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MARS ORBIT SELECTION

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ABSTRACT

Parking orbits for a manned Mars mission are examined for ease of access to the Martian moons. Delta V plots for a variety of burns versus elliptical orbit apoapsis are included. A high elliptical orbit (24 hour period, 500 km periapsis, 20 to 30 deg. inclination) minimizes delta V to the Martian moons and Mars orbit insertion (MOI) and trans-Earth injection (TEI) delta Vs.

MARS ORBIT SELECTION

Use of an elliptical Mars orbit has been suggested by mission designers for years. It reduces both MOI and TEI delta Vs by the same amount: the difference between circular velocity at periapsis and elliptical velocity at periapsis.

Figure 1 plots MOI and TEI delta V versus apoapsis altitude (500 km periapsis) for a 1999 conjunction trajectory. MOI and TEI both continue to decrease as apoapsis increases, however, after a 48 hour period orbit is reached (500 x 57,000 km), a 1,240 m/sec reduction in both MOI and TEI has been achieved and less than 150 m/sec additional gain is possible. Figure 2 shows the same plot as Figure 1 with a different scale that makes this flattening of the MOI and TEI curves more apparent. Figures 3 and 4 show the same plots for a 2001 Venus swingby trajectory.

The next step beyond the extremely high ellipse is to let the Mission Module (the large crew module that might not enter Mars orbit at all and fly on by. The lander then enters directly from the interplanetary trajectory and ascends to rendezvous with another Mission Module flying by. The National Commission on Space has recently studied this option in some detail. Several Mission Modules will be required, depending on the scenario.

If the Mission Module is parked in Mars orbit, the parking orbit should have a periapsis as low as possible without encountering atmospheric drag. This minimizes deorbit delta V (for the lander) and for the same apoapsis also minimizes MOI and TEI.

