(NASA-TM-86477) MARS EXPLORATION, VENUS SWINGBY AND CONJUNCTION CLASS MISSION MODES, TIME PERIOD 2000 TO 2045 (NASA) 82 p HC A05/MF A01 CSCL 03B

N85-11961

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G3/91 24707

# NASA Technical Memorandum

NASA TM-86477

# MARS EXPLORATION
# VENUS SWINGBY AND CONJUNCTION CLASS MISSION MODES
# TIME PERIOD 2000 TO 2045

By Archie C. Young, John A. Mulqueen, and James E. Skinner

Program Development

August 31, 1984

National Aeronautics and Space Administration
George C. Marshall Space Flight Center

MSFC - Form 3190 (Rev. May 1983)

TECHNICAL REPORT STANDARD TITLE PAGE

| | | |
|---|---|---|
| 1. REPORT NO. NASA TM-86477 | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
| 4. TITLE AND SUBTITLE Mars Exploration Venus Swingby and Conjunction Class Mission Modes Time Period 2000 to 2045 | | 5. REPORT DATE August 31, 1984 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) Archie C. Young, John A. Mulqueen, and James E. Skinner | | 8. PERFORMING ORGANIZATION REPORT # |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812 | | 10. WORK UNIT NO. |
| | | 11. CONTRACT OR GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546 | | 13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum |
| | | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

Prepared by Program Development Office.

16. ABSTRACT

Trajectory and mission requirement data is presented for Earth-Mars opposition class and conjunction class round trip stopover mission opportunities available during the time period year 2000 to year 2045. The opposition class mission employs the gravitational field of Venus to accelerate the space vehicle on either the outbound or inbound leg. The gravitational field of Venus was used to reduce the propulsion requirement associated with the opposition class mission. Representative space vehicle systems are sized to compare the initial mass required in low Earth orbit of one mission opportunity with another mission opportunity. The interplanetary space vehicle is made up of the spacecraft and the space vehicle acceleration system. The space vehicle acceleration system consists of three propulsion stages. The first propulsion stage performs the Earth escape maneuver, the second stage brakes the spacecraft and Earth braking stage into the Mars elliptical orbit and effects the escape maneuver from the Mars elliptical orbit. The third propulsion stage brakes the mission module into an elliptical orbit at Earth return. The interplanetary space vehicle was assumed to be assembled in and depart from the Space Station circular orbit.

| | |
|---|---|
| 17. KEY WORDS Mars Exploration Venus Swingby Conjunction Class Mission | 18. DISTRIBUTION STATEMENT Unclassified — Unlimited |

| | | | |
|---|---|---|---|
| 19. SECURITY CLASSIF. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. NO. OF PAGES | 22. PRICE |
| Unclassified | Unclassified | 81 | NTIS |

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

## ACKNOWLEDGMENTS

The authors acknowledge and appreciate the following contributicns to this work.

Mr. Robert E. Austin and Mr. Donald R. Saxton for initiating and providing guidelines in performing this work. Mr. Charles M. Akridge and Thomas C. French for their recommendations, discussions, and support in developing the data contained in this report. Mr. Bobby G. Brothers for determining the dimensions of the interplanetary space vehicle propulsion stages and Mr. Howard E. Lanier for implementing the interplanetary trajectory computer program on the VAX 11/780 computer.

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# TIME PERIOD 2000 TO 2045

## INTRODUCTION

This report presents information on performance, operation requirements and their sensitivity for the Venus swingby and conjunction class stopover missions to Mars. The time period considered to develop this information is year 2000 to 2045. Initial mass required in Earth orbit was determined for each launch opportunity associated with the two classes of missions. The Venus swingby mode allows a short stopover time, 60 days, at Mars and can be considered as a precursor mission for the long stopover time, up to 550 days, at Mars which occurs with the conjunction class missions.

A manned space station, to be built and serviced with the aid of the Space Shuttle, will open space to a limitless range of opportunities for explorations. Using the Space Station as a stepping stone, manned missions to Mars can be achieved during the 21st century. With the technology being developed today, the space industry could be mining large amounts of material, expanding our economic activities in space and bringing the benefits back to Earth. The data contained in this report can be used for NASA planning, research and advanced technology programs.

Direct trajectories to and from Mars for a roundtrip stopover mission, stay time up to 60 days, require very high propulsive energy at some of the departure and/or arrival planets. This type of mission is referred to as opposition class mission. A method used for reducing this energy requirement is the Venus swingby mode. A Venus swingby utilizes the gravitational field of Venus to either accelerate or decelerate the space vehicle as it passes by the planet. An accelerated effect is desired for an outbound Venus swingby enroute from Earth to Mars and a decelerated effect is desired for an inbound Venus swingby enroute from Mars to Earth. The conjunction class mission requires relatively low propulsive energy for all the powered maneuvers effected at the planets. This low energy requirement can be achieved by optimizing the stopover time at Mars so that near-Hohmann type transfers can be made on both the outbound and inbound legs.

## ASSUMPTIONS

The pertinent assumptions used in this study to develop the Mars mission opportunities and resultant requirements are given for the departure and capture orbit parameters, propulsion stage and planetary spacecraft elements. Figure 1 gives the assumptions for the Venus swingby mission mode and Figure 16 gives the assumptions for the conjunction class missions. The interplanetary space vehicle was assumed to be assembled in and depart from the 270 n.mi. altitude Space Station circular orbit. Mars capture and escape orbit was considered to be an elliptical orbit with a 24-hr period and periapsis altitude of 270 n.mi. The interplanetary mission module returns to an Earth elliptical orbit with a 24-hr period and a perigee altitude of 270 n.mi. The interplanetary spacecraft required velocity increments are achieved by three propulsion stages. The first propulsion stage effects the Earth escape maneuver, the second stage brakes the spacecraft and Earth braking stage into the Mars elliptical capture orbit and effects the escape maneuver from the Mars elliptical orbit. The third propulsion stage brakes the mission module into a 24-hr elliptical orbit at Earth return. Each of the three propulsion stages has a mass fraction ($\lambda$) of 0.90 and uses cryogenic $LOX/LH_2$ propellant with a specific impulse of 480 sec. The mass fraction of 0.90 is relatively low for the propulsive stage loading required for the Mars mission, but this low mass fraction was assumed in order to account for micro-meteoroid protection and propellant boiloff. Propellant boiloff was not considered to be a problem since insulation technology would result in insulations that would solve this problem.

Venus swingby, outbound, inbound, or double swingby, was used to lower the energy required for the Mars opposition class missions. The Venus closest approach distance was constrained to be equal to or greater than 0.1 planet radii (330 n.mi.).

For the conjunction class missions, type I (<180 deg) or type II (>180 deg) transfer trajectories were considered. The Mars stopover time was optimized to achieve minimum initial weight in Earth orbit.

The weight of the interplanetary spacecraft for the Venus swingby mission is as follows. Weight of the mission module is 83,000 lb and the probes weight is 42,000 lb. The Mars excursion module weight equals 95,000 lb. The interplanetary spacecraft weight for the conjunction class mission is as follows. Weight of the mission module is 117,000 lb, the Mars excursion module weighs the same as for the Venus swingby mission mode, and the pioneer Mars base weight is 57,000 lb.

## MISSION OPPORTUNITIES

Mission opportunities for standard direct flights to Mars and return will occur near the Earth-Mars opposition, and precede by 90 to 180 days the opposition dates which occur on the average every 26 months. Two general classes of direct roundtrip mission modes to Mars are available; they are (1) opposition class mode with short stopover time at Mars and (2) conjunction class mission mode with long stopover time at Mars.

Because of the eccentricity of Mars orbit, the mission trajectory profile changes from one opposition to the next. The cyclic pattern of mission profile variation repeats every 15 years or every 7 oppositions [1]. The relative positions of the Earth-Mars oppositions are indicated in Figure 2 for two periodic cycles of oppositions from year 2000 to 2031. The slight inclination of the Mars orbit with respect to the ecliptic plane causes an interplanetary transfer trajectory also to be inclined to the ecliptic, but this effect is small compared to the effect caused by the eccentricity. The relative position of Earth and Mars for an opposition class mission, stopover time at Mars approximately 60 days, causes the energy requirement to be excessive for the propulsive stages to perform a standard roundtrip Mars mission. One approach to reduce the required energy level for the opposition class mission is to use the gravity field of Venus either enroute to Mars for an outbound swingby or enroute to Earth for an inbound swingby. The cause of high energy required for a standard roundtrip mission is due to the following relative planetary motion. The flight time for a near-Hohmann outbound leg is such that, at Mars arrival, Earth is ahead of Mars in heliocentric longitude, i.e., Mars arrival occurs after opposition. This makes it impossible to employ a near-Hohmann transfer for the inbound leg; the required heliocentric transit angle must greatly exceed the Hohmann transfer angle of 180 deg. Thus, it is never possible to leave Earth on a minimum energy transfer outbound leg and arrive at Mars soon enough to leave Mars on a minimum energy inbound leg. The relative position of Earth at Mars arrival can be adjusted with a swingby of Venus enroute to Mars on an outbound leg or a swingby of Venus enroute to Earth on an inbound leg. The major advantage of making a swingby of Venus is that the hyperbolic encounter with the planet changes the velocity of the space vehicle relative to the Sun. The magnitude of the velocity change can be large enough to make a significant desirable change in the heliocentric trajectory. The high energy level required can be avoided in the conjunction class mission mode where near-Hohmann transfers can be used on both the outbound and inbound leg by adjusting the stay time at Mars appropriately.

The availability of a Venus swingby mode can be determined by the following facts [1]: (1) The space vehicle passes inside or near the orbit of Venus either on the outbound leg or on the inbound leg of a direct roundtrip mission to Mars. Figure 3 illustrates these conditions for an outbound leg and an inbound leg. (2) The gravity field of Venus is sufficiently powerful to significantly shape the interplanetary transfer trajectory in a desirable way. (3) The angular rate of Venus orbit is large compared to that of Mars, so that Venus is generally available either on the outbound leg or on the inbound leg.

The initial step in determining a Venus swingby trajectory profile for a given mission opportunity is the determination of the relative heliocentric position of the three planets, Venus, Earth, and Mars. A plot of the relative position of the three planets was developed to determine whether an inbound or an outbound Venus swingby was available near a given Earth-Mars opposition. A procedure which has proven useful is a continuous plot of the dates of conjunction (Earth-Venus Alignment), alignment of Venus-Mars, and opposition (Earth-Mars alignment) [4]. Figures 4, 5, and 6 give the plots of the planets continuous relative position for years 2000 to 2031. Considering the first outbound Venus swingby, a search is made for a region in which the Earth-Venus conjunction is followed, approximately 200 days later, by a Venus-Mars alignment which, in turn, is followed 200 days later by an Earth-Mars opposition. Looking at Figure 4, it can be predicted that an inbound swingby associated with the 2001 opposition would prove desirable because of the proper relative position of the planets alignments. For the 2003 opposition, the time phasing between appropriate planetary position is almost equal for the outbound and inbound swingby, but successive events are separated by something less than 200 days. Thus, Venus may be available both for the outbound and inbound leg. However, the usefulness of the double swingby must be determined by detailed trajectory analysis. The symmetrical alignment of the planets about an opposition occurs every third opposition. Based on an analysis of the planetary positions, Venus swingby should be available as shown in Figures 4, 5, and 6. Having narrowed the area down where an opportunity exists, the problem is to locate the precise launch and arrival dates which will allow an economic transfer to Venus, followed by an economic transfer to Mars.

## MISSION CHARACTERISTICS

Mission characteristic data has been developed for launch opportunities during the years 2000 to 2031 for opposition class missions via Venus swingby and for launch opportunities during the years 2030 to 2045 for conjunction class missions.

Figure 7 presents the Venus swingby, outbound or inbound, employed for each of the opposition class missions during the time period. Also given in Figure 7 is the year and month of the launch window for Earth departure and the total mission time associated with each opportunity. The shortest total trip time experienced is 558 days for the September 2007 launch opportunity employing an inbound Venus swingby; this launch opportunity precedes the December 2007 Earth-Mars opposition. The longest total trip time required during the time period considered is 737 days for the March 2028 launch opportunity employing a double Venus swingby, i.e., swingby Venus on both the outbound and inbound leg.

Table 1 contains the mission characteristics for the Venus swingby profiles. Information is given for the Julian date (J.D.) and the speed, hyperbolic excess speed given in units of Earth mean orbital speed (EMOS), at each one of the planets. The Earth-Mars opposition date is also given. The Earth launch window date precedes the Earth-Mars opposition date from 3 to 6 months for the inbound Venus swingby mission mode. For the outbound Venus swingby mission mode, the Earth launch window occurs 12 to 19 months before the Earth-Mars opposition. The minimum value for hyperbolic excess speeds at Earth and Mars is approximately 0.10 EMOS for near-Hohmann type transfer trajectories. From Table 1, it can be seen that an economical propulsion energy requirement would be associated with the 2001 inbound swingby opportunity since the speeds on the outbound leg are near a minimum value at Earth departure and Mars arrival. The speed at Mars departure, however, is slightly high with a value of 0.2050 EMOS. The Earth arrival speed of 0.1418 EMOS is relatively low for an opposition class mission.

Mars conjunction class stopover mission summary data is given in Figure 19. The summary data contains dates of Earth-Mars opposition, Earth launch dates, stopover times at Mars, and total mission time. The minimum total mission time is 950 days for the April 2033 launch opportunity; the optimum stopover time at Mars is 550 days for this opportunity. The maximum total mission time is 1004 days for the June 2035 launch opportunity; the optimum stopover time at Mars for this opportunity is 530 days.

Table 22 gives the mission characteristics for the opportunities during the time period year 2030 to 2045. The Earth launch date precedes the Earth-Mars opposition by three to four months which can be seen by comparing the Earth-Mars opposition dates with the leave Earth dates. Most of the hyperbolic excess speeds at the planets are close to a minimum value of approximately 0.10 EMOS. The shortest trip time occurring during this time period is 200 days for the outbound and inbound legs of the year 2033 opportunity. The longest trip time is 356 days for the outbound leg of the year 2037 opportunity. The data contained in this table should cover the envelope of values for the conjunction class stopover mission since it covers one complete synodic period of Earth and Mars.

## INTERPLANETARY SPACE VEHICLE

The interplanetary space vehicle is made up of the spacecraft and the space acceleration system. The interplanetary space vehicle was assumed to be assembled in and depart from the Space Station circular orbit.

The spacecraft acceleration system is made up of three propulsion stages. The first propulsion stage effects the Earth escape maneuver, the second stage brakes the spacecraft and Earth braking stage into the Mars elliptical capture orbit and effects the escape maneuver from the Mars elliptical orbit. The third propulsion stage brakes the mission module into a 24-hr elliptical orbit at Earth return.

The total weight required in the Space Station orbit for the interplanetary space vehicle has been determined for the Mars mission employing the Venus swingby mission mode and the conjunction class mission. The weight in the Space Station orbit can be compared from one opposition opportunity to another for the two classes of Mars missions considered.

The time period considered for the Venus swingby mission mode is years 2000 to 2031. The conjunction class mission mode launch opportunity considered is during the time period year 2030 to 2045. The Venus swingby mode has a stopover time at Mars of 60 days and could be used as a precursor mission for the conjunction class missions which have stopover times at Mars of up to 550 days.

The spacecraft is made up of a mission module (the living and work area for the crew), a Mars excursion module, and experimenter accommodations. A number of unmanned probes and orbiters are included to complement the manned activity. Major elements of the spacecraft are interconnected by pressurized tunnels allowing shirt-sleeve passage between them. A minimum crew of 6 is necessary to operate the space systems and perform a reasonable scientific exploration program.

The mission module is the control center for the entire space vehicle and provides a habitable living, operations, and experiment center for the mission crew. The basic mission module provides the environmental control, power system radiators, and the communications system for the most stringent mission. Provisions are made for incremental loading of meteoroid shielding, expendables, and system spares as necessary. The mission module contains all the subsystems necessary for life support, command and control functions, experiments analysis, and information transfer during the course of the mission. It is pressurized to a 7-psia ($48.23(10^3)$ Newton/m$^2$) oxygen-nitrogen atmosphere, providing a viable shirtsleeve environment for the crew.

The Mars excursion module transports three of the crew members and equipment from the space vehicle in Mars orbit to the Mars surface. It provides living quarters and a laboratory during the 30-day stay on the Mars surface; then transports the crew, scientific data, and samples back to the orbiting vehicle.

Two to five days are spent surveying the planet for landing sites, performing orbital experiments (including deployment of probes), and preparing the Mars excursion module for operation. Three of the six-man crew then descend to the planet surface in the Mars excursion module. After aeroballistic entry, the Mars excursion module is slowed by a ballute retardation system, and, using propulsion descends to the surface. After a 30-day stay on the planet, the ascent module of the Mars excursion module brings the three men and scientific payload back to the space vehicle. During planetary operations, the men in the space vehicle continue the orbital experimentation, monitor the planetary operations. and maintain the space vehicle operations. The ascent vehicle is discarded in the planet orbit after the crew has transferred to the mission module [5]. Figure 8 shows the spacecraft used in the Venus swingby mission mode.

Interplanetary trajectory parameters (launch dates, trip times, heliocentric transfer angles, etc.) have been determined which result in a minimum total initial weight to be assembled in the Space Station's orbit. The three variable size propulsion stages were sized using general scaling weight laws which are dependent upon propellant loading and whose coefficients are input to the interplanetary trajectory shaping program. Up to five major interplanetary maneuvers can be optimized.

The propulsion stage weights for each opposition class mission opportunity during year 2000 to 2031 are given in Figures 9 and 10. The stage weight required for the first propulsion stage ranges from 870,000 to 2,720,000 lb. Propulsion stage weight required for the second stage ranges from 353,000 to 1,094,000 lb, and the Earth braking propulsion stage, stage three, weight ranges from 24,000 to 102,000 lb.

The initial mass required in low Earth orbit for each mission opportunity is given in Figures 11 and 12. The initial mass required ranges from 1,470,000 to 4,065,000 lb. The initial mass in Earth orbit can be equated to cost and used to determine the favorable mission opportunities. Double swingbys are available every third opportunity and are generally characterized by having a higher energy requirement than the other opportunities. However, there is an exception for the opportunity in year 2007 where the energy requirement is greater than the double swingby year 2010. Generally there should be two favorable opportunities for every unfavorable, high-energy requirement opportunity.

The interplanetary space vehicle configuration is given in Figure 13 for the opposition class mission via Venus swingby for the year 2025 opposition opportunity. The spacecraft length and information for each of the propulsion stages is given. The interplanetary space vehicle total length is 276.5 ft. Also given is the propellant loading for each of the propulsion stages and total initial weight required in the Space Station orbit. The total initial weight required for this mission opportunity is 2.08 million pounds.

Propulsion stage and interplanetary weight data for the Mars conjunction class stopover mission is given in Figures 21 and 22. The propulsion stage weights for each conjunction class mission during year 2030 to 2045 are given in Figure 21. The stage weight for the first propulsion stage ranges from 600,000 to 725,000 lb. Propulsion stage weight required for the second stage ranges from 112,000 to 169,000 lb. The Earth braking stage, stage three, weight ranges from 25,000 to 36,500 lb. The initial mass required in low Earth orbit for each mission opportunity is given in Figure 22. The mass requirement ranges from 1,010,000 to 1,170,000 lb.

The interplanetary space vehicle sized to perform the conjunction class mission for the year 2031 opposition opportunity is given in Figure 23. The total vehicle length is 211.5 ft for the three propulsion stages plus the spacecraft. The propellant loadings are given for each of the propulsion stages. The total weight required in low Earth orbit is 1.17 million pounds.

## INTERPLANETARY TRAJECTORY CALCULATIONS

The computer program used in this work to compute the interplanetary trajectory characteristics is based on the restricted two-body (patched conic) approximation of the interplanetary space vehicle trajectory. While the vehicle is within the sphere of influence of Venus, the swingby planet, it is assumed to be on a free-flight hyperbolic trajectory about Venus, and gravitational effects of all other bodies are neglected. There is no change of energy with respect to the swingby planet, Venus. Conservation of energy requires that the magnitude of the vehicle's velocity, relative to Venus, as it leaves the sphere of influence of Venus must equal to the magnitude of its velocity as it enters the sphere of influence approaching Venus. If the required angle of deflection, bend angle, at Venus is too large to be achieved by constraining the periapsis altitude to one-tenth of the planet radii, a propulsive maneuver is effected in conjunction with the Venus gravity field to give the required bend angle.

Because of the relative positions of Earth, Venus and Mars, a compromise transfer profile has to be made for the opposition class mission mode, over a true optimum Hohmann transfer on the outbound and inbound legs. The pertinent trajectory parameters for each of the launch opportunities during year 2000 and 2031 are given in Tables 2 through 18. Description of each of the parameters is given in the Appendix. The hyperbolic excess velocity at each of the planets is defined in terms of $C_3$, right ascension and declination. The heliocentric trajectory inclination relative to the ecliptic plane, semi-major axis, and eccentricity are also given in the tables.

Independent optimization of each leg is possible when the conjunction class roundtrip missions are considered. The outbound leg takes place near one opposition, and by adjusting the stopover time at Mars appropriately, the inbound leg will take place near the following opposition. Examination of single leg trajectory data [2] indicates that if the outbound and inbound legs of a roundtrip mission could be optimized separately, then departure and arrival hyperbolic excess speeds at both Earth and Mars of less than 0.10 to 0.15 EMOS (Earth Mean Orbital Speed of 97,700 ft/sec) could be attained. The total mission time for conjunction class missions is greater than the mission time of the Venus swingby opposition class mission; 950 to 1004 days, for conjunction class compared to 558 to 737 days for Venus swingby. Tables 23 through 29 give the trajectory data for the conjunction class missions for opportunities occurring during the years 2030 through 2045.

## REPRESENTATIVE MISSION PROFILES

Representative mission profiles are given for Venus swingby and conjunction class mission modes. The Venus swingby is used for the opposition class missions with short stopover times at Mars to reduce the total propulsive energy required to perform the mission. The conjunction class mission mode can optimize the stopover time at Mars in order to employ minimum energy trajectories for both the outbound and inbound legs.

Figure 14 illustrates mission profiles for the inbound Venus swingby associated with the year 2014 opposition opportunity and outbound Venus swingby for the year 2025 opposition opportunity. Both Venus swingby missions have a 60-day stopover time at Mars. On the inbound Venus swingby mission profile, the heliocentric transit angle of the Earth to Mars outbound leg is slightly greater than 180 deg; because of the higher average angular rate of Earth orbit, Earth is about 45 deg ahead of Mars at Mars arrival. This angular position of Earth relative to Mars necessitates a large transfer angle on the inbound leg with perihelion occurring inside Venus orbit in order to attain a sufficiently large angular rate to catch up with Earth. Utilizing the swingby of Venus on the inbound leg permits a trajectory with the high angular rate needed to overtake Earth and results in near-tangential trajectory conditions for departure from Mars and arrival at Earth. The near-tangential mission profile associated with a Venus swingby reduces the propulsive energy required compared to a standard Mars opposition class mission. The total mission time for the year 2014 opposition opportunity is 634 days. Detailed characteristics for this mission are given in Tables 1 and 9.

The year 2025 outbound Venus swingby has essentially the same desirable characteristics as the favorable inbound swingby. The outbound swingby is characterized by a heliocentric transfer angle between Earth and Venus of over 180 deg; with a transfer angle between Venus and Mars of less than 180 deg. The total angle is slightly over 360 deg. Of paramount importance is the fact that the average angular rate of the outbound trajectory is much greater than that of Earth in its orbit. Thus, Earth is far behind Mars at Mars arrival, i.e., Mars arrival occurs much sooner than opposition. This situation permits, as shown, a near-Hohmann Mars-Earth trajectory to be utilized on the inbound leg. The total mission time for the year 2025 outbound Venus swingby opposition opportunity is 614 days. Detailed characteristics for this mission are given in Tables 1 and 14. The characteristics of the outbound and inbound Venus swingby trajectories will yield lower required initial weight in low Earth orbit to perform the mission.

The mission profile for the conjunction class mission associated with the year 2031 opposition opportunity is given in Figure 24. Earth launch date occurs on December 25, 2030 and the outbound trajectory to Mars has a trip time of 282 days; arriving at Mars on October 3, 2031. Stopover time at Mars, for year 2031 opposition opportunity is 500 days; this length of stopover time allows for a near-Hohmann type trajectory on the return leg to Earth. Mars departure date for the Earth return leg is February 14, 2033 and the return trip time to Earth is 216 days; arriving back at Earth September 18, 2033. The total mission time for the year 2031 opposition opportunity is 998 days. Minimum energy trajectories were used both on the outbound and inbound leg. Detailed characteristics of this mission are given in Tables 22 and 23.

## CONCLUSION

Optimum transfers for opposition class missions to Mars via Venus swingby have been computed for the attractive launch and arrival dates between years 2000 and 2031. Also optimum transfer for conjunction class missions to Mars have been completed for the attractive opportunities between years 2030 and 2045.

It is possible to employ an outbound or inbound Venus swingby for every Earth-Mars opposition; oppositions occur approximately every 26 months. Venus swingby permits the heliocentric transfer trajectory to be nearly tangential relative to Earth and Mars orbit upon planet departure and arrival; thus reducing the required propulsive maneuver energy requirement. Two out of every three mission opportunities to Mars should be favorable when employing the Venus swingby mode. The mission time is increased from 20 to 50 percent employing the Venus swingby mode over the direct flights to Mars.

Summary results obtained for the Venus swingby mission are presented in Figure 15. The initial mass required in low Earth orbit over the 31-year time period ranges from 1.47 to 4.1 million pounds. If the unfavorable opportunities are disregarded, the initial mass required would not exceed 3.0 million pounds. Stage weight required for the Earth escape stage, first stage, ranges from 870,000 to 2,720,000 lb. The first stage weight is approximately 2-1/2 times the weight of the second stage. Mission duration for the Venus swingby mode ranges from 558 to 737 days.

The short stopover time, approximately 60 days, at Mars associated with the opposition class mission may be extended to over 100 days by utilizing Venus swingby on both the outbound and inbound leg during the favorable opportunities. It may also be possible to launch one vehicle to Mars via Venus swingby and have it arrive at Mars just prior to launching a second vehicle which proceeds directly to Mars. The two vehicles could rendezvous at Mars and still have time for an economical return to Earth utilizing a Venus swingby. Other combinations are feasible which utilize this unique flexibility.

Optimum roundtrip trajectories for the conjunction class missions to Mars and return can be achieved by adjusting the stopover time at Mars. Near-Hohmann type trajectories can be employed both on the outbound and inbound leg with the conjunction class mission. Data has been developed for one Earth-Mars synodic period between years 2030 and 2045 which consists of seven launch opportunities associated with the oppositions occurring during this time period. The minimum and maximum envelop requirement for any other opportunity will be represented by the data covered during this synodic period.

Summary results of work completed on the conjunction class mission is presented in Figure 25. Mission opportunity for the conjunction class mission occurs approximately every 26 months. Initial mass required in low Earth orbit ranges from 1.01 to 1.17 million pounds. The escape stage, the first stage, weight minimum and maximum is 600,000 and 725,000 lb, respectively. The first stage weight is about four times the weight of the Mars braking and escape stage, the second stage. The variation in total mission time ranges from 950 to 1004 days. Stopover time at Mars varies from 340 to 550 days; the shorter stopover time is associated with longer outbound and inbound leg flight time. Earth departure energy, $C_3$, varies from 8.9 to 16.2 $km^2/sec^2$ across the 15 years considered.

Requirements for the conjunction class mission can be extrapolated for opportunities occurring before or after the time period years 2030 to 2045 since the requirements are approximately repetitive every seven opportunities. For example, the requirements for the year 2029 conjunction class opportunity should be similar to the year 2044 opportunity requirements. Figures 2 and 17 give information when opportunities occur before or after the year 2030 to 2045 time period.

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TIME PERIOD OF CONSIDERATION: YEAR 2000 TO 2031

**PLANET DEPARTURE AND CAPTURE ORBIT PARAMETERS**

| | |
|---|---|
| EARTH DEPARTURE | CIRCULAR ORBIT ALTITUDE = 270 N. MI |
| MARS CAPTURE | 24 HR ELLIPTIC ORBIT PERIAPSIS ALTITUDE = 270 N. MI |
| MARS ESCAPE | 24 HR ELLIPTIC ORBIT PERIAPSIS ALTITUDE = 270 N. MI |
| EARTH CAPTURE | 24 HR ELLIPTIC ORBIT PERIAPSIS ALTITUDE = 270 N. MI |

**HELIOCENTRIC PROFILE**

VENUS SWINGBY MODE (OUTBOUND, INBOUND OR DOUBLE SWINGBY)

VENUS MINIMUM CLOSET APPROACH EQUAL 0.1 PLANET RADII (330 N. MI)

**INTERPLANETARY SPACE VEHICLE**

| | | |
|---|---|---|
| SPACECRAFT: | MISSION MODULE WEIGHT | = 83,000 LBS |
| | MARS EXECURSION MODULE WEIGHT | = 95,000 LBS |
| | PROBES WEIGHT | = 42,000 LBS |

| PROPULSION STAGES | FIRST STAGE | SECOND STAGE | THIRD STAGE |
|---|---|---|---|
| MASS FRACTION ($\lambda$) | 0.90 | 0.90 | 0.90 |
| $I_{SP}$ (SEC) | 480 | 480 | 480 |
| PROPELLANT | $LOX/LH_2$ | $LOX/LH_2$ | $LOX/LH_2$ |

Figure 1. Study assumptions for Venus swingby mode.

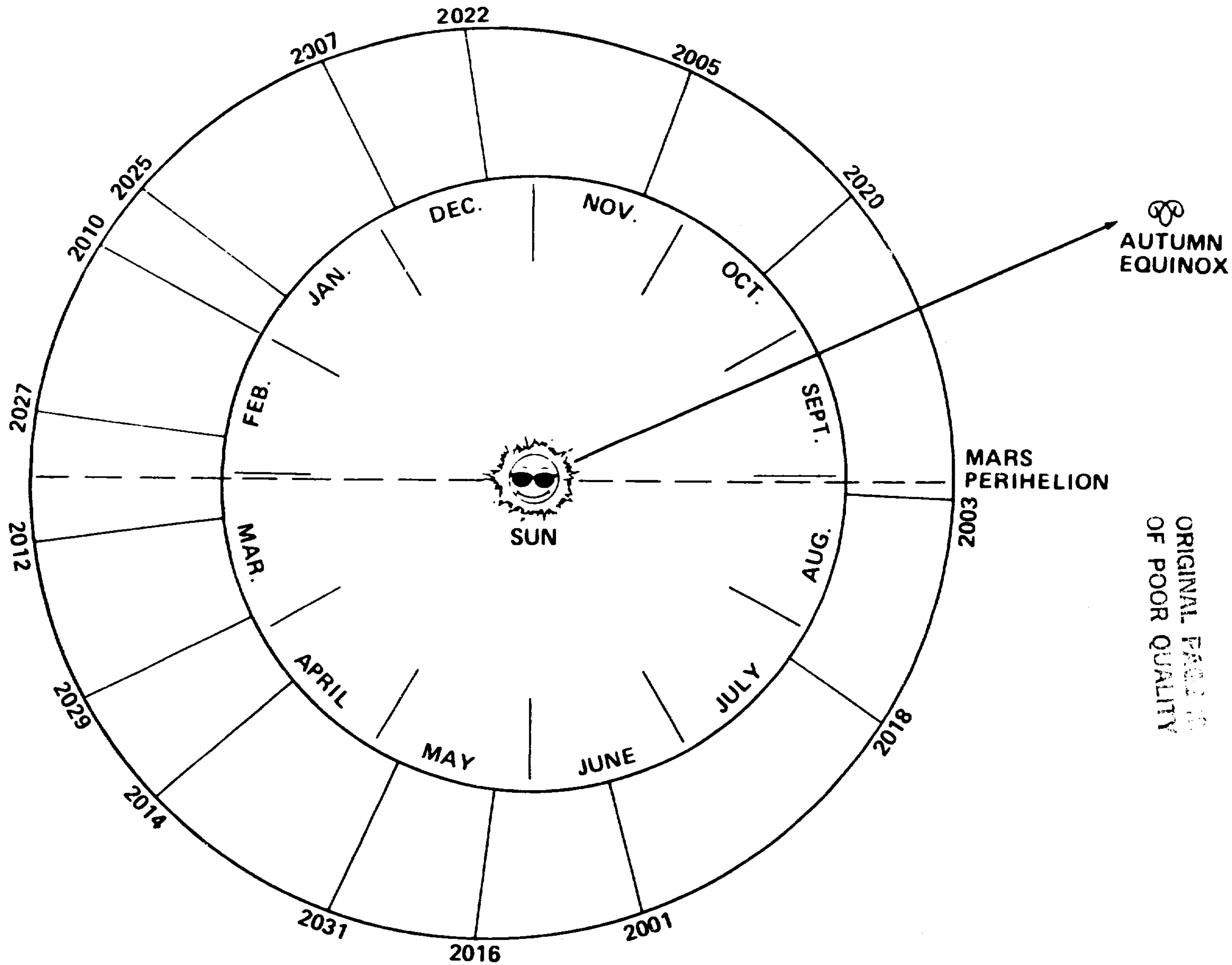





Figure 2. Earth-Mars opposition year 2000 to 2031 time period.

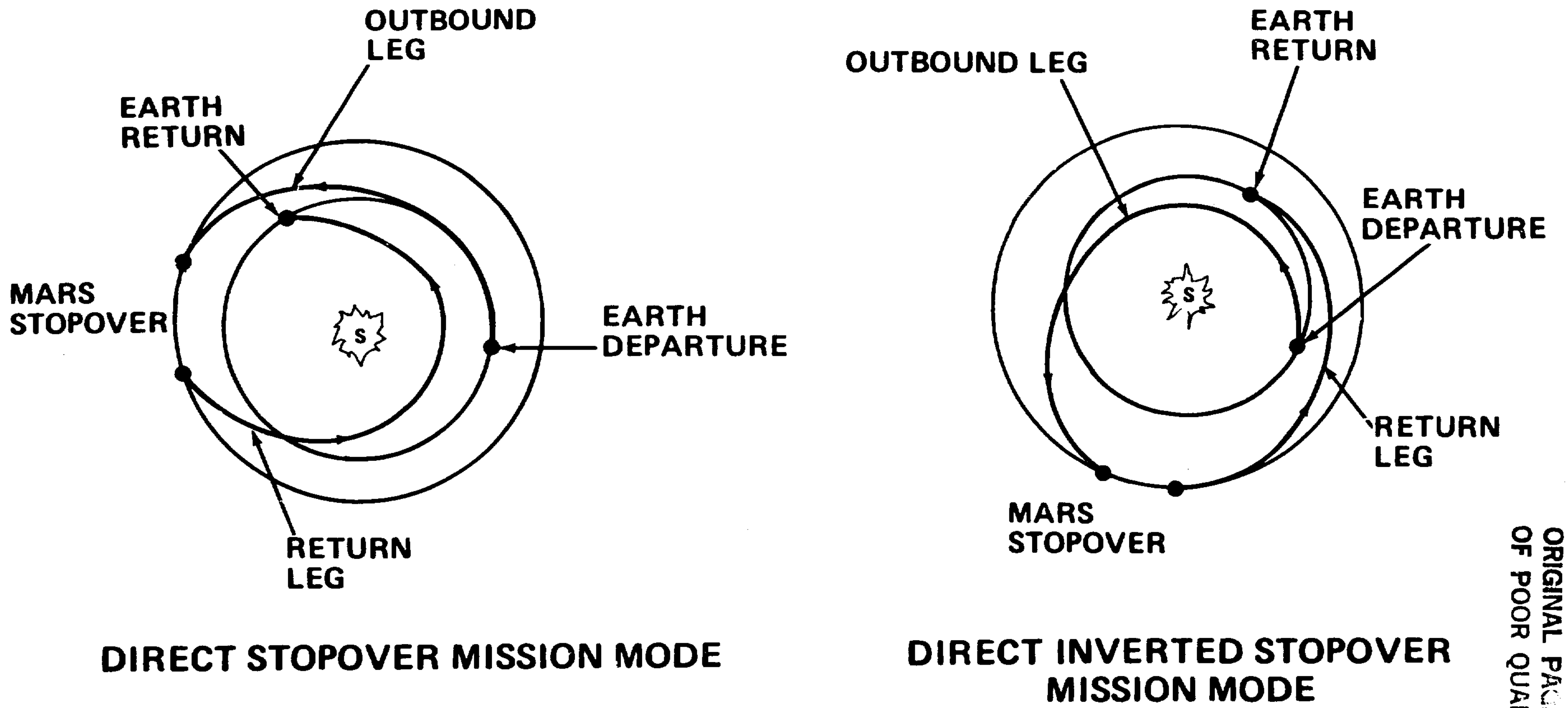



Figure 3. Direct stopover mission to Mars, example profile for opposition class stopover mission.

