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European Space Traffic Management System: Micrometeoroids and space debris as a possible threat for future missions

Alexandra Adamišinová

MENDELU Working Papers in Business and Economics
Research Centre
Faculty of Business and Economics
Mendel University in Brno
Zemědělská 1, 613 00 Brno
Czech Republic
http://vyzc.pef.mendelu.cz/en
+420 545 132 605

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Abstract

Alexandra Adamišinová: **European Space Traffic Management System: Micrometeoroids and space debris as a possible threat for future missions**

The article offers a basic overview about space debris and European approach towards it. At first, the author briefly describes current space situation, then sums up space debris definition and brings the last status of numbers of space remains. The article mentions Kessler syndrome which deals with the question of sustainable space for future generations and focus on necessary steps that must be taken. The article summarizing different kinds of guidelines, law implementation and conditions under which space operations can take place.

Key words

Space debris, European Space Policy, Space Traffic Management System

JEL: F68, I28, O38

Contacts

Alexandra Adamišinová, Department of Economics, Faculty of Business and Economics, Mendel university in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: xadamisi@mendelu.cz.

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Introduction

Since the 50's space industry has dramatically changed. The news informs us about successful launching or landing of a space rocket, and other new incredible achievements. When we mention space, it is not only successes linked with NASA. Today we associate it with commercial companies, such as SpaceX or Blue Origin. Every day we are closer to a possibility populate another planet of the solar system. We are witnesses of overtaking the space industry by private companies, and we experience impressive sequence of space accomplishments than ever before. Private companies push the possibility frontier forward, and we watch them while they fulfill their ambitious plans. The space industry is moving forward like never before.

Space industry, as we know it today, is completely different than the one from the era of the Cold War. The space is not just about two countries and state companies. It is not just a politic game, it means economy, services, data, progress, and of course it represents our daily possibilities. In May 2020, for the first time, commercial orbital crew flew to the space (Mann, 2020). It belongs to the most watched online event on the Internet (Wall, 2020), but it still did not break the view record of Apollo 11. Interest in space rise rapidly among population and along with society is more focusing on the overall results. The attractiveness of the space bring higher invests from governments and also from private subjects.

The new technologies enable us various possibilities that we use every day. Increasing interest in space activities from the view of countries or enlarging portfolio of private companies and start-ups, rapidly helped the space evolution (Datta, 2017). The costs of launches decreased (Zimmerman, 2017), rockets became reusable (Weinzierl, 2018), and size of satellites minimize (Nightingale and col., 2015). Many industries proved us that private companies in certain conditions can boost whole industry (Chirwa, 2004), (Popov and col., 2012). But the increasing shares of private companies, also brings externalities that may not be visible for us. Every launch to the space, produce debris which remain on orbit. Those remains pose risks for satellites, rockets, and others space objects and dramatically speaking, they may endanger also lives. An eventual collision may cause huge loss. Space players differ with their approach to space exploitation and exploration. While the USA consider space defense as one of the top priority space topics (de Montluc & Bonniot, 2012), Europe lacks in those strategic interests.

At first, in the article we define space debris and what does it mean sustainable usage of the space. After that we have look at European perspective and its policy. The article will help the author to have a better insight to European approach towards space policy, what will be helpful for suitable implementation of some steps which can be taken from foreign policies.

1 Space Debris Definition

One may ask, why tracking remains in the space should be important when the humanity still does not have even an idea how enormously big the space is. The unlimited airspace gives us endless possibilities. So, is there a slightly chance that a “space junk” can somehow endangers us? NASA (2021) describes space debris and distinguishes them from the orbital debris: “*Space debris encompasses both natural meteoroid and artificial (human-made) orbital debris. Meteoroids are in orbit about the sun, while most artificial debris is in orbit about the Earth (hence the term “orbital” debris). Orbital debris is any human-made object in orbit about the Earth that no longer serves a useful function. Such debris includes nonfunctional spacecraft, abandoned launch vehicle stages, mission-related debris, and fragmentation debris.*”. Space objects are tracked by the Department of Defense’s global Space Surveillance Network (SSN) sensors. Even though, there is the institution which tracks “space junk” on the Earth orbit, it is not possible to identify every flying space object, which can be considered as a threat.

Countries which operate in the space, proceeded to various space situational awareness programs. The one of the programs is Geosynchronous Space Situational Awareness Program (GSSAP) (Spaceforce, 2017). Operating satellites allow more accurate tracking and characterizing of the space objects. The satellites communicate information through the world-wide Air Force Satellite Control Network (AFSCN). Tracked objects are registered in their catalogue, which covers objects larger than about 5-10 cm in low-Earth orbit (LEO) and sizes from 30 cm to 1 m at geostationary (GEO) altitudes.

