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P6_9 Laser Diode Another Day

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Abstract
This paper considers the feasibility of the Icarus satellite weapon in the film *Die another day.* We find that the power requirement of Icarus exceeds the total world power demand 500 times over. Even with the current largest space based solar panels (aboard the ISS), it would take several years to store the energy required for a ten second burst of the weaponized beam of light depicted in the film.

Introduction
In the movie *Die another day* [1] the villain Gustav Graves uses a mirror on a satellite placed in geosynchronous orbit to focus light from the Sun and using some very advanced "physics", manipulates this energy into a narrow, non-diverging beam of light which chases James Bond across an ice sheet, melting the ice in its path. By calculating the volume of the ice melted this paper aims to quantify the power required from the Sun, and hence the size of mirror required for this to work. This paper will not take into account the logistics of building such a reflector or the satellite.

Theory
In the film [1], the beam is focused onto a small point on the Earths surface, which then chases James Bond across the ice and finally carves off a slice of ice from the side of a cliff. By examining the footage from the film we estimate the depth of ice which is cut through to be $\sim 150m$, and the beam width to be $\sim 25m$. The beam traces a line of length $\sim 100m$. This gives a total volume of ice carved out as $\sim 450,000m^3$ as depicted in Fig 1.

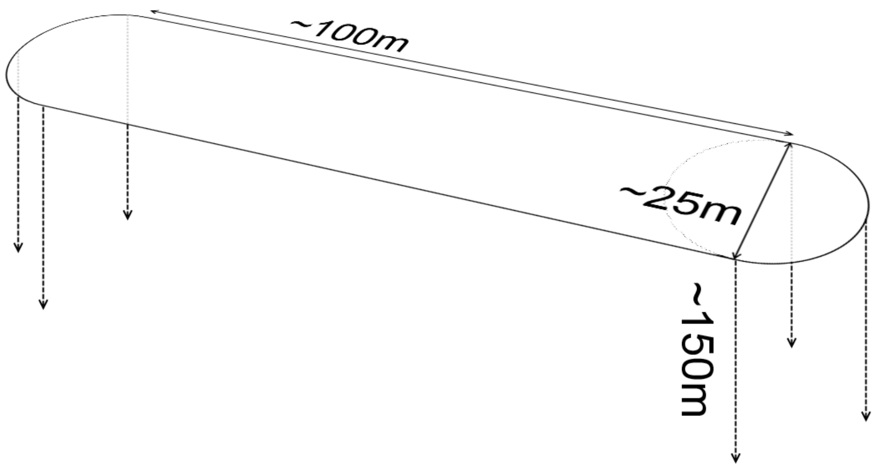

Fig. 1: our estimates of the dimensions of the beam used in the film.

To estimate the energy required for such a beam to melt the amount of ice described in Fig 1, we use the following equation, where we assume there is no increase in temperature (the ice is already at $0°C$ and the melt-water remains at $0°C$). This is therefore the minimum energy requirement:

$$E_{min} = H_f m_i, \tag{1}$$

where H_f is the latent heat of fusion of water ($334kJkg^{-1}$ [2]) and m_i is the mass of ice. The density of ice is $920kgm^{-3}$ [3]. For the purposes of approximation it is assumed that the cliffs in the film have a similar density to that of pure ice, although the density may be slightly less as they may be formed from compacted snow. The total mass of ice melted is then $4.1 \times 10^8 kg$. This gives $E_{min} = 1.4 \times 10^{11} kJ$. We find power P_{min} by using $P_{min} = E_{min}/t$ and assume $t = 10s$ (from examining the footage [1]) to give an average power $P_{min} = 1.4 \times 10^{13} W$. For scale this is 500 times greater than the average world power demand [4].

The satellite is assumed to be in geosynchronous orbit, approximately $1AU$ from the Sun, and as such the power it will receive is $1.37kWm^{-2}$ [6]. If it assumed the satellite can use and reflect all wavelengths, the total area of the satellite required to produce the power we calculated ($1.4 \times 10^{13} W$) would be $10^{10} m^2$, or a circle with radius $5.6 \times 10^4 m$. This is much larger than anything humankind has yet achieved; the area of the solar panels on the International Space Station (ISS) is $4047m^2$ [5].

In order for a satellite with solar panels of a similar area to those on the ISS to save up enough energy to allow the Bond villain to carry out this single act of megalomania, it would need to be capturing and storing energy for $\sim 1yr$. This is an underestimate however, as the panels are not 100% efficient, but are $\sim$ 14% efficient [7]. This gives a time requisite of $\sim 6yr$.

Conclusion

Although the scenario as presented in the film, in which Icarus is just reflecting light, is not feasible, both from an energy conservation standpoint and from an engineering one, a similar scenario could potentially play out. If Icarus contained an efficient enough battery and large enough solar panels (and James Bond was able to give the villains a few years' notice of his planned escape) then the entire scenario could play out as shown in the film. The largest problem however would arise from aiming the beam, taking into account atmospheric disturbances and the time delay involved in directing the beam of light, and of course the incredible precision the aiming would require. This paper has not discussed these complications, although it may be possible to consider these factors in a future paper.

References

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