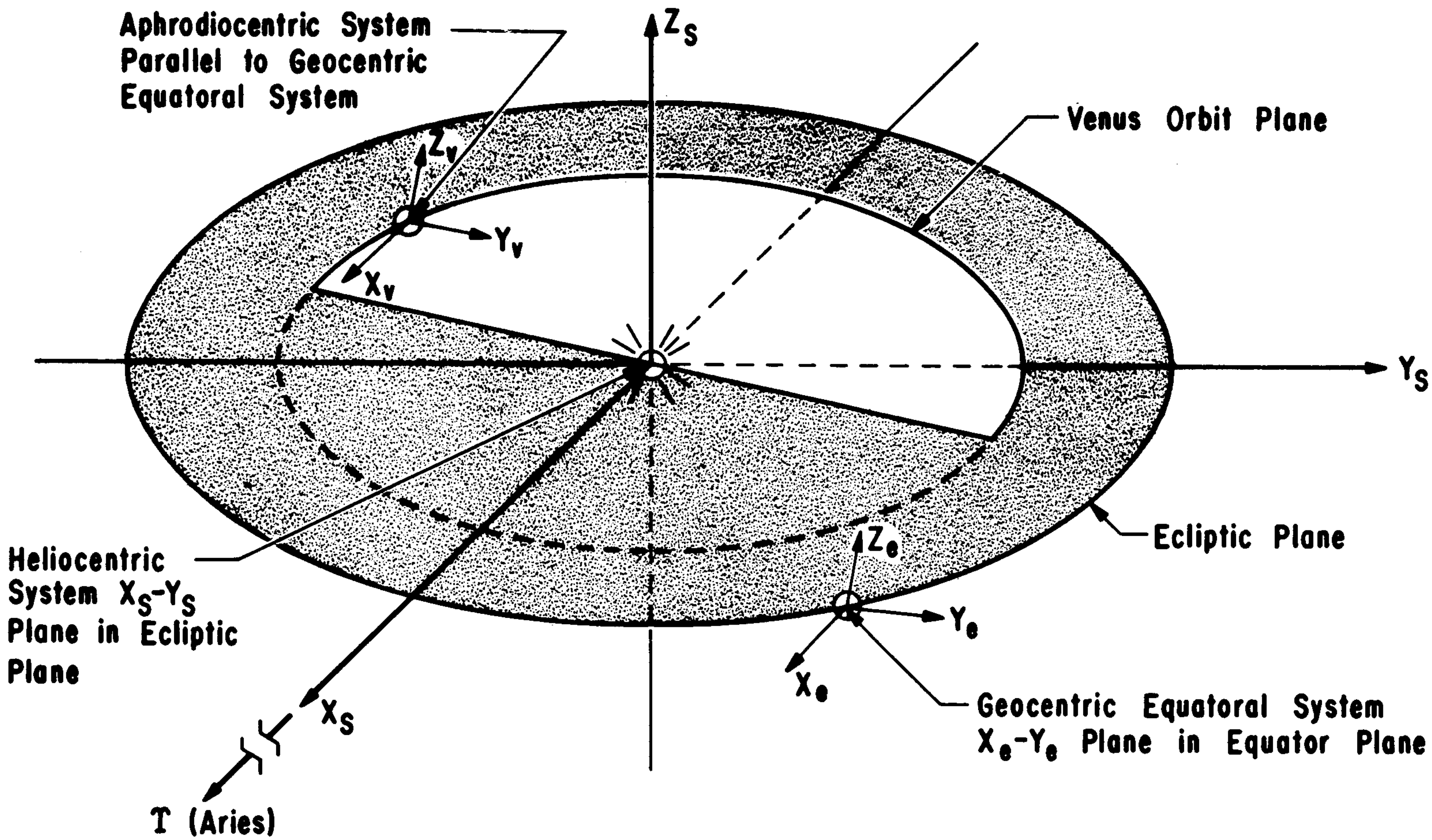


FIG. 10. COORDINATE SYSTEMS

TABLE 1

COMPARISON BETWEEN INTEGRATED AND CONIC CALCULATIONS

	CONIC	INTEGRATED
Launch Date (J. D.)	2442570.0	2442570.5 (Jun 7, 1975)
Earth-Venus Trip Time (days)	117.0	116.0
Hyperbolic Excess Velocity Leaving Earth (EMOS)*	.1086	.1091
Right Ascension of Incoming Asymptote at Venus (deg)	180.140	180.510
Declination of Incoming Asymptote at Venus (deg)	3.771	4.287
Hyperbolic Excess Velocity Approaching and Leaving Venus (EMOS)	0.1554	0.1554
Right Ascension of Outgoing Asymptote at Venus (deg)	91.448	89.042
Declination of Outgoing Asymptote at Venus (deg)	22.193	24.056
Venus-Earth Trip Time (days)	249.4	249.9
Hyperbolic Excess Velocity Arriving Earth (EMOS)	0.2546	0.2544

NOTE: All angles listed above are referenced to aphrodiocentric coordinate system with Xv-Yv plane parallel to the earth's equatorial plane

*EMOS = Earth Mean Orbital Speed (29.7849 km/sec)

TABLE 2

Tabulated Data Using First R Matrix

	1	2	3	4	5	6	7	8	9
T_L (sec)	23221.138	23221.138	23221.392		23222.041		23221.754		23221.897
T_{CO}(sec)	818.77031	818.77525	818.75439		818.67252		818.69659		818.68561
T_{BU}(sec)	393.59926	393.59917	393.59964		393.60125		393.60072		393.60097
$T_{F_{\oplus-♀}}$ (days)	116.02469	116.02482	116.02474		116.02385		116.02396		116.02393
$\bar{B} \cdot \hat{T}$ (km)	-14699.955	-14803.894	-14703.172	+867.50	-13835.113	-130.43	-13963.902	+39.73	-13923.027
$\bar{B} \cdot \hat{R}_♀$ (km)	5963.7008	5963.2620	6063.4319	+230.60 (468.89)*	+6294.5922	-107.85	6185.4590	+55.75	+6240.6796
$V(H)_♀$ (km/sec)	4.6292998	4.6293008	4.6293014		4.6293015		4.6292981		4.6292995
$T_{F_{\oplus-\oplus}}$ (days)	368.95452	369.34723	369.08412		365.56653		366.00687		365.89891
$\bar{B} \cdot \hat{T}_\oplus$ (km)	-5699612.7	-6657481.4	-6185185.6		+690325.94		-81221.369		73574.560
$\bar{B} \cdot \hat{R}_\oplus$ (km)	-252162.39	-226600.41	-153139.49		+75061.852		-45535.313		9226.6734
$V(H)_\oplus$ (km/sec)	6.6170573	6.4626176	6.5420835		7.6924048		7.5591120		7.5866815
$RCA_\oplus$ (km)	5696091.9	6651799.8	6177775.0		687691.31		86399.911		67548.257

*Actual calculated value for $\Delta\bar{B} \cdot \hat{T}_B$.