AVAILABILITY OF SWINGBYS

| MISSION | YEAR* OF EARTH–MARS OPPOSITION 1999 | 2001 | 2003 | 2005 | 2007 |
|---|---|---|---|---|---|
| OUTBOUND SWINGBY | YES | NO | MAYBE | YES | NO |
| INBOUND SWINGBY | NO | YES | MAYBE | NO | YES |

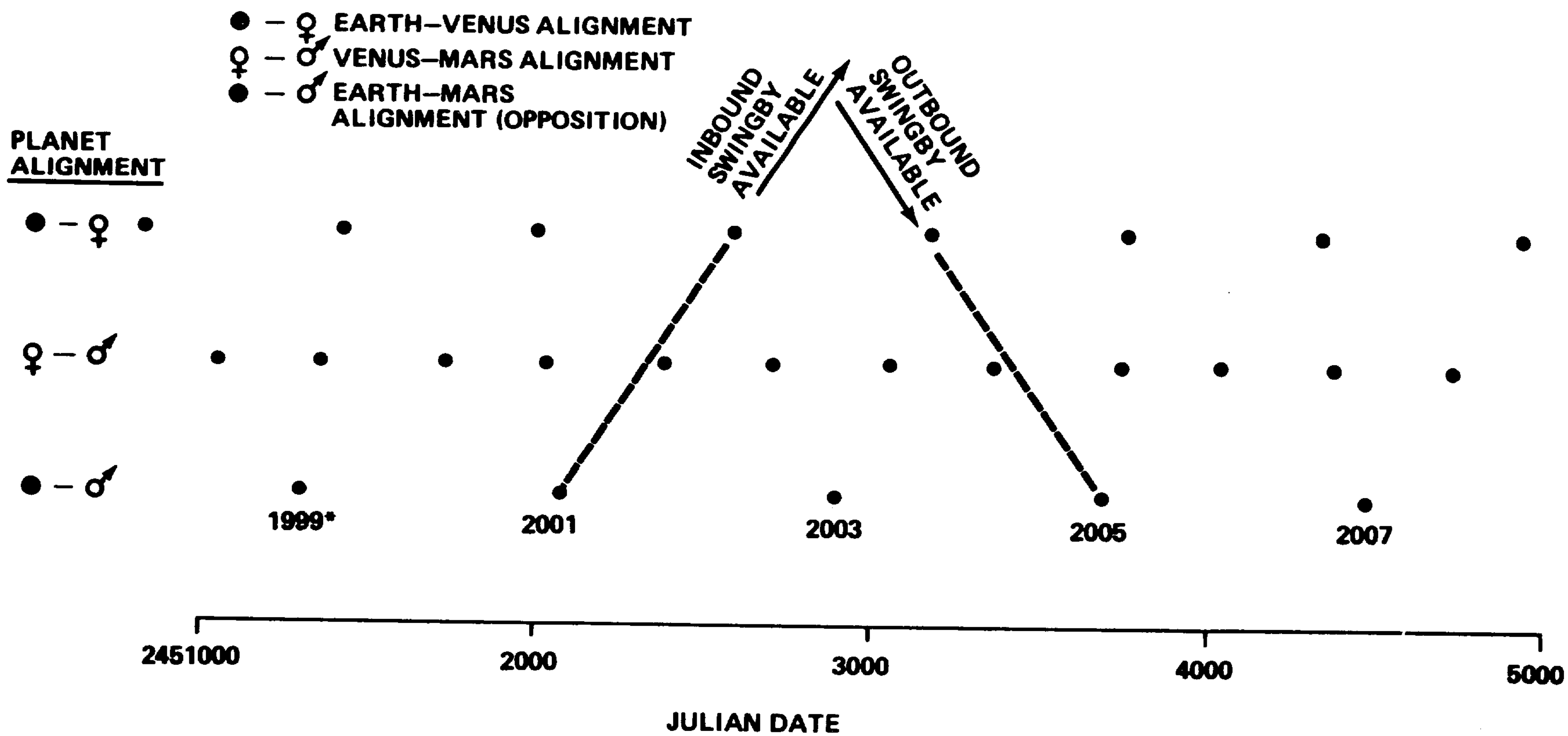



Figure 4. Planetary position data year 1999 to 2007.

**AVAILABILITY OF SWINGBYS**

| MISSION | YEAR* OF EARTH–MARS OPPOSITION 2010 | 2012 | 2014 | 2016 | 2018 | 2020 |
|---|---|---|---|---|---|---|
| OUTBOUND SWINGBY | MAYBE | YES | NO | MAYBE | YES | NO |
| INBOUND SWINGBY | MAYBE | NO | YES | MAYBE | NO | YES |

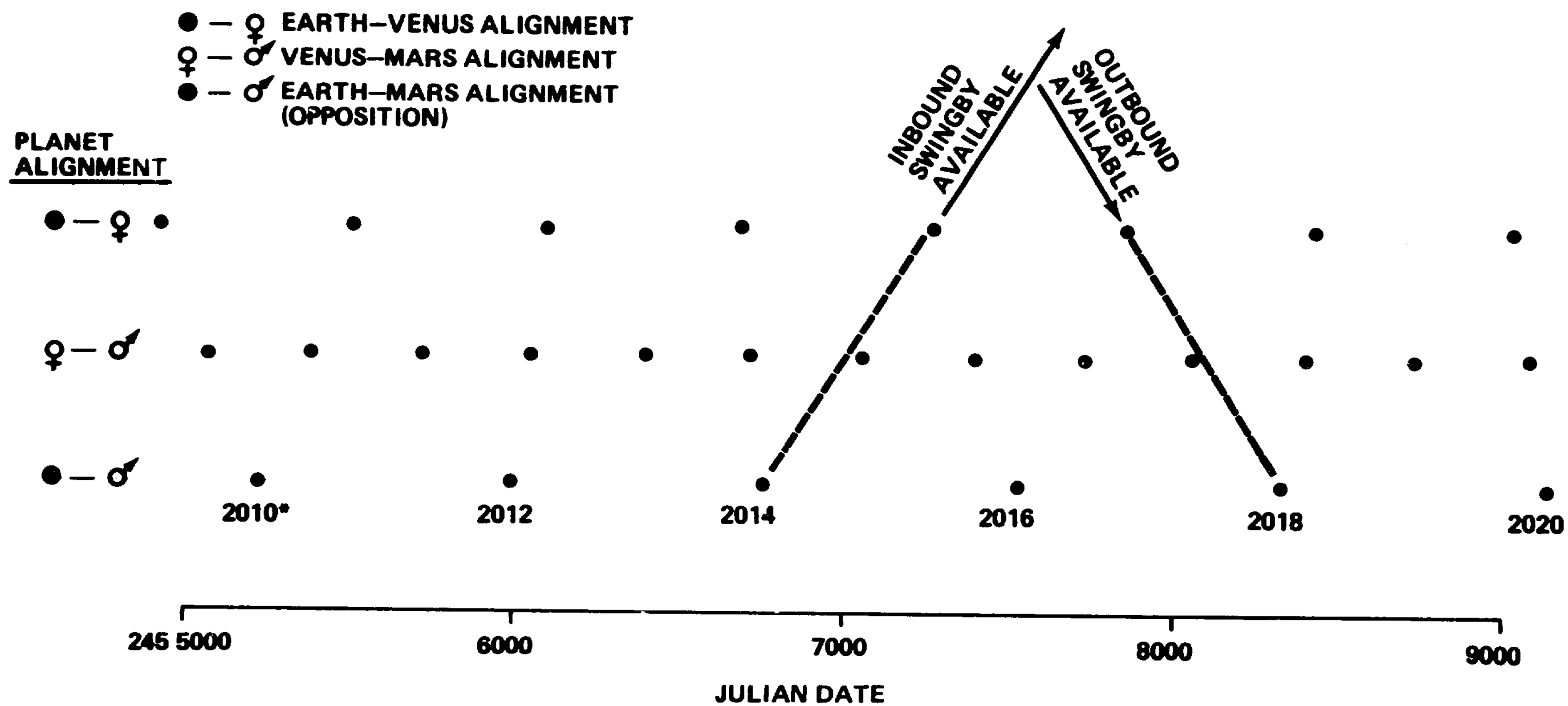



Figure 5. Planetary position data year 2010 to 2020.

AVAILABILITY OF SWINGBYS

| MISSION | YEAR* OF EARTH—MARS OPPOSITION 2020 | 2022 | 2025 | 2027 | 2029 | 2031 |
|---|---|---|---|---|---|---|
| OUTBOUND SWINGBY | NO | MAYBE | YES | NO | MAYBE | YES |
| INBOUND SWINGBY | YES | MAYBE | NO | YES | MAYBE | NO |

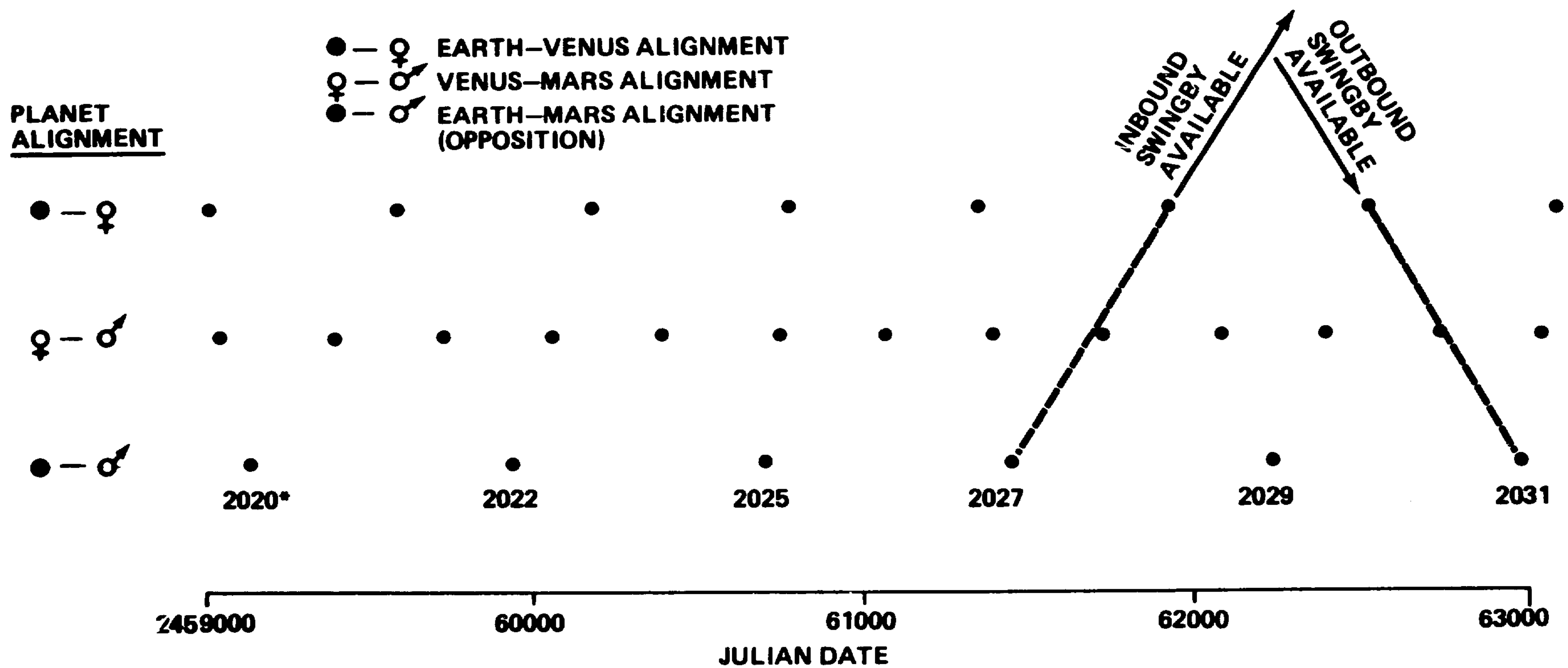
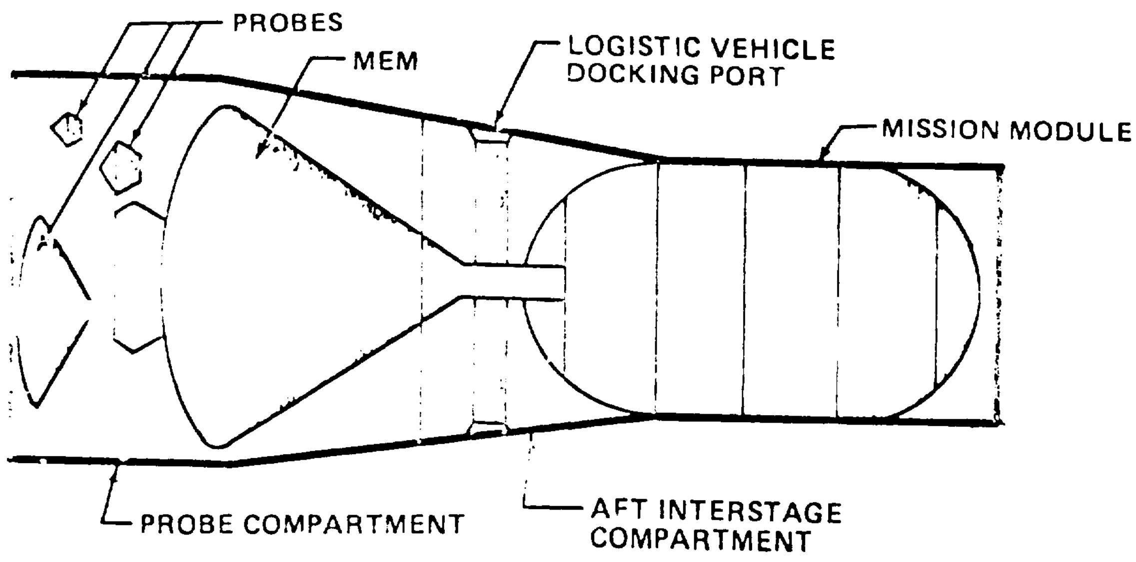



Figure 6. Planetary position data year 2020 to 2031.

## STOPOVER TIME EQUAL 60 DAYS
## TIME PERIOD 2000 TO 2031

| MISSION | EARTH LAUNCH DATE | TOTAL TRIP TIME (DAYS) |
|---|---|---|
| INBOUND SWINGBY | MARCH 2001 | 606 |
| OUTBOUND SWINGBY | AUGUST 2002 | 610 |
| OUTBOUND SWINGBY | JUNE 2004 | 659 |
| INBOUND SWINGBY | SEPTEMBER 2007 | 558 |
| DOUBLE SWINGBY | JANUARY 2009 | 736 |
| OUTBOUND SWINGBY | NOVEMBER 2010 | 650 |
| INBOUND SWINGBY | NOVEMBER 2013 | 634 |
| INBOUND SWINGBY | NOVEMBER 2015 | 577 |
| OUTBOUND SWINGBY | APRIL 2017 | 638 |
| INBOUND SWINGBY | JUNE 2020 | 594 |
| OUTBOUND SWINGBY | OCTOBER 2021 | 636 |
| OUTBOUND SWINGBY | SEPTEMBER 2023 | 614 |
| INBOUND SWINGBY | NOVEMBER 2026 | 570 |
| DOUBLE SWINGBY | MARCH 2028 | 737 |
| OUTBOUND SWINGBY | JANUARY 2030 | 654 |

Figure 7. Mars stopover mission with Venus swingby.




| WEIGHTS | MARS OPPOSITION CLASS WEIGHTS (LBS) |
|---|---|
| MM (INCLUDES EXPERIMENTS) | 83,000 |
| MEM | 95,000 |
| PROBES | 42,000 |
| TOTAL | 220,000 |

Figure 8. Interplanetary spacecraft for Mars opposition class mission.

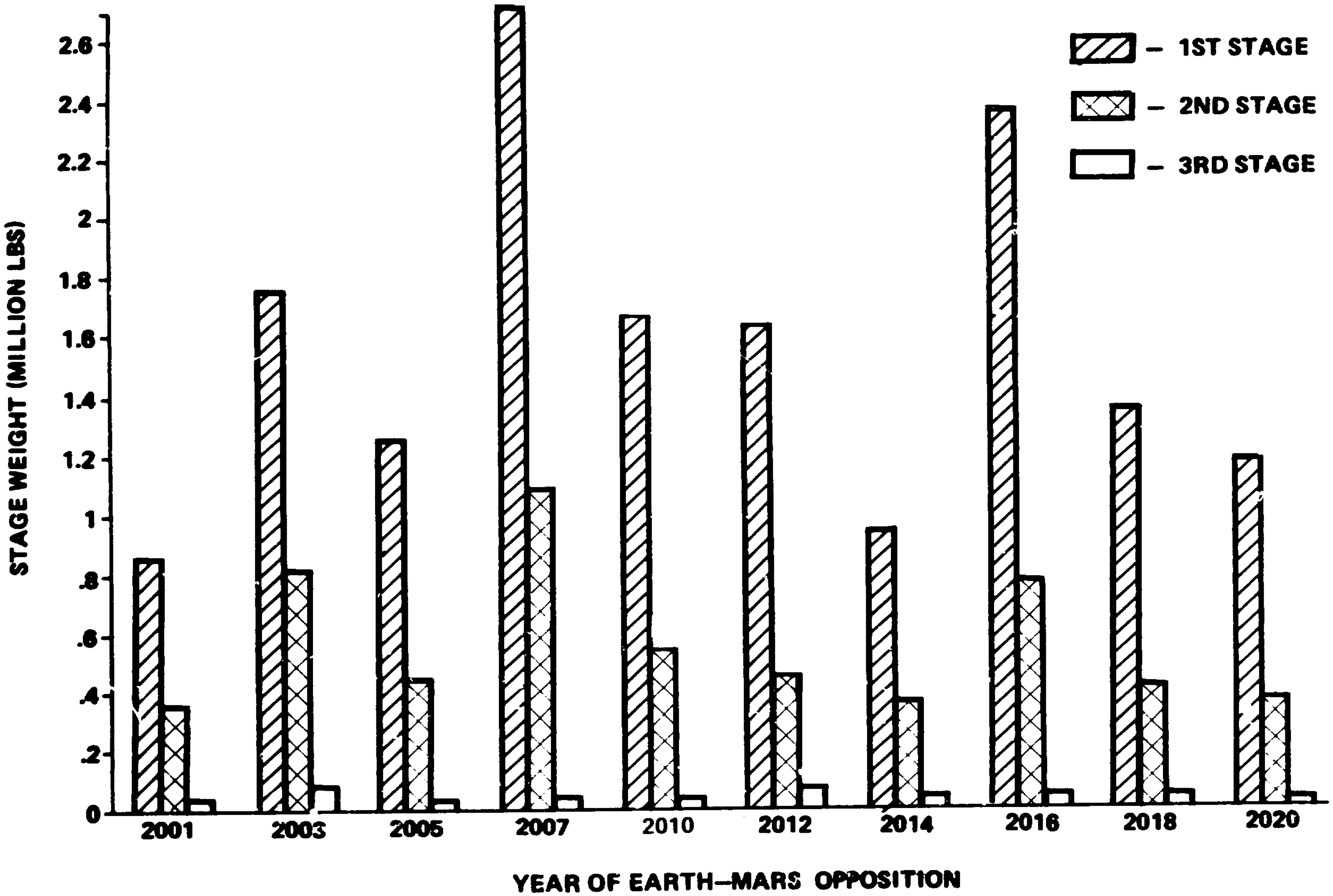



Figure 9. Stage weight as a function of year of Earth-Mars opposition year 2001 to 2020.

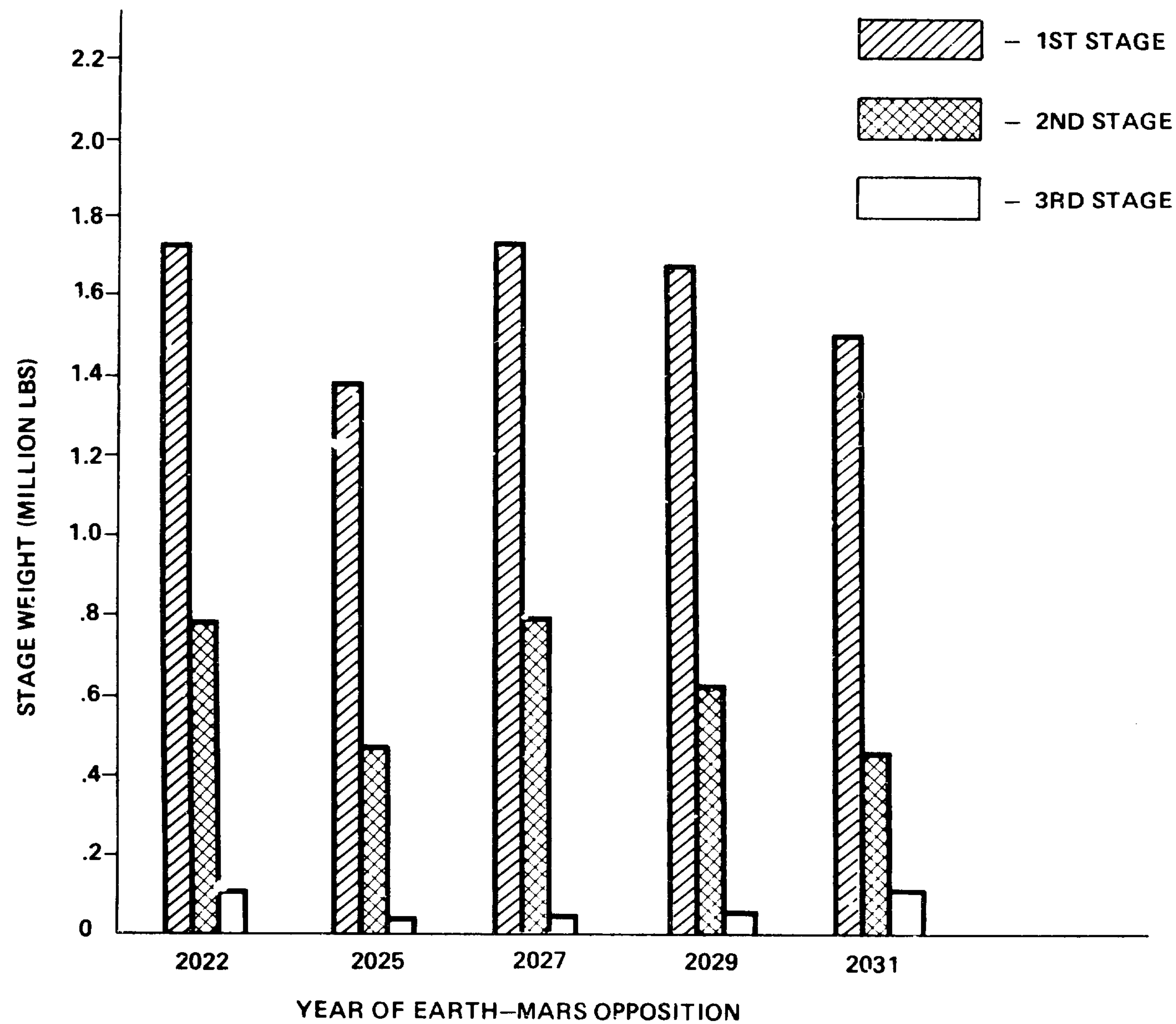



Figure 10. Stage weight as a function of year of Earth-Mars opposition year 2022 to 2031.

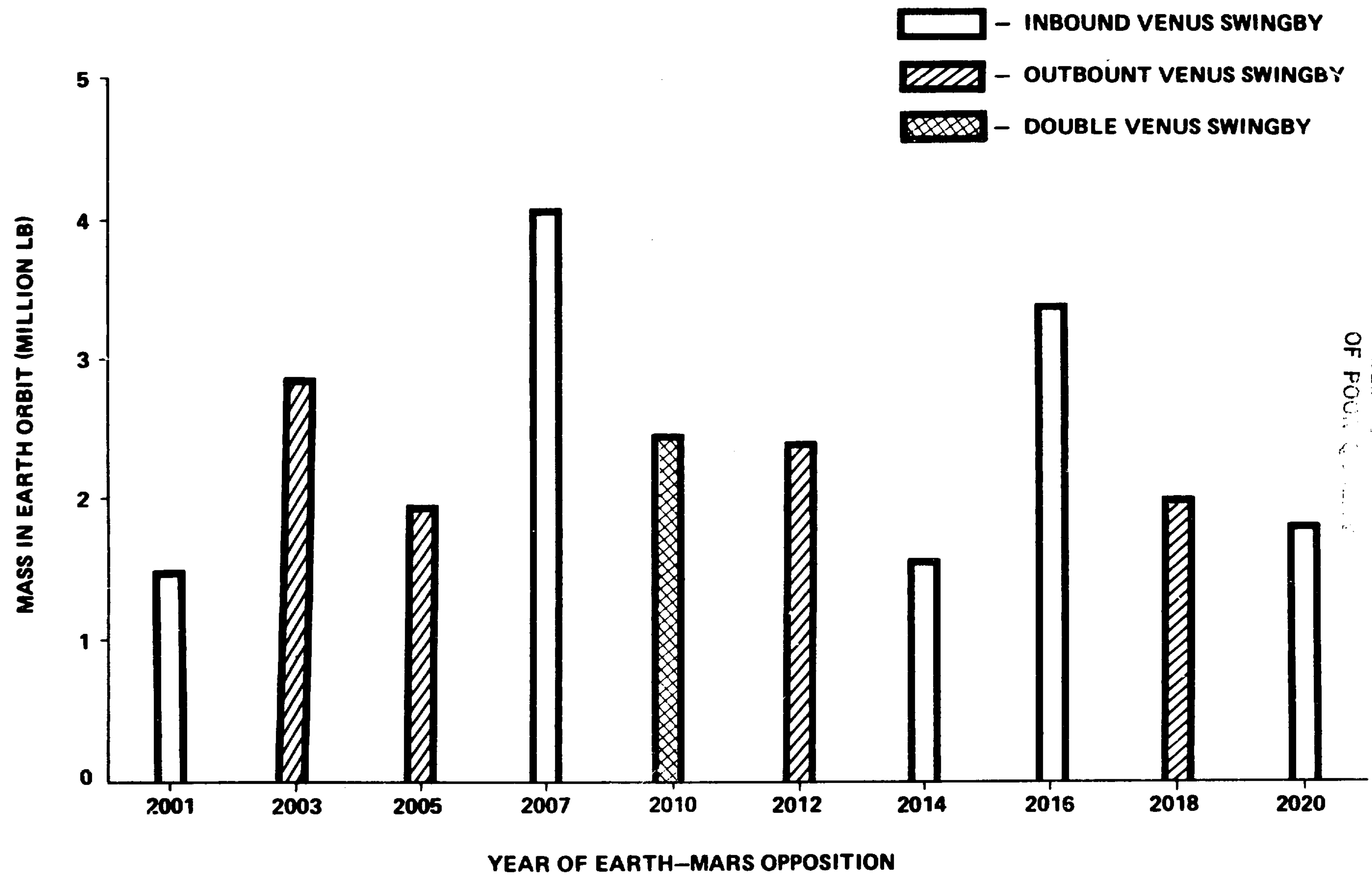



Figure 11. Weight in Earth orbit as a function of year of opposition year 2001 to 2020.

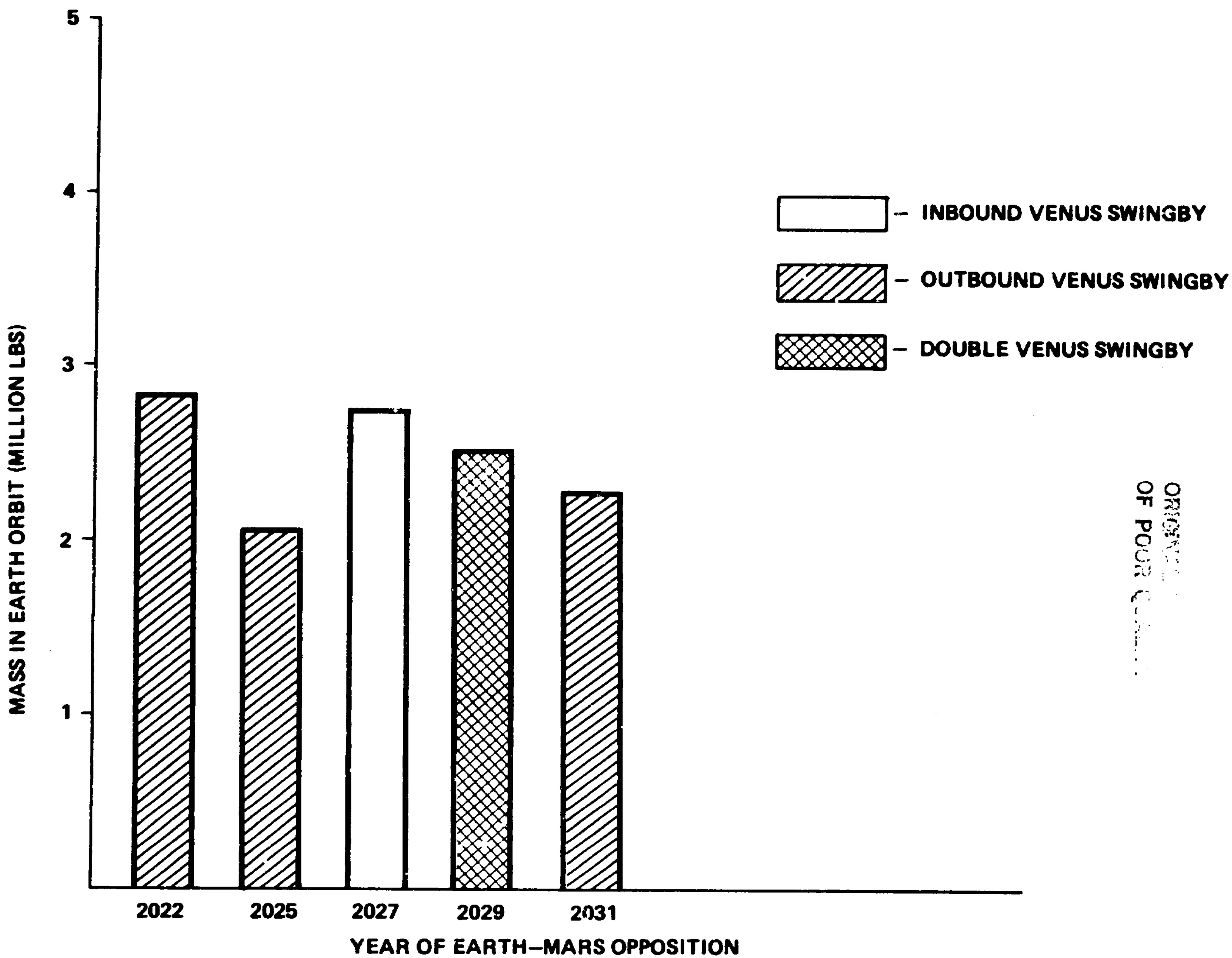
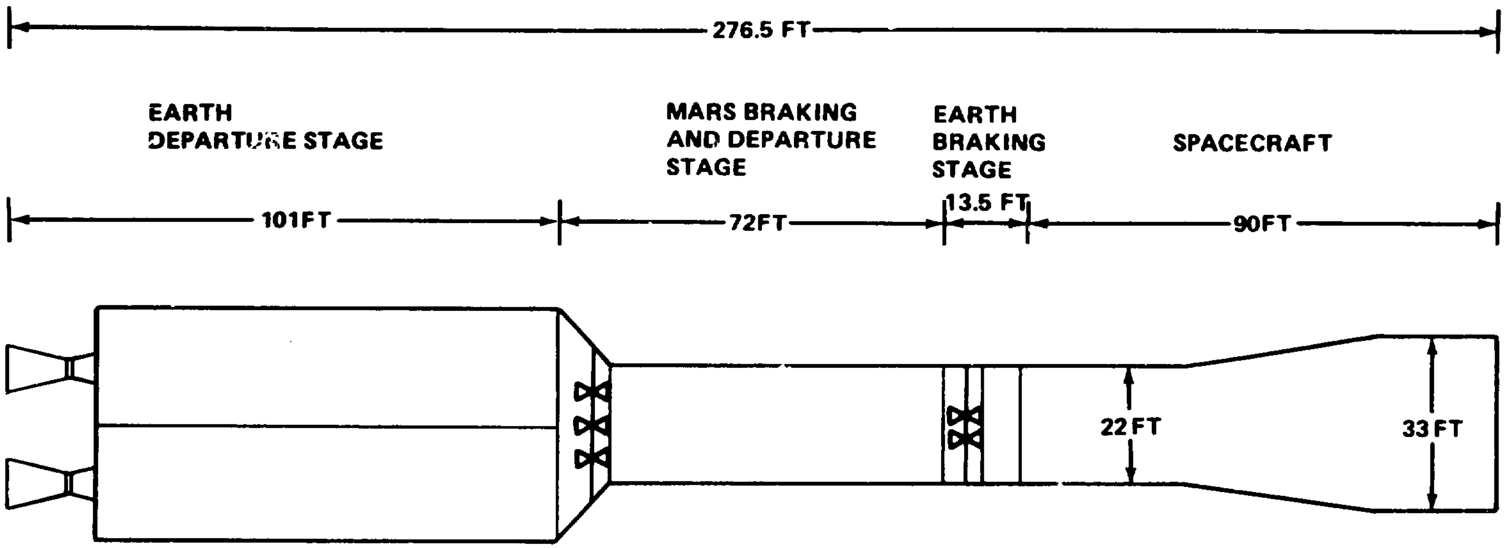



Figure 12. Weight in Earth orbit as a function of year of opposition year 2022 to 2031.




- LOX/$LH_2$ PROPULSION
- EARTH DEPARTURE STAGE
  - 1,241K LBS PROPELLANT
  - 2 UPRATED SSME ENGINES ($I_{SP}$ = 480 SEC)
- MARS BRAKING AND DEPARTURE STAGE
  - 422K LBS PROPELLANT
  - 5 OTV TYPE (ASE) ENGINES ($I_{SP}$ = 480 SEC)
- EARTH BRAKING STAGE
  - 16K LBS PROPELLANT
  - 2 OTV TYPE (ASE) ENGINES ($I_{SP}$ = 480 SEC)
- TOTAL EARTH ORBIT DEPARTURE MASS
  - 2.08 MILLION LBS



Figure 13. Interplanetary vehicle sized for 2025 opposition Venus outbound swingby opportunity.

