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Advanced Mission Design Branch
MISSION PLANNING AND ANALYSIS DIVISION

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HOUSTON, TEXAS

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PROJECT APOLLO

A SURVEY OF 30-DAY STAYTIME ORBITAL MISSIONS TO VENUS (1972 - 2000)

By Gregory A. Zambo, Victor R. Bond, and Ellis W. Henry
Advanced Mission Design Branch

July 23, 1969

MISSION PLANNING AND ANALYSIS DIVISION
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A SURVEY OF 30-DAY STAYTIME

ORBITAL MISSIONS TO VENUS

(1972 - 2000)

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1.0 SUMMARY

A study of 30-day stay time orbital missions to Venus between the years 1972 and 2000 was recently conducted. Maximum basic values[a] for these missions were found to be the following.

ΔV depart Earth (262-n. mi. altitude) = 12 550 fps

ΔV arrive Venus (200- by 20 000-n. mi. altitude) = 5500 fps

ΔV depart Venus (200- by 20 000-n. mi. altitude) = 7150 fps

Earth entry velocity (400 000-ft altitude) = 49 600 fps

The total trip time of these missions varies from 465 days to 550 days, with launch opportunities approximately every 580 days.

2.0 INTRODUCTION

Double-Hohmann missions to Venus have low ΔV requirements, low earth entry velocities, and 470-day staytimes; but their total trip times (TTT's) vary between 725 days and 900 days. Thirty-day staytime orbital missions (STOM's) to Venus, as presented in this internal note, offer significant decreases in TTT (TTT's vary between 465 and 550 days) at the expense of increases in the ΔV requirements and earth entry

[a]No allowance for launch windows, gravity losses, midcourse corrections, etc.

velocities. The purpose of this note is to present the launch dates, flight times, and ΔV's associated with each 30-day STOM from 1972 to 2000.

3.0 SYMBOLS

h	altitude
RB	radius of body (planet)
r	magnitude of position vector
V_∞	magnitude of $\overline{V}_\infty$
$\overline{V}_\infty$	hyperbolic excess velocity (V-infinity) vector
α_∞	angle (measured in the direction of motion on the ellipse) from periapsis vector and of the ellipse to $\overline{V}_\infty$
ΔV	magnitude of velocity increment
η	angle between periapsis and asymptote of a hyperbolic orbit
Θ	angle between $\overline{V}_{\infty AV}$ and $\overline{V}_{\infty DV}$
μ	gravitational constant

Subscripts

AV	arrive Venus
DE	depart Earth
DV	depart Venus
π	periapsis

4.0 TRAJECTORY ANALYSIS

Information about the missions discussed in this document were obtained from a massless planet analysis[b] that used minimum total ΔV

[b]In a massless planet analysis, the $\overline{V}_\infty$ is defined as the heliocentric transfer conic velocity vector minus the velocity vector of the planet.

as the primary selection criterion. The ΔV to depart Earth (ΔV_{DE}) was computed as a collinear impulse from a 262-n. mi. circular orbit, while ΔV at Venus arrival (ΔV_{AV}) was computed as a collinear impulse into a 200- by 20 000-n. mi. altitude Venusian parking orbit (VPO). The plane and orientation of the VPO were determined (fig. 1) by the V-infinity vector at Venus arrival ($\overline{V}_{\infty AV}$) and the V-infinity vector at Venus departure ($\overline{V}_{\infty DV}$). Venus departure was constrained to occur 30 days after arrival at Venus, and the VPO was assumed to remain unperturbed during the 30-day staytime. From figure 1, it is seen that, in general, the VPO and $\overline{V}_{\infty DV}$ are not properly positioned for a collinear VPO periapsis departure burn. Therefore, the ΔV to depart Venus (ΔV_{DV}) was obtained from data presented in figure 2 (which takes this improper positioning into account). The $\alpha_{\infty DV}$ of figure 2 is found from

$$\alpha_{\infty DV} = \pi - \eta_{AV} + \Theta$$

where η_{AV} is given in figure 3 and Θ is the angle between $\overline{V}_{\infty AV}$ and $\overline{V}_{\infty DV}$.