TABLE 2A

Tabulated Data Using Second R Matrix

	1	2	3	4	5	6
T_L (sec)	23221.887	23221.893	23221.912		23221.875	
T_{CO}(sec)	818.68660	818.68713	818.68552		818.68741	
T_{BU}(sec)	393.60093	393.60093	393.60099		393.60093	
$T_{F\,\oplus-♀}$ (days)	116.02400	116.02398	116.02395		116.02395	
$\bar{B} \cdot \hat{T}_{♀}$ (km)	-13943.148	-13953.168	-13942.006	+10.80	-13933.352	.32
$\bar{B} \cdot \hat{R}_{♀}$ (km)	6240.2494	6240.3775	6249.3932	- 7.30	6231.1895	1.49
$V(H)_{♀}$ (km/sec)	4.6292921	4.6292973	4.6293013		4.6292991	
$T_{F\,\oplus-\oplus}$ (days)	366.00573	366.06384	366.02007		365.91835	
$\bar{B} \cdot \hat{T}_{\oplus}$ (km)	-114902.54	-211618.18	-144285.35		+15119.884	
$\bar{B} \cdot \hat{R}_{\oplus}$ (km)	4736.7712	2839.0598	12625.913		-844.93385	
$V(H)_{\oplus}$ (km/sec)	7.5557355	7.5404456	7.5513546		7.5778970	
$RCA_{\oplus}$ (km)	108229.78	204742.84	138015.08		9717.2015	

TABLE 2B

Listing of R Matrix Elements

1. First R Matrix

$\partial\downarrow$ / $\partial\rightarrow$	$\bar{B}\cdot\hat{T}_{♀}$	$\bar{B}\cdot\hat{R}_{♀}$
$\bar{B}\cdot\hat{T}_{\oplus}$	+9218.57	-4871.73
$\bar{B}\cdot\hat{R}_{\oplus}$	- 245.93	+ 992.90

2. Second R Matrix

$\partial\downarrow$ / $\partial\rightarrow$	$\bar{B}\cdot\hat{T}_{♀}$	$\bar{B}\cdot\hat{R}_{♀}$
$\bar{B}\cdot\hat{T}_{\oplus}$	+9652.26	-3213.41
$\bar{B}\cdot\hat{R}_{\oplus}$	+ 189.39	862.79

TABLE 3A

THRUSTING TRAJECTORY FOR EARTH ESCAPE

Definition of tabulated trajectory values contained in the thrusting trajectory for Earth escape.

T = time from June 7, 1975 (6 hours, 49 minutes, 27.591 sec)

Line #1 Geocentric Equatorial

$\left.\begin{array}{l} Xe \\ Ye \\ Ze \end{array}\right\}$	Vehicle Cartesian position components. (Coordinate system origin at center of earth, X-axis in direction of earth's of date vernal equinox, X-Y plane is in the earth's equatorial plane) (km)
$\left.\begin{array}{l} \dot{X}e \\ \dot{Y}e \\ \dot{Z}e \end{array}\right\}$	Vehicle Cartesian velocity components measured in same coordinate system as above (km/sec)

Line #2 Geocentric Equatorial

RE	Radius from center of earth to vehicle (km)
LATE	Geocentric latitude (deg)
LONGE	Geocentric longitude (deg)
VE	Earth-fixed speed of vehicle (km/sec)
PTE	Earth-fixed path angle from the horizontal (deg)
AZE	Earth-fixed azimuth angle from north (deg)

TABLE 3B
THRUSTING TRAJECTORY FOR EARTH ESCAPE

t (sec)	Xe (km) RE (km)	Ye (km) LATE (deg)	Ze (km) LONGE (deg)	$\dot{X}e$ (km/sec) V_E (km/sec)	$\dot{Y}e$ (km/sec) PTE (deg)	$\dot{Z}e$ (km/sec) AZE (deg)
(June 7, 1975 6 hr. 49 min. 27.591) WEIGHT AT START OF INJECTION THRUSTING 634,230 (lbs) - 287,680 (kg)						
0	.63484269 04	-.22454365 04	.12767967 04	.28657800 01	.62360631 01	-.33295904 01
	.68538108 04	.10736355 02	.34310433 03	.71913981 01	-.70560975-01	.11810003 03
20	.64046261 04	-.21191453 04	.12093464 04	.27536880 01	.63932253 01	-.34155367 01
	.68536509 04	.10163218 02	.34419124 03	.73171902 01	-.48441408-01	.11829896 03
40	.64585566 04	-.19897015 04	.11401719 04	.26389065 01	.65513200 01	-.35020105 01
	.68536019 04	.95763058 01	.34529327 03	.74467379 01	.17358926-01	.11848779 03
60	.65101638 04	-.18570854 04	.10692620 04	.25213490 01	.67104845 01	-.35890864 01
	.68537816 04	.89754089 01	.34641102 03	.75801615 01	.12658304 00	.11866606 03
80	.65593915 04	-.17212741 04	.99660390 03	.24009231 01	.68708734 01	-.36768484 01
	.68543141 04	.83603307 01	.347545 08 03	.77176063 01	.27898761 00	.11883324 03
100	.66061810 04	-.15822412 04	.92218288 03	.22775287 01	.70326608 01	-.37653914 01
	.68553292 04	.77308998 01	.34869605 03	.78592465 01	.47432334 00	.11898878 03
120	.66504722 04	-.14399570 04	.84598235 03	.21510566 01	.71960452 01	-.38548231 01
	.68569632 04	.70869632 01	.34986456 03	.80052894 01	.71233664 00	.11913211 03
140	.66922022 04	-.12943874 04	.76798329 03	.20213863 01	.73612529 01	-.39452668 01
	.68593591 04	.64283930 01	.35105125 03	.81559804 01	.99277140 00	.11926260 03
160	.67313055 04	-.11454931 04	.68816403 03	.18883830 01	.75285441 01	-.40368634 01
	.68626671 04	.57550925 01	.35225678 03	.83116083 01	.13153535 01	.11937957 03
180	.67677144 04	-.99322984 03	.60650004 03	.17518936 01	.76982179 01	-.41297758 01
	.68670449 04	.50669877 01	.35348182 03	.84725128 01	.16797937 01	.11948233 03

