United Nations Educational, Scientific and Cultural Organization · Junior Academy of Sciences of Ukraine under the auspices of UNESCO

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APPLICATION OF AUTONOMOUS PROBES TO SOLVE THE SPACE DEBRIS PROBLEM

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Abstract

Objective of the work: to study the problem of space debris, propose and justify its solution.

The following tasks have been formulated to solve the problem of space debris:

1. To get acquainted with space debris problem and the principle of semiconductor lasers working.
2. To choose how to power and control the probes.
3. To consider the impact on the trajectory of debris particles in the Earth's gravitational and magnetic fields.

Research object: space debris.

Methods of research: analytical method.

The problem of space debris is urgent nowadays and needs solving. In recent years, its amount in orbit has been increasing continuously and will eventually make some orbits unusable.Consequently, it threatens the further space and astronomical research, making it much more difficult to output telescopes and spacecraft into Earth orbit.Several orbital launches of new telescopes, including a low one, are currently being planned.These telescopes include IXPE and XRISM, which are scheduled to be launched in 2021 and 2022 respectively. However, space debris is not only a threat to future missions and research.The satellites and spacecraft which are currently in orbit are also threatened. They include the International Space Station, communication satellites, Hubble, Astrosat, Chandra, WISE and other important objects, most of which are currently in low-Earth orbit.

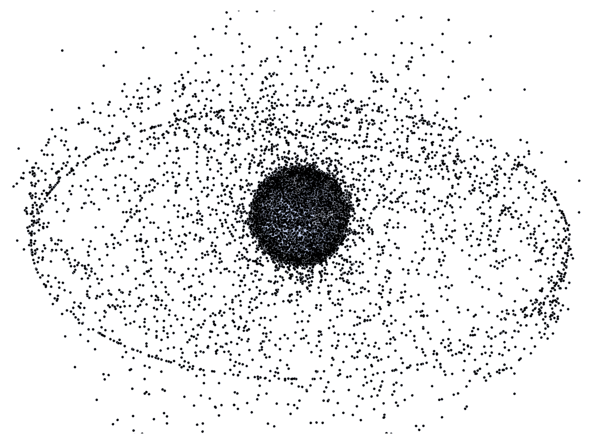

Fig. 1 High Earth orbit [1]

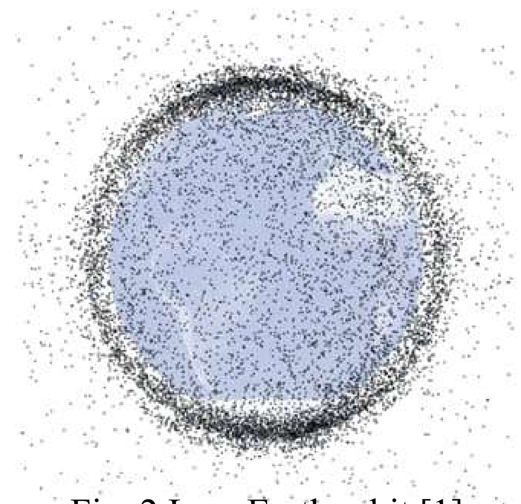

Fig. 2 Low Earth orbit [1]

