S E S   2 0 1 7
Thirteenth International Scientific Conference
SPACE, ECOLOGY, SAFETY
2 – 4 November 2017, Sofia, Bulgaria

SPACE WASTE

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Keywords: *space waste, ecology, space radiation, nuclear waste*

Abstract: *There are tons of unusable debris in Earth's orbit, representing a type of anthropogenic pollution. Because they are concentrated in the area, covering spacecraft's trajectory, as the number of debris increases, so does the threat of collision with shuttles, satellites and the International Space Station. Additionally, planning future cosmic missions is also hampered.*

The aim of the present work is a brief overview of the situation with space waste and the potential risky consequences. It emphasizes the possible methods for their purification and the pressing need to remove them. Consideration is being given to the possibilities of developing materials and technologies that can convert photonic energy in the form of X-rays, gamma rays and charged particles with higher energy into electricity etc.

КОСМИЧЕСКИ ОТПАДЪЦИ

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Ключови думи: *космически отпадъци, екология, космическа радиация, космически радиоактивни отпадъци*

Резюме: *В земната орбита циркулират тонове непотребни отломки, представляващи вид антропогенно замърсяване. Бидейки концентрирани в пространството, обхващащо траекторията на космическите апарати, с нарастването на количеството отломки се увеличава и заплахата от сблъсък със совалки, сателити и Международната космическа станция. В допълнение се възпрепятсва и планирането на бъдещи космически мисии.*

Цел на текущата работа е кратък обзор на ситуацията с космическите отпадъци и потенциалните рискови последствия. Акцентира се върху възможните методи за тяхното пречистване и належащата нужда те да бъдат премахнати. Разглеждат се възможностите за разработване на материали и технологии, които могат да превърнат фотонни енергии под формата на рентгенови лъчи, гама-лъчи и заредени частици с по-висока енергия в електричество и др.

Introduction

Mankind has been sending objects in space for more than 50 years. But despite the positive results of the development of space technologies, the negative consequences could not be denied. In the immediate vicinity of our planet, there are many unnecessary debris of various sizes - circulating man-made objects that are no longer beneficial to humanity. Most of them are fragments and elements of satellites, as well as out of use satellites [2].

Space waste is mostly concentrated in low Earth orbit (LEO) which boundaries are not firmly defined, but it is generally assumed that the orbit up until 2000 km altitude is low Earth orbit [3]. Hubble Space Telescope, International Space Station and about 500 active satellites are also circulating at this height [2] (Fig. 1, Table 1).

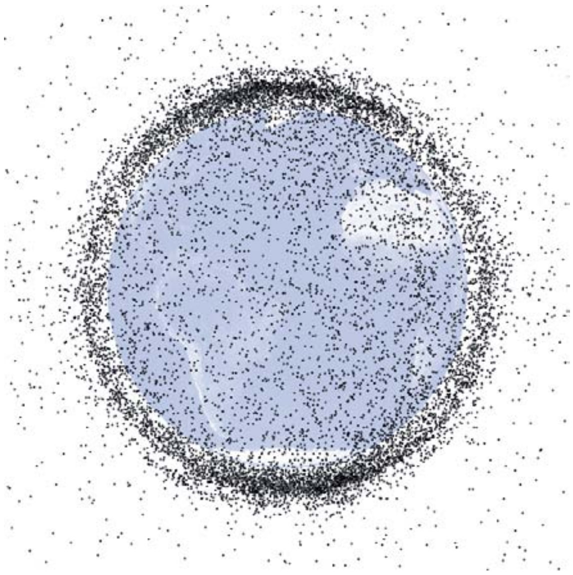


Fig. 1. Space waste larger than 10 cm in LEO, August 25, 2009. NASA Image

Table 1. Random Collisions between Catalogued Objects [8]

Date	Objects involved	Altitude	Number of fragments
23 Dec 1991	Cosmos 1934 Debris from Cosmos 926	980 km	2
4 July 1996	Cerise spacecraft 1986 Ariane explosion fragment	685 km	1
17 Jan 2005	Thor-Burner 2A rocket 2000 Chinese explosion fragment	885 km	4
10 Feb 2009	Iridium 33 Cosmos 2251	790 km	>1500

Risks and incidents

In 1987, the American astrophysicist and former NASA scientist Donald J. Kessler suggested a hypothesis stating that with the continued growth of space debris in LEO there is an increased risk of collisions between objects that would cause a cascade, where each collision would generate even more space debris increasing the likelihood of further collisions (Table 1) [6–8].

Velocity of the collision is directly connected to orbital inclinations of the objects in orbit, the higher orbital inclination the higher collision velocity, which will lead to further smaller fragments smashing into larger functioning and nonfunctioning objects [7]. Subsequently this phenomenon gained popularity with the term "Kessler syndrome". Low Earth orbit is the most threatened, nevertheless the region in danger is expanding (Fig. 2, Fig. 3).

