Transmittal Note No. 69-FM-311

NOV 2 3 1970

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-311

December 2, 1969

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VELOCITY REQUIREMENTS FOR MARS STOPOVER/VENUS SWINGBY MISSIONS IN 1981

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MISSION PLANNING AND ANALYSIS DIVISION

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(NASA-TM-X-69686) VELOCITY REQUIREMENTS FOR MARS STOPOVER/VENUS SWINGBY MISSIONS IN 1981 (NASA) 34 p

N74-70864

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By Joseph R. Thibodeau III
Advanced Mission Design Branch

December 2, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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VELOCITY REQUIREMENTS FOR MARS STOPOVER/VENUS SWINGBY MISSIONS IN 1981

By Joseph R. Thibodeau III

1.0 SUMMARY AND INTRODUCTION

Launch dates, flight times, and impulsive ΔV requirements are presented for minimum sum ΔV Mars stopover missions with Venus swingbys. Minimum sum ΔV mission plans are presented for the Earth departure opportunity in late 1981 and early 1982. Orbital staytimes at Mars of 20 days, 30 days, 40 days, 60 days, and 80 days are considered. The ΔV costs for the spacecraft capture and escape maneuvers at Mars are calculated by considering the plane changes and flight-path angle corrections that may be required. Perturbations of the parking orbit caused by the oblateness of the gravitational field of Mars are used to minimize the required plane changes and flight-path angle corrections. The orbital elements of the parking orbits at Mars are presented.

2.0 DISCUSSION

The 1981 Mars stopover Venus swingby mission consists of a direct interplanetary transfer from Earth to Mars, a short orbital stopover at Mars, and a return transfer from Mars to Earth which is also a free flyby of Venus. This mission is illustrated in figure 1.

The direct transfer from Earth to Mars can have either a type I (heliocentric transfer angle $< 180°$) or a type II (heliocentric transfer angle $> 180°$) trajectory. Both transfer trajectories have the same arrival dates at Mars; however, the Earth departure dates are separated by 40 to 60 days which gives rise to two separate Earth departure opportunities, one in November of 1981 and the other in January of 1982.

The return trajectory from Mars to Earth is also a free flyby of Venus. The flyby altitude at Venus is constrained to be between 500 n. mi. and 10 000 n. mi. above the planet's surface. The periapsis velocities of the Venus approach and departure trajectories are matched

to within a ±10-fps tolerance. The trajectory from Mars to Venus is type I; the Venus-Earth trajectory is type II. This description pertains to the category 3 Mars stopover/Venus swingby mission described by Deerwester in reference 1.

The Earth entry velocities for these missions are nearly constant at 40 000 fps for an entry altitude of 400 000 feet.

The Earth departure velocity requirements vary from a minumum of 11 700 fps to a maximum of 12 700 fps. The 12 700-fps value was used as a constraint for Earth departure ΔV in the mission selection and optimization program. In regions of the mission launch window where the Earth departure ΔV is below this value, the optimization criterion is minimum sum ΔV. In regions of the window where the Earth departure ΔV is above this value, the optimization criterion is minimum sum ΔV subject to the constraint that the Earth departure ΔV is equal to or less than 12 700 fps. Mission plans with lower total ΔV requirements could be found if the Earth departure constraint were relaxed. Such mission plans would have higher injection velocities, but the spacecraft velocity requirements would be lower.

The magnitude of the spacecraft velocity requirements at Mars, and particularly at Mar's departure, is controlled predominantly by the length of the orbital staytime at Mars. For staytimes between 20 and 80 days, the Mars departure ΔV increases as the staytime is increased. In this report, orbital staytimes of 20, 30, 40, 60, and 80 days are considered. The staytime is varied to illustrate the effect of the staytime on the velocity requirements for Earth departure and on the spacecraft velocity requirements at Mars.

The spacecraft velocity requirements at Mars are represented by both scalar and vector computations of the ΔV for the capture and escape maneuvers. The scalar ΔV's represent the minimum capture and escape velocities required for a spacecraft in a fixed 200- by 10 000-n. mi. altitude parking orbit at Mars. These scalar ΔV's are calculated assuming the parking orbit is ideally alined with the approach and departure asymptotes. They do not include ΔV costs to account for possible misalinements of the parking orbit. Thus, they may yield unrealistically low estimates of the actual ΔV costs.

In contrast, the computations of the vector ΔV's do include possible plane change requirements. The method of computation of these ΔV's is presented in reference 2. This method, which uses the oblateness of Mars gravitational field to rotate the parking orbit, yields ΔV's which more accurately reflect the cost of the actual ΔV; at the same time, it establishes an upper bound for the plane change requirements at Mars.

The vector ΔV's are generally higher for the shorter staytimes because the apoapsis altitude is adjusted to a value below 10 000 n. mi. to minimize ΔV costs for parking orbit alinement. Therefore, they are calculated for a lower energy parking orbit. Thus, for the short staytimes, the vector ΔV's may become unreasonable high when very low energy orbits must be used.

For the 80-day Mars stopover, this method results in ΔV's 5 percent to 6 percent greater than the scalar values. The method will be discussed in more detail in section 3.

The scalar and vector ΔV curves together define a ΔV design envelope for the capture and escape maneuvers at Mars. Although the optimum flight plan for these maneuvers is not known, it must result in ΔV's which lie within the bounds of the envelope.

3.0 PROCEDURE AND ANALYSIS

Optimization and analysis of any mission plan requires prior knowledge of the existence and gross characteristics of the mission to be investigated. Accordingly, for the Venus swingby mission to Mars, the initial estimates and flight times were provided by reference 1.

The analysis is a two-step process beginning with the initial estimates for the launch date and flight times. Both steps are phases of the operation of a computer program.

In step one, the weighted least squares technique is used to find minimum sum ΔV mission plans subject to various constraints on the dependent and independent variables. This technique is discussed in reference 3. The result of this step is the calculation of a reference trajectory or nominal mission. The nominal mission represents the best mission that can be found and, therefore, is the optimum mission plan subject to all the constraints on the dependent and independent variables.

The second step is the production of the velocity requirements and flight plans for the Earth orbital launch window. The flight times and orbital staytime of the optimum mission determined in step 1 are used as the initial estimates to re-optimize the mission for a new launch date which is then held fixed. The launch date is incremented at 5-day intervals over a 50-day period centered to include 25 days on each side of the launch date of the optimum mission. In this step then, the mission is re-optimized for each new launch date so that the best possible mission, subject to the constraints, is found for each new launch date.

The computation of the possible parking orbits at Mars and fhe fly-by trajectory parameters at Venus are part of the computer program output module. The spacecraft vector ΔV costs are calculated after the optimum mission plan is selected. Thus, there remains a distinct possibility that the vector ΔV requirements can be reduced by modeling them during the mission selection process, particularly for the very short staytimes.

3.1 The Parking Orbit at Mars

The parking orbits at Mars and the spacecraft vector ΔV's are determined by the method presented in reference 2. This method, programed as part of the program printout module, accommodates both the geometry of approach and departure and the effects of planetary oblateness. The basic approach is to choose the orbital eccentricity and inclination so that the resultant nodal and apsidal notions will shift the original orbit into proper alinement for departure on the intended date. The program determines all parking orbit configurations which match the arrival and departure trajectories at Mars. The output consists of the orbital elements of the parking orbit, the approach and departure hyperbolas, and the spacecraft vector ΔV's. The orbital elements are calculated for an epoch corresponding to the time of periapsis passage on the approach hyperbola. They are specified in a non-rotating, Mars-centered, rectangular Cartesian coordinate system. The XY plane of this system is defined by the Mars equator. The positive Z-axis points north along the Mars spin axis. The positive X-axis is defined by the intersection of the planetary orbit and equatorial planes and corresponds to the descending node of the planetary orbit on the equatorial plane. The positive Y-axis is 90° east of X and completes a right-handed system. The transformation equations for this system are presented in reference 4.

4.0 RESULTS

4.1 The Earth Departure Windows

Mars stopover/Venus swingby mission plans were generated for orbital staytimes at Mars of 20 days, 30 days, 40 days, 60 days, and 80 days. The basic mission velocity requirements are presented for these missions in figure 2. The ΔV's shown in these figures are scalar differences as computed from conic trajectories. The injection ΔV is the impulsive ΔV required to escape a 262-n. mi. altitude circular parking orbit at earth. The total ΔV is the sum of the injection ΔV and the impulsive velocities required for capture and escape at Mars. The spacecraft parking orbit is assumed to be elliptical with a 200-n. mi. altitude periapsis and

a 10 000-n. mi. altitude apoapsis. There is no ΔV required at Venus. Because a free flyby of Venus is desired, the periapsis velocities of the Venus approach and departure trajectories are matched to within a ±10-fps tolerance. The trans-Mars injection velocity requirements are presented in more detail in reference 5.