Materials and methods

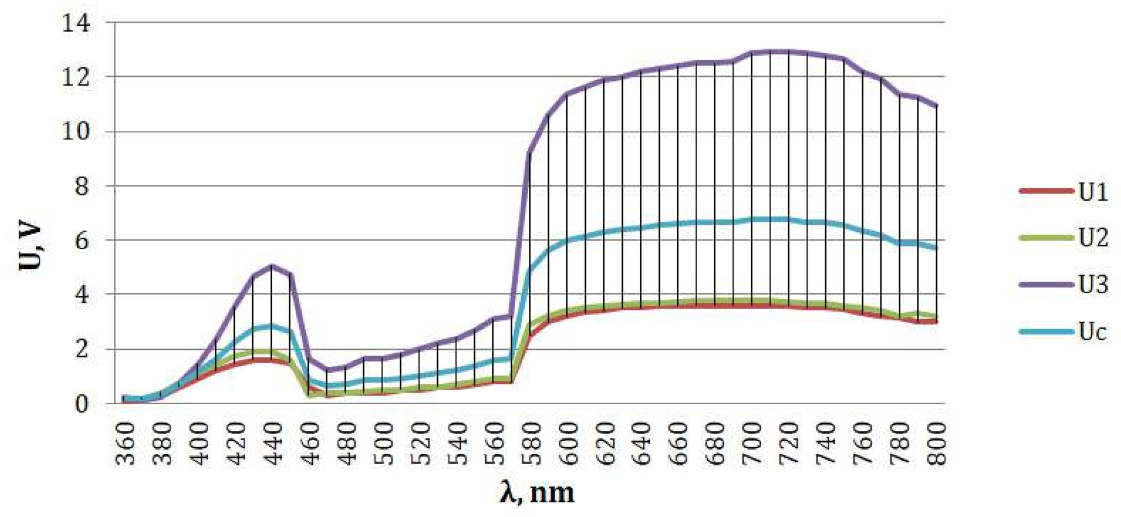

Fig. 3 Voltage-to-wavelength graph for three panels U1, U2, U3 and average Uc

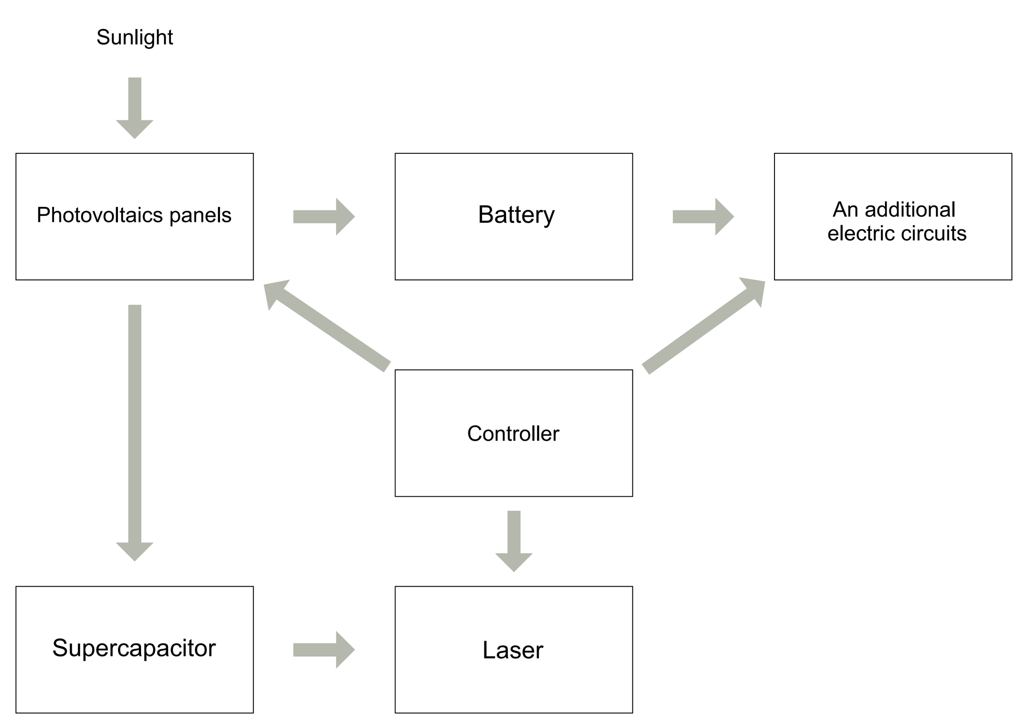

Fig. 4 Device component diagram

Orbital debris, or “space junk,” is any man-made object in orbit around the Earth that no longer serves a useful purpose [1]. Orbital debris is the number one threat to spacecraft, satellites, and astronauts. Collisions with orbital debris can pit or damage spacecraft in the best case scenario and cause catastrophic failures in the worst.

