Using Mathematics to Put Humans on Mars (or not)

Formulae and data

F-1 Engine parameters

- Engine mass (with fuel tank[1]): 26,000kg
- Fuel mass: 432,000kg
- Exhaust velocity: 2.98km/s

Astronomical data

- Mass of sun $M \approx 1.989 \times 10^{30}$kg
- Gravitational constant $G \approx 6.674 \times 10^{-11}\text{m}^3\text{kg}^{-1}\text{s}^{-2}$
- $\mu = GM \approx 1.327 \times 10^{20}\text{m}^3\text{s}^{-2}$ (This combination appears frequently.)
- Earth orbit radius (assuming circular) 1au (astronomical unit) $\approx 1.496 \times 10^{11}$m
- Earth year length: 365.25 days (not forgetting leap years!)
- Earth mean orbital speed: 29.78km/s.
- Mars orbit radius (assuming circular) 1.52au $\approx 2.27 \times 10^{11}$m.
- Mars year length: 687 days.

Simplified Tsiolkovsky rocket equation

$$v = v_e \ln\left(\frac{m_0}{m}\right) \quad \text{or} \quad m_0 = m\mathrm{e}^{v/v_e}$$

- v = rocket velocity now
- v_e = exhaust velocity
- m_0 = initial mass (engine mass + fuel mass)
- m = mass now

Specific orbital energy

$$\varepsilon = \frac{v^2}{2} - \frac{\mu}{r}$$

- $\vec{v}$ = planet velocity (so $v = |\vec{v}|$ = speed)
- $\vec{r}$ = vector from planet to sun (so $r = |\vec{r}|$ = distance)

[1] rough estimate, based on 20% stage 1 of Saturn V