The data of figure 4 indicate the reason that a 20 000-n. mi. apoapsis altitude was chosen for the VPO. It is seen that much of the ΔV reduction to be gained from the use of a large apoapsis altitude at Venus is present in an apoapsis altitude of 20 000-n. mi.

Heliocentric views of the 1976 and 1978 Venus 30-day STOM's are presented in figures 5 and 6, respectively.

5.0 RESULTS

The results of this study are given in tables I and II. The launch dates, flight times, and ΔV's for each opportunity are presented in table I, and the V-infinity vectors for each opportunity are presented in table II. Each mission is the minimum (or near minimum) total ΔV mission for its given launch opportunity.

6.0 CONCLUSIONS

Because of the ΔV requirements and total trip times of 30-day staytime orbital missions to Venus from 1972 to 2000, it is recommended that these missions be given serious consideration as early manned orbital expeditions to the planets. For any known class of 30-day staytime Mars orbital missions, the total ΔV requirement is at least 15 percent higher than it is for the 30-day staytime Venus orbital missions presented in this note.

TABLE I.- TRAJECTORY DATA FOR VENUS 30-DAY STAY TIME ORBITAL MISSIONS (1972 - 2000)

Mission number	Julian date of Earth departure (-2440000)	Calendar date of Earth departure	Earth to Venus flight time, day	Staytime at Venus, day	Venus to Earth flight time, day	Total trip time day	ΔV depart Earth at 262- by 262-n. mi. altitude, fps	ΔV arrive Venus at 200- by 20 000-n. mi. altitude, fps	ΔV depart Venus at 200- by 20 000-n. mi. altitude, fps	Earth entry velocity at 400 000-ft altitude, fps
1	1 370	Feb. 23, 1972	190	30	330	550	12 429	5439	7122	47 433
2	1 990	Nov. 4, 1973	160	30	335	525	11 479	5145	6984	49 264
3	2 570	June 7, 1975	160	30	335	525	11 671	4192	6534	48 154
4	3 130	Dec. 18, 1976	180	30	325	535	12 484	3972	6596	48 412
5	3 760	Sept. 9, 1978	110	30	325	465	12 537	5498	7004	47 829
6	4 290	Feb. 21, 1980	190	30	330	550	12 452	5425	7111	47 456
7	4 910	Nov. 2, 1981	160	30	335	525	11 492	5258	7003	49 272
8	5 490	June 3, 1983	160	30	335	525	11 617	4220	6565	48 134
9	6 050	Dec. 16, 1984	180	30	325	535	12 453	3978	6591	48 451
10	6 680	Sept. 7, 1986	110	30	325	465	12 541	5496	6998	47 803
11	7 210	Feb. 19, 1988	190	30	330	550	12 474	5410	7099	47 481
12	7 830	Oct. 21, 1989	160	30	335	525	11 508	5371	7023	49 278
13	8 410	June 3, 1991	160	30	335	525	11 568	4258	6596	48 115
14	8 970	Dec. 14, 1992	180	30	325	535	12 422	3989	6588	48 490
15	9 600	Sept. 5, 1994	110	30	325	465	12 545	5491	6996	47 777
16	10 130	Feb. 17, 1996	190	30	330	550	12 495	5394	7085	47 507
17	10 760	Nov. 8, 1997	160	30	335	525	11 553	5501	7154	49 599
18	11 330	June 1, 1999	160	30	335	525	11 524	4306	6630	48 097

TABLE II.- V-INFINITY VECTORS FOR VENUS 30-DAY STAYTIME ORBITAL MISSIONS (1972 - 2000)