t (sec)	Xe (km) RE (km)	Ye (km) LATE (deg)	Ze (km) LONGE (deg)	$\dot{X}e$ (km/sec) VE (km/sec)	$\dot{Y}e$ (km/sec) PTE (kn/sec)	$\dot{Z}e$ (km/sec) AZE (deg)
200	.68013570 04	-.83754633 03	.52296303 03	.16117428 01	.78706199 01	-.42241919 01
	.68726583 04	.43640409 01	.35472710 03	.86390933 01	.20857716 01	.11957014 03
220	.68321584 04	-.67838427 03	.43752093 03	.14677268 01	.80461520 01	-.43203301 01
	.68796816 04	.36462478 01	.35599335 03	.88118190 01	.25329287 01	.11964219 03
240	.68600389 04	-.51567643 03	.35013675 03	.13196064 01	.82252807 01	-.44184441 01
	.68882983 04	.29136374 01	.35728136 03	.89912405 01	.30208569 01	.11969766 03
260	.68849135 04	-.34934558 03	.26076810 03	.11670973 01	.84085520 01	-.45188310 01
	.68987013 04	.21662722 01	.35859197 03	.91780075 01	.35490824 01	.11973566 03
280	.69066914 04	-.17930264 03	.16936613 03	.10098591 01	.85966049 01	-.46218385 01
	.69110941 04	.14042544 01	.35992604 03	.93728859 01	.41170493 01	.11975525 03
300	.69252740 04	-.54447131 01	.75874478 02	.84747940 00	.87901922 01	-.47278763 01
	.69256917 04	.62771658 00	.12845384 01	.95767840 01	.47240977 01	.11975544 03
320	.69405533 04	.17234764 03	-.19772229 02	.67945521 00	.89902034 01	-.48374293 01
	.69427209 04	-.16317407 00	.26684986 01	.97907818 01	.53694379 01	.11973518 03
340	.69524105 04	.35421303 03	-.11764982 03	.50516742 00	.91976967 01	-.49510736 01
	.69624222 04	-.96821944 00	.40790568 01	.10016171 02	.60521212 01	.11969334 03
360	.69607133 04	.54031342 03	-.21784683 03	.32384805 00	.94139370 01	-.50694992 01
	.69850503 04	-.17872052 01	.55174860 01	.10254507 02	.67709978 01	.11962873 03
380	.69653115 04	.73083857 03	-.32046697 03	.13453624 00	.96404490 01	-.51935373 01
	.70108766 04	-.26199000 01	.69852075 01	.10507675 02	.75246751 01	.11954007 03
393.60093	.69662356 04	.86304469 03	-.39169912 03	.62282639-03	.98012849 01	-.52816025 01
	.70304132 04	-.31938852 01	.80008855 01	.10689470 02	.80562320 01	.11946533 03

END OF INJECTION THRUSTING _ BURN OUT WEIGHT 264,652 lbs. (120,044 kg)
INJECTED PAYLOAD 172,583 lbs (78,282 kg.)

TABLE 4A

1975 VENUS FLYBY TRAJECTORY

<u>Geocentric</u>

Definition of tabulated trajectory values contained in the Earth Depart trajectory and Earth Return trajectory.

T = time from injection from earth (days)

Line #1 Geocentric Equatorial

Xe, Ye, Ze	Vehicle Cartesian position components. (Coordinate system origin at center of earth, X-axis in direction of earth's of-date vernal equinox, X-Y plane of earth's equator) (km)
$\dot{X}e$, $\dot{Y}e$, $\dot{Z}e$	Vehicle Cartesian velocity components measured in same coordinate system as above (km/sec)

Line #2 Geocentric Equatorial

Re	Radius from center of earth to spacecraft (km)
LATe	Geocentric Latitude (deg)
LONGe	Geocentric Longitude (deg)
Ve	Earth-fixed speed of spacecraft (km/sec)
PTe	Earth-fixed path angle from the horizontal (deg)
AZe	Earth-fixed azimuth angle from north (deg)

Line #3 Heliocentric Ecliptic*

Rs	Radius from center of sun of spacecraft (km)
LATs	Celestial latitude of spacecraft (deg)
LONGs	Celestial longitude of spacecraft (deg)
Vs	Inertial speed of spacecraft (km/sec)
PTs	Path angle from the normal to the heliocentric radius vector (deg)
AZs	Azimuth angle from celestial north (deg)

Heliocentric

Definition of tabulated trajectory values contained in the heliocentric Earth-Venus transfer trajectory and heliocentric Venus-Earth transfer trajectory.

T = time from injection from earth (days)

Line #1 Heliocentric Ecliptic

$$\left.\begin{array}{l} Xs \\ Ys \\ Zs \end{array}\right\}$$ Vehicle Cartesian position components. (Coordinate system origin at center of sun, X-axis in direction of earth's of-date vernal equinox, X-Y plane in the ecliptic) (km)

$$\left.\begin{array}{l} \dot{X}s \\ \dot{Y}s \\ \dot{Z}s \end{array}\right\}$$ Cartesian velocity components measured in same coordinate system as above (km/sec)

Line #2 (Same as Geocentric Line #2)

Line #3 (Same as Geocentric Line #3)

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* (Origin of coordinate system at center of sun, X-axis in direction of earth's of-date vernal equinox, X-Y plane in ecliptic plane.)

Aphrodiocentric

Definition of tabulated trajectory values contained in the Venus passage trajectory.

T = time from injection from earth (days)

Line #1 Aphrodiocentric Earth Equatorial

$\left.\begin{array}{l} Xv \\ Yv \\ Zv \end{array}\right\}$ Vehicle Cartesian position components. (Coordinate system origin at center of Venus, X-axis in the direction of earth's of-date vernal equinox, X-Y plane of earth's equator) (km)

$\left.\begin{array}{l} \dot{X}v \\ \dot{Y}v \\ \dot{X}v \end{array}\right\}$ Vehicle Cartesian velocity components measured in same coordinate system as above (km/sec)

Line #2 (Same as Geocentric Line #2)

Line #3 (Same as Geocentric Line #3)

Line #4 Aphrodiocentric Earth Equatorial*

Rv	Radius from center of Venus to spacecraft (km)
DECv	Declination (deg)
RAv	Right ascension (deg)
Vv	Speed relative to Venus (km/sec)
PTv	Path angle from the horizontal (deg)
AZv	Azimuth angle as referenced to geocentric equatorial coordinate system (deg)

* Reference plane is the earth's equator plane.