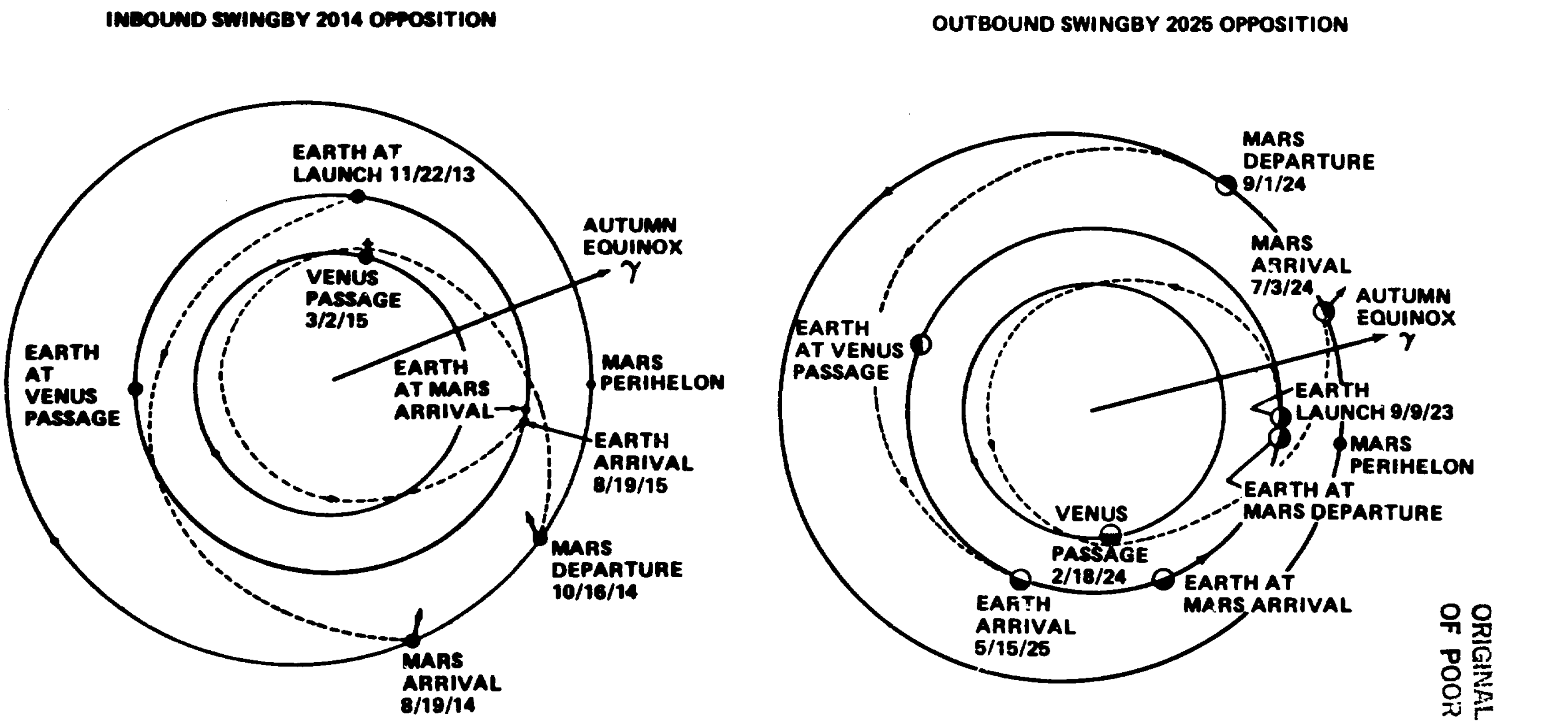





Figure 14. Venus inbound and outbound mission profile.

- TWO MISSION OPPORTUNITIES OUT OF EVERY THREE SHOULD BE FAVORABLE
- INITIAL MASS REQUIRED IN LOW EARTH ORBIT RANGES FROM 1.47 TO 4.1 MILLION POUNDS
- WEIGHT RANGE OF PROPULSION STAGES
  - THIRD STAGE: 24,000 TO 102,000 POUNDS
  - SECOND STAGE: 353,000 TO 1,094,000 POUNDS
  - FIRST STAGE: 870,000 TO 2,720,000 POUNDS
- MISSION TIME RANGES FROM 558 TO 737 DAYS
- EARTH DEPARTURE $C_3$ RANGE FROM 9.2 TO 37.0 $KM^2/SEC^2$

Figure 15. Venus swingby summary results.

TIME PERIOD OF CONSIDERATION: YEAR 2030 TO 2045

**PLANET DEPARTURE AND CAPTURE ORBIT PARAMETERS**

| | |
|---|---|
| **EARTH DEPARTURE** | CIRCULAR ORBIT ALTITUDE = 270 N. MI |
| **MARS CAPTURE** | 24 HR ELLIPTIC ORBIT PERIAPSIS ALTITUDE = 270 N. MI |
| **MARS ESCAPE** | 24 HR ELLIPTIC ORBIT PERIAPSIS ALTITUDE = 270 N. MI |
| **EARTH CAPTURE** | 24 HR ELLIPTIC ORBIT PERIAPSIS ALTITUDE = 270 N. MI |

**HELIOCENTRIC PROFILE**

TYPE I OR TYPE II TRANSFER TRAJECTORY

MARS STOPOVER TIME OPTIMIZED TO MINIMIZE INITIAL WEIGHT IN EARTH ORBIT

**INTERPLANETARY SPACE VEHICLE**

| | | |
|---|---|---|
| **SPACECRAFT:** | **MISSION MODULE WEIGHT** | = 117,000 LBS |
| | **MARS EXECURSION MODULE WEIGHT** | = 95,000 LBS |
| | PIONEER MARS BASE | = 57,000 LBS |

| **PROPULSION STAGES** | **FIRST STAGE** | **SECOND STAGE** | **THIRD STAGE** |
|---|---|---|---|
| **MASS FRACTION ( $\lambda$ )** | 0.90 | 0.90 | 0.90 |
| **$I_{SP}$ (SEC)** | 480 | 480 | 480 |
| **PROPELLANT** | $LOX/LH_2$ | $LOX/LH_2$ | $LOX/LH_2$ |

Figure 16. Study assumptions for conjunction class missions.

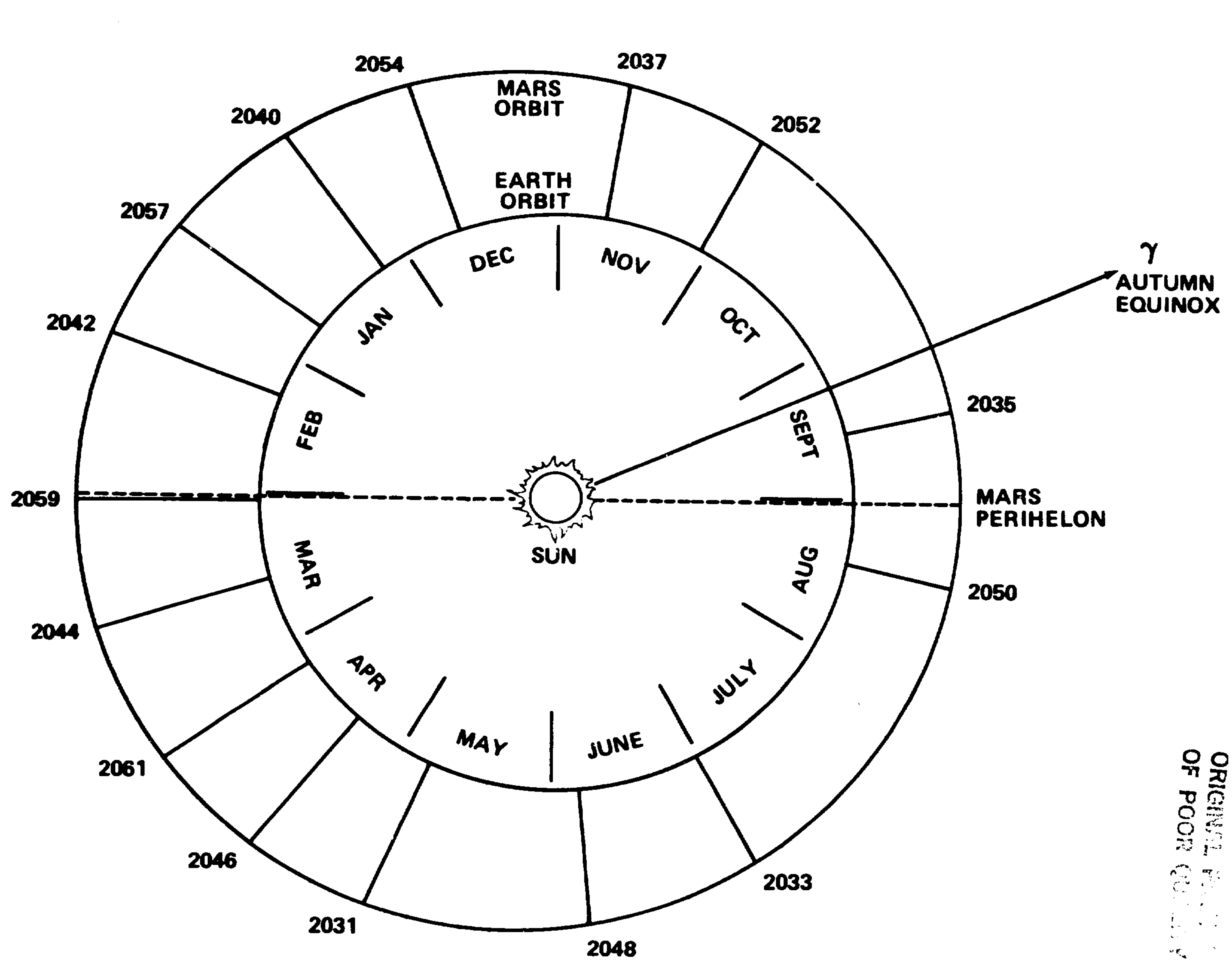



Figure 17. Earth-Mars opposition for years 2030 to 2061.

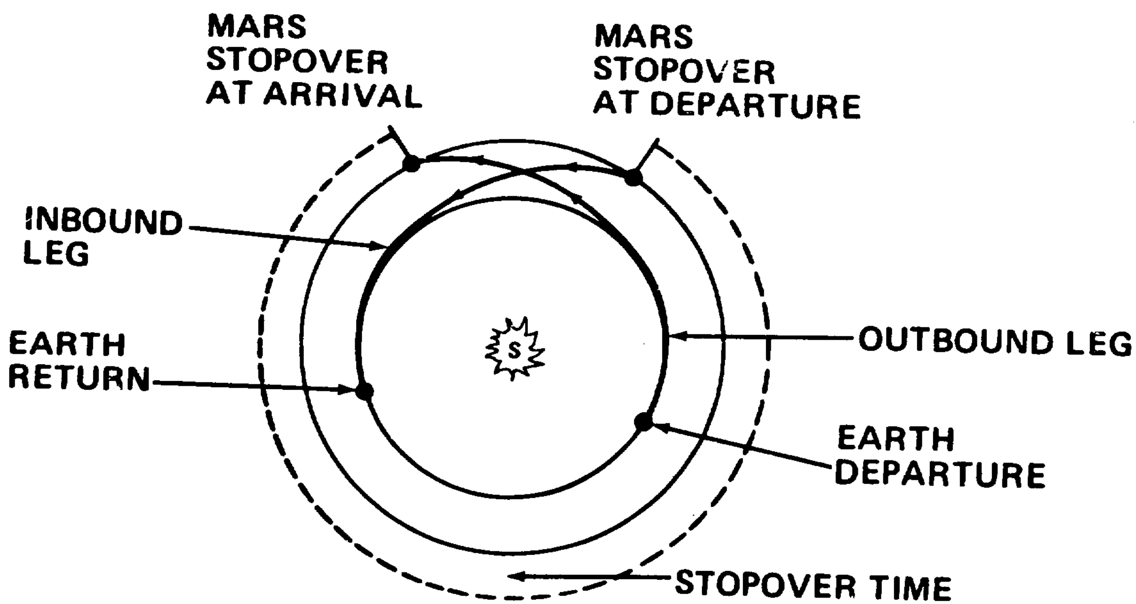
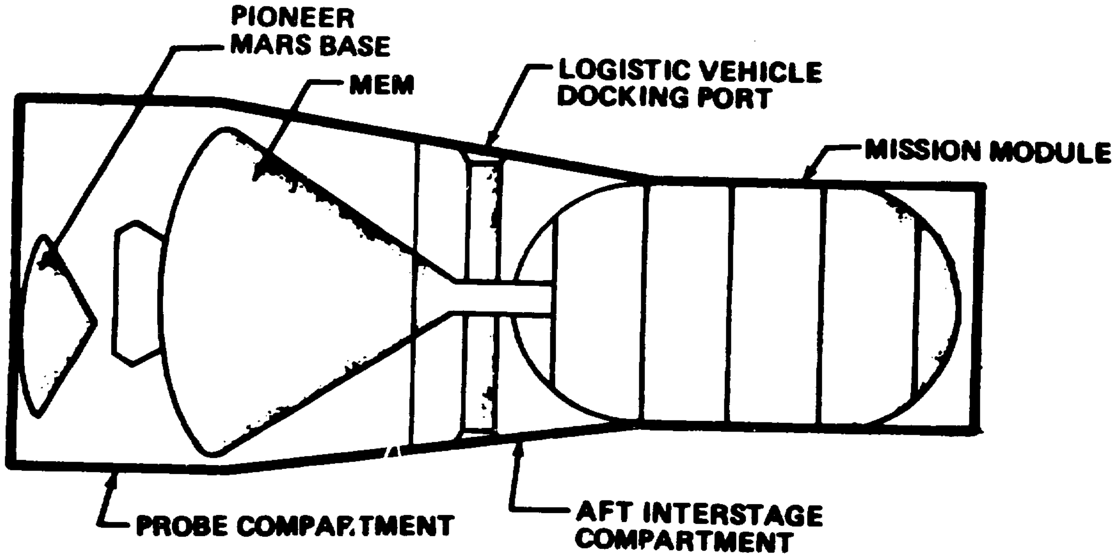



Figure 18. Direct stopover mission to Mars, example profile for conjunction class stopover missions.

| DATE OF OPPOSITION | | EARTH LAUNCH DATE | | MARS STOPOVER TIME (DAYS) | TOTAL MISSION TIME (DAYS) |
|---|---|---|---|---|---|
| MAY | 2031 | DECEMBER | 2030 | 500 | 998 |
| JUNE | 2033 | APRIL | 2033 | 550 | 950 |
| SEPTEMBER | 2035 | JUNE | 2035 | 530 | 1004 |
| NOVEMBER | 2037 | AUGUST | 2037 | 340 | 986 |
| JANUARY | 2040 | SEPTEMBER | 2039 | 340 | 984 |
| FEBRUARY | 2042 | OCTOBER | 2041 | 340 | 990 |
| MARCH | 2044 | NOVEMBER | 2043 | 340 | 996 |

Figure 19. Mars conjunction class stopover mission.




| WEIGHTS | MARS CONJUNCTION CLASS WEIGHTS (LBS) |
|---|---|
| MM (INCLUDES EXPERIMENTS) | 117,000 |
| MEM | 95,000 |
| PIONEER MARS BASE | 57,000 |
| TOTAL | 269,000 |

Figure 20. Interplanetary spacecraft for Mars conjunction class missions.

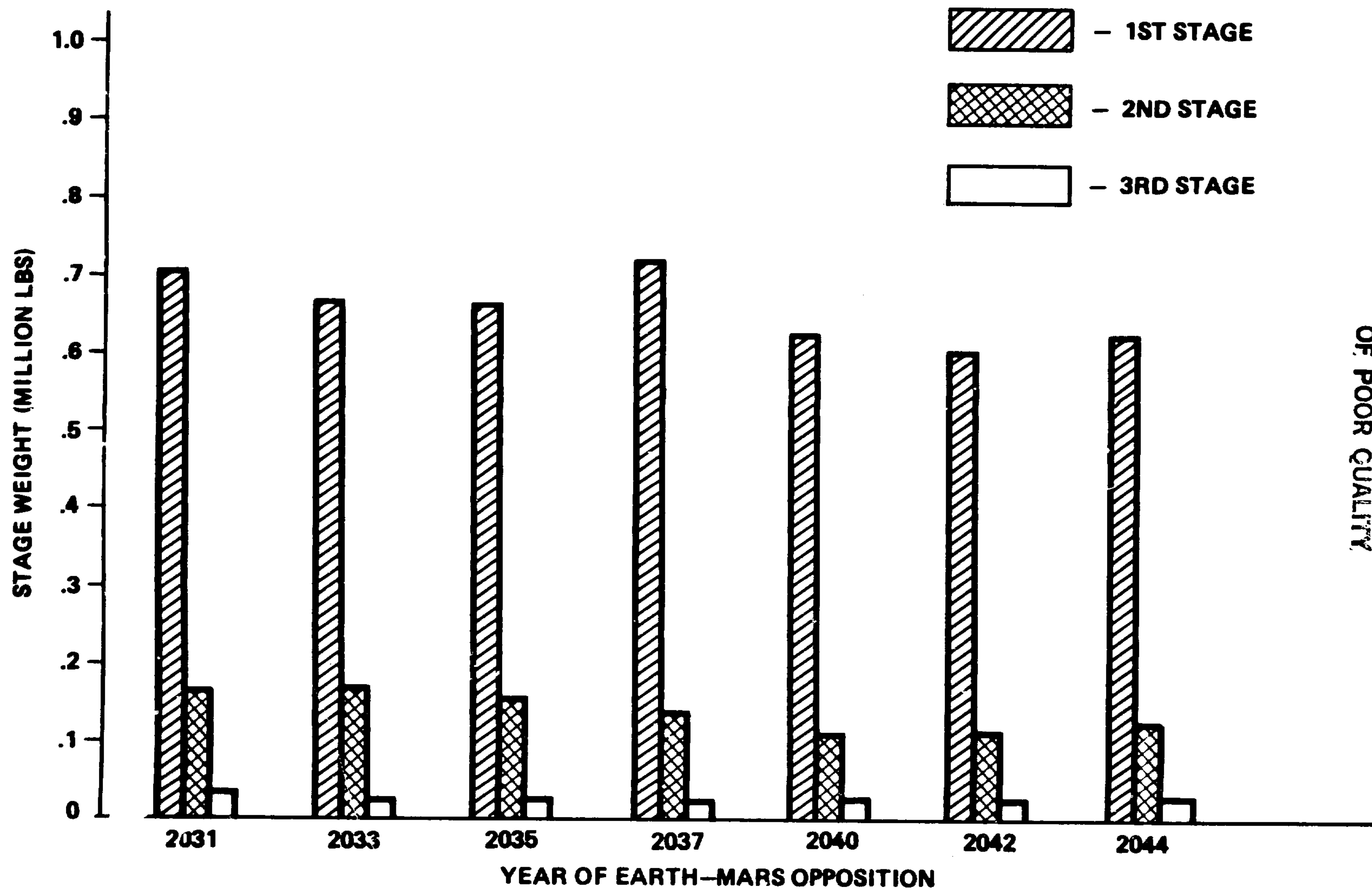



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Figure 21. Stage weight as a function of year of Earth-Mars opposition.

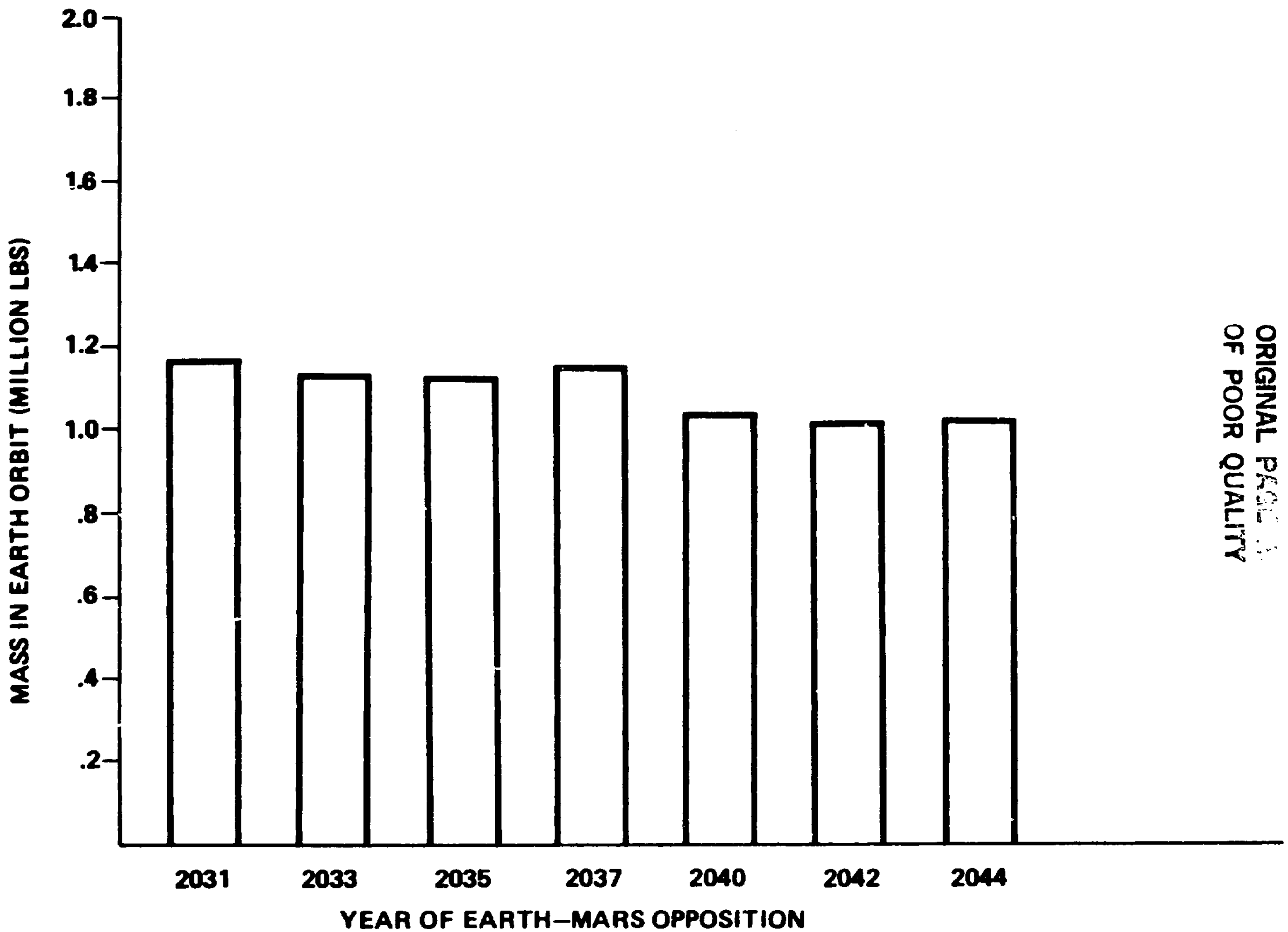
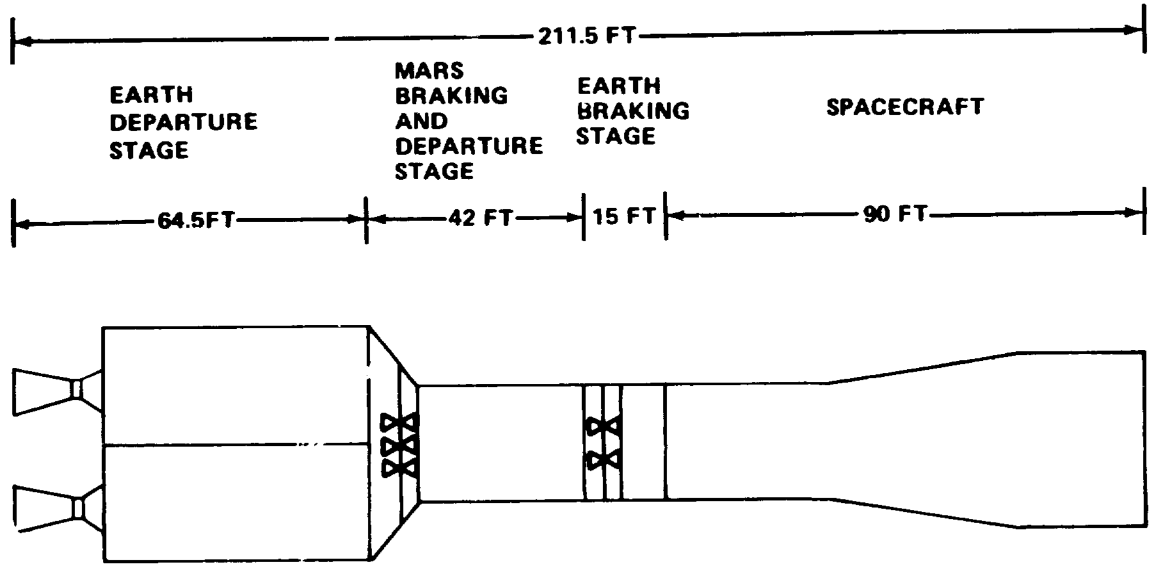





Figure 22. Weight in Earth orbit as a function of year of Earth-Mars opposition.

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- LOX/$LH_2$ PROPULSION
  EARTH DEPARTURE STAGE
  - 631K LBS PROPELLANT
  - 2 UPRATED SSME ENGINES ($I_{SP}$ = 480 SEC)
- MARS BRAKING AND DEPARTURE STAGE
  - 151K LBS PROPELLANT
  - 3 OTV TYPE (ASE) ENGINES ($I_{SP}$ = 480 SEC)
- EARTH BRAKING STAGE
  - 29K LBS PROPELLANT
  - 2 OTV TYPE (ASE) ENGINES ($I_{SP}$ = 480 SEC)
- TOTAL EARTH ORBIT DEPARTURE MASS
  - 1.17 MILLION LBS

Figure 23. Interplanetary vehicle sized for 2031 opposition opportunity for conjunction class mission.

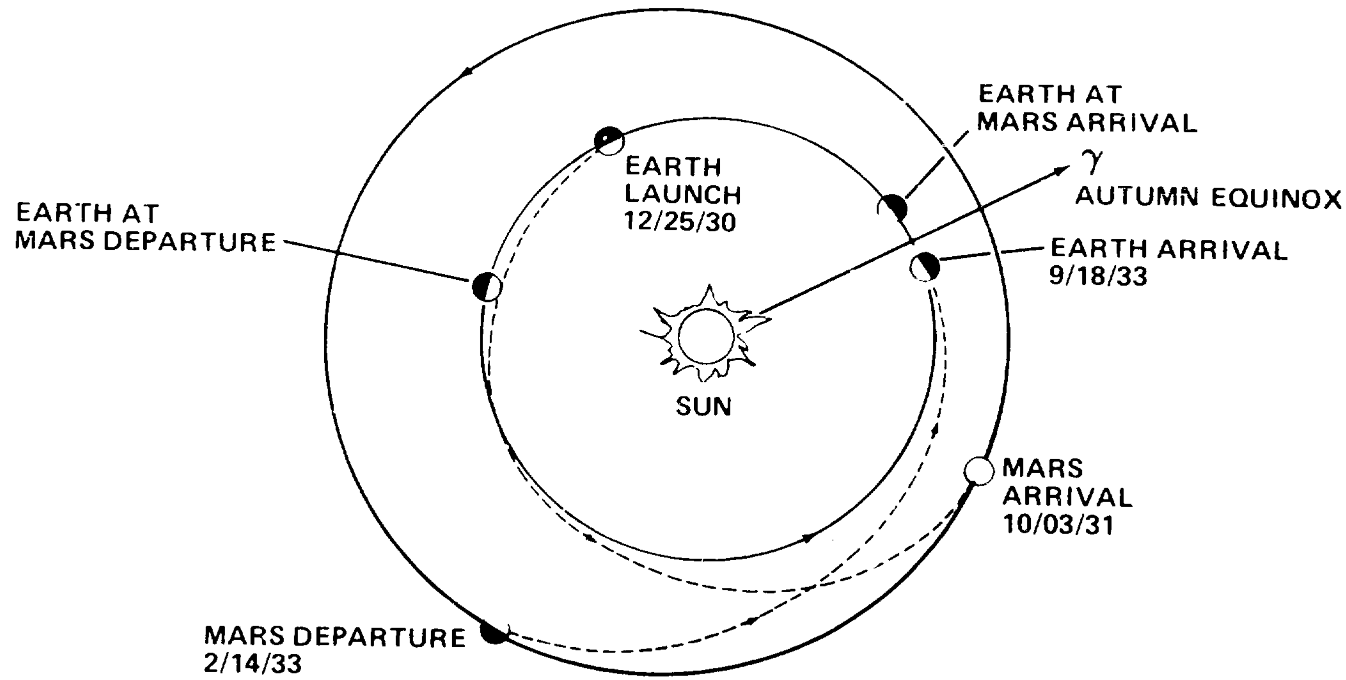


Figure 24. Mars conjunction class mission profile for 2031 opposition.

- MISSION OPPORTUNITY OCCURS APPROXIMATELY EVERY 26 MONTHS
- INITIAL MASS REQUIRED IN LOW EARTH ORBIT RANGES FROM 1.01 TO 1.17 MILLION POUNDS
- WEIGHT RANGE OF PROPULSION STAGE

| | |
|---|---|
| THIRD STAGE: | 25,000 TO 36,500 POUNDS |
| SECOND STAGE: | 112,000 TO 169,000 POUNDS |
| FIRST STAGE: | 600,000 TO 725,000 POUNDS |

- STOPOVER TIME AT MARS RANGES FROM 340 TO 550 DAYS
- TOTAL MISSION TIME RANGES FROM 950 TO 1004 DAYS
- EARTH DEPARTURE $C_3$ RANGES 8.9 TO 16.2 $KM^2/SEC^2$

Figure 25. Conjunction class summary results.

TABLE 1. MARS STOPOVER MISSION WITH VENUS SWINGBY MISSION DEFINITION

| MISSION | EARTH–MARS OPPOSITION J.D. 2450000 OR 2460000 | L V EARTH J.D. 2450000 OR 2460000 (EMOS) | PASS VENUS | ARRIVE MARS | LEAVE MARS | PASS VENUS | ARRIVE EARTH | TOTAL MISSION TIME (DAYS) |
|---|---|---|---|---|---|---|---|---|
| 2001 INBOUND SWINGBY | 2073 | 1996 (.1018) | --- | 2182 (.1283) | 2242 (.2050) | 2436 (.2531) | 2602 (.1418) | 606 |
| 2003 OUTBOUND SWINGBY | 2880 | 2510 (.1272) | 2631 (.1781) | 2812 (.2183) | 2872 (.1623) | --- | 3120 (.2343) | 610 |
| 2005 OUTBOUND SWINGBY | 3683 | 3164 (.1549) | 3330 (.3259) | 3505 (.2061) | 3565 (.1230) | --- | 3823 (.1256) | 659 |
| 2007 INBOUND SWINGBY | 4460 | 4350 (.1741) | --- | 4532 (.2028) | 4592 (.2446) | 4747 (.3308) | 4908 (.1515) | 558 |
| 2010 DOUBLE SWINGBY | 5225 | 4854 (.1735) | 4983 (.2463) | 5196 (.1456) | 5256 (.2294) | 5433 (.2370) | 5590 (.1497) | 736 |
| 2012 OUTBOUND SWINGBY | 5991 | 5528 (.1778) | 5689 (.3570) | 5842 (.1795) | 5902 (.1402) | --- | 6178 (.2535) | 650 |
| 2014 INBOUND SWINGBY | 6755 | 6618 (.1162) | --- | 6888 (.1229) | 6948 (.2135) | 7083 (.3321) | 7252 (.1491) | 634 |
| 2016 INBOUND SWINGBY | 7529 | 7336 (.1957) | --- | 7596 (.1642) | 7656 (.2447) | 7834 (.3958) | 7913 (.1828) | 577 |
| 2018 OUTBOUND SWINGBY | 8325 | 7854 (.1709) | 8007 (.3345) | 8198 (.1865) | 8258 (.1223) | --- | 8492 (.1886) | 638 |
| 2020 INBOUND SWINGBY | 9134 | 9010 (.1612) | --- | 9196 (.1326) | 9256 (.2114) | 9437 (.2764) | 9604 (.1365) | 594 |
| 2022 OUTBOUND SWINGBY | 9922 | 95[illegible]8 (.1229) | 9666 (.2012) | 9820 (.1946) | 9880 (.1736) | --- | 60154 (.2744) | 636 |
| 2025 OUTBOUND SWINGBY | 0694 | 0196 (.1679) | 0358 (.3758) | 0494 (.2146) | 0554 (.1216) | --- | 0810 (.0947) | 614 |
| 2027 INBOUND SWINGBY | 1455 | 1346 (.1349) | --- | 1554 (.1978) | 1614 (.2132) | 1751 (.3440) | 1916 (.1614) | 570 |
| 2029 DOUBLE SWINGBY | 2219 | 1856 (.1711) | 2008 (.2460) | 2210 (.1789) | 2270 (.1864) | 2437 (.2374) | 2592 (.1956) | 737 |
| 2031 OUTBOUND SWINGBY | 2989 | 2530 (.1674) | 2693 (.3516) | 2884 (.1712) | 2944 (.1265) | --- | 3184 (.2764) | 654 |

TABLE 2. MARS STOPOVER MISSION WITH INBOUND VENUS SWINGBY MISSION DATA FOR 2001 OPPOSITION

```
DEPARTURE PLANET - MARS                                                                                   DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS                                                                                  PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH                                                                                  ARRIVAL   PLANET - EARTH

LAUNCH   STOP      C3-DD  R A   DECL    I 1   V 1    PSI 1    ECCEN SMA   THET1 THET2  PERIH APHEL   I 2   V 2    PSI 2    R A   DECL    VHP
DEPART   PASS      C3-DD  R A   DECL    I 1   V 1    PSI 1    ECCEN SMA   THET1 THET2  PERIH APHEL   I 2   V 2    PSI 2    R A   DECL   C3-PD
PASS     ARRIVE    C3-PD  R A   DECL    I 1   V 1    PSI 1    ECCEN SMA   THET1 THET2  PERIH APHEL   I 2    V 2   PSI 2    R A   DECL   C3-AD
RCP      KAPPA      VP     AH   EH      ANMAX INH   RAP          DECP     RAS  DECS  ETA        PASS CONDITION                          DVCP
   CORD1      CORD2      CORD3
  DV1       DV2        DV3        DV4       GAM1       GA    M2       GAM3       GAM4       ETA1      ETA2       ETA3       ETA4       ETA0

51984.0 52182.0    10.18 241.6 -67.0  -4.01 1.083  88.5   .168  1.193  10.6 163.4   ---   ---    3.31  .780  93.3  347.5 16.3   3.94
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.61607   1.66303   3.23870    1.23852   2.15597   1.42378   1.98987   1.30099   8.91892   5.46773   1.79050   1.03424   19.22890

51986.0 52182.0     9.71 240.5 -64.4  -3.76 1.082  88.2   .169  1.193  12.4 163.3   ---   ---    3.03  .780  93.3  348.4 14.9   3.90
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.59521   1.63979   3.23870    1.23852   2.14643   1.41676   1.98987   1.30099   8.85718   5.46331   1.79050   1.03424   19.01134

51988.0 52182.0     9.39 239.3 -62.0  -3.54 1.082  87.9   .169  1.193  14.3 163.2   ---   ---    2.77  .780  93.3  349.2 13.6   3.87
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.58086   1.62183   3.23870    1.23852   2.13990   1.41137   1.98987   1.30099   8.81072   5.45992   1.79050   1.03424   18.35405

51990.0 52182.0     9.19 238.2 -59.6  -3.35 1.081  87.7   .169  1.193  16.2 163.1   ---   ---    2.55  .780  93.4  349.9 12.5   3.85
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.57196   1.60842   3.23870    1.23852   2.13586   1.40735   1.98987   1.30099   8.77714   5.45739   1.79050   1.03424   18.74673

51992.0 52182.0     9.10 237.2 -57.4  -3.19 1.081  87.4   .170  1.192  18.2 163.0   ---   ---    2.35  .780  93.4  350.4 11.4   3.84
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.56783   1.59850   3.23870    1.23852   2.13309   1.40439   1.98987   1.30099   8.75360   5.45553   1.79050   1.03424   18.68006

51994.0 52182.0     9.10 236.2 -55.2  -3.04 1.080  87.1   .170  1.192  20.1 163.0   ---   ---    2.17  .779  93.4  351.0 10.5   3.83
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.56798   1.59143   3.23870    1.23852   2.13405   1.40228   1.98987   1.30099   8.73842   5.45421   1.79050   1.03424   18.64826

51996.0 52182.0     9.19 235.3 -53.1  -2.91 1.079  86.8   .171  1.191  22.1 163.0   ---   ---    2.00  .779  93.4  351.4  9.5   3.82
52242.0 52435.6    37.30 351.8  20.3   6.29  .695  88.4   .327  1.054 176.8 340.3   ---  1.398  -6.80 1.353  85.2  164.9-39.1  56.83
52435.6 52602.0    58.29 210.4  -4.6   -.98 1.240 101.6   .226   .806 286.1 537.7  .624  ---    3.57  .886  90.7  332.8 13.4  17.84
  1.106  53.6   .4141   .908  2.218  116.8  46.7  81.08-37.55 217.77   .00 125.23    DARK SIDE   TRAILING EDGE         .00000
   .8658    1.2539     1.2411
 3.57207   1.58676   3.23870    1.23852   2.13591   1.40089   1.98987   1.30099   8.73040   5.45333   1.79050   1.03424   18.64731
```