By the January 2021, 4550 satellites were orbiting the Earth, from which 3790 were at LEO (UCS, 2021). Along with more than 28 000 space remains are tracked by US Space Surveillance Network, and other thousands of them are unidentified.

Table 1. Space debris by the numbers (data updated on the 5th of January 2022)

Number of rocket launches since the start of the space age in 1957	About 6 170 (excluding failures)
Number of satellites these rocket launches have placed into Earth orbit	About 12 450
Number of these still in space	About 7 840
Number of these still functioning	About 5 000
Number of debris objects regularly tracked by Space Surveillance Networks and maintained in their catalogue	About 30 630
Estimated number of break-ups, explosions, collisions, or anomalous events resulting in fragmentation	More than 630
Total mass of all space objects in Earth orbit	More than 9 800 tones
Number of debris objects estimated by statistical models to be in orbit	36 500 objects greater than 10 cm
	1 000 000 objects 1 – 10 cm
	million objects 1 mm – 1 cm

Source: https://sdup.esoc.esa.int/discosweb/statistics/Hammings point-of-view

2 Sustainable Usage of Space

Every space activity produces a footprint, an externality in the outer space. With space activities we can discuss about satellite sustainability footprint and orbital capacity (Palmroth & col., 2021). The existence of rapidly increasing objects such as space debris in outer space, shows study for ESA provided by Frey and Lemmens from 2017. Flying space remains endanger future missions and that is why Inter-Agency Space Debris Coordination Committee (IADC) protects region of the Low Earth Orbit (LEO) and the Geostationary Orbit (GEO). Almost 18 500 objects were observed at least once in 2016. ESA definition of object types in outer space in Table 1.

Table 2. Definition of object types which can be found in the outer space

Type	**Description**
PL	Payload
PM	Payload Mission Related Object
PD	Payload Debris
RB	Rocket Body
RM	Rocket Mission Related Object
RD	Rocket Debris
UI	Unidentified

Source: Frey and Lemmens, 2017

Table 3. Number of defined or undefined objects in the outer space to January 2017

	PL	**PM**	**PD**	**RB**	**RM**	**RD**	**UI**	**Total**
LEO	2300	113	5959	822	490	2474	72	12230
GEO	708	3	4	67	0	0	30	812

Source: Frey and Lemmens, 2017

The numbers of flying object are increasing during past decades. With the current space debris status, it is enormous likelihood of a collision. And every 7 years the probability will rapidly rise (Cai et al., 2022), (Duzellier et al., 2022).

To deal with a situation like this it is necessary to maintain a traffic management system. Current systems can track 20 000 debris and active satellites around 10 cm while they are orbiting on the LEO and from 30 to 50 cm on the GEO. Nonetheless, it represents just 0.02 % (Undseth, Jolly, Olivari, 2020) of all flying objects bigger than 1 mm. ESA (2019) estimates that number of flying objects in the outer space can be around 130 million. A closer look on MMOD (Micro-Meteoroid and Orbital Debris) impact onto a solar array can be founded in Krag et. al. (2017). Keeping long-term sustainability of the orbit means saved economies related with space activities and also lower damages which can cause fatal disfunctions of important connections. Will be the LEO still usable for future generations? That is the main question which represents Kessler syndrome. In other words, Kessler syndrome

(Drmola and Hubik, 2018), (Adilov, Alexander, & Cunningham, 2018) describes increasing risks of hinder human space missions due to rising amount of space junks.

3 European Background in Space Industry

Approach between particular European countries varies. In the last decades, we can observe while the USA space topics are no more just about political discussion, Europe still has not moved on more important economic discussions. On the other hand, almost every European country got involved into the space industry. It is becoming a solid political topic and politician begin to be aware of importance of this policy. The essence of the European Union is to unify various countries and create a greater influence in the world. With the same thought the European Space Agency (ESA) was established in the mid of 70's. Today, ESA has 22 members, when in 2015 Estonia and Hungary became the last members and in 2017, Slovenia became an ESA Associate Member State. Between ESA members there are different memberships in other important organizations such as NATO, EU, and EDA (European Defense Agency). Space activities bring along with questions about national security (Hoerber, Forganni, 2020). It is relevant to say that European Space policy has a its place among others European policies, and it is necessary to boost this segment. Solutions which we can gain with proper EU space program, will ensure us for future advantages, and strengthen European position and integration. An opportunity for ESA consists in proactive approach like dealing with space environment, space traffic management and debris management.

The most of European members have a positive attitude toward space activities, and since 2013 (Machay and Pochylá, 2013) they have improved their expenditures on space exploration and exploitation. Results show that countries strengthened their positions, and they focus more on long-term goals. Cooperation between countries embedded possibilities for smaller countries and the industry opened for startups which cannot be competitive enough.

