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Toward the degrowth of the economics of orbital space and space debris: A preliminary theoretical application in low-Earth orbit

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The advent of space mega-trends such as satellite mega-constellations and space tourism have escalated a spatial debris problem. Driven by the arrival of the "New Space", this revolution is not without consequences for terrestrial and orbital activities, as the world becomes more and more digitized and interconnected. Existing debris coupled with the multiplication of these commercial space launches will progressively hinder future low Earth-orbit utilization. Despite emerging risks awareness, little technical or centralized cooperation has yet emerged in this global common-pool resource. I suggest tackling this issue as a degrowth approach with a preliminary theoretical application, called RCE Model, providing a sustainable solution to obtain both physical and economic access to orbital space, while reducing orbital debris.

1. Growing in a finite space

In 2020, the space industry reached $447 billion, a 176% increase since the initial analysis in 2005 (Figure 1). This growth has accelerated through two mechanisms. First, improved technology has led to lower costs and higher performance of satellites. Second, the opening of the sector to private players (SpaceX, OneWeb, etc.) has led to strong growth in commercial activities, which account for nearly 80% of revenues and 92% of launches in 2020 (Conn, 2021). This revolution, called New Space, is reflected in the appearance of mega-satellite constellations (e.g., Starlink), which are gradually becoming a profitable business. In the third half of 2021, the space sector saw record investment of $10 billion (Conn, 2021).

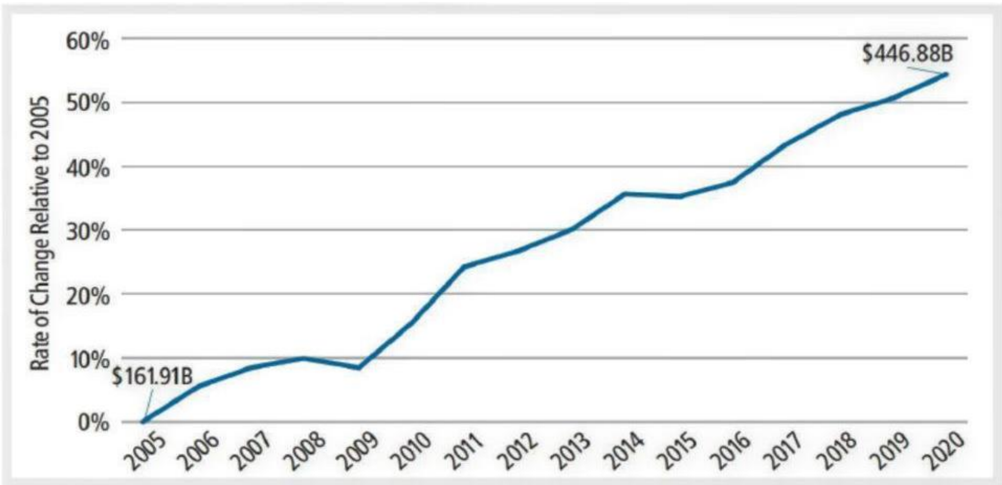

Figure 1: The Global Space Economy, 2005-2020 (Source: Space Foundation Database).

This network is being mediated by the Space Economy Initiative, which is under the auspices of the United Nations Office for Outer Space Affairs. This Initiative provides expertise and peer-to-peer exchange with established space-faring members to bring insights, case studies, and guidelines in the space sector (UNOOSA, 2021). The key objectives are (i) integrate and promote the space industry in socio-economic development in line with the 2030 Agenda, (ii) support countries in creating a strong, responsible and sustainable national space economy, and (iii) strengthen collaboration between public and private actors to promote inclusive and sustainable growth of the global space economy (UNOOSA, 2021).