TABLE 4B

1975 VENUS FLYBY TRAJECTORY

EARTH DEPART TRAJECTORY

GEOCENTRIC

(June 7, 1975 06 Hrs. 56 Min. 01.192 Sec. GMT)

T (days)	Xe (km) Re (km) Rs (km)	Ye (km) LATe (deg) LATs (deg)	Ze (km) LONGe (deg) LONGs (deg)	$\dot{X}$e (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$e (km/sec) PTe (deg) PTs (deg)	$\dot{Z}$e (km/sec) AZe (deg) AZs (deg)
0.00	.69662356 04	.86304469 03	-.39169912 03	.62282639-03	.98012849 01	-.52816025 01
	.70304133 04	-.31938852 01	.80008855 01	.10689470 02	.80562320 01	.11946533 03
	.15182600 09	-.42360669-03	..25593464 03	.29737899 02	-.12534521 02	.10752994 03
0.25	-.71441215 05	.73668543 05	-.40405890 05	-.32260095 01	.23708654 01	-.13097760 01
	.11028842 06	-.21491650 02	.44812728 02	.79864790 01	.31334267 02	.27191237 03
	.15180033 09	-.25203397-01	.25614060 03	.25922636 02	-.13724471 01	.94745586 02
0.50	-.13772239 06	.12156511 06	-.66877797 05	-.29580272 01	.21151271 01	-.11693490 01
	.19549469 06	-.20004576 02	.31901143 03	.13567342 02	.16261544 02	.27061013 03
	.15178805 09	-.41557431-01	.25635264 03	.26207038 02	-.11792390 01	.94188122 02
0.75	-.20024867 06	.16606890 06	-.91485730 05	-.28438844 01	.20172352 01	-.11155636 01
	.27576810 06	-.19374952 02	.23052988 03	.19060829 02	.11039754 02	.27030940 03
	.15177659 09	-.56758017-01	.25656631 03	.26329250 02	-.11456746 01	.93976206 02
1.00	-.26092146 06	.20901925 06	-.11524079 06	-.27791261 01	.19641594 01	-.10864601 01
	.35362337 06	-.19019241 02	.14125528 03	.24435989 02	.83903614 01	.27018933 03
	.15176519 09	-.71430117-01	.25678079 03	.26399493 02	-.11534046 01	.93861870 02
2.00	-.49525374 06	.37413015 06	-.20661013 06	-.26670476 01	.18756732 01	-.10384005 01
	.65416922 06	-.18411283 02	.14189863 03	.45279412 02	.43315326 01	.27005579 03
	.15171671 09	-.12787992 00	.25764250 03	.26526234 02	-.12899538 01	.93673383 02

T (days)	Xe(km) Re (km) Rs (km)	Ye (km) LAT e (deg) LAT s (deg)	Ze(km) LONGe (deg) LONG s(deg)	$\dot{X}$e(km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$ e(km/sec) PT e(deg) PT s (deg)	$\dot{Z}$e(km/sec) AZ e (deg) AZ s (deg)
3.00	-.72354784 06	.53454200 06	-.29544965 06	-.26224388 01	.18414976 01	-.10201688 01
	.94686171 06	-.18181634 02	.14152528 03	.65607970 02	.29372246 01	.27002654 03
	.15166152 09	-.18279294 00	.25850726 03	.26582421 02	-.14690900 01	.93602380 02
4.00	-.94891821 06	.69275348 06	-.38311083 06	-.25961976 01	.18223360 01	-.10097429 01
	.12357698 07	-.18060312 02	.14086467 03	.85679614 02	.22261772 01	.27001552 03
	.15159882 09	-.23702122 00	.25937380 03	.26619518 02	-.16585304 01	.93563118 02
5.00	-.11723685 07	.84962504 06	-.47001429 06	-.25769734 01	.18097642 01	-.10021827 01
	.15222430 07	-.17984775 02	.14007898 03	-.10558483 03	.17933310 01	.27001030 03
	.15152834 09	-.29085080 00	.26024174 03	.26649399 02	-.18517061 01	.93536778 02
6.00	-.13943044 07	.10055865 07	-.55631860 06	-.25607286 01	.18009908 01	-.99568266 00
	.18068700 07	-.17932164 02	.13922495 03	.12536428 03	.15014873 01	.27000755 03
	.15144999 09	-.34441229 00	.26111095 03	.26676337 02	-.20463921 01	.93516740 02
7.00	-.16148986 07	.11609110 07	-.64207467 06	-.25457272 01	..17949044 01	-.98939244 00
	.20899453 07	-.17891821 02	.13832739 03	.14503910 03	.12911141 01	.27000608 03
	.15136373 09	-.39777058 00	.26198139 03	.26702255 02	-.22416040 01	.93500054 02
8.00	-.18342196 07	.13158073 07	-.72727866 06	-.25311720 01	.17910229 01	-.98284582 00
	.23716333 07	-.17857898 02	.13739879 03	.16462189 03	.11321525 01	.27000535 03
	.15126951 09	-.45096751 00	.26285308 03	.26728151 02	-.24368313 01	.93485208 02
9.00	-.20522886 07	.14704580 07	-.81189500 06	-.25167176 01	.17891241 01	-.97576115 00
	.26520385 07	-.17826756 02	.13644607 03	.18412141 03	.10077594 01	.27000510 03
	.15116735 09	-.50402697 00	.26372609 03	.26754590 02	-.26317675 01	.93471332 02