TABLE 3. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2003 OPPOSITION

```
DEPARTURE PLANET - EARTH                                                                              DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS                                                                              PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                               ARRIVAL   PLANET - MARS

DEPART    PASS     C3-DD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA    THET1 THET2  PERIH APHEL   I 2   V 2    PSI 2    R A  DECL  C3-PD
PASS      ARRIVE   C3-PD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA    THET1 THET2  PERIH APHEL   I 2   V 2    PSI 2    R A  DECL  C3-AD
RCP       KAPPA    VP     AH     EH      ANMAX INH    RAP        DECP    RAS  DECS  ETA          PASS CONDITION                        DVCP

RESTART RETURN     C3-RS  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA    THEL  T1 THET2  PERIH APHE I 2  V 2    PSI 2    R A  DECL  C3-RD
  CORD1    CORD2     CORD3
  DV1       DV2       DV3       DV4       GAM1       GA     ME       GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETA0


52508.0 52631.3   14.78 223.7  27.7   5.47  .909   93.5    .175    .869 197.0 350.8   ---   ---   -7.30 1.278  88.6   99.8-61.4  30.29
52631.3 52810.0   29.06  82.3  11.5   1.53 1.361   90.3    .332   1.075 358.9 527.9   .719  ---   -3.41  .694  95.9  333.6-22.7  43.39
  1.157  74.3   .3680  1.762  1.656  127.1  98.4 246.92-63.27 170.59    .00  83.89    LIGHT SIDE   LEADING EDGE         .00000
52870.0 53118.0   22.97 309.3 -16.1    .61  .743   95.4    .253   1.119 196.5 440.6   .835 1.402  -2.03 1.047 103.5  212.3-22.5  47.86
   .5282     .6308      .3786
  3.81890   3.62503   2.24386   2.47073   2.25090   2.16007   1.61077   1.69031  15.64552   6.00686   2.22896   1.08217   33.86599

52510.0 52631.3   14.35 221.5  25.9   5.12  .910   93.9    .176    .870 199.0 350.8   ---   ---   -6.91 1.278  88.6   99.6-59.7  28.13
52631.3 52812.0   29.46  82.2  14.7   1.95 1.361   90.3    .330   1.073 358.9 529.2   .719  ---   -3.83  .694  95.2  333.4-24.4  42.26
  1.143  75.7   .3685  1.816  1.629  127.9  98.6 245.01-65.55 170.59    .00  83.62    LIGHT SIDE   LEADING EDGE         .00000
52872.0 53120.0   23.37 310.1 -16.3    .54  .743   95.4    .254   1.117 196.5 441.3   .833 1.401  -2.01 1.045 103.6  214.0-22.9  48.69
   .5282     .6184      .3764
  3.80009   3.55475   2.27397   2.50299   2.24192   2.12866   1.62111   1.70193  14.89737   6.04410   2.24792   1.08367   33.39877

52512.0 52632.5   15.30 220.9  26.4   5.32  .912   94.3    .176    .871 200.8 352.8   ---   ---   -7.00 1.279  88.9   97.7-60.4  28.49
52632.5 52814.0   29.37  80.7  15.3   2.02 1.360   89.8    .329   1.071    .8 170.3   ---   ---   -3.89  .694  94.7  332.9-25.0  40.99
  1.100  76.9   .373[illegible]  1.807  1.609  128.4  98.2 244.31-65.64 172.62    .00  82.55    LIGHT SIDE   LEADING EDGE         .00072
52874.0 53122.0   23.78 311.0 -16.4    .47  .742   95.5    .256   1.116 196.4 441.9   .830 1.401  -1.99 1.044 103.7  215.7-23.3  49.53
   .5374     .6061      .3748
  3.84201   3.47593   2.30459   2.53595   2.26198   2.09272   1.63168   1.71389  14.77660   6.08076   2.26751   1.08522   33.42440

52514.0 52634.4   17.05 221.2  27.9   5.78  .913   94.7    .177    .873 202.6 355.7   ---   ---   -7.32 1.280  89.4   94.9-62.0  30.25
52634.4 52814.0   29.04  78.4  11.9   1.57 1.360   89.1    .329   1.071   3.7 170.1   ---   ---   -3.43  .694  94.8  332.5-23.6  40.66
  1.131  75.1   .3711  1.764  1.641  127.5  97.8 244.21-63.41 175.67    .00  80.58    LIGHT SIDE   LEADING EDGE         .00000
52874.0 53122.0   23.78 311.0 -16.4    .47  .742   95.5    .256   1.116 196.4 441.9   .830 1.401  -1.99 1.044 103.7  215.7-23.3  49.53
   .5514     .6061      .3748
  3.91804   3.45403   2.30459   2.53595   2.29882   2.08301   1.63168   1.71389  14.75962   6.07338   2.26751   1.08522   33.92965

52516.0 52635.0   1[illegible].43 219.8  27.0   5.69  .915   95.1    .178    .874 204.6 356.8   ---   ---   -7.15 1.281  89.5   93.6-61.3  29.30
52635.0 52816.0   29.32  77.6  13.4   1.77 1.359   88.8    .328   1.068   4.7 171.3   ---   ---   -3.62  .694  94.2  332.0-24.6  39.57
  1.123  75.7   .3715  1.784  1.630  127.9  97.7 243.04-64.52 176.68    .00  80.06    LIGHT SIDE   LEADING EDGE         .00000
52876.0 53124.0   24.21 311.8 -16.5    .40  .742   95.5    .257   1.114 196.4 442.6   .828 1.401  -1.97 1.043 103.9  217.5-23.7  50.40
   .5560     .5941      .3737
  3.93456   3.38487   2.33569   2.56963   2.30689   2.05263   1.64250   1.72620  14.66104   6.11577   2.28775   1.08682   33.82148

52518.0 52636.3   18.60 219.4  27.1   5.86  .916   95.4    .179    .875 206.5 358.7   ---   ---   -7.21 1.281  89.8   91.5-61.5  29.74
52636.3 52816.0   29.55  76.0  11.6   1.54 1.359   88.4    .329   1.068   6.7 171.2   ---   ---   -3.38  .694  94.3  331.8-23.8  39.43
  1.165  74.1   .3669  1.764  1.661  127.0  97.4 242.30-63.64 178.71    .00  78.61    LIGHT SIDE   LEADING EDGE         .00000
52876.0 53124.0   24.21 311.8 -16.5    .40  .742   95.5    .257   1.114 196.4 442.6   .828 1.401  -1.97 1.043 103.9  217.5-23.7  50.40
   .5654     .5941      .3737
  3.98511   3.37628   2.33569   2.56963   2.33180   2.04888   1.64250   1.72620  14.67448   6.11293   2.28775   1.08682   34.21800

52520.0 52636.9   19.13 218.2  26.1   5.76  .918   95.9    .181    .877 208.5 359.8   ---   ---   -7.03 1.282  90.0   90.2-60.5  28.84
52636.9 52816.0   29.78  75.3  10.8   1.45 1.359   88.1    .329   1.068   7.7 171.2   ---   ---   -3.29  .694  94.3  331.7-23.5  39.40
  1.239  72.3   .3581  1.784  1.694  126.2  97.5 241.28-63.72 179.73    .00  77.83    LIGHT SIDE   LEADING EDGE         .00000
52876.0 53124.0   24.21 311.8 -16.5    .40  .742   95.5    .257   1.114 196.4 442.6   .828 1.401  -1.97 1.043 103.9  217.5-23.7  50.40
   .570[illegible]     .5941      .3737
  4.00736   3.37398   2.33569   2.56963   2.34310   2.04788   1.64250   1.72620  14.68688   6.11217   2.28775   1.08682   34.41209
```

TABLE 4. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2005 OPPOSITION

```
DEPARTURE PLANET - EARTH                                                                                         DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS                                                                                         PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                          ARRIVAL   PLANET - MARS

DEPART   PASS     C3-DD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL  C3-PD
PASS     ARRIVE   C3-PD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL  C3-AD
RCP      KAPPA    UP     AH    EH     ANMAX INH  RAP       DECP    RAS  DECS  ETA         PASS CONDITION                     DUCP

RESTART RETURN    C3-RS  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THEL  T1 T ET2  PERIH APHE I 2  V 2   PSI 2   R A  DECL  C3-RD
   CORD1      CORD2      CORD3
   DV1        DV2        DV3        DV4      GAM1      GA   M2      GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETAO


53154.0 53330.6   22.70 162.5 -12.2  -3.40  .840  87.2    .288    .789 173.1 448.8   .562 1.017   -.56 1.230 106.0   31.7 -2.0  99.50
533[illegible].6 53500.0   98.59  53.8   1.8     .46 1.345  76.6    .374   1.029  51.9 181.7   ---  1.414  -2.20  .666  89.0  309.5-26.2  38.99
  2.187  22.4   .4069   .528  5.143  101.2   9.7 312.69 -9.74 211.62    .00 100.91     DARK SIDE   LEADING EDGE           .00000
53560.0 53822.0   13.23 328.0   1.3    2.14  .771  90.7    .178   1.173 183.1 399.3   .964 1.382  -3.06 1.073  95.7  208.5-41.2  13.69
  1.3560    1.3309    .9620
  4.16053   3.34816   1.47368   1.05759   2.42035   2.03668   1.36764   1.25193  10.46622   4.33598   1.60242   1.02850   25.33190

53156.0 53331.3   22.47 162.3 -12.2  -3.40  .839  87.6    .288    .789 174.1 449.0   .561 1.016   -.45 1.230 106.0   32.6 -1.6  99.57
53331.3 53505.0   99.02  54.6   2.4     .61 1.345  76.5    .374   1.027  52.2 184.1   ---  1.411  -2.29  .668  87.6  307.2-27.1  38.43
  2.195  22.3   .4071   .527  5.168  101.2  10.3 313.65-10.25 212.63    .06 100.84     DARK SIDE   LEADING EDGE           .00000
53565.0 53823.0   13.43 325.9   1.0    2.22  .772  91.2    .178   1.173 185.4 399.4   .964 1.383  -3.21 1.073  95.7  209.0-42.4  13.99
  1.3593    1.2979    .9334
  4.15082   3.31201   1.49039   1.07079   2.41536   2.02110   1.37250   1.25545  10.39963   4.34443   1.60762   1.02891   25.11885

53158.0 53330.6   21.65 159.5 -11.4  -3.39  .840  88.6    .285    .790 176.4 448.3   .564 1.015   -.33 1.231 105.8   31.9 -1.2  97.14
53330.6 53505.0   95.72  54.4   2.5     .62 1.345  76.8    .371   1.029  51.1 184.0   ---  1.411  -2.31  .669  87.7  307.6-27.1  38.06
  2.207  22.7   .4027   .542  5.071  101.4   9.3 313.25 -9.28 211.62    .00 101.48     DARK SIDE   LEADING EDGE           .00000
53565.0 53823.0   13.43 325.9   1.0    2.22  .772  91.2    .178   1.173 185.4 399.4   .964 1.383  -3.21 1.073  95.7  209.0-42.4  13.99
  1.3560    1.2979    .9334
  4.11582   3.28820   1.49039   1.07079   2.39747   2.01090   1.37250   1.25545  10.31005   4.33894   1.60762   1.02891   24.71801

53160.0 53329.4   20.97 155.4 -10.0  -3.38  .842  89.7    .282    .792 179.2 447.2   .569 1.014   -.22 1.232 105.5   30.4  -.3  94.00
53329.4 53500.0   92.03  53.4   1.9     .47 1.346  77.2    .370   1.032  49.6 181.5   ---  1.414  -2.22  .668  89.1  310.2-26.2  38.32
  2.237  23.2   .3970   .562  4.980  101.6   6.8 311.98 -6.78 209.59    .00 102.30     DARK SIDE   LEADING EDGE           .00000
53560.0 53822.0   13.23 328.0   1.3    2.14  .771  90.7    .178   1.173 183.1 399.3   .964 1.382  -3.08 1.073  95.7  208.5-41.2  13.69
  1.3494    1.3309    .9620
  4.08682   3.30468   1.47368   1.05759   2.38274   2.01796   1.36764   1.25193  10.29548   4.32592   1.60242   1.02850   24.53144

53162.0 53329.4   21.01 153.9  -9.4  -3.39  .842  90.4    .281    .792 180.9 447.0   .570  ---    -.11 1.233 105.5   30.5  -.4  93.55
53329.4 53500.0   92.03  53.4   1.9     .47 1.346  77.2    .370   1.032  49.6 181.5   ---  1.414  -2.22  .668  89.1  310.2-26.2  38.32
  2.260  23.0   .3960   .564  5.011  101.5   5.8 312.05 -5.79 209.59    .00 102.39     DARK SIDE   LEADING EDGE           .00000
53560.0 53822.0   13.23 328.0   1.3    2.14  .771  90.7    .178   1.173 183.1 399.3   .964 1.382  -3.08 1.073  95.7  208.5-41.2  13.69
  1.3494    1.3309    .9620
  4.08843   3.30468   1.47368   1.05759   2.38356   2.01796   1.36764   1.25193  10.29657   4.32592   1.60242   1.02850   24.54247

53164.0 53330.0   21.28 153.6  -9.2  -3.39  .841  90.8    .282    .792 182.1 447.2   .569  ---     .01 1.232 105.5   31.4   .0  94.23
53330.0 53505.0   92.51  54.2   2.5     .63 1.346  77.1    .369   1.031  50.0 183.9   ---  1.411  -2.32  .670  87.7  307.9-27.1  37.71
  2.261  22.9   .3968   .560  5.038  101.4   6.5 312.96 -6.35 210.61    .00 102.28     DARK SIDE   LEADING EDGE           .00000
53565.0 53823.0   13.43 325.9   1.0    2.22  .772  91.2    .178   1.173 185.4 399.4   .964 1.383  -3.21 1.073  95.7  209.0-42.4  13.99
  1.3527    1.2979    .9334
  4.09979   3.26530   1.49039   1.07079   2.38931   2.00114   1.37250   1.25545  10.23680   4.33371   1.60762   1.02891   24.45892

53166.0 53330.0   21.58 152.1  -8.5  -3.41  .842  91.5    .282    .793 183.8 447.0   .569  ---     .12 1.233 105.5   31.5   .4  94.08
53330.0 53505.0   92.51  54.2   2.5     .63 1.346  77.1    .369   1.031  50.0 183.9   ---  1.411  -2.32  .670  87.7  307.9-27.1  37.71
  2.280  22.8   .3961   .560  5.068  101.4   5.5 313.00 -5.33 210.61    .00 102.34     DARK SIDE   LEADING EDGE           .00000
53565.0 53823.0   13.43 325.9   1.0    2.22  .772  91.2    .178   1.173 185.4 399.4   .964 1.383  -3.21 1.073  95.7  209.0-42.4  13.99
  1.3527    1.2979    .9334
  4.11281   3.26530   1.49039   1.07079   2.39593   2.00114   1.37250   1.25545  10.24561   4.33371   1.60762   1.02891   24.54778
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# TABLE 5. MARS STOPOVER MISSION WITH INBOUND VENUS SWINGBY MISSION DATA FOR 2007 OPPOSITION

```
DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH

LAUNCH   STOP      C3-DD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA    THET1 THET2   PERIH AF
DEPART   PASS      C3-DD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA    THET1 THET2   PERIH AF
PASS     ARRIVE    C3-PD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA    THET1 THET2   PERIH AF
RCP      KAPPA     VP     AH     EH      ANMAX INH    RAP      DECP      RAS   DECS  ETA
   CORD1      CORD2       CORD3
  DV1        DV2         DV3         DV4       GAM1       GA     M2        GAM3       GAM4       ETA1

54340.0 54530.0    32.12 102.0  46.2    3.77 1.140  95.8    .327  1.470 336.2 487.8   .989  -
54590.0 54746.9    50.62  99.7  24.7     .40  .627 107.5    .445  1.239 205.0 325.4   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.120  37.7   .4644   .535  3.994  108.9  12.4 213.12 -7.25 320.72   .00 107.45     DARK
   1.0688     1.6491     1.3531
  4.55375    3.11138    4.05997     1.34687   2.63125    1.93676    2.36918    1.33129  16.31778

54342.0 54532.0    30.51 101.5  46.1    3.67 1.140  95.4    .325  1.468 337.7 488.3   .991  -
54592.0 54746.9    53.09  99.3  24.7     .40  .631 108.2    .448  1.246 206.1 325.6   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.107  38.0   .4659   .533  3.075  109.0  12.4 212.98 -7.18 320.72   .00 107.59     DARK
   1.0882     1.6536     1.3531
  4.48743    3.04961    4.20398     1.34687   2.59442    1.91151    2.44279    1.33129  16.45708

54344.0 54532.0    29.45 101.2  45.2    3.46 1.141  95.1    .326  1.473 339.0 487.7   .993  -
54592.0 54746.9    53.09  99.3  24.7     .40  .631 108.2    .448  1.246 206.1 325.6   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.107  38.0   .4659   .533  3.075  109.0  12.4 212.98 -7.18 320.72   .00 107.59     DARK
   1.0882     1.6536     1.3531
  4.44373    3.08038    4.20398     1.34687   2.57044    1.92405    2.44279    1.33129  16.53755

54346.0 54532.0    28.51 100.8  44.5    3.28 1.143  94.8    .327  1.478 340.4 487.1   .995  -
54592.0 54746.9    53.09  99.3  24.7     .40  .631 108.2    .448  1.246 206.1 325.6   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.107  38.0   .4659   .533  3.075  109.0  12.4 212.98 -7.18 320.72   .00 107.59     DARK
   1.0882     1.6536     1.3531
  4.40449    3.11314    4.20398     1.34687   2.54910    1.93749    2.44279    1.33129  16.63330

54348.0 54532.0    27.66 100.3  43.8    3.12 1.144  94.5    .328  1.482 341.8 486.6   .996  -
54592.0 54746.9    53.09  99.3  24.7     .40  .631 108.2    .448  1.246 206.1 325.6   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.107  38.0   .4659   .533  3.075  109.0  12.4 212.98 -7.18 320.72   .00 107.59     DARK
   1.0882     1.6536     1.3531
  4.36923    3.14729    4.20398     1.34687   2.53007    1.95159    2.44279    1.33129  16.74121

54350.0 54532.0    26.90  99.8  43.1    2.98 1.145  94.2    .329  1.487 343.1 486.0   .997  -
54592.0 54746.9    53.09  99.3  24.7     .40  .631 108.2    .448  1.246 206.1 325.6   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.107  38.0   .4659   .533  3.075  109.0  12.4 212.98 -7.18 320.72   .00 107.59     DARK
   1.0882     1.6536     1.3531
  4.33766    3.18240    4.20398     1.34687   2.51316    1.96621    2.44279    1.33129  16.85921

54352.0 54532.0    26.23  99.1  42.6    2.86 1.147  93.8    .330  1.491 344.6 485.5   .999  -
54592.0 54746.9    53.09  99.3  24.7     .40  .631 108.2    .448  1.246 206.1 325.6   ---   -
54746.9 54908.0    98.99 321.0  11.8    3.36 1.214 105.4    .274   .783 269.1 533.8   .568  -
  1.107  38.0   .4659   .533  3.075  109.0  12.4 212.98 -7.18 320.72   .00 107.59     DARK
   1.0882     1.6536     1.3531
  4.30960    3.21812    4.20398     1.34687   2.49822    1.98118    2.44279    1.33129  16.98551
```

```
RTURE PLANET - MARS
AGE   PLANET - VENUS
VAL   PLANET - EARTH

  PSI 2    R A   DECL    VHP
  PSI 2    R A   DECL   C3-PD
  PSI 2    R A   DECL   C3-AD
                        DVCP
 ETA3      ETA4         ETA0

3 107.9   193.9-20.6    5.95
4  79.5   283.0  7.1   96.64
6  92.3    93.7 18.3   20.36
 EDGE          .00000
2095    1.03782    42.93616

2 107.7   194.8-20.6    5.87
6  79.5   282.7  7.1   97.09
6  92.3    93.7 18.3   20.36
 EDGE          .00000
3944    1.03782    42.69652

3 107.8   195.7-19.9    5.91
6  79.5   282.7  7.1   97.09
6  92.3    93.7 18.3   20.36
 EDGE          .00000
3944    1.03782    42.50881

5 108.0   196.5-19.3    5.95
6  79.5   282.7  7.1   97.09
6  92.3    93.7 18.3   20.36
 EDGE          .00000
3944    1.03782    42.39993

6 108.1   197.2-18.8    5.99
6  79.5   282.7  7.1   97.09
6  92.3    93.7 18.3   20.36
 EDGE          .00000
3944    1.03782    42.35650

8 108.3   197.9-18.4    6.04
6  79.5   282.7  7.1   97.09
6  92.3    93.7 18.3   20.36
 EDGE          .00000
3944    1.03782    42.36991

9 108.4   198.5-17.9    6.08
6  79.5   282.7  7.1   97.09
6  92.3    93.7 18.3   20.36
 EDGE          .00000
3944    1.03782    42.43362
```

TABLE 6. MARS STOPOVER MISSION WITH DOUBLE VENUS SWINGBY MISSION DATA FOR OUTBOUND LEG FOR 2010 OPPOSITION

DEPARTURE PLANET - EARTH
PASSAGE PLANET - VENUS
ARRIVAL PLANET - MARS

DEPARTURE PLANET - EARTH
PASSAGE PLANET - VENUS
ARRIVAL PLANET - MARS

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPART | PASS | C3-DD | R A | DECL | I 1 | V 1 | PSI 1 | ECCEN | SMA | THET1 | THET2 | PERIH | APHEL | I 2 | V 2 | PSI 2 | R A | DECL | C3-PD |
| PASS | ARRIVE | C3-PD | R A | DECL | I 1 | V 1 | PSI 1 | ECCEN | SMA | THET1 | THET2 | PERIH | APHEL | I 2 | V 2 | PSI 2 | R A | DECL | C3-AD |
| RCP | KAPPA | VP | AH | EH | ANMAX | INH | RAP | DECP | RAS | DECS | ETA | PASS | CONDITION | | | | | | DUCP |
| CORD1 | CORD2 | | | | | | | | | | | | | | | | | | |
| DV1 | DV2 | DV3 | | DV4 | GAM1 | | GA | M2 | GAM3 | | GAM4 | ETA1 | | ETA2 | | ETA3 | ETA4 | | ETA0 |
| 54848.0 | 54979.5 | 24.15 | 26.6 | -45.1 | -7.90 | .932 | 92.5 | .152 | .858 | 194.0 | 362.3 | .728 | --- | 10.74 | 1.258 | 90.3 | 240.7 | 73.9 | 52.79 |
| 54979.5 | 55196.0 | 58.33 | 279.9 | 12.5 | 2.32 | 1.378 | 96.1 | .395 | 1.179 | 338.4 | 529.5 | .713 | --- | -.39 | .617 | 96.7 | 128.4 | 17.5 | 18.45 |
| 1.100 | 65.3 | .4121 | .942 | 2.168 | 117.5 | 79.1 | 111.15 | 38.58 | 333.28 | .00 | 125.44 | DARK SIDE | | LEADING EDGE | | | | | 1.34826 |
| .6301 | .7466 | | | | | | | | | | | | | | | | | | |
| .6301 | .7466 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.22166 | 3.24672 | .00000 | | .00000 | 2.45198 | | 1.99326 | | .00000 | | .00000 | 2.66310 | | 1.12266 | | .00000 | .00000 | | 6.52987 |
| 54850.0 | 54980.5 | 24.98 | 25.7 | -45.1 | -8.00 | .932 | 92.8 | .153 | .859 | 195.8 | 363.7 | .728 | --- | 10.77 | 1.259 | 90.5 | 238.7 | 73.8 | 53.21 |
| 54986.5 | 55196.0 | 57.28 | 279.7 | 14.7 | 2.70 | 1.379 | 95.7 | .394 | 1.180 | 339.7 | 529.3 | .715 | --- | -.78 | .618 | 96.8 | 128.6 | 15.7 | 18.43 |
| 1.100 | 63.4 | .4117 | .947 | 2.162 | 117.6 | 78.6 | 111.82 | 38.21 | 334.86 | .00 | 125.05 | DARK SIDE | | LEADING EDGE | | | | | 1.07375 |
| .6381 | .7466 | | | | | | | | | | | | | | | | | | |
| .6381 | .7466 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.25688 | 2.97065 | .00000 | | .00000 | 2.47940 | | 1.87971 | | .00000 | | .00000 | 2.48265 | | 1.10714 | | .00000 | .00000 | | 6.13314 |
| 54852.0 | 54981.5 | 25.84 | 24.8 | -45.0 | -8.08 | .933 | 93.1 | .154 | .860 | 197.6 | 365.0 | .728 | --- | 10.79 | 1.259 | 90.7 | 236.8 | 73.7 | 53.54 |
| 54981.5 | 55204.0 | 56.63 | 280.4 | 15.3 | 2.78 | 1.379 | 95.6 | .393 | 1.180 | 340.2 | 532.0 | .716 | --- | -.87 | .614 | 95.1 | 126.3 | 15.9 | 17.83 |
| 1.100 | 63.3 | .4115 | .949 | 2.159 | 117.6 | 77.9 | 113.22 | 37.68 | 336.29 | .00 | 125.33 | DARK SIDE | | LEADING EDGE | | | | | 1.04667 |
| .6461 | .7082 | | | | | | | | | | | | | | | | | | |
| .6461 | .7082 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.29294 | 2.89562 | .00000 | | .00000 | 2.48940 | | 1.84999 | | .00000 | | .00000 | 2.44066 | | 1.10314 | | .00000 | .00000 | | 6.07578 |
| 54854.0 | 54982.5 | 26.72 | 23.9 | -44.8 | -8.15 | .933 | 93.5 | .155 | .861 | 199.5 | 366.4 | .727 | --- | 10.80 | 1.259 | 90.9 | 235.0 | 73.4 | 53.80 |
| 54982.5 | 55196.0 | 57.74 | 279.1 | 22.2 | 4.03 | 1.379 | 94.9 | .393 | 1.183 | 342.4 | 528.8 | .718 | --- | -2.12 | .620 | 97.1 | 128.4 | 9.9 | 18.80 |
| 1.100 | 56.5 | .4124 | .938 | 2.173 | 117.4 | 77.2 | 114.27 | 37.00 | 338.02 | .00 | 125.23 | DARK SIDE | | LEADING EDGE | | | | | .21559 |
| .6541 | .7466 | | | | | | | | | | | | | | | | | | |
| .6541 | .7466 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.33013 | 2.14091 | .00000 | | .00000 | 2.50915 | | 1.57592 | | .00000 | | .00000 | 2.01741 | | 1.06764 | | .00000 | .00000 | | 5.06198 |
| 54856.0 | 54983.5 | 27.64 | 23.0 | -44.5 | -8.22 | .934 | 93.8 | .156 | .862 | 201.3 | 367.8 | .727 | --- | 10.80 | 1.260 | 91.1 | 233.2 | 73.0 | 53.99 |
| 54983.5 | 55200.0 | 57.78 | 279.1 | 24.4 | 4.40 | 1.379 | 94.7 | .392 | 1.183 | 343.4 | 530.0 | .719 | --- | -2.50 | .618 | 96.3 | 127.1 | 8.5 | 18.57 |
| 1.107 | 54.5 | .4118 | .936 | 2.182 | 117.3 | 76.4 | 115.66 | 36.35 | 339.61 | .00 | 125.44 | DARK SIDE | | LEADING EDGE | | | | | .00000 |
| .6621 | .7261 | | | | | | | | | | | | | | | | | | |
| .6621 | .7261 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.36836 | 1.90763 | .00000 | | .00000 | 2.52961 | | 1.49972 | | .00000 | | .00000 | 1.90799 | | 1.05817 | | .00000 | .00000 | | 4.82646 |
| 54858.0 | 54984.5 | 28.60 | 22.1 | -44.2 | -8.27 | .934 | 94.2 | .158 | .863 | 203.2 | 369.2 | .727 | --- | 10.78 | 1.260 | 91.3 | 231.5 | 72.6 | 54.14 |
| 54984.5 | 55204.0 | 57.75 | 279.2 | 26.0 | 4.66 | 1.379 | 94.4 | .391 | 1.183 | 344.3 | 531.3 | .720 | --- | -2.77 | .616 | 95.5 | 126.0 | 7.6 | 18.41 |
| 1.152 | 53.2 | .4067 | .935 | 2.232 | 116.6 | 75.6 | 116.87 | 35.20 | 341.06 | .00 | 125.87 | DARK SIDE | | LEADING EDGE | | | | | .00000 |
| .6701 | .7082 | | | | | | | | | | | | | | | | | | |
| .6701 | .7082 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.40847 | 1.89504 | .00000 | | .00000 | 2.55126 | | 1.4957 | | .00000 | | .00000 | 1.90746 | | 1.05767 | | .00000 | .00000 | | 4.86643 |
| 54860.0 | 54985.5 | 29.61 | 21.2 | -43.7 | -8.32 | .935 | 94.5 | .160 | .864 | 205.0 | 370.6 | .726 | --- | 10.75 | 1.261 | 91.5 | 229.9 | 72.0 | 54.24 |
| 54985.5 | 55210.0 | 56.86 | 279.4 | 26.4 | 4.70 | 1.379 | 94.1 | .390 | 1.183 | 345.3 | 533.3 | .721 | --- | -2.83 | .613 | 94.3 | 124.4 | 7.6 | 18.12 |
| 1.172 | 52.9 | .4040 | .941 | 2.245 | 116.5 | 74.7 | 118.01 | 34.61 | 342.77 | .00 | 125.76 | DARK SIDE | | LEADING EDGE | | | | | .00000 |
| .6782 | .6865 | | | | | | | | | | | | | | | | | | |
| .6782 | .6865 | 1.3977 | | | | | | | | | | | | | | | | | |
| 4.45043 | 1.87214 | .00000 | | .00000 | 2.57410 | | 1.48845 | | .00000 | | .00000 | 1.90237 | | 1.05678 | | .00000 | .00000 | | 4.89688 |

# TABLE 7. MARS STOPOVER MISSION WITH DOUBLE VENUS SWINGBY MISSION DATA FOR INBOUND LEG FOR 2010 OPPOSITION

```
DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS                                                                                              DEPARTURE PLANET - MARS
ARRIVAL   PLANET - EARTH                                                                                              PASSAGE   PLANET - VENUS
DEPAPT    PASS     C3-DD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL  I 2  ARRIVAL   PLANET - EARTH
PASS      ARRIVE   C3-PD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL  I 2  V 2   PSI 2   R A  DECL  C3-PD
RCP       KAPPA    UP     AH    EH     ANMAX INH  RAP       DECP   RAS  DECS  ETA        PASS CONDITION  V 2   PSI 2   R A  DECL  C3-AD
   CORD1     CORD2                                                                                                            DVCP
   DV1       DV2       DV3     DV4     GAM1     GA    M2     GAM3     GAM4     ETA1     ETA2     ETA3     ETA4     ETA0

55256.0 55433.5   46.68  87.9  22.3  -0.64 0.635 105.8  0.418  1.249 204.8 354.3   ---   ---    2.40 1.395  88.3  261.7 14.6  49.84
55433.5 55590.0   44.27 276.7  ?3.5   5.59 1.257  91.4  0.151  0.856 349.0 545.1  0.726 0.985  -7.09 0.929  89.1   43.2-36.6  19.89
  1.271  56.6  0.3818  1.112  2.143  117.8  83.9 253.55-47.10 340.64  0.00  88.02    LIGHT SIDE   TRAILING EDGE      0.00000
  1.4749    2.3764
  1.4749    2.3764    1.3971
  3.82548   1.32674   0.00000   0.00000   2.25405   1.32560   0.00000   0.00000   1.88485   1.03715   0.00000   0.00000   4.24856

55258.0 55436.8   48.43  87.8  21.5  -0.95 0.637 106.3  0.420  1.255 205.7 357.9   ---   ---    2.73 1.396  89.4  258.7 16.3  49.74
55435.8 55594.0   45.71 276.4  70.5   9.80 1.257  91.2  0.152  0.857 350.8 547.5  0.727 0.987  -7.47 0.929  88.7   43.4-37.4  21.56
  1.268  55.3  0.3232  1.096  2.156  117.6  83.2 249.68-45.54 344.21  0.00  93.17    DARK SIDE    TRAILING EDGE      0.00000
  1.5033    2.3754
  1.5033    2.3754    1.3971
  3.93070   1.39783   0.00000   0.00000   2.30500   1.34578   0.00000   0.00000   1.92538   1.03954   0.00000   0.00000   4.43800

55260.0 55432.8   51.48  87.4  22.6  -0.52 0.640 107.2  0.424  1.261 207.0 353.6   ---   ---    2.35 1.398  88.1  261.8 13.8  51.13
55432.8 55588.0   46.06 276.8  70.0   9.82 1.256  91.5  0.151  0.855 348.5 543.7  0.726 0.985  -7.26 0.929  89.3   44.1-37.1  20.37
  1.181  57.0  0.3932  1.077  2.097  118.5  84.1 253.87-47.30 339.46  0.00  87.01    LIGHT SIDE   TRAILING EDGE      0.00000
  1.4654    2.3768
  1.4654    2.3768    1.3971
  4.11038   1.34750   0.00000   0.00000   2.39470   1.33146   0.00000   0.00000   1.92757   1.03784   0.00000   0.00000   4.61594

55262.0 55432.8   54.02  87.2  22.7  -0.51 0.644 107.9  0.427  1.268 208.2 353.8   ---   ---    2.34 1.400  88.2  261.3 13.7  51.61
55432.8 55588.0   46.06 276.8  70.0   9.82 1.256  91.5  0.151  0.856 348.5 543.7  0.726 0.985  -7.26 0.929  89.3   44.1-37.1  20.37
  1.169  57.1  0.3948  1.072  2.091  118.6  83.9 253.20-47.32 339.46  0.00  87.47    LIGHT SIDE   TRAILING EDGE      0.00000
  1.4654    2.3768
  1.4654    2.3768    1.3971
  4.25710   1.34750   0.00000   0.00000   2.47052   1.33146   0.00000   0.00000   1.94675   1.03784   0.00000   0.00000   4.80947

55264.0 55432.8   56.70  87.1  22.8  -0.50 0.647 108.6  0.430  1.276 209.3 354.1   ---   ---    2.32 1.401  88.2  260.8 13.5  52.13
55432.8 55588.0   46.06 276.8  70.0   9.82 1.256  91.5  0.151  0.855 348.5 543.7  0.726 0.985  -7.26 0.929  89.3   44.1-37.1  20.37
  1.157  57.3  0.3965  1.066  2.085  118.7  83.7 252.49-47.34 339.46  0.00  87.95    LIGHT SIDE   TRAILING EDGE      0.00000
  1.4654    2.3768
  1.4654    2.3768    1.3971
  4.40989   1.34750   0.00000   0.00000   2.55203   1.33146   0.00000   0.00000   1.96779   1.03784   0.00000   0.00000   5.02187

