New Soyuz-Apollo from space debris

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Space debris can lead to a global catastrophe as a result of the instantaneous loss of all communication on Earth. This can be avoided only as a result of cooperation between Russia, the United States and China.

In mid-August, Jonathan McDowell of the Center for Astrophysics at Harvard, after analyzing refined data in the catalog of Space-Track.org made a sensational statement: "Note for object 48078, 1996-051Q: Collided with a satellite." Earlier, in March of this year, there was a report that the Chinese satellite Yunhai 1-02 was destroyed, and Jonathan McDowell came to the conclusion that the reason for this was a space fragment called SATCAT 48078. This is a fragment of the body of the Russian missile "Zenit-2" (SL-16), launched in 1996.

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This event is also notable for the fact that Zenit-2, which is listed in the Satellite Catalog Number catalog as SATCAT 24298, is included in the list of the 50 most dangerous objects of space debris according to the "rating" given in the article "Identifying the 50 Statistically-Most-Concerning Derelict Objects in LEO". The article by 19 scientists from around the world, including three authors from Russia, was prepared for a report at the annual congress of the International Astronautical Federation in 2020, which was postponed to October this year and will be held in Dubai.

To avoid possible accusations of bias even a large group of scientists, the "List of 50" from the article by Darren McKythe (for simplicity, let's call the study by the name of the first author) can be compared with another - called "List of 70". Thirty-one objects from the first list are also categorized as the most dangerous objects of space debris in the study published this year by scientists from the Polytechnic University of Milan, "A comprehensive ranking framework for active debris removal missions candidates". The methods of Italian scientists are somewhat different from those given in McKnith's article, but the estimates for the 19 most dangerous candidates, and among them the object SATCAT 24298 ("Zenit-2"), in both articles coincide.

Kill Tesla with a tennis ball

To understand what "space debris" is, which in English is often referred to by one word debris, you can turn to the works of Russian scientists who are actively engaged in this problem. The answer can be found in the

materials of the All-Russian Conference "Space Debris: Fundamental and Practical Aspects of the Threat", which was held in April 2019 at the Space Research Institute of the Russian Academy of Sciences.

- Chuck Dickey, Fellow of the International Institute of Space Law, Deputy General Counsel of Lockheed Martin Space System Company (1981–2019)

FROM CHUCK DICKIE'S PERSONAL ARCHIVE

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FROM THE PERSONAL ARCHIVE OF VALENTIN UVAROV

Director of the Institute of Astronomy of the Russian Academy of Sciences Boris Shustov in his article "On fundamental research on the problem of space debris" gives the following definition: "Space debris (CM) usually means all unused artificial objects, mainly in near-Earth space (OKP). These include failed satellites, spent rocket stages, as well as fragments formed during their decay and collisions. " The Russian scientist notes that all these objects are a dangerous factor in influencing functioning spacecraft, and the main danger of space debris is the threat of collisions with working vehicles, as a result of which the latter can fail. According to Boris Shustov, another danger is associated with the fall on our planet of large man-made objects that have descended from orbit. Especially resonant are the falls, accompanied by the threat of chemical damage to large areas by highly toxic fuel of missile stages, as well as the fall of objects with nuclear energy sources on board.

Near-Earth space (OKP) is a space limited by a sphere, the radius of which is equal to the average distance from the Earth to the Moon (380 thousand km).As for the "low Earth orbit" (LEO), this is the outer space around the Earth from 100 to 2000 km above the surface of our planet. At all altitudes in the OKP there are 130 million objects measuring 0.1-1 cm, and if such a piece of debris gets into the spacecraft, it can cause serious damage. Twenty million of these "peas" are in low Earth orbit at altitudes up to 2000 km.

The number of objects measuring 1-10 cm at all altitudes is 900 thousand, and on LEO - 500 thousand, each of which can cause serious damage to the spacecraft or destroy it. For clarity, the following comparison can be made. Let's say a small piece of space debris the size of a tennis ball meets a Tesla Roadster on its way, and as a result, a car flying about its business will not receive a dent or a through hole, but will be completely destroyed.

Finally, each of the objects larger than 10 cm (a total of 34 thousand objects, of which 23 thousand are on LEO) in a collision is guaranteed to destroy the spacecraft.

All this space debris was the result of more than 5,000 rocket launches, which since the beginning of the space age have launched almost 50,000 vehicles for various purposes into orbit. Of that number, roughly 5,000 continue to fly, and more and more new ones are being added to them, primarily through the deployment of low-orbit constellations such as OneWeb and Starlink.