HELIOCENTRIC EARTH-VENUS TRANSFER TRAJECTORY

HELIOCENTRIC

T(days)	Xs (km) Re (km) Rs (km)	Ys (km) LATe(deg) LATs (deg)	Zs (km) LONG e (deg) LONG s (deg)	$\dot{X}$s (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$s (km/sec) PT e (deg) PTs (deg)	$\dot{Z}$s (km/sec) AZ e (deg) AZ s (deg)
10.00	-.14213856 08	-.15037984 09	-.14683715 07	.26707899 02	-.11823182 01	-.16004822 01
	.29312373 07	-.17795992 02	.13547359 03	.20354465 03	.90775945 00	.27000520 03
	.15105723 09	-.55696008 00	.26460046 03	..26781921 02	-.28262110 01	.93457910 02
20.00	.89653245 07	-.14922537 09	-.28177670 07	.268 10802 02	.38759117 01	-.15174171 01
	.56 712456 07	-.17277509 02	.12504779 03	.39501677 03	.45405390 00	.27001322 03
	.14952099 09	-.10798187 01	.27343814 03	.27131980 02	-.47188880 01	.93306846 02
30.00	.31882347 08	-.14365713 09	-.40781945 07	.26095146 02	.90211088 01	-.13923831 01
	.83590930 07	-.16157940 02	.11388306 03	.58574093 03	.30345676 00	.27002415 03
	.14720899 09	-.15874922 01	.28251304 03	.27645538 02	-.64659061 01	.93086778 02
40.00	.53807237 08	-.13363563 09	-.52095389 07	.24501999 02	.14168201 02	-.12178252 01
	.11064165 08	-.14279937 02	.10214641 03	. 78236258 03	.23415767 00	.27003845 03
	.14415561 09	-.20710226 01	.29193176 03	.28329648 02	-.80039886 01	.92781297 02
50.00	.73947881 08	-.11920457 09	-.61671574 07	.21950138 02	.19206412 02	-.98962069 00
	.13983996 08	-.11411645 02	.89949659 02	.10002335 04	.20784351 00	.27005444 03
	.14041386 09	-.25173131 01	.30181316 03	.29183457 02	-.92717913 01	.92382446 02
60.00	.91435880 08	-.10052123 09	-.69031670 07	.18346130 02	.23980714 02	-.70433664 00
	.17452177 08	-.76655494 01	.77941453 02	.12619074 04	.20292321 00	.27006485 03
	.13606135 09	-.29081878 01	.31229021 03	.30201841 02	-.10207357 02	.91883875 02

T(days)	Xs (km) Re (km) Rs (km)	Ys (km) LAT e (deg) LAT s (deg)	Z s (km) LONG e (deg) LONG s (deg)	$\dot{X}$e (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$s (km/sec) PT e (deg) PT s (deg)	$\dot{Z}$s (km/sec) AZ e (deg) AZ s (deg)
70.00	.10532144 09	-.77903277 08	-.73671710 07	.13597715 02	.28271145 02	-.35980093 00
	.21840828 08	-.34728173 01	.66750985 02	.15900757 04	.20822258 00	.27006748 03
	.13120900 09	-.32187565 01	.32351072 03	.31373316 02	-.10747366 02	.91281575 02
80.00	.11458470 09	-.51894696 08	-.75080457 07	.76406256 01	.31769670 02	.43095707 -01
	.27578748 08	.61763095 00	.56916248 02	.20104911 04	.21569481 00	.27006092 03
	.12601224 09	-.34158126 01	.33563452 03	.32675571 02	-.10827703 02	.90577021 02
90.00	.11817919 09	-.23350536 08	-.72778425 07	.48808911 00	.34061615 02	.49724650 00
	.35000196 08	.40430306 01	.48834391 02	.25440298 04	.21717013 00	.27004713 03
	.12068361 09	-.34573273 01	.34882313 03	.34068740 02	-.10387000 02	.89782760 02
100.00	.11513076 09	.64692155 07	-.66390450 07	-.76892209 01	.34630146 02	.98475266 00
	.44288171 08	.64675410 01	.42533020 02	.32050954 04	.21228569 00	.27002982 03
	.11550333 09	-.32951334 01	.32160769 01	.35487192 02	-.93761814 01	.88930507 02
110.00	.10471665 09	.35833472 08	-.55760287 07	-.16466567 02	.32918694 02	.14723352 01
	.55508998 08	.77400915 01	.37886009 02	.40042880 04	.20130019 00	.27001084 03
	.11081835 09	-.28841592 01	.18890670 02	.36836883 02	-.77847575 01	.88079979 02

VENUS PASSAGE TRAJECTORY

APHRODIOCENTRIC

T (days)	Xv (km) Re (km) Rs (km) Rv (km)	Yv(km) LAT e (deg) LAT s (deg) DEC v (deg)	Zv(km) LONG e (deg) LONG s (deg) RAv (deg)	$\dot{X}$v (km/sec) Ve (km/sec) Vs (km/sec) Vv (km/sec)	$\dot{Y}$v (km/sec) PTe (deg) PTs (deg) PTv (deg)	$\dot{Z}$v (km/sec) AZe (deg) AZs (deg) AZv (deg)
111.0	.20778284 07	.12000943 05	-.15840341 06	-.47196282 01	-.90042302 01	.33039111 00
	.56733492 08	.78016452 01	.37505050 02	.40918564 04	.19989829 00	.27000893 03
	.11039164 09	-.28281499 01	.20528516 02	.36964897 02	-.75976334 01	.87998234 02
	.20838922 07	-.43594424 01	.33091839 00	.47320351 01	-.89160726 02	.24494242 03
112.0	.16708962 07	.49350415 04	-.12957342 06	-.47017634 01	-.73963397-01	.33687637 00
	.57975832 08	.78512862 01	.37138358 02	.41807964 04	.19846737 00	.27000702 03
	.10997390 09	-.27693684 01	.22178891 02	.37092261 02	-.74078976 01	.87917472 02
	.16759199 07	-.44342373 01	.16922434 00	.47143965 01	-.89196155 02	.24527546 03
113.0	.12650369 07	-.85549191 03	-.10020377 06	-.46953711 01	-.60586662-01	.34289962 00
	.59235948 08	.78890545 01	.36785762 02	.42711110 04	.19703559 00	.27000511 03
	.10956527 09	-.27078122 01	.23841737 02	.37220375 02	-.72185886 01	.87837750 02
	.12689996 07	-.45289507 01	.35996125 03	.47082652 01	-.89147855 02	.24559721 03
114.0	.85902179 06	-.56209414 04	-.70323023 05	-.47073746 01	-.50270664-01	.34884978 00
	.60514075 08	.79149905 01	.36447231 02	.43628222 04	.19568577 00	.27000322 03
	.10916558 09	-.26434727 01	.25517081 02	.37353611 02	-.70383536 01	.87759025 02
	.86191377 06	-.46799303 01	.35962509 03	.47205506 01	-.88921459 02	.24584988 03
115.0	.45024848 06	-.96235684 04	-.39856407 05	-.47710608 01	-.42646685-01	.35752331 00
	.61811665 08	.79291008 01	.36123348 02	.44560279 04	.19478589 00	.27000131 03
	.10877348 09	-.25763226 01	.27205347 02	.37513108 02	-.69067068 01	.87680702 02
	.45211154 06	-.50575399 01	.35877555 03	.47846277 01	-.88104726 02	.24602811 03
115.25	.34676940 06	-.10522390 05	-.32090019 05	-.48142267 01	-.40460554-01	.36194483 00
	.62139758 08	.79307690 01	.30604498 03	.44796022 04	.19484480 00	.27000083 03
	.10867603 09	-.25590823 01	.27629645 02	.37569500 02	-.69036580 01	.87660795 02
	.34840997 06	-.52846718 01	.35826194 03	.48279830 01	-.87578612 02	.24608450 03