55266.0 55432.8   59.53  86.9  22.8  -0.49 0.650 109.3  0.434  1.283 210.5 354.4   ---   ---    2.31 1.403  88.3  260.3 13.4  52.68
55432.8 55588.0   46.06 276.8  70.0   9.82 1.256  91.5  0.151  0.855 348.5 543.7  0.726 0.985  -7.26 0.929  89.3   44.1-37.1  20.37
  1.144  57.5  0.3984  1.060  2.079  118.8  83.6 251.76-47.35 339.46  0.00  88.44    LIGHT SIDE   TRAILING EDGE      0.00000
  1.4654    2.3768
  1.4654    2.3768    1.3971
  4.56800   1.34750   0.00000   0.00000   2.63920   1.33146   0.00000   0.00000   1.99082   1.03784   0.00000   0.00000   5.25417

55268.0 55437.3   61.07  87.3  21.5  -1.05 0.653 109.7  0.435  1.289 211.2 361.3  0.728  ---    2.78 1.404  90.4  254.7 16.2  52.80
55437.3 55596.0   48.99 275.9  71.9  10.24 1.257  91.0  0.152  0.857 352.2 548.5  0.727 0.988  -8.00 0.929  88.6   44.3-38.6  23.78
  1.123  57.1  0.4030  1.028  2.092  118.5  82.6 245.11-44.65 346.57  0.00  98.13    DARK SIDE    TRAILING EDGE      0.00000
  1.5221    2.3748
  1.5221    2.3748    1.3971
  4.65290   1.49263   0.00000   0.00000   2.68724   1.37316   0.00000   0.00000   2.06523   1.04280   0.00000   0.00000   5.54978
```

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TABLE 8. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2012 OPPOSITION

```
DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                     DEPARTURE PLANET - EARTH
                                                                                                            PASSAGE   PLANET - VENUS
                                                                                                            ARRIVAL   PLANET - MARS
DEPART    PASS     C3-DD  R A    DECL    I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A   DECL  C3-PD
PASS      ARRIVE   C3-PD  R A    DECL    I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A   DECL  C3-AD
RCF       KAPPA    UP     AH     EH      ANMAX INH   RAP        DECP    RAS  DECS  ETA        PASS CONDITION                        DVCP
RESTART RETURN     C3-RS  R A    DECL    I 1   V 1   PSI 1   ECCEN SMA    THEL  T1 THET2  PERIH APHE I 2  V 2   PSI 2   R A   DECL  C3-RD
   CORD1      CORD2      CORD3
   DV1        DV2        DV3     DV4       GAM1      GA      M2       GAM3      GAM4     ETA1      ETA2      ETA3      ETA4      ETA0

55520.0 55689.4   30.48 334.8   6.7    3.49  .840  88.1   .304    .759 175.7 460.2  .528  .989     1.20 1.196 107.6  205.4  3.7 119.35
55689.4 55838.0  117.50 237.1   1.0     .29 1.373  76.5   .430   1.158  46.2 159.6  ---   ---      1.81  .633 104.1  128.2 25.5  30.68
  1.170   31.8    .4841   .442 3.650 105.9    5.5 131.02  4.88   29.85    .00 101.13    DARK SIDE   LEADING EDGE            .00000
55898.0 56176.0   16.75  74.9  10.4   -2.62  .666  95.2   .287   1.286 193.1 413.5   .917 1.656   2.73 1.098 101.2  358.0 12.2  54.40
  1.4692     1.7966     1.3082
 4.48616    2.79639    1.76293   2.72386   2.59372   1.81140   1.45432   1.78370  12.10875  5.51286  2.31780  1.09434  31.40664

55522.0 55689.4   29.52 333.2   6.3    3.46  .841  88.9   .302    .759 177.4 459.9  .530  .988     1.07 1.196 107.4  205.5  3.4 117.52
55689.4 55842.0  115.71 237.3    .8     .22 1.372  76.7   .428   1.155  46.0 161.3  ---   ---      1.84  .628 102.9  126.8 26.0  28.87
  1.187   31.8    4805    .448 3.646 105.9    5.1 131.22  4.65   29.85    .00 101.33    DARK SIDE   LEADING EDGE            .00000
55902.0 56178.0   17.44  75.9  11.1   -2.57  .664  95.6   .291   1.287 194.1 414.6   .912 1.662   2.75 1.099 101.5  359.1 12.4  57.00
  1.4692     1.7683     1.2717
 4.44643    2.67040    1.81828   2.82314   2.57191   1.76355   1.47152   1.82172  11.97931  5.61818  2.37598  1.09937  30.80976

55524.0 55688.8   28.45 330.3   5.3    3.42  .843  90.0   .299    .760 179.9 459.4  .533  .987      .94 1.197 107.2  204.8  3.0 114.82
55688.8 55840.0  112.56 237.2   1.0     .25 1.373  77.0   .427   1.159  44.9 160.3  ---   ---      1.82  .632 103.5  127.8 25.7  29.46
  1.188   32.4    .4769   .460 3.583 106.2    4.2 130.87  3.67   28.86    .00 101.98    DARK SIDE   LEADING EDGE            .00000
55900.0 56178.0   16.79  76.0  11.1   -2.53  .664  95.2   .290   1.285 193.1 414.6   .912 1.657   2.68 1.099 101.4  359.2 12.2  56.39
  1.4661     1.7828     1.2899
 4.40197    2.71183    1.76622   2.79980   2.54774   1.77914   1.45533   1.81271  11.92028  5.55933  2.35881  1.09817  30.36976

55526.0 55688.8   28.13 328.7   4.7    3.40  .844  90.7   .298    .761 181.7 459.1  .534  ---       .82 1.198 107.1  204.9  2.6 113.79
55688.8 55840.0  112.56 237.2   1.0     .25 1.373  77.0   .427   1.159  44.9 160.3  ---   ---      1.82  .632 103.5  127.8 25.7  29.46
  1.201   32.3    .4752   .462 3.599 106.1    3.5 130.96  3.01   28.86    .00 102.09    DARK SIDE   LEADING EDGE            .00000
55900.0 56178.0   16.79  76.0  11.1   -2.53  .664  95.2   .290   1.285 193.1 414.6   .912 1.657   2.68 1.099 101.4  359.2 12.2  56.39
  1.4661     1.7828     1.2899
 4.38865    2.71183    1.76622   2.79980   2.54054   1.77914   1.45533   1.81271  11.90891  5.55933  2.35881  1.09817  30.25501

55528.0 55688.8   28.06 327.0   4.0    3.39  .845  91.5   .297    .761 183.5 458.9  .535  ---       .70 1.198 107.1  205.1  2.3 113.06
55688.8 55842.0  111.70 237.3    .8     .22 1.373  77.0   .426   1.157  44.8 161.2  ---   ---      1.83  .630 103.0  127.1 26.8  28.59
  1.211   32.2    .4734   .465 3.603 106.1    3.0 131.10  2.56   28.86    .00 102.22    DARK SIDE   LEADING EDGE            .00000
55902.0 56178.0   17.44  75.9  11.1   -2.57  .664  95.6   .291   1.287 194.1 414.6   .912 1.662   2.75 1.099 101.5  359.1 12.4  57.00
  1.4661     1.7688     1.2717
 4.38601    2.65126    1.81828   2.82314   2.53911   1.75640   1.47152   1.82172  11.86868  5.61335  2.37598  1.09937  30.13591

55530.0 55688.8   28.26 325.1   3.3    3.38  .846  92.2   .296    .762 185.3 458.7  .536  ---       .58 1.199 107.1  205.2  1.9 112.66
55688.8 55844.0  110.84 237.4    .7     .19 1.372  77.1   .425   1.156  44.7 162.0  ---   ---      1.85  .627 102.4  126.4 26.3  27.81
  1.218   32.2    .4720   .468 3.603 106.1    2.5 131.23  2.11   28.86    .00 102.36    DARK SIDE   LEADING EDGE            .00000
55904.0 56180.0   17.48  77.1  11.7   -2.48  .663  95.7   .294   1.285 194.1 415.7   .907 1.663   2.70 1.099 101.8     .4 12.5  59.03
  1.4661     1.7546     1.2533
 4.39435    2.59563    1.82108   2.90016   2.54361   1.73576   1.47240   1.85177  11.85574  5.67053  2.41891  1.1033   30.15643

55532.0 55688.8   28.71 323.8   2.6    3.37  .847  93.0   .296    .763 187.1 458.5  .537  ---       .46 1.199 107.0  205.3  1.5 112.53
55688.8 55844.0  110.84 237.4    .7     .19 1.372  77.1   .425   1.156  44.7 162.0  ---   ---      1.85  .627 102.4  126.4 26.3  27.81
  1.225   32.1    .4714   .468 3.617 106.1    1.8 131.30  1.42   28.86    .00 102.44    DARK SIDE   LEADING EDGE            .00000
55904.0 56180.0   17.48  77.1  11.7   -2.48  .663  95.7   .294   1.285 194.1 415.7   .907 1.663   2.70 1.099 101.8     .4 12.5  59.03
  1.4661     1.7546     1.2533
 4.41301    2.59563    1.82108   2.90016   2.55372   1.73576   1.47240   1.85177  11.87163  5.67643  2.41891  1.10338  30.31678
```

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# TABLE 9. MARS STOPOVER MISSION WITH INBOUND VENUS SWINGBY MISSION DATA FOR 2014 OPPOSITION

```
DEPARTURE PLANET - MARS                                                                                      DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS                                                                                     PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH                                                                                     ARRIVAL   PLANET - EARTH

LAUNCH   STOP      C3-DD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA     THET1 THET2   PERIH APHEL   I 2   V 2    PSI 2    R A   DECL    VHP
DEPART   PASS      C3-DD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA     THET1 THET2   PERIH APHEL   I 2   V 2    PSI 2    R A   DECL    C3-PD
PASS     ARRIVE    C3-PD  R A    DECL    I 1   V 1    PSI 1    ECCEN SMA     THET1 THET2   PERIH APHEL   I 2   V 2    PSI 2    R A   DECL    C3-AD
RCP      KAPPA     VP     AH     EH      ANMAX INH    RAP        DECP     RAS  DECS  ETA          PASS CONDITION                           DVCP
   CORD1     CORD2      CORD3
  DV1       DV2       DV3       DV4       GAM1      GA      M2       GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETA0

56618.0 56888.0    11.98 197.9  18.0    2.43 1.097  94.2    .202  1.218 334.4 540.8   .972 1.464   -.68  .738  89.8  304.2-24.4   3.66
56948.0 57083.1    40.44 286.7 -28.1   -1.58  .682  99.0    .378  1.041 195.5 308.5   ---   ---    -.67 1.345  76.5   79.4 -2.6  97.84
57083.1 57252.0    98.82 102.7 -11.1   -3.13 1.225 105.9    .285   .788 270.4 540.4   .563 1.012  -1.32  .840  89.8  232.7-26.7  19.71
  1.959  24.7   .4136   .532  4.684  102.3  21.4     3.50 20.11 102.44   .00  98.39     DARK SIDE   LEADING EDGE         .00000
   1.2950    1.6164    1.3814
  3.69589   1.48527   3.44017   1.31914   2.19284   1.37101   2.07689   1.32346   9.00274   5.70489   1.84029   1.03689   19.74156

56620.0 56888.0    11.79 198.8  20.0    2.62 1.098  94.0    .201  1.219 336.1 540.4   .973 1.464   -.89  .738  89.9  305.2-25.4   3.68
56948.0 57083.1    40.44 286.7 -28.1   -1.58  .682  99.0    .378  1.041 195.5 308.5   ---   ---    -.67 1.345  76.5   79.4 -2.6  97.84
57083.1 57252.0    98.82 102.7 -11.1   -3.13 1.225 105.9    .285   .788 270.4 540.4   .563 1.012  -1.32  .840  89.8  232.7-26.7  19.71
  1.959  24.7   .4136   .532  4.684  102.3  21.4     3.50 20.11 102.44   .00  98.39     DARK SIDE   LEADING EDGE         .00000
   1.2950    1.6164    1.3814
  3.68775   1.49837   3.44017   1.31914   2.18905   1.37483   2.07689   1.32346   9.02745   5.70739   1.84029   1.03689   19.76153

56622.0 56894.0    11.21 199.1  21.5    2.69 1.097  93.6    .198  1.216 337.8 543.5   .975 1.458   -.99  .742  89.1  303.8-26.7   3.52
56954.0 57084.4    43.38 283.3 -28.1   -1.51  .690 100.8    .378  1.048 198.9 310.2   ---   ---    -.78 1.348  76.9   80.1 -3.2  94.60
57084.4 57252.0    96.74 104.3 -11.3   -3.13 1.226 105.7    .283   .789 271.2 539.2   .566  ---   -1.21  .842  90.3  235.8-26.8  19.41
  1.943  25.4   .4106   .547  4.554  102.7  20.1     4.59 18.61 104.45   .00  99.34     DARK SIDE   LEADING EDGE         .00000
   1.3301    1.6457    1.3750
  3.66198   1.39998   3.62429   1.30603   2.17710   1.34639   2.15974   1.31978   9.09309   5.87920   1.85448   1.03646   19.79654

56624.0 56894.0    11.17 199.9  23.8    2.90 1.098  93.4    .198  1.217 339.5 543.2   .976 1.458  -1.22  .742  89.2  304.8-28.0   3.54
56954.0 57084.4    43.38 283.3 -28.1   -1.51  .690 100.8    .378  1.048 198.9 310.2   ---   ---    -.78 1.348  76.9   80.1 -3.2  94.60
57084.4 57252.0    96.74 104.3 -11.3   -3.13 1.226 105.7    .283   .789 271.2 539.2   .566  ---   -1.21  .842  90.3  235.8-26.8  19.41
  1.943  25.4   .4106   .547  4.554  102.7  20.1     4.59 18.61 104.45   .00  99.34     DARK SIDE   LEADING EDGE         .00000
   1.3301    1.6457    1.3750
  3.66004   1.41345   3.62429   1.30603   2.17620   1.35025   2.15974   1.31978   9.12213   5.88180   1.85448   1.03646   19.85161

56626.0 56894.0    11.26 200.9  26.5    3.16 1.098  93.1    .197  1.218 341.1 542.8   .978 1.457  -1.50  .742  89.3  305.8-29.5   3.57
56954.0 57084.4    43.38 283.3 -28.1   -1.51  .690 100.8    .378  1.048 198.9 310.2   ---   ---    -.78 1.348  76.9   80.1 -3.2  94.60
57084.4 57252.0    96.74 104.3 -11.3   -3.13 1.226 105.7    .283   .789 271.2 539.2   .566  ---   -1.21  .842  90.3  235.8-26.8  19.41
  1.343  25.4   .4106   .547  4.554  102.7  20.1     4.59 18.61 104.45   .00  99.34     DARK SIDE   LEADING EDGE         .00000
   1.3301    1.6457    1.3750
  3.66428   1.43023   3.62429   1.30603   2.17816   1.35507   2.15974   1.31978   9.16203   5.88504   1.85448   1.03646   19.95640

56628.0 56894.0    11.55 202.0  29.6    3.47 1.099  92.8    .196  1.218 342.8 542.5   .979 1.457  -1.83  .743  89.4  306.9-31.3   3.50
56954.0 57084.4    43.38 283.3 -28.1   -1.51  .690 100.8    .378  1.048 198.9 310.2   ---   ---    -.78 1.348  76.9   80.1 -3.2  94.60
57084.4 57252.0    96.74 104.3 -11.3   -3.13 1.226 105.7    .283   .789 271.2 539.2   .566  ---   -1.21  .842  90.3  235.8-26.8  19.41
  1.943  25.4   .4106   .547  4.554  102.7  20.1     4.59 18.61 104.45   .00  99.34     DARK SIDE   LEADING EDGE         .00000
   1.3301    1.6457    1.3750
  3.67676   1.45193   3.62429   1.30603   2.18394   1.36133   2.15974   1.31978   9.21770   5.88926   1.85448   1.03646   20.13094

56630.0 56894.0    12.99 203.4  33.0    3.85 1.099  92.5    .196  1.219 344.6 542.2   .980 1.457  -2.24  .743  89.5  308.1-33.5   3.65
56954.0 57084.4    43.38 283.3 -28.1   -1.51  .690 100.8    .378  1.048 198.9 310.2   ---   ---    -.78 1.348  76.9   80.1 -3.2  94.60
57084.4 57252.0    96.74 104.3 -11.3   -3.13 1.226 105.7    .283   .789 271.2 539.2   .566  ---   -1.21  .842  90.3  235.8-26.8  19.41
  1.943  25.4   .4106   .547  4.554  102.7  20.1     4.59 18.61 104.45   .00  99.34     DARK SIDE   LEADING EDGE         .00000
   1.3301    1.6457    1.3750
  3.70074   1.48122   3.62429   1.30603   2.19510   1.36983   2.15974   1.31978   9.29740   5.89500   1.85448   1.03646   20.40871
```

TABLE 10. MARS STOPOVER MISSION WITH INBOUND VENUS SWINGBY MISSION DATA FOR 2016 OPPOSITION

```
DEPARTURE PLANET - MARS                                                                                          DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS                                                                                         PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH                                                                                         ARRIVAL   PLANET - EARTH

LAUNCH   STOP      C3-DD  R A   DECL    I 1   V 1    PSI 1   ECCEN SMA     THET1 THET2  PERIH APHEL   I 2  V 2    PSI 2    R A  DECL   VHP
DEPART   PASS      C3-DD  R A   DECL    I 1   V 1    PSI 1   ECCEN SMA     THET1 THET2  PERIH APHEL   I 2  V 2    PSI 2    R A  DECL  C3-PD
PASS     ARRIVE    C3-PD  R A   DECL    I 1   V 1    PSI 1   ECCEN SMA     THET1 THET2  PERIH APHEL   I 2    V 2  PSI 2    R A  DECL  C3-AD
RCP      KAPPA     UP     AH    EH     ANMAX INH    RAP       DECP     RAS  DECS  ETA          PASS CONDITION                          DVCP
   CORD1       CORD2       CORD3
  DV1          DV2         DV3         DV4         GAM1        GA     M2      GAM3       GAM4        ETA1       ETA2       ETA3        ETA4       ETA0

57324.0 57590.0   40.52 203.4  -1.9    1.50 1.073 102.0    .251  1.160 292.1 531.6   .869  ---       .56  .722  92.8   315.5-14.7   4.90
57650.0 57831.9   48.86 293.3 -29.8   -2.63  .676 100.0    .397  1.022 195.9 420.5   .616  ---      1.29 1.342 106.1    59.6  4.3 130.36
57831.9 57908.0  127.97  39.0   -.7    -.24 1.216  71.6    .322   .769  97.6 175.6   ---   ---     -3.44  .819  92.1   164.0-10.6  27.83
  1.799  21.2   .4596   .495  5.443  100.5 166.0 139.77 13.92 223.33   .00  83.75    LIGHT SIDE   LEADING EDGE             .00000
   .6615      .9938    .2859
  4.89448    2.31987    3.95643    1.66268    2.82876    1.63699    2.31764    1.42367  14.04837   6.85547   2.03876   1.04888   39.73948

57326.0 57594.0   38.71 205.0  -2.0    1.55 1.073 101.7    .247  1.159 293.0 532.9   .873  ---       .49  .724  92.3   315.8-14.9   4.76
57654.0 57834.4   51.40 294.1 -29.4   -2.61  .676 100.5    .402  1.019 196.4 422.5   .609  ---      1.35 1.340 106.8    62.4  4.4 138.43
57834.4 57913.0  138.85  41.7    .1     .05 1.210  70.7    .334   .761 100.6 179.2   ---   ---     -3.38  .810  90.4   161.7 -8.6  29.65
  1.681  21.1   .4759   .377  5.457  100.6 168.0 142.48 11.73 227.37   .00  85.00    LIGHT SIDE   LEADING EDGE             .00000
   .6819     1.0169    .2826
  4.82176    2.22032    4.10603    1 [illegible]847    2.78540    1.60273    2.39248    1.44678  14.21554   7.12764   2.09200   1.05169   39.59590

57328.0 57596.0   37.38 206.4  -2.1    1.60 1.074 101.5    .244  1.160 294.0 533.1   .877  ---       .42  .726  92.2   316.6-15.0   4.71
57656.0 57834.4   53.11 293.1 -29.6   -2.67  .678 101.2    .404  1.021 197.5 422.4   .609  ---      1.44 1.341 106.8    62.5  4.7 138.97
57834.4 57913.0  138.85  41.7    .1     .05 1.210  70.7    .334   .761 100.6 179.2   ---   ---     -3.38  .810  90.4   161.7 -8.6  29.65
  1.665  21.2   .4769   .376  5.424  100.6 167.4 142.58 12.37 227.37   .00  84.92    LIGHT SIDE   LEADING EDGE             .00000
   .6923     1.0284    .2826
  4.76825    2.18726    4.20485    1.73847    2.75391    1.59152    2.44324    1.44678  14.33243   7.26809   2.10588   1.05169   39.47018

57330.0 57596.0   36.48 207.9  -2.4    1.63 1.075 101.3    .242  1.162 295.1 532.1   .880  ---       .35  .727  92.5   318.0-14.9   4.75
57656.0 57834.4   53.11 293.1 -29.6   -2.67  .678 101.2    .404  1.021 197.5 422.4   .609  ---      1.44 1.341 106.8    62.5  4.7 138.97
57834.4 57913.0  138.85  41.7    .1     .05 1.210  70.7    .334   .761 100.6 179.2   ---   ---     -3.38  .810  90.4   161.7 -8.6  29.65
  1.665  21.2   .4769   .376  5.424  100.6 167.4 142.58 12.37 227.37   .00  84.92    LIGHT SIDE   LEADING EDGE             .00000
   .6923     1.0284    .2826
  4.73168    2.21693    4.20485    1.7384[illegible]    2.73260    1.60158    2.44324    1.44673  14.39833   7.27670   2.10588   1.05169   39.34483

57332.0 57596.0   35.61 209.3  -2.6    1.67 1.076 101.1    .241  1.164 296.1 531.2   .884  ---       .29  .728  92.8   319.3-14.8   4.80
57656.0 57834.4   53.11 293.1 -29.6   -2.67  .678 101.2    .404  1.021 197.5 422.4   .609  ---      1.44 1.341 106.8    62.5  4.7 138.97
57834.4 57913.0  138.85  41.7    .1     .05 1.210  70.7    .334   .761 100.6 179.2   ---   ---     -3.38  .810  90.4   161.7 -8.6  29.65
  1.665  21.2   .4769   .376  5.424  100.6 167.4 142.58 12.37 227.37   .00  84.92    LIGHT SIDE   LEADING EDGE             .00000
   .6923     1.0284    .2826
  4.69647    2.24774    4.20485    1.73847    2.71223    1.61210    2.44324    1.44678  14.47081   7.28573   2.10588   1.05169   39.24818

57334.0 57596.0   34.78 210.8  -2.7    1.71 1.077 100.9    .240  1.167 297.2 530.2   .887  ---       .21  .729  93.1   320.6-14.8   4.84
57656.0 57834.4   53.11 293.1 -29.6   -2.67  .678 101.2    .404  1.021 197.5 422.4   .609  ---      1.44 1.341 106.8    62.5  4.7 138.97
57834.4 57913.0  138.85  41.7    .1     .05 1.210  70.7    .334   . 61 100.6 179.2   ---   ---     -3.38  .810  90.4   161.7 -8.6  29.65
  1.665  21.2   .4769   .376  5.424  100.6 167.4 142.58 12.37 227.37   .00  84.92    LIGHT SIDE   LEADING EDGE             .00000
   .6923     1.0284    .2826
  4.66256    2.27961    4.20485    1.73847    2.69276    1.62305    2.44324    1.44678  14.54960   7.29516   2.10588   1.05169   39.17862

57336.0 57596.0   33.98 212.2  -2.8    1.76 1.079 100.7    .239  1.169 298.2 529.2   .890  ---       .13  .730  93.3   321.8-14.8   4.89
57656.0 57834.4   53.11 293.1 -29.6   -2.67  .678 101.2    .404  1.021 197.5 422.4   .609  ---      1.44 1.341 106.8    62.5  4.7 138.97
57834.4 57913.0  138.85  41.7    .1     .05 1.210  70.7    .334   .761 100.6 179.2   ---   ---     -3.38  .810  90.4   161.7 -8.6  29.65
  1.665  21.2   .4769   .376  5.424  100.6 167.4 142.58 12.37 227.37   .00  84.92    LIGHT SIDE   LEADING EDGE             .00000
   .5923     1.0284    .2826
  4.62991    2.31248    4.20485    1.73847    2.67415    1.63442    2.44324    1.44678  14.63445   7.30497   2.10588   1.05169   39.13473
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# TABLE 11. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2018 OPPOSITION

```
DEPARTURE PLANET - EARTH                                                                                   DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS                                                                                   PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                    ARRIVAL   PLANET - MARS

DEPART   PASS     C3-DD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL  C3-PD
PASS     ARRIVE   C3-PD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL  C3-AD
RCP      KAPPA    VP     AH    EH     ANMAX INH  RAP       DECP    RAS  DECS  ETA       PASS CONDITION                         DVCP

RESTART RETURN    C3-RS  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THEL  T1 THET2  PERIH APHE I 2  V 2   PSI 2   R A  DECL  C3-RD
  CORD1     CORD2      CORD3
  DV1        DV2        DV3        DV4      GAM1       GA   M2       GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETA0

57854.0 58006.9   25.90  77.8  17.7  -1.06  .856  94.9    .277    .792 193.0 446.7   .572  ---   -2.94 1.232 105.3  323.6-10.5  99.27
58006.9 58198.0   96.99 351.5  -9.0  -2.22 1.370  78.1    .399   1.106  42.9 179.9   ---   ---     .41  .623  90.0  254.7-21.8  30.87
  1.706  27.5   .4240   .533  4.201  103.8  10.5 247.00 -3.04 142.71    .00 104.27     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.3952     1.2146      .6996
 4.29553    2.80925    1.47682    1.81650    2.49080    1.81635    1.36855    1.47096  10.07159   4.63565   1.87744   1.05464   25.08528

57856.0 58008.1   26.79  79.0  17.3  -1.18  .855  95.1    .280    .791 193.5 447.2   .569  ---   -2.87 1.232 105.5  325.3-10.1 101.33
58008.1 58198.0  103.54 351.6  -8.4  -2.14 1.369  77.5    .403   1.103  45.1 180.1   ---  1.547    .30  .621  89.9  254.0-22.1  31.27
  1.756  26.0   .4274   .510  4.440  103.0  10.3 247.87 -3.80 144.73    .00 103.11     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.4018     1.2146      .6996
 4.33306    2.83689    1.47682    1.81650    2.51071    1.82705    1.36855    1.47096  10.17065   4.64165   1.87744   1.05464   25.53553

57858.0 58008.1   28.52  78.0  17.3  -1.19  .856  95.8    .282    .793 195.3 447.1   .569  ---   -2.83 1.233 105.5  325.4 -9.9 102.56
58008.1 58198.0  103.54 351.6  -8.4  -2.14 1.369  77.5    .403   1.103  45.1 180.1   ---  1.547    .30  .621  89.9  254.0-22.1  31.27
  1.754  25.9   .4283   .507  4.456  103.0  10.0 247.99 -3.36 144.73    .00 103.24     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.4018     1.2146      .6996
 4.49501    2.83689    1.47682    1.81650    2.54938    1.82705    1.36855    1.47096  10.22281   4.64165   1.87744   1.05464   26.06182

57860.0 58008.8   30.01  78.2  17.2  -1.26  .856  96.3    .285    .794 196.4 447.3   .567  ---   -2.77 1.233 105.7  326.3 -9.6 104.40
58008.8 58198.0  106.98 351.7  -8.1  -2.10 1.368  77.1    .405   1.101  46.2 180.2   ---  1.547    .25  .620  89.8  253.6-22.3  31.49
  1.777  25.2   .4307   .495  4.592  102.6   9.7 248.51 -3.44 145.74    .00 102.75     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.4051     1.2146      .6996
 4.46668    2.85178    1.47682    1.81650    2.58300    1.83284    1.36855    1.47096  10.30835   4.64491   1.87744   1.05464   26.62650

57862.0 58008.1   32.66  76.4  17.4  -1.22  .858  97.3    .288    .797 198.9 446.8   .568  ---   -2.74 1.235 105.8  325.6 -9.5 105.71
58008.1 58198.0  103.54 351.6  -8.4  -2.14 1.369  77.5    .403   1.103  45.1 180.1   ---  1.547    .30  .621  89.9  254.0-22.1  31.27
  1.743  25.8   .4309   .500  4.487  102.9   9.5 248.24 -2.39 144.73    .00 103.50     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.4018     1.2146      .6996
 4.57619    2.83689    1.47682    1 81650    2.64381    1.82705    1.36855    1.47096  10.35242   4.64165   1.87744   1.05464   27.36979

57864.0 58009.4   33.87  77.8  17.1  -1.34  .857  97.6    .291    .796 199.4 447.3   .565  ---   -2.66 1.235 106.0  327.3 -9.1 108.07
58009.4 58198.0  110.55 351.9  -7.8  -2.07 1.368  76.8    .407   1.099  47.3 180.3   ---  1.547    .20  .619  89.8  253.2-22.4  31.72
  1.796  24.3   .4347   .478  4.754  102.1   9.1 249.19 -2.92 146.76    .00 102.41     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.4084     1.2146      .6996
 4.62566    2.86742    1.47682    1.81650    2.67174    1.83894    1.36855    1.47096  10.47409   4.64834   1.87744   1.05464   27.98393

57866.0 58008.8   37.07  76.4  17.4  -1.31  .860  98.5    .294    .800 201.8 446.8   .565  ---   -2.63 1.237 106.1  326.6 -8.9 109.89
58008.8 58198.0  106.98 351.7  -8.1  -2.10 1.368  77.1    .405   1.101  46.2 180.2   ---  1.547    .25  .620  89.8  253.6-22.3  31.49
  1.757  24.9   .4352   .482  4.643  102.4   8.9 248.91 -1.84 145.74    .00 103.16     DARK SIDE   LEADING EDGE          .00000
58258.0 58492.0   13.27 255.3    .0    3.79  .733  97.3    .244   1.214 204.0 408.4   .919 1.510  -2.47 1.100  98.9  128.0  4.0  31.54
  1.4051     1.2146      .6996
 4.75580    2.85178    1.47682    1.81650    2.74663    1.83284    1.36855    1.47096  10.53802   4.64491   1.87744   1.05464   28.94409
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TABLE 12. MARS STOPOVER MISSION WITH INBOUND VENUS SWINGBY MISSION DATA FOR 2020 OPPOSITION

```
DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH
                                                                                          DEPARTURE PLANET - MARS
                                                                                          PASSAGE   PLANET - VENUS
                                                                                          ARRIVAL   PLANET - EARTH
LAUNCH  STOP     C3-DD  R A   DECL   I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL  I 2   V 2   PSI 2   R A   DECL   UHP
DEPART  PASS     C3-DD  R A   DECL   I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL  I 2   V 2   PSI 2   R A   DECL   C3-PD
PASS    ARRIVE   C3-PD  R A   DECL   I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL  I 2     V 2 PSI 2   R A   DECL   C3-AD
RCP     KAPPA    UP     AH    EH     ANMAX INH   RAP     DECP     RAS    DECS  ETA        PASS CONDITION                         DVCP
   CORD1     CORD2     CORD3
  DV1       DV2       DV3      DV4      GAM1      GA      M2      GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETA0

59004.0 59194.0   24.94  28.9  14.5     .42 1.103  96.1   .255  1.324 329.3 490.3   .986  ---   -2.25  .771 103.1   106.9 10.1    3.92
59254.0 59436.9   38.18  42.2  24.8    2.56  .633  95.3   .386  1.133 188.6 329.6   ---   ---    -.90 1.372  81.7   233.6 -4.5   67.53
59436.9 59602.0   68.57 269.9  10.8    2.49 1.229 102.4   .233   .798 280.6 536.2   .612  ---    1.77  .883  91.2    30.4 24.6   16.60
 1.524  39.2    .3926   .768 2.983  109.6  23.6 163.07-23.30 274.99   .00 110.06    DARK SIDE   LEADING EDGE
   .7150    1.2665    1.2560                                                                                           .00000
 4.25513   1.65016   3.29611   1.18485   2.46948   1.41989   2.01428   1.29624   9.28292   5.48099   1.77623   1.03251   22.92400

59006.0 59194.0   24.40  28.7  14.5     .39 1.104  95.9   .256  1.328 330.3 489.4   .988  ---   -2.21  .772 103.3   108.0 10.3    3.96
59254.0 59436.9   38.18  42.2  24.8    2.56  .633  95.3   .386  1.133 188.6 329.6   ---   ---    -.90 1.372  81.7   233.6 -4.5   67.53
59436.9 59602.0   68.57 269.9  10.8    2.49 1.229 102.4   .233   .798 280.6 536.2   .612  ---    1.77  .883  91.2    30.4 24.6   16.60
 1.524  39.2    .3926   .768 2.983  109.6  23.6 163.07-23.30 274.99   .00 110.06    DARK SIDE   LEADING EDGE
   .7150    1.2665    1.2560                                                                                           .00000
 4.23247   1.67538   3.29611   1.18485   2.45762   1.42752   2.01428   1.28624   9.32650   5.48581   1.77623   1.03251   22.92101

59008.0 59196.0   23.56  29.0  15.3     .47 1.104  95.7   .255  1.329 331.4 489.7   .990  ---   -2.28  .771 103.2   108.8  9.6    3.91
59256.0 59436.9   39.65  41.7  24.3    2.50  .633  96.0   .387  1.136 189.7 329.7   ---   ---    -.84 1.372  81.7   233.5 -4.1   67.77
59436.9 59604.0   69.04 270.0  11.0    2.55 1.229 102.4   .234   .798 280.4 538.0   .611  ---    1.75  .882  90.6    28.6 23.9   16.54
 1.507  39.3    .3942   .764 2.971  109.7  23.3 163.18-23.02 274.99   .00 110.00    DARK SIDE   LEADING EDGE
   .7311    1.2862    1.2560                                                                                           .00000
 4.19705   1.64571   3.39036   1.18219   2.43920   1.41855   2.05502   1.28551   9.39309   5.57329   1.78426   1.03242   22.91140

59010.0 59196.0   23.04  29.6  15.2     .43 1.105  95.5   .256  1.334 332.5 488.8   .992  ---   -2.24  .773 103.4   109.9  9.8    3.95
59256.0 59436.9   39.65  41.7  24.3    2.50  .633  96.0   .387  1.136 189.7 329.7   ---   ---    -.84 1.372  81.7   233.5 -4.1   67.77
59436.9 59604.0   69.04 270.0  11.0    2.55 1.229 102.4   .234   .798 280.4 538.0   .611  ---    1.75  .882  90.6    28.6 23.9   16.54
 1.507  39.3    .3942   .764 2.971  109.7  23.3 163.18-23.02 274.99   .00 110.00    DARK SIDE   LEADING EDGE
   .7311    1.2862    1.2560                                                                                           .00000
 4.17478   1.67035   3.39036   1.18219   2.42769   1.42599   2.05502   1.28551   9.43624   5.57808   1.78426   1.03242   22.90823

59012.0 59196.0   22.53  30.2  15.2     .40 1.106  95.3   .257  1.338 333.6 488.0   .994  ---   -2.20  .774 103.6   110.9  9.9    3.99
59256.0 59436.9   39.65  41.7  24.3    2.50  .633  96.0   .387  1.136 189.7 329.7   ---   ---    -.84 1.372  81.7   233.5 -4.1   67.77
59436.9 59604.0   69.04 270.0  11.0    2.55 1.229 102.4   .234   .798 280.4 538.0   .611  ---    1.75  .882  90.6    28.6 23.9   16.54
 1.507  39.3    .3942   .764 2.971  109.7  23.3 163.18-23.02 274.99   .00 110.00    DARK SIDE   LEADING EDGE
   .7311    1.2862    1.2560                                                                                           .00000
 4.15304   1.69587   3.39036   1.18219   2.41650   1.43374   2.05502   1.28551   9.48217   5.58308   1.78426   1.03242   22.91364