4.2 The Spacecraft Velocity Requirements

The spacecraft velocity requirements are presented in figure 3. The Mars capture ΔV is called MOI (Mars orbit insertion); the escape ΔV is called TEI (transearth injection). Two curves are shown for each ΔV. The scalar ΔV's are repeated from figure 2 and the MOI and TEI ΔV's are replotted. The vector ΔV's are shown for an elliptical parking orbit which has its orbital elements selected so that it will shift into proper alinement for departure on the intended date. The spacecraft ΔV maneuvers for capture and escape are coplanar and occur at periapsis of the parking orbit. The ΔV's for this type parking orbit are generally higher than the scalar value because the apoapsis altitude must be lowered to force the parking orbit into proper alinement.

For the 80-day stay mission, this method yields ΔV's which are from 5 percent to 6 percent above the minimum scalar values. As the staytime is shortened, the percentage increase in ΔV costs for this technique become greater, reaching 50 percent for the 20-day stay.

The minimum sum ΔV mission flight times are shown in table I. The velocity requirements for these missions are shown in table II. The orbital elements of the parking orbit at Mars and the vector ΔV's are shown in table III. The Venus flyby mission parameters are shown in table IV.

TABLE I.- LAUNCH DATES AND FLIGHT TIMES FOR MINIMUM ΔV MARS STOPOVER/VENUS SWINGBY MISSIONS LAUNCHED IN 1981 AND 1982

Calendar date of launch, month/day/yr	Julian date of launch (add 2 440 000)	Outbound flight time, days	Mars arrival date (add 2 440 000)	Orbital staytime, fps	Intermediate flight time, days	Venus flyby date[a] (add 2 440 000)	Return flight time, days	Total trip time, days	Outbound trajectory type
11/19/1981	4928	297	5225	20	144	5389	157	618	II
1/10/1982	4980	233	5213	20	154	5387	155	562	I
11/12/1981	4920	297	5217	30	142	5389	157	626	II
1/8/1982	4978	228	5209	30	149	5388	156	562	I
11/5/1981	4914	294	5208	40	141	5389	157	633	II
1/12/1982	4981	224	5205	40	143	5388	156	563	I
11/10/1981	4919	278	5197	60	133	5390	152	624	II
12/30/1981	4969	224	5193	60	137	5390	160	581	I
11/9/1981	4918	267	5185	80	126	5391	172	646	II
12/23/1981	4961	219	5180	80	131	5391	165	594	I

[a]The Venus flyby altitudes vary between 2500 and 2600 n. mi. above the planet's surface.

TABLE II.- VELOCITY REQUIREMENTS FOR MINIMUM SUM ΔV MARS STOPOVER/VENUS SWINGBY MISSION LAUNCHED IN 1981 AND 1982

Calendar date of launch, month/day/yr	Julian date of launch (add 2 440 000)	Orbital stay-time, days	ΔV of Earth departure,[a] fps	ΔV of Mars arrival,[b] fps	ΔV of Mars departure,[b] fps	ΔV of Earth entry[c], ft	ΔV total,[d] fps	ΔV spacecraft,[e] fps	Outbound trajectory type
11/19/1981	4928	20	11 900	4100	11 300	40 000	27 300	15 400	II
1/10/1982	4980	20	12 800	5500	11 400	40 200	29 700	16 900	I
11/12/1981	4920	30	12 000	4200	11 400	40 000	27 700	15 600	II
1/11/1982	4978	30	12 600	5600	11 300	40 000	29 500	16 900	I
11/5/1981	4914	40	12 300	4500	11 400	40 000	28 200	15 900	II
1/12/1982	4981	40	12 400	5800	11 400	40 400	29 600	17 200	I
11/10/1981	4919	60	12 200	5000	11 800	40 300	29 000	16 800	II
12/30/1981	4969	60	12 000	6390	11 560	39 800	30 000	17 950	I
11/9/1981	4918	80	12 300	5800	12 600	39 800	30 700	18 400	II
12/23/1981	4961	80	11 800	7555	12 000	39 700	31 200	19 500	I

[a]Parking orbit = 262-n. mi. altitude circular.

[b]Parking orbit = 200 by 10 000 n. mi.

[c]400 000-ft entry altitude.

[d]Sum of columns 5, 6, and 7.

[e]Sum of columns 5 and 6.

TABLE III.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1981 VENUS SWINGBY MISSION

[Type II Outbound Trajectory]

(a) 20-day Mars stay, Earth departure date November 19, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445225.05 CALENDAR DATE 9/12/1982

ORBITAL STAYTIME = 19.85 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 10052.97 RA= 107.15 DEL= -26.22
OUTGOING V-INFINITY= 20482.07 RA= 109.04 DEL= -29.08

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	4.0	.193348+08	.357675	30.4990	230.4214	183.7031	.158485	5706.	12886.	30453.

TABLE III.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1981 VENUS SWINGBY MISSION - Continued

[Type II outbound trajectory]

(b) 30-day Mars stay, Earth departure date, November 12, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445217.38 CALENDAR DATE 9/ 4/1982

ORBITAL STAYTIME = 29.82 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 10247.44 RA= 108.07 DEL= -23.29
OUTGOING V-INFINITY= 20527.92 RA= 108.09 DEL= -29.12

N	P	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	4.0	.231012+08	.462399	29.5140	238.5680	175.9218	.207027	5324.	12435.	29817.
2	4.0	.132602+08	.063419	56.1200	271.2722	150.9805	.090045	7293.	14403.	33754.
3	4.0	.132590+08	.063334	123.8770	304.8746	150.9794	.090033	7293.	14404.	33755.

TABLE III.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1981 VENUS SWINGBY MISSION - Continued

[Type II outbound trajectory]

(c) 40-day Mars stay, Earth departure date, November 5, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445208.11 CALENDAR DATE 8/26/1982

ORBITAL STAYTIME = 40.17 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 10644.68 RA= 109.45 DEL= -20.92
OUTGOING V-INFINITY= 20560.44 RA= 107.63 DEL= -29.14

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	2.0	.131562+08	.056019	48.8200	128.9793	272.9405	.088952	7553.	14469.	34339.
2	2.0	.132337+08	.061543	131.4650	89.7061	272.8051	.089738	7524.	14439.	34280.
3	3.0	.239736+08	.481964	88.3250	288.6048	142.1851	.219113	5456.	12372.	30144.
4	4.0	.266986+08	.534836	29.1490	246.1842	168.3954	.257259	5218.	12134.	29669.
5	4.0	.145115+08	.144180	55.8430	274.4147	146.8177	.103101	7089.	14004.	33410.
6	4.0	.146755+08	.153747	124.3800	304.6050	146.8905	.104854	7039.	13955.	33311.

TABLE III.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1981 VENUS SWINGBY MISSION - Continued

[Type II outbound trajectory]

(d) 60-day Mars stay, Earth departure date, November 10, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445196.71 CALENDAR DATE 8/15/1982

ORBITAL STAYTIME = 59.98 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 11595.97 RA= 116.46 DEL= -21.37
OUTGOING V-INFINITY= 21105.72 RA= 103.80 DEL= -29.19

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	1.0	.243858+08	.490720	83.6030	118.9696	276.9203	.224784	5968.	12748.	30920.
2	1.0	.132691+08	.064047	131.6730	96.0700	269.2318	.090098	8062.	14862.	35108.
3	2.0	.147011+08	.155219	49.3190	136.1107	269.7120	.105099	7583.	14384.	34151.
4	2.0	.125474+08	.010216	107.5210	109.3585	275.9659	.082939	8354.	15154.	35692.
5	2.0	.153891+08	.192985	132.7080	95.2808	268.7018	.112561	7390.	14191.	33765.
6	3.0	.303558+08	.590878	29.1920	251.9941	166.7771	.311923	5522.	12322.	30028.
7	3.0	.277450+08	.552381	79.4590	292.2792	140.1895	.272789	5691.	12492.	30367.
8	4.0	.162336+08	.234968	56.1260	281.2246	144.4672	.122005	7180.	13980.	33344.
9	4.0	.177657+08	.300945	125.5460	312.6915	145.0402	.139683	6856.	13656.	32696.