What can certain events lead to as a result of the destruction or collision of objects in space? In 2009, two active spacecraft, Kosmos-2251 and Iridium-33, were completely destroyed as a result of the collision. The explosion in August 2018 of the Atlas Centaur 2014-055B unit dramatically increased the number of dangerous objects in geotransfer orbits. India's deliberate destruction in March 2019 of its Microsat-R satellite weighing about 700 kg in an orbit 350 km high led to the appearance of more than a hundred pieces of debris. An accident in 2019 in the geostationary orbit of the Intelsat-29e space system as a result of damage to the propulsion system led to the disabling of a large satellite weighing more than six tons.

The situation with space debris can be compared to a time bomb, and an example of this is the destruction in 2018 in geostationary orbit of the upper stage of the Transtage (SATCAT 3692) of the American Titan IIIC launch vehicle. The event took place almost 50 years after the launch of the rocket in February 1969, as a result of which 183 new fragments of space debris were discovered.

However, the most terrible thing that can lead to one separate collision in space of working or completed the period of active existence of spacecraft, was called "Kessler syndrome (effect) - theoretically possible such a development of events in Earth orbit, when as a result of the collision of two objects will begin a chain reaction and mass destruction of spacecraft. In turn, this can lead to a man-made catastrophe on the planet, taking into account that with the help of target equipment communication and navigation, monitoring of emergency situations, and in general, the life support of all mankind may be threatened.

Everyone agrees, and the garbage is still there.

Advances in the study of space debris and its impact on the space environment and space activities have advanced significantly in recent decades, starting with a study conducted in 1978 by NASA scientist Donald Kessler. Scientific research has led the space community to realize the importance of sustainable space operations and the exploitation of space resources. In 2002, the Inter-Agency Committee on Space Debris (IADC) put forward proposals and developed guidelines that would help prevent future debris from entering orbit. A number of studies have highlighted the need for an active strategy to control the space debris situation. These works show that approximately five large objects need to be removed per year to avoid a steady increase in the amount of debris due to further collisions and explosions.

With more and more launches in the world, this need is becoming more urgent. A number of countries are introducing Active Debris Remediation (ADR) technologies. Work under the e.Deorbit mission, carried out during the Clean Space Initiative, aims to deorbit the large Earth observation satellite ENVISAT. In 2020, the European Space Agency (ESA) commissioned the first mission to actively remove space debris under the Clean Space program to remove the VESPA adapter from orbit. In Japan, several projects are being implemented to develop technologies for various ADR missions. Russia's plans in this direction "Roscosmos" shared in the media in the spring of this year. Active space debris disposal concepts are also being developed as a paid service for large groupings in space, including for the benefit of commercial organizations.

As the International Conference on Space Exploration Conference (GLEX-2021), held in St. Petersburg on June 14-18, showed, the concern of the expert community with this problem is growing. This trend was reflected in the fact that within the framework of the technical session "International cooperation in space exploration", a number of presentations were devoted to the topic of space debris, this issue was raised in the speeches of the congress participants at the plenary sessions.

Not without questions that were asked during a video conference held at the forum with the participation of Roscosmos Director General Dmitry Rogozin and NASA head Bill Nelson.

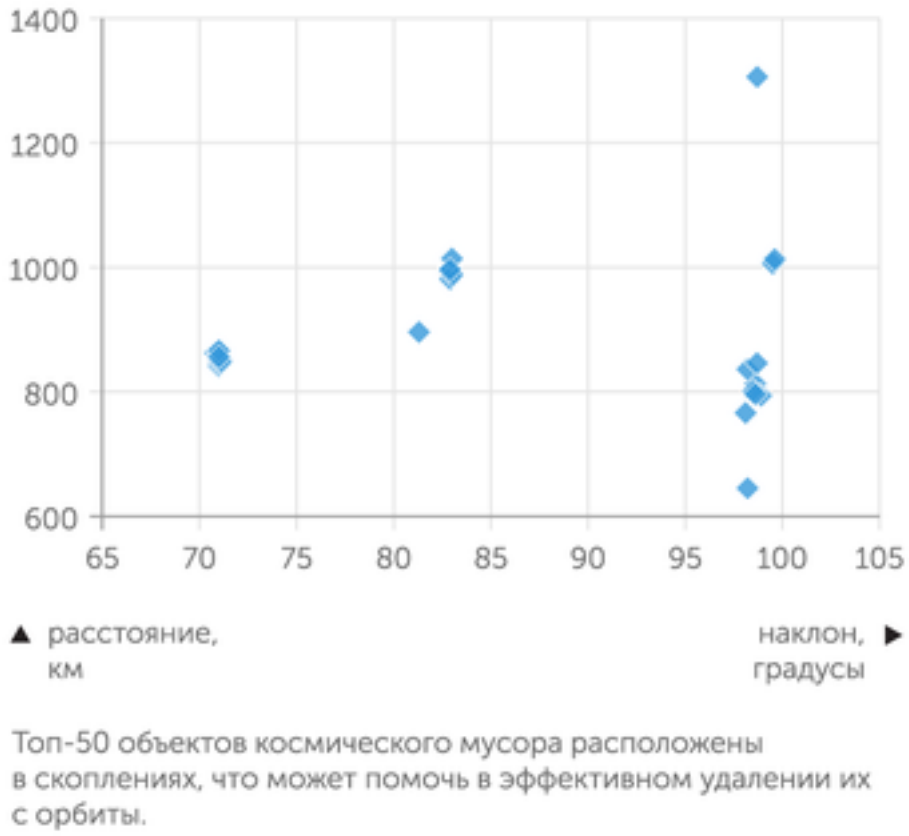
Nelson urged countries to take steps to litter less in space. That concern came in the context of China's Long March-5B (CZ-5B) launch vehicle when NASA said in early May that China's practices did not meet space debris standards.

