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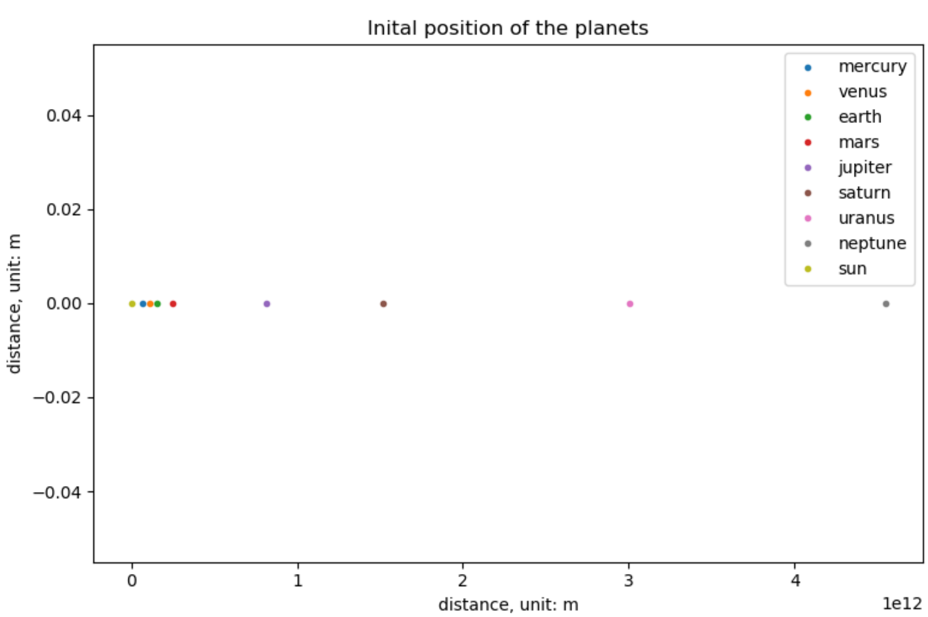
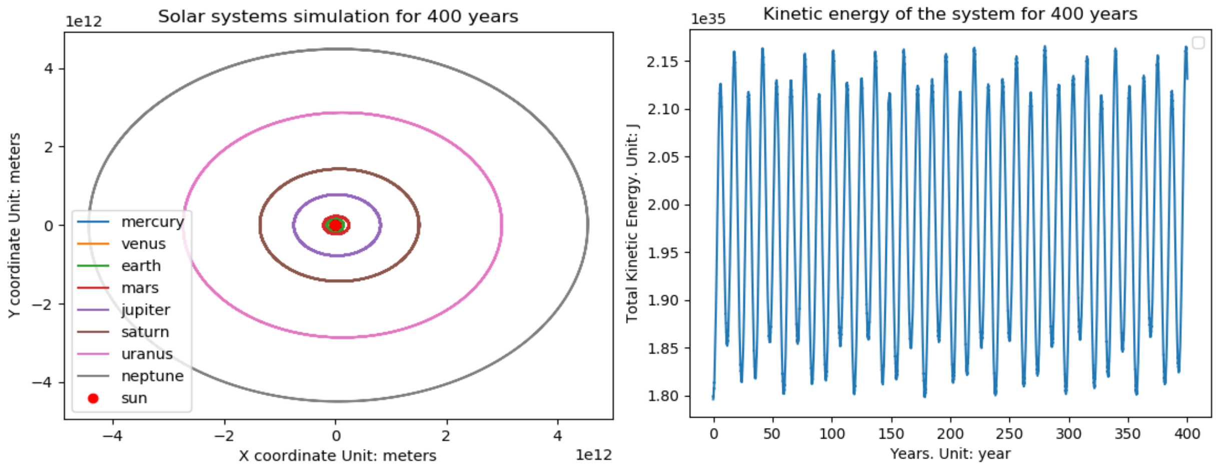
Feasibility of the Wandering Earth Project

The purpose of this study is to determine the feasibility of the project shown in the movie "The Wandering Earth". In the movie, humans build 12,000 thrusters to deorbit the Earth and use the gravity assist from Jupiter to reach escape velocity of the solar system. Simulations using verlet integration method concludes that the project is impossible to complete in the movie's time frame.

