Research note

Opportunities and threats of the rapidly developing Space sector on sustainability transitions: Towards a research agenda

Xiao-Shan Yap[1,2,*] and Bernhard Truffer[1,2]

[1] Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands
[2] Eawag, Swiss Federal Institute of Aquatic Science and Technology, Switzerland

**Corresponding author*

Email:

xiaoshan.yap@eawag.ch

bernhard.truffer@eawag.ch

Full postal address: Department Environmental Social Sciences, Eawag, Ueberlandstrasse 133, 8600 Dübendorf, Switzerland.

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Highlights

1. Space-based infrastructures may become a key pillar of future modes of environmental management.
2. New satellite systems can support sustainability transitions in a variety of industrial sectors.
3. But there are rebound effects and pose new threats to Earth's and orbital environments.
4. There is an urgent need for sustainable Space governance.
5. We identify Space-related research avenues in terms of sustainability transitions challenges.

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Abstract

Sustainability transitions research has increasingly adopted global perspectives on how to deal with sustainability challenges. However, "global" has so far been limited to Earth's surface and atmosphere. We argue that transitions research should include developments that relate to the orbit and outer space (hereinafter also Space). The Space sector has grown substantially over the last decade in terms of the number of rocket launches, the diversity of actors involved or new essential services that depend on Space-based infrastructures. This entails fundamentally new opportunities to manifold industrial sectors, and enables developing countries to potentially leapfrog polluting industrial development pathways. At the same time, the expansion of the Space sector creates manifold sustainability pressures like atmospheric pollution, high energy consumption, or Space debris in the orbit. This led to recent surges in arguably "green" innovations such as reusable rockets, but also the development of new governance arrangements protecting outer space as a finite resource for humankind. This research note sketches major recent developments in the Space sector and points to promising avenues of research for innovation and transition studies, not only in terms of a new empirical application field but also as an inspiration for new theoretical insights and innovation policies.

Keywords: Outer space; Sustainability transitions; Mission; Governance; Commons; Beyond national jurisdiction

1. Introduction

Prominent scholars in innovation studies have argued that we are experiencing the emergence of a new techno-economic paradigm, in which new information and communication technologies combine with increasing globalization, and the need to cope with societal and environmental sustainability. These new emphases engender rapid transformations of industries, life styles and geographical leadership positions (Perez, 2013; Schot & Kanger, 2018). The outer space (hereinafter also Space) sector is likely to play an increasingly strong role in this transformation. Over the past decade, fundamental changes have led to what is called "New Space", i.e. a multiplication of private actors from around the world entering the Space sector (Mazzucato & Robinson, 2018; Robinson & Mazzucato, 2019), even with some such as SpaceX leading private Space missions. New satellite networks are constructed by international Space agencies and private entrepreneurs. Among other things, they enable Space-driven green application services offering new ways to combat climate change, to tackle water scarcity and a host of other new options to tackle environmental problems. However, on the other side, a rapidly expanding Space sector is also likely to cause severe pollution on and beyond the earth's surface. Amidst these diverging challenges and opportunities a rush of socio-technical innovations is currently unfolding: Space companies compete on developing new generations of spacecrafts and launch systems such as recyclable rockets, while policy makers are urgently called to transform Space regulations addressing carbon emissions and the excessive accumulation of Space debris. Despite these increasing dynamics, the outer space realm has received little or no scholarly attention in innovation and transition studies so far. The goal of this research note is therefore to outline the most salient recent developments in the sector and sketch out a number of associated research avenues for transition studies. In the following, we will first elaborate how the Space sector might influence sustainability transitions in other sectors. Then we elaborate dynamics of the sector itself before we delineate the contours of a research agenda.