Dmitry Rogozin agreed with his colleague about the severity of the problem, but noted that Roscosmos, NASA and other major partners could specifically gather to talk about the legal and technical aspects of the case.

The questions "what to do?" and "who is to blame?" are periodically heard at different international venues in various combinations and contexts. In one of the reports at GLEX-2021, two options for estimating the "contributions" of the main countries littering in space were given: China - 40%, the United States - 25.5%, Russia - 25.5%, other countries - 7%; in the second case, the ratio was as follows: Russia - 39.7%, the United States - 28.9%, China - 22.8%. Unfortunately, the methods of counting were not disclosed, but the main thing is that the composition of the main "troika" does not cause any doubts.

In this article, we turn to the studies that resulted in the "List of 50" and "List 70". First, in these articles it is not so much about the importance of the problem as a whole, but about highlighting the most dangerous objects that can provoke the same "Kessler effect". Secondly, the articles provide the methods by which the calculations were carried out. Thirdly, despite the fact that both teams used different methods, their opinions converged on 31 objects, and 19 objects included in the "top list" are fragments of the hulls of Soviet or Russian launch vehicles.

Graph 1**50 of the most dangerous objects of space debris**



Identifying the 50 Statistically-Most-Concerning Derelict Objects in LEO, 71st International Astronautical Congress (IAC) – The CyberSpace Edition, Dubai, UAE, October 2020

These articles do not draw conclusions or make recommendations on how to organize the process of active garbage disposal, and their topic is the scientific justification for the choice of priority goals.

Italian scientists in the above-mentioned article draw attention to the fact that while the necessary steps are being taken to develop technologies for active garbage disposal, two other problems remain unresolved. The implementation of the systematic approach is slowed down by economic issues and political problems associated with approaching objects belonging to different countries.

McKnith's article identifies three main problems on which further progress depends: 1) the cost of garbage disposal operations is difficult to calculate, and they are probably quite expensive, and their feasibility has not been proven; 2) the issues of ownership and the right of physical influence and disposal of objects registered in other states are not defined and are potentially controversial; 3) objects that should first of all be removed are not defined at the level of a multinational forum in order to improve the security of space and ensure the long-term sustainability of space activities.

In their article, the multinational group of scientists notes that they are focusing on a third problem: prioritizing a list of junk sites for disposal. They also expressed the hope that this would encourage relevant organizations to develop space debris disposal options that were effective and economicly sound, which in turn would encourage Governments to finance such projects as soon as possible.

At the same time, the governments of individual countries are unlikely to be able to unilaterally begin such work. All unilateral plans are economically ineffective in light of the market realities they may face, and will not lead to a significant reduction in overall risk unless all governments that own "shares" in space act independently and simultaneously, which is highly unlikely. Moreover, unilateral and non-systemic actions of countries in this direction will have undesirable consequences both in political terms and in terms of consequences for the national security of individual countries.

e.Deorbit's Clean Space Initiative mission to deorbit the large Earth observation satellite ENVISAT so that it burns up in dense layers of the atmosphere

Space Debris Collection Cooperative

We see that there is a consensus on the potential threat of space debris, the proximity of opinions at the level of the scientific community regarding the most dangerous objects of this debris and the understanding that the most "interested" countries are the United States, Russia, China and the European Union. Why do we say "interested countries" rather than follow the path of defining some kind of proportional responsibility index? Significant risk reduction requires the removal of russian-origin objects of large mass on LEO, but only a cooperative approach involving cost-sharing is the only viable way. In other words, why should Russia pay

significantly more money than others to remove proportionately more debris simply so that the U.S., China, Europe, and other space-related activities can take advantage of future opportunities? If this path is followed, other countries will benefit disproportionately.