Mission number	$\bar{V}$ depart Earth			$\bar{V}$ arrive Venus			$\bar{V}$ depart Venus			$\bar{V}$ arrive Earth		
	Right ascension, deg	Declination, deg	Magnitude, deg	Right ascension, deg	Declination, deg	Magnitude, fps	Right ascension deg	Declination, deg	Magnitude, fps	Right ascension deg	Declination, deg	Magnitude fps
1	106.75	49.41	12 284	75.43	-15.64	14 902	154.38	-12.25	18 459	157.93	8.31	30 491
2	323.64	-22.27	8 982	291.47	13.69	14 176	22.16	28.64	18 327	26.06	3.84	33 269
3	151.27	-21.02	9 730	149.81	13.50	11 560	231.85	-29.68	17 347	234.97	-9.40	31 601
4	16.44	39.86	12 449	5.99	-10.93	10 878	83.03	24.65	16 956	78.77	12.92	31 993
5	219.85	15.20	12 608	209.38	-64.88	15 044	284.12	-20.48	17 130	270.95	-12.97	31 104
6	104.06	49.99	12 352	73.68	-15.68	14 870	152.74	-11.37	18 447	156.04	8.70	30 527
7	322.00	-24.83	9 034	289.42	14.31	14 459	19.76	28.15	18 369	24.21	3.36	33 280
8	150.14	-18.28	9 525	146.82	11.28	11 645	229.26	-29.78	17 400	233.04	-9.04	31 571
9	14.87	38.41	12 355	2.98	-10.00	10 899	80.62	25.30	16 974	76.89	12.73	32 052
10	217.23	15.33	12 619	205.44	-63.88	15 040	281.76	-21.47	17 074	268.95	-12.92	31 064
11	101.32	50.50	12 419	71.91	-15.51	14 833	151.09	-10.48	18 432	154.14	9.08	30 566
12	320.30	-27.31	9 097	287.42	14.88	14 737	17.40	27.64	18 410	22.35	2.86	33 290
13	149.01	-15.46	9 335	143.91	9.12	11 759	226.69	-29.84	17 457	231.11	-8.66	31 542
14	13.33	36.94	12 262	0.00	-9.08	10 934	78.19	25.90	16 995	75.02	12.52	32 111
15	214.59	15.45	12 631	201.77	-62.81	15 029	279.37	-22.43	17 023	266.95	-12.85	31 024
16	98.55	50.95	12 482	70.12	-15.32	14 793	149.45	-9.58	18 414	152.24	9.45	30 606
17	315.62	-12.26	9 276	292.82	1.64	15 053	20.01	26.66	18 605	30.15	4.00	33 763
18	147.85	-12.57	9 162	141.06	7.02	11 899	224.13	-29.86	17 516	229.19	-8.28	31 514

