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A5_2 Big MAC: Worth it?

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Abstract

This paper aims to ascertain the power requirements and practicality of an orbital Magnetic Accelerator Cannon (MAC) from the Halo franchise. This was done by calculating the energy of the projectile using referenced values, and treating the MAC as a linear accelerator. The power required was calculated to be $P = 1.60 \times 10^{24}$ W. It was also calculated that it would take the UK approximately 70 years to charge the MAC, with a total capacitance of 8.16×10^{15} F needed to store the required energy.

Introduction

The term coilgun refers to a type of electromagnetic linear accelerator, used to fire a ferromagnetic projectile without the use of chemical propellant. There are various potential applications for this technology in real life, such as placing payloads in orbit or as a weapon. In the Halo franchise, this latter concept is taken to the extremes in the form of the Magnetic Accelerator Cannons (MACs) used by Humanity's United Nations Space Command (UNSC), which are used as both ship-borne and planetary defence weapons. In this paper we go about calculating the power and energy storage requirements of one such MAC, specifically the "Super-MAC" used on the Orbital Defence Platforms in orbit around the planet Reach, and its practicality as a weapon.

Method

To go about calculating the required power of the MAC, we first had to calculate the energy that needs to be provided to the projectile to reach the stated speed. Then we needed to calculate the time over which the MAC transfers the energy to the projectile. We assumed that in this system the projectile is initially at rest, there is no air resistance and that the MAC transfers the energy with 100% efficiency.

To calculate the energy of the projectile we simply calculated the kinetic energy the projectile would have upon leaving the cannon. This can be calculated using the equation,

$$E = \frac{1}{2}mv^2 \tag{1}$$

where E is the kinetic energy of the projectile, m is the projectile mass and v is the projectile velocity.

To calculate the time taken to travel the length of the cannon barrel we used the rearrangement of a SUVAT equation to give the equation,

$$t = \frac{2x}{u+v} \tag{2}$$

where t is the time taken, u is the initial velocity, v is the final velocity and x is the length of the cannon barrel.

Once these values had been calculated we then used the equation,

$$P = \frac{E}{t} \tag{3}$$

where P is the power required to fire the MAC. To determine the capacitance needed to store the calculated energy we used the equation,

$$C = \frac{2E}{V^2} \tag{4}$$

where C is the total capacitance and V is the supplied voltage.

Results

For the calculation of E, we used the values $m = 3.00 \times 10^6$ kg and $v = 0.04c$, where $c = 3.00 \times 10^8$ ms^{-1} [1]. This produced a value of $E = 2.16 \times 10^{20}$ J. For the calculations of t we used $u = 0$ ms^{-1}, $v = 0.04c$ as before, and $x = 802$ m [1]. This produced a value of $t = 1.35 \times 10^{-4}$ s. We then used the values calculated for E and t to calculate a value of $P = 1.60 \times 10^{24}$ W. Finally we used the value for E and $V = 230$ V, the UK standard voltage [2], to obtain a value of $C = 8.16 \times 10^{15}$ F.

Conclusion

This is a colossal value for P and is comparative to the power of some of the largest nuclear weapons ever detonated, such as the Tsar Bomba at 5.30×10^{24} W [3]. The charge time for the system can be calculated using a rearranged form of Equation 3 for t. Using the E value calculated earlier in the paper and the power output of the entire United Kingdom, $P = 9.71 \times 10^{10}$ W [4], we calculated a charge time of approximately 70 years. Additionally, the capacitance calculated to store the energy required to fire the MAC was extremely large. To provide a total capacitance of $C = 8.16 \times 10^{15}$ F an array of capacitors would be required. The largest commercially available capacitors have capacitance around 10000 F [5]. Using capacitors of this size an array of 8.16×10^{11} individual capacitors arranged in parallel would be required to store the energy. These values clearly show the MAC would be unviable given modern power generation technology and would require absurdly large power storage systems.

However all the calculations made in the paper operate off of the assumptions we stated earlier. Our first assumption stated that the projectile is initially at rest. Though not strictly true due to the MAC being in orbit, the orbital velocity would be negligible compared to v of the projectile. Next we stated that there is no air resistance experienced by the projectile. We believe this assumption to be valid, due to the exo-atmospheric location of the MAC. Finally we assumed that the MAC is able to accelerate the projectile with 100% efficiency. This would have an effect on the values calculated in the paper, as some energy will be wasted, mainly due to internal heating. This would lead to a larger energy requirement, increasing the charge time and total capacitance needed by potentially significant amounts.

In conclusion, though a MAC would be an extremely powerful weapon, the electrical power requirements of a coilgun of this magnitude would prove to be very costly for anyone endeavouring to operate it. The charging time alone would render such a weapon ineffective for rapid planetary defense, especially if modern Earth found itself in situations such as those presented in the Halo franchise. Additionally, the cost of constructing and maintaining such a large capacitor array further decreases the practicality of such a weapon.

References

[1] `https://tinyurl.com/y3te9b9d` [Accessed 1 December 2020]

[2] `https://tinyurl.com/yxoawrtu` [Accessed 1 December 2020]

[3] `https://tinyurl.com/yxqaeyx5` [Accessed 1 December 2020]

[4] `https://tinyurl.com/yyjh59bq` [Accessed 1 December 2020]

[5] `https://tinyurl.com/y48hnj6b` [Accessed 1 December 2020]