2. Can Space-based infrastructures accelerate Earth's sustainable development?

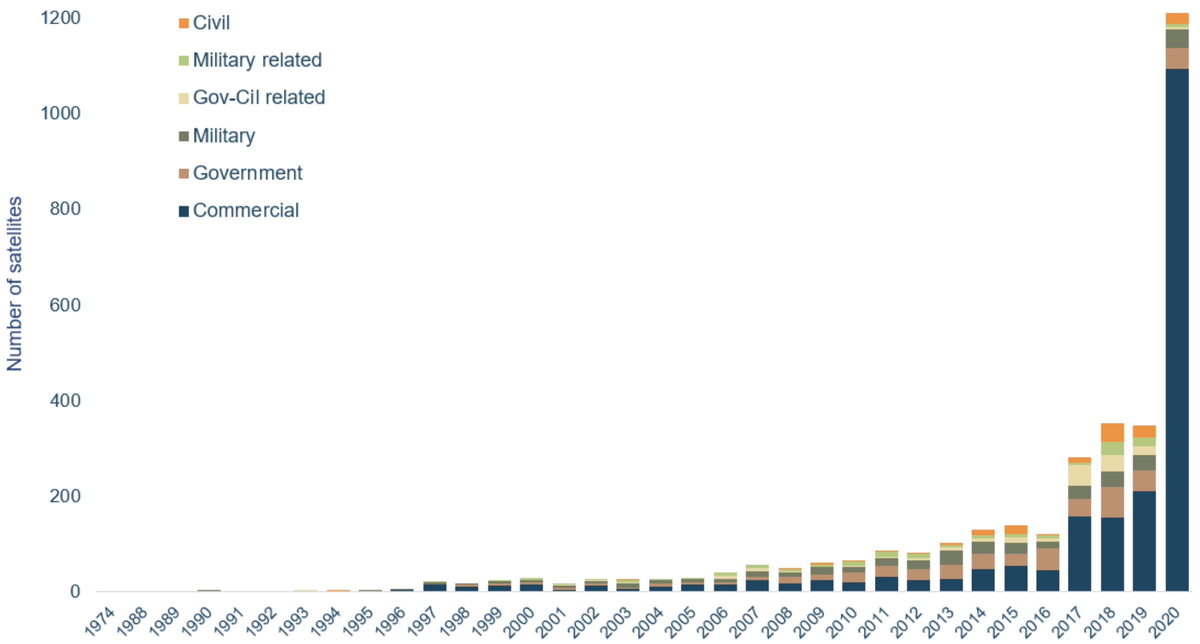
Opportunities and threats of the Space sector to the natural environment

There has been a boom in Space activities in the last few years, especially in terms of satellite launches. Figure 1 shows the exponential growth in the number of operating satellites orbiting the Earth based on different types of users. On the positive side, the rapid progress in the New Space era leads to significant new opportunities and challenges for environmental sustainability. Constellations of advanced satellite systems provide new Earth observation capabilities that support more encompassing forms of environmental management. Figure 2 illustrates the number of satellites launched by national governments over the years differentiated by various purposes. In particular, Space-based Earth observation activities began to gain traction in the late 2000s and in the last five years it became a dominant activity among government users.

More specifically, the Earth observation program launched by the European Union, known as the 'Copernicus – Europe's eyes on Earth', generates unprecedentedly unique and precise data for Earth surface and climate change monitoring. This opens up a whole new range of opportunities for governments and businesses across the world to better manage and tackle environment related challenges. For example, satellite remote sensing can provide new solutions for water resource management even in some of the poorest places in the world (Sheffield et al., 2018; UNESDOC, 2010). Advanced satellite monitoring technologies such as Interferometric Synthetic Aperture Radar (InSAR) are, for instance, feeding image data and filling up data gaps related to groundwater management.

InSAR can observe where or when groundwater is being over-extracted or recharged, and potentially use artificial algorithms to fill in data gaps (WEF, 2018; WIPO, 2020). It is a radar technology applicable under any weather conditions while informing water managers about the latest state of an aquifer.