59014.0 59196.0   22.02  30.6  15.3     .38 1.106  95.1   .258  1.343 334.7 487.2   .956  ---   -2.18  .776 103.7   111.9 10.1    4.03
59256.0 59436.9   39.65  41.7  24.3    2.50  .633  96.0   .387  1.136 189.7 329.7   ---   ---    -.84 1.372  81.7   233.5 -4.1   67.77
59436.9 59604.0   69.04 270.0  11.0    2.55 1.229 102.4   .234   .798 280.4 538.0   .611  ---    1.75  .882  90.6    28.6 23.9   16.54
 1.507  39.3    .3942   .764 2.971  109.7  23.3 163.18-23.02 274.99   .00 110.00    DARK SIDE   LEADING EDGE
   .7311    1.2862    1.2560                                                                                           .00000
 4.13152   1.72158   3.39036   1.18219   2.40547   1.44160   2.05502   1.28551   9.52907   5.58815   1.78426   1.03242   22.92193

59016.0 59198.0   21.21  30.7  15.8     .44 1.106  94.9   .257  1.343 335.8 487.5   .998  ---   -2.23  .775 103.6   112.6  9.5    3.98
59258.0 59436.9   41.23  41.2  23.9    2.45  .633  96.7   .389  1.139 190.8 329.8   ---   ---    -.77 1.373  81.7   233.4 -3.8   68.02
59436.9 59604.0   69.04 270.0  11.0    2.55 1.229 102.4   .234   .798 280.4 538.0   .611  ---    1.75  .882  90.6    28.6 23.9   16.54
 1.505  39.3    .3945   .763 2.972  109.7  22.9 163.14-22.49 274.99   .00 110.11    DARK SIDE   LEADING EDGE
   .7474    1.3058    1.2560                                                                                           .00000
 4.09714   1.68747   3.49025   1.18219   2.38797   1.43119   2.09910   1.28551   9.60351   5.68568   1.79410   1.03242   22.93288
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TABLE 13. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2022 OPPOSITION

```
DEPARTURE PLANET - EARTH                                                                                   DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS                                                                                   PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                    ARRIVAL   PLANET - MARS

DEPART   PASS      C3-DD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL   C3-PD
PASS     ARRIVE    C3-PD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL   C3-AD
RCP      KAPPA     UP     AH    EH     ANMAX INH  RAP       DECP    RAS  DECS  ETA        PASS CONDITION                          DVCP

RESTART RETURN     C3-RS  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA    THEL  T1 THET2  PERIH APHE I 2  V 2   PSI 2   R A  DECL   C3-RD
   CORD1      CORD2      CORD3
   DV1        DV2        DV3         DV4      GAM1      GA    M2       GAM3      GAM4       ETA1       ETA2       ETA3      ETA4      ETAO

59512.0 59663.1    13.36 313.9 -60.9  -5.08  .917  91.4   .165    .855 186.9 385.1   .714  ---      7.83 1.262  93.5  144.4 59.6  35.11
59663.1 59816.0    37.65 174.1  24.3   3.58 1.361  87.8   .343   1.099   8.5 155.7   ---   ---     -2.88  .713 101.6   46.2  7.3  35.85
  2.672  41.0    .2918 1.438  2.858  110.5  69.6  22.12 40.13 277.48    .00 101.14     DARK SIDE    TRAILING EDGE          .00000
59876.0 60150.0    26.17  14.4  -2.0  -1.87  .704  92.9   .274   1.163 187.9 437.5   .845 1.481      .05 1.053 104.2  310.8-18.0  62.46
   .7113     1.0028      .6609
  3.75689    3.14398    2.47892    3.02903   2.22144   1.95022   1.69325   1.90317  15.04920   6.67986   2.55819   1.11031   33.43094

59514.0 59663.8    13.73 312.8 -61.5  -5.19  .918  91.7   .165    .855 188.4 385.6   .714  ---      7.99 1.262  93.6  144.5 60.0  36.25
59663.8 59818.0    37.82 173.6  24.4   3.59 1.360  87.6   .342   1.096   9.3 156.8   ---   ---     -2.86  .710 101.1   45.5  7.0  34.67
  2.627  40.9    .2944 1.412  2.860  110.5  70.3  20.73 40.43 278.48    .00  99.30     DARK SIDE    TRAILING EDGE          .00000
59878.0 60152.0    26.47  15.4  -1.6  -1.88  .702  93.0   .277   1.162 187.8 438.3   .840 1.483      .09 1.053 104.4  312.3-17.4  64.59
   .7162      .9914      .6509
  3.77324    3.06646    2.50001    3.10867   2.22917   1.91837   1.70086   1.93565  15.02082   6.77131   2.60885   1.11473   33.48404

59516.0 59664.4    14.19 311.6 -62.1  -5.31  .919  91.9   .165    .855 189.9 386.1   .714  ---      8.16 1.262  93.6  144.6 60.0  37.51
59664.4 59820.0    38.05 173.0  24.4   3.61 1.360  87.4   .341   1.094  10.2 157.8   ---   ---     -2.84  .708 100.6   44.8  6.7  33.62
  2.572  41.0    .2974 1.384  2.858  110.5  70.9  19.42 40.69 279.48    .00  97.52     DARK SIDE    TRAILING EDGE          .00000
59880.0 60154.0    26.75  16.5  -1.1  -1.89  .699  93.0   .280   1.161 187.7 439.0   .836 1.486      .13 1.053 104.6  313.7-16.9  66.78
   .7211      .9800      .6412
  3.79325    2.99621    2.52032    3.18968   2.23867   1.88995   1.70821   1.96925  15.02996   6.86902   2.66161   1.11934   33.64709

59518.0 59665.6    13.40 309.2 -60.1  -4.92  .919  92.2   .166    .855 191.1 387.3   .713  ---      7.84 1.262  93.8  145.4 58.5  35.90
59665.6 59820.0    38.52 171.6  22.9   3.42 1.359  86.9   .342   1.094  12.2 157.8   ---   ---     -2.62  .708 100.7   44.6  7.5  33.58
  2.676  40.3    .2933 1.406  2.904  110.1  70.8  18.54 42.41 281.48    .00  95.21     DARK SIDE    TRAILING EDGE          .90000
59880.0 60154.0    26.75  16.5  -1.1  -1.89  .699  93.0   .280   1.161 187.7 439.0   .836 1.486      .13 1.053 104.6  313.7-16.9  66.78
   .7309      .9800      .6412
  3.75853    2.99376    2.52032    3.18968   2.22222   1.88896   1.70821   1.96925  14.98895   6.86820   2.66161   1.11934   33.30874

59520.0 59666.3    13.90 307.9 -60.5  -5.03  .920  92.5   .166    .855 192.7 387.8   .712  ---      7.99 1.261  93.9  145.5 58.8  37.10
59666.3 59818.0    38.92 170.7  21.5   3.25 1.360  86.6   .343   1.096  13.3 156.7   ---   ---     -2.44  .710 101.2   45.3  8.5  34.66
  2.515  41.4    .2995 1.376  2.828  110.7  71.9  16.22 43.68 282.47    .00  92.71     DARK SIDE    TRAILING EDGE          .00000
59878.0 60152.0    26.47  15.4  -1.6  -1.88  .702  93.0   .277   1.162 187.8 438.3   .840 1.483      .09 1.053 104.4  312.3-17.4  64.59
   .7358      .9914      .6509
  3.78039    3.06589    2.50001    3.10867   2.23256   1.91814   1.70086   1.93565  15.02504   6.77112   2.60885   1.11473   33.54429

59522.0 59666.9    14.49 306.7 -60.9  -5.16  .920  92.8   .167    .855 194.2 388.4   .712  ---      8.16 1.261  94.0  145.6 59.1  38.42
59666.9 59820.0    39.31 170.2  21.5   3.26 1.359  86.4   .343   1.093  14.1 157.8   ---   ---     -2.42  .707 100.7   44.5  8.3  33.60
  2.451  41.5    .3032 1.346  2.822  110.8  72.5  14.96 43.95 283.47    .00  91.07     DARK SIDE    TRAILING EDGE          .00000
59880.0 60154.0    26.75  16.5  -1.1  -1.89  .699  93.0   .280   1.161 187.7 439.0   .836 1.486      .13 1.053 104.6  313.7-16.9  66.78
   .7407      .9800      .6412
  3.89633    2.99485    2.52032    3.18968   2.24490   1.88940   1.70821   1.96925  15.03656   6.86856   2.66161   1.11934   33.75555

59524.0 59668.1    13.70 304.1 -58.3  -4.71  .921  93.1   .168    .855 195.5 389.6   .711  ---      7.77 1.261  94.2  146.4 56.9  36.48
59668.1 59820.0    40.40 168.8  20.1   3.11 1.358  85.9   .344   1.093  16.2 157.9   ---   ---     -2.23  .707 100.8   44.3  8.9  33.66
  2.587  40.3    .2281 1.361  2.901  110.2  72.4  14.43 45.71 285.47    .00  89.28     LIGHT SIDE   TRAILING EDGE          .80000
59880.0 60154.0    26.75  16.5  -1.1  -1.89  .699  93.0   .280   1.161 187.7 439.0   .836 1.486      .13 1.053 104.6  313.7-16.9  66.78
   .7504      .9800      .6412
  3.77182    2.99873    2.52032    3.18968   2.22850   1.89096   1.70821   1.96925  15.02044   6.86987   2.66161   1.11934   33.47308
```

TABLE 14. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2025 OPPOSITION

```
DEPARTURE PLANET - EARTH                                                                                    DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS                                                                                    PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                     ARRIVAL   PLANET - MARS

DEPART   PASS     C3-DD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL  C3-PD
PASS     ARRIVE   C3-PD  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THET1 THET2  PERIH APHEL   I 2  V 2   PSI 2   R A  DECL  C3-AD
RCP      KAPPA    VP     AH    EH     ANMAX INH  RAP       DECP    RAS  DECS  ETA         PASS CONDITION                      DVCP

RESTART RETURN    C3-RS  R A   DECL   I 1  V 1   PSI 1   ECCEN SMA   THEL  T1 THET2  PERIH APHE I 2  V 2   PSI 2   R A  DECL  C3-RD
   CORD1     CORD2     CORD3
   DV1       DV2       DV3       DV4       GAM1      GA    M2      GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETA0

60194.0 60357.5   25.16 253.7 -21.3    .27  .824  90.6   .316    .766 181.3 459.3   .524  ---     3.42 1.203 108.2   125.2 10.4 126.20
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.747   22.4   .4554   .421  5.146  101.2  12.3  45.13  8.37 309.79   .00  95.29     DARK SIDE    TRAILING EDGE         .00600
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.26438    3.46570    1.46368     .80288   2.47434   2.08818   1.36473   1.18599  10.55187   4.23363   1.52181   1.02089   26.10893

60196.0 60357.5   24.99 251.8 -21.1    .27  .825  91.4   .315    .766 183.0 459.1   .525  ---     3.41 1.204 108.1   125.3 10.4 125.32
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.764   22.3   .4542   .423  5.172  101.1  12.4  45.18  8.46 309.79   .00  95.33     DARK SIDE    TRAILING EDGE         .00000
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.25717    3.46570    1.46368     .80288   2.47055   2.08818   1.36473   1.18599  10.54663   4.23363   1.52181   1.02089   26.05603

60198.0 60357.5   25.06 249.9 -20.8    .27  .826  92.2   .315    .767 184.7 458.9   .526  ---     3.40 1.204 108.1   125.4 10.4 124.76
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.778   22.2   .4532   .424  5.196  101.1  12.4  45.22  8.51 309.79   .00  95.38     DARK SIDE    TRAILING EDGE         .00000
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.26003    3.46570    1.46368     .80288   2.47206   2.08818   1.36473   1.18599  10.54871   4.23363   1.52181   1.02089   26.07701

60200.0 60357.5   25.35 247.9 -20.6    .27  .828  92.9   .314    .768 186.4 458.7   .527  ---     3.39 1.205 108.1   125.5 10.4 124.45
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.791   22.1   .4525   .424  5.222  101.0  12.4  45.28  8.53 309.79   .00  95.43     DARK SIDE    TRAILING EDGE         .00000
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.27228    3.46570    1.46368     .80288   2.47850   2.08818   1.36473   1.18599  10.55764   4.23363   1.52181   1.02089   26.16710

60202.0 60357.5   25.87 246.1 -20.3    .27  .829  93.7   .314    .769 188.2 458.4   .527  ---     3.39 1.205 108.1   125.6 10.4 124.41
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.802   22.0   .4520   .424  5.247  101.0  12.4  45.33  8.51 309.79   .00  95.48     DARK SIDE    TRAILING EDGE         .00000
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.29420    3.46570    1.46368     .80288   2.49007   2.08818   1.36473   1.18599  10.57371   4.23363   1.52181   1.02089   26.32925

60204.0 60357.5   26.63 244.3 -20.1    .27  .831  94.5   .315    .770 189.9 458.2   .528  ---     3.38 1.206 108.1   125.7 10.4 124.67
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.811   21.9   .4519   .424  5.272  100.9  12.3  45.39  8.47 309.79   .00  95.55     DARK SIDE    TRAILING EDGE         .00000
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.32628    3.46570    1.46368     .80288   2.50709   2.08818   1.36473   1.18599  10.59745   4.23363   1.52181   1.02089   26.56880

60206.0 60357.5   27.63 242.6 -19.8    .27  .833  95.3   .315    .771 191.7 458.0   .528  ---     3.37 1.207 108.1   125.8 10.3 125.16
60357.5 60494.0  122.00 147.6   7.1   2.06 1.333  74.5   .387   1.024  59.2 168.7   ---   ---     -.75  .670  97.0    21.3  6.7  40.84
  1.818   21.8   .4519   .423  5.297  100.9  12.3  45.46  8.40 309.79   .00  95.61     DARK SIDE    TRAILING EDGE         .00000
60554.0 60810.0   13.11   9.4  -2.3   -.96  .746   90.4   .184   1.237 182.0 369.3  1.009 1.465    -.89 1.082  91.4   319.8-26.4   7.95
  1.4440     1.7335     1.4349
 4.36787    3.46570    1.46368     .80288   2.52935   2.08818   1.36473   1.18599  10.62863   4.23363   1.52181   1.02089   26.88351
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# TABLE 15. MARS STOPOVER MISSION WITH INBOUND VENUS SWINGBY MISSION DATA FOR 2027 OPPOSITION



```
DEPARTURE PLANET - MARS                                                                                   DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS                                                                                  PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH                                                                                  ARRIVAL   PLANET - EARTH
LAUNCH  STOP     C3-DD  R A   DECL   I 1  V 1   PSI 1  ECCEN SMA  THET1 THET2  PERIH APHEL  I 2  V 2   PSI 2  R A  DECL  VHP
DEPART  PASS     C3-DD  R A   DECL   I 1  V 1   PSI 1  ECCEN SMA  THET1 THET2  PERIH APHEL  I 2  V 2   PSI 2  R A  DECL  C3-PD
PASS    ARRIVE   C3-PD  R A   DECL   I 1  V 1   PSI 1  ECCEN SMA  THET1 THET2  PERIH APHEL  I 2  V 2   PSI 2  R A  DECL  C3-AD
RCP     KAPPA    VP     AH    EH     ANMAX INH  RAP    DECP   RAS   DECS  ETA     PASS CONDITION                          DVCP
  CORD1    CORD2    CORD3
  DV1      DV2      DV3       DU4      GAM1      GA      M2      GAM3      GAM4      ETA1      ETA2      ETA3      ETA4      ETAO

613.4.0 61554.0   16.66 151.7  36.0   2.69 1.132  92.3   .275  1.365 349.5 505.5   .989 ---   -.96  .703 101.4  264.8-27.3   5.86
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.90685  3.04367  3.43379   1.46330   2.29043   1.90910   2.07407   1.36462  13.79856   6.20181   1.89561   1.04178  31.60467

61346.0 61554.0   16.15 149.9  35.1   2.49 1.133  91.9   .275  1.366 351.2 505.1   .990 ---   -.75  .703 101.5  265.1-26.5   5.89
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.87895  3.06496  3.43379   1.46330   2.27980   1.91775   2.07407   1.36462  13.85689   6.20838   1.89561   1.04178  31.59100

61348.0 61554.0   15.77 148.2  34.4   2.33 1.134  91.5   .276  1.367 352.9 504.8   .990 ---   -.56  .703 101.6  265.3-25.9   5.91
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.86249  3.08708  3.43379   1.46330   2.27184   1.92679   2.07407   1.36462  13.92340   6.21525   1.89561   1.04178  31.63176

61350.0 61554.0   15.51 146.4  33.8   2.15 1.134  91.2   .276  1.368 354.6 504.6   .990 ---   -.40  .704 101.7  265.5-25.3   5.94
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.85083  3.10906  3.43379   1.46330   2.26622   1.93581   2.07407   1.36462  13.99397   6.22212   1.89561   1.04178  [illegible].71346

61352.0 61554.0   15.34 144.6  33.3   2.06 1.135  90.8   .277  1.369 356.3 504.3   .990 ---   -.26  .704 101.8  265.7-24.8   5.97
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.84370  3.13866  3.43379   1.46330   2.26279   1.94471   2.07407   1.36462  14.06753   6.22892   1.89561   1.04178  31.83189

61354.0 61554.0   15.28 142.8  32.8   1.96 1.136  90.4   .277  1.370 358.1 504.1   .990 ---   -.13  .705 101.8  265.8-24.4   6.00
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.84092  3.15173  3.43379   1.46330   2.26146   1.95344   2.07407   1.36462  14.14338   6.23560   1.89561   1.04178  31.98463

61356.0 61554.0   15.31 141.0  32.4   1.86 1.136  90.0   .278  1.370 359.9 503.9   .990 ---   -.02  .705 101.9  265.9-24.0   6.02
61614.0 61750.5   40.34 178.4  -4.4  -1.58  .662 108.8   .437  1.197 208.7 319.1   ---  ---   1.80 1.383  77.8  348.3  7.1 104.95
61750.5 61916.0  106.10  21.9   2.6    .79 1.212 106.7   .295   .782 266.4 537.6   .552 ---  -3.28  .835  91.0  150.0 -6.2  23.09
  1.212  33.7    .4650   .496  3.447  106.9   9.2 274.47  7.67  20.67   .00 106.05     DARK SIDE    TRAILING EDGE          .00000
  1.2930   1.7470   1.3769
  3.84241  3.17216  3.43379   1.46330   2.26217   1.96193   2.07407   1.36462  14.22106   6.24212   1.89561   1.04178  32.17045
```

TABLE 16. MARS STOPOVER MISSION WITH DOUBLE VENUS SWINGBY MISSION DATA FOR OUTBOUND LEG FOR 2029 OPPOSITION

```
DEPARTURE PLANET - EARTH                                                                                DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS                                                                                PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                 ARRIVAL   PLANET - MARS

DEPAPT   PASS     C3-DD  R A    DECL    I 1    V 1   PSI 1    ECCEN SMA    THET1 THET2  PERIH APHEL    I 2   V 2    PSI 2    R A   DECL  C3-PD
PASS    ARRIVE    C3-PD  R A    DECL    I 1    V 1   PSI 1    ECCEN SMA    THET1 THET2  PERIH APHEL    I 2   V 2    PSI 2    R A   DECL  C3-AD
RCP     KAPPA      VP     AH    EH     ANMAX INH     RAP          DECP      RAS  DECS  ETA        PASS CONDITION                            DVCP
   CORD1      CORD2
  DV1         DV2         DV3       DV4       GAM1       GA    M2        GAM3      GAM4       ETA1       ETA2       ETA3       ETA4       ETA0


61850.0 62003.8   27.86  46.6   75.6    9.09  .917  90.7     .162     .857 183.7 382.5   .718   ---   -10.34 1.261   93.1   287.3-66.1  54.25
62003.8 62206.0   57.28 319.8  -31.9   -5.56 1.387  87.8     .397    1.201   7.7 167.9   ---    ---     5.73  .614   97.7   221.5  3.4   31.15
  1.858  39.3    .3558   .938  2.973   109.7  73.0 163.09-34.95    65.98    .00  95.82     DARK SIDE    TRAILING EDGE           .00000
   .7828      .6853
   .7828      .6853      1.3977
 4.37759    2.82878     .00000     .00000   2.53458    1.82390     .00000     .00000   2.41300    1.09966     .00000     .00000     6.11593

61852.0 62005.6   27.23  47.4   74.8    8.89  .917  91.0     .164     .857 185.0 383.8   .717   ---   -10.26 1.261   93.3   287.8-65.2  54.13
62005.0 62206.0   56.34 318.4  -29.1   -5.07 1.387  87.3     .398    1.200   9.6 167.9   ---    ---     5.21  .613   97.8   221.1  1.9   30.59
  1.768  40.8    .3591   .947  2.867   110.4  73.4 161.04-37.18    67.97    .00  92.44     DARK SIDE    TRAILING EDGE           .00000
   .7925      .6853
   .7925      .6853      1.3977
 4.35115    2.79024     .00000     .00000   2.52038    1.80903     .00000     .00000   2.38454    1.09769     .00000     .00000     6.00994

61854.0 62006.3   26.60  48.4   73.9    8.69  .916  91.2     .165     .857 186.3 385.1   .715   ---   -10.16 1.262   93.5   288.3-64.3  53.95
62006.3 62210.0   57.51 316.8  -28.7   -5.06 1.386  86.7     .397    1.195  11.7 169.8   ---    ---     5.13  .612   96.6   220.1  3.5   28.78
  1.810  39.9    .3577   .938  2.929   110.0  73.5 159.53-38.07    69.97    .00  89.65    LIGHT SIDE    TRAILING EDGE           .00000
   .8022      .6709
   .8022      .6709      1.3977
 4.32473    2.66394     .00000     .00000   2.50629    1.76113     .00000     .00000   2.30377    1.09138     .00000     .00000     5.77392

61856.0 62007.5   25.98  49.4   72.8    8.47  .915  91.5     .166     .857 187.6 386.4   .714   ---   -10.05 1.262   93.7   288.9-63.3  53.70
62007.5 62210.0   57.73 315.5  -26.2   -4.66 1.386  86.1     .398    1.194  13.7 169.8   ---    ---     4.70  .611   96.6   219.6  1.2   28.38
  1.741  41.0    .3613   .939  2.854   110.5  74.0 157.73-40.20    71.96    .00  86.77    LIGHT SIDE    TRAILING EDGE           .00000
   .8118      .6709
   .8118      .6709      1.3977
 4.29874    2.63645     .00000     .00000   2.49247    1.75088     .00000     .00000   2.28338    1.09003     .00000     .00000     5.69126

61858.0 62008.1   27.77  48.0   73.0    8.80  .915  91.8     .167     .857 189.2 387.0   .713   ---   -10.46 1.262   93.8   288.5-63.9  57.44
62008.1 62214.0   59.15 314.8  -26.9   -4.84 1.385  85.8     .396    1.189  14.8 171.6   ---    ---     4.83  .610   95.4   218.7  3.5   26.99
  1.676  40.8    .3689   .897  2.869   110.4  74.6 156.15-39.84    72.96    .00  84.78    LIGHT SIDE    TRAILING EDGE           .00000
   .8166      .6598
   .8166      .6598      1.3977
 4.37399    2.53753     .00000     .00000   2.53263    1.71447     .00000     .00000   2.23881    1.08529     .00000     .00000     5.66806

61860.0 62009.4   27.10  49.3   71.8    8.55  .914  92.1     .169     .857 190.5 388.3   .712   ---   -10.32 1.262   94.0   289.3-62.8  56.97
62009.4 62216.0   60.50 313.7  -25.4   -4.65 1.385  85.2     .397    1.187  16.8 172.6   ---    ---     4.59  .609   94.8   217.8  3.1   26.13
  1.662  40.8    .3703   .890  2.867   110.4  74.9 154.80-41.41    74.95    .00  82.40    LIGHT SIDE    TRAILING EDGE           .00000
   .8263      .6554
   .8263      .6554      1.3977
 4.34573    2.47552     .00000     .00000   2.51747    1.69203     .00000     .00000   2.19840    1.08240     .00000     .00000     5.53443

51862.0 62010.6   26.45  50.7   70.6    8.30  .914  92.4     .171     .857 191.7 389.6   .711   ---   -10.16 1.263   94.2   290.1-61.7  56.45
62010.6 62212.0   61.33 312.7  -21.7   -4.04 1.386  84.6     .400    1.189  18.9 170.9   ---    ---     3.97  .609   96.0   218.0  -.7   27.12
  1.540  42.9    .3781   .888  2.733   111.5  75.6 153.08-44.27    76.95    .00  80.12    LIGHT SIDE    TRAILING EDGE           .00000
   .8358      .6649
   .8358      .6649      1.3977
 4.31842    2.54677     .00000     .00000   2.50291    1.71784     .00000     .00000   2.23452    1.08573     .00000     .00000     5.59281
```

# TABLE 17. MARS STOPOVER MISSION WITH DOUBLE VENUS SWINGBY MISSION DATA FOR INBOUND LEG FOR 2029 OPPOSITION

```
DEPARTURE PLANET - MARS                                                                                           DEPARTURE PLANET - MARS
PASSAGE   PLANET - VENUS                                                                                          PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - EARTH                                                                                          ARRIVAL   PLANET - EARTH

DEPART   PASS     C3-DD  R A   DECL   I 1  V 1   PSI 1    ECCEN SMA   THET1 THET2  PERIH APHEL    I 2  V 2   PSI 2    R A  DECL  C3-PD
PASS     ARRIVE   C3-PD  R A   DECL   I 1  V 1   PSI 1    ECCEN SMA   THET1 THET2  PERIH APHEL    I 2  V 2   PSI 2    R A  DECL  C3-AD
RCP      KAPPA    UP     AH    EH     ANMAX INH  RAP        DECP    RAS  DECS  ETA      PASS CONDITION                              DVCP
   CORD1     CORD2
  DV1       DV2        DV3       DV4       GAM1       GA     M2       GAM3        GAM4       ETA1       ETA2       ETA3       ETA4       ETA0

62264.0 62437.0   27.64 164.6  -6.4   -3.39  .646 104.4    .403  1.213 203.6 351.3   ---   ---    3.55 1.388  87.5  324.8 21.2  49.98
62437.0 62592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.559  48.1   .3613  1.074  2.452  114.1  77.4 307.92-42.87  40.31   .00  91.75    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 2.58392   1.91445    .00000    .00000   1.73145   1.50190    .00000    .00000   2.00063   1.05843    .00000    .00000    3.46398

62266.0 62437.0   28.62 164.3  -5.8   -3.30  .649 104.9    .404  1.216 204.6 351.3   ---   ---    3.45 1.389  87.5  324.8 23.6  49.96
62437.0 62592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.529  48.7   .3634  1.074  2.423  114.4  77.5 307.96-43.19  40.31   .00  91.71    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 2.65308   1.91445    .00000    .00000   1.75707   1.50190    .00000    .00000   2.00678   1.05843    .00000    .00000    3.52606

62268.0 62437.0   29.68 164.   -5.1   -3.22  .652 105.4    .406  1.219 205.6 351.3   ---   ---    3.35 1.389  87.5  324.7 20.0  49.97
62437.0 62592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.500  49.3   .3654  1.074  2.396  114.7  77.5 307.97-43.50  40.31   .00  91.69    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 2.72704   1.91445    .00000    .00000   1.78490   1.50190    .00000    .00000   2.01350   1.05843    .00000    .00000    3.59391

62270.0 62437.0   30.83 163.6  -4.5   -3.15  .655 106.0    .407  1.223 206.5 351.4   ---   ---    3.26 1.390  87.5  324.7 19.4  50.03
62437.0 62592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.471  49.9   .3675  1.073  2.371  114.9  77.5 307.94-43.79  40.31   .00  91.71    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 2.80699   1.91445    .00000    .00000   1.81548   1.50190    .00000    .00000   2.02094   1.05843    .00000    .00000    3.66898

62272.0 62437.0   32.09 163.3  -3.9   -3.08  .658 106.5    .409  1.226 207.5 351.4   ---   ---    3.17 1.391  87.5  324.5 18.9  50.12
62437.0 [illegible]592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.444  50.5   .3697  1.072  2.346  115.2  77.5 307.86-44.07  40.31   .00  91.76    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 2.89259   1.91445    .00000    .00000   1.84880   1.50190    .00000    .00000   2.02911   1.05843    .00000    .00000    3.75142

62274.0 62437.0   33.44 163.0  -3.3   -3.01  .661 107.1    .411  1.230 208.6 351.5   ---   ---    3.09 1.392  87.5  324.4 18.4  50.24
62437.0 62592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.417  51.0   .3719  1.071  2.323  115.5  77.5 307.74-44.32  40.31   .00  91.83    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 2.98401   1.91445    .00000    .00000   1.88506   1.50190    .00000    .00000   2.03808   1.05843    .00000    .00000    3.84190

62276.0 62437.0   34.90 162.7  -2.7   -2.95  .665 107.7    .413  1.235 209.6 351.6   ---   ---    3.01 1.393  87.5  324.3 17.8  50.41
62437.0 62592.0   47.43 350.6  66.4    9.70 1.260  93.0    .162   .860 338.5 537.3  .720   ---  -10.54  .916  90.5   93.2-35.6  33.93
   1.390  51.5   .3741  1.069  2.301  115.8  77.5 307.58-44.57  40.31   .00  91.94    DARK SIDE   TRAILING EDGE         .00000
  1.1570    2.3906
  1.1570    2.3906     1.3974
 3.08143   1.91445    .00000    .00000   1.92448   1.50190    .00000    .00000   2.04792   1.05843    .00000    .00000    3.[illegible]116
```

TABLE 18. MARS STOPOVER MISSION WITH OUTBOUND VENUS SWINGBY MISSION DATA FOR 2031 OPPOSITION

```
DEPARTURE PLANET - EARTH
PASSAGE   PLANET - VENUS
ARRIVAL   PLANET - MARS                                                                                 DEPARTURE PLANET - EARTH
                                                                                                        PASSAGE   PLANET - VENUS
                                                                                                        ARRIVAL   PLANET - MARS
DEPART   PASS      C3-PD  R A   DECL   I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL  I 2   V 2   PSI 2    R A  DECL  C3-PD
PASS     ARRIVE    C3-FD  R A   DECL   I 1   V 1   PSI 1   ECCEN SMA    THET1 THET2  PERIH APHEL  I 2   V 2   PSI 2    R A  DECL  C3-AD
RCP      KAPPA     UP     AH    EH     ANMAX INH   RAP       DECP   RAS  DECS  ETA          PASS CONDITION                         DVCP

RESTART RETURN     C3-RS  R A   DECL   I 1   V 1   PSI 1   ECCEN SMA    THEL  T1 THET2  PERIH APHE I 2  V 2   PSI 2    R A  DECL  C3-RD
   CORD1      CORD2     CORD3
   DV1        DV2       DV3        DV4      GAM1      GA   M2      GAM3      GAM4       ETA1      ETA2      ETA3      ETA4       ETA0

62520.0 62694.4   28.19  38.0  24.6    1.92  .849  86.4    .297    .762 171.5 457.5    .536  .988   -2.32 1.206 107.0   268.6 -7.4 117.86
62694.4 62880.0  118.02 300.7  -8.5   -2.30 1.381  77.0    .433   1.166  44.3 172.1    ---   ---     2.09  .590  96.0   202.3 -2.1  27.61
  1.177   31.8   .4829   .443 3.655   105.9   8.5 194.91   2.08   92.78   .00 102.13      DARK SIDE    TRAILING EDGE          .00000
62940.0 63182.0   13.56 160.3   8.0    -.09  .679 101.4    .317   1.293 207.1 416.4    .884 1.703    1.93 1.117 102.7     61.4 28.7  65.94
  1.4744    1.4364     .8452
  4.39131   2.58140   1.50099   3.15877   2.54197   1.73052   1.37560   1.95636  11.66110   5.59553   2.54136   1.11757   29.64222

62522.0 62694.4   27.04  36.3  24.2    1.90  .849  87.2    .294    .763 173.2 457.2    .538  .987   -2.39 1.206 106.9   268.7 -7.7 115.99
62694.4 62884.0  115.01 300.9  -9.0   -2.40 1.381  77.3    .430   1.164  43.6 173.5    ---   ---     2.16  .590  94.9   201.7 -1.4  26.32
  1.199   31.8   .4781   .453 3.649   105.9   9.0 195.15   2.42   92.39   .00 102.75      DARK SIDE    TRAILING EDGE          .00000
62944.0 63184.0   14.20 161.7   8.2     .04  .680 101.8    .320   1.292 207.9 417.4    .879 1.705    1.81 1.117 102.9     63.1 28.4  67.78
  1.4744    1.3956     .8111
  4.34346   2.48930   1.55504   3.22670   2.51626   1.69699   1.39148   1.98480  11.58102   5.68621   2.58735   1.12149   29.14087

62524.0 62693.1   25.42  31.5  23.3    1.97  .851  88.5    .289    .764 176.3 456.2    .544  .985   -2.45 1.207 106.5   267.2 -8.0 111.64
62693.1 62880.0  110.51 300.6  -9.1   -2.37 1.382  77.7    .429   1.170  42.0 171.8    ---   ---     2.19  .592  96.1   203.1 -2.0  27.29
 '.186    33.0   .4740   .471 3.519   106.5   9.1 194.18   1.89   90.77   .00 103.40      DARK SIDE    TRAILING EDGE          .00030
62940.0 63182.0   13.56 160.3   8.0    -.09  .679 101.4    .317   1.293 207.1 416.4    .834 1.703    1.93 1.117 102.7     61.4 28.7  65.94
  1.4681    1.4364     .8452
  4.27516   2.55887   1.50099   3.15877   2.48002   1.72226   1.37560   1.95636  11.49958   5.59001   2.54136   1.11757   28.51912

62526.0 62693.1   24.99  29.6  22.7    1.96  .851  89.2    .287    .765 178.1 456.0    .545  .985   -2.52 1.207 106.4   267.3 -8.3 110.72
62693.1 62880.0  110.51 300.6  -9.1   -2.37 1.382  77.7    .429   1.170  42.0 171.8    ---   ---     2.19  .592  96.1   203.1 -2.0  27.29
  1.197   32.9   .4725   .473 3.532   106.4   9.2 194.17   1.42   90.77   .00 103.39      DARK SIDE    TRAILING EDGE          .00000
62940.0 63182.0   13.56 160.3   8.0    -.09  .679 101.4    .317   1.293 207.1 416.4    .884 1.703    1.93 1.117 102.7     61.4 28.7  65.94
  1.4681    1.4364     .8452
  4.25743   2.55887   1.50099   3.15877   2.47069   1.72226   1.37560   1.95636  11.48550   5.59001   2.54136   1.11757   28.37712

62528.0 62693.1   24.81  27.7  22.1    1.95  .851  89.9    .286    .765 179.9 455.7    .546  .985   -2.59 1.208 106.3   267.4 -8.5 110.08
62693.1 62880.0  119.51 300.6  -9.1   -2.37 1.382  77.7    .429   1.170  42.0 171.8    ---   ---     2.19  .592  96.1   203.1 -2.0  27.29
  1.207   32.8   .4713   .474 3.545   106.4   9.2 194.16    .96   90.77   .00 103.38      DARK SIDE    TRAILING EDGE          .00000
62940.0 63182.0   13.56 160.3   8.0    -.09  .679 101.4    .317   1.293 207.1 416.4    .884 1.703    1.93 1.117 102.7     61.4 28.7  65.94
  1.4681    1.4364     .8452
  4.24978   2.55887   1.50099   3.15877   2.46668   1.72226   1.37560   1.95636  11.47946   5.59001   2.54136   1.11757   28.31611

