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MANNED MARS MISSION TRANSFER FROM MARS PARKING ORBIT TO PHOBOS OR DEIMOS

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ABSTRACT

This paper addresses the problem of orbit transfers from a Mars parking orbit with an inclination of 165 degrees to the Mars moons. The transfer can be accomplished using a three impulse transfer.

The current 1999 baseline manned Mars mission requires a Mars parking orbit with an inclination of 165 degrees. This orbit inclination is necessary due to the direction of the Mars arrival and departure asymptotes of the interplanetary trajectory. The selection of this inclination for the parking orbit minimized the delta velocity requirements at Mars arrival and departure. This presents a problem in making transfers from this orbit to either Phobos or Deimos since it is a retrograde orbit. It is possible to make this transfer efficiently using a three impulse transfer and an intermediate transfer orbit with a very large apogee altitude. This paper will show how the intermediate transfer orbit apogee can be determined based on a preselected transfer time, the delta velocities required as a function of transfer time, and the propellant required as a function of mission module weight for a transfer time of 5 days. The data presented in this paper is specifically for the 1999 opposition class mission but the methods outlined are applicable to any other mission which requires a high inclination parking orbit.

DISCUSSION

The three impulse transfer begins with a propulsive burn at the apogee or perigee of the parking orbit which puts the spacecraft into an orbit with a very high apogee. The apogee of this intermediate orbit is selected on the basis of a desired transfer time. When the spacecraft reaches the apogee of the intermediate orbit, its orbital velocity is at its minimum value. At this point, the second impulse is made to perform the desired plane change. The second propulsive burn puts the spacecraft into a posigrade transfer orbit to Phobos or Deimos which is in the plane of the moons' orbit. The third impulse is made when the spacecraft reaches Phobos or Deimos. This propulsive burn puts the spacecraft into the moons' orbit. To return from Phobos or Deimos to the original parking orbit, the sequence is reversed.

The calculations required to determine the altitude of the intermediate transfer orbit are as follows:

$$a_x = \frac{r_1 + r_2}{2}$$

$$a_x = \frac{r_2 + r_3}{2}$$

$$\Delta V_1 = \left| \sqrt{\mu\left(\frac{2}{r_1} - \frac{1}{a_1}\right)} - \sqrt{\mu\left(\frac{2}{r_1} - \frac{1}{a_{x_A}}\right)} \right|$$

$$\Delta V_2 = \sqrt{V_{x_A}^{2} + V_{x_B}^{2} - 2V_{x_A} V_{x_B} \cos(\Delta i)}$$

where:

$$V_{x_A} = \sqrt{\mu\left(\frac{2}{r_2} - \frac{1}{a_{x_A}}\right)}$$

$$V_{x_B} = \sqrt{\mu\left(\frac{2}{r_2} - \frac{1}{a_{x_B}}\right)}$$

$$\Delta V_3 = \left| \sqrt{\mu\left(\frac{2}{r_3} - \frac{1}{a_3}\right)} - \sqrt{\mu\left(\frac{2}{r_3} - \frac{1}{a_{x_B}}\right)} \right|$$

$$t_x = \pi\left(\sqrt{\frac{a_{x_A}^{3}}{\mu}} + \sqrt{\frac{a_{x_B}^{3}}{\mu}}\right)$$

The value of r_2 can be found by iteration of the above calculations until the desired transfer time, t_x is achieved.

Phobos and Deimos could be visited sequentially during the same mission. The delta velocity required between the orbits of Phobos and Deimos is 2,460 feet per second. The total delta velocity for the sequential visit is obtained by adding this value to that for a one way transfer from the parking orbit to the first moon plus the delta velocity for a one-way transfer from the second moon back to the parking orbit. Figure 1 shows a profile of the three-impulse transfer from the parking orbit to either Phobos or Deimos. Figure 2 shows the altitude of the apogee of the transfer orbit as a function of transfer time. Figure 3 shows the one-way delta velocity requirement as a function of transfer time. Figure 4 shows the propellant required for a 5 day transfer to Phobos or Deimos as a function of mission module weight. These data are based on the assumption of a mass fraction of .84 and an I_{sp} of 370 seconds.