Figure 1: Total number of operating satellites in Earth's orbit by type of users, 1974-2020

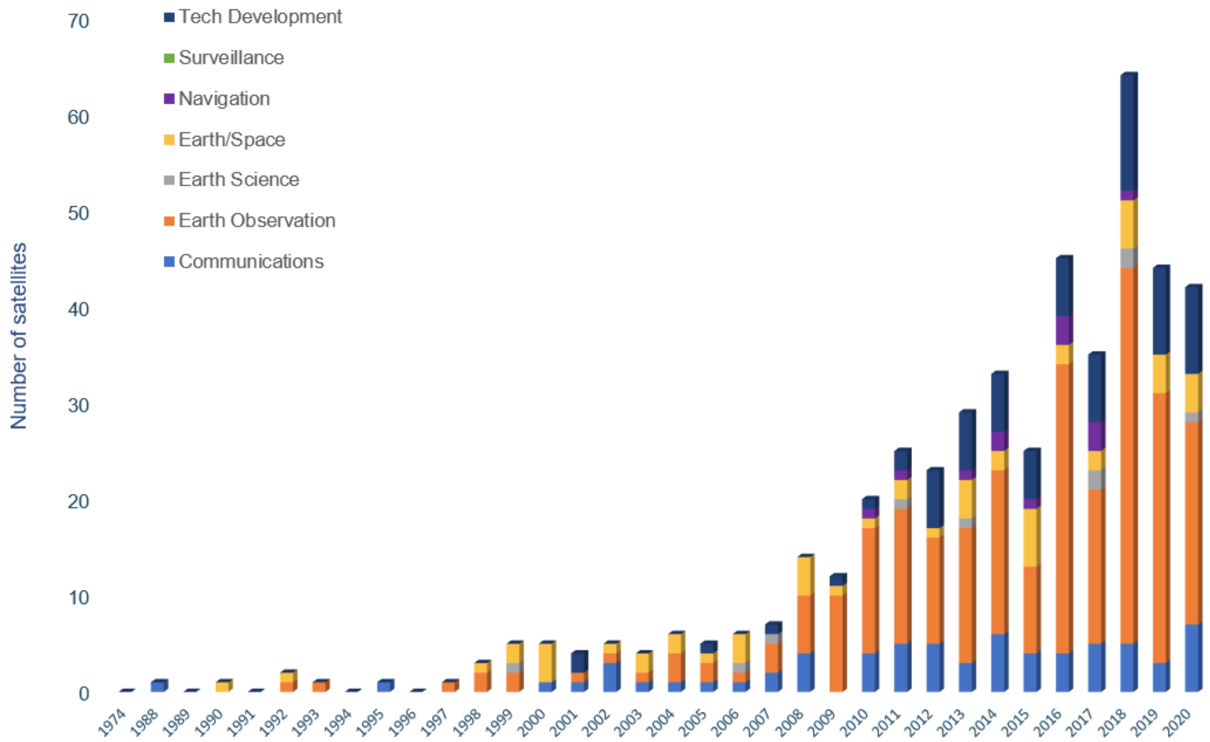


Source: Own illustration based on data from Union of Concerned Scientists (UCSUSA) 2020.
*Note: Gov-Civil = mixture of government and civil users**
**civil usage includes communications, weather, remote sensing, etc.*

On the negative side, colonizing outer space engenders new kinds of environmental problems. A prominent issue is an increasing amount of soot[1] in the stratosphere as a result of rocket launching activities, contributing to climate change while at the same time further depleting the ozone layer. Furthermore, there are currently 6'000 satellites in the orbit, of which only about 3'000 are in operation. The rising amount of Space 'junks' or Space debris does not only make Space missions more complex and riskier but might also incur catastrophic consequences on Earth in the event that chained collisions take place in outer space causing damages to operational satellites for daily purposes like communication and navigation. The orbit thus has to be increasingly seen as a novel 'territory' that deserves urgent protection as a resource for future opportunities. Sustainability concerns might expand to even farther away spaces into the future, as more probes are launched to the Moon and Mars for exploration and exploitation activities or when on-orbit manufacturing and Space mining get popularized (Jakhu, Pelton, & Nyampong, 2017; J. Nelson, 2020).[2,3]