Two incidents stand out as especially severe. In 2007 China destroyed FY 1C – one of their Fengyun (FY) weather satellites in a test of an anti-satellite missile. According to NASA data, this is the case that has caused the largest amount of space debris in history to this point [4]. In 2009 there was a collision between the satellites Iridium-33 and Kosmos-2251 which produced space waste. In March 2011 International Space Station made a maneuver in order to avoid debris from this particular incident [9].

In 1977 USSR launched a reconnaissance satellite with a nuclear reactor onboard named Kosmos 954 [5]. A malfunction diverted the satellite from its orbit, and it fell on the territory of northwestern Canada around the Great Slave Lake on January 24, 1987. This incident caused a radioactive contamination and USSR was obliged to indemnify Canada with 3 million Canadian dollars, although Canada claimed that the damage exceeds six million dollars [10].

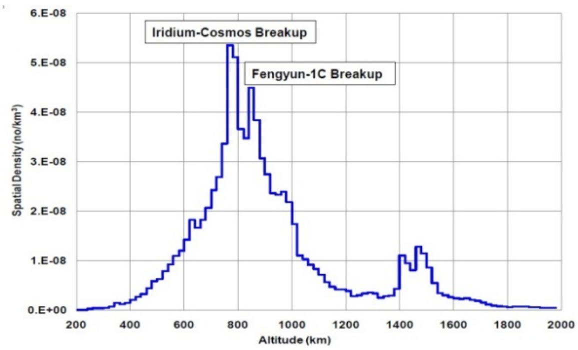


Fig. 2. Spatial density of LEO space debris by altitude. NASA 2011 Report to the United Nations Office for Outer Space Affairs

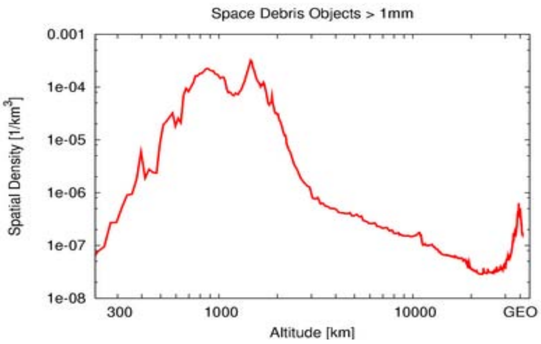


Fig. 3. Spatial density of space debris by altitude. ESA MASTER-2001 Report (before the 2009 collision events)

Radioactive materials

Radioactive materials, like uranium-235, can power a tiny satellite for years. They're more reliable than batteries and provide more energy than solar panels. During nuclear fission a heavy nucleus of a given atom is split into 2 fragments with a relatively equal atomic masses and the process is accompanied with release of energy. For insuring the power supply of satellites nuclear energy is produced from radioisotope thermoelectric generators (RTG). Nuclear energy production requires larger volume compared to the use of conventional batteries, however it do not requires so large surface as solar panels. It is accepted that nuclear energy for the purposes of satellites is unlimited, as it will be available longtime after the satellite becomes unusable due to other reasons.

Nuclear powered satellites however, may cause problems at the end of their lifetime. It was reported at the Fourth European Conference on Space Debris, held in Darmstad (Germany), that the space junk includes about a ton of radioactive waste from non-functioning reactors, supplying power to satellites, launched into orbit between 1967 and 1988.

The danger from the use of nuclear energy for powering satellites in near Earth orbit is due to the fact that during the lowering of the orbit and the falling down of the satellite, a treat exist for spreading radioactive particles over the whole Earth. Another danger for radioactive contamination is the case of accident with the rocket holding the satellite, before its propulsion to the designated orbit. Such cases are registered at the beginning of the satellite's propulsion when for example a Russian nuclear powered satellite crashed over Canada and contaminated the area with radioactive particles.

The Soviet program using a spacecraft equipped with a nuclear-powered radar started operations in 1967. There were five serious accidents from 33 missions in total. Two nuclear reactors crashed back to Earth from orbit. The nuclear reactor is powered by fuel assembly consisted of 37 cylindrical fuel elements with 31.1 kg of 90% enriched uranium (highly enriched uranium). Almost half of the Russian satellites powered by reactors lost radioactive reactor coolant during the ejection of the nuclear fuel.

The United States has launched 22 missions with nuclear power sources. US satellites use plutonium-238 in deep space missions for a power-generating source. Three accidents have occurred, one resulting in release of radioactive materials. In addition one experimental space reactor was launched in 1965. It is still in orbit.

The last satellite containing a nuclear power source was launched in 1988. As a result of termination of the activity of the satellites launched until 1988, tens of radioisotope thermoelectric generators, nuclear reactor fuel cores and nuclear reactors are still in orbit around the Earth below 1700 km from the ground.