TABLE III.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1981 VENUS SWINGBY MISSION - Concluded

[Type II outbound trajectory]

(e) 80-day Mars stay, Earth departure date, November 9, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445185.44 CALENDAR DATE 8/ 3/1982

ORBITAL STAYTIME = 79.81 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 12856.51 RA= 119.40 DEL= -20.55
OUTGOING V-INFINITY= 22236.09 RA= 99.67 DEL= -29.08

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	1.0	.276632+08	.551057	80.2320	123.1039	274.2902	.271585	6473.	13414.	32194.
2	1.0	.147269+08	.156700	132.3510	99.4228	266.7989	.105368	8352.	15293.	35951.
3	2.0	.160942+08	.228339	49.5030	138.0744	267.6660	.120404	7989.	14930.	35226.
4	2.0	.132591+08	.063346	71.2530	126.7131	273.3983	.090094	8842.	15782.	36931.
5	2.0	.138273+08	.101836	107.3680	112.6707	273.5769	.095953	8637.	15578.	36522.
6	2.0	.173913+08	.285896	133.7580	98.3679	266.0787	.135248	7705.	14646.	34658.
7	3.0	.345144+08	.640172	29.3700	257.6380	160.8555	.378204	6083.	13024.	31414.
8	3.0	.307331+08	.595901	74.6270	293.4881	136.5037	.318011	6276.	13217.	31799.
9	3.0	.144562+08	.140905	132.7050	319.6449	143.6881	.102471	8433.	15374.	36114.
10	4.0	.177851+08	.301706	55.9670	284.7391	140.2150	.139918	7629.	14569.	34505.
11	4.0	.127960+08	.029448	75.8710	293.9893	136.3761	.085426	9025.	15966.	37297.
12	4.0	.131654+08	.056677	102.3600	304.1156	136.2151	.089156	8877.	15818.	37002.
13	4.0	.207984+08	.402875	126.9410	315.7758	141.2066	.176949	7148.	14088.	33543.

TABLE IV.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1982 VENUS SWINGBY MISSION

[Type I outbound trajectory]

(a) 20-day Mars stay, Earth departure date, January 10, 1982

DATE OF MARS ORBIT INSERTION IS J.D. 2445212.79 CALENDAR DATE 8/31/1982

ORBITAL STAYTIME = 20.04 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 12390.31 RA= 109.95 DEL= 2.41
OUTGOING V-INFINITY= 20622.28 RA= 112.99 DEL= -28.82

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	3.0	.235648+08	.472975	54.5920	291.6643	113.3582	.213426	6532.	12462.	31752.
2	3.0	.272930+08	.544967	70.2230	290.8186	113.7536	.266122	6208.	12138.	31104.
3	3.0	.211415+08	.412566	125.4070	288.2422	113.3583	.181355	6810.	12740.	32308.

TABLE IV.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1982 VENUS SWINGBY MISSION - Continued

[Type I outbound trajectory]

(b) 30-day Mars stay, Earth departure date, January 8, 1982

DATE OF MARS ORBIT INSERTION IS J.D. 2445207.53 CALENDAR DATE 8/26/1982

ORBITAL STAYTIME = 30.01 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 12564.18 RA= 112.67 DEL= .95

OUTGOING V-INFINITY= 20483.30 RA= 111.64 DEL= -28.93

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	2.0	.124391+08	.001599	130.8110	113.4877	297.1261	.081768	8993.	14704.	36270.
2	3.0	.262872+08	.527556	52.2710	293.4024	114.6712	.251460	6394.	12105.	31071.
3	3.0	.282445+08	.560296	68.8480	293.0352	114.8536	.280155	6248.	11959.	30780.
4	3.0	.272908+08	.544930	127.7280	291.9332	114.6712	.266002	6316.	12027.	30916.
5	4.0	.131511+08	.055650	53.1010	293.3807	114.6844	.088921	8699.	14410.	35681.
6	4.0	.132230+08	.060787	127.0620	291.9507	114.6818	.089651	8671.	14382.	35626.

TABLE IV.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1982 VENUS SWINGBY MISSION - Continued

[Type I outbound trajectory]

(c) 40-day Mars stay, Earth departure date, January 12, 1982

DATE OF MARS ORBIT INSERTION IS J.D. 2445205.79 CALENDAR DATE 8/24/1982

ORBITAL STAYTIME = 39.99 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 12484.80 RA= 113.06 DEL= -2.14
OUTGOING V-INFINITY= 20507.91 RA= 108.70 DEL= -29.09

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	2.0	.133765+08	.071563	49.4710	114.8876	293.2606	.091202	8564.	14344.	35667.
2	2.0	.135949+08	.086479	131.2550	111.1866	293.2296	.093445	8484.	14265.	35508.
3	3.0	.285575+08	.565116	46.5760	291.0385	119.0112	.284707	6177.	11957.	30894.
4	3.0	.299701+08	.585612	70.8300	292.3181	118.3313	.306227	6087.	11867.	30713.
5	3.0	.330788+08	.624556	133.4230	295.0831	119.0111	.354954	5917.	11697.	30373.
6	4.0	.143042+08	.131775	53.6610	291.4891	118.7217	.100887	8247.	14027.	35032.
7	4.0	.146769+08	.153822	127.0240	294.6723	118.7454	.104856	8133.	13913.	34804.

TABLE IV.- ORBITAL ELEMENTS OF PARKING OTBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1982 VENUS SWINGBY MISSION - Continued

[Type I outbound trajectory]

(d) 60-day Mars stay, Earth departure date, December 30, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445193.06 CALENDAR DATE 8/11/1982

ORBITAL STAYTIME = 59.89 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 13765.49 RA= 119.16 DEL= -1.72

OUTGOING V-INFINITY= 20770.41 RA= 105.47 DEL= -29.20

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	1.0	.130162+08	.045863	50.0570	120.6089	290.8340	.087539	9525.	14691.	36262.
2	1.0	.219365+08	.433856	85.1500	119.3104	291.3529	.191784	7593.	12759.	32398.
3	1.0	.134913+08	.079464	131.4200	117.6418	290.7835	.092376	9345.	14511.	35902.
4	2.0	.150223+08	.173279	49.9110	120.6164	290.8291	.108569	8856.	14022.	34924.
5	2.0	.125122+08	.007432	106.5720	118.6506	291.2843	.082593	9735.	14901.	36682.
6	2.0	.159110+08	.219459	132.4360	117.5865	290.7466	.118344	8623.	13789.	34458.
7	3.0	.312185+08	.602183	52.3880	297.8347	115.2612	.325463	6838.	12004.	30887.
8	3.0	.628191+08	.802302	127.6110	300.4932	115.2611	.929174	5989.	11156.	29191.
9	4.0	.160771+08	.227520	53.9260	297.9070	115.2178	.120234	8582.	13749.	34377.
10	4.0	.176345+08	.295742	128.3660	300.5298	115.2837	.138123	8247.	13413.	33706.

TABLE IV.- ORBITAL ELEMENTS OF PARKING ORBITS WHICH SHIFT INTO ALINEMENT

FOR THE 1982 VENUS SWINGBY MISSION - Concluded

[Type I outbound trajectory]

(e) 80-day Mars stay, Earth departure date, December 23, 1981

DATE OF MARS ORBIT INSERTION IS J.D. 2445180.24 CALENDAR DATE 7/29/1982

ORBITAL STAYTIME = 79.81 PERIAPSIS ALTITUDE = 200.00

INCOMING V-INFINITY= 15389.74 RA= 122.88 DEL= -5.06
OUTGOING V-INFINITY= 21395.00 RA= 101.97 DEL= -29.19

N	M	SMA	ECC	INCL	NODE	OMEGA	PERIOD	MOI DV	TEI DV	TOTLDV
1	1.0	.255808+08	.514509	82.0900	123.5888	284.7953	.241505	8333.	12894.	32998.
2	1.0	.149780+08	.170836	132.2500	118.2759	283.0626	.108078	9976.	14536.	36284.
3	2.0	.163763+08	.241634	49.9320	127.1516	283.2875	.123590	9619.	14180.	35571.
4	2.0	.132246+08	.060900	71.8400	124.5473	284.5783	.089744	10551.	15112.	37435.
5	2.0	.138081+08	.100583	106.6040	121.3731	284.6235	.095755	10340.	14901.	37013.
6	2.0	.179648+08	.308693	133.7510	118.0268	282.8927	.141999	9291.	13852.	34915.
7	3.0	.340900+08	.635693	51.5480	298.8567	116.3595	.371392	7799.	12360.	31931.
8	4.0	.176459+08	.296198	54.2700	299.2362	116.1306	.138270	9352.	13912.	35036.
9	4.0	.129065+08	.037757	75.0690	301.5330	115.1314	.086534	10676.	15237.	37684.
10	4.0	.133396+08	.068993	103.0790	304.0621	115.0893	.090930	10508.	15069.	37348.
11	4.0	.206896+08	.399736	129.4450	307.0581	116.4510	.175549	8859.	13419.	34050.