62530.0 62693.1   24.87  25.9  21.4    1.95  .852  90.7    .286    .766 181.7 455.5    .547  ---    -2.65 1.208 106.3   267.5 -8.8 109.70
62693.1 62884.0  107.76 300.8  -9.6   -2.47 1.382  78.0    .427   1.168  41.3 173.3    ---   ---     2.27  .592  95.0   202.5 -1.2  26.01
  1.226   32.9   .4683   .481  .536   106.4   9.7 194.40   1.45   90.38   .00 104.01      DARK SIDE    TRAILING EDGE          .00000
62944.0 63184.0   14.20 161.7   8.2     .04  .680 101.8    .320   1.292 207.9 417.4    .879 1.705    1.81 1.117 102.9     63.1 28.4  67.78
  1.4681    1.3956     .8111
  4.25216   2.46688   1.55504   3.22670   2.46793   1.68893   1.39148   1.98480  11.44191   5.68075   2.58735   1.12149   28.23781

62532.0 62693.1   25.16  24.1  20.6    1.94  .852  91.4    .285    .767 183.5 455.3    .548  ---    -2.72 1.209 106.3   267.6 -9.0 109.60
62693.1 62884.0  107.76 300.8  -9.6   -2.47 1.382  78.0    .427   1.168  41.3 173.3    ---   ---     2.27  .592  95.0   202.5 -1.2  26.01
  1.226   32.7   .4677   .481 3.548   106.4   9.8 194.39   1.04   90.38   .00 104.00      DARK SIDE    TRAILING EDGE          .00000
62944.0 63184.0   14.20 161.7   8.2     .04  .680 101.8    .320   1.292 207.9 417.4    .879 1.705    1.81 1.117 102.9     63.1 28.4  67.78
  1.4681    1.3956     .8111
  4.26448   2.46688   1.55504   3.22670   2.47439   1.68893   1.39148   1.98480  11.45162   5.68075   2.58735   1.12149   28.33579
```

TABLE 19. PLANETARY MISSION STAGE SIZING FOR VENUS SWINGBY OPPOSITIONS 2001 TO 2010

DATE 2001 INBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 28715. | WF3 | 25844. | WBO3 | 2871. | | |
| WSTG2 | 352989. | WF2 | 317693. | WBO2 | 35296. | WSTG1 | 869021. | WF1 | 782127. | WBO1 | 86894. | WO | 1470725. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 3.57210 | DV0 | 0.00000 | DVS1 | 1.58680 | DVS2 | 3.23870 | DV4 | 1.23850 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2003 OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 78203. | WF3 | 63183. | WBO3 | 7020. | | |
| WSTG2 | 808803. | WF2 | 727930. | WBO2 | 80873. | WSTG1 | 1759089. | WF1 | 1583196. | WBO1 | 175893. | WO | 2858094. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 3.80010 | DV0 | 0.00000 | DVS1 | 3.55480 | DVS2 | 2.27400 | DV4 | 2.50300 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2005 OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 24244. | WF3 | 21820. | WBO3 | 2424. | | |
| WSTG2 | 447263. | WF2 | 402541. | WBO2 | 44722. | WSTG1 | 1262168. | WF1 | 1135962. | WBO1 | 126205. | WO | 1953675. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.09980 | DV0 | 0.00000 | DVS1 | 3.26530 | DVS2 | 1.49040 | DV4 | 1.07080 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2007 INBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 31718. | WF3 | 28546. | WBO3 | 3171. | | |
| WSTG2 | 1093887. | WF2 | 984508. | WBO2 | 109379. | WSTG1 | 2719261. | WF1 | 24473[illegible]. | WBO1 | 271902. | WO | 4064865. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.33770 | DV0 | 0.00000 | DVS1 | 3.18240 | DVS2 | 4.20400 | DV4 | 1.34690 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2010 DOUBLE SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 31151. | WF3 | 28036. | WBO3 | 3115. | | |
| WSTG2 | 574101. | WF2 | 516696. | WBO2 | 57405. | WSTG1 | 1662341. | WF1 | 1496122. | WBO1 | 166219. | WO | 2487593. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.33010 | DV0 | 0.00000 | DVS1 | 2.14050 | DVS2 | 3.82550 | DV4 | 1.32670 | G2 | 0.1111 | G3 | 0.1111 | | |

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TABLE 20. PLANETARY MISSIONS STAGE SIZING FOR VENUS SWINGBY OPPOSITION 2012 TO 2020

DATE 2012 — OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 83384. | WF3 | 75046. | WB03 | 8338. | | |
| WSTG2 | 495227. | WF2 | 445708. | WB02 | 49518. | WSTG1 | 1647219. | WF1 | 1482512. | WB01 | 164707. | WC | 2445829. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.30 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.38600 | DV0 | 0.00000 | DVS1 | 2.65130 | DVS2 | 1.81839 | DV4 | 2.82310 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2014 — INBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 30939. | WF3 | 27845. | WB03 | 3094. | | |
| WSTG2 | 365309. | WF2 | 328781. | WB02 | 36528. | WSTG1 | 941438. | WF1 | 847303. | WB01 | 94135. | WC | 1557686. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 3.69590 | DV0 | 0.00000 | DVS1 | 1.48530 | DVS2 | 3.44020 | DV4 | 1.31910 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2016 — INBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 43352. | WF3 | 39017. | WB03 | 4335. | | |
| WSTG2 | 774196. | WF2 | 696783. | WB02 | 77413. | WSTG1 | 2370706. | WF1 | 2133657. | WB01 | 237049. | WC | 3408254. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.62990 | DV0 | 0.00000 | DVS1 | 2.31250 | DVS2 | 4.20490 | DV4 | 1.73850 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2018 — OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 45827. | WF3 | 41245. | WB03 | 4582. | | |
| WSTG2 | 403517. | WF2 | 363169. | WB02 | 40348. | WSTG1 | 1328670. | WF1 | 1195815. | WB01 | 132855. | WC | 1998015. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.29560 | DV0 | 0.00000 | DVS1 | 2.80930 | DVS2 | 1.47680 | DV4 | 1.81650 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2020 — INBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 27191. | WF3 | 24472. | WB03 | 2719. | | |
| WSTG2 | 383401. | WF2 | 345065. | WB02 | 38337. | WSTG1 | 1188768. | [illegible] | 1069902. | WB01 | 118866. | WC | 1819361. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | [illegible] | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 | 0.1111 |
| DV1 | 4.17480 | DV0 | 0.00000 | DVS1 | 1.67040 | DVS2 | 3.39040 | DV | 1.18220 | G2 | 0.1111 | G3 | 0.1111 | | |

TABLE 21. PLANETARY MISSION STAGE SIZING FOR VENUS SWINGBY OPPOSITION 2022 TO 2031

DATE 2022 OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 100164. | WF3 | 90148. | WBO3 | 19015. | G1 | 0.1111 |
| WSTG2 | 781842. | WF2 | 703665. | WBO2 | 78177. | WSTG1 | 1731473. | WF1 | 1558341. | WBO1 | 173132. | WO | 2833479. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | | |
| DV1 | 3.75850 | DV0 | 0.00000 | DVS1 | 2.99380 | DVS2 | 2.52030 | DV4 | 3.18970 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2025 OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 17513. | WF3 | 15762. | WBO3 | 1751. | G1 | 0.1111 |
| WSTG2 | 468466. | WF2 | 421623. | WBO2 | 46842. | WSTG1 | 1378652. | WF1 | 1240799. | WBO1 | 137853. | WO | 2084630. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | | |
| DV1 | 4.25720 | DV0 | 0.00000 | DVS1 | 3.46570 | DVS2 | 1.46370 | DV4 | 0.80290 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2027 INBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 35043. | WF3 | 31539. | WBO3 | 3504. | G1 | 0.1111 |
| WSTG2 | 792239. | WF2 | 713022. | WBO2 | 79217. | WSTG1 | 1735927. | WF1 | 1562350. | WBO1 | 173577. | WO | 2783209. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | | |
| DV1 | 3.87900 | DV0 | 0.00000 | DVS1 | 3.06500 | DVS2 | 3.43380 | DV4 | 1.46330 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2029 DOUBLE SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 49017. | WF3 | 44115. | WBO3 | 4901. | G1 | 0.1111 |
| WSTG2 | 572377. | WF2 | 515144. | WBO2 | 57233. | WSTG1 | 1672040. | WF1 | 1504851. | WBO1 | 167189. | WO | 2513434. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | | |
| DV1 | 4.29820 | DV0 | 0.00000 | DVS1 | 2.63650 | DVS2 | 2.80700 | DV4 | 1.91450 | G2 | 0.1111 | G3 | 0.1111 | | |

DATE 2031 OUTBOUND SWINGBY PROFILE

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 83000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 42000. | WSTG3 | 101967. | WF3 | 91771. | WBO3 | 10196. | G1 | 0.1111 |
| WSTG2 | 449763. | WF2 | 404790. | WBO2 | 44972. | WSTG1 | 1503840. | WF1 | 1353470. | WBO1 | 150371. | WO | 2275570. | | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | | |
| DV1 | 4.25220 | DV0 | 0.00000 | DVS1 | 2.46690 | DVS2 | 1.55500 | DV4 | 3.22670 | G2 | 0.1111 | G3 | 0.1111 | | |

TABLE 22. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DEFINITION

| MISSION FOR OPPOSITION YEAR | EARTH–MARS OPPOSITION J.D. 2460000 | LEAVE EARTH J.D. 246000 (EMOS) | ARRIVE MARS | LEAVE MARS | ARRIVE EARTH | OUTBOUND TRIP TIME (DAYS) | MARS STOPOVER TIME (DAYS) | INBOUND TRIP TIME (DAYS) | TOTAL MISSION TIME (DAYS) |
|---|---|---|---|---|---|---|---|---|---|
| 2031 | 2989 | 2860 (.1107) | 3142 (.1165) | 3642 (.0826) | 3858 (.1202) | 282 | 500 | 216 | 998 |
| 2033 | 3775 | 3706 (.1016) | 3906 (.1111) | 4456 (.0996) | 4656 (.1013) | 200 | 550 | 200 | 950 |
| 2035 | 4584 | 4508 (.1091) | 4712 (.0876) | 5242 (.1202) | 5512 (.1129) | 204 | 530 | 270 | 1004 |
| 2037 | 5382 | 5290 (.1353) | 5646 (.0947) | 5986 (.1046) | 6276 (.0957) | 356 | 340 | 290 | 986 |
| 2040 | 6157 | 6052 (.1193) | 6392 (.0833) | 6732 (.0922) | 7036 (.0968) | 340 | 340 | 304 | 984 |
| 2042 | 6920 | 6812 (.1050) | 7130 (.0836) | 7470 (.0870) | 7802 (.1127) | 318 | 340 | 332 | 990 |
| 2044 | 7688 | 7568 (.1003) | 7874 (.0940) | 8214 (.0866) | 8564 (.1318) | 306 | 340 | 350 | 996 |

# TABLE 23. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2031 OPPOSITION

DEPARTURE PLANET • EARTH
ARRIVAL PLANET • MARS

| DEPART / RESTART / CORD1 / DU1 | ARRIVE / RETURN / CORD2 / DU2 | C3 / C3 / DU3 | R A / R A / DU4 | DECL / DECL / GAM1 | I 1 / I 1 / GAM2 | V 1 / V 1 / GAM3 | PSI 1 / PSI 1 / GAM4 | ECCEN / ECCEN / ETA1 | SMA / SMA / ETA2 | THET1 / THET1 / ETA3 | THET2 / THET2 / ETA4 | PERIH / PERIH / ETAO | APHEL / APHEL | I 2 / I 2 | V 2 / V 2 | PSI 2 / PSI 2 | R A / R A | DECL / DECL | VHP / C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 62854.0 | 63138.0 | 11.58 | 227.1 | 11.5 | 2.82 | 1.091 | 94.0 | 0.184 | 1.187 | 333.6 | 552.9 | 0.968 | 1.406 | -1.72 | 0.767 | 87.1 | 312.4 | -30.1 | 3.45 |
| 63638.0 | 63858.0 | 6.02 | 201.1 | 20.0 | 3.07 | 0.697 | [illegible] | 0.242 | 1.322 | 200.2 | 350.4 | --- | --- | -1.61 | 1.111 | 88.1 | 93.8 | 8.4 | 12.93 |
| 1.2349 | 1.4694 | | | | | | | | | | | | | | | | | | |
| 3.67828 | 1.36059 | 0.83140 | 1.02419 | 2.18465 | 1.33517 | 1.19319 | 1.24308 | 6.02825 | 3.92661 | 1.56039 | 1.02747 | 13.16961 | | | | | | | |
| 62856.0 | 63140.0 | 11.30 | 227.9 | 12.5 | 2.89 | 1.091 | 93.8 | 0.183 | 1.187 | 334.9 | 553.5 | 0.970 | 1.406 | -1.84 | 0.768 | 87.0 | 312.4 | -30.9 | 3.46 |
| 63640.0 | 63858.0 | 6.03 | 200.1 | 19.5 | 2.98 | 0.698 | 96.4 | 0.242 | 1.322 | 201.0 | 350.3 | --- | --- | -1.51 | 1.111 | 88.1 | 94.0 | 9.3 | 12.87 |
| 1.2461 | 1.4598 | | | | | | | | | | | | | | | | | | |
| 3.66572 | 1.36453 | 0.83249 | 1.02141 | 2.17883 | 1.33629 | 1.19347 | 1.24235 | 6.02874 | 3.92654 | 1.55956 | 1.02739 | 13.13569 | | | | | | | |
| 62858.0 | 63142.0 | 11.04 | 228.5 | 13.4 | 2.95 | 1.092 | 93.6 | 0.183 | 1.188 | 336.3 | 554.1 | 0.971 | 1.405 | -1.95 | 0.769 | 86.9 | 312.4 | -31.7 | 3.47 |
| 63642.6 | 63858.0 | 6.06 | 199.2 | 19.1 | 2.90 | 0.699 | 96.6 | 0.242 | 1.323 | 201.9 | 350.2 | --- | --- | -1.42 | 1.111 | 88.1 | 94.2 | 10.1 | 12.82 |
| 1.2573 | 1.4295 | | | | | | | | | | | | | | | | | | |
| 3.65443 | 1.37046 | 0.83505 | 1.01918 | 2.17361 | 1.33797 | 1.19412 | 1.24176 | 6.03401 | 3.92761 | 1.55897 | 1.02732 | 13.11559 | | | | | | | |
| 62860.0 | 63142.0 | 10.88 | 229.1 | 15.3 | 3.10 | 1.092 | 93.3 | 0.182 | 1.188 | 338.0 | 553.8 | 0.973 | 1.404 | -2.13 | 0.769 | 87.0 | 313.5 | -32.7 | 3.47 |
| 63642.0 | 63858.0 | 6.06 | 199.2 | 19.1 | 2.90 | 0.699 | 96.6 | 0.242 | 1.323 | 201.9 | 350.2 | --- | --- | -1.42 | 1.111 | 88.1 | 94.2 | 10.1 | 12.82 |
| 1.2573 | 1.4295 | | | | | | | | | | | | | | | | | | |
| 3.64729 | 1.37537 | 0.83505 | 1.01918 | 2.17032 | 1.33937 | 1.19412 | 1.24176 | 6.03876 | 3.92824 | 1.55897 | 1.02732 | 13.10601 | | | | | | | |
| 62862.0 | 63144.0 | 10.70 | 229.6 | 16.4 | 3.17 | 1.092 | 93.1 | 0.181 | 1.185 | 339.4 | 554.4 | 0.974 | 1.404 | -2.26 | 0.770 | 86.9 | 313.4 | -33.5 | 3.49 |
| 63644.0 | 63860.0 | 6.14 | 198.9 | 19.2 | 2.92 | 0.701 | 96.8 | 0.242 | 1.323 | 202.6 | 351.9 | --- | --- | -1.41 | 1.111 | 88.4 | 92.9 | 10.2 | 12.64 |
| 1.2685 | 1.4208 | | | | | | | | | | | | | | | | | | |
| 3.63913 | 1.38436 | 0.84287 | 1.01159 | 2.16655 | 1.34193 | 1.19616 | 1.23976 | 6.05025 | 3.93006 | 1.55692 | 1.02709 | 13.10819 | | | | | | | |
| 62864.0 | 63146.0 | 10.54 | 230.1 | 17.5 | 3.25 | 1.092 | 92.9 | 0.180 | 1.189 | 340.8 | 555.0 | 0.976 | 1.403 | -2.39 | 0.771 | 86.8 | 313.4 | -34.4 | 3.51 |
| 63646.0 | 63860.0 | 6.19 | 197.9 | 18.8 | 2.84 | 0.702 | 97.1 | 0.243 | 1.324 | 203.5 | 351.8 | --- | --- | -1.32 | 1.112 | 88.4 | 93.1 | 11.0 | 12.60 |
| 1.2796 | 1.3895 | | | | | | | | | | | | | | | | | | |
| 3.63233 | 1.39558 | 0.84716 | 1.00971 | 2.16343 | 1.34513 | 1.19719 | 1.23926 | 6.06646 | 3.93276 | 1.55652 | 1.02703 | 13.1243[illegible] | | | | | | | |
| 62866.0 | 63146.0 | 10.56 | 230.5 | 19.7 | 3.43 | 1.092 | 92.6 | 0.179 | 1.190 | 342.5 | 554.7 | 0.977 | 1.403 | -2.60 | 0.772 | 86.9 | 314.5 | -36.6 | 3.53 |
| 63646.0 | 63860.0 | 6.19 | 197.9 | 18.8 | 2.84 | 0.702 | 97.1 | 0.243 | 1.324 | 203.5 | 351.8 | --- | --- | -1.32 | 1.112 | 88.4 | 93.1 | 11.0 | 12.60 |
| 1.2796 | 1.3895 | | | | | | | | | | | | | | | | | | |
| 3.63290 | 1.40670 | 0.84716 | 1.00971 | 2.16369 | 1.34820 | 1.19719 | 1.23926 | 6.08261 | 3.93414 | 1.55652 | 1.02703 | 13.16087 | | | | | | | |

DEPARTURE PLANET • EARTH
ARRIVAL PLANET • MARS

TABLE 24. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2033 OPPOSITION

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

| DEPART / RESTART / CORD1 | ARRIVE / RETURN / CORD2 | C3 / C3 | R A / R A | DECL / DECL | I 1 / I 1 | V 1 / V 1 | PSI 1 / PSI 1 | ECCEN / ECCEN | SMA / SMA | THET1 / THET1 | THET2 / THET2 | PERIH / PERIH | APHEL / APHEL | I 2 / I 2 | V 2 / V 2 | PSI 2 / PSI 2 | R A / R A | DECL / DECL | VHP / C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63700.0 | 63900.0 | 9.00 | 279.2 | -59.3 | -3.14 | 1.076 | 87.5 | 0.166 | 1.194 | 17.6 | 168.0 | --- | --- | 1.73 | 0.778 | 92.4 | 354.2 | 10.6 | 3.35 |
| 64450.0 | 64654.0 | 8.84 | 281.0 | -28.4 | -0.64 | 0.747 | 94.0 | 0.199 | 1.229 | 196.7 | 347.7 | --- | --- | 2.38 | 1.100 | 88.0 | 179.3 | 29.6 | 9.17 |
| 0.5469 | 1.0685 | | | | | | | | | | | | | | | | | | |
| 63702.0 | 63902.0 | 9.01 | 269.0 | -57.8 | -3.03 | 1.075 | 87.3 | 0.166 | 1.194 | 19.2 | 168.9 | --- | --- | 1.58 | 0.777 | 92.2 | 354.0 | 9.4 | 3.33 |
| 64452.0 | 64654.0 | 8.81 | 280.5 | -28.3 | -0.61 | 0.748 | 94.2 | 0.199 | 1.228 | 197.4 | 347.3 | --- | --- | 2.36 | 1.100 | 87.9 | 179.8 | 29.1 | 9.16 |
| 0.9602 | 1.0527 | | | | | | | | | | | | | | | | | | |
| 63704.0 | 63904.0 | 9.06 | 268.0 | -56.3 | -2.93 | 1.076 | 87.1 | 0.167 | 1.193 | 20.8 | 169.8 | --- | --- | 1.44 | 0.776 | 92.0 | 353.7 | 8.2 | 3.32 |
| 64454.0 | 64654.0 | 8.79 | 279.8 | -28.2 | -0.59 | 0.749 | 94.4 | 0.199 | 1.227 | 198.2 | 346.9 | --- | --- | 2.33 | 1.100 | 87.8 | 180.4 | 28.5 | 9.15 |
| 0.9737 | 1.0371 | | | | | | | | | | | | | | | | | | |
| 63706.0 | 63906.0 | 9.15 | 267.1 | -54.8 | -2.82 | 1.074 | 86.9 | 0.167 | 1.193 | 22.3 | 170.6 | --- | --- | 1.30 | 0.776 | 91.9 | 353.5 | 7.0 | 3.31 |
| 64456.0 | 64656.0 | 8.80 | 279.5 | -29.3 | -0.74 | 0.751 | 94.5 | 0.198 | 1.227 | 198.9 | 348.5 | --- | --- | 2.45 | 1.100 | 88.1 | 180.4 | 30.2 | 9.10 |
| 0.9772 | 1.0215 | | | | | | | | | | | | | | | | | | |
| 63708.0 | 63908.0 | 9.28 | 266.4 | -53.2 | -2.72 | 1.073 | 86.6 | 0.168 | 1.193 | 23.9 | 171.5 | --- | --- | 1.16 | 0.775 | 91.7 | 353.2 | 5.9 | 3.31 |
| 64458.0 | 64656.0 | 8.80 | 278.7 | -29.1 | -0.71 | 0.752 | 94.7 | 0.198 | 1.227 | 199.7 | 348.1 | --- | --- | 2.42 | 1.100 | 88.0 | 180.9 | 29.6 | 9.08 |
| 1.0008 | 1.0061 | | | | | | | | | | | | | | | | | | |
| 63710.0 | 63908.0 | 9.48 | 264.9 | -51.2 | -2.59 | 1.073 | 86.3 | 0.169 | 1.192 | 25.9 | 171.5 | --- | --- | 1.00 | 0.775 | 91.7 | 353.7 | 4.8 | 3.31 |
| 64458.0 | 64656.0 | 8.80 | 278.7 | -29.1 | -0.71 | 0.752 | 94.7 | 0.198 | 1.227 | 199.7 | 348.1 | --- | --- | 2.42 | 1.100 | 88.0 | 180.9 | 29.6 | 9.08 |
| 1.0008 | 1.0061 | | | | | | | | | | | | | | | | | | |
| 63712.0 | 63910.0 | 9.72 | 264.6 | -49.8 | -2.50 | 1.072 | 86.1 | 0.169 | 1.191 | 27.4 | 172.4 | --- | --- | 0.87 | 0.774 | 91.5 | 353.4 | 3.7 | 3.31 |
| 64460.0 | 64656.0 | 8.81 | 278.0 | -29.0 | -0.69 | 0.753 | 94.9 | 0.198 | 1.226 | 200.5 | 347.8 | --- | --- | 2.39 | 1.100 | 88.0 | 181.3 | 29.1 | 9.07 |
| 1.0146 | 0.9907 | | | | | | | | | | | | | | | | | | |

| DV1 | DV2 | DV3 | DV4 | GAM1 | GAM2 | GAM3 | GAM4 | ETA1 | ETA2 | ETA3 | ETA4 | ETAO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.56363 | 1.30120 | 1.09131 | 0.85752 | 2.13208 | 1.31843 | 1.26093 | 1.19983 | 5.98840 | 3.97645 | 1.52044 | 1.02248 | 12.76774 |
| 3.56381 | 1.29017 | 1.08859 | 0.85687 | 2.13216 | 1.31533 | 1.26020 | 1.19967 | 5.96993 | 3.97348 | 1.52012 | 1.02246 | 12.72887 |
| 3.56597 | 1.28238 | 1.08694 | 0.85651 | 2.13314 | 1.31317 | 1.25976 | 1.19957 | 5.95797 | 3.97156 | 1.51993 | 1.02245 | 12.70920 |
| 3.57008 | 1.27784 | 1.08741 | 0.85427 | 2.13500 | 1.31190 | 1.25989 | 1.19900 | 5.95177 | 3.97033 | 1.51927 | 1.02238 | 12.70706 |
| 3.57613 | 1.27641 | 1.08758 | 0.85338 | 2.13775 | 1.31151 | 1.25993 | 1.19878 | 5.95134 | 3.96988 | 1.51901 | 1.02235 | 12.72250 |
| 3.58491 | 1.27711 | 1.08758 | 0.85338 | 2.14174 | 1.31170 | 1.25993 | 1.19878 | 5.95534 | 3.96997 | 1.51901 | 1.02235 | 12.75479 |
| 3.59664 | 1.28041 | 1.08907 | 0.85280 | 2.14663 | 1.31262 | 1.26033 | 1.19863 | 5.96455 | 3.97087 | 1.51890 | 1.02234 | 12.80367 |

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TABLE 25. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2035 OPPOSITION

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

| DEPART / RESTART | ARRIVE / RETURN | C3 / C3 | R A / R A | DECL / DECL | I 1 / I 1 | V 1 / V 1 | PSI 1 / PSI 1 | ECCEN / ECCEN | SMA / SMA | THET1 / THET1 | THET2 / THET2 | PERIH / PERIH | APHEL / APHEL | I 2 / I 2 | V 2 / V 2 | PSI 2 / PSI 2 | R A / R A | DECL / DECL | VHP / C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64504.0 | 64710.0 | 10.41 | 358.0 | 10.4 | 1.02 | 1.090 | 89.8 | 0.209 | 1.284 | 1.0 | 152.8 | --- | --- | -2.69 | 0.740 | 96.7 | 74.6 | 0.1 | 2.63 |
| 65240.0 | 65510.0 | 12.93 | 337.1 | 5.7 | 2.21 | 0.774 | 89.1 | 0.172 | 1.180 | 175.8 | 391.0 | 0.977 | 1.382 | -3.15 | 1.076 | 94.4 | 217.6 | -48.5 | 11.14 |
| 64506.0 | 64710.0 | 10.43 | 357.0 | 9.3 | 0.96 | 1.090 | 89.5 | 0.209 | 1.285 | 2.7 | 152.6 | --- | --- | -2.62 | 0.740 | 96.7 | 75.0 | 0.7 | 2.62 |
| 65240.0 | 65510.0 | 12.93 | 337.1 | 5.7 | 2.21 | 0.774 | 89.1 | 0.172 | 1.180 | 175.8 | 391.0 | 0.977 | 1.382 | -3.15 | 1.076 | 94.4 | 217.6 | -48.5 | 11.14 |
| 64508.0 | 64712.0 | 10.55 | 355.9 | 9.2 | 1.01 | 1.090 | 89.3 | 0.209 | 1.285 | 4.2 | 153.2 | --- | --- | -2.64 | 0.739 | 96.6 | 74.8 | 0.5 | 2.61 |
| 65242.0 | 65512.0 | 12.81 | 337.2 | 4.9 | 2.09 | 0.774 | 89.2 | 0.172 | 1.179 | 176.3 | 392.1 | 0.976 | 1.382 | -3.08 | 1.075 | 94.6 | 218.9 | -47.7 | 11.31 |
| 64510.0 | 64712.0 | 10.68 | 354.8 | 8.1 | 0.95 | 1.090 | 89.0 | 0.209 | 1.285 | 6.0 | 153.1 | --- | --- | -2.58 | 0.739 | 96.7 | 75.2 | 1.0 | 2.61 |
| 65242.0 | 65512.0 | 12.81 | 337.2 | 4.9 | 2.09 | 0.774 | 89.2 | 0.172 | 1.179 | 176.3 | 392.1 | 0.976 | 1.382 | -3.08 | 1.075 | 94.6 | 218.9 | -47.7 | 11.31 |
| 64512.0 | 64714.0 | 10.90 | 353.7 | 7.9 | 0.99 | 1.090 | 88.7 | 0.210 | 1.285 | 7.6 | 153.8 | --- | --- | -2.59 | 0.737 | 96.5 | 74.9 | 0.9 | 2.60 |
| 65244.0 | 65512.0 | 12.75 | 336.3 | 5.0 | 2.16 | 0.774 | 88.4 | 0.172 | 1.179 | 177.3 | 391.8 | 0.976 | 1.382 | -3.16 | 1.075 | 94.5 | 218.9 | -48.6 | 11.36 |
| 64514.0 | 64714.0 | 11.15 | 352.6 | 6.9 | 0.94 | 1.090 | 88.4 | 0.210 | 1.285 | 9.4 | 153.7 | --- | --- | -2.53 | 0.737 | 96.5 | 75.1 | 1.4 | 2.60 |
| 65244.0 | 65512.0 | 12.75 | 336.3 | 5.0 | 2.16 | 0.774 | 89.4 | 0.172 | 1.179 | 177.3 | 391.8 | 0.976 | 1.382 | -3.16 | 1.075 | 94.5 | 218.9 | -48.6 | 11.36 |
| 64516.0 | 64716.0 | 11.49 | 351.6 | 6.6 | 0.38 | 1.090 | 88.1 | 0.211 | 1.284 | 11.0 | 154.6 | --- | --- | -2.54 | 0.736 | 96.4 | 74.8 | 1.2 | 2.59 |
| 65246.0 | 65514.0 | 12.67 | 336.4 | 4.3 | 2.04 | 0.774 | 89.5 | 0.172 | 1.178 | 177.7 | 393.0 | 0.975 | 1.382 | -3.09 | 1.074 | 94.7 | 220.2 | -47.7 | 11.55 |

| CORD1 | CORD2 | DV1 | DV2 | DV3 | DV4 | GAM1 | GAM2 | GAM3 | GAM4 | ETA1 | ETA2 | ETA3 | ETA4 | ETA0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1790 | 1.1162 | 3.62646 | 0.91671 | 1.44834 | 0.94501 | 2.16073 | 1.21502 | 1.36030 | 1.22234 | 5.77612 | 4.14696 | 1.56501 | 1.02507 | 12.48064 |
| 1.1790 | 1.1162 | 3.62724 | 0.91186 | 1.44834 | 0.94501 | 2.16109 | 1.21376 | 1.36030 | 1.22234 | 5.76962 | 4.14638 | 1.56501 | 1.02507 | 12.46865 |
| 1.1977 | 1.1049 | 3.63246 | 0.90789 | 1.43822 | 0.95273 | 2.16349 | 1.21274 | 1.35737 | 1.22436 | 5.76305 | 4.14390 | 1.56695 | 1.02530 | 12.46828 |
| 1.1977 | 1.1049 | 3.63828 | 0.90152 | 1.43822 | 0.95279 | 2.16616 | 1.21187 | 1.35737 | 1.22436 | 5.76031 | 4.14350 | 1.56695 | 1.02530 | 12.47779 |
| 1.2165 | 1.0937 | 3.64806 | 0.90158 | 1.43344 | 0.95483 | 2.17067 | 1.21111 | 1.35600 | 1.22489 | 5.75719 | 4.14149 | 1.56734 | 1.02537 | 12.49695 |
| 1.2165 | 1.0937 | 3.65942 | 0.89970 | 1.43344 | 0.95483 | 2.17502 | 1.21063 | 1.35600 | 1.22489 | 5.75840 | 4.14126 | 1.56734 | 1.02537 | 12.52979 |
| 1.2353 | 1.0825 | 3.67429 | 0.89800 | 1.42626 | 0.96318 | 2.18280 | 1.21019 | 1.35393 | 1.22707 | 5.76081 | 4.14089 | 1.56961 | 1.02562 | 12.57469 |

TABLE 26. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2037 OPPOSITION

ORIGINAL PAGE IS
OF POOR QUALITY

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

| DEPART | ARRIVE | C3 | R A | DECL | I 1 | V 1 | PSI 1 | ECCEN | SMA | THET1 | THET2 | PERIH | APHEL | I 2 | V 2 | PSI 2 | R A | DECL | VHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESTART | RETURN | C3 | R A | DECL | I 1 | V 1 | PSI 1 | ECCEN | SMA | THET1 | THET2 | PERIH | APHEL | I 2 | V 2 | PSI 2 | R A | DECL | C3 |
| CORD1 | CORD2 | | | | | | | | | | | | | | | | | | |
| DV1 | DV2 | | DV3 | DV4 | | GAM1 | GAM2 | | GAM3 | | GAM4 | ETA1 | | ETA2 | ETA3 | | ETA4 | ETA0 | |
| 65284.0 | 65638.0 | 17.15 | 331.4 | -20.7 | -2.51 | 1.110 | 93.0 | 0.254 | 1.350 | 345.0 | 561.1 | 1.006 | 1.693 | 3.14 | 0.684 | 83.1 | 71.5 | 24.0 | 2.76 |
| 65978.0 | 66272.0 | 19.17 | 310.5 | 5.0 | 0.73 | 0.779 | 85.8 | 0.170 | 1.209 | 158.7 | 372.5 | 1.003 | 1.414 | -2.41 | 1.077 | 91.8 | 193.0 | -28.3 | 8.10 |
| 2.4623 | 1.5443 | | | | | | | | | | | | | | | | | | |
| 3.92232 | 0.97988 | | 1.21033 | 0.80962 | | 2.30091 | 1.23143 | | 1.29322 | | 1.18768 | 5.71366 | | 3.97589 | 1.51147 | | 1.02108 | 13.14660 | |
| 65286.0 | 65642.0 | 16.78 | 331.2 | -20.5 | -2.46 | 1.111 | 92.8 | 0.255 | 1.351 | 346.2 | 562.2 | 1.007 | 1.695 | 3.15 | 0.685 | 82.8 | 72.4 | 23.9 | 2.79 |
| 65982.0 | 66274.0 | 9.90 | 309.2 | 4.3 | 0.62 | 0.777 | 86.1 | 0.170 | 1.209 | 160.3 | 373.6 | 1.003 | 1.414 | -2.34 | 1.076 | 92.0 | 192.9 | -27.4 | 8.10 |
| 2.4775 | 1.5253 | | | | | | | | | | | | | | | | | | |
| 3.90638 | 0.99393 | | 1.18568 | 0.80957 | | 2.29313 | 1.23511 | | 1.28647 | | 1.18767 | 5.71007 | | 3.96550 | 1.51030 | | 1.02108 | 13.09393 | |
| 65288.0 | 65644.0 | 16.45 | 330.4 | -21.0 | -2.49 | 1.112 | 92.5 | 0.254 | 1.352 | 347.7 | 562.6 | 1.008 | 1.695 | 3.22 | 0.686 | 82.7 | 73.0 | 24.4 | 2.80 |
| 65984.0 | 66274.0 | 9.79 | 308.4 | 4.4 | 0.65 | 0.776 | 86.3 | 0.170 | 1.209 | 161.3 | 373.3 | 1.003 | 1.414 | -2.37 | 1.076 | 91.9 | 193.5 | -27.8 | 8.11 |
| 2.4847 | 1.5157 | | | | | | | | | | | | | | | | | | |
| 3.89307 | 1.00235 | | 1.17636 | 0.80984 | | 2.28665 | 1.23732 | | 1.28392 | | 1.18774 | 5.71061 | | 3.96208 | 1.50994 | | 1.02109 | 13.05819 | |
| 65290.0 | 65646.0 | 16.23 | 329.6 | -21.4 | -2.53 | 1.112 | 92.2 | 0.254 | 1.352 | 349.2 | 563.1 | 1.008 | 1.696 | 3.29 | 0.687 | 82.6 | 73.5 | 24.8 | 2.82 |
| 65986.0 | 66276.0 | 9.70 | 307.9 | 3.5 | 0.52 | 0.775 | 86.4 | 0.170 | 1.209 | 162.0 | 374.7 | 1.003 | 1.414 | -2.27 | 1.076 | 92.1 | 192.7 | -26.4 | 8.13 |
| 2.4917 | 1.5060 | | | | | | | | | | | | | | | | | | |