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FIGURE 1.
TRANSFERS TO MARS MOONS
3–IMPULSE TRANSFER

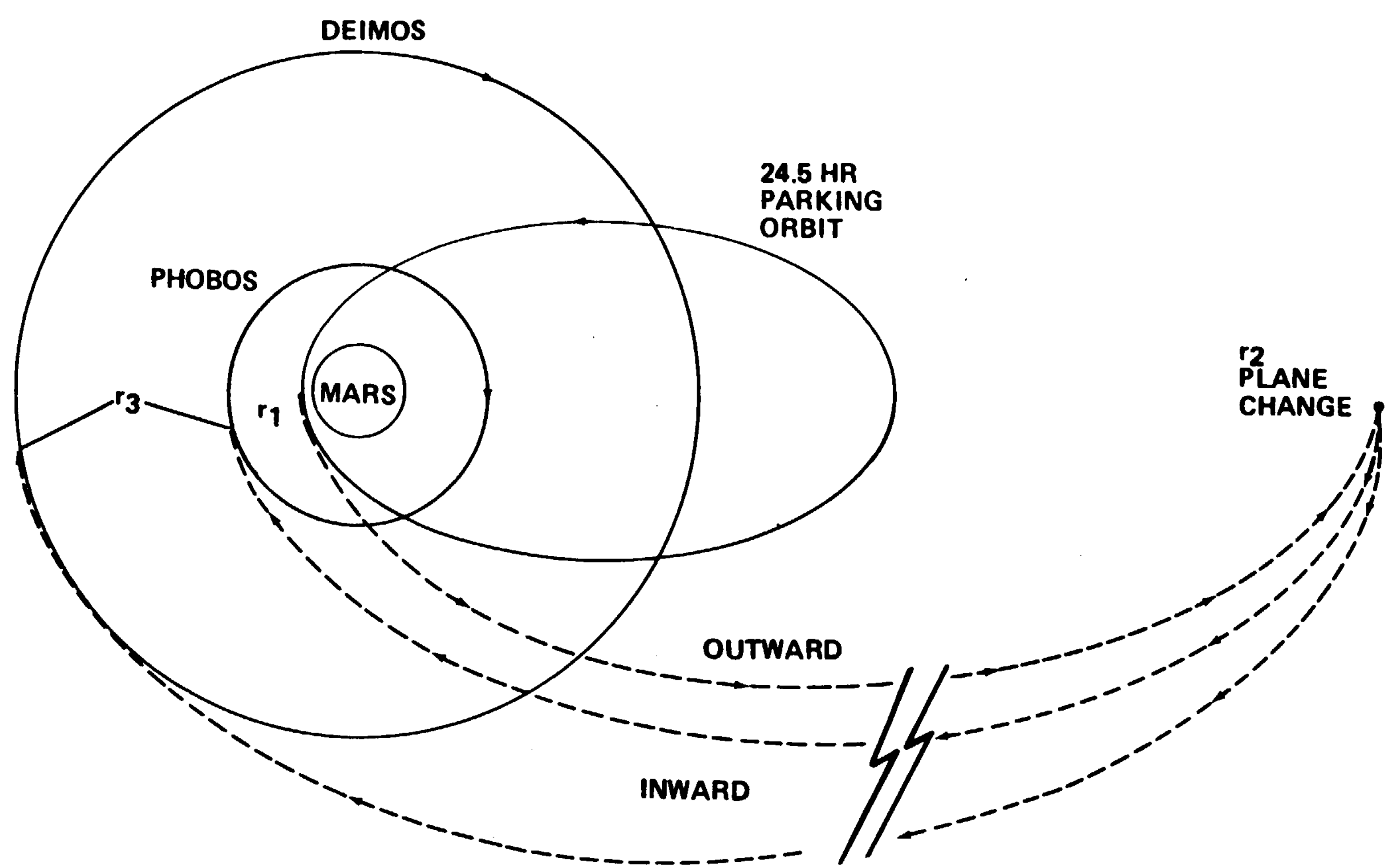

FIGURE 2
TRANSFER ORBIT APOGEE AS A FUNCTION OF TRANSFER TIME FOR TRANSFERS FROM MARS PARKING ORBIT TO PHOBOS OR DEIMOS