In the situation with space debris, the requirements for a "proportional" contribution to the cleaning of outer space of one State can be compared with a situation where municipal authorities for some reason cannot organize the removal of garbage from one of the streets in the settlement. In this case, it is foolish to demand from one of the families in which there are more children than in the others that this family would pay based on the number and age of the children when paying for the services of the contractor. Smart neighbors in this case, so as not to drown in garbage and quickly solve the problem, are likely to throw off equally.

The Chinese satellite Yunhai 1-02 was destroyed as a result of a collision with the wreckage of the Zenit-2 rocket, launched in 1996

Our point of view: Russia cannot be blamed for the fact that in the 1970s and 1990s it conducted a large number of missile launches is based on the following arguments:

1) everyone did it then, so it was an international custom that cannot be legally challenged;

2) the commercial use of space later moved to LEO and should accept the space environment as it is, so it is necessary to work in space, providing for evasion of fragments of missiles;

3) ADR is about eliminating risks, not liability for collisions. In practice, any ADR formula based on the principle of "clean yourself up at your own expense" will fail because Russia will put forward the first two

arguments mentioned above and can simply refuse to clean up space, as well as responsibility for any collision. Moreover, the world cannot force Russia to do so, even if there are collisions with its objects in space, because points 1) and 2) will be pushed forward as arguments and, probably, Russia will prevail.

To clarify that the solution to the problem of space debris cannot be based on the principle of proportional responsibility, the following analogies can be drawn. As you know, gunpowder was invented in China. However, it does not occur to anyone to assign responsibility to the country-inventor for the millions of human lives that humanity has lost as a result of the use of the substance for fireworks. An example of solidarity mechanisms would be the International Committee of the Red Cross. While the warring parties cannot stop in their efforts to inflict as much damage as possible on the other side, the Red Cross, a neutral and independent organization, is engaged in a purely humanitarian mission to protect the lives and dignity of victims of war and internal violence and to assist the victims.

Table**Five types of objects that need to be urgently removed from orbit**

	Количество	Наклон (градусы)	Расстояние (по длинной полуоси; км)	Типичная масса (кг)	Типы объектов
1	23	70–71	7193–7281	Более 9000	18 «Зенит-2 (вторая ступень), 3 Thor-Agena (вторая ступень) и 2 «Протон» (четвертая ступень)
2	11	74	7122–7152	1435	«Космос-3М» (вторая ступень)
3	28	81	7211–7262	1100	«Восток-2М» (вторая ступень)
4	52	83	7318–7358	1443	«Космос-3М» (вторая ступень) и «Циклон-3» (третья ступень)
5	46	97–100	6973–7500	от 820 до 9000 (чаще всего 4000)	Другие

Source: Identifying the 50 Statistically-Most-Concerning Derelict Objects in LEO, 71st International Astronautical Congress (IAC) — The CyberSpace Edition, Dubai, UAE, October 2020

Plastic bottles are made from polyethylene terephthalate (PET), which was produced in the early 1940s in England. Mass production began in the 1970s, when DuPont decided to use PET to make bottles into which various drinks would be bottled. The bottles that appeared immediately attracted such large corporations as Coca-Cola and PepsiCo. And after a little more time, almost all manufacturers of carbonated and still drinks switched to their bottling in plastic bottles. According to UN environmentalists, about 13 million tons of plastic waste enter the ocean every year. Hardly anyone can charge Coca-Cola or PepsiCo, which derives revenue from beverage sales around the world, the highest cost of cleaning up the planet. But Greenpeace tried to find a common denominator and equalize the contributions of different companies to clean up the planet from garbage.

These analogies may be relevant both in terms of the potential danger and the general humanities of the space debris problem. The comparison with the Soyuz-Apollo project is also quite appropriate, given that it arose not from the desire of countries to make friends, but from purely pragmatic interests - to provide additional opportunities in space. No one denies that then cooperation in this project had an additional positive effect in the form of easing international tensions.

