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DOI: 10.35117/A_ENG_25_07_08_08

Security in Space

Abstract: The paper formulates the golden rules of space security. On this basis, the problem of security of objects orbiting the Earth was selected for detailed analysis: satellites moving in a crowded LEO (Low Earth Orbit) or slightly less exploited GEO (Geosynchronous Equatorial Orbit), and to a lesser extent MEO (Medium Earth Orbit). The growing importance of the title problem, the legal aspects, including attempts at restrictions under international and European law, the consequences of ASAT weapons, space debris tracking systems, as well as the concept of passive and active cleaning of Earth's orbits are shown. The signaled problem creates a new market space, and also requires binding legal regulations and intensive exploratory, design and, in the future, implementation work.

Keywords: space security, golden rules of space security, space debris, ASAT weapons, space surveillance and tracking systems, active debris removal, space law, Zero Debris Charter

Introduction

Issues of security in the broadest sense have accompanied mankind since the dawn of time. They have always been extremely important. They have undergone modifications over the centuries with the development of technologies used by man.

For several decades now, mankind has been trying to go beyond the Earth not only in terms of observation. Recent years have brought an acceleration in this field, which is also accompanied by the development and use of the most advanced technologies.

For years, the applied slogan "Safety First" known from classical technologies, has also penetrated the space area. Comparing with the well-known development of land transportation, it can be said that space is currently at an early stage of development in this regard, that is, the perception and definition of the first risks specific to the new field of science and technology and both in the civilian and military areas.

Theoretical considerations are accompanied by practical solutions that are being implemented quickly due to the significant costs associated with the space field [4].

The growing field requires the involvement of more groups dealing with security issues. It so happens that the development is taking place, so to speak, in parallel with the progress in IT areas and in this area the acceleration is significant and not only in the area of practice but also in didactics. The first specialized studies in cyber security in Poland were launched at the

Wrocław University of Technology in 2019 delivering so far many graduates both after the first and second degree. Thus, new knowledge of the broader IT area has been added to the classic knowledge of transportation security. Based on these observations, one may be tempted to formulate 10 Golden Rules of Space Security, which will be proposed in this article. In addition, among the many possible detailed issues, specific selected problems of space debris and Orbit congestion are discussed in more detail, as examples, showing some regulations important for future considerations.

The Golden Rules of Space Security.

Following the example of similar principles formulated in many areas of modern industry, e.g., refining, the following is a proposal for 10 Golden Rules for Space Safety modeled after other similar work [3], which can help improve safety at all stages of operations in the broader space area.

1. "Safety first" should be the basic principle used at all, and especially the earliest, stages of space technology activities. Information in this regard should be provided to all participants in space projects before any conceptual work begins.
2. Due to the early development of this area, it is recommended to use any safety experience from the analysis of events known from space development regardless of the country of origin of the technology.
3. Safety principles developed in other areas-for example, transportation, geology, modern chemistry, mechanical engineering, and electronics-should be used in the early stages of design work by the direct designers of individual systems.
4. The principles described and currently being developed in the field of cybersecurity should be treated with special attention because of the turbulent development of this area of knowledge.
5. Detailed analyses and guidelines should be prepared by independent specialists. It is unacceptable to put this area in the hands of inexperienced amateurs.
6. Given the high level of competition and growing international cooperation, the rules for the selection of networking partners should be given special attention by those responsible for the security of the business unit's projects.
7. The security of special projects should be under the special supervision of the most prominent practitioners in the field.
8. Knowledge and practices in the area of safety should be disseminated in closed groups clearly defined and verified and companies, including those participating as subcontractors, should also follow these or their own specially prepared safety rules based on their own knowledge and experience.
9. It is advisable to follow the development of space technology security issues at all possible conferences, meetings, presentations, events, demonstrations and the like.
10. Follow the activities and achievements of the National Committee on Cyber Security established on December 12, 2024 together with the National Committee on Space Technology. The Golden Rules given are not the only possible ones it is recommended that each organizational unit develop its own depending on its activities, encapsulate with examples and regulatory acts if they exist.