Fig. 1

MARS MOON VISITS FROM ELLIPTICAL ORBIT

1999 CONJ. MISS.(500 KM.PERIAPSIS, 0° INCLINATION)

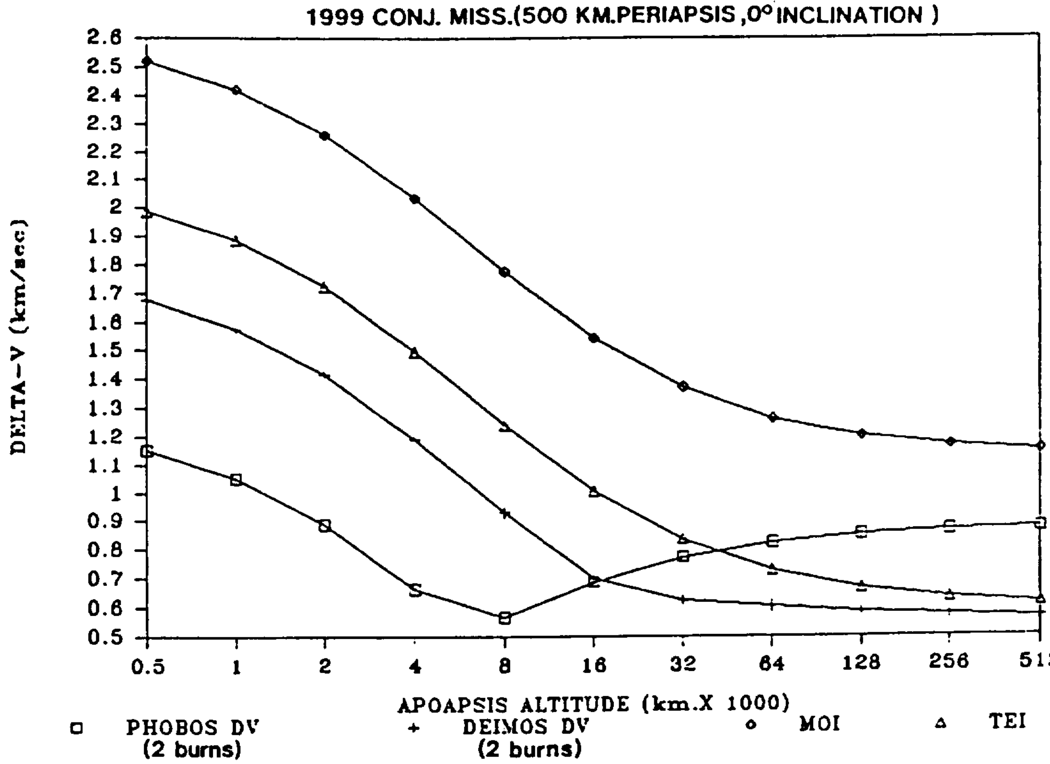


Fig. 2

MARS MOON VISITS FROM ELLIPTICAL ORBIT

1999 CONJ. MISS.(500 KM.PERIAPSIS, 0° INCLINATION)