According to the European Space Agency (2019), the space economy is "the full range of activities and the use of resources that create value and benefits to human beings in the course of exploring, researching, understanding, managing, and utilizing space". The mere vastness of space represents a significant issue with this definition as it appears to consider everything beyond the Earth as space exploration resources. Indeed, resources used in space may be anything from massive bodies (such as planets, moons, or wandering rocky bodies), stars (especially the Sun), or specific regions in relative proximity to the Earth (Earth orbits, Lagrange points, etc.). In order to comprehend the diversity of resources and their respective regions, more fine-grained analyses are needed.

Here, the resource under consideration is low Earth-orbit (LEO) located between 160 km to 2000 km above the Earth. In this region, an orbital ray is monopolized by actors with satellites and allows them to provide different types of services. For example, placing communication satellites into orbit produce private services for consumers, business and governments, such as internet access, GPS or broadcasting, military activities (espionage and monitoring); national public services such as defense; and observations of the Earth deliver global public goods such as predicting weather, monitoring Earth's climate activity, or other environmental information (Adilov et al., 2022). The actors appropriating this resource are countries, space agencies and private companies who can deploy or purchase the means to reach orbit. From the legal side, the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies" has been opened to signature since 1967 to agree on a military framework of international space law (UNOOSA, 1967). As of September 2022, 112 countries are parties to the treaty, including all major spacefaring nations[1].

Today, LEO is where most of our satellites and space debris are located, making it a true economy that I called Economics of Orbital Space and Space Debris (EOSSD). Conforming to Samuelson's taxonomy of goods, LEO (and space in general) is a common-pool resource (Samuelson, 1954). In fact, no actor can be excluded from consuming this good (principle of

[1] United Nations Office for Outer Space Affairs: https://treaties.unoda.org/t/outer_space [Accessed in September 2022].

non-excludability) and one cannot use an orbital ray in LEO that is already being used by another nation or organization (principle of rivalry).

According to Hardin (1968), this type of good is subject to the tragedy of the commons because the lack of clearly defined property rights leads to overuse of resources or significant pollution, as in the case of orbital space. As a consequence, economic theory recommends either privatization or centralization under the authority of a state to sustainably manage the resource. In “Governing the Commons”, Elinor Ostrom (1990) showed that communal and co-operative governance represent another way of commons management. Weeden and Chow (2012) applied Ostrom’s eight principles of common pool resources to identify current space governance mechanisms. The main finding is that there is a failure or even an absence of institutions to improve the space rights regimes developed during the Cold War. Moreover, Ostrom’s work for managing global commons required adjustments and scaling-up as her study design was conducted from local resources (Chaddha, 2013). To move beyond these limitations, Lambach and Wesel (2021) suggested a system of polycentric governance. The authors noted that current organizations under the auspices of the United Nations are too centralized and there is a lack of lower-level actors in the management process.

Regarding the spatial debris management, privatization of orbital space is not a realistic option as binding international rules are already difficult to implement on Earth for climate change issues and a centralized system is not sufficiently suited for this rapidly evolving environment (Imbugia, 2011; Pusey, 2010). In my view, a promising outcome would be the governance of the common by allowing all orbital stakeholders in the decision process (such as private companies) to encourage them to share precious knowledge on positional information of their own debris, participate in the development and deployment of technologies for a collective debris removal, address legal questions (such as graduated sanctions to encourage stakeholders to comply with the guidelines) or establish transparency regulation and mitigation guidelines according their type of activity and purpose in LEO. Nevertheless, it is necessary to move up a gear and to take into account the gravity of the situation. In the last twenty years we have observed the formation of a debris belt around the Earth that makes some orbital spaces inaccessible. This plague is referred to as the physical Kessler syndrome (Kessler, 1978), a worst-case incident in which a cascading series of collisions could make Earth orbits unusable. Despite physical Kessler-like event remains uncertain, Adilov & Cunningham (2015) showed that, in some scenarios, this phenomenon will first be first preceded by an economic Kessler syndrome, which will make orbital space unprofitable for business operations in the medium-term perspective.