To obtain a relatively accurate simulation of the solar system's planetary motion, the varlet method was used for all the simulations in this study. There are two main reasons for choosing the varlet method for integration. First, the system's total energy is conserved when integrating using the verlet integration. Second, the algorithm is relatively simple to program and compare to other algorithms, the verlet methods provide a better error to runtime ratio since we are not integrating over a long period. The error of the varlet method is in the magnitude of O(Δt^2), which is accurate enough for this study.

The orbital and physical parameters of the planets are acquired from NASA's solar system fact sheet. The simulation assumes that at the very start, all the planet is on a straight line and are also on their aphelion point in their orbit and their orbital speed is at their minimum. In all simulations, we use step $\Delta t = 3600s$.





Solar system simulation for 400 years to verify the algorithm is correct, note that the oscillation in total kinetic energy is caused by planets exchanging their potential energy for kinetic energy in their elliptical orbits. From the energy, we can see that the energy is conserved throughout the simulation.

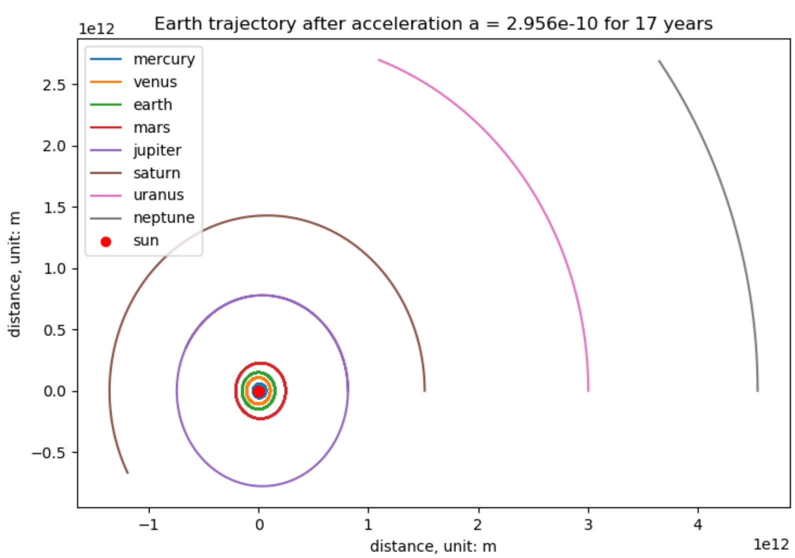
By the original film, there are 1,2000 Earth Engines in total, and each of them is capable to produce 1.5×10^{10} kg of continuous thrust, which is 1.5×10^{11} N for each of the engines. Therefore, the total combine thrusts will be

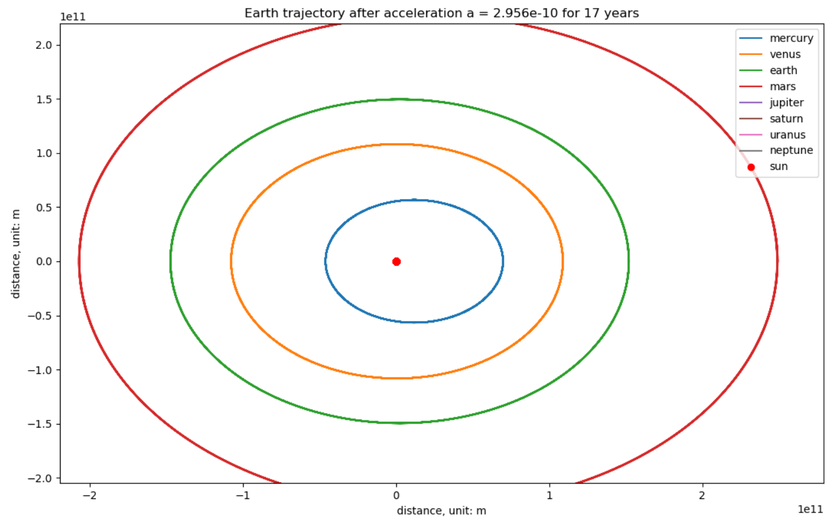
$$1.5 \times 10^{11} N \times 12000 = 1.76526 \times 10^{15} N$$