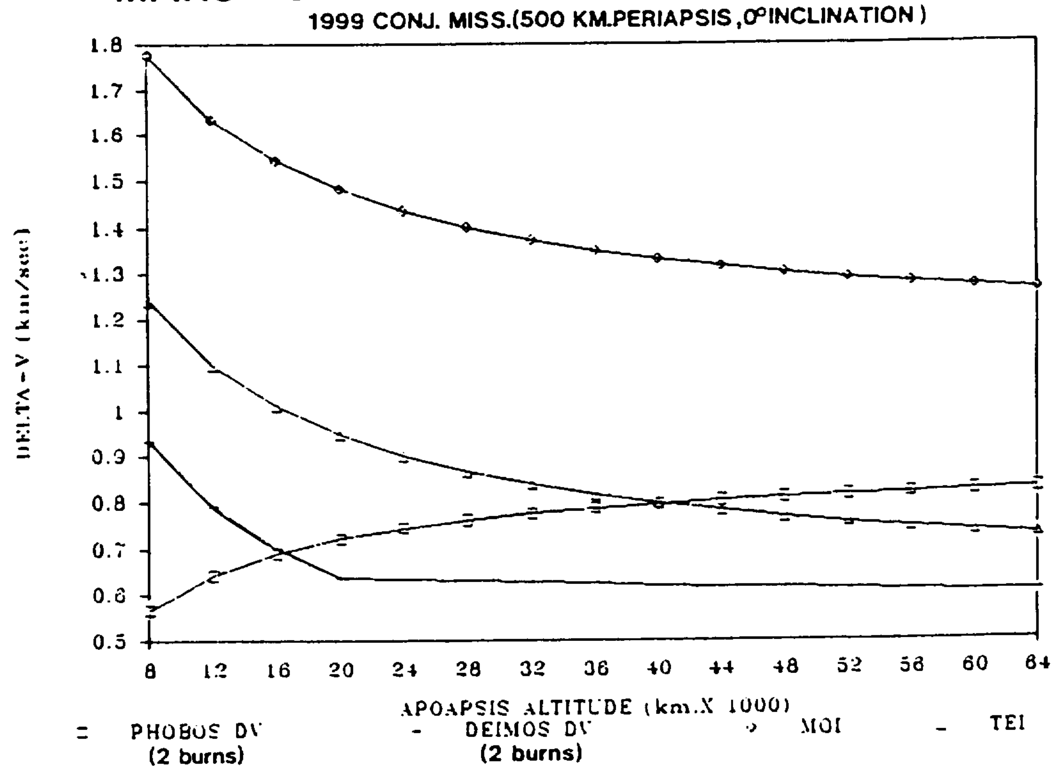


Fig.3

MARS MOON VISITS FROM ELLIPTICAL ORBITS

2001 VENUS SWINGBY MISS.(500 KM.PERI., 0° INCLINATION)

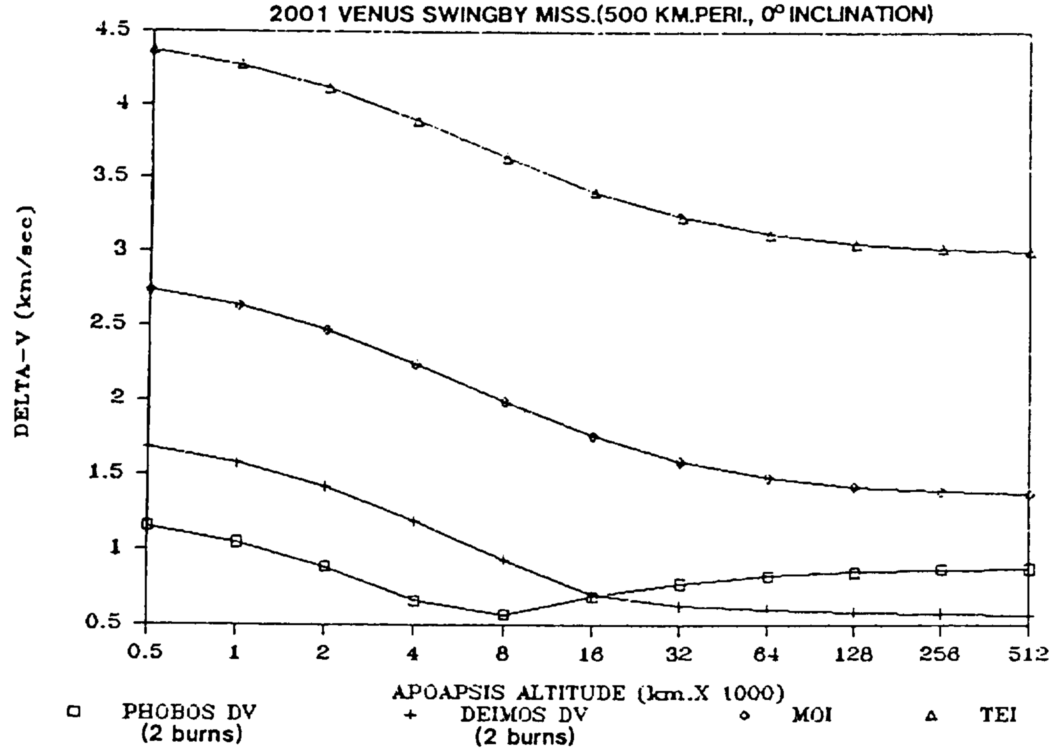
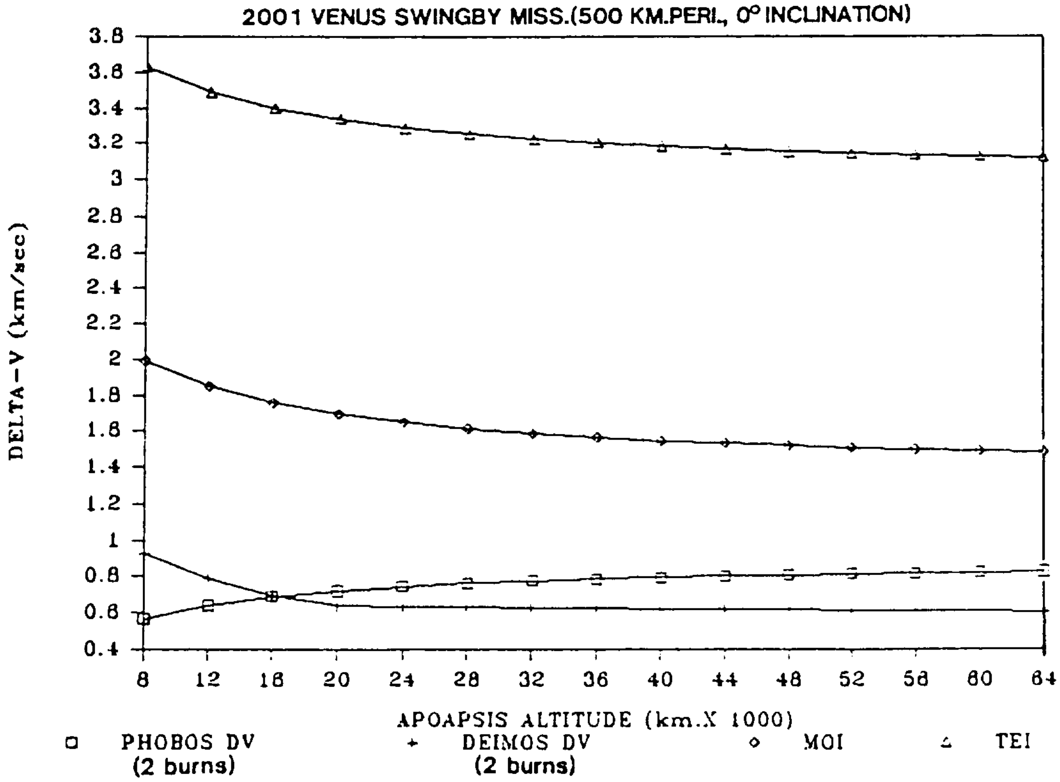