The first kick-off of discussion about policy perspectives of a sustainable use of space in Europe has started with First Sustainable Space Workshop in Finland in January 2019[1]. Several different fields represented their point of view on this topic. The whole session focused on the issue of space debris and sustainability of the outer space. LEO orbits are becoming especially crowded. Every launch creates at least one debris object. Space pollution represents also additional costs to satellite protection or mitigation. It was estimated that those costs represent from 5-10 % of a total cost

[1] https://spaceworkshop.fi/2019.html

considering GEO missions. Missions operated on LEO require even higher protection costs (Undseth, Jolly, Olivari, 2020).

3.1 Space Security Policy in Europe

When we talk about space matters, we should imagine space as a market. The market that should be available for private companies. To make it run, we need to stick with some simple conditions such as a legal framework (Ziemblicki, Oralova, 2021), supporting industry competition, foster industry development. In the merit of the space industry, protection of the space market is not meant as intention interventions to protect state operators, but as physical protection of space missions. Those missions can be endangered by space debris and an unorganized space traffic.

To prevent ineligible collisions, we should focus on policy that will encourage private or state companies to overtake possible collisions and create an environment to cut space externalities made by every space operator. Space traffic control (Slann, 2014) is indispensable part of the sustainable space. Policy makers (ref. e.g., Gustetic et al., 2018) stand in front of three possible ways how to deal with space debris.

Table 4. Debris mitigation measures

Debris limitation	it is expected to minimize space debris and prevent collisions by carry out post-mission disposals
Active debris removal	set a minimum removal of five objects (might be more)
Space situational awareness	networks of terrestrial and space-based sensors that monitor space environment, track objects, and warn operators

Source: OECD, 2020, s. 36, available at: https://read.oecd-ilibrary.org/science-and-technology/space-sustainability_a339de43-en#page36

What are instruments how to protect space and achieve its sustainability for the next generations? OECD (2017) suggested several tools that can be easily applied on national and international frameworks. OECD (2020, s. 38) distinguishes six different categories, and those are: environmentally related taxes; fees, and charges for polluting; tradable permits; deposit-refund system; subsidies; voluntary approaches. Suggested policies require a strong political background and agreement of views (Pace, 2014).

The relationship between the EU and ESA can be still marked as insufficient in some ways. In many questions is needed a greater power than ESA has in relation to space activities and a greater involvement of EU. The appropriate boundary would create common space policy. Significant power used the European Commission during the Galileo project (Oikonomou, 2015). However, Hoerber (2018) assumes that it was one and the only time and there still remains space for necessary steps that must be taken by the EU and ESA to create a complex and functionate European Space Policy.

Europe systematically push its boundaries towards space implementation into national policy. Countries are still more and more involved into the space industry. The question of security space objects become essential for common discussion.

Space debris as a danger can be understand in two different time frames. Policy makers cannot work just with current situation, they must perceive them as a big future threat. Damages are in the range from economic losses to social losses. OECD (2020) defines current costs and impacts as debris related damage, satellite, and constellation design. Operations costs, orbit clearance costs and insurance costs. Potential future impacts are considered as more dangerous with more dramatic impact. For instance, they mention loss of unique applications and functionalities – loss of weather and earth observation satellites, live lost – threats of collision with ISS and other future stations, interrupted time series for earth science and climate research – may cause lower accuracy in weather and climate predictions, curbs economic growth and slowdown in investments - affection of LEO communication services and distributional effects. For example, the future perspective in the accessible Internet (provided by OneWeb) consists in group of satellites orbiting at LEO. Satellites orbiting at LEO can provide faster and cheaper Internet and they can help to decrease social gaps. Damage of those satellites can hold back developing countries from accessible Internet and drop-out can create enormous social and economic losses.

3.2 Inter-Agency Debris Coordination Commitee

The Inter-Agency Debris Coordination Committee (IADC) is an international agency dealing with space debris mitigation and its location updates. It is recognized as the technical authority on space debris. The primary purposes of the IADC (2019) are to exchange information about space debris position, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options. IADC divide its activities into 4 specific Working Groups. WG1 covers measurements, WG2 environment and database, WG3 protection and WG4 mitigation.