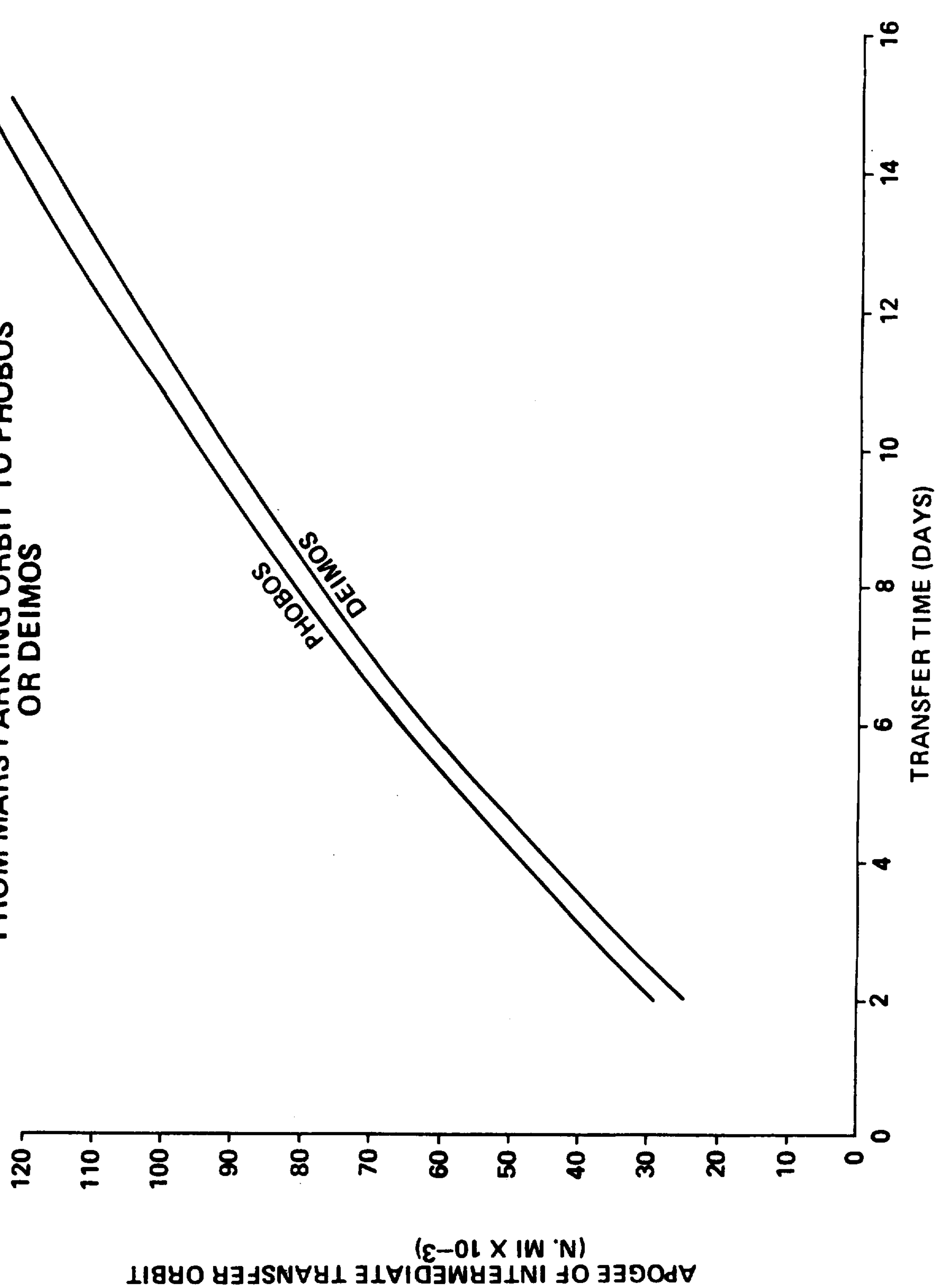

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FIGURE 3
DELTA VELOCITY AS A FUNCTION OF TRANSFER TIME FOR TRANSFERS FROM MARS PARKING ORBIT TO PHOBOS OR DEIMOS