T (days)	Xv (km) Re (km) Rs (km) Rv (km)	Yv (km) LATe(deg) LATs (deg) DECv(deg)	Zv(km) LONGe(deg) LONGs (deg) RAv (deg)	$\dot{X}$v(km/sec) Ve (km/sec) Vs (km/sec) Vv (km/sec)	$\dot{Y}$v(km/sec) PTe (deg) PTs (deg) PTv (deg)	$\dot{Z}$v(km/sec) AZe (deg) AZs (deg) AZv (deg)
115.50	.24200955 06	-.11359616 05	-.24194284 05	-.48955680 01	-.36507013-01	.37016260 00
	.62469988 08	.79316792 01	.21596796 03	.45033215 04	.19532377 00	.27000034 00
	.10857818 09	-.25416465 01	.28055051 02	.37650729 02	-.69435796 01	.87640209 02
	.24348106 06	-.57027921 01	.35731258 03	.49096781 01	-.86604697 02	.24618092 03
115.75	.13444223 06	-.12032998 05	-.16003075 05	-.51044849 01	-.21723589-01	.39329320 00
	.62803721 08	.79318140 01	.12589285 03	.45272470 04	.19725757 00	.26999983 03
	.10847872 09	-.25239854 01	.28482040 02	.37819977 02	-.71241510 01	.87617160 02
	.13592499 06	-.67613792 01	.35488548 03	.51196598 01	-.84170359 02	.24644673 03
116.00	.12874321 05	-.10094539 05	-.55366682 04	-.75593311 01	.93106167 00	.10137643 01
	.63152000 08	.79315946 01	.35823014 02	.45518953 04	.23022518 00	.27000259 03
	.10836931 09	-.25058444 01	.28914906 02	.40225280 02	-.89594629 01	.87556584 02
	.17271437 05	-.18697271 02	.32190060 03	.76836242 01	-.57829841 02	.25395283 03
*116.02	-.45652787 04	-.41570304 04	-.15009975 04	-.76931676 01	.70840007 01	.37795179 01
	.63193680 08	.79332672 01	.27193458 02	.45601145 04	.27525833 00	.27003130 03
	.10835693 09	-.25038799 01	.28960903 02	.45816382 02	-.38970122 01	.87589017 02
	.63541847 04	-.13663659 02	.22232022 03	.11119921 02	.10749024-05	.29047425 03
116.25	0.12589128 05	.10367727 06	.47418993 05	.43505315-01	.47516487 01	.21242782 01
	.63481798 08	.79718184 01	.30562144 03	.45823051 04	.17420995 00	.27002368 03
	.10840330 09	-.24871638 01	.29378821 02	.39561664 02	.34610438 01	.87705433 02
	..11469971 06	.24419768 02	.96923310 02	.52050567 01	.83202124 02	.26872718 03

* PERI-CENTER PASSAGE AT VENUS ON OCTOBER 1, 1975 07 HRS 30 MIN 30.252 SEC. (GMT.)

T (days)	Xv (km)	Yv (km)	Zv (km)	$\dot{X}$v (km/sec)	$\dot{Y}$v (km/sec)	$\dot{Z}$v (km/sec)
	Re (km)	LATe (deg)	LONG e (deg)	Ve (km/sec)	PT e (deg)	AZ e (deg)
	Rs (km)	LAT s (deg)	LONG s (deg)	Vs (km/sec)	PT s (deg)	AZ s (deg)
	Rv (km)	DEC v (deg)	R. A. v (deg)	Vv (km/sec)	PT v (deg)	AZ v (deg)
116.50	-.11329312 05	.20305970 06	.91821481 05	.65848520-01	.45042028 01	.20117192 01
	.63780846 08	.80071510 01	.21542079 03	.46031830 04	.17169132 00	.27002190 03
	.10845411 09	-.24691159 01	.29827776 02	.39293403 02	.34111723 01	.87685795 02
	.22314296 06	.24298578 02	.93193393 02	.49334768 01	.86315423 02	.26718924 03
116.75	-.98486514 04	.29928811 06	.13479443 06	.70483354-01	.44169677 01	.19723035 01
	.64078358 08	.80404457 01	.12522452 03	.46240974 04	.17050201 00	.27002087 03
	.10850474 09	-.24509971 01	.30274660 02	.39191651 02	.34456656 01	.87666454 02
	.32838986 06	.24234411 02	.91884749 02	.48378251 01	.87439978 02	.26665401 03
117.00	-.82997459 04	.39416189 06	.17715576 06	.72789771-01	.43717487 01	.19518914 01
	.64375468 08	.80723153 01	.35031362 02	.46450296 04	.16963116 00	.27002005 03
	.10855600 09	-.24327742 01	.30720422 02	.39132330 02	.35048167 01	.87647364 02
	.43222291 06	.24196749 02	.91206282 02	.47882527 01	.88023572 02	.26638082 03
118.00	-.16682914 04	.76814702 06	.34410508 06	.81190032-01	.43006788 01	.19195330 01
	.65564314 08	.81884285 01	.34282617 02	.47289719 04	.16688116 00	.27001730 03
	.10877093 09	-.23587170 01	.32496293 02	.39001969 02	.38075785 01	.87572943 02
	.84170121 06	.24130791 02	.90124437 02	.47103117 01	.88896018 02	.26599558 03
119.00	.58623084 04	.11385065 07	.50937489 06	.93995307-01	.42757286 01	.19075698 01
	.66755725 08	.82884669 01	.33566862 02	.48132733 04	.16432325 00	.27001484 03
	.10900402 09	-.22827866 01	.34262930 02	.38911704 02	.41361072 01	.87501309 02
	.12472747 07	.24103757 02	.89704978 02	.46828958 01	.89117013 02	.26594973 03
120.00	.14728402 05	.15073458 07	.67388141 06	.11215045 00	.42635617 01	.19010035 01
	.67949415 08	.83735907 01	.32880869 02	.48978861 04	.16173034 00	.27001251 03
	.10925596 09	-.22050693 01	.36020823 02	.38827800 02	.44687195 01	.87432407 02
	.16511888 07	.24086724 02	.89440176 02	.46695128 01	.89132946 02	.26600430 03