In the context of EOSSD, economic tools to mitigate pollution such as taxation, charges/fees, subsidies or voluntary approaches (Undseth et al., 2021), or strategic game-theoretic approaches (Klima et al., 2016), can help to ensure a good balance between space activities and orbital debris. However, in the absence of cooperation for regulating space, it is complex to set up such tools today. Moreover, the current abundance of debris requires quick and efficient measures, such as direct debris removal, but this option is hampered by development costs.

2. Degrowth

Degrowth is a current born in the 1970s and refers initially to the Meadows report (Meadow et al., 1972) and the writings of Nicholas Georgescu-Roegen et al. (1995). Later, Serge Latouche (2006) defined degrowth as “a societal project of frugal abundance” (author’s translation) allowing a return to a standard of living compatible with the reproduction of ecosystems. The unlimited production of wealth is measured by non-rigorous indicators and has led to (i) inequality, (ii) illusory well-being, and (iii) individualism. In this sense, this movement aims at redefining prosperity by integrating more physical and natural laws into economic models and breaking out of the “iron cage of consumerism” (Jackson, 2010) in which irresponsible capitalism has trapped itself. Laurent Lieven’s (2015) degrowth map, Fabrice Flipo’s (2017) five sources of degrowth, Giorgos Kallis’s (2018) nine principles, and Yves-Marie Abraham’s (2019) three principles showed that there have been some improvements at theorizing degrowth.

The current increase of EOSSD is at odds with the dangerous accumulation of orbital space debris. This hypothesis is in line with Georgescu-Roegen's observation: “We cannot produce larger airplanes without building larger debris” (Latouche, 2011; author’s translation). A simple analogy is sufficient to understand that we cannot build bigger rockets without producing bigger orbital debris. Thus, the terrestrial issues concerning the unsustainable management of resources and excessive growth seem to be progressively transposed into orbital space since the underlying economic logic is the same.

The lack of legal, technical, economic, and political cooperation in this common-pool resource is the major nature of the problem. In addition, it is clear that the economic growth of EOSSD is closely linked to its commercial opening and contributes to this ever-increasing growth of orbital debris. Based on the reasonable assumption that EODDS growth is intimately correlated with space debris growth (Adilov & Cunningham, 2015), the objective is to develop a preliminary theoretical degrowth model to maintain a sustainable balance between space activities and debris, while reducing the amount of orbital debris. As we have seen before, efforts to remove debris or mitigate their propagations are often studied through the lens of technical solutions or centralized structure. In my view, a more pragmatic and holistic approach is required as the multidisciplinary nature of space debris does not allow to bring monocausal explanations (Lambach & Wesel, 2021).

3. Reflections around a preliminary theoretical model

To structure my considerations around a theoretical model, I proceed in three steps. I want to apply the principles of economic degrowth to initiate a slowdown of activities around EOSSD. The objective is not to explain a phenomenon that already exists. Based on the principles of the transition to a sustainable economy drawn by Tim Jackson (2010), I propose a model on a sustainable solution to obtain both physical and economic access to orbital space, while reducing the number of orbital debris. As a result, my methodology is therefore more normative than descriptive. Indeed, the theory is developed according to how something should be, rather than what it actually is in reality (Parrique, 2019).

The first step is to establish the scope. I am focused on the impacts of the space industry in LEO as, today, the greatest concentration of debris is located near 750-1000 km. The concept of space debris is broadly defined as any non-operational man-made objects that resides in Earth's orbital space (Liou, 2006). The actors involved are countries, space agencies, and private companies who reach an orbital ray with a satellite or a spacecraft.

The second step is to identify the major negative externalities. In fact, the debris caused by space launches leads to six types of effects (non-exhaustive list):

- Environmental: Kessler's physical syndrome (debris belt), collisions between large debris lead to smaller unintentional on-orbit debris that are difficult to detect, and pollution restricting access to orbits.
- Safety: Atmospheric fallout, accidents for astronauts during extravehicular activities, direct damage to the ISS, and explosion of satellites.
- Research & Development: Threats to scientific research because orbital space is an ideal environment for testing and studying the stellar system and threats to innovation.
- Economic: Orbits are economically unprofitable as more satellites are destroyed and need to be replaced (Kessler economic syndrome). Insurance costs, orbit clearance costs, operations costs and debris related damage increase total mission costs for actors (Undseth et al., 2021)
- Communication/observational: Damage to satellites threatens Earth observations activities (climate change, environment) and communication (GPS, telecommunication).
- Geopolitical: Spacecraft destruction/damage or hijacked satellites can lead to geopolitical conflicts if they threaten the national defense of countries (Kallberg, 2012).