[1] Soots, mainly comprised of black carbon, are impure carbon particles produced by burning coal, diesel, wood, etc. Black carbon steadily absorbs sunlight that could significantly exacerbate the global warming crisis (Shiga, 2010).
[2] 'Making Stuff in Space: Off-Earth Manufacturing Is Just Getting Started'. Retrieved from https://www.space.com/40552-space-based-manufacturing-just-getting-started.html
[3] 'In-Space Manufacturing'. Retrieved from https://www.nasa.gov/oem/inspacemanufacturing

Figure 2: Number of satellites launched by government purpose, 1974-2020



Source: Own illustration based on data from Union of Concerned Scientists (UCSUSA) 2020.*

Note: Tech development = technology development including research and development, technology demonstrations and educational activities; Earth/Space = mixture of Space Science or Astronomy activities with other Earth observation related activities; Earth Science = mixture of Earth Science (i.e. geoscience of the planet Earth) with other Earth observation related activities[4]

** Although the numbers in this figure only represent government launches, the figure highlights the increasing amount of Earth observation activities. It furthermore shows that these activities slowed down only relatively in year 2020, despite the covid-19 pandemic.*

Contribution of Space technologies to sustainability transitions in other sectors

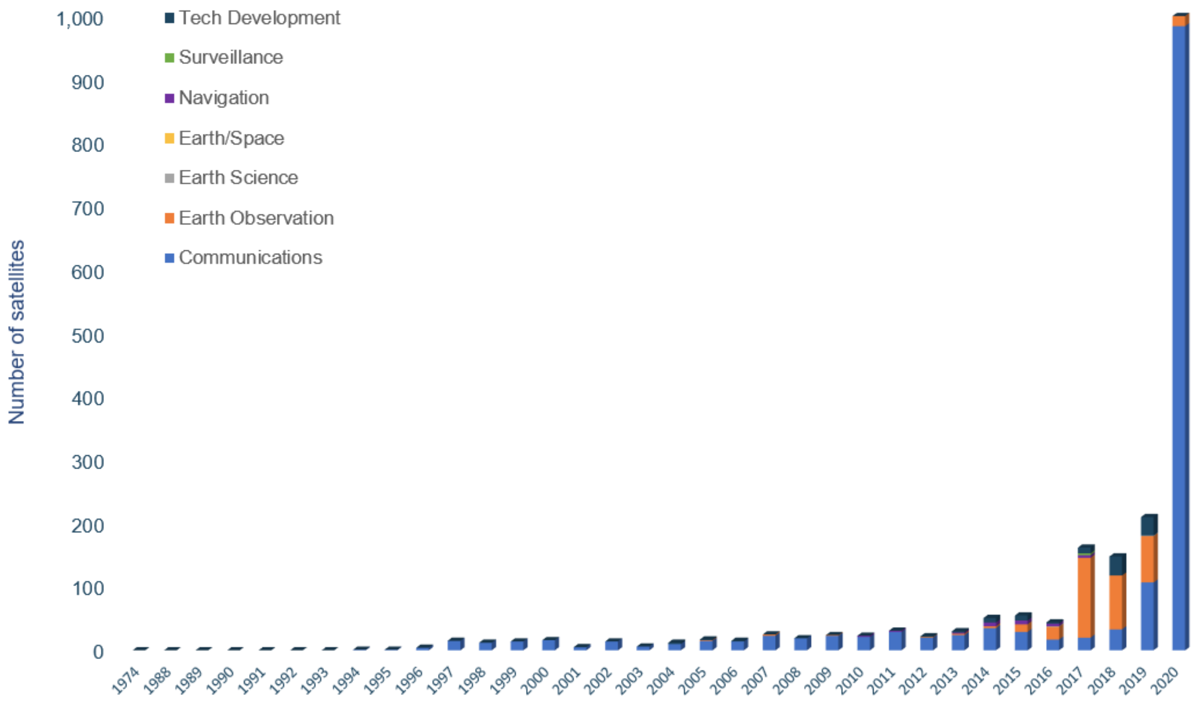
Despite these environmental challenges, the promises of Space technologies might increasingly contribute to the emerging green techno-economic paradigm across the global economy (Al-Ekabi & Ferretti, 2018; UNOOSA, 2018, 2019). One of the most promising cases is the provision of next-generation global basic infrastructures like ubiquitous access to high speed 5G Internet (ITU & UNESCO, 2019; World Bank, 2016).[5] In year 2020, all satellites launched by private actors focused on Internet and telecommunication purposes (see Figure 3), most of which formed part of large satellite megaconstellation projects owned by billionaire companies like SpaceX and Amazon - known as Starlink and Project Kuiper respectively (Witze, 2020). The advancements of Internet satellites and the consequential mobility of data are creating new windows of opportunity to many sectors or industries across the globe. The promise of ubiquitous access to the Internet through satellites extends in