of thrust. From Newton's second law, the maximum acceleration the earth can achieve is:

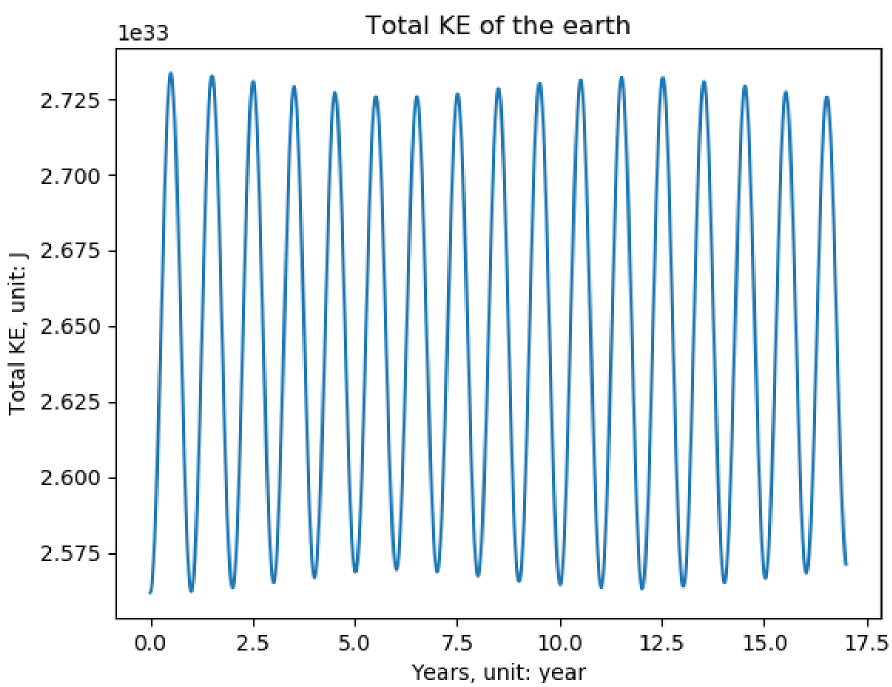
$$\frac{F}{M} = \frac{1.76526 \times 10^{15} N}{5.9723 \times 10^{24} kg} = \ 2.956 \times 10^{-10} m/s^2$$

The narrator in the film states that the engines were running on full power for 17 continuous years. However, the narrator did not stat the direction of the thrust, so we assume the acceleration is tangent to the trajectory for the Earth to achieve maximum angular velocity. However, the simulation shows that the trajectory had barely changed, and it is less than the error of the algorithm.



