Journal of Physics Special Topics
An undergraduate physics journal

P1 1 Evaluating Elite Dangerous's Propulsion System

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October 13, 2026

Abstract

This paper investigates whether the systems used to power spaceships in the video game Elite Dangerous would be viable in the real world. Modelling the ship's thrusters as ion thrusters fuelled by the products of nuclear fusion, a maximum acceleration of 1.08 μms^{-2} was calculated. It was also found that in-flight refuelling may be realistic for a fusion reactor, as the velocities required within the sun's corona have been achieved by previous missions.

Introduction

The video game Elite Dangerous simulates mankind as it may exist in the 34th century. The player can pilot a number of spaceships that utilise nuclear fusion to power all systems [1], and can optionally harvest hydrogen from a star's corona to refuel using a 'fuel scoop' [2]. While current fusion reactors use tritium and deuterium as fuel [3], these isotopes are highly uncommon in the sun's corona [4][5]. It is therefore assumed that the fusion reactors in Elite Dangerous utilise the same series of fusion reactions as the sun [6]:

$$^1\mathrm{H} + {}^1\mathrm{H} \longrightarrow {}^2\mathrm{H} + \mathrm{e}^+ + \nu. \tag{1}$$

$$^2\mathrm{H} + {}^1\mathrm{H} \longrightarrow {}^3\mathrm{He} + \gamma. \tag{2}$$

$$^3\mathrm{He} + {}^3\mathrm{He} \longrightarrow {}^4\mathrm{He} + 2\,{}^1\mathrm{H} + \gamma. \tag{3}$$

The energy Q released by a single fusion reaction can be found from the following [7]:

$$Q = (m_i - m_f)c^2, \tag{4}$$

where m_i is the mass of the starting nuclei, and m_f is the mass of the resulting nuclei [8][9][10]. If the total power output of the reactor is known, the Q value can be used to find the required rate of fusion and number of ions.

The energy released from fusion is harvested as electrical power, after which the ^{4}He ions cool. It is then assumed that all of the resulting ^{4}He ions enter the thrusters. The thrusters' description closely resembles that of ion thrusters [11] so the thrust F they produce is [12]:

$$F = 2\frac{\eta P}{g_0 I_{sp}}, \tag{5}$$

where η is the efficiency of the thrusters, P is their power draw, g_0 is standard gravity at Earth's surface, and I_{sp} is the specific impulse of the thrusters in seconds. Furthermore, the specific impulse of the thrusters is given by the following [13]:

$$I_{sp} = \frac{v_e}{g_0}, \tag{6}$$

where v_e is the exhaust velocity. The exhaust velocity is found by assuming that all power consumed by the thrusters is used to give the ^{4}He ions equal kinetic energies. The kinetic energy

E of each ion is therefore:

$$E = \frac{P}{N}, \tag{7}$$

where N is the number of complete fusion chains required per second to fuel the power plant. The energies considered are non-relativisitc, so the exhaust velocity is found from:

$$v_e = \sqrt{\frac{2E}{m}}, \tag{8}$$

where m is the mass of a ^{4}He ion. From the exhaust velocity, specific impulse and thrust, the maximum accleration of the ship can be calculated from Newton's second law, and the feasibility of these thrusters evaluated.

The necessary properties of the fuel scoop can also be investigated, as the rate of atoms gained r is:

$$r = nXAv, \tag{9}$$

where n is the number density of ions in the corona, X is the relative abundance of hydrogen atoms in the corona, A is the scoop's surface area, and v is the ship's velocity. The number density of atoms in the sun's corona has been found to be 2×10^{14} m^{-3} [14][15], and the abundance of hydrogen in is taken to be 91% [16].

Results

Using Eq. (4), the Q values of Eq. (1), (2) and (3) are 1.21 MeV, 5.43 MeV and 12.81 MeV respectively. A complete fusion chain therefore releases 19.45 MeV. The largest power plant in the game can output up to 36 MW of power [1], which requires 1.16×10^{19} complete fusion chains per second to sustain. The most powerful thrusters in the game consume 10.8 MW [11], so from Eq. (7), each ^{4}He ion gains 5.81 MeV of kinetic energy. Eq. (8) therefore gives an exhaust velocity of 1.67×10^7 ms^{-1}. This can then be used in Eq. (6) to find a specific impulse of 1.70×10^6 s. Assuming a 100% efficient thruster, Eq. (5) gives a maximum thrust of 1.30N. The most massive ship in the game has a mass of 1.2×10^6 kg [17], so the maximum acceleration achievable with this ship is 1.08 μms^{-2}.

As six ^{1}H ions are required to form a single ^{4}He ion, 6.93×10^{19} hydrogen ions are required per second to fuel the power plant. The relationship between the required area of the fuel scoop and the ship's velocity is reciprocal as shown in Fig. (1). The fastest human-made object, the

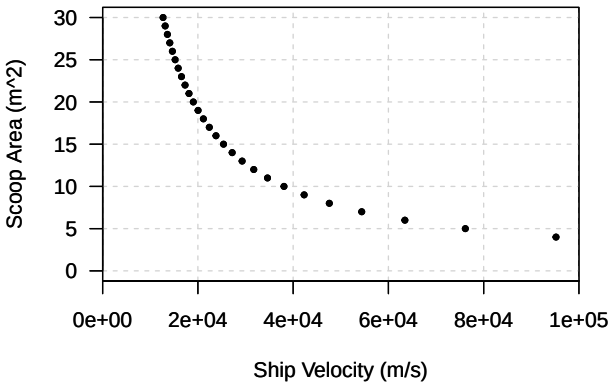

Figure 1: The relation between the fuel scoop area and ship velocity required to match the fuel usage of a 36 MW power plant, according to Eq. (9).

Parker Solar Probe, reached a maximum velocity of 1.9×10^5 ms^{-1} within the sun's corona, in a gravitionational field of around 2.7 ms^{-2} [18]. At this velocity, the fuel scoop would need a surface area of 2.00 m^2 to match the fuel usage of the power plant.

Conclusion

The thrust available from the ion thrusters in Elite Dangerous is far below what is necessary for high-speed space travel. While providing a greater number of ^{4}He ions to the thrusters would increase thrust, the maximum acceleration is currently six orders of magnitude smaller than that of the gravity in the sun's corona.

Scooping fuel from a star's corona would be possible with a gravity assist. At velocities achieved by human-made spacecraft, scoop areas on the order of a few m^2 would match the fuel burn rate. At this speed, a scoop of similar size to the James Webb Space Telescope could refuel up to ten times faster than the power plant consumes the fuel [19], suggesting this is viable.

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