Journal of Physics Special Topics

A4_7 Terraforming Mars – Orbital Mirrors: Construction

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November 16, 2011

Abstract

This report examines the feasibility of building orbital mirrors at Mars to increase the surface temperature by reflecting used solar energy. It was found that while a large solar mirror can be constructed with current technology the infrastructure to carry out the operation over Mars does not exist.

Introduction

As the population of Earth continues to grow then it may become prudent to colonise other planets for resources. One such planet is Mars, however it is currently unsuitable for human living without pressure suits and breathing apparatus. A dream of many scientists is to terraform it into an Earth like state.

One proposed option is to use large mirrors in orbit of Mars to perform several tasks [1]. Tasks such as heating the surface to a more acceptable level and releasing water trapped in the polar caps. This report shall look into the properties of such mirrors such as, required altitude, size and materials used in construction.

Altitude and Density

Large mirrors placed in orbit would be low maintenance in terms of station keeping as any space objects of large enough surface area in the solar system are effected by a significant solar radiation pressure. This concept is described by figure 1 with the mirror being in a stationary orbit in alignment with Mars and the Sun. Solar radiation pressure arises from the Sun emitting a flux of photons, which have momentum that upon impact with an object can be transferred. This force would keep pushing a mirror away from the Sun and thus by balancing it with the force of gravity at a Mars orbit an stationary satellite is achieved. Equation 1, [2] gives the radiation pressure, P_{rad}, where c is the speed of light and f is the flux at a given point. The factor of 2 is from assuming that the mirror will completely reflect the photons.

$$P_{rad} = 2f/c \quad . \qquad (1)$$

By putting in f at the distance of Mars, D, and assuming that the altitude of the mirror, h, is insignificant compared to the distance from the Sun, and balanced with the gravitational strength of Mars, again assuming the gravitational pull from the Sun is negligible, then equation 2 is found. L is the luminosity of the Sun, M is the mass of Mars, m is the mass of the mirror and R is the radius of Mars.

$$\frac{2L\pi r^2}{4\pi D^2 c} = \frac{GMm}{(R+h)^2} \quad . \qquad (2)$$

Since the mirrors would behave similar to a solar sail then the mass can be split into areal density (density per unit area), ρ, assuming the mirror to be thin, multiplied by the area of the mirror. Thus rearranging for density equation 3 can be used to find required densities of materials at different orbital heights.

$$\rho = \frac{(R+h)^2 L}{2\pi D^2 cGM} \quad . \qquad (3)$$

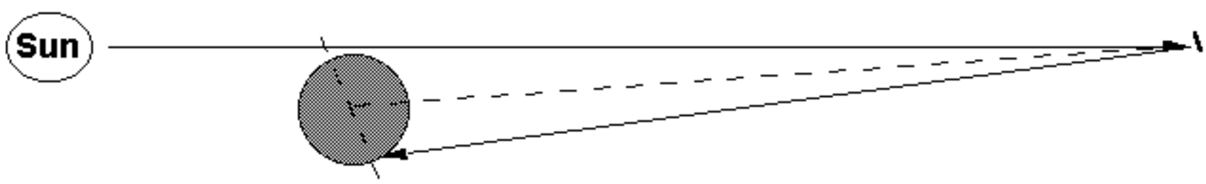

Figure 1. A diagram showing the stationary orbit of the mirror over Mars while in alignment with the Sun

Using equation 3, figure 2 was created. This figure shows the required density of material needed to maintain a specific altitude above Mars.

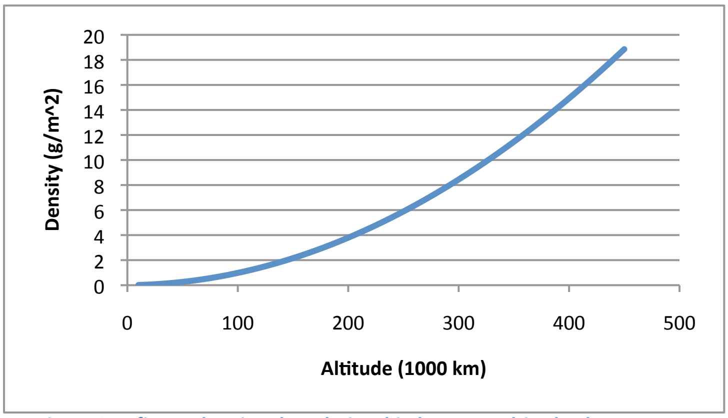

Figure 2. A figure showing the relationship between altitude above Mars and the required areal density to maintain the orbit.

By observing this graph it is possible to find the minimum altitude of a mirror with currently available materials. Current theory of useable materials point towards the use of Mylar, this fabric material (polyester film of stretched polyethylene terephthalate) is highly lightweight, chemically stable and has a high tensile strength, and also it is often used in experiments with solar sails. The common type is not as reflective as would be needed for a mirror. To increase it reflectivity (to about 90%) this Mylar can be aluminized by condensing vaporized aluminium on the surface to create a strong bond between the materials [3]. Commercially available sheets can be found with densities ranging from 2.6-6.8g/m^2 depending on thickness [4]. The minimum value means an altitude of 170,000 km is needed above mars.

Mass

The minimum height calculated does not include the mass of the superstructure that would support the shape of the mirror. However there are plenty of light weight building materials that could be used such are carbon nanotubes with a density of 1.4 g/cm^3 [5]. To look at how massive a mirror could be an average density of 4 g/m^2 is assumed, needed a height of 210,000 km. Mass was calculated by multiplying the areal density by the circular area given a radius.

Ideally the largest possible radius would by preferable but the mass of the mirror quickly becomes unmanageable. A mirror capable of warming the entire Martian surface is not feasible, however many models only require the mirror to warm certain areas, causing the polar caps and regolith (loose soil) to release water and green house gases to start a run away global warming effect. A substantial mirror of 125 km radius would illuminate a polar region of Mars (~650 km) and start this process. This corresponded to a mass of 200,000 tonnes [6].

Conclusions

The materials to build a solar mirror are commercially available to be used to date so the challenge lies in the construction. The mass of material has been shown to be greater that what could be lunched from Earth. However in situ building over Mars would be possible, with the construction of the ISS it has been demonstrated to the world that a larger artificial object can be built in space one component at a time. The main problem thus is transporting the materials the construction site, the local moons and asteroids could be exploited to produce the materials required.

In conclusion the current technological horizon allows for the construction of a large orbital mirror to terraform Mars but large-scale transportation and long term accommodation to construct/produce at Mars orbit is currently beyond the capabilities of different space agencies, and their budgets.

References

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