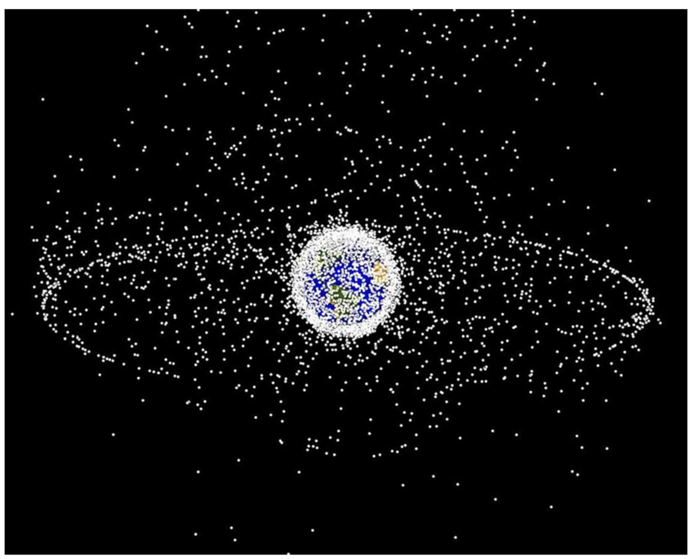
    Most broadly, such areas can be divided into:
    - security of the entire program implemented by the entity,
    - device security,
    - information security,
    - Netiquette or culture on the web,
    - security with space technology applications in other areas,
    - security related to the completion of the project.

It goes without saying that it is necessary to keep track of all activities at the national level, for example, through CERT Poland [17]. It is recommended that each business entity and each organizational unit and individually everyone involved in the development of space technology should have and follow appropriate security rules.

Among the many safety issues for further consideration, an example of a topic that is discussed at conferences and in space journalism and is of general interest has been selected. The remainder of this article will address the example problems of space debris and Orbit congestion as issues specific to space technology.

Space garbage

In addition to cosmic radiation, high temperature amplitude, or space weather (spaceweather), one of the main problems facing satellite operators is space debris. The space around the earth is becoming increasingly littered. According to NASA's Orbital Debris Program Office (ODPO), there are currently about 25,000 objects with diameters of more than 10 cm, 500,000 with diameters of 1-10 cm, and 100 mil. with diameters of 1 mm and less moving around the Earth. The so-called space debris does not occur uniformly. ODPO specialists say that most of the debris and other contaminants occur up to an altitude of 2,000 km., or in LEO orbit, with the largest concentration between 750 and 1,000 km. from Earth [9]. Space debris reaches velocities in orbit around the Earth that are close to the first space velocity, which consequently, in the event of a collision with a satellite or manned space station, can give kinetic energies several times greater than that of a rifle bullet, so their increasing number is a growing problem.



1. Visualization of GEO, MEO and clearly dense LEO orbits showing the population of objects around the Earth. Source: NASA ODPO

The increasingly noticeable littering of the Earth's orbits is due not only to the natural processes of satellite exploitation but also to their increasing number. Already on February 10, 2009, the first-ever collision occurred between two satellites: the US telecommunications satellite Iridium 33 and the defunct Russian reconnaissance satellite Kosmos 2251. The collision resulted in two "clouds" of debris, amounting to about 700 debris. Nowadays, an important role in the surge of new satellites is played especially by the "megaconstellations" like Starlink and OneWeb, which have been appearing for several years, and earlier by the process of miniaturization of satellite components and the significant cheapening of their cost allowing mass launches of CubeSats. In the middle of 2024, Starlink counted 5200 satellites, with a target of 12,000. According to the UN register kept by the office of the Committee on the Peaceful Uses of Outer Space, from 1957 to this moment (August 18, 2024), 18761 objects have been launched or sent into far space, 2890 of them in 2023 alone. For example, 30 years earlier, in 1993, only 108 objects were registered. Even if we take into account the fact that a significant percentage of them have already been deorbit (according to the register, 5316), 13445 objects remain in orbit [6] [16]. Thus, one can see a significant and increasing congestion of orbits. Only a small fraction of defunct satellites (101) have been pushed into so-called graveyard orbits located outside geostationary orbit [10].