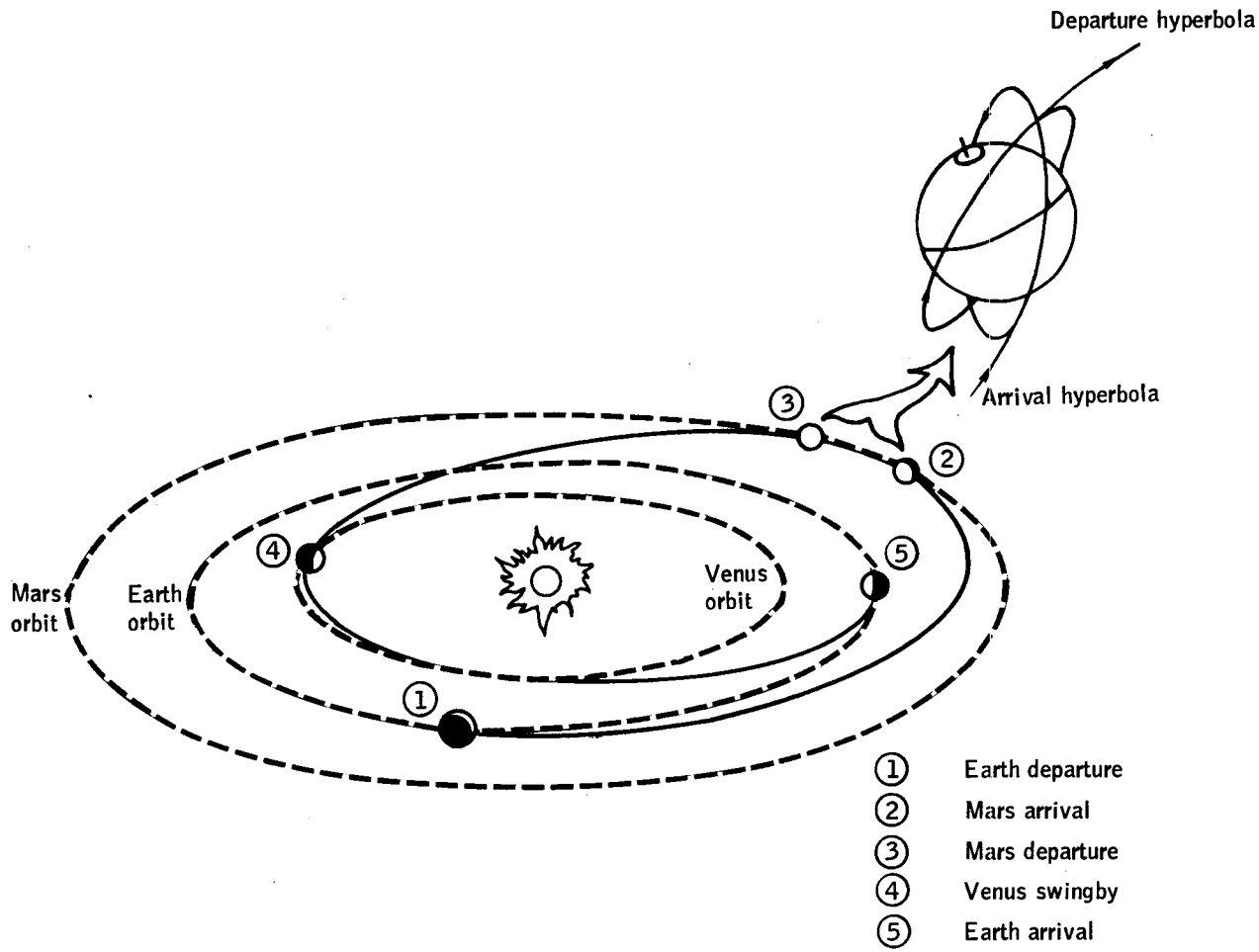
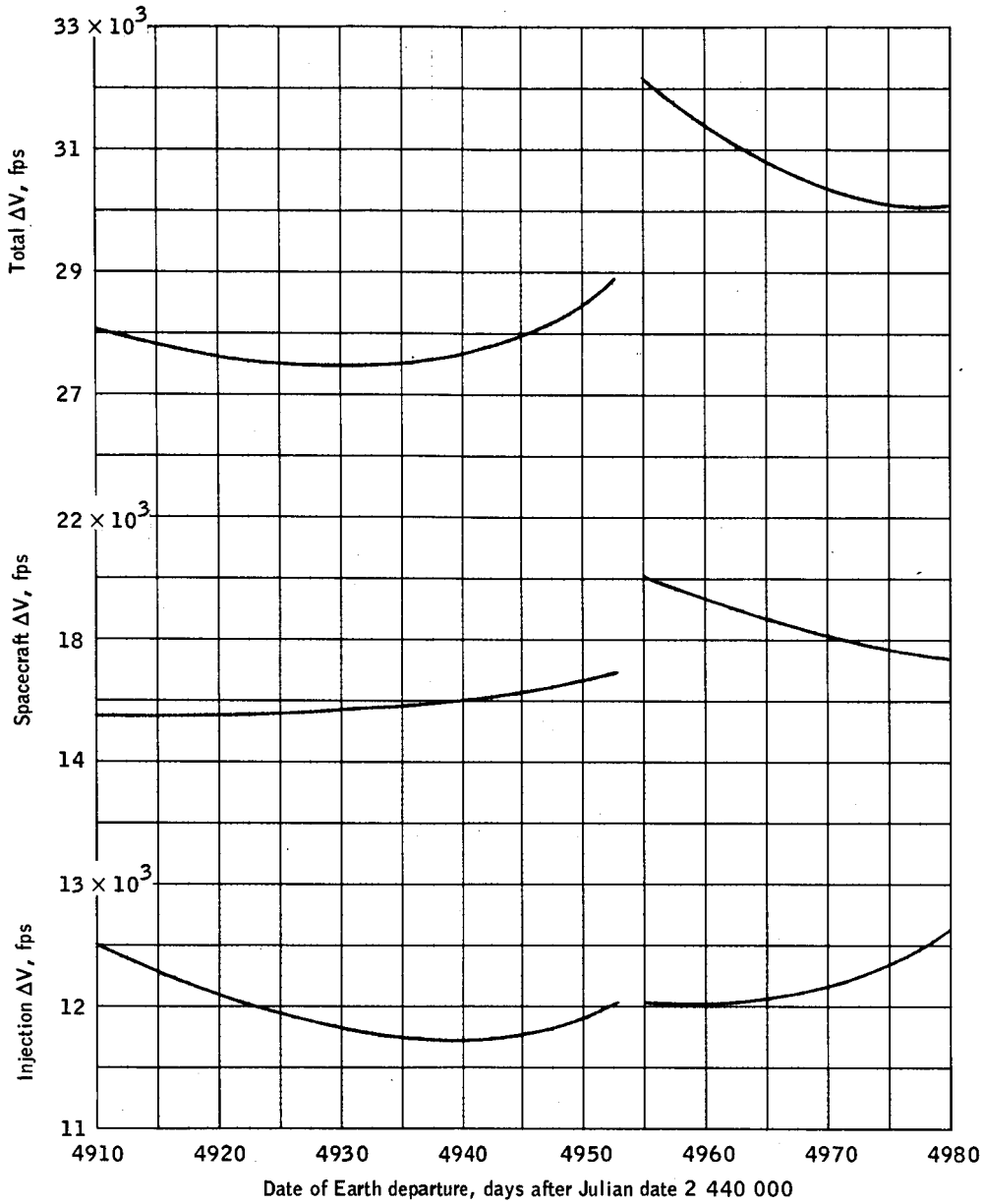
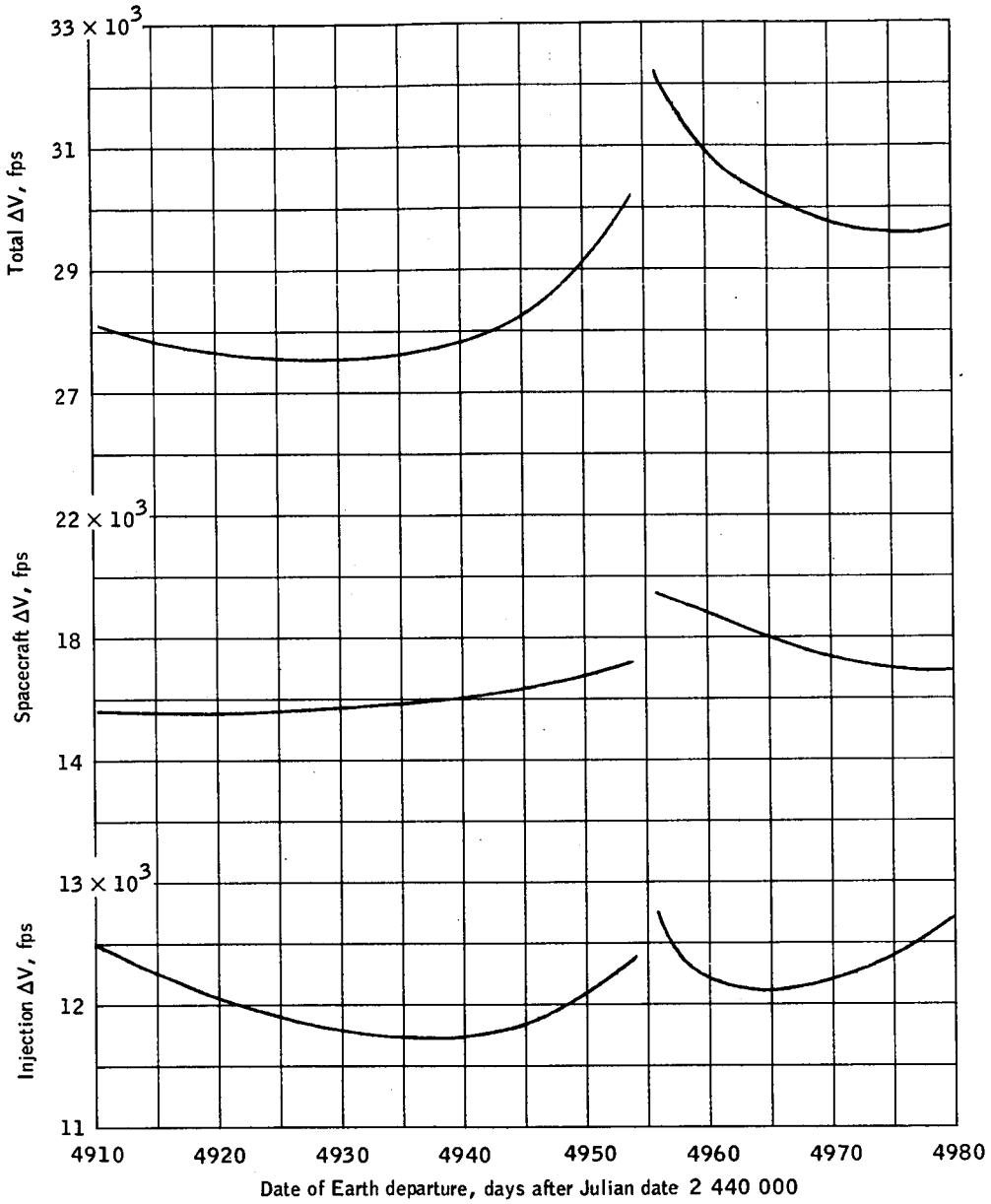