In 2001, IDAC has produced a set of mitigation guidelines, which were updated in 2007 (IDAC, 2007). IADC has conducted annual meetings to discuss research results in debris measurements, modelling, protection, and mitigation. In 2018, IDAC served as input to a set of space debris mitigation guidelines adopted by the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS) and approved a much wider set of 21 long-term sustainability guidelines (UN COUPUOS, 2010). The key recommendations from the guidelines are following:

- Limit debris release during normal operations, e.g.: Payloads and rocket bodies should be designed not to release debris during normal operation.
- Minimize the potential for break-ups during operational phases, e.g.: To minimize the potential for post-mission break-ups resulting in stored energy (in tanks, batteries, etc.).
- Limit the probability of accidental collisions.
- Refrain from intentional destruction and other harmful activities.
- Minimize the potential for post-mission break-ups resulting from stored energy, e.g.: Non-functional man-made objects should be cleared from the orbit. Limit the long-term presence of spacecraft and launch vehicle orbital stages in protected regions after the end of their missions.
- Preventing of in-orbit collision, e.g.: Future projects of missions should estimate and limit the probability of accidental collision with known objects during payload or object's orbital lifetime.

3.3 ESA tools

The Space Debris Office coordinates ESA's research activities in all major debris disciplines. It operates on international (European) level but also individually on national levels with space agencies in Italy, the UK, France, and Germany.

In the last decade, the principle of international and national recommendations and standards has continued to cumulate. To achieve successful implementation of those politics, is necessary to come with international consensus. As a good example ESA (2017) mentions the 2011 ISO standard 24113 which define key debris mitigation requirements. To apply this standard in every ESA project, they had to be at first adopted by the European Cooperation for Space Standardization. But only standardization is not enough. When we want to create an effective instrument, not just a definition of debris mitigation requirements, we need to transfer guidelines into actual regulations. While some countries have already taken this step and reflected space debris mitigation in their national regulations, worldwide implementation is still pending.

3.4 European Space Surveillance System

The European approach toward mitigation of space debris is still framing, Decades of challenges with increasing numbers of space pollution and along with increasing chance of collision, made ESA try numbers of possible solutions. Antisatellite test caused 25 % more debris (Weeden, 2010), what is not an applicable solution. The Chinese Antisatellite test which targeted on the Feng Yun-1C weather satellite on 11 January 2007, what has created approximately 3 400 trackable pieces, and another 2 300 are result of the first orbital collision between Iridium-33 and Cosmos-2251, on 10 February 2009 (ESA, 2017).

This project is now part of the preparatory program of the more comprehensive Space Situational Awareness (SSA) programme (Polkowska, 2020). The Space Debris Office supports related research activities on sensor design options, system performance requirements and catalogue maintenance concepts. The SSA (de Montluc, 2012), (Yu, 2012) provides us with advance warning of orbiting space objects that might cause collision. It is a helpful tool for determination and identification of the space environment and to keep the space area as much under control as it is possible. To create a validate system we must meet following conditions:

- At first, we need to know about the space debris environment as much as possible.
- We need to measure many debris of all possible sizes which enables us the radar called TIRA. The TIRA (Tracking and Imaging Radar) operates as tracking campaign, and besides that it detects debris and determines coarse orbit information (ESA, 2017).
- With appropriate model we need to characterize the debris environment and its evolution (MASTER, PROOF, DELTA, DISCOS). For example, MASTER (Meteoroid and Space Debris Terrestrial Environment Reference) is used as a debris and meteoroids risk assessment tool (ESA, 2017). It provides with us prediction of debris and meteoroid particle fluxes on user-defined target orbits and gives us predictions of the space environment for up to 50 years into the future. Another tool is called PROOF (Program for Radar and Optical Observation Forecasting), which validate model predictions by planning and simulating of radar and optical debris observation campaigns. With rising number of launches per year, the prediction of number of objects larger than 10 cm in LEO is dramatically rising.
- Mitigation as standard mission design must be matter of developed analysis so called DRAMA. The DRAMA (Debris Risk Assessment and Mitigation Analysis) is a software tool to verify the compliance of space missions with mitigation guidelines.

- Besides detecting rocket and other remains of all possible sizes and calculating possibility of collision, it is also necessary to have a protection plan. Some of the satellites are orbiting still unprotected. The solution can be either to protect satellites with protective fabric layers or moving them away from the impact direction. For example, the ISS is protected with two metal sheets, which have and effect of bulletproof vest.

4 Conclusion

The current space evolution could be unsustainable for future missions. The number of the space remains rapidly raises after every launch. Artificial orbital debris and meteoroids are tracked by the Department of Defence’s global Space Surveillance Network sensors, nonetheless, the number of tracked debris only represents 0.02 % of all flying objects. European steps to secure space missions consist in implementing meaningful policy to encourage debris limitation, active debris removal, and more efficient space situational awareness. ESA uses different tools, standards, and channels to provide a better space mitigation system, on the other hand still lacks coordination on national levels. While some countries implemented recommended guidelines and regulations on their national level, some of them did not. The whole inconsistency causes insufficient results and thus indirectly endangers future space missions.

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