The legal status of "space junk" is quite clear: under the 1967 Convention, states are obliged to keep a register of spacecraft (an obligation reaffirmed in the 1974 Treaty on the Registration of Space Objects). This also means that the sending state has jurisdiction over such objects (and their crew), and therefore it is the sending state that is responsible for the objects it sends out - and any debris they leave behind (including, among other things, drops of coolant frozen at low temperatures and even paint splatters). However, the actual problem with collecting space junk is primarily one of cost and technological problems: collecting it is many times more expensive than sending it.

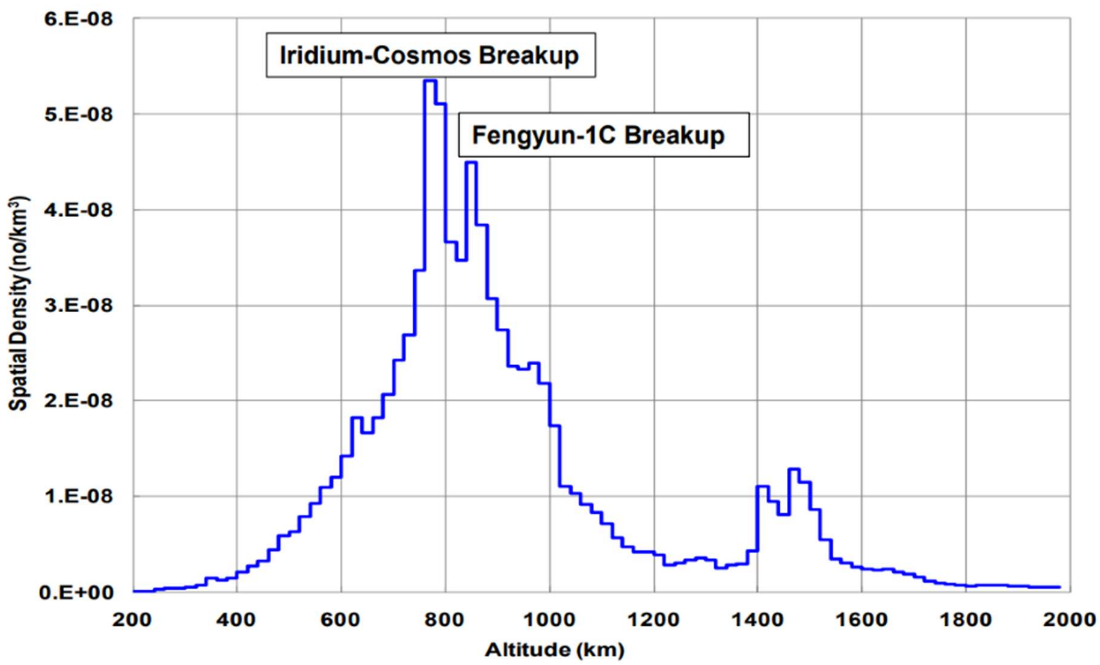
The definition of "space junk" is given in Article 2(4) of Regulation No. 2021/696 of the EU Parliament and of the Council of April 28, 2021, establishing the EU Space Program and the European Union Space Program Agency: "'space junk' means all space objects, including spacecraft or parts and components thereof, in the Earth's orbit or entering the Earth's atmosphere, which are not functioning or no longer serve a specific purpose, including parts of rockets or artificial satellites, or inactive artificial satellites."[1]

Consequences of using ASAT weapons

A major influence on the level of contamination of Earth's orbits is the use of anti-satellite weapons, commonly known as ASAT (Anti-satellite weapons). Over the past several years we have seen several spectacular attempts to use these weapons, so far using rockets launched from Earth (so-called direct ascent). Among them can be mentioned:

- January 11, 2007. - China's CS-19 missile test and destruction of its own defunct weather satellite Fengyun-1C at an altitude of 865 km.
- February 20, 2008. - US test of SM-3 missile and destruction of its own broken spy satellite USA-193 at an altitude of 240 km. The operation was carried out under the pretext of the danger of contaminating the environment with a large amount of toxic hydrazine.
- March 27, 2019. - India's test of a Prithvi Defense Vehicle missile and the shooting down of its own satellite at an altitude of about 300 km.
- November 15, 2021. - Russian test of the Nurod anti-ballistic missile with the Nariad anti-satellite platform and the destruction of its own defunct Kosmos 1408 satellite at an altitude of 485 km. The test caused an immediate threat to the International Space Station, an alert and preparations for evacuation