Source: PHOTO FROM ITAR-TASS DOSSIER 10.32

Today, the only difference is that in the conditions of a sharp change in the quantitative and qualitative composition of the subjects conducting space activities, the super-heavy inertia in the delivery of state interests into space should be complemented by the possibilities of rapid response from business, supported by the competencies of the expert community.

Thus, in our opinion, the best formula for allocating ADR costs is not based on an assessment of the harm already done, but on an assessment of future benefits. More precisely, on the economic value of the missed opportunity as a result of future collisions that will make the cost and risk of working in space higher and more dangerous, rather than on potential fault. By this criterion, the U.S., Europe, China, and Russia together should make the greatest contribution. Based on the principle of co-financing based on future opportunities, rather than on the largest number of hazardous facilities, the formula is better proportional.

We understand that this formula can be the target of criticism, since no country wants to pay (levy taxes on its citizens to pay) to solve the problems of another country. But this formula solves many common problems, moreover, only it has a chance of success.

There are three types of cooperative models for ADR (see diagram). First, it is the path of public-private partnership. Within its framework, a private non-governmental organization can be involved for effective and transparent cooperation between the participating countries. Such a role is ready, for example, to take on the organization "Trusted mediator of three countries" (Three Country-Trusted Broker, TCTB), which is headed by one of the authors of this article Chuck Dickey.

Secondly, it is a way to create a mediator with the participation of intergovernmental organizations (see "Who can unite the United States, China and Russia"). Third, within the framework of bilateral agreements, which seems to be the least sustainable construct.

All models of cooperation, whether public-private partnerships or purely public ones, achieve a certain degree of economic efficiency by generally reducing risks while reducing overall costs: cooperation allows for multi-purpose missions without separating space debris by national origin.

As we can see, there is no real alternative to the cooperative model of solving the problem of space debris, but it is necessary to choose the most effective of them from the point of view of the participating countries, and this should be done as soon as possible. ADR planning will take several years before the first mission becomes possible. Missions will last decades before significant risk reduction is achieved, and joint stakeholder planning has not even begun.

ADR missions will be costly, and it will take time to negotiate costs, but the cost of planning missions is much less expensive. Therefore, it is possible and extremely important to start effective and trusting cooperation right now in order to have time to clear space of debris before the fatal collision that can lead to Kessler syndrome and a global man-made catastrophe.

Other options for cooperative problem solving

Existing international organizations and some initiatives to create a specialized organization can be considered as a platform for a cooperative solution to the problem of space debris.

The International Civil Aviation Organization (ICAO) was established in 1944 when 52 countries signed the Chicago Convention on International Civil Aviation. Today, it has 193 member Governments that elect 36 members three times a year to develop and adopt standards and recommended practices relating to air navigation, its infrastructure, flight inspection, prevention of unlawful interference and facilitation of border crossing procedures for international civil aviation.

Intelsat Corporation began operations in 1964 as IGO (International Telecommunications Satellite Organization), created from seven countries to manage a fleet of telecommunications satellites providing international broadcasting services. Its charter provided for commercial participation, allowing private organizations from participating States to act in the interests of their countries.

International Debris Removal Satellite (INREMSAT). In 2020, McGill University proposed the creation of an MGO based on the INTELSAT model, but specifically to solve the problem of space debris. Under the INREMSAT proposal, each participating Government should agree (through a treaty or agreement) to remove on a commercial basis a number of existing large space debris ("dead" satellites and spent upper stages) created as a result of their national space activities. It is proposed to finance these operations through national taxes on "space debris collection" levied on end-users of space commercial services in the country itself.

The Inter-Agency Space Debris Coordination Committee (IADC), established in 1993, is an intergovernmental forum for coordinating research activities related to orbital debris. It includes space agencies from Italy, France, China, Canada, Germany, India, Japan, South Korea, the United States, Russia, Ukraine, the United Kingdom, and ESA. Its main purpose is the exchange of information between space debris research member space agencies.

The International Maritime Organization (IMO), a specialized agency in the United Nations, is responsible for regulating navigation on the high seas. It was established through the ratification of the multilateral convention on the International Maritime Organization, and today has 174 member States. Like ICAO for global airspace, IMO views maritime space in the context of the "global commons" in a similar way to outer space.

The International Telecommunication Union (ITU) is a specialized agency of the United Nations and establishes, among other things, general principles for the use at the international level of the radio frequency spectrum and the orbital frequency resource of spacecraft in geostationary orbit.

Finally, any number of cooperating Governments may decide to establish an entirely new international organization dedicated solely to the disposal of orbital debris. However, here the restrictions imposed by the public law nature of such organizations come into force, which, in turn, may lead to an increase in the time frame for solving the problem.