[a]Coordinate system: earth equatorial

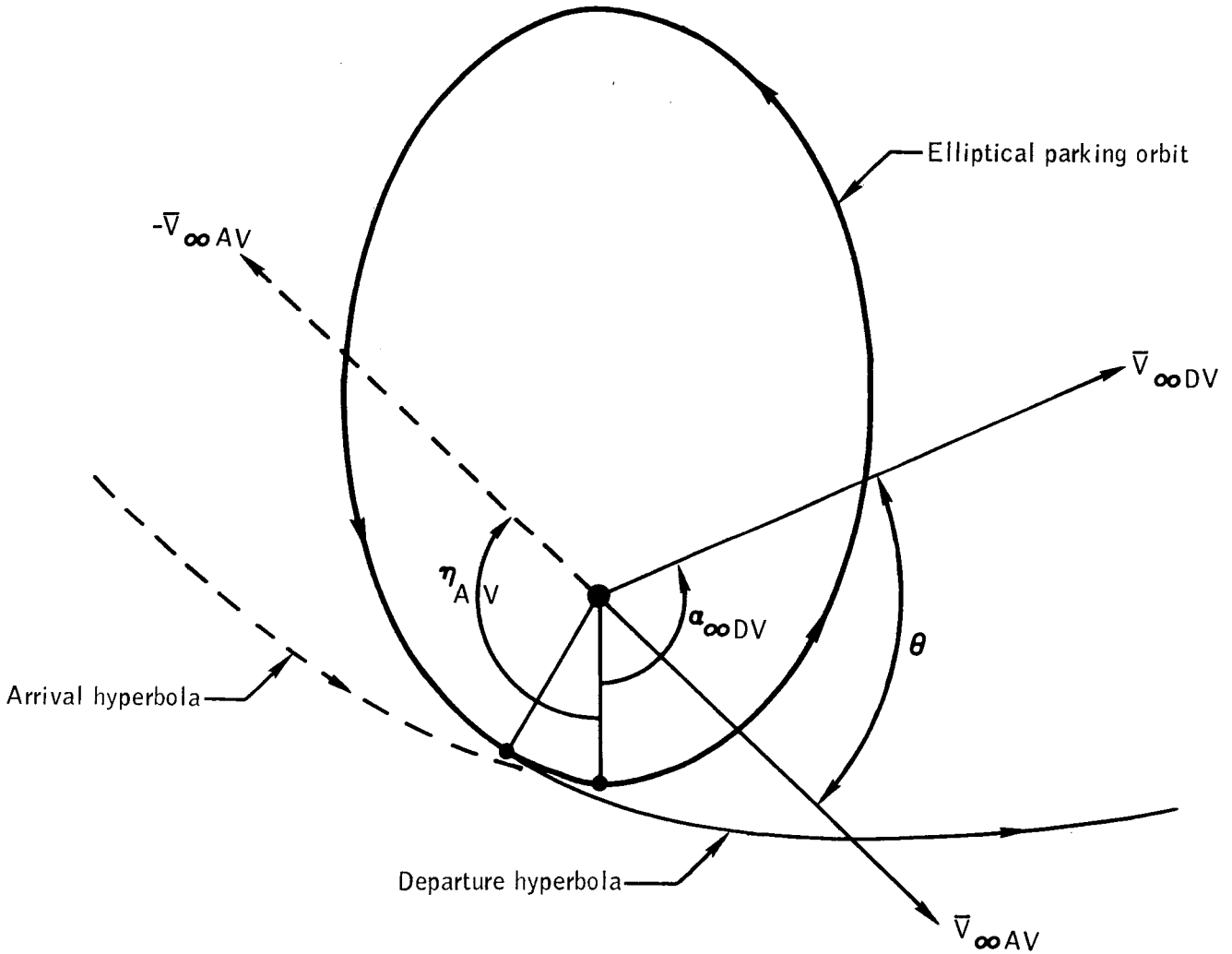

Figure 1.- Orbital orientations at Venus.