The sunlight is the most effective power sourse in the space for energy supply of autonomous probes. Photovoltaic panelas are using for the conversion of light energy into electricity [3]. The measurings have been made for determine the panels. The graph of voltage-to-wavelength relationship of the radiation was plotted using this data (Fig. 3). These photovoltaic panels work efficiently in the visible red spectrum and show the lowest value in the green spectrum. **Method for using autonomous probes to remove space debris from orbit.** It is inefficient to use large spacecraft to influence the trajectory of space debris, as it is costly to place them in orbit.Their navigational manoeuvres are energy-intensive, and eventually they will increase the amount of space debris by themselves when they cease to operate. Instead, a large number of small space probes with photovoltaic panels, semiconductors lasers, microcontrollers and electrical control and navigation circuits are proposed (Fig. 4). One way to reduce the amount of small debris in Earth’s orbit is to reroute it to the Earth’s atmosphere, where they will burn.

The evaluation of the number of photons in a pulse needed. In order to determine the effectiveness of using laser beam to change the velocity of the debris particle, an evaluation of the required momentum energy was carried out. Two cases of laser action of a debris particle were considered in the evaluation:

1. The laser decelerate the particle and it goes into a lower orbit, where the atmosphere already exists, and burns there (Fig. 5)

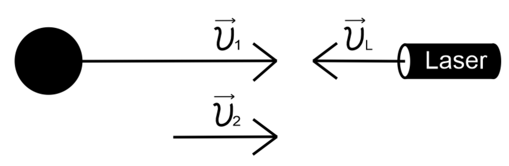

Fig. 5 The laser decelerate the piese of debris

$$N = \frac{\lambda m}{h}\sqrt{\frac{GM}{R_1}}\left(1-\sqrt{2-\frac{R_1}{R_2}}\right), R_2 < R_1 \qquad (1)$$

2. The laser accelerates the a bit of dust and it goes into a higher orbit. (Fig. 6)

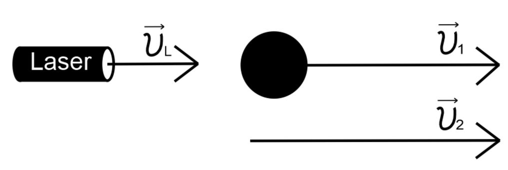

Fig. 6 The laser accelerates the a bit of debris

$$N = \frac{\lambda m}{h}\sqrt{\frac{GM}{R_1}}\left(\sqrt{2-\frac{R_1}{R_2}}-1\right), R_2 > R_1 \qquad (2)$$

By sibstituting constants to formulas (1) and (2), it is possible to plot dependencies of the required pulse energy according to the orbital radius (Fig.6) (Fig. 8) and the length of the rib of the debris (Fig. 7). Figure 6 shows the amount needed to bring the particle closer to Earth amount of photons increase as the distance to the Earth decreases. Figure 7 shows that the number of photons required increases with the increase the rib lengths of the debris particle. Therefore, great energy is needed to steer the large debris. Figure 8 shows that the necessary number of photons increases when the radius of the orbit to which it has to be moved is increased. It can also be seen that in order for to reach the Hill sphere requires a very high energy input, which makes it impossible to realize it. From this it can be deduced that it is not energetically feasible to move debris into high orbits.