[4] The proportion of Earth observation activities in overall satellite activities is therefore higher than shown by the orange bar.

[5] 'Super-fast internet from satellites is the next big thing in the space race'. Retrieved from https://www.cnbc.com/2019/07/22/fast-internet-via-satellites-is-the-next-big-thing-in-the-space-race.html

particular to rural places including poor regions in developing countries (World Bank, 2016; World Economic Forum, 2019). National governments see opportunities offered by satellite technologies for achieving sustainable development and so in recent years even developing countries such as Kenya, Pakistan or South Africa have ventured into satellite launching activities. Recent research finds that even in the poorest 20% of households in developing countries, seven in ten people own a mobile phone, making cellphones more accessible than even toilets and clean water (World Bank, 2016). This indicates potentially improved access to healthcare information for those without access to a hospital, but with access to the Internet. The satellite infrastructure might therefore facilitate rapid progress in addressing a number of sustainable development goals for latecomer countries in the near future.

Figure 3: Number of commercial satellites launched by segments, 1974-2020



Source: Own illustration based on data from Union of Concerned Scientists (UCSUSA) 2020.
Note: Tech development = technology development; Earth/Space = mixture of Space Science or Astronomy activities with other Earth observation related activities

Besides Internet and telecommunication purposes, advanced satellite navigation systems are expected to enable disruptive changes to mass-market applications like vehicle navigation, smart agriculture, disaster prevention, and improving the precision of power grid management systems for the electricity sector. A prominent example is the government owned Chinese BeiDou Navigation Satellite System – for which the constellation of satellites was fully completed in the middle of 2020 – has already been widely deployed in different regions in China, e.g. Jiangsu, Hubei, Zhejiang and Sichuan for agricultural purposes (China Satellite Navigation Office, 2018). In Zhejiang, the use of unmanned rice planter equipped with a BeiDou navigation-assisted driving system has been introduced, which allows unmanned and high-speed automatic seed planting with precise row spacing and seedling distance (Global Times, 2020a). As of 2020, BeiDou has also been adopted in more than 10, 000 unmanned farm tractors and spraying drones in Xinjiang (Global Times, 2020a). During the Covid-19 pandemic in 2020, BeiDou navigation system experimented precise positioning system for unmanned vehicle delivery services in China to help minimize human contacts. It is expected that unmanned delivery vehicles and drones will be increasingly common in the coming decade (European Environment Agency, 2020; Global Times, 2020b). Precise satellite systems may therefore become a major driver for socio-technical transitions across several sectors, which might be more or less sustainable.

The need for a sustainable Space governance system

Driven by new application opportunities and increasing pressures to respond to sustainability challenges, the Space sector itself also increasingly moves towards fundamental restructuration. Recyclable (or reusable) rockets and Space debris removal are among the most salient topics regarding the 'greening' of the Space sector and therefore respond to the ecological dimension of sustainability. The effects of such greening measures are however not easy to predict, as it may lead to undesirable rebound effects. For instance, recyclable rockets substantially reduce rocket launching costs, which in turn increase the volume of Space travels.