Figure 1.- Illustration of the 1981 Mars stopover/Venus swingby mission.



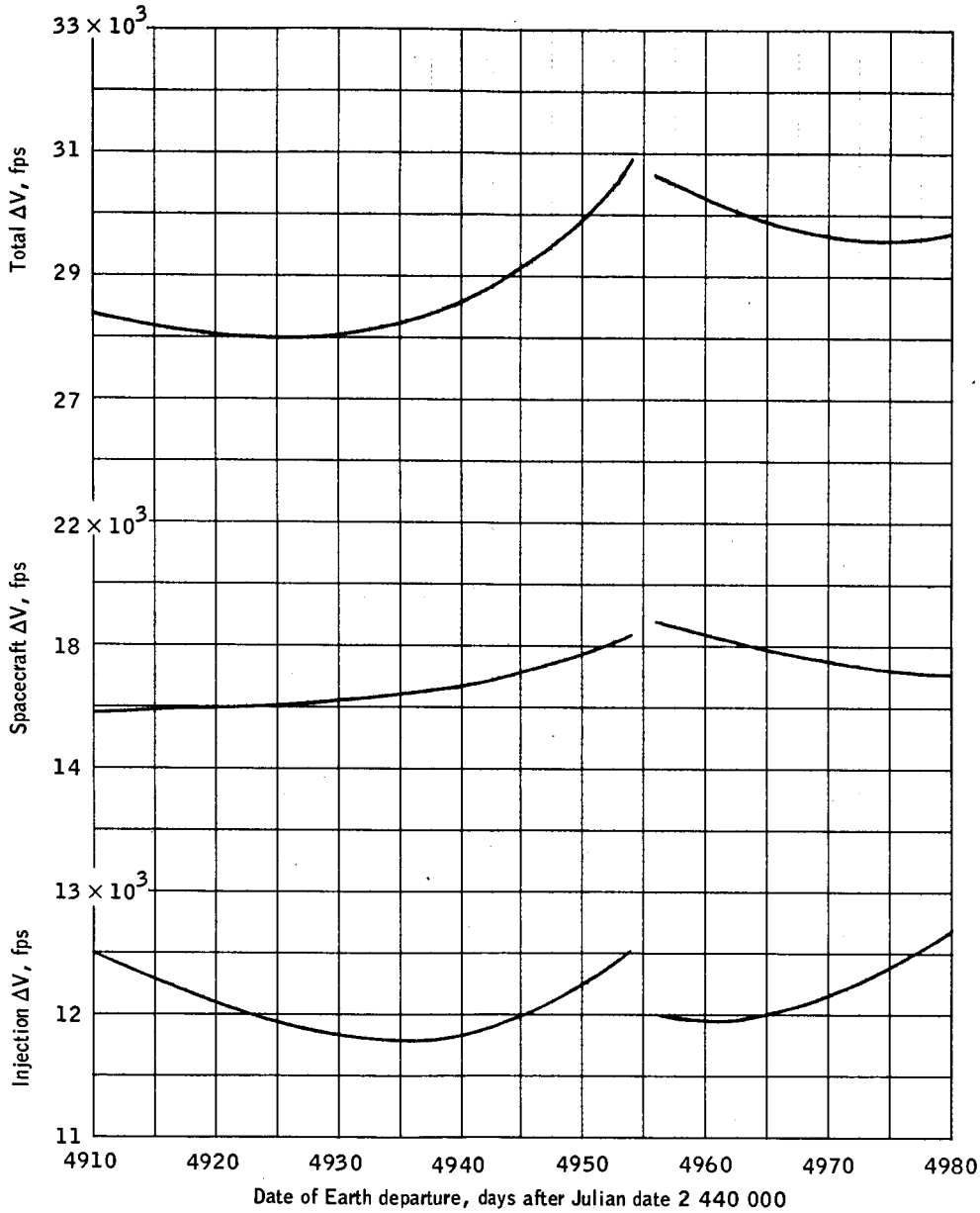
(a) 20-day stay.

Figure 2.- Mission velocity requirements.