Moreover, the dispersion of debris within this space is uneven. Some orbital rays in LEO are more affected than others, depending on the number or size of objects in suspension. Finally, some satellites are better equipped to monitor the debris, deviate from the orbit, and protect themselves from debris.

In a third step, I build the preliminary theoretical degrowth model and name it "RCE" (Figure 2), an acronym for its three pillars: renewing the perception of orbital space, changing the economic mechanism, and establishing physical limits.

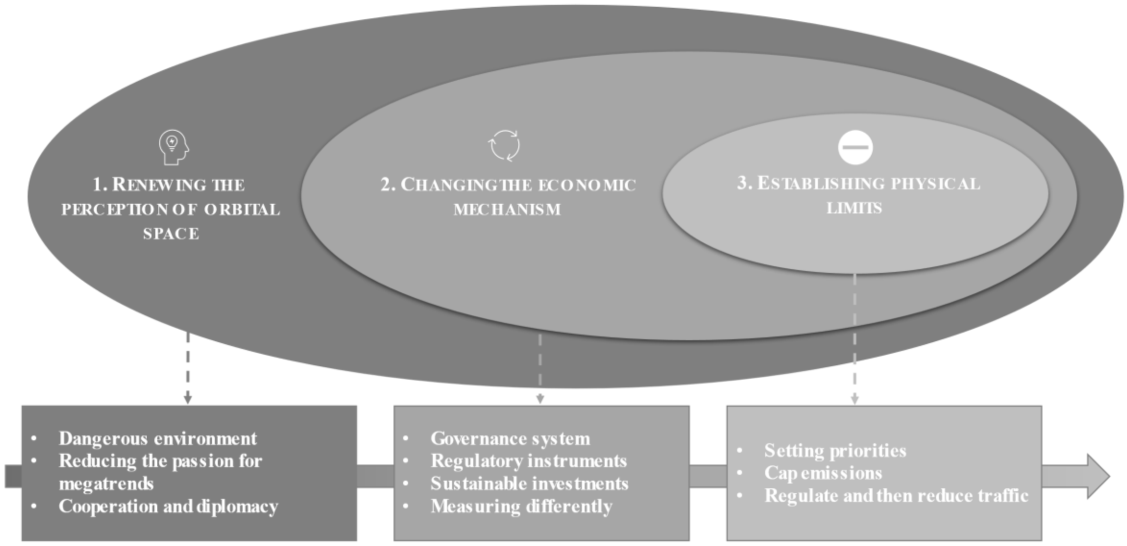

Figure 2: RCE Model.

Commentary: By gradually (i) renewing our perception of orbital space, (ii) changing its economic mechanism, and (iii) establishing physical limits, Jackson's (2010) underlying principles of degrowth applied to LEO (for instance, reducing the passion for mega-trends, measuring prosperity differently or capping emissions) would maintain socio-economic and ecological prosperity, while allowing the reduction of space debris.