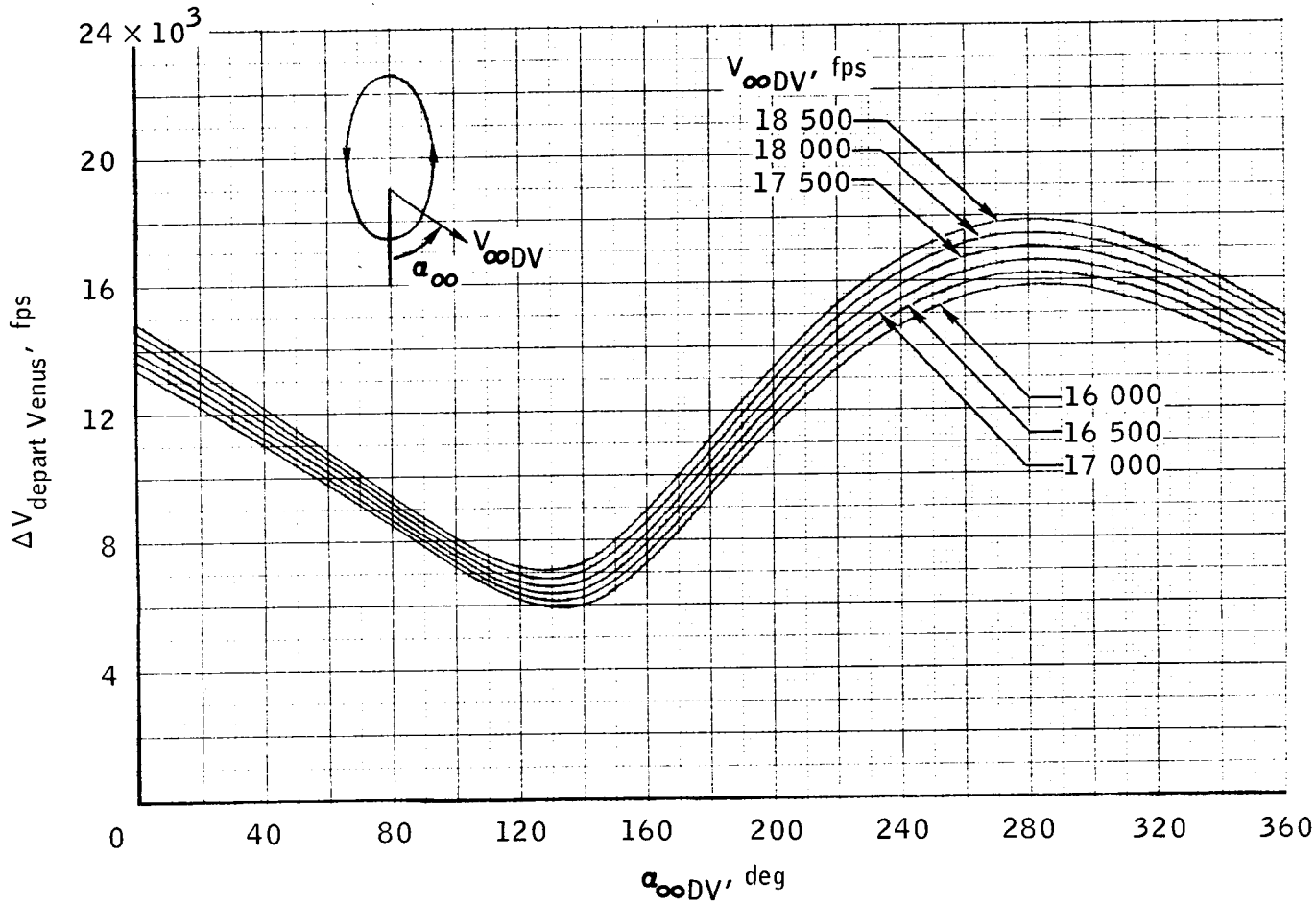

Figure 2.- ΔV to depart Venus from a 200 by 20 000-nautical mile altitude orbit to an inplane $V_{\infty DV}$.