Fig.4

MARS MOON VISITS FROM ELLIPTICAL ORBIT

2001 VENUS SWINGBY MISS.(500 KM.PERI., 0° INCLINATION)



The lander ascent stage pays a penalty for high elliptical orbit. Its ascent delta V is increased by the same amount as the TEI savings. Lander deorbit is essentially aerobraked and is not penalized significantly so long as the periapsis is low.

Reference 1 plots lander mass and initial mass in low Earth orbit (LEO) versus apoapsis altitude for a variety of lander designs and overall mission propulsion and trajectory options. In general, lander mass is increased 30 % or so going from a 500 km circular to a high elliptical orbit. The effect of this small increase (a lander will mass 40 to 80 metric tons, depending on the design) on initial mass in LEO is swamped by the effect of increasing MOI and TEI by one km/sec or more each. Low circular Mars orbit therefore results in an increase in initial LEO mass over high elliptical from 30 to 100 % depending on the trajectory and propulsion scheme.

MARTIAN MOON ACCESS

Low delta V from the parking orbit to the two moons of Mars is highly desired. Both moons are in near circular, almost equatorial orbits (Phobos - 6,068 km alt., 1.02 deg. inclination, Deimos - 20,168 km alt., 1.82 deg. inclin.). Figures 1 through 4 show the in-plane transfer from various parking orbits to Phobos and Deimos. In these figures it is assumed that the line of apsides of the elliptical orbit is in the plane of the moon's orbit. The validity of this assumption for various missions requires more study.

The delta V to Phobos reaches a minimum of approximately 600 m/sec at an apoapsis of 6,000 to 8,000 km and grows thereafter to a fairly steady value of about 850 m/sec for apoapsis above 40,000 to 50,000 km. The delta V to Deimos decreases steadily to a virtually constant minimum of 650 m/sec for apoapsis above 20,000 km.

In-plane operations to the moons of Mars will not be the normal situation however. Geometry forces the parking orbit to have an inclination at least as great as the declination of both the MOI and TEI V-infinity vectors. These declinations are typically on the order of 15 to 20 degrees from the equator. In addition, some inclination is necessary to provide parking orbit precession so as to achieve a correct plane for TEI. The moons are in essentially equatorial orbits so a plane change is necesary for transport from an inclined parking orbit.

Figures 5, 6, and 7 show the delta Vs to Phobos and Deimos from ellipses of variable apoapsis inclined 30, 60, and 90 degrees to the equator respectively. All the plots show a steady, sharp reduction in moon visit delta V as apoapsis increases, indicating, the higher the ellipse, the better. Figures 8, 9, 10, and 11 show moon visit delta V from a 72, 48, 24, and 14 hour ellipses as a function of required plane change or inclination of the parking orbit. The plots are all similar. Plane change from high elliptical orbit is not expensive if it can be made at apoapsis. These figures assume the elliptical orbit line of apsides is in the plane of the moons' orbit. If approach and departure asymptotes prevent this, then these conclusions may not be applicable.

CONCLUSIONS

Orbits in the range of 48 to 24 hour periods allow plane changes to be made quite inexpensively at apoapsis and minimize moon visit, MOI, and TEI delta Vs. The 24 hour orbit (500 x 32,963 km), chosen as a baseline by many mission designers, does not have an excessive period and is not so high that serious stability problems would be expected.

REFERENCES

1. Stump, William R., Babb, Gus R., and Davis, Hubert, P.,, Mars Lander Survey, Eagle Engineering Inc., Houston, Texas, NASA JSC Contract # NAS9-17317, presented at the Marshall Spaceflight Center Mars Workshop, June 10-14, 1985, Huntsville, Alabama.