HELIOCENTRIC VENUS-EARTH TRANSFER TRAJECTORY

HELIOCENTRIC

T (days)	Xs (km) Re (km) Rs (km)	Ys (km) LATe (deg) LATs (deg)	Zs (km) LONGe (deg) LONGs (deg)	$\dot{X}$s (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$s (km/sec) PTe (deg) PTs (deg)	$\dot{Z}$s (km/sec) AZe (deg) AZs (deg)
130.00	.67779651 08	.90076201 08	-.26698310 07	-.26867479 02	.26546936 02	.19082968 01
	.79768033 08	.85213199 01	.27298144 02	.57442973 04	.13292658 00	.26999337 03
	.11276050 09	-.13567180 01	.53039629 02	.37818551 02	.76147046 01	.86899427 02
140.00	.42579725 08	.10979092 09	-.95077600 06	-.31058392 02	.19006154 02	.20464738 01
	.90684828 08	.76736893 01	.23233115 02	.65422732 04	.10342955 00	.26998030 03
	.11776240 09	-.46259334 00	.68802430 02	.36469790 02	.10223876 02	.86647563 02
150.00	.14771159 08	.12289915 09	.82816149 06	-.32962069 02	.11384397 02	.20519420 01
	.10000304 09	.61664449 01	.19898592 02	.72366758 04	.76769618-01	.26997212 03
	.12378640 09	.38332643 00	.83146533 02	.34932978 02	.12201730 02	.86637577 02
160.00	-.13845112 08	.12961853 09	.25663275 07	-.33009095 02	.42911565 01	.19578024 01
	.10738303 09	.42607385 01	.16829658 02	.77940821 04	.54191574-01	.26996749 03
	.13038112 09	.11278410 01	.96096889 02	.33344375 02	.13545462 02	.86809079 02
170.00	-.41876408 08	.13055578 09	.41918885 07	-.31685380 02	-.19696541 01	.17961645 01
	.11272639 09	.21403593 01	.13799643 02	.81989197 04	.34898851-01	.26996530 03
	.13717149 09	.17511999 01	.10778390 03	.31797312 02	.14298882 02	.87103689 02
180.00	-.68327120 08	.12648247 09	.56581095 07	-.29412761 02	-.73031560 01	.15925936 01
	.11602116 09	-.58744749-01	.10701299 02	.84446932 04	.17998402-01	.26996500 03
	.14386947 09	.22539120 01	.11837837 03	.30347701 02	.14524304 02	.87474951 02
190.00	-.92524196 08	.11819661 09	.69371635 07	-.26514539 02	-.11729715 02	.13654120 01
	.11736044 09	-.22342334 01	.74753508 01	.85360101 04	.32047632-02	.26996595 03
	.15026407 09	.26460844 01	.12805380 03	.29025357 02	.14286680 02	.87889525 02
200.00	-.11403343 09	.10645255 09	.80143545 07	-.23222378 02	-.15321276 02	.11269690 01
	.11689066 09	.43188703 01	.41145315 01	.84844583 04	-.10419741 -01	.26996777 03
	.15620499 09	.29409445 01	.13696920 03	.27844036 02	.13646743 02	.88324889 02

T (days)	Xs (km) Re (km) Rs (km)	Ys (km) LATe (deg) LATs (deg)	Zs (km) LONGe (deg) LONGs (deg)	Ẋs (km/sec) Ve (km/sec) Vs (km/sec)	Ẏs (km/sec) PTe (deg) PTs (deg)	Żs (km/sec) AZe (deg) AZs (deg)
210.00	-.13258758 09	.91934636 08	.88836677 07	-.19696239 02	-.18165045 02	.88527393 00
	.11474050 09	-.62593295 01	.61799466 00	.83026489 04	-.23441209-01	.26997036 03
	. 16158701 09	.31515731 01	.14526302 03	.26808476 02	.12659224 02	.88766392 02
220.00	-.14803407 09	.75252208 08	.95446555 07	-.16044278 02	-.20345750 02	.64538813 00
	.11109225 09	-.80143961 01	.35697339 03	.80082125 04	-.35849101-01	.26997345 03
	.16633725 09	.32895155 01	.15305377 03	.25918814 02	.11373487 02	.89204735 02
230.00	-16029790 09	.56944446 08	.10000344 08	-.12338684 02	-.21938010 02	.41045165 00
	.10613760 09	-.95596487 01	.35318728 03	.76195161 04	-.48366276-01	.26997689 03
	.17040567 09	.33643642 01	.16044285 03	.25173158 02	.98350129 01	.89634126 02
240.00	-.16935482 09	.37492340 08	.10255910 08	-.86276949 01	-.23003583 02	.18239474 00
	.10003716 09	-.10872727 02	.34924811 03	.71523102 04	-.61250574-01	.26998071 03
	.17375820 09	.33837944 01	.16751700 03	.24568989 02	.80869576 01	.90050986 02
250.00	-.17521502 09	.17329448 08	.10317855 08	-.49438740 01	-.23591397 02	-.37581920-01
	.93001002 08	-.11939269 02	.34512626 03	.66246749 04	-.74399541-01	.26998468 03
	.17637196 09	.33537483 01	.17435159 03	.24103885 02	.61714660 01	.90453070 02
260.00	-.17791239 09	-.31485498 07	.10193526 08	-.13097891 01	-.23738453 02	-.24868250 00
	.85227872 08	-.12755751 02	.34080927 03	.60524179 04	-.88636217-01	.26998875 03
	.17823198 09	.32786752 01	.18101387 03	.23775860 02	.41305748 01	. 90838891 02
270.00	-.17749752 09	-.23572950 08	.98908631 07	.22576757 01	-.23470852 02	-.45029199 00
	.76887218 08	-.13318746 02	.33625449 03	.54481125 04	-.10411342 00	.26999285 03
	.17932898 09	.31617432 01	.18756502 03	.23583485 02	.20067036 01	.91207301 02
280.00	-.17403419 09	-.43593283 08	.94183217 07	.57442378 01	-.22804839 02	-.64181006 00
	.68193547 08	-.13635143 02	.33140619 03	.48261193 04	-.12096009 00	.26999675 03
	.17965795 09	.30050296 01	.19406249 03	.23525918 02	-.15725998 00	.91557180 02