Among the most important accidents involving nuclear powered space crafts are 6 accidents with Russian space vehicles and 3 with American ones. All of them include spread of nuclear materials (Uranium-235, Uranium-238 and Plutonium-238) into the environment.

With the aim to protect human health from radioactive contamination from falling to the Earth nuclear powered satellites, most of them were retired into orbits of between 700 and 1500 kilometers above the Earth. These orbits are considered to be stable and the satellites are expected to remain there for hundreds of years as their radioactivity decays. These orbits do not prevent them from collisions with other space bodies. If any of these nuclear-reactor-powered satellites collide with another object in space, or suddenly crash to the ground, they could release radioactivity.

There are plans to build nuclear reactors to power also rocket engines for propulsion of satellites, flights to Mars or for deep space investigations. It is assumed that nuclear energy is usable for satellites foreseen for deep space investigations, as they may move away sufficiently far from the Sun using solar panels and then to switch to nuclear power, which will power them enough longtime during their travel through the space. Nuclear power sources are assumed to be very efficient, durable and cheap for the purposes of space research.

Power Supply Technology

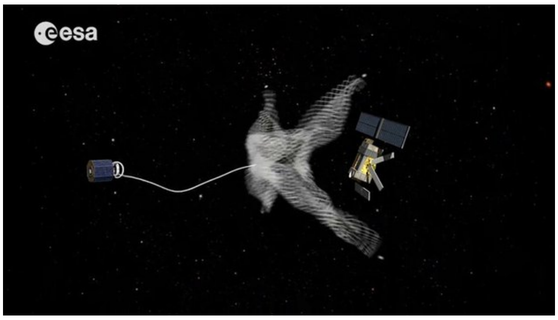
Satellites consume electricity to serve their purpose and one possible power source is solar panel technology. Nuclear energy is also a possibility as it does not require such a large surface like solar panels do. For the supply of satellites, nuclear energy is produced by radioisotope thermoelectric generators. It is assumed that this power option is unlimited for the needs of satellites, as it will be available even after the satellite becomes unusable. The danger of using nuclear energy in LEO satellites stems from emergency cases such as a satellite falling back to Earth, which is likely to cause nuclear contamination. Such is the Kosmos 954 case.

It is assumed that nuclear energy is usable in space exploration satellites to power them for a long period of time on their journey into outer space. Nuclear sources of energy are considered to be very effective and affordable for the needs of space research.

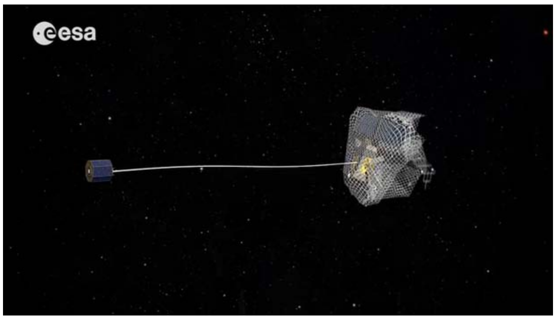
Space waste cleanup project

In 2011 United Nations Committee on the Peaceful Uses of Outer Space agreed that the problem concerning space debris has to be solved and it is necessary to combine forces and work in this direction [5]. International rules recommend owners to remove debris from LEO 25 years after a mission is completed. According to European Space Agency data only 60 % of the missions fulfill the recommendation. According to experts from the Japan Aerospace Exploration Agency, over 100 objects should be removed in the next 5 years to prevent the spread of new fragments resulting from collisions [11].

The European Space Agency has designed a mission called e.Deorbit scheduled for the year of 2023 [11]. The project is a result of the necessity for removing large objects from LEO. The most likely target of e.Deorbit will be the 26 meters Environmental Satellite (Envisat), which has been inactive since 2012. Envisat cannot deorbit naturally in the next 150 years, and if an object heavier than just 10 kilograms collides into the satellite, both will disintegrate into thousands of space debris [12]. At present the mission plans to use either a net or a robotic arm [11]. The robotic arm option includes a spacecraft equipped with mechanical appendages which would capture a holding point and the target with a clamping mechanism. The other option includes a spacecraft equipped with a large net which could entangle the target [1]. Both options end up with the spacecraft deorbiting itself and burning along with the target in the atmosphere [12].



a)



b)

Fig. 4. Capturing the large target – a). Artist’s conception of e.Deorbit mission – b) [11, 13]

Conclusion

The Kessler syndrome depends on objects’ size and density, and even though the amount of space debris is huge, many years are required to oversaturate the low Earth orbit [7]. However preventive measures ought to be taken. The removal of space waste undoubtedly would be expensive, but it would also be a good investment and a great prevention of collisions and catastrophes which could possibly make LEO impassible. At some point it might turn out that space is unreachable for humanity, maybe not forever, but for a very long period of time.

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