| 3.88239 | 1.01196 | | 1.16849 | 0.81061 | | 2.28147 | 1.23985 | | 1.28178 | | 1.18793 | 5.71505 | | 3.95971 | 1.50981 | | 1.02111 | 13.03871 | |
| 65292.0 | 65646.0 | 16.13 | 328.2 | -22.7 | -2.66 | 1.112 | 91.8 | 0.254 | 1.352 | 351.0 | 563.0 | 1.009 | 1.695 | 3.45 | 0.687 | 82.6 | 73.9 | 26.0 | 2.83 |
| 65986.0 | 66276.0 | 9.70 | 307.9 | 3.5 | 0.52 | 0.775 | 86.4 | 0.170 | 1.209 | 162.0 | 374.7 | 1.003 | 1.414 | -2.27 | 1.076 | 92.1 | 192.7 | -26.4 | 8.13 |
| 2.4917 | 1.5060 | | | | | | | | | | | | | | | | | | |
| 3.87789 | 1.01832 | | 1.16849 | 0.81061 | | 2.27929 | 1.24153 | | 1.28178 | | 1.18793 | 5.72227 | | 3.96046 | 1.50981 | | 1.02111 | 13.04269 | |
| 65294.0 | 65646.0 | 16.15 | 326.7 | -24.1 | -2.82 | 1.113 | 91.5 | 0.253 | 1.352 | 352.8 | 562.9 | 1.010 | 1.695 | 3.63 | 0.687 | 82.7 | 74.2 | 27.2 | 2.85 |
| 65986.0 | 66276.0 | 9.70 | 307.9 | 3.5 | 0.52 | 0.775 | 86.4 | 0.170 | 1.209 | 162.0 | 374.7 | 1.003 | 1.414 | -2.27 | 1.076 | 92.1 | 192.7 | -26.4 | 8.13 |
| 2.4917 | 1.5060 | | | | | | | | | | | | | | | | | | |
| 3.87887 | 1.02826 | | 1.16849 | 0.81061 | | 2.27976 | 1.24415 | | 1.28178 | | 1.18793 | 5.73642 | | 3.96163 | 1.50981 | | 1.02111 | 13.07758 | |
| 65296.0 | 65646.0 | 16.31 | 325.1 | -25.6 | -2.99 | 1.113 | 91.1 | 0.253 | 1.352 | 354.6 | 562.7 | 1.010 | 1.694 | 3.83 | 0.687 | 82.7 | 74.5 | 28.5 | 2.88 |
| 65936.0 | 66276.0 | 9.70 | 307.9 | 3.5 | 0.52 | 0.775 | 86.4 | 0.170 | 1.209 | 162.0 | 374.7 | 1.003 | 1.414 | -2.27 | 1.076 | 92.1 | 192.7 | -26.4 | 8.13 |
| 2.4917 | 1.5060 | | | | | | | | | | | | | | | | | | |
| 3.88589 | 1.04231 | | 1.16849 | 0.81061 | | 2.28317 | 1.24787 | | 1.28178 | | 1.18793 | 5.75849 | | 3.96330 | 1.50981 | | 1.02111 | 13.14760 | |

# TABLE 27. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2040 OPPOSITION



DEPARTURE PLANET : EARTH
ARRIVAL PLANET : MARS

DEPARTURE PLANET : EARTH
ARRIVAL PLANET : MARS

| DEPART / RESTART | ARRIVE / RETURN | C3 / C3 | R A / R A | DECL / DECL | I 1 / I 1 | V 1 / V 1 | PSI 1 / PSI 1 | ECCEN / ECCEN | SMA / SMA | THET1 / THET1 | THET2 / THET2 | PERIH / PERIH | APHEL / APHEL | I 2 / I 2 | V 2 / V 2 | PSI 2 / PSI 2 | R A / R A | DECL / DECL | VHP / C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 66044.0 | 66388.0 | 13.56 | 97.2 | 11.5 | -1.31 | 1.110 | 92.8 | 0.244 | 1.323 | 345.6 | 561.8 | 1.000 | 1.646 | 2.73 | 0.698 | 83.3 | 197.1 | 18.5 | 2.45 |
| 66728.0 | 67034.0 | 7.53 | 44.5 | 6.4 | -1.27 | 0.758 | 84.6 | 0.188 | 1.249 | 155.4 | 361.8 | 1.014 | 1.484 | -0.62 | 1.083 | 90.3 | 343.9 | -14.4 | 8.37 |
| 66046.0 | 66388.0 | 13.24 | 95.9 | 10.8 | -1.37 | 1.110 | 92.5 | 0.243 | 1.323 | 347.4 | 561.7 | 1.001 | 1.645 | 2.81 | 0.698 | 83.4 | 197.9 | 18.9 | 2.45 |
| 66728.0 | 67034.0 | 7.53 | 44.5 | 6.4 | -1.27 | 0.758 | 84.6 | 0.188 | 1.249 | 155.4 | 361.8 | 1.014 | 1.484 | -0.62 | 1.083 | 90.3 | 343.9 | -14.4 | 8.37 |
| 66048.0 | 66388.6 | 12.99 | 94.5 | 10.0 | -1.44 | 1.111 | 92.1 | 0.243 | 1.323 | 349.2 | 561.5 | 1.002 | 1.644 | 2.90 | 0.698 | 83.4 | 198.6 | 19.4 | 2.46 |
| 66728.0 | 67034.0 | 7.53 | 44.5 | 6.4 | -1.27 | 0.758 | 84.6 | 0.188 | 1.249 | 155.4 | 361.8 | 1.014 | 1.484 | -0.62 | 1.083 | 90.3 | 343.9 | -14.4 | 8.37 |
| 66050.0 | 66390.0 | 12.78 | 93.4 | 10.0 | -1.43 | 1.111 | 91.8 | 0.242 | 1.323 | 350.8 | 562.1 | 1.003 | 1.644 | 2.92 | 0.700 | 83.3 | 198.6 | 19.4 | 2.47 |
| 66730.0 | 67034.0 | 7.53 | 43.8 | 5.7 | -1.33 | 0.75[illegible] | 84.8 | 0.188 | 1.249 | 156.3 | 361.6 | 1.014 | 1.484 | -0.56 | 1.083 | 90.2 | 343.9 | -13.6 | 8.36 |
| 66052.0 | 66392.0 | 12.63 | 92.3 | 10.1 | -1.42 | 1.112 | 91.5 | 0.242 | 1.324 | 352.5 | 562.8 | 1.003 | 1.644 | 2.93 | 0.701 | 83.1 | 198.6 | 19.4 | 2.48 |
| 66732.0 | 67036.0 | 7.54 | 43.4 | 4.8 | -1.42 | 0.756 | 84.9 | 0.189 | 1.249 | 157.2 | 363.2 | 1.014 | 1.485 | -0.46 | 1.083 | 90.5 | 342.3 | -13.1 | 8.32 |
| 66054.0 | 66394.0 | 12.54 | 91.2 | 10.2 | -1.41 | 1.112 | 91.2 | 0.248 | 1.324 | 354.1 | 563.4 | 1.003 | 1.644 | 2.94 | 0.702 | 82.9 | 198.6 | 19.4 | 2.50 |
| 66734.0 | 67036.0 | 7.57 | 42.7 | 4.1 | -1.48 | 0.754 | 85.1 | 0.189 | 1.250 | 158.2 | 363.0 | 1.014 | 1.485 | -0.40 | 1.083 | 90.5 | 342.3 | -12.3 | 8.31 |
| 66056.0 | 66396.0 | 12.51 | 90.0 | 10.3 | -1.39 | 1.113 | 90.8 | 0.242 | 1.324 | 355.7 | 564.0 | 1.003 | 1.645 | 2.95 | 0.703 | 82.3 | 198.5 | 19.4 | 2.52 |
| 66736.0 | 67036.0 | 7.62 | 42.0 | 3.3 | -1.55 | 0.763 | 85.3 | 0.189 | 1.250 | 159.1 | 362.9 | 1.014 | 1.486 | -0.32 | 1.083 | 90.5 | 342.3 | -11.4 | 8.31 |

| CORD1 | CORD2 | DU1 | DU2 | DU3 | DU4 | GAM1 | GAM2 | GAM3 | GAM4 | ETA1 | ETA2 | ETA3 | ETA4 | ETA0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.3221 | 1.8734 | 3.76584 | 0.82813 | 0.97256 | 0.82138 | 2.22567 | 1.19236 | 1.22952 | 1.19065 | 5.30713 | 3.85085 | 1.50414 | 1.02142 | 11.81193 |
| 2.3221 | 1.8734 | 3.75139 | 0.82930 | 0.97256 | 0.82138 | 2.21885 | 1.19266 | 1.22952 | 1.19065 | 5.30403 | 3.85097 | 1.50414 | 1.02142 | 11.76893 |
| 2.3221 | 1.8734 | 3.74060 | 0.83216 | 0.97256 | 0.82138 | 2.21377 | 1.19338 | 1.22952 | 1.19065 | 5.30426 | 3.85129 | 1.50414 | 1.02142 | 11.74241 |
| 2.3300 | 1.8648 | 3.73128 | 0.83857 | 0.97173 | 0.82092 | 2.20[illegible]39 | 1.19501 | 1.22930 | 1.19054 | 5.30875 | 3.85144 | 1.50396 | 1.02141 | 11.72911 |
| 2.3376 | 1.8560 | 3.72459 | 0.84577 | 0.97348 | 0.81929 | 2.20625 | 1.19684 | 1.22976 | 1.19013 | 5.31611 | 3.85241 | 1.50355 | 1.02136 | 11.72867 |
| 2.3450 | 1.8471 | 3.72055 | 0.85377 | 0.97617 | 0.81895 | 2.20436 | 1.19888 | 1.23046 | 1.19004 | 5.32661 | 3.85440 | 1.50356 | 1.02135 | 11.74177 |
| 2.3522 | 1.8380 | 3.71922 | 0.86265 | 0.96082 | 0.81877 | 2.20373 | 1.20114 | 1.23168 | 1.18999 | 5.34046 | 3.85744 | 1.50372 | 1.02135 | 11.76894 |

TABLE 28. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2042 OPPOSITION

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

| DEPART / RESTART | ARRIVE / RETURN | C3 / C3 | R A / R A | DECL / DECL | I 1 / I 1 | V 1 / V 1 | PSI 1 / PSI 1 | ECCEN / ECCEN | SMA / SMA | THET1 / THET1 | THET2 / THET2 | PERIH / PERIH | APHEL / APHEL | I 2 / I 2 | V 2 / V 2 | PSI 2 / PSI 2 | R A / R A | DECL / DECL | VHP / C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 66804.0 | 67130.0 | 10.39 | 124.9 | 20.9 | 0.12 | 1.107 | 92.3 | 0.227 | 1.285 | 347.4 | 561.6 | 0.994 | 1.577 | 1.75 | 0.719 | 84.0 | 233.4 | -4.1 | 2.50 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |
| 66806.0 | 67130.0 | 10.14 | 123.4 | 21.3 | 0.13 | 1.108 | 92.0 | 0.226 | 1.285 | 349.3 | 561.4 | 0.995 | 1.576 | 1.74 | 0.719 | 84.0 | 233.8 | -4.3 | 2.50 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |
| 66808.0 | 67130.0 | 9.96 | 121.9 | 21.7 | 0.14 | 1.108 | 91.6 | 0.226 | 1.285 | 351.1 | 561.2 | 0.995 | 1.576 | 1.73 | 0.719 | 84.1 | 234.1 | -4.4 | 2.49 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |
| 66810.0 | 67130.0 | 9.84 | 120.3 | 22.1 | 0.14 | 1.109 | 91.3 | 0.226 | 1.285 | 353.0 | 561.1 | 0.995 | 1.575 | 1.72 | 0.719 | 84.1 | 234.4 | -4.6 | 2.49 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |
| 66812.0 | 67130.0 | 9.79 | 118.7 | 22.5 | 0.16 | 1.109 | 90.9 | 0.226 | 1.285 | 354.9 | 561.0 | 0.995 | 1.575 | 1.71 | 0.719 | 84.2 | 234.7 | -4.8 | 2.49 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |
| 66814.0 | 67130.0 | 9.80 | 117.0 | 22.9 | 0.17 | 1.110 | 90.6 | 0.225 | 1.285 | 356.8 | 560.9 | 0.995 | 1.575 | 1.70 | 0.718 | 84.2 | 234.8 | -4.9 | 2.49 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |
| 66816.0 | 67130.0 | 9.89 | 115.3 | 23.3 | 0.18 | 1.110 | 90.2 | 0.226 | 1.285 | 358.7 | 560.8 | 0.995 | 1.575 | 1.68 | 0.718 | 84.2 | 235.0 | -5.1 | 2.49 |
| 67470.0 | 67802.0 | 6.72 | 81.0 | -0.5 | -2.80 | 0.734 | 83.2 | 0.214 | 1.292 | 153.4 | 365.5 | 1.016 | 1.568 | 1.28 | 1.092 | 91.0 | 357.9 | 12.7 | 11.26 |

| CORD1 | CORD2 | DV1 | DV2 | DV3 | DV4 | GAM1 | GAM2 | GAM3 | GAM4 | ETA1 | ETA2 | ETA3 | ETA4 | ETA0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.0846 | 2.1714 | 3.62533 | 0.85360 | 0.89693 | 0.95029 | 2.16021 | 1.19883 | 1.20992 | 1.22371 | 5.31565 | 3.86806 | 1.54015 | 1.02523 | 11.48273 |
| 2.0846 | 2.1714 | 3.61443 | 0.85181 | 0.89693 | 0.95029 | 2.15522 | 1.19838 | 1.20992 | 1.22371 | 5.30692 | 3.86787 | 1.54015 | 1.02523 | 11.44401 |
| 2.0846 | 2.1714 | 3.60635 | 0.85049 | 0.89693 | 0.95029 | 2.15152 | 1.19804 | 1.20992 | 1.22371 | 5.30575 | 3.86772 | 1.54015 | 1.02523 | 11.41542 |
| 2.0846 | 2.1714 | 3.60111 | 0.84967 | 0.89693 | 0.95029 | 2.14912 | 1.19783 | 1.20992 | 1.22371 | 5.30310 | 3.86763 | 1.54015 | 1.02523 | 11.39703 |
| 2.0846 | 2.1714 | 3.59877 | 0.84930 | 0.89693 | 0.95029 | 2.14806 | 1.19774 | 1.20992 | 1.22371 | 5.30192 | 3.86759 | 1.54015 | 1.02523 | 11.38882 |
| 2.0846 | 2.1714 | 3.59940 | 0.84934 | 0.89693 | 0.95029 | 2.14834 | 1.19775 | 1.20992 | 1.22371 | 5.30216 | 3.86759 | 1.54015 | 1.02523 | 11.39087 |
| 2.0846 | 2.1714 | 3.60302 | 0.84974 | 0.89693 | 0.95029 | 2.15000 | 1.19785 | 1.20992 | 1.22371 | 5.30377 | 3.86764 | 1.54015 | 1.02523 | 11.40311 |

# TABLE 29. MARS CONJUNCTION CLASS STOPOVER MISSION, MISSION DATA FOR 2044 OPPOSITION

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

DEPARTURE PLANET - EARTH
ARRIVAL PLANET - MARS

| DEPART / RESTART | ARRIVE / RETURN | C3 / C3 | R A / R A | DECL / DECL | I 1 / I 1 | V 1 / V 1 | PSI 1 / PSI 1 | ECCEN / ECCEN | SMA / SMA | THET1 / THET1 | THET2 / THET2 | PERIH / PERIH | APHEL / APHEL | I 2 / I 2 | V 2 / V 2 | PSI 2 / PSI 2 | R A / R A | DECL / DECL | VHP / C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67564.0 | 67872.0 | 9.10 | 163.9 | 27.6 | 1.73 | 1.102 | 92.2 | 0.206 | 1.243 | 347.0 | 560.9 | 0.986 | 1.499 | 0.15 | 0.743 | 84.8 | 265.4 | -22.8 | 2.80 |
| 68212.0 | 68564.0 | 6.69 | 121.2 | -7.0 | -3.23 | 0.710 | 82.2 | 0.238 | 1.329 | 152.9 | 367.6 | 1.013 | 1.646 | 2.45 | 1.104 | 91.5 | 15.0 | 29.3 | 15.35 |
| 67566.0 | 67872.0 | 8.98 | 163.2 | 29.3 | 1.82 | 1.103 | 91.9 | 0.206 | 1.243 | 348.8 | 560.7 | 0.987 | 1.499 | 0.03 | 0.743 | 84.8 | 265.9 | -23.7 | 2.80 |
| 68212.0 | 68564.0 | 6.69 | 121.2 | -7.0 | -3.23 | 0.710 | 82.2 | 0.238 | 1.329 | 152.9 | 367.6 | 1.013 | 1.646 | 2.45 | 1.104 | 91.5 | 15.0 | 29.3 | 15.35 |
| 67568.0 | 67874.0 | 8.92 | 162.7 | 30.9 | 1.93 | 1.103 | 91.6 | 0.206 | 1.243 | 350.5 | 561.5 | 0.987 | 1.498 | -0.09 | 0.745 | 84.7 | 265.2 | -24.6 | 2.80 |
| 68214.0 | 68564.0 | 6.65 | 120.8 | -7.7 | -3.31 | 0.709 | 82.3 | 0.238 | 1.329 | 153.6 | 367.4 | 1.013 | 1.645 | 2.55 | 1.104 | 91.4 | 15.0 | 30.2 | 15.42 |
| 67570.0 | 67874.0 | 8.93 | 161.9 | 32.8 | 2.05 | 1.103 | 91.3 | 0.205 | 1.243 | 352.4 | 561.4 | 0.988 | 1.498 | -0.23 | 0.745 | 84.7 | 265.5 | -25.8 | 2.80 |
| 68214.0 | 68564.0 | 6.65 | 120.8 | -7.7 | -3.31 | 0.709 | 82.3 | 0.238 | 1.329 | 153.6 | 367.4 | 1.013 | 1.645 | 2.55 | 1.104 | 91.4 | 15.0 | 30.2 | 15.42 |
| 67572.0 | 67874.0 | 9.03 | 161.1 | 34.8 | 2.19 | 1.104 | 91.0 | 0.205 | 1.243 | 354.3 | 561.3 | 0.988 | 1.497 | -0.39 | 0.745 | 84.7 | 265.8 | -27.0 | 2.80 |
| 68214.0 | 68564.0 | 6.65 | 120.8 | -7.7 | -3.31 | 0.709 | 82.3 | 0.238 | 1.329 | 153.6 | 367.4 | 1.013 | 1.645 | 2.55 | 1.104 | 91.4 | 15.0 | 30.2 | 15.42 |
| 67574.0 | 67876.0 | 9.18 | 160.6 | 36.6 | 2.33 | 1.104 | 90.7 | 0.205 | 1.242 | 356.0 | 562.1 | 0.988 | 1.497 | -0.55 | 0.746 | 84.6 | 265.0 | -28.3 | 2.81 |
| 68216.0 | 68564.0 | 6.62 | 120.4 | -8.4 | -3.39 | 0.708 | 82.5 | 0.238 | 1.329 | 154.3 | 367.2 | 1.013 | 1.644 | 2.65 | 1.104 | 91.4 | 15.0 | 31.1 | 15.52 |
| 67576.0 | 67878.0 | 9.39 | 160.0 | 38.4 | 2.48 | 1.104 | 90.4 | 0.205 | 1.242 | 357.8 | 563.0 | 0.988 | 1.496 | -0.72 | 0.747 | 84.4 | 264.2 | -29.5 | 2.82 |
| 68218.0 | 68566.0 | 6.51 | 120.7 | -8.0 | -3.32 | 0.706 | 82.7 | 0.238 | 1.328 | 154.9 | 368.7 | 1.012 | 1.645 | 2.61 | 1.104 | 91.7 | 14.4 | 30.3 | 15.83 |

| CORD1 | CORD2 | DV1 | DV2 | DV3 | DV4 | GAM1 | GAM2 | GAM3 | GAM4 | ETA1 | ETA2 | ETA3 | ETA4 | ETA0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.7766 | 2.3949 | 3.56793 | 1.00007 | 0.89396 | 1.13025 | 2.13403 | 1.23672 | 1.20916 | 1.27141 | 5.58741 | 3.95433 | 1.59728 | 1.03077 | 11.92370 |
| 1.7766 | 2.3949 | 3.56238 | 0.99876 | 0.89396 | 1.13025 | 2.13152 | 1.23638 | 1.20916 | 1.27141 | 5.58387 | 3.95418 | 1.59728 | 1.03077 | 11.90212 |
| 1.7863 | 2.3882 | 3.55986 | 0.99860 | 0.89044 | 1.13355 | 2.13038 | 1.23634 | 1.20825 | 1.27230 | 5.58237 | 3.95381 | 1.59820 | 1.03088 | 11.89254 |
| 1.7863 | 2.3882 | 3.56032 | 0.99888 | 0.89044 | 1.13355 | 2.13058 | 1.23641 | 1.20825 | 1.27230 | 5.58289 | 3.95385 | 1.59820 | 1.03088 | 11.89479 |
| 1.7863 | 2.3882 | 3.56459 | 1.00051 | 0.89044 | 1.13355 | 2.13252 | 1.23684 | 1.20825 | 1.27230 | 5.58645 | 3.95404 | 1.59820 | 1.03088 | 11.91320 |
| 1.7959 | 2.3812 | 3.57130 | 1.00450 | 0.88802 | 1.13756 | 2.13556 | 1.23789 | 1.20763 | 1.27338 | 5.59465 | 3.95497 | 1.59939 | 1.03100 | 11.94769 |
| 1.8053 | 2.3740 | 3.58106 | 1.01123 | 0.87730 | 1.15107 | 2.13999 | 1.23966 | 1.20488 | 1.27704 | 5.60739 | 3.95610 | 1.60332 | 1.03143 | 11.99976 |

TABLE 30. PLANETARY MISSION STAGE SIZING FOR MARS CONJUNCTION CLASS MISSION, OPPOSITION 2031 TO 2040



DATE 2031 — CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 32294. | WF3 | 29065. | WBO3 | 3229. | |
| WSTG2 | 167914. | WF2 | 151124. | WBO2 | 16790. | WSTG1 | 701248. | WF1 | 631129. | WBO1 | 70118. | WO | 1170455. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.64730 | DV0 | 0.00000 | DVS1 | 1.37540 | DVS2 | 0.83510 | DV4 | 1.01920 | G2 | 0.1111 | G3 | 0.1111 | |

DATE 2033 — CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 26454. | WF3 | 23809. | WBO3 | 2645. | |
| WSTG2 | 168974. | WF2 | 152078. | WBO2 | 16896. | WSTG1 | 670145. | WF1 | 603136. | WBO1 | 67008. | WO | 1134573. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.57010 | DV0 | 0.00000 | DVS1 | 1.27780 | DVS2 | 1.08740 | DV4 | 0.85430 | G2 | 0.1111 | G3 | 0.1111 | |

DATE 2035 — CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 29911. | WF3 | 26920. | WBO3 | 2991. | |
| WSTG2 | 152324. | WF2 | 137093. | WBO2 | 15231. | WSTG1 | 669878. | WF1 | 602896. | WBO1 | 66982. | WO | 1121113. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.63250 | DV0 | 0.00000 | DVS1 | 0.90790 | DVS2 | 1.43820 | DV4 | 0.95280 | G2 | 0.1111 | G3 | 0.1111 | |

DATE 2037 — CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 24950. | WF3 | 22455. | WBO3 | 2495. | |
| WSTG2 | 142780. | WF2 | 128504. | WBO2 | 14277. | WSTG1 | 724991. | WF1 | 652498. | WBO1 | 72493. | WO | 1161721. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.88240 | DV0 | 0.00000 | DVS1 | 1.01200 | DVS2 | 1.16850 | DV4 | 0.81060 | G2 | 0.1111 | G3 | 0.1111 | |

DATE 2040 — CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 25248. | WF3 | 22724. | WBO3 | 2525. | |
| WSTG2 | 113777. | WF2 | 102400. | WBO2 | 11377. | WSTG1 | 631430. | WF1 | 568292. | WBO1 | 63137. | WO | 1039454. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.72460 | DV0 | 0.00000 | DVS1 | 0.84580 | DVS2 | 0.97350 | DV4 | 0.81930 | G2 | 0.1111 | G3 | 0.1111 | |

TABLE 31. PLANETARY MISSION STAGE SIZING FOR MARS CONJUNCTION CLASS MISSION, OPPOSITIONS 2042 AND 2044

DATE 2042 CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 29822. | WF3 | 26840. | WB03 | 2982. | |
| WSTG2 | 112263. | WF2 | 101037. | WB02 | 11225. | WSTG1 | 600994. | WF1 | 540900. | WB01 | 60024. | WO | 1012079. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.59880 | DV6 | 0.00000 | DVS1 | 0.84930 | DVS2 | 0.89690 | DV4 | 0.95030 | G2 | 0.1111 | G3 | 0.1111 | |

DATE 2044 CONJUNCTION PROFILE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WPL | 117000. | WMEM | 95000. | WPROB1 | 0. | WPROB2 | 57000. | WSTG3 | 36502. | WF3 | 32852. | WB03 | 3650. | |
| WSTG2 | 131330. | WF2 | 118198. | WB02 | 13132. | WSTG1 | 627389. | WF1 | 564656. | WB01 | 62733. | WO | 1064221. | |
| C1 | 1.00 | C2 | 1.00 | C3 | 1.00 | C4 | 1.00 | ISP1 | 480.000 | ISP2 | 480.000 | ISP3 | 480.000 | G1 0.1111 |
| DV1 | 3.55990 | DV0 | 0.00000 | DVS1 | 0.99860 | DVS2 | 0.89840 | DV4 | 1.13360 | G2 | 0.1111 | G3 | 0.1111 | |

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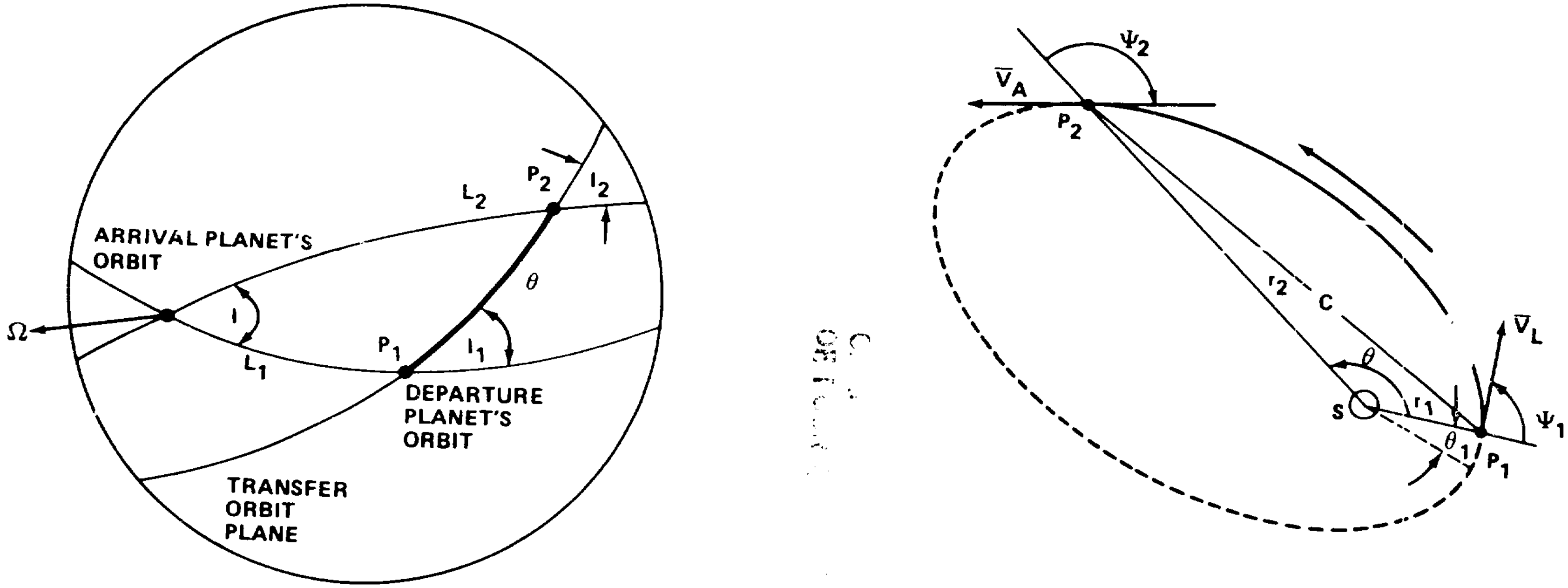
APPENDIX




a. SINGLE PLANE TRANSFER GEOMETRY

b. RELATIONSHIPS IN THE TRANSFER PLANE

Figure 26. Interplanetary transfer geometry.

# DESCRIPTION OF PLANETARY TRAJECTORY DATA

Following is a list of definitions and descriptions for the parameters contained in the tabular data.

| SYMBOL | DESCRIPTION |
|---|---|
| DEPART | Julian date of departure; reckoned from JD 240-0000. |
| PASS | Julian date of passage; reckoned from JD 240-0000. |
| ARRIVE | Julian date of arrival; reckoned from JD 240-0000. |
| C3 | Hyperbolic excess velocity squared; expressed in kilometers squared per second squared. |
| C3-DD | Square of the hyperbolic excess velocity at the departure planet; expressed in kilometers squared per second squared. |
| C3-AD | Square of the hyperbolic excess velocity at the arrival planet; expressed in kilometers squared per second squared. |
| RA | Right ascension of hyperbolic excess velocity vector (hyperbolic asymptote); measured in degrees along the local planetary equator eastward from the "vernal equinox," i.e., where in Sun's path rises above the planet's equator. |
| DECL | Declination of hyperbolic excess velocity vector; measured in degrees positively northward and negatively southward from the planet's equator. |
| I1 | Inclination of transfer orbit to the planet's orbit at the start of the transfer in degrees; zero is forward, -90 deg is perpendicular southward, +90 deg is perpendicular northward and ±180 deg is backward. |
| V1 | Heliocentric speed; at the start of the transfer normalized to Earth's mean orbital speed. |
| PSI1 | Heliocentric angle at the start of the transfer, in degrees; measured counterclockwise from the outward heliocentric radius vector to the velocity vector in the transfer plane. |
| ECCEN | Eccentricity of the heliocentric transfer conic. |
| SMA | Semi-major axis of the transfer conic, in AU (asterisk indicates near-parabolic transfer). |
| THET1 | True anomaly at the start of the transfer, in degrees; reduced to $0 \leq \theta \leq 360$ deg. |
| THET2 | True anomaly at the end of the transfer, in degrees. |
| PERIH | Perihelion distance of the transfer conic, in AU. This value is listed only if the vehicle traverses perihelion during the transfer. |

| SYMBOL | DESCRIPTION |
|---|---|
| APHEL | Aphelion distance of the transfer conic, in AU. This value is listed only if the vehicle traverses aphelion during the transfer. |
| V2 | Heliocentric speed at the end of the transfer; normalized to Earth's mean orbit speed. |
| PSI2 | Heliocentric angle at the end of the transfer, in degrees; measured counterclockwise from the outward heliocentric radius vector to the velocity vector in the transfer plane. |
| VHP | Hyperbolic excess velocity; expressed in kilometers per second. |
| RCP | Radius of closest approach to passage planet, in planet radii. |
| KAPPA | Bend angle at passage planet measured from the positive approach asymptote to the positive departure asymptote written in degrees. |
| VP | Velocity at pericenter passage; normalized to Earth's mean orbital speed. |
| AH | Semi-major axis of the passage hyperbola; in planet radii. |
| EH | Eccentricity of the passage hyperbola. |
| ANMAX | Maximum value of true anomaly; also the angle between the pericenter radius vector and either asymptote; in degrees. |
| INH | Inclination of the plane of the passage hyperbola to the equator of the passage planet, in degrees. |
| RAP DECP | Right ascension and declination of pericenter with respect to the passage planet's equator and equinox; in degrees. |
| RAS DECS | Right ascension and declination of the Sun with respect to the passage planet's equator and equinox; in degrees. |
| ETA | Angle between the vector to pericenter and the vector to the Sun, in degrees. |
| PASS CONDITION | Lighting condition at sub-pericenter point (Light Side or Dark Side). |
| DVCP | Power maneuver required at swingby planet, in kilometers per second. |
| CORD1 | Communication distance between Earth and the first planet encountered, at the time of encounter; in AU. |
| CORD2 | Communication distance: in AU<br>Direct missions; the distance between the stopover planet and Earth at the time of arrival at the stopover planet.<br>Outbound swingby; the distance between the stopover planet and Earth at the time of arrival at the stopover planet. |

| SYMBOL | DESCRIPTION |
|---|---|
| CORD2 (Cont.) | Inbound swingby; the distance between the stopover planet and Earth at the time of departure from the stopover planet. |
| CORD 3 | Communication distance: in AU<br>Outbound swingby; the distance between the stopover planet and Earth at the time of departure from the stopover planet.<br>Inbound swingby; the distance between the passage planet and Earth at the time of passage. |
| DELV1, DV1 | Impulsive velocity increment for the Earth departure injection maneuver; in kilometers per second. |
| DELV2, DV2 | Impulsive velocity increment for the target planet capture maneuver; in kilometers per second. |
| DELV3, DV3 | Impulsive velocity increment for the target planet departure injection maneuver; in kilometers per second. |
| DELV4, DV4 | Impulsive velocity increment for the Earth braking maneuver; in kilometers per second. |
| GAMA1 | Weight ratio for the Earth departure injection maneuver. |
| GAMA2 | Weight ratio for the target planet capture maneuver. |
| GAMA3 | Weight ratio for the target planet injection maneuver. |
| GAMA4 | Weight ratio for the Earth braking maneuver. |
| ETA1 | Payload ratio for the Earth departure injection maneuver. |
| ETA2 | Payload ratio for the target planet capture maneuver. |
| ETA3 | Payload ratio for the target planet injection maneuver. |
| ETA4 | Payload ratio for the Earth braking maneuvers. |
| ETA0 | Ratio of terminal weight to the initial weight in Earth orbit. |

STS UPPER STAGE SIZING PROGRAM
PLANETARY MISSION STAGE SIZING

## DEFINITION OF VARIABLES

| SYMBOL | DEFINITION |
|---|---|
| $W_{PL}$ | Mission module (lb). |
| Wmem | Mars excursion model (lb). |
| WPROBE 1 | Planetary probes ejected before braking into Mars orbit (lb). |
| WPROBE 2 | Planetary probes carried into Mars orbit or Pioneer Mars base for conjunction class missions (lb). |
| WSTG 3 | Total weight of Earth braking stage (lb). |
| WF 3 | Propellant required by Earth braking stage (lb). |
| WBO 3 | Dry weight of Earth braking stage (lb). |
| WSTG 2 | Total weight of Mars braking and escape stage (lb). |
| WF 2 | Propellant required by Mars braking and escape stage (lb). |
| WBO 2 | Dry weight of Mars braking and escape stage (lb). |
| WSTG 1 | Total weight of Earth escape stage (lb). |
| WF1 | Propellant required by Earth escape stage (lb). |
| WBO 1 | Dry weight of Earth escape stage (lb). |
| WO | Total initial weight required in low Earth orbit to perform the mission (lb). |
| $C_1$, $C_2$ $C_3$, $C_4$ | Gravity loss factor for each of the four major planetary maneuvers. |
| $I_{SP1}$ | Specific impulse of first stage propellant (sec). |
| $I_{SP2}$ | Specific impulse of second stage propellant (sec). |
| $I_{SP3}$ | Specific impulse of third stage propellant (sec). |
| DV1 | Impulsive velocity increment for Earth escape maneuver (km/sec). |
| DV0 | Impulsive velocity increment for Venus powered swingby maneuver on the outbound leg (km/sec) |
| $DV_{S1}$ | Inpulse velocity increment for Mars braking maneuver (km/sec) |

| SYMBOL | DESCRIPTION |
|---|---|
| $DV_{S2}$ | Impulsive velocity increment for Mars escape maneuver (km/sec). |
| $DV_4$ | Impulsive velocity increment for Earth braking maneuver (km/sec). |
| $G_1$, $G_2$, $G_3$ | Equal $(1/\lambda_I - 1)$ where $\lambda I$ is the mass fraction of stage 1, 2, and 3. |

APPROVAL

MARS EXPLORATION
VENUS SWINGBY AND CONJUNCTION CLASS MISSION MODES
TIME PERIOD 2000 TO 2045

By Archie C. Young, John A. Mulqueen, and James E. Skinner

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

William R. Marshall

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Director, Program Development