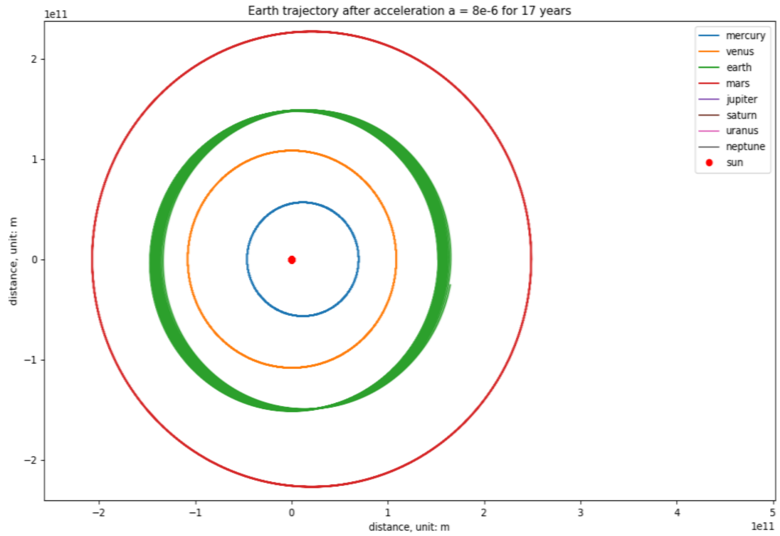


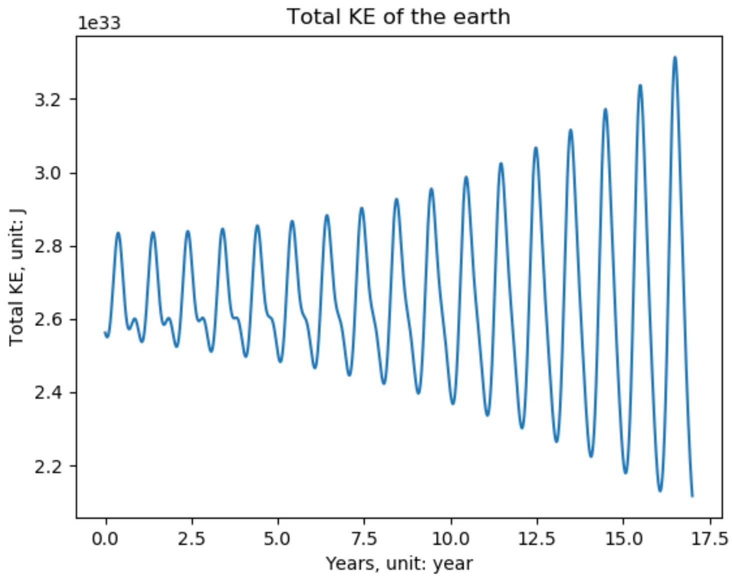
This zoomed-in picture from the last picture shows the Earth orbit is unchanged



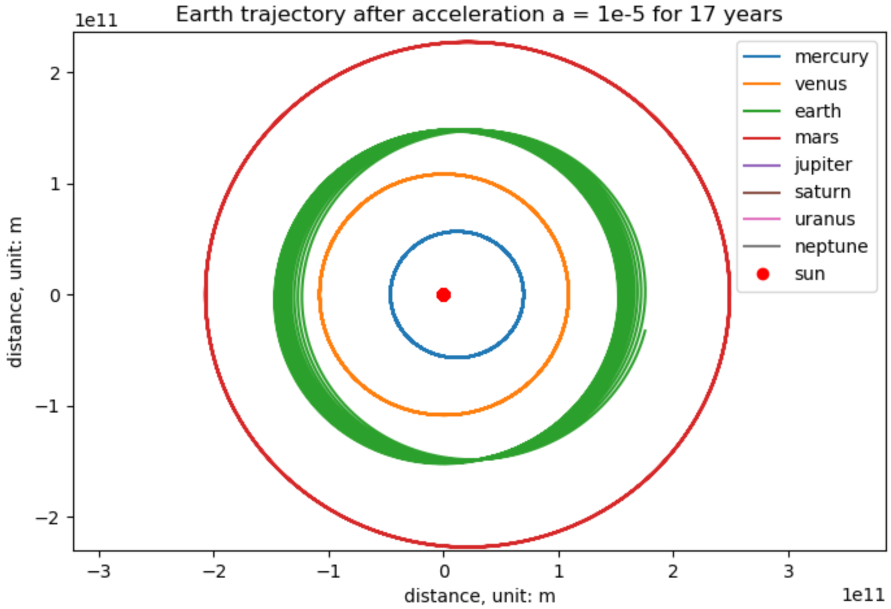
The total Kinetic energy of the earth in 17 years time span, the large energy fluctuation with period p = 1 is due to Earth exchanging gravitational potential energy with kinetic energy in its orbit. The other fluctuation with period p around 12 is due to Jupiter's gravitational force (Jupiter's orbital period is 12.5 years).

