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A2_12 None Like It Hot II

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Abstract
This article presents an extension of the work in 'A2_9 None Like It Hot', and investigates whether a feat such as moving the Earth would be plausible given conventional rocket technology. It is found that the mass of fuel necessary to perform the Hohmann transfer is only a few orders of magnitude smaller than the mass of the Earth. The number of rockets will make only a small difference due to the nature of the relationship between the two values.

Introduction

The article 'A2_9 None Like It Hot' [1] presented a possible solution to global warming through the use of a Hohmann transfer to move the Earth further away from the Sun, thereby reducing its effective surface temperature. It was found that the total delta-v required to perform this manoeuvre was 118.7 ms^{-1}.

This article examines the ability to perform this manoeuvre by looking at available rocket technologies.

Investigation

The ideal rocket equation (Eq. 1) is an equation that relates the delta-v, Δv to the effective exhaust velocity, v_e and the initial and final mass (m_0 and m_f respectively) of a rocket engine [2].

$$\Delta v = v_e \ln \frac{m_0}{m_f}. \tag{1}$$

The effective exhaust velocity can be expressed in terms of the specific impulse I_{sp} provided by the engine as follows [3]:

$$v_e = I_{sp}\, g, \tag{2}$$

where g is the acceleration due to gravity (9.81 ms^{-1}). The final mass, m_f will simply be the mass of the Earth, M_E (5.97×10^{24} kg [4]), and the initial mass will be the mass of the fuel, m_{fuel} in addition to the mass of the Earth. The mass of the rocket(s) will be ignored as this value will be negligible compared to that of the Earth. With this, it is possible to substitute Eq. 2 into Eq. 1 and rearrange to find the mass of fuel required:

$$m_{fuel} = M_E \left(e^{\frac{\Delta v}{I_{sp} g}} - 1 \right). \tag{3}$$

The most powerful liquid propellant rocket engine is the RD-170, which has a specific impulse of 309 s (at sea level) [5]. If one of these engines is used, the mass of fuel required to perform the first of the delta-v manoeuvres comes to $\sim 1.18 \times 10^{23}$ kg. Below in Fig. 1 is a graph showing how the mass of the fuel required scales with the number of rockets used.

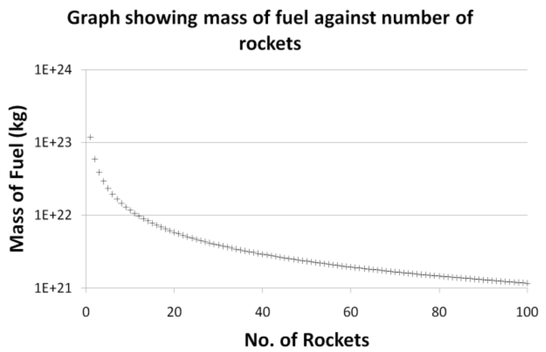

Fig.1 Graph showing the mass of fuel against the number of rockets required to perform the first half of the Hohmann transfer.

Discussion

From Fig. 1, it would appear that the mass of fuel required to perform the first stage of the transfer orbit greatly exceeds that which could be produced on Earth (even with 100 rockets the mass of fuel is only 3 orders of magnitude less than the mass of the Earth). If more rockets are used, the mass of fuel slowly drops due to the exponential nature of the relationship, but not by enough to make this feasible. As more rockets are used, a greater area of the Earths surface will be required to mount them, meaning that unless a flat mount is made for the rockets, some of the thrust provided by the rockets will be wasted due to the spherical nature of the Earth.

Conclusion

It is found that attempting to move the Earth further away from the Sun using conventional rockets is not plausible, due to the vast amount of fuel and number of rockets required. Even with 100 of the most powerful rockets (RD-170s), the mass of fuel is still only 3 orders of magnitude less than that of the mass of the Earth. If this manoeuvre is to be attempted using such a method, it would appear that a revolutionary form of rocket engine is necessary.

References

[1] S. Clapton et al., Physics Special Topics **9**, A2_9 **(2011).**
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[3] http://www.grc.nasa.gov/WWW/K-12/airplane/specimp.html (16/03/2011)
[4]http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html (16/03/2011)
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