The rapid expansion of Space activities also needs consideration of the social and economic dimensions of Earth-Space sustainability. In particular, there is an increasingly perceived urgency for new governance arrangements in global policy circles. The United Nations Office for Outer Space Affairs (UNOOSA) for instance pointed out that in building resilient and sustainable societies, more peaceful use of the outer space is necessary. During the Committee on Space Research assembly 2018, the inclusion of outer space environment as one of the Sustainable Development Goals became a point of discussion (Galli & Losch, 2019). The rapid progress made in private satellite megaconstellation projects also prompted a surge in reform activities attempting to revise Space policies, treaties, laws and regulations on the repercussions of excessive Space debris and sustainable management of the launch industry. For instance, 'sustainable Space logistics' is becoming an emerging concept for the booming Space economy and its associated activities near Earth.[6] From Space agencies like ESA to universities, satellite launching companies and even incumbent logistics companies like DHL are looking into questions of how to sustainably transport objects into outer space; how will supply lines for Space activities be planned and managed from Earth to the orbit; and how to minimize or reverse the accumulation of Space debris. A Space logistics and orbital transport company D-Orbit based in Italy had recently developed the world's first microsatellite cargo vehicle and had successfully deployed satellites into precise orbital slots. This carrier service allows longer lifespan of satellites of up to five years, reduces deployment costs by 40 percent, and aims to offer orbital services in the near future (including moving satellites between orbits, repairing and refueling) to optimize resources and maintain cleanliness in outer space.[7,8] We could therefore anticipate a future Space sector that increasingly tries to accommodate for sustainability considerations and will promote a large range of sustainability oriented innovation processes. These innovations are expected to develop in an increasingly globalized innovation system. Intergovernmental bodies, national policy makers, companies and academia will have to cooperate in order to find new forms of more sustainable and peaceful uses of outer space.

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[6] 'Sustainable Space Logistics'. Retrieved from https://espace.epfl.ch/research/ssl/
[7] 'Space logistics: The final frontier'. Retrieved from https://www.dhl.com/global-en/spotlight/globalization/space-logistics-satellite-transportation.html
[8] InOrbit NOW launch and deployment services. Retrieved from https://www.dorbit.space/launch-deployment

3. Towards a research agenda on sustainability transition challenges in the Space sector

These challenges and opportunities open up a promising field in which innovation studies and sustainability transitions research can find inspiration and provide a better understanding of the upcoming challenges to contribute to new types of solutions. First of all, we maintain that the future Space developments represent a sort of generic technological enabler with a high potential for supporting radical change in many different sectors. Second, and more specifically, Space-based infrastructures could speed up technological and societal change in the Global South by providing windows of opportunity for leapfrogging and new service development. Third, understanding the transformation of the Space sector itself represents a typical application domain for innovation and transition studies. Fourth, all these socio-technical transformations need to consider the protection of the orbit in order to prevent the unfolding of another tragedy of the commons. We will elaborate on these four points in the following.

i) Sustainability transitions fueled by new Space-based infrastructures

Space-based infrastructures, especially through the construction of advanced satellite networks for Earth observation systems, will increasingly enable new sustainability oriented services in realms like agriculture, water management, land use, energy, transport, urban planning, as well as disaster management. Theoretical insights from transitions studies, especially through the process-oriented views of technological innovation systems and sectoral regime transformations, provide useful analytical frameworks to analyze the conditions for sustainability transition. For instance, although tackling water related challenges is a topmost priority in the EU Copernicus Earth observation program, the water management sector faces huge resistance from the regime actors in replacing in-situ (ground based) field inspections with Space-based observations when checking for dam breaks or when managing floods (Haarler, 2020). An innovation system perspective will help identify the inducing or blocking mechanisms that may lead to (un)successful sectoral transformation (Weber & Rohracher, 2012).

Not only Space commercialization continues to prevail beyond individual nations, Space-based infrastructures – through Earth observation, precise navigation, and highspeed Internet provision - can enable instantly available services. We therefore have to address an increasingly globalized innovation system in which complex value chains between global and local companies are built. While the future supplies of Space-based technologies and services may be dominated by global private actors, the user base may be a complex mixture of global and local private organizations, as well as, international, national, and local governments. Although this creates greater opportunities in expediting sectoral transformations and enabling the attainment of the SDGs, the intensified competitive market forces and the complex mix of actors will inevitably lead to the emerging issues in trust, privacy and conflicting interests. Transition studies should therefore aim at providing guidance to understand these interrelated institutional and technological dynamics.