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Fig.5

MARS MOON VISITS FROM ELLIPTICAL ORBITS

1999 CONJ. (500 KM.PER.,inc.=30 deg.)

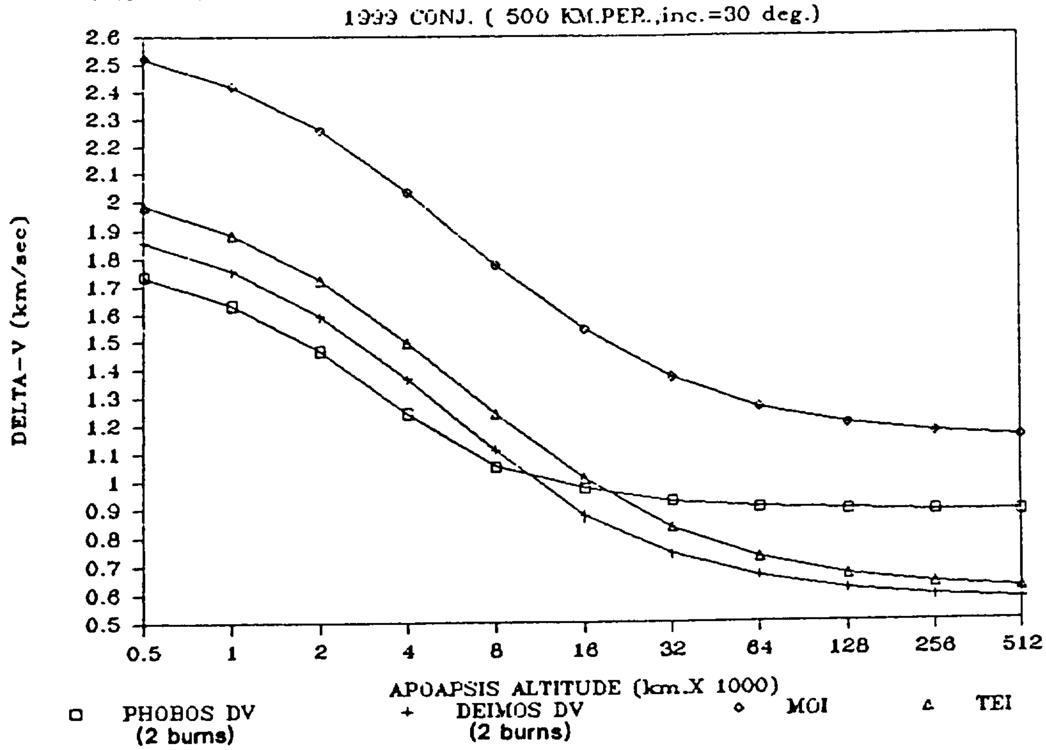

Fig.6

