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A2 3 Rattle The Stars

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Abstract

In this paper we investigate the energy consumption of the engines powering the vehicles in the 2002 Disney film Treasure Planet, and hence find the minimum power output of the solar sails prominent in the designs of these vessels. We find that the engines aboard the frigate RLS Legacy require a minimum of 1.2 GW of power, and the small engines on the Solar Surfer require 40 MW, both of which are far outside the maximum possible output of a purely solar power system.

Introduction

The 2002 Disney film Treasure Planet features a number of science-fiction, space-faring vehicles based on the designs and aesthetics of old sailing ships. Most vehicles in this setting make use of 'solar sails' which, unlike real solar sails that use radiation pressure to provide fuel-less propulsion, appear to be some kind of power generation system.

Given that the engines only seem to function when these sails are activated it seems reasonable to assume they use some form of electric propulsion. Specifically, we model these ships as using magnetoplasmadynamic thrusters [1], an experimental engine that uses magnetic fields to turn a fuel in plasma and accelerate it out of the nozzle at much higher velocities than allowed by conventional rockets. This allows for much more efficient fuel use, at the cost of massive amounts of electrical energy.

Outer space in the universe of Treasure Planet is not a vacuum, but rather filled with a breathable atmosphere called the Aetherium. This allows for the sailing-inspired designs of the spaceships, while also placing a top speed restriction on any vessel proportional to the force imparted by its engines. Thus, we can work out the force output of the engines from the ship's top speed.

The RLS Legacy

The first ship we will be investigating is the RLS Legacy, the ship that carries our main characters from their home to the titular treasure planet. It is designed like a large sailing ship, with rigging, masts, sails and a general boat profile. More specifically, it has three masts, which classifies it as a frigate [2].

The presence of the Aetherium means we can calculate the engine force from the drag forces, using the top speed shown in the movie and making some assumptions about the ship's drag profile.

The formula for this is

$$F = \frac{1}{2}\rho v^2 C_d A \tag{1}$$

where F is the force, ρ is the fluid density, which is about 1.3 kg m^{-3} assuming the Aetherium is of a similar composition to Earth's atmosphere, v is the ship's velocity, C_d is the drag coefficient, assumed to be about 1.3 given

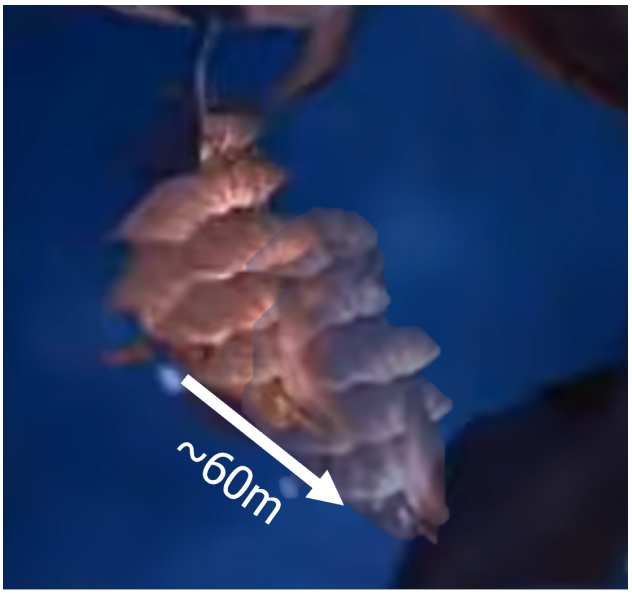

Figure 1: The RLS Legacy moves roughly its own length (60m) in about 4.5 seconds.

its front profile when the sails are extended, and A is the cross sectional area, estimated at 400 m^2.

Based on footage from the movie (Figure 1) we estimate the ship's top cruising speed to be around 13.3 m s^{-1}. Inputting that into the drag equation gives a force of ∼60,000 N. The most power efficient MPD thruster mode has a power/force ratio of 20 kW N^{-1} [1], which means the Legacy's engines require 1.2 GW of power to function at minimum.

The Solar Surfer

Another vehicle shown in the movie is the solar surfer, which is functionally a flying windsurfer with rocket engines. During the scene near the beginning of the movie (Figure 2), we can see the craft covers roughly its own length in about a single animation frame, which amounts to about 1/24th of a second. Estimating the craft as about 2 m long, we can give a velocity of 48 m s^{-1}. Inputting that into equation 1, assuming a 1 m^2 cross-section and a 1.3 coefficient of drag, gives us a force of about 2000 N,

Figure 2: The solar surfer moves roughly its own length (2m) in a single animation frame (1/24s).

which results in a power consumption of 40 MW.

Conclusions

The Sun provides about 1600 W m^{-2} of power to Earth. Modelling the planet as receiving the same power, and estimating the surface area of the surfer's sail as 4 m^2, it should generate 6.4 kW if perfectly efficient. Thus the solar surfer is powered by 99.984% Disney magic.

Similarly, if we estimate the Legacy's sails to have a surface area of 300 m^2 and assume it is receiving a similar amount of solar power, its sails have a power output of 480 kW and its engines are powered by 99.96% Disney magic.

Both vehicles are wildly impractical real-life vehicles, and would likely have issues far outstripping an insufficient power supply, such as overheating from the plasma engines, having no real attitude control systems and having most of the command and control systems exposed to the vacuum of space. For the purposes of the movie's plot and visual identity, however, these vehicles serve their purposes perfectly.

References

[1] E. Choueiri, *New Dawn for Electric Rockets*, (Scientific American, 2009) Vol. 300, p. 2

[2] `https://www.thepirateking.com/ships/ship_types.htm` [Accessed 25 October 2023]