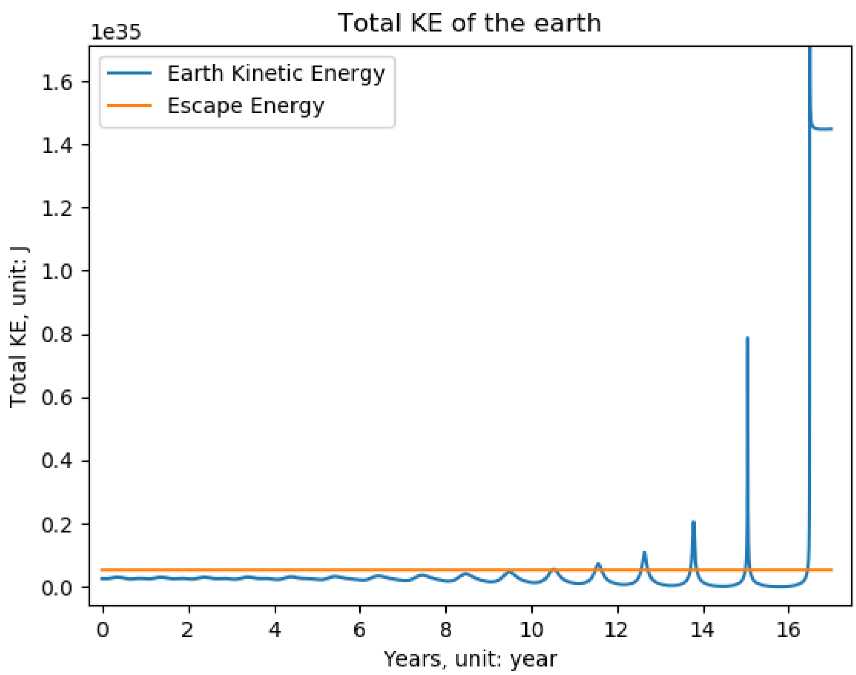
The simulation concludes that the given thrust is not enough to deorbit the Earth in the given time frame. This means that the wandering earth project will not succeed under previous assumptions. To experiment how much force will be needed to accelerate Earth out of its orbit to reach Jupiter's orbit, I ran the simulation with a few different acceleration parameters, the result is shown below:





The kinetic energy of Earth, I believe this is because, at the start of the acceleration, Earth's orbit becomes more elliptical hence closer to Venus. After some time of acceleration, the orbit of the earth raises so the bump in energy disappears since the gravitational pull from Venus is not that significant anymore.





The simulation concludes that we need at least a = $8 \times 10^{-6}\ m/s^2$ to have an impact on Earth's orbit. This is already around 10^4 times more acceleration than that of the movie suggests. However, as we increase the acceleration on Earth, we observed that the trajectory of the Earth become chaotic and eventually it will pass through the Sun for a gravity assist and slingshot itself to outer space before it reaches the orbit of Jupiter when the acceleration reaches a = $2 \times 10^{-5}\ m/s^2$. This trajectory will bring the earth very close to the sun, much closer than the trajectory of Mercury. Since the algorithm has an error of $O(\Delta t^2)$, the real trajectory might cause the Earth to crush into the sun.

In conclusion, the Wandering Earth project in the movie “The wandering earth”, is not feasible since the energy needed is much more than the what the movie suggests. And even if the energy is enough, acquire gravitational assist from the sun required less energy than getting the gravitational assistance from Jupiter.

References:

Orbital data:

https://nssdc.gsfc.nasa.gov/planetary/factsheet/

Escape Velocity:

https://en.wikipedia.org/wiki/Escape_velocity

“The Wandering Earth movie”:

https://en.wikipedia.org/wiki/The_Wandering_Earth