The first pillar is fundamental. It is about the renewal of our perception of orbital space. Sending objects and people into space requires significant technological investments that do not always guarantee the safety of astronauts during launch or levitation. Space mega-trends, defined as societal and global space projects that will affect all areas of our lives in the years to come, have been set in motion. These include mega constellations of satellites, space tourism, space hotels, orbital elevators, etc. The emergence of private companies seeking to democratize orbital flight will accelerate testing and launches, which will increase pressure on the space debris issues if no collective action is taken. Although shielding systems are improving, there is a risk of collisions between debris, not to mention the human damage involved. Moreover, orbital space has been highly politicized since the Cold War and became a military zone where strategy and surveillance can lead to conflict through deliberate jamming or destruction of satellites (Gaillard-Sborowsky et al., 2016). To avoid escalation of conflict, it is necessary to understand this zone as a place of international cooperation. In response to these three observations, I propose to (i) redouble caution, (ii) not use this space to satisfy new irresponsible needs, and (iii) cooperate and act diplomatically while dismantling this "Star Wars" culture, because orbital space is not a playground like any other. It is a harmful environment, confronted with mortal solar radiation and less gravity.

The second pillar aims to change the current economic logic in four ways. A law framework to orbital space must be established to (i) create a forum for resolving international disputes, (ii) promote transparency and scrutiny of activities, (iii) strengthen security for all, and (iv) sanction illegal behavior. To my mind, cooperation by all actors (countries, space agencies, private companies, etc.) is paramount for the realization of the second and third pillars. Today, shifting national laws to the international level, such as the Space Law Treaty (2015), represents a transgression of the Res Nullius principle of orbital space and will not lead to a common agreement. In addition, economic policy must include instruments to induce sustainable behavior. For instance, taxation, deposit-refund systems, subsidies, or voluntary approaches can initiate positive developments to regulate the rapid growth of the space industry (Undseth et al., 2021). Moreover, sustained investment in jobs, assets, and orbit-clearing infrastructure will boost the sector's prosperity while reducing its impact on the ecosystem. Finally, traditional yardsticks for calculating the prosperity of the space industry are skewed and one challenge is to include the costs associated with the major negative externalities I identified earlier.

The third pillar provides for greater efficiency by imposing physical limits in three ways. The priorities for use must be established. At a time when space debris is accumulating, we must (i) keep the orbit clean for Earth observation missions that benefit human activity, (ii) reduce the number of space launches, especially for commercial purposes, to relieve orbital access, (iii) prioritize funding for science launches, (iv) develop debris cleanup of the orbit, and (iv) stop funding space tourism. Moreover, a debris cap must be established and reduced. This suggests the establishment of development standards and debris quotas. The reuse of launch vehicle first stages or the use of cubesats are notable improvements in this area, but their development is primarily motivated by cost considerations rather than preservation of the orbital environment. A tightening of standards is needed. The "polluter pays" principle and "polluter cleans" principle are implementable, even if the application is not obvious in this context. Moreover, it is necessary to regulate orbital traffic. With the help of a space traffic law, fatal collisions could be avoided and the congestion that leads to an ever-widening spread of debris is reduced. Without this, a vicious circle is to be feared. This is because the more the debris belt expands, the more satellites must move away. This increases the risk of failure, as they must first traverse a debris field and then reach a position where the Earth's magnetic field becomes less and less robust against the Sun. The satellites will then probably have to be replaced more frequently, which in turn will lead to new debris.

Finally, this RCE model supports a scale up of Ostrom's Work (Lambach & Wesel, 2021; Chaddha, 2013; Weeden and Chow, 2012), through collective decision-making and information sharing. As we have seen before, privatization is not a possible option and the current centralized and independent initiatives failed to mitigate space debris. If this common remains unregulated and privatization continues, the arrival of space mega-trends will exacerbate the aforementioned externalizations as launches will become more frequent and more satellites will enter LEO.

4. Conclusion

By applying this preliminary RCE Model, I aimed to take a multidisciplinary approach to the space debris phenomenon as it is a legal, technical, economic, and political issue. Following the three pillars of this model, the degrowth of the EOSSD, of which one of the concrete applications is LEO, would allow the reduction of space debris, which was the main objective of our proposal. In this way, it would be possible to preserve the sustainability of this environment while maintaining socio-economic and ecological prosperity. But by and large, a cooperation culture between all actors is needed to achieve this degrowth objective.

Conflict of interest

The author has no conflict of interest to disclose.

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