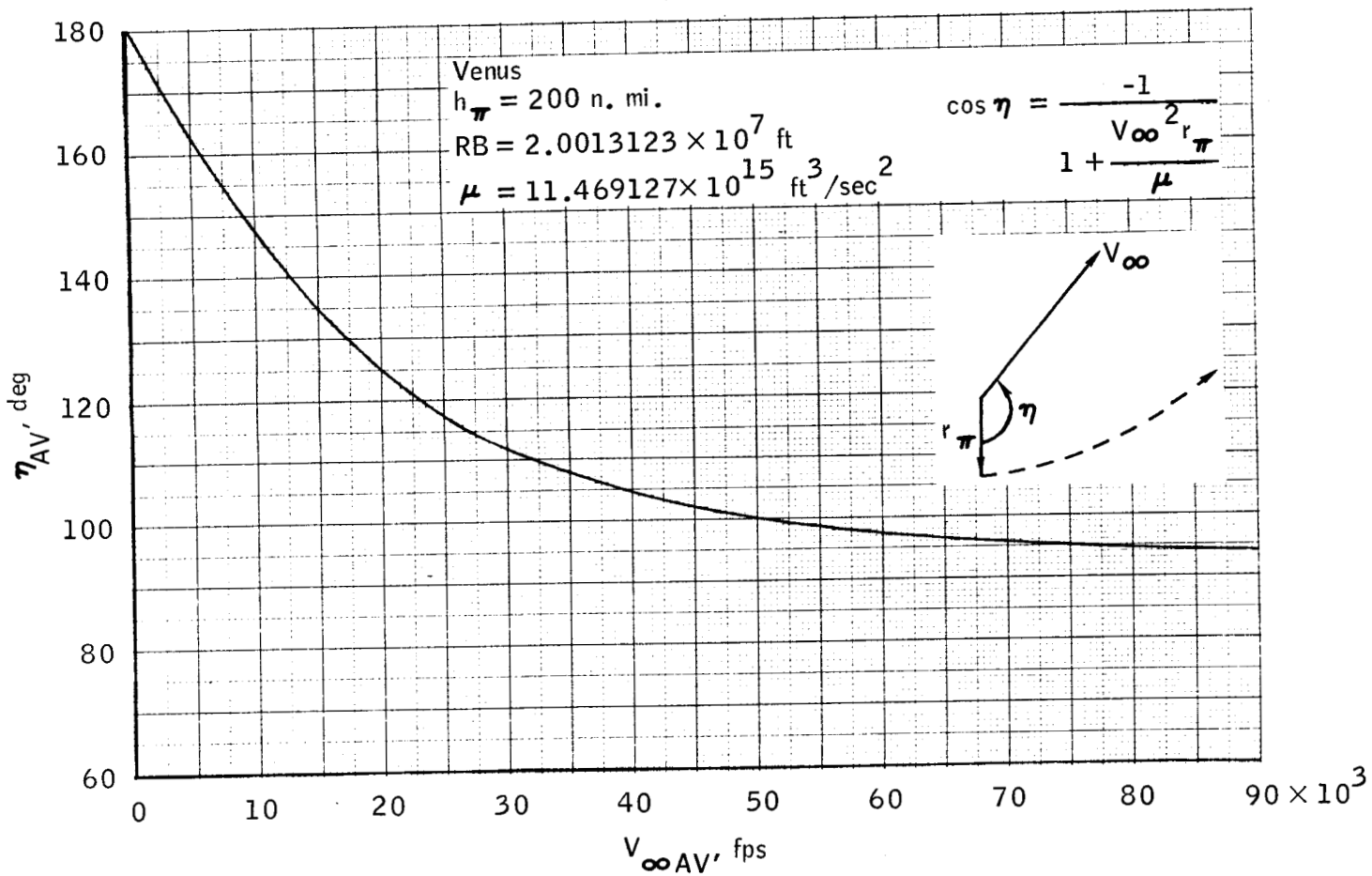

Figure 3.- Variation in asymptote angle, η.

