Journal of Physics Special Topics
An undergraduate physics journal

A6_8 When The Enterprise Fell To Earth

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December 13, 2021

Abstract
In the 2013 film *Star Trek: Into Darkness*, the titular vessel, *U.S.S. Enterprise*, is seen to accelerate towards the Earth from orbit, with its imminent crash on the surface of the Earth stopped by the firing of RCS Thrusters at the cloud layer of the atmosphere. Here we estimate the forces and deceleration experienced by the crew of the *Enterprise* when the ship is prevented from crashing on the surface of the Earth, and assess whether the stunt would have killed the crew or not. We find that the required force applied over the observed thruster burn time in the film to bring the *Enterprise* to a constant altitude is $\sim 1.08\text{x}10^{12}N$, which is equivalent to $\sim$ 31,400 Saturn V Rockets. The deceleration required is approximately $730ms^{-2}$, which is equal to $\sim$ 75 G, and would have most likely have killed the crew.

Introduction

The film Star Trek: Into Darkness depicts the *U.S.S. Enterprise* falling from an altitude of $270,000$ km [1], where it is initially at rest, only to prevent a crash landing into the Earth's surface by firing RCS thrusters at the cloud layer of the atmosphere, which is at ~ 18 km [2].

In this paper we determine the required force needed to be applied to *Enterprise* to bring her to rest in Earth's atmosphere, using the film to determine the thruster fire duration.

Method and Calculations

Firstly, we will set the assumption that any drag forces on the ship are negligible, hence can be ignored. Additionally, we will neglect the visuals shown in the film depicting the ship to be close to the Moon, and instead use the stated altitude of $270,000$ km [1]. We will use the runtime of the film to find the thruster firing duration, which is $\sim 30s$. However, as the ship returns to the position it starts firing thrusters at, we assume that the ship is brought to rest in half this time, $t_{firing} = 15s$.

The mass of *Enterprise* is actually unknown, so we will make an estimate using the well known mass of *U.S.S. Voyager* at $700,000$ metric tonnes [4]. *Voyager* has a length of 343 m [4], with *Enterprise* having an approximate length of 725 m [5]. If we assume the mass is proportional to length, this gives an approximate mass of $m = 1.48\text{x}10^9$ kg.

This problem will be tackled using python code, iterating over time intervals of $1s$. As this scenario takes place over a large altitude range, the gravitational acceleration will be recalculated after each time interval of $1s$. The gravitational acceleration is given by Eq. (1):

$$g = \frac{GM}{r^2} \tag{1}$$

where $G = 6.67\text{x}10^{-11}m^3kg^{-1}s^{-2}$, $M =$

$5.97\text{x}10^{24} kg$ (mass of the Earth) and r is the altitude including the Earth's radius r_e, given as $r_e = 6371\ km$. We give this equation as a positive value as we can neglect the vector notation for this calculation.

In order to find the new velocity at each time interval, we use the following equation:

$$v = u + gt \tag{2}$$

Where v is the new (final) velocity, u is the previous (starting) velocity, g is the gravitational acceleration and t is the time interval, set at $t = 1s$.

By iterating over the altitude using Eq. (2) in each time interval until the ship reaches $r_f = 18km$, we find that the velocity of the ship at this point is $v \approx 11,000 ms^{-1}$. Assuming that the acceleration provided by the thrusters is constant, we find that the required acceleration, $a_{thruster}$, is $a_{thruster} \approx 730 ms^{-2}$.

Now, by using Newton's Second Law, $F = ma$, we can find the force required by the thrusters to achieve this acceleration. By using our values such that $F_{thruster} = ma_{thruster}$, we find that $F_{thruster} = 1.08\text{x}10^{12} N$.

Conclusion

As seen in the Methods and Calculations section, we found that the force required to bring the *U.S.S. Enterprise* to rest after accelerating towards the Earth from an altitude of $270,000 km$ is approximately $F_{thruster} = 1.08\text{x}10^{12} N$, with a deceleration of $\sim 730 ms^{-2}$. A Saturn V rocket has a launch thrust of approximately $34.5\text{x}10^{6} N$ [6], meaning that the *Enterprise* would need to experience the equivalent of $\sim$ 31,400 Saturn V rockets.

Additionally, the maximum acceleration endured by a human, and surviving, is 46.2G's [7]. This is approximately half of the calculated value for the acceleration experienced by the *Enterprise* crew. Furthermore, the human only experienced an acceleration of 46.2G for $\sim$ 5 seconds, whereas the *Enterprise* crew were under an acceleration of approximately 75G for 15 seconds. This makes it highly unlikely that the crew would have survived the acceleration.

The system used here has some assumptions, of which the main ones are discussed here. The *Enterprise* entered the atmosphere ventral side first, hence the ship will have had a very large drag profile. This will have enacted a terminal velocity which is possibly lower that the value found here. Additionally, the assumption of the thruster firing time is made from viewing the film itself, which does not show the exact time the *Enterprise* comes to rest. Therefore, it is possible the thrusters are decelerating the ship for longer, hence lowering the G forces experienced by the crew.

References

[1] Star Trek: Into Darkness, time index 1:17:40.

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[3] Star Trek: Into Darkness, time index 1:47:04-1:47:34.

[4] Star Trek: Voyager: Season 5 Episode 23 - Relativity.

[5] Approximate Length of *Enterprise*, Star Trek: The Art of the Film, ISBN-10: 1848566204, Author: Mark Cotta Vaz.

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