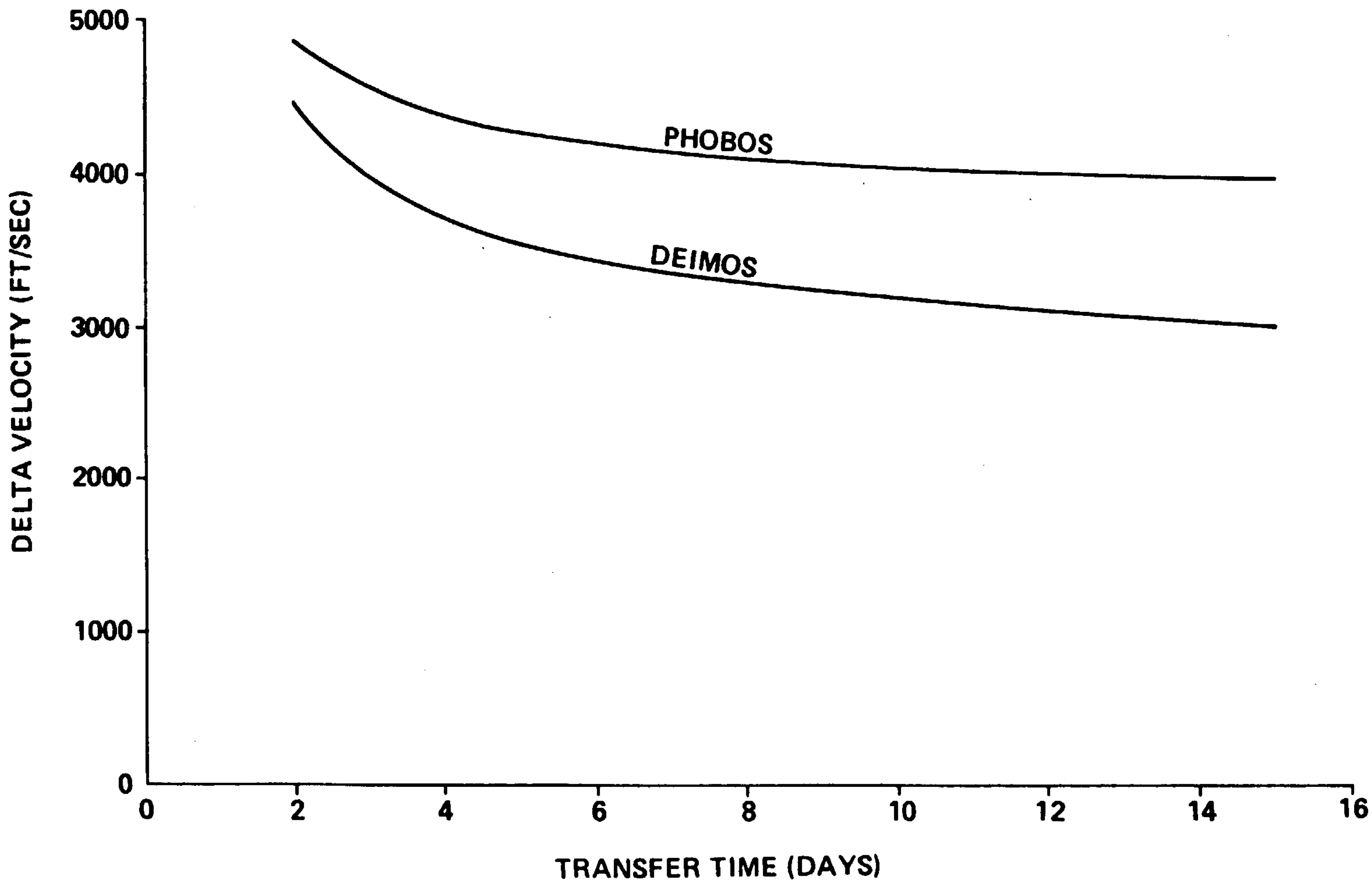

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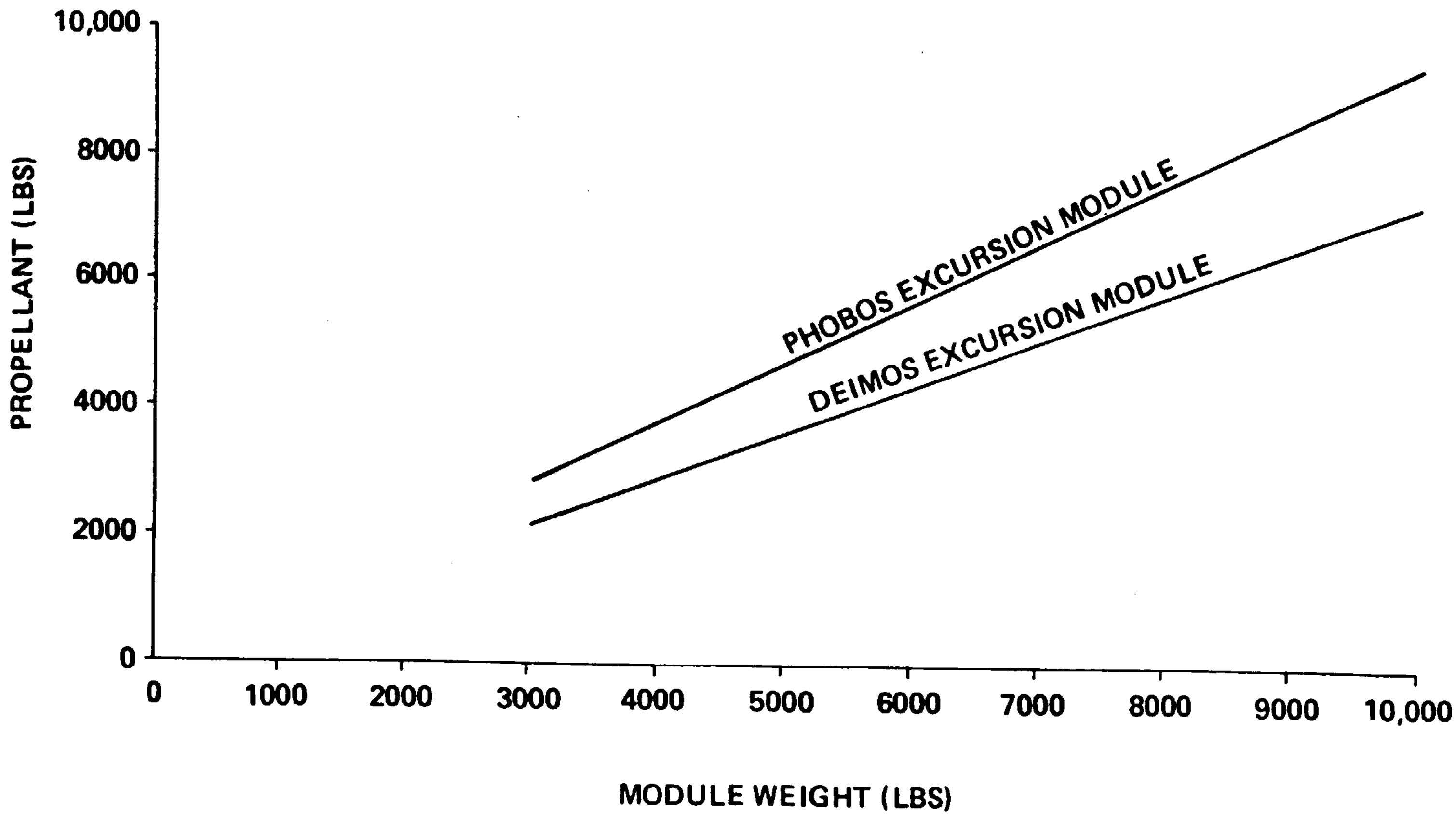
FIGURE 4

PROPELLANT WEIGHT REQUIRED AS A FUNCTION OF EXCURSION MODULE WEIGHT FOR A ROUND TRIP FROM A 24.5 HR. PARKING ORBIT TO THE MARS MOONS.

– PARKING ORBIT: 270 X 18050 AT 165° INCL.
– 3 IMPULSE TRANSFER
– ISP = 370



LIST OF SYMBOLS

a_1 = semi-major sxis of Mars parking orbit

a_3 = semi-major axis of Mars moon orbit

a_{XA} = semi-major axis of first transfer leg

a_{XB} = semi-major axis of second transfer leg

Δi = plane change angle

ΔV_1 = first delta velocity

ΔV_2 = second delta velocity

ΔV_3 = third delta velocity

V_{XA} = apogee velocity of transfer orbit before the second impulse

V_{XB} = apogee velocity of transfer orbit after the second impulse

r_1 = orbit radius at first impulse

r_2 = apogee of intermediate transfer orbit

r_3 = orbit radius at third impulse

t_x = transfer time

μ = gravitational constant for Mars = 42,860 $\frac{km^3}{sec^2}$

I_{sp} = specific impulse