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P4_2 Visibility of the Great Fire of London

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Abstract

The Great Fire of London is investigated to determine whether it would have been visible to a human on a satellite in both high and low Earth orbit, had such technology been available. Both resolving and radiated power are tested and it is found that the resolving power has a greater influence on whether or not the fire can be recognised by an observer. In low Earth orbit the Great Fire would have been visible with the naked eye, but in geostationary orbit a camera with an aperture of diameter 25mm or greater is required.

Introduction

The Great Fire of London of 1666 is estimated to have destroyed the homes of 70,000 of the city's 80,000 inhabitants [1]. It raged uncontrollably for three days wiping out over 1.5 square kilometres of the city (see fig.1). This paper investigates whether the destructive force of the fire would have been visible from either low or high Earth orbit, testing both the resolving power of the observer and the radiant power of the fire itself. Only the visibility of the fire is considered, the smoke given off and its impact on visibility is neglected.

Resolving Power

Fig.1 shows a map of the city of London as it would have looked in 1666.

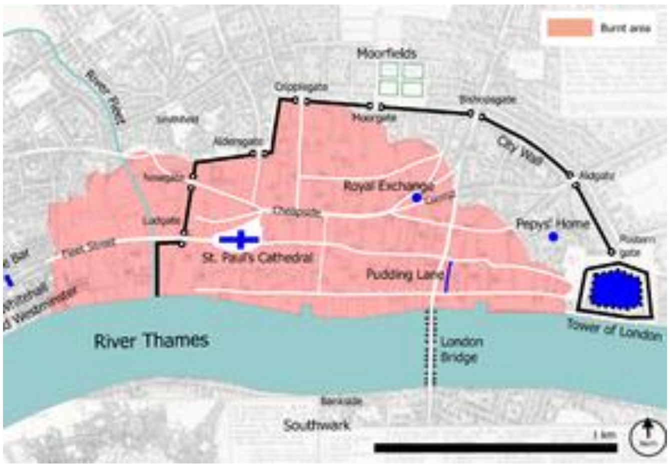

Fig.1: Map of London in 1666. The pink area shows the area destroyed by the Great Fire [2].

Estimating the coloured region shown to be a semi-circle, the area can be calculated using $A = \frac{\pi r^2}{2}$. Using 1km for the radius *r,* as seen on the diagram, gives an area of 1.57km^2.

The angular resolution was then found using Rayleigh's criterion:

$$sin\theta = 1.22\frac{\lambda}{D}, \quad (1)$$

where θ is the angular resolution in radians, λ is the wavelength of light and D is the diameter of the aperture. As this paper examines whether a person would have been able to resolve the fire, the aperture of the eye was considered, and as such was estimated to have a diameter of 5mm. Using this, the angular resolution and some trigonometry the linear resolution can be calculated. The two orbital altitudes used were 380km for low-Earth-orbit [3] and 35,700km for geostationary orbit [4]. The wavelength of light was approximated at 580nm indicating yellow light as is generally associated with fire. Using these figures gives the resolution for each orbit height of 54m and 5.1km respectively. This means that somebody aboard the International Space Station (ISS) would be able to resolve the area of the fire, but somebody aboard a geostationary satellite would not. Repeating this process in reverse for a geostationary satellite, it is found that in order to resolve the fire an aperture of at least 25mm must be used.

Radiation Power

To find the power radiated by the fire compared with that of the background, the Stefan-Boltzmann law was used

$$P = \sigma T^4, \qquad (2)$$

where *P* is the power of radiation emitted, *σ* is the Stefan-Boltzmann constant and *T* is the temperature of the black body. In order to compare the fire to the background, an area equal to that of the fire is modelled as a black body (as is the fire) and the two points are assumed to radiate isotropically. In order to find the effective temperature of the Earth, the energy received from the sun and the energy radiated by the Earth are equated using a form of the Stefan-Boltzmann equation where the surface albedo of the Earth is approximately 0.3 [5]. This gives the Earth's effective temperture as 279K, modelled as a black body, which means the radiation power is around 345W. For the fire, however, the radiation power is of the order 110kW. This is based on a temperature of 900°C (or 1173K) which is comparable to Austrailian wildfire flames [6]. The power received from the fire in low Earth orbit is $5.9\text{x}10^{-8}\text{Wm}^{-2}$, compared with $1.9\text{x}10^{-10}\text{Wm}^{-2}$ from the background, so there is around 300 times more from the fire. Similarly in geostationary orbit, the radiation from the fire is 300 times greater than that from the background ($6.7\text{x}10^{-12}\text{Wm}^{-2}$ compared with $2.2\text{x}10^{-14}\text{Wm}^{-2}$).

Conclusion

These results show that the resolution has a much greater impact than radiative power on whether a fire can be recognised from space. This is without accounting for the proportion of the radiation from the fire that is blocked by atmospheric effects or from the smoke that the fire produces, as well as not taking into account the proportion of the emitted radiation that is visible light (since the blackbody calculations consider all wavelengths, not just optical light). These are, however, concluded not to affect the result since over 300 times more radiation reaches both satellites from the fire compared with the background.

In the case of the Great Fire of London, the dimensions of the affected area are not equal. Although these results are not affected by this, similar situations have the potential to be resolvable in one dimension but not in another. Since the resolution at low Earth orbit is around 50m, this means the fire would easily have been resolvable by the human eye. From geostationary orbit an aperture of at least 25mm is required therefore the human eye would not be able to resolve the fire but a large aperture camera would be able to.

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