Each of the aforementioned tests led to additional litter in LEO orbit and increased the risks to the orbital infrastructure. It should be remembered, however, that the higher a given satellite is destroyed, the longer its debris will deorbit. The latest Russian test proved particularly dangerous to human life in orbit.



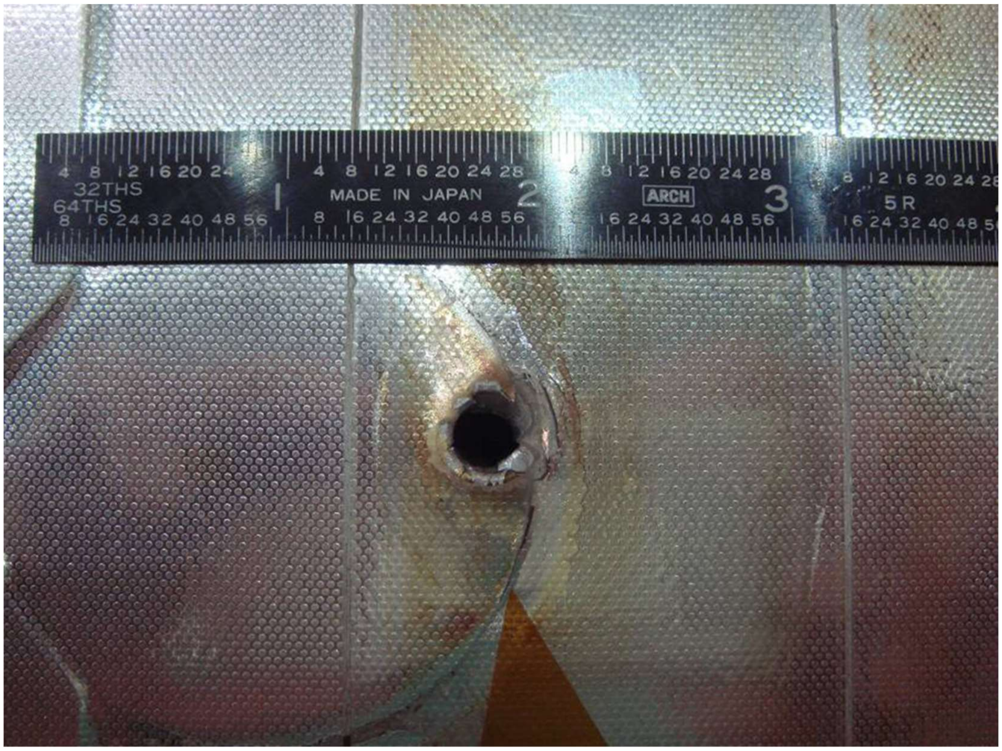
2.Graph showing the increase in the density of space junk after the collision of Iridium 33 with Kosmos 2251, and after China shot down its own satellite Fengyun-1C . Source: 2011 NASA report to UNOOSA

ASAT direct ascent weapons are so far particularly eager to be tried out, as they are less technologically challenging compared to other types of anti-satellite weapons. More advanced impact weapons operating with effectors from orbits are being developed alongside them, along with so-called beam weapons (including laser and microwave weapons) and many others [2]. Fortunately, international treaties prohibit the testing and use of nuclear weapons in space around the earth and deeper space. However, it is impossible to rule out conducting the relevant tests without the use of nuclear payloads, as was already the case with the US in the 1950s. Yet, as experts prove, "the art of destroying satellites without side effects does not exist," relatively the least unfriendly to the space environment seems to be cyberattacks, as long as they are not combined with attempts to use the satellite thus seized as an impactor destroying other objects in space and thus increasing the amount of space debris.

