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A4_04 "Crimes of the Hot", Possible or Not?

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Abstract

In this paper we investigate the feasibility of moving the Earth to reduce global warming in the manner depicted in the Futurama episode "Crimes of the Hot". We determined that using a chemical rocket with either ethanol or hydrogen as the fuel would not be viable, as at least 6.11% of the mass of the Earth would have to be used as fuel.

Introduction

In the Futurama episode "Crimes of the Hot" a solution to anthropogenic climate change is enacted that involves moving the Earth away from the sun using a thermal rocket. In this paper we discuss the viability of this method, using the change in velocity required to perform a Hohmann transfer to move the Earth into a new orbit further away from the Sun. In this paper a delta-V of 235.5 ms^{-1} is used for a best case, and 465.4 ms^{-1} for a worst case scenario [1].

Ethanol Rocket

The rocket used in the Futurama episode was an ethanol fuel rocket, comprising of a large group of robots igniting their exhaust gases to move the Earth. For the purpose of this paper we will be assuming the exhaust gas acts like a conventional rocket motor; this will be done to analyse whether it would be possible in a best case scenario. For a stoichiometric ratio (fuel to oxidiser mixing ratio) of 1.5 the specific impulse of an ethanol-liquid oxygen is 249.5 s [2]; we picked this stoichiometric ratio as it provided the best possible specific impulse, and therefore efficiency. This specific impulse provides an exhaust velocity of 2447.6 ms^{-1}, as specific impulse is the ratio between the exhaust velocity of a rocket and the acceleration due to gravity at the Earth's surface. Using this value and the rearrangement of the simple rocket equation shown in Eq. (3) below we can calculate what fraction of the Earth's mass needs to be ejected as fuel to produce the required delta-V.

$$\Delta v = v_e \ln\left(\frac{m_0}{m_f}\right) \tag{1}$$

$$\frac{m_0}{m_f} = e^{\frac{\Delta v}{v_e}} \tag{2}$$

$$m_{\%} = 1 - \frac{m_f}{m_0} = 1 - e^{-}\frac{\Delta v}{v_e} \tag{3}$$

Using the exhaust velocity (v_e) stated earlier we calculated that for a delta-V (Δv) of 235.5 ms^{-1} the fraction of the Earth's mass ($m_{\%}$) needed would be 0.0917, and for a delta-V of 465.4 ms^{-1} it would be 0.1732. These are 5.4763×10^{23} kg and 1.0344×10^{24} kg respectively. Current worldwide production of bioethanol is 25.68×10^9 US gallons [3], or 76.70×10^9 kg, this means for

a change in velocity of 235.5 ms^{-1}, 7.14 trillion years production of bioethanol would be required, or 13.45 trillion years for 465.4 ms^{-1}. This makes it apparent that an ethanol rocket is not viable for moving the Earth to combat global climate change.

Hydrogen Rocket

By plotting specific impulse against the fraction of Earth mass needed for a transfer, it can easily be seen that a higher specific impulses result in a lesser mass fraction being required, this is shown in Fig. (1). Hydrogen-liquid oxygen

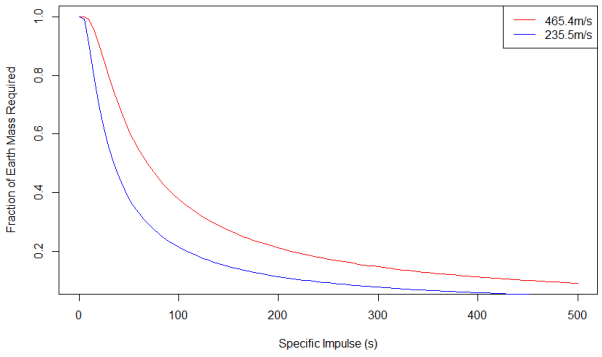

Figure 1: Specific impulse vs fraction of mass required for transfer.

rockets provide the best specific impulse of any currently used chemical rocket, providing up to 381 s at sea level [4]. Using Eq. (3) we can calculate a mass fraction of 0.0611 for 235.5 ms^{-1} and 0.1171 for 465.4 ms^{-1}. These are much lower than the requirements for an ethanol rocket, but still extremely high, meaning that a large source of hydrogen and oxygen would have to be utilised. When hydrogen and oxygen combust they form H_2O, which is the main component of the Earth's oceans. This makes the oceans an obvious source for the necessary fuel, with the water being electrolysed to form elemental hydrogen and oxygen. The oceans however only comprise 0.023% of the Earth's total mass [5], therefore making a hydrogen rocket using electrolysed water as fuel non-viable.

Conclusion

We have come to the conclusion that moving Earth as depicted in the Futurama episode "Crimes of the Hot" through the use of a chemical rocket is not viable, even when using a more abundant and efficient fuel (hydrogen) than depicted in the show. This is as the reaction mass needed is not readily available on the Earth, with a minimum of 6.11% of the Earth's mass in fuel being required. This is without accounting for the irreparable damage to the Earth's atmosphere the burning of such large quantity of fuel would cause; as both the energy emitted by the process, and any increase in greenhouse gases caused by the combustion could increase the temperature of the Earth.

References

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