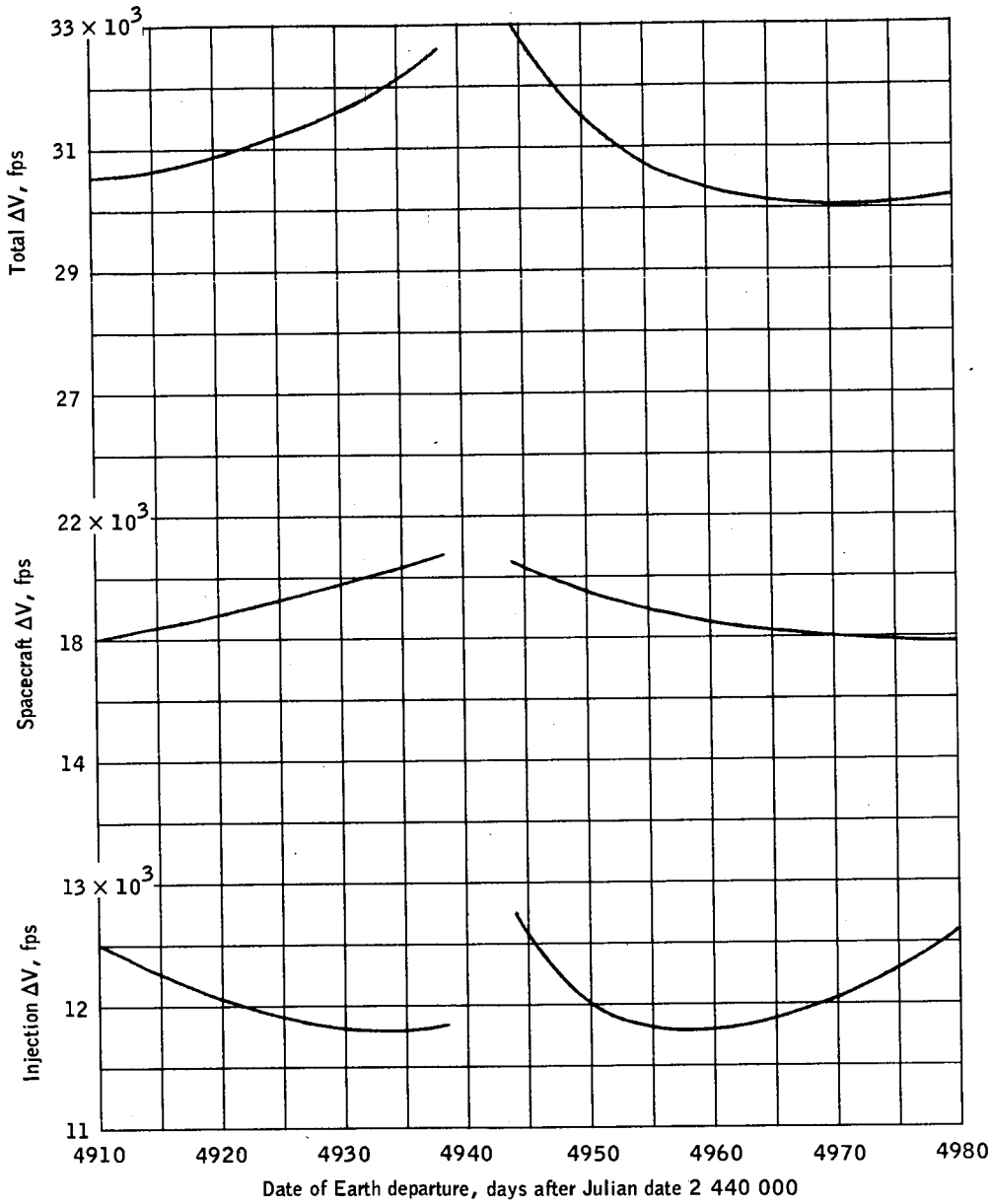
(b) 30-day stay.

Figure 2.- Continued.



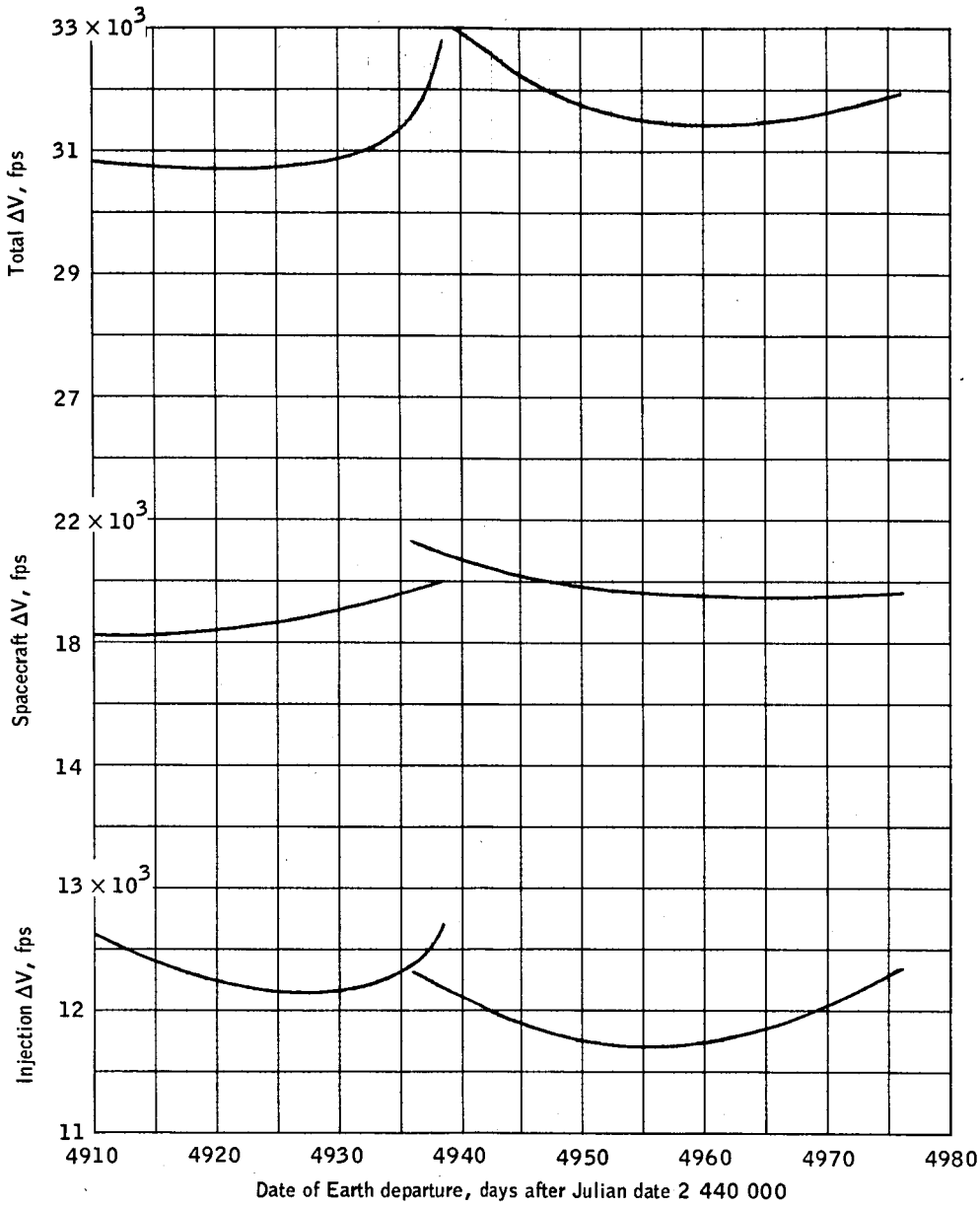
(c) 40-day stay.

Figure 2.- Continued.



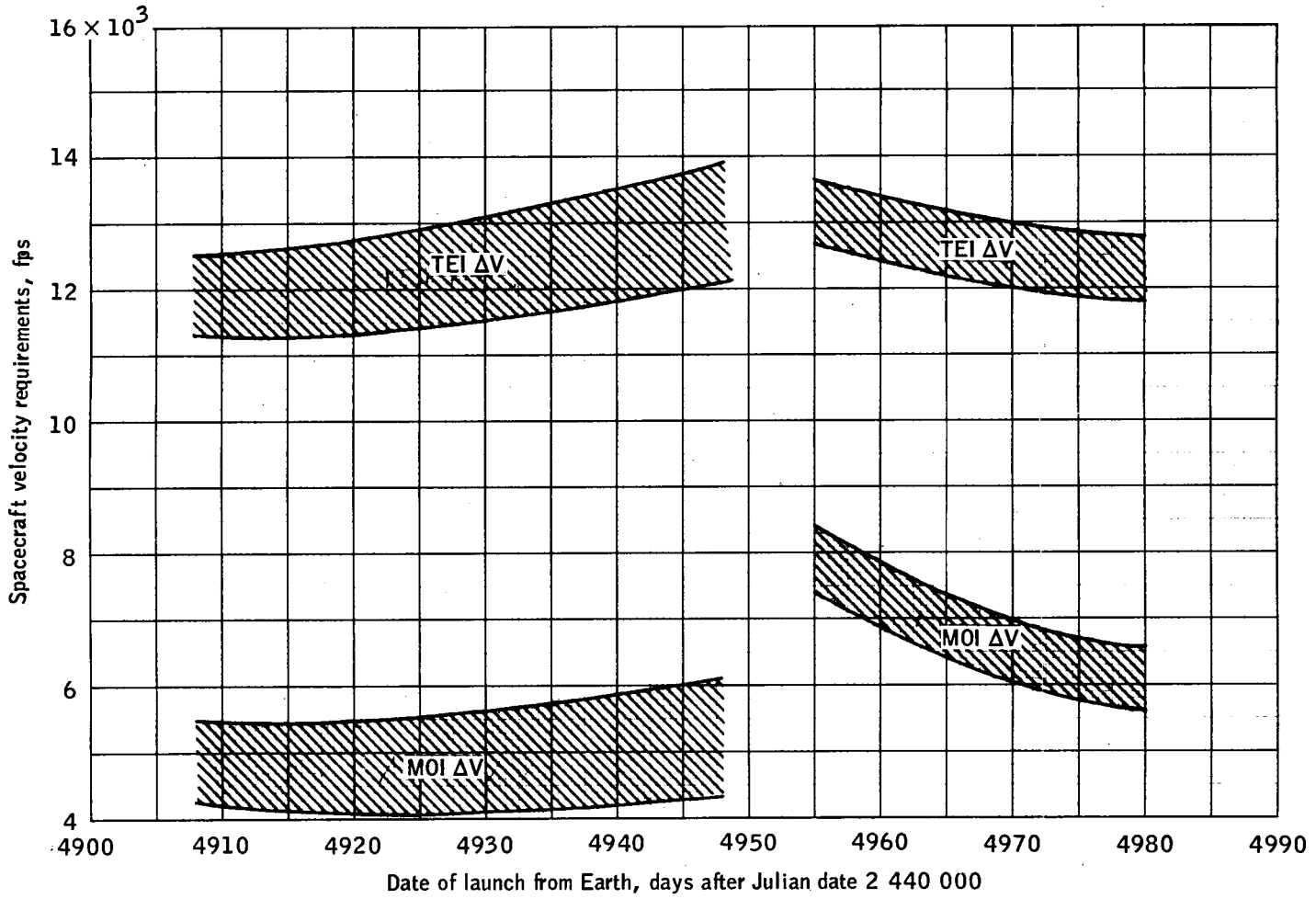
(d) 60-day stay.