T (days)	Xs (km) Re (km) Rs (km)	Y(km) LATe(deg) LATs (deg)	Zs (km) LONG e (deg) LONG s (deg)	$\dot{X}$s (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$s (km/sec) PTe(deg) PTs (deg)	$\dot{Z}$s (km/sec) AZe (deg) AZs (deg)
290.00	-.16759847 09	-.62868760 08	.87849186 07	.91356453 01	-.21747662 02	-.82251942 00
	.59328605 08	-.13719992 02	.32623117 03	.41976438 04	-.14065835 00	.27000043 03
	.17921747 09	.28096606 01	.20056184 03	.23602910 02	-.23181329 01	.91887209 02
300.00	-.15827950 09	-.81061432 08	.8003825 07	.12415495 02	-.20298197 02	-.9914636 00
	.50448835 08	-.13591225 02	.32064909 03	.35717835 04	-.16380416 00	.27000369 03
	.17800944 09	.25759443 01	.20711885 03	.23814791 02	-.44327739 01	.92195643 02
310.00	-.14618190 09	-.97829698 08	.70754229 07	.15562965 02	-.18447317 02	-.11473181 01
	.41740716 08	-.13282607 02	.31458177 03	.29594712 04	-.19210248 00	.27000628 03
	.17603936 09	.23034676 01	.21379172 03	.24162486 02	-.64583912 01	.92480074 02
320.00	-.13143171 09	-.11281973 09	.60220965 07	.18549889 02	-.16178428 02	-.12882470 01
	.33328840 08	-.12834483 02	.30798519 03	.23677331 04	-.23064609 00	.27000819 03
	.17331720 09	.19912050 01	.22064248 03	.24647504 02	-.83527244 01	.92737172 02
330.00	-.11418386 09	-.12566023 09	.48543355 07	.21337533 02	-.13467969 02	-.14117187 01
	.25309043 08	-.12299316 02	.30074534 03	.18020975 04	-.28660071 00	.27000900 03
	.16985879 09	.16376582 01	.22773947 03	.25271910 02	-.10073939 02	.92962352 02
340.00	-.94631864 08	-.13595773 09	.35886385 07	.23872342 02	-.10286149 02	-.15142861 01
	.17764988 08	-.11755375 02	.29281127 03	.12677391 04	-.38222336 00	.27000847 03
	.16568818 09	.12410650 01	.23516058 03	.26038177 02	-.11580245 02	.93149387 02
350.00	-.73024504 08	-.14329044 09	.22449625 07	.26079912 02	-.65988886 01	-.15913618 01
	.10666369 08	-.11278457 02	.28423807 03	.76262370 03	-.60030959 00	.27000673 03
	.16084081 09	.79974001 00	.24299543 03	.26948833 02	-.12829713 02	.93290018 02
360.00	-.49687054 08	-.14720546 09	.84764200 06	.27857485 02	-.23679501 01	-.16377532 01
	.39215412 07	-.10960159 02	.27505646 03	.28080820 03	-.15627626 01	.27000335 03
	.15536720 09	.31259299 00	.25134863 03	.28005872 02	-.13787308 02	.93375295 02

EARTH RETURN TRAJECTORY

GEOCENTRIC

T (days)	Xe (km) Re (km) Rs (km)	Ye (km) LATe(deg) LATs(deg)	Ze (km) LONGe (deg) LONGs (deg)	$\dot{X}$e (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$e (km/sec) PTe (deg) PTs (deg)	$\dot{Z}$e(km/sec) AZe (deg) AZs (deg)
361.00	-.55283500 05	-.32009730 07	-.61884999 06	.17249274 00	.74969757 01	.14620523 01
	.32607152 07	-.10940507 02	.27413123 03	.23353549 03	-.18747435 01	.27000302 03
	.15478773 09	.26133755 00	.25221704 03	.28119704 02	-.13868147 02	.93380954 02
362.00	-.40655000 05	-.25537820 07	-.49289200 06	.16656327 00	.74850547 01	.14540163 01
	.26012316 07	-.10922670 02	.27322300 03	.18635715 03	-.23454750 01	.27000279 03
	.15420255 09	.20960997 00	.25309195 03	.28235047 02	-.13948197 02	.93386543 02
363.00	-.26424277 05	-.19073872 07	-.36752708 06	.16316208 00	.74791040 01	.14484030 01
	.19426529 07	-.10905415 02	.27235568 03	.13925129 03	-.31366849 01	.27000288 03
	.15361163 09	.15740171 00	.25397351 03	.28351938 02	-.14029931 02	.93392621 02
364.00	-.12389162 05	-.12611052 07	-.24251409 06	.16206973 00	.74836168 01	.14461198 01
	.12842713 07	-.10884746 02	.27160089 03	.92192843 02	-.47431035 01	.27000418 03
	.15301469 09	.10468375 00	.25486181 03	.28470517 02	-.14121713 02	.93401264 02
365.00	.16378847 04	-.61337846 06	-.11743731 06	.16283192 00	.75207353 01	.14514483 01
	.62452167 06	-.10838634 02	.27133111 03	.45199152 02	-.97559160 01	.27001468 03
	.15241063 09	.51351922-01	.25575689 03	.28591268 02	-.14266869 02	.93423156 02
365.25	.51570972 04	-.45065093 06	-.86035207 05	.16295349 00	.75497054 01	.14567523 01
	.45881904 06	-.10807768 02	.18158736 03	.33508354 02	-.13261425 02	.27002754 03
	.15225800 09	.37880228-01	.25598170 03	.28621929 02	-.14340320 02	.93437853 02
365.50	.86702475 04	-.28700111 06	-.54461367 05	.16192768 00	.76125193 01	.14685526 01
	.29225134 06	-.10739917 02	.92415689 02	.21957443 02	-.20653199 02	.27007191 03
	.15210416 09	.24300959-01	.25620687 03	.28652551 02	-.14479961 02	.93469131 02

T(days)	Xe (km) Re (km) Rs (km)	Ye (km) LATe (deg) LATs (deg)	Ze (km) LONGe (deg) LONGs (deg)	$\dot{X}$e (km/sec) Ve (km/sec) Vs (km/sec)	$\dot{Y}$e (km/sec) PTe (deg) PTs (deg)	$\dot{Z}$e (km/sec) AZe (deg) AZs (deg)
365.75	.12078743 05	-.12075608 06	-.22399526 05	.14686714 00	.78458452 01	.15122458 01
	.12340853 06	-.10457557 02	.61509451 01	.11214887 02	-.45052026 02	.27052629 03
	.15194753 09	.10471968-01	.25643222 03	.28675809 02	-.14955905 02	.93586732 02
* 365.92	.89014954 04	.36909441 04	.12507277 04	-.46831697 01	.10696889 02	.17634493 01
	.97172015 04	.73952139 01	.52182978 02	.11115361 02	.14401921-06	.80794233 02
	.15183119 09	-.18302203-04	.25658116 03	.24204310 02	-.21656824 02	.96734906 02

*Earth Peri-center Passage June 7, 1976 04 Hrs. 58 Min. 27.824 sec. GMT

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APPROVAL TM X-53434

ANALYSIS OF AN INTERPLANETARY TRAJECTORY TARGETING TECHNIQUE WITH APPLICATION TO A 1975 VENUS FLYBY MISSION

By Bobby Ellison

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This document has also been reviewed and approved for technical accuracy.

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