MARS MOON VISITS FROM ELLIPTICAL ORBITS

1999 CONJ. (500 KM.PER.,inc.=60 deg.)

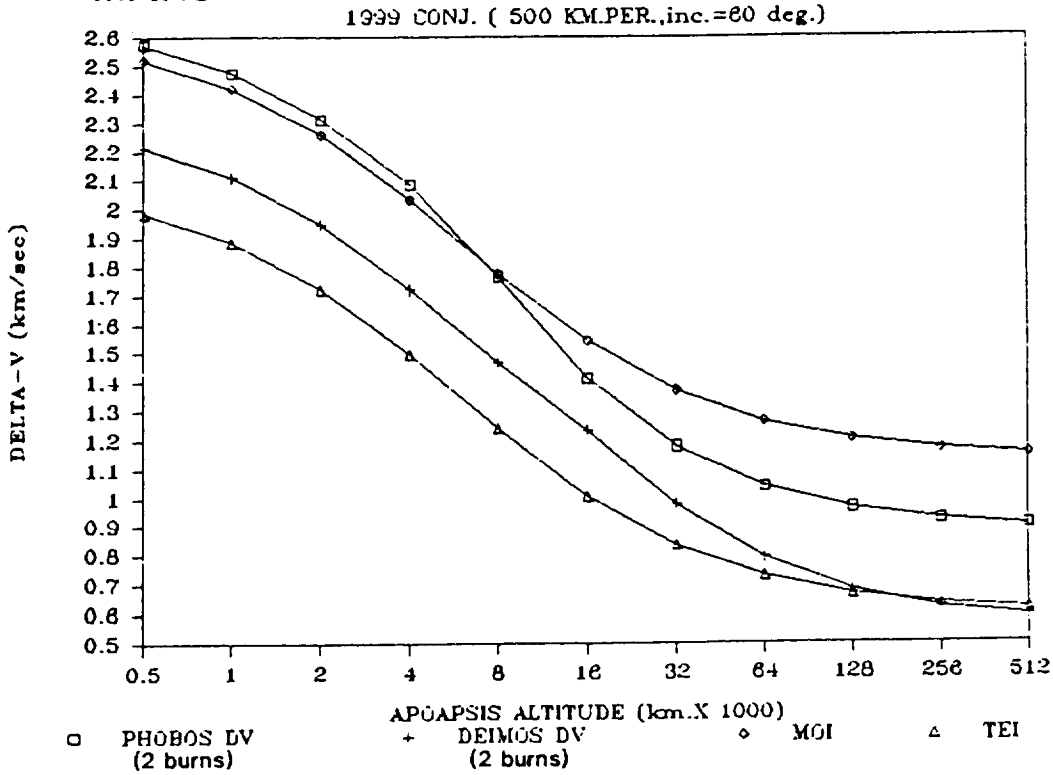

Fig.7

MARS MOON VISITS FROM ELLIPTICAL ORBITS