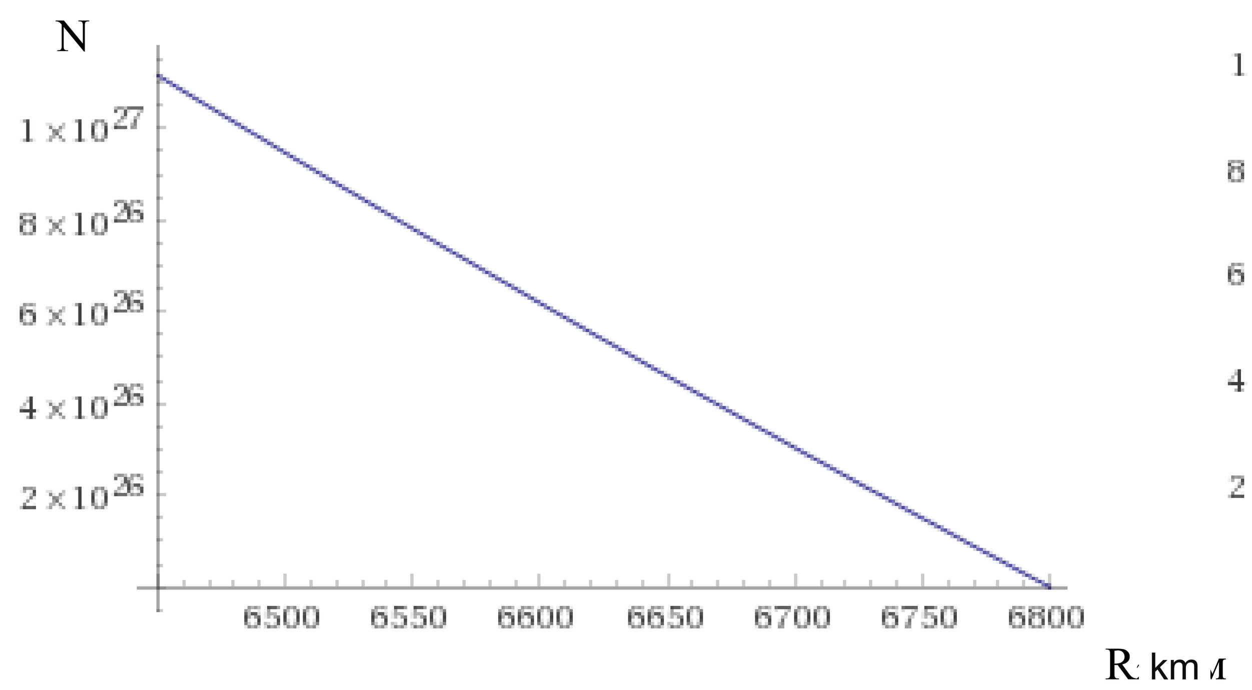

Fig. 7 Graph of the dependence of the necessary energy from distance

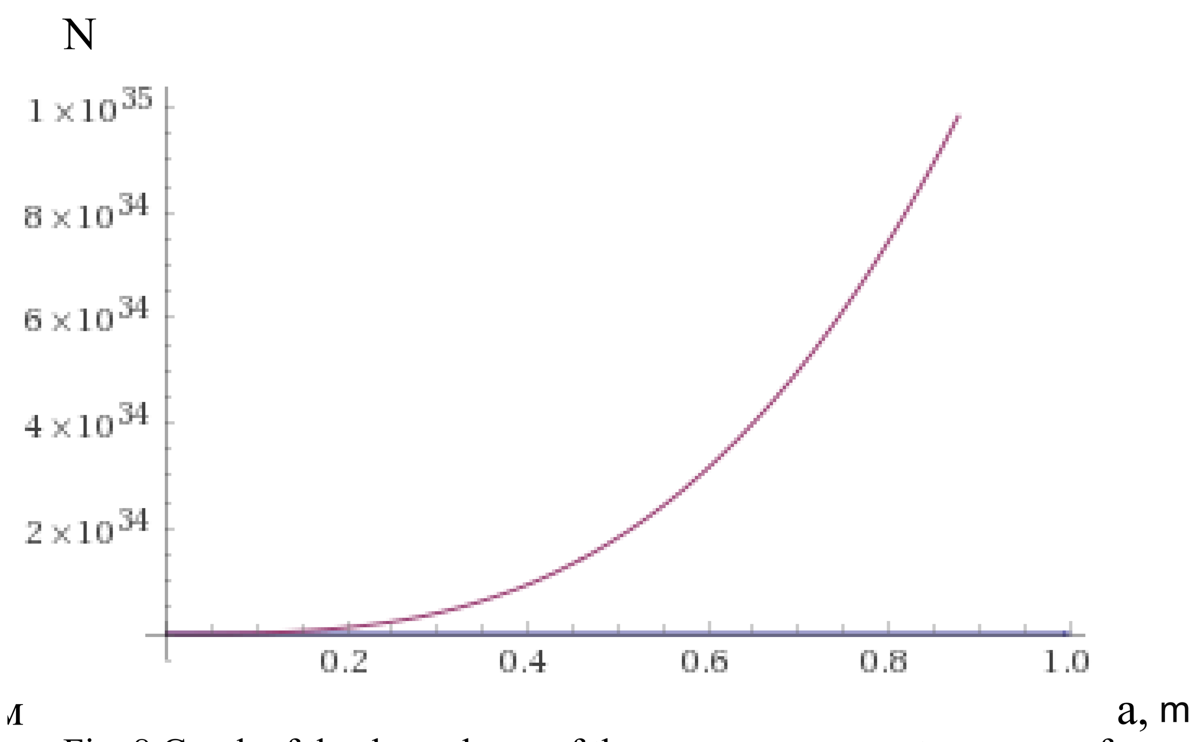

Fig. 8 Graph of the dependence of the necessary momentum energy from length of debris edge