On November 1, 2022. The UN General Assembly's Committee on Disarmament and Security adopted a (non-binding) resolution calling for the abandonment of further ASAT weapons testing [7]. The motion was supported by the US, India and Pakistan, among others, abstained from the vote, countries opposing the resolution (Belarus, Bolivia, China, Cuba, Iran, Nicaragua, Russia and Syria) noted that the US has already achieved ASAT missile capability, and therefore the resolution limits real progress towards preventing an arms race in space and therefore freezes the status quo, convenient for the US and disadvantageous for other countries.

Space Situational Awareness Systems (SSA/SST)

The problem of space debris has contributed to the emergence of Space Situational Awareness (SST) systems, especially in the Space Surveillance and Tracking (SST) segment. Data acquired by SSTs are used to predict threats and avoid collisions with junk, including inactive satellites or rocket members. Such systems detect and catalog space junk, determine and predict their orbits [15]. In the case of Europe, both the European Space Agency (ESA) and the European Union Space Program Agency (EUSPA) have their SST system. Both organizations exchange data. There has also been cooperation with NOAA's Office of Space Commerce (OSC). [7] Telescopes and scanners, however, are able to locate sufficiently large debris at least a few centimeters in diameter. Smaller ones are still undetectable and thus more dangerous.



3.Perforation of a radiator aboard the US space shuttle Endeavour in 2007. Source: public domain

Attempts to improve the situation in orbits

The "passivation" of satellites used so far, (passive debris removal - PDR), i.e. burning the remains of usually toxic fuel, turning off electronics, neutralizing fluids in batteries, was characterized by not reducing the amount of orbital debris. Research to develop active debris removal ADR) technology for space debris is therefore gaining popularity. Bold ideas ranging from pushing space debris out of busier orbits using lasers, to catching entire spent satellites in special nets, to various forms of initiating the deorbit of objects left in orbit are being implemented in this way [8].

For some time now, we have been hearing about "Zero Debris" initiatives known in the classical economic fields, which aim to reduce the amount of debris left in orbits. It is recognized that, the exponential increase in their amount poses a growing threat to satellites and astronauts and could render some valuable orbits completely useless. In November 2023, the ESA-EU Summit launched *Zero Debris Charter Zero Debris Charter . Towards a Safe Sustainable Space Envirenment* [13]. The document envisions a roadmap for standards, technologies and technical solutions to help reduce the amount of debris in space by 2030. In addition, the document's signatory space companies, scientific research institutes, national space agencies and non-governmental organizations have pledged to undertake information and promotion activities to raise awareness about the problem of space debris and the need to reduce it in the future [11]. It is assumed that measurable results will be achieved by 2030. [14].

In addition to creating a regulatory framework, ESA is also taking practical steps: in 2025 it plans to launch a telescope capable of capturing objects as small as a few millimeters. ESA's first step toward cleaning up space will be the ClearSpace-1 mission, scheduled for

2028[5]. As part of it, space junk (the PROBA-1 satellite, which has been orbiting the Earth since 2001) is to be captured with a special grapple, to be burned up in the atmosphere. Tests are planned to catch the more than 100-kilogram Vespa payload adapter, orbiting since 2013[6].

Applications

A natural consequence of the increasing use of space around the Earth is the pollution of Earth's orbits. This problem is closely linked to the safety of astronauts and satellites launched into space. It is also arousing increasing interest from commercial companies developing technologies for active removal of space debris. A market is emerging for orbit cleaning services and servicing of depleted satellites. We are slowly beginning to understand that greater responsibility for equipment left behind beyond Earth is necessary. This theme is appearing more and more in international and European documents, although for the time being it does not take the more binding form of treaties or resolutions. Even if the specter of Kesssler Syndrome is still a distant prospect of the future, it is in humanity's common interest to deal with the problem of space debris. What is also needed is a consensus not to compound its quantity by the participants in the space arms race currently taking place. This is especially true of the trials of ASAT weapons, which are particularly harmful to the space environment.

The examples given above are the result of interest in the topic at various conferences and also in public discourse. They show how complex these issues are and what regulations they are subject to. Further interest in the topic and other issues in the field of specific space security should be expected. The authors pledge all assistance in addressing such issues.

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