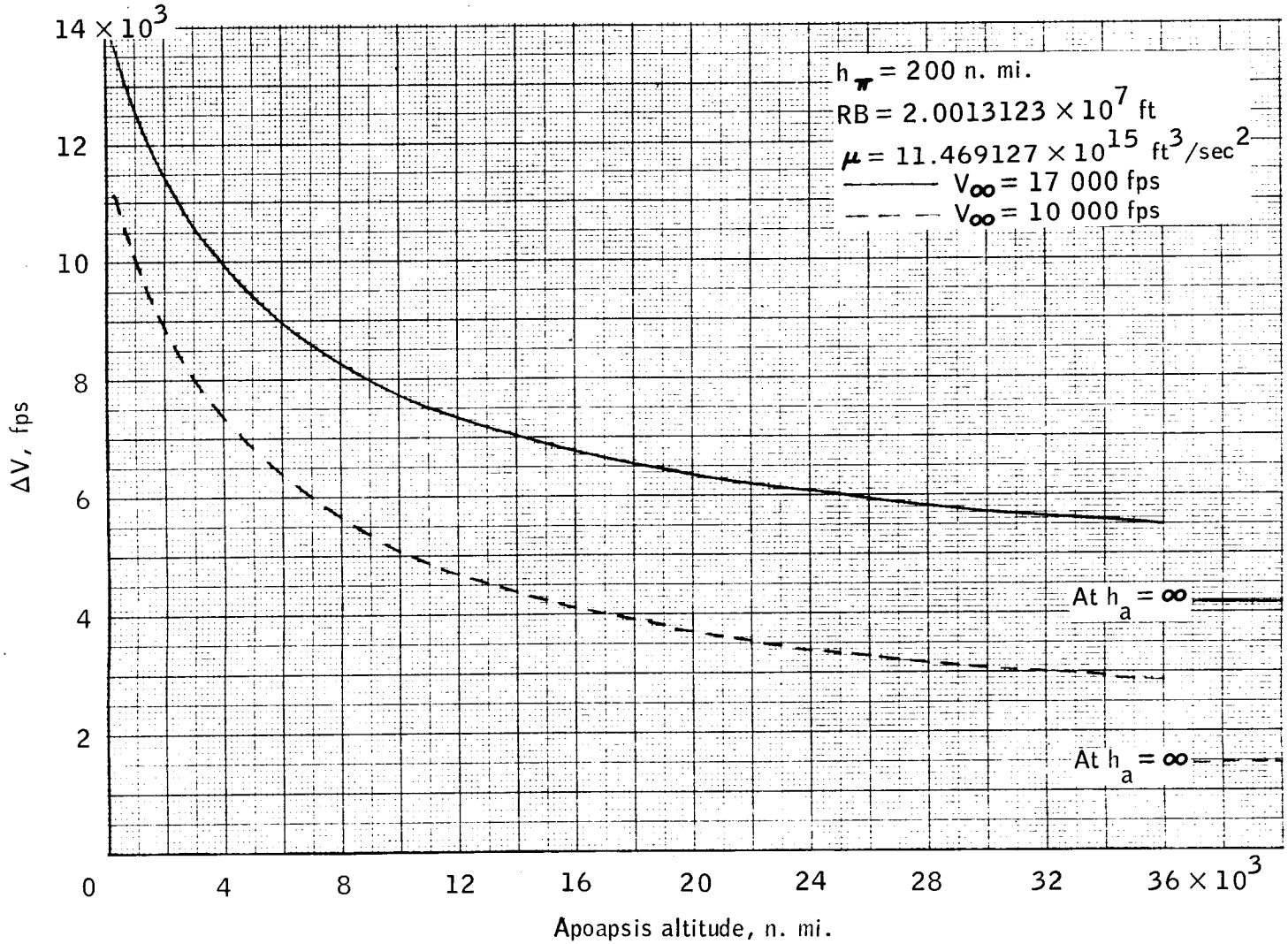

Figure 4.- Venus orbit insertion ΔV requirements for 200-nautical mile altitude elliptical parking orbits.