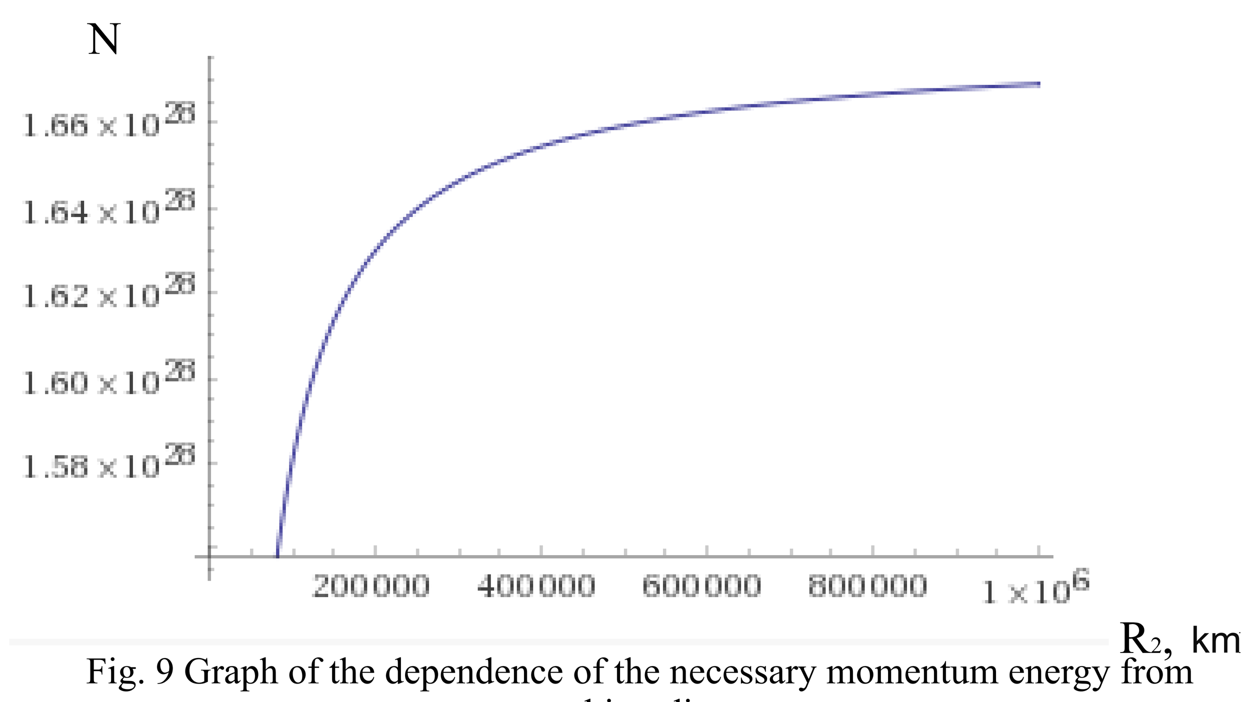

Fig. 9 Graph of the dependence of the necessary momentum energy from orbit radius

Conclusions

In this work, the method of using small spacecraft (probes) to solve the problem of space debris is justified.A method for feeding and controlling probes was selected, and the problems of navigating probes and influencing the trajectory of debris particles in the Earth's gravitational and magnetic fields were considered. But this method is useful only for particles up to 10 cm in size, will not cause great damage to the Earth's atmosphere and will not disturb its ecological state. Consequently, it is not feasible in these conditions to divert a particle of debris to higher orbits, where it will be transferred to another space body such as the Sun it is necessary a great amount of energy which is not efficient in these conditions.

References

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