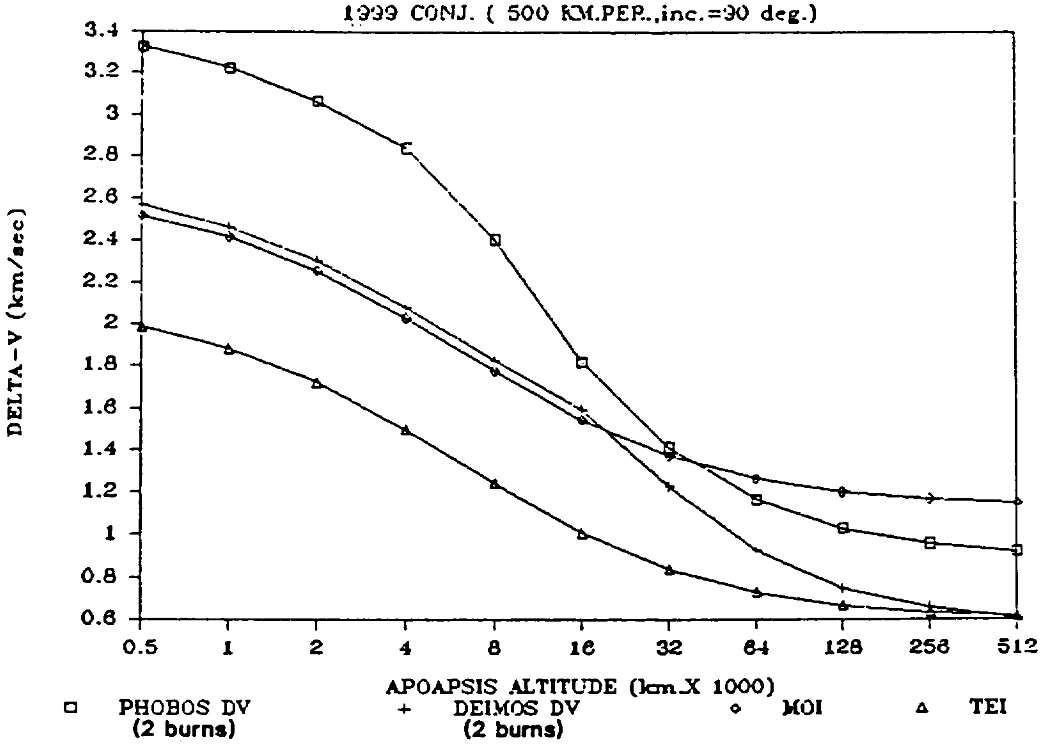

Fig.8

MARS MOON VISITS FROM ELLIPTICAL ORBITS

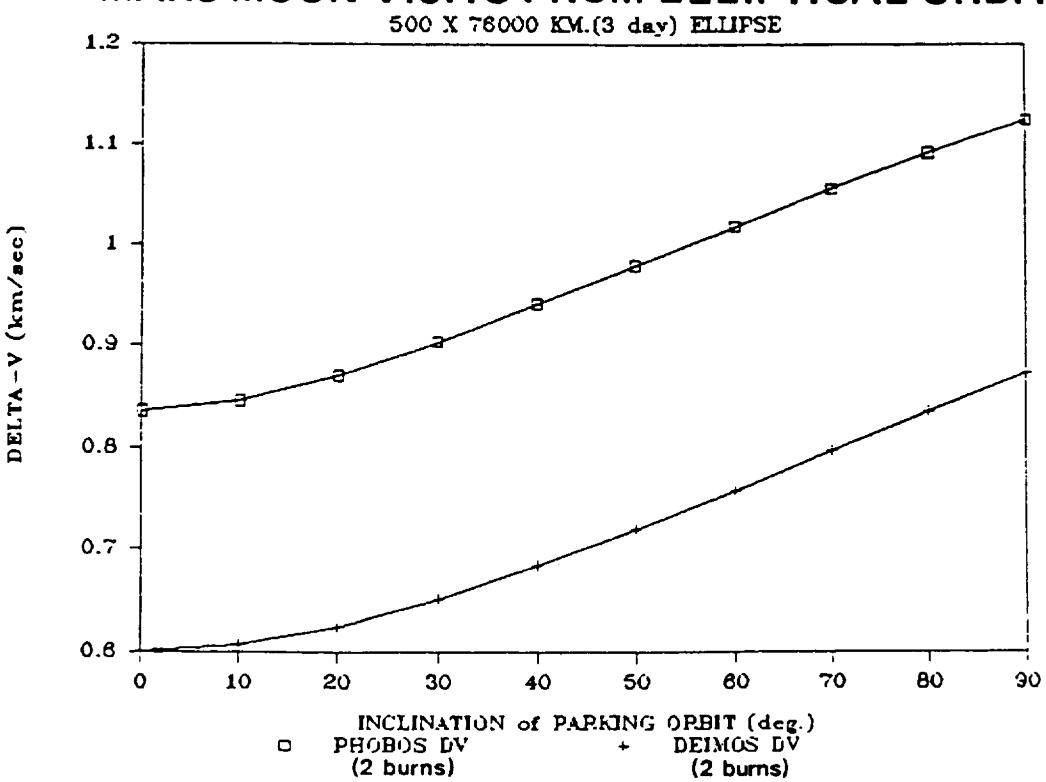

Fig.9

MARS MOON VISITS FROM ELLIPTICAL ORBITS

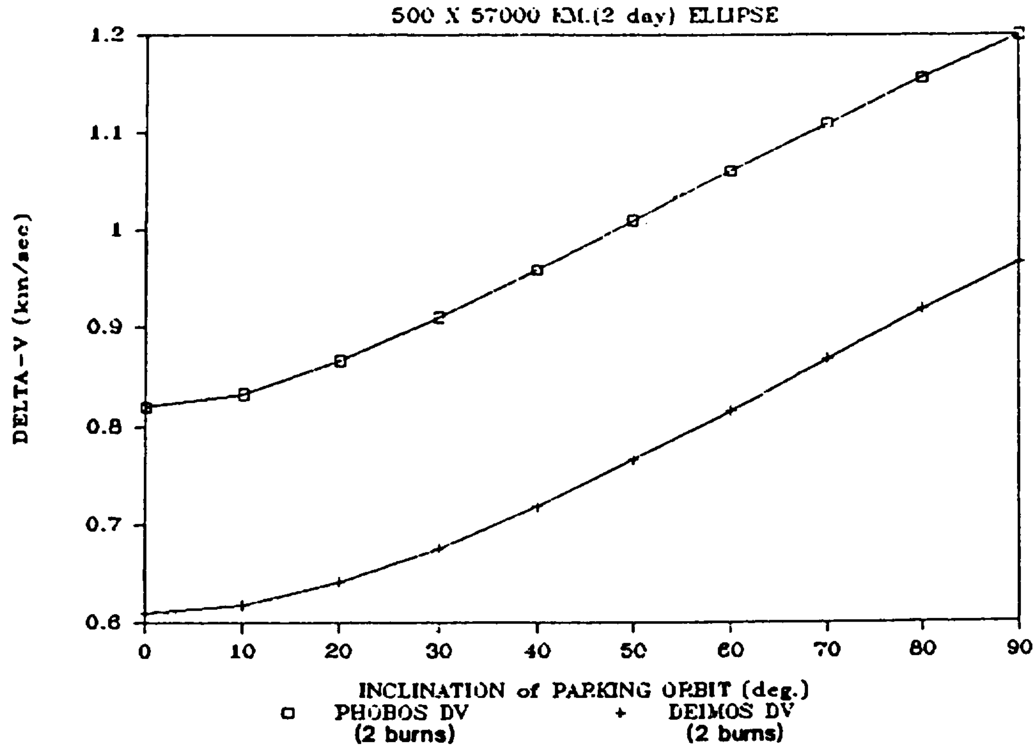