Figure 2.- Continued.



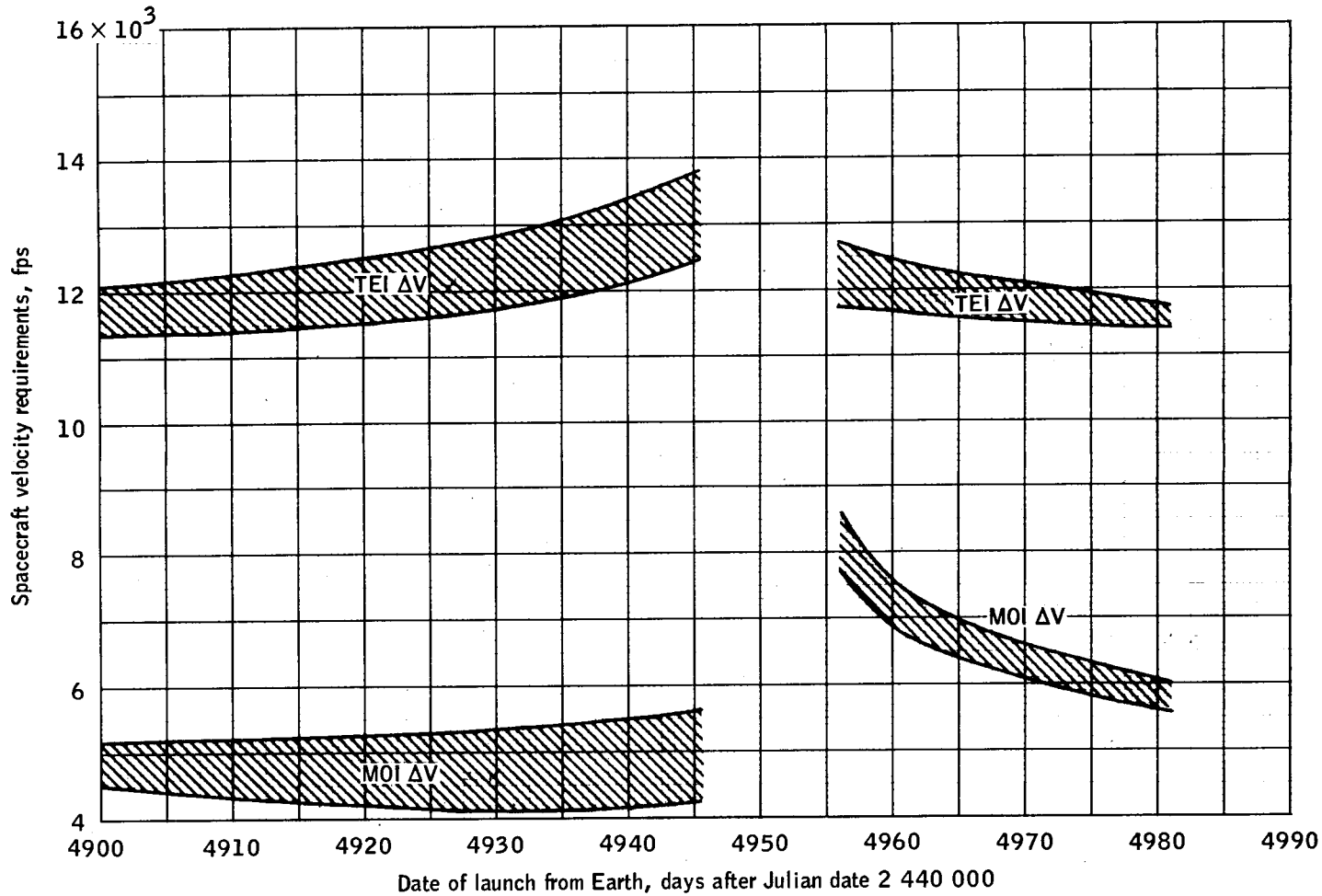
(e) 80-day stay.

Figure 2.- Concluded.



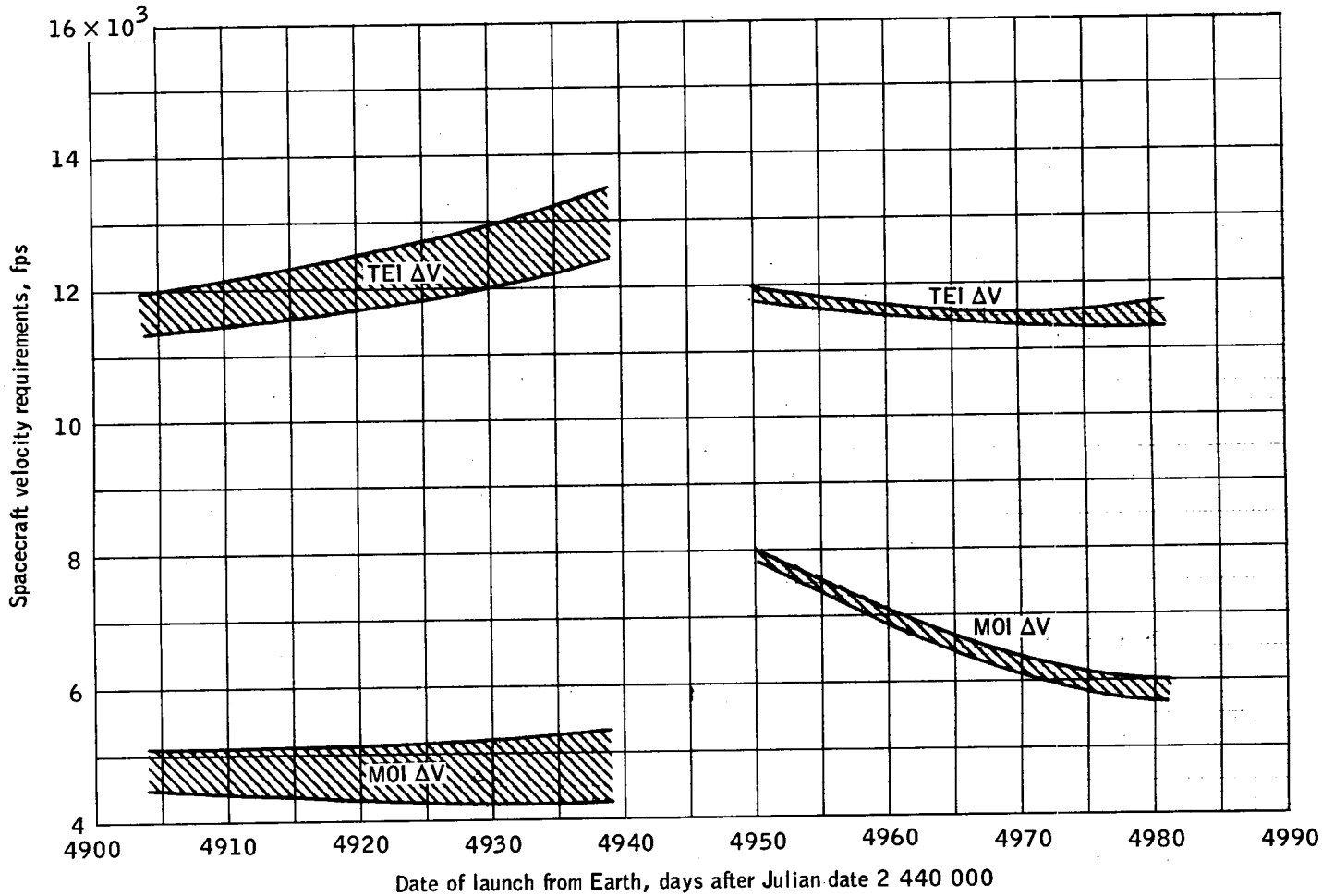
(a) 20-day stay Mars stopover/Venus swingby.