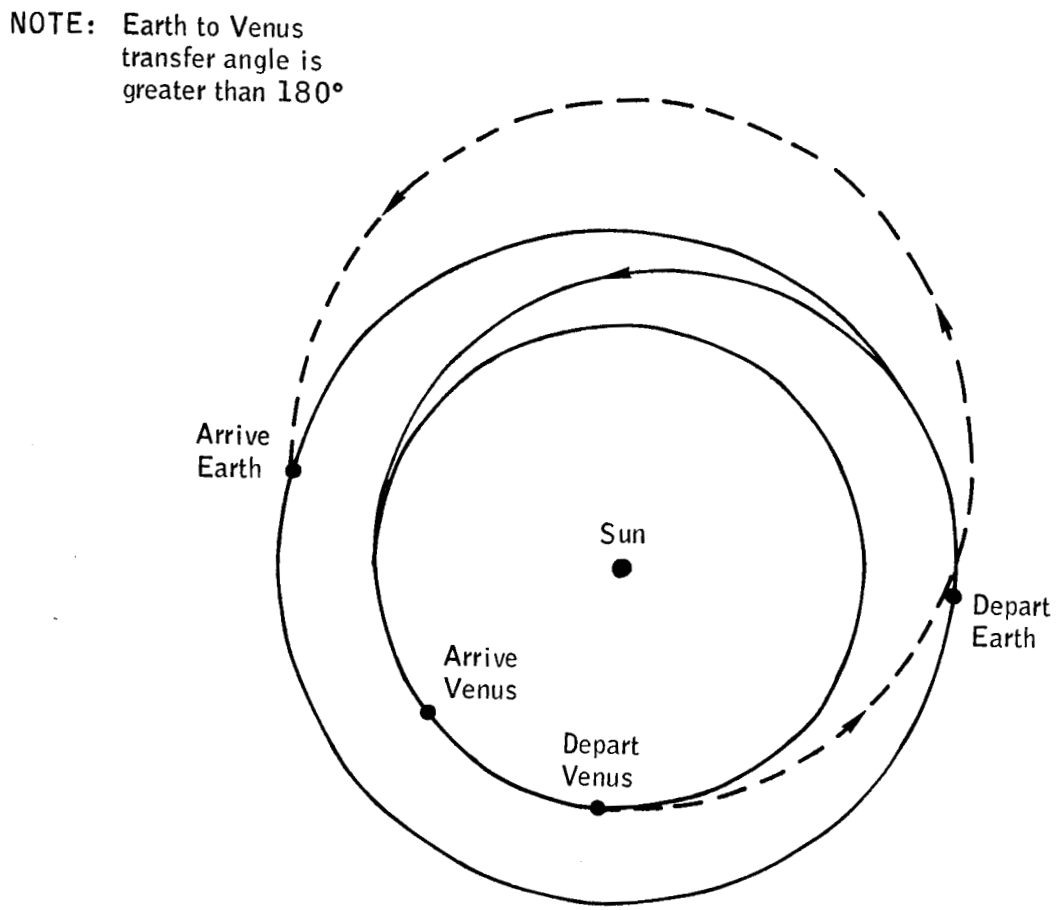

Figure 5.- A heliocentric view of the 1976 Venus 30-day staytime orbital mission.

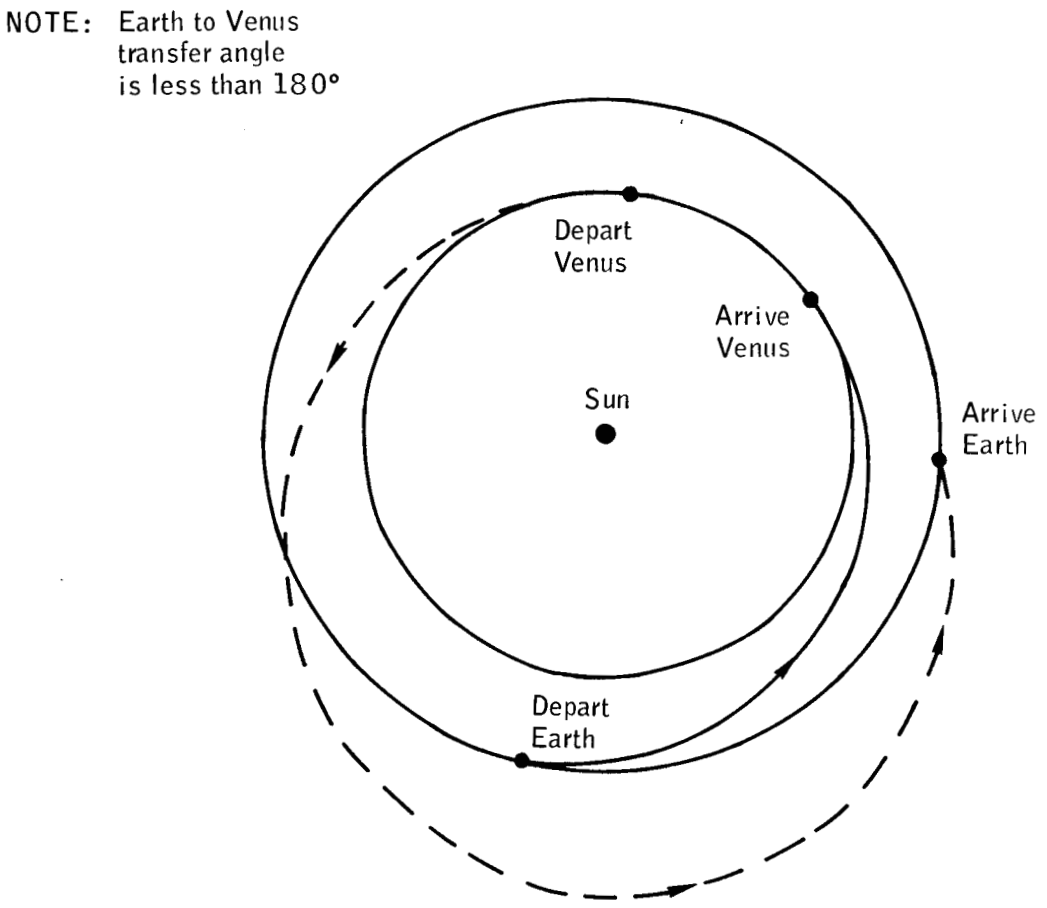

Figure 6.- A heliocentric view of the 1978 Venus 30-day staytime orbital mission.