ii) Leapfrogging of the Global South in basic services

The new Space-based infrastructures may bring even more fundamental leapfrogging opportunities to the Global South in terms of economic development, sustainability transitions and living standards. The promise of Internet satellite megaconstellations in providing ubiquitous highspeed Internet access will allow poorer countries with inferior infrastructure to rapidly transform multiple sectors with new application services (ITU & UNESCO, 2019; World Economic Forum, 2019). Since countries in the Global

South have less hardware based infrastructures, they are less path-dependent and new Space-based infrastructures may enable them to find new development trajectories that do not require repeating the polluting trajectories of old industrialized countries. The case of Mpesa in Kenya has been a typical example of how developing countries may leapfrog in service deliveries, in this case by cellphone based payment services (Mbiti & Weil, 2015; Mbogo, 2010). Therefore, the emergence of Space-based infrastructures could finally bridge the long-standing global digital divide. This will subsequently open up manifold opportunities for local businesses to develop new application services. New jobs would follow suit, especially in software and IT engineering, as can be seen in the recent development in India and increasingly also among the startups in Kenya (Baumüller, 2016; Bharadwaj, Jack, & Suri, 2019; Guild, 2017). This overall corresponds with recent engagements of transitions studies in development context, which have increasingly pointed to the role of latecomer countries in proactively appropriating new windows of opportunities to shape new development trajectories (Yap & Truffer, 2019).

The public access to Space-derived data and the promises of smarter service structures could potentially lead to more equitable access to global innovation systems. However, this opportunity may be hampered by geopolitical strategies of leading spacefaring nations such as the US, China and Europe. Due to increasing commercialization of the Space sector, smaller companies would face lower entry barriers in satellite launches (Akyildiz & Kak, 2019).[9] More importantly, as Space-based infrastructures enable real-time information to be globally 'instant' more than ever, developing countries may no longer depend on actors from more advanced parts of the world as they can increasingly act independently. These rather optimistic visioning however requires urgent and careful planning to ensure inclusivity, as well as, capacity building of main users in these places. It therefore points to the question under which global rules and regulations, fair business models can be devised. Furthermore, how can the transitions community maintain a critical perspective on these Space-related opportunities? Will these emerging New Space dynamics essentially reinforce the current capitalist development patterns and ignore inequality? Or, how can we elaborate on the conditions for truly sustainable development trajectories building on these emerging opportunities?

iii) Understanding institutional conditions for a more sustainable Space sector

The above subsequently leads us to enquire the underlying conditions for a more sustainable Space sector in the future. Who should be responsible in ensuring sustainable development of the Space sector itself? Since the last decade the sustainability aspects of Space activities have gained increasing attention among intergovernmental and regulatory bodies, policy makers, and scientists, especially concerning emerging problems like Space debris. Among them, international agencies like UNOOSA, the European Space Agency and the World Economic Forum have been most active in driving the discourse of Space sustainability issues. For example, the UN Committee on the Peaceful Uses of Outer Space (COPUOS) has since the last decade called for the member states to formulate international agreements in addressing problems of Space congestion. These efforts have gained high resonance in media and public discourses. However, due to rapid technological advancements in satellite systems and increasing commercialization of the sector, the privatized Space activities have outpaced the progress made in regulatory changes, exacerbating the problem of Space debris.

[9] CubeSats: Tiny Payloads, Huge Benefits for Space Research. Retrieved from https://www.space.com/34324-cubesats.html