Figure 3.- Spacecraft velocity requirements.



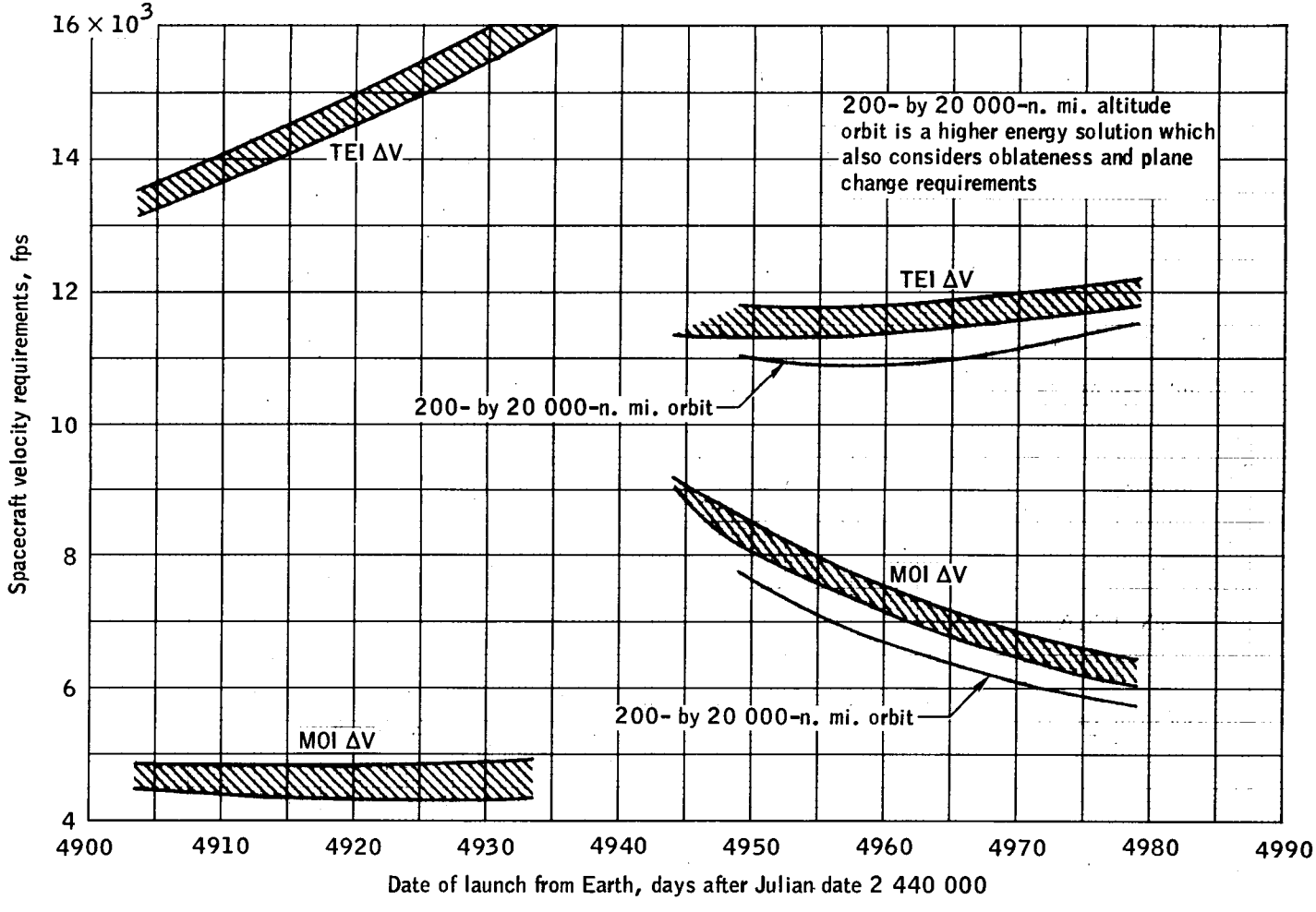
(b) 30-day stay Mars stopover/Venus swingby.

Figure 3.- Continued.



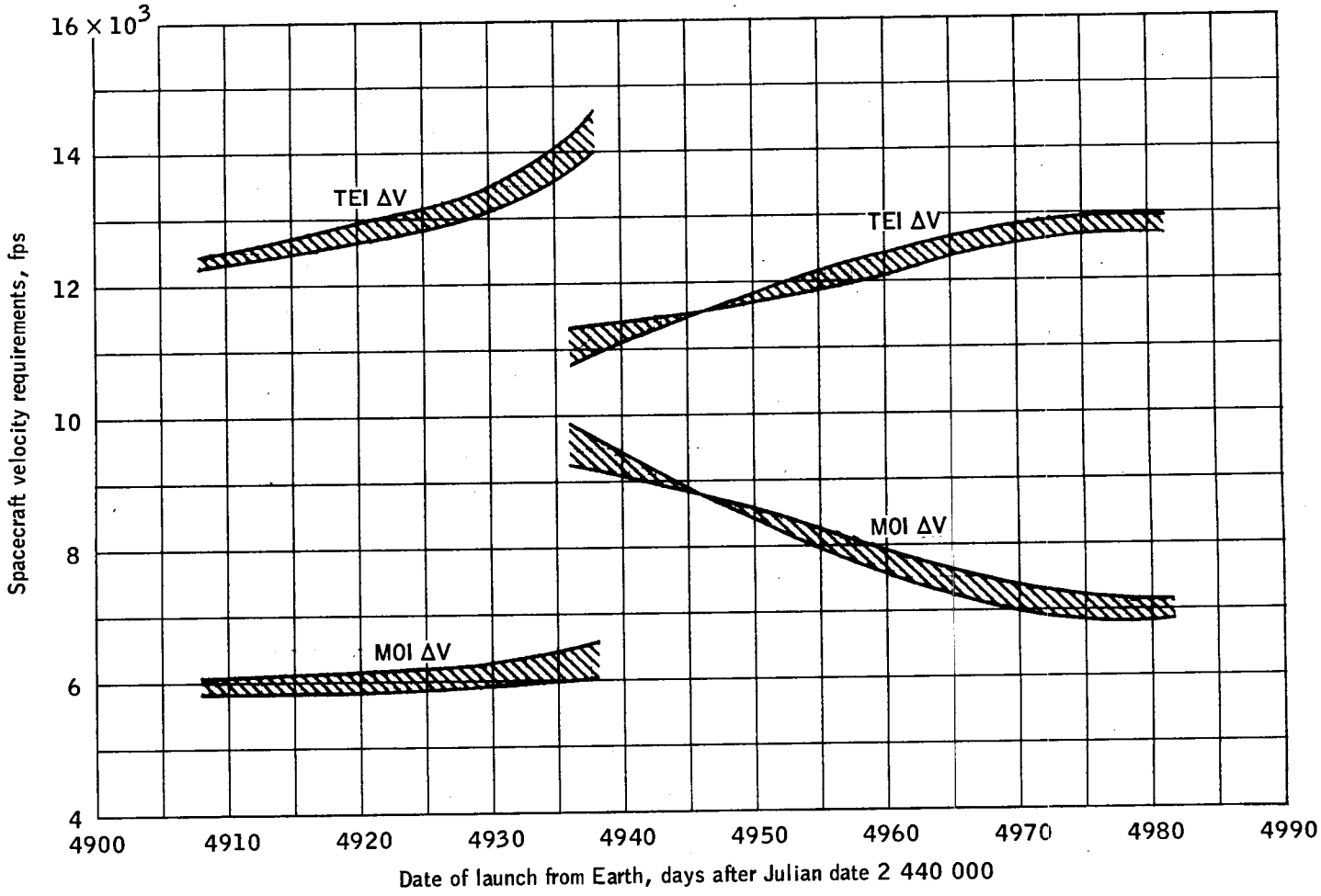
(c) 40-day stay Mars stopover/Venus swingby.

Figure 3.- Continued.



(d) 60-day stay Mars stopover/Venus swingby.

Figure 3.- Continued.



(e) 80-day stay Mars stopover/Venus swingby.

Figure 3.- Concluded.

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