Fig.10

MARS MOON VISITS FROM ELLIPTICAL ORBITS

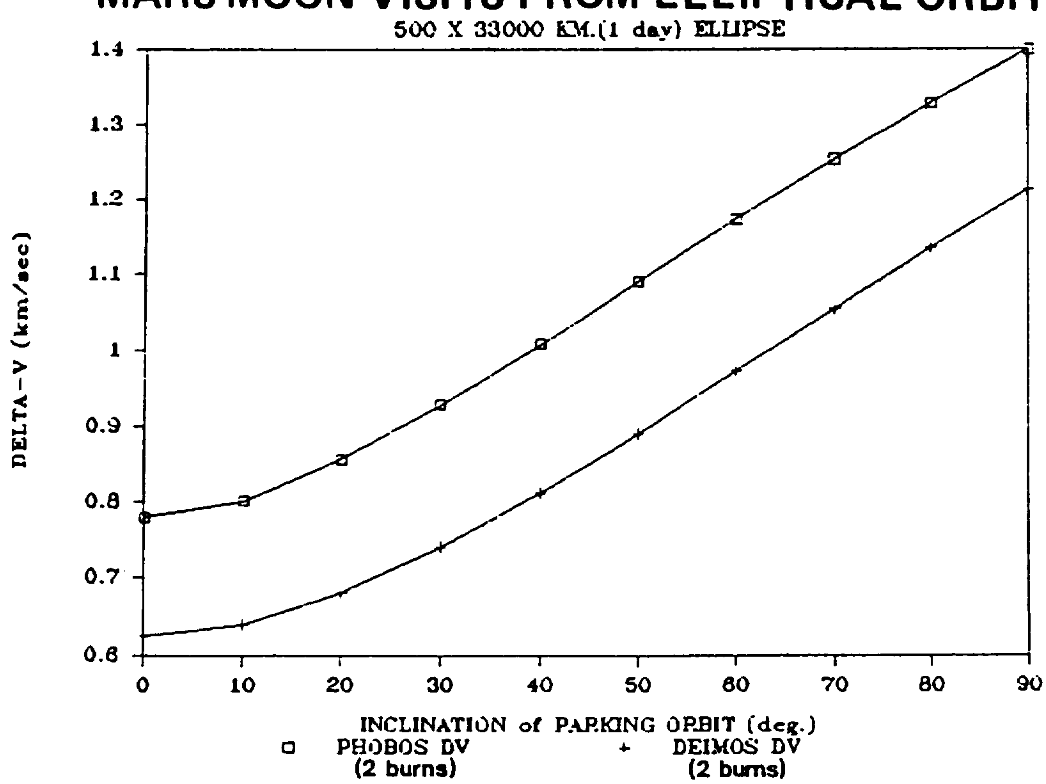

Fig.11

MARS MOON VISITS FROM ELLIPTICAL ORBITS

500 X 21000 KM.(14 hr.) ELLIPSE