In conceptual terms, the recently proposed framework of global socio-technical regimes (Fuenfschilling & Binz, 2018) can be fruitfully applied to the recent developments in the Space sector. New actors, technologies and rules increasingly converge to form new socio-technical configurations. With increasing institutionalization of these configuration, we will therefore witness the “birth” of a new socio-technical regime, which will shape the developments for the decades to come. The emergent field of Space debris management may serve as an illustration for these dynamics: About a decade ago when the concern over Space sustainability first emerged, regulators, policy makers and scientists in the field were mainly debating about whether new technologies should be developed in order to tackle Space debris. Over time, actors in the field increasingly resonated with and accepted the idea of deploying new technologies into orbit to actively remove debris. In recent years, the main concern in the field has rather been on governance-related challenges, such as who should take over leadership in cleaning up the orbit, policy coordination, and reformulation of international Space regulations. Meanwhile, corresponding with ‘New Space’ dynamics, there has also been an increasing number of private organizations entering the business of Space debris cleaning while instigating the urgency of the problem. We may therefore expect continuous restructuration of the Space sector into the future, in which multiple actors and innovation activities emerge in response to its sustainability challenges (Mazzucato & Robinson, 2018; Robinson & Mazzucato, 2019).

iv) Protecting the orbit against the tragedy of the commons

The rapid development of the Space sector could also lead us to better understanding and assessing possible rebound effects of such developments in order to judge whether the recent Space sector actually lead to unsustainable transitions (*anonymized*) (J. Van Den Bergh, Truffer, & Kallis, 2011). Although the rapid advancement in the Space sector (e.g. lower costs for building satellites and launching rockets) enables a wide range of potential system transformations, new externalities such as soot emissions and Space debris become increasingly pertinent. Transitions studies offer useful analytical frameworks that could shed light on dealing with these challenges, especially through recent analyses of the destabilization or phasing-out of less sustainable regimes (Turnheim & Geels, 2013).

Dealing with the Space sector however require even more fundamental theorizing that balances the potentials for system transformations while dealing with rebound effects. More specifically, the issue of outer space congestion as a result of increasing private activities calls for an interdisciplinary engagement. As outer space becomes increasingly competed and congested due to a growing number of satellites and Space debris, the orbit has become a new kind of scarce resource (OECD, 2020). The scarcity of the orbit goes beyond just the physical room to place and maneuver these satellites. About 16,000 new satellites have been approved to be launched into orbit in this new decade, with tens of thousands more under application at the International Telecommunication Union in Geneva for Internet and telecommunications purposes (Greenbaum, 2020; Witze, 2020). In order for these telecommunications satellites to operate, they require access to radio frequency in the orbit, or more specifically known as the radio spectrum, which is essentially limited. In other words, the regulations and planning for the distribution of radio spectrum will determine which countries and corporations get how much access to the potential manifold Space-based benefits. Space-based competition over limited resources mirrors for instance the ongoing conflicts taking place in the Antarctic region, as there is no clear ownership of these places and so countries compete over resources below the sea ice (Byers, 2019; Naylor, Siegert, Dean, & Turchetti, 2008; Salazar, 2017).

In the context of these critical cases, international regulatory frameworks become all the more urgent in finding appropriate governance strategies for tackling the exploitation of limited resources and the distribution of global common interest (Biermann & Kim, 2020; Young, 2020). This requires transition studies to mobilize a more integrated approach between sociotechnical and socioecological perspectives as has been recently proposed by transition and environmental governance scholars (Ahlborg, Ruiz-Mercado, Molander, & Masera, 2019; Feola, 2015, 2020; Patterson et al., 2017; Smith & Stirling, 2010; Smith, Stirling, & Berkhout, 2005). Although new Space technologies may lead to multi-sectoral reconfigurations that are substantially more sustainable, these reconfiguration processes require just distribution of limited resources without destroying the natural environment. Otherwise, the potential benefits that Space activities can bring for sustainability may not realize and the orbital environment may eventually become a new polluted territory of humanity. These questions remain highly relevant as Space exploration and exploitation extend to farther places into the future, such as to the Moon, Mars and different asteroids (Jakhu et al., 2017; Lee-Myers & Chang, 2020). A core challenge is therefore to ensure sustainable development of the Space sector so that the Earth's orbital environment and beyond will not end up as yet another illustration of the tragedy of the commons (Ostrom, 1990, 2009).

4. Implications for policy and governance

Confronting the abovementioned challenges and opportunities will require new kinds of innovation policies to support the positive developments while preventing negative consequences in the course of the sector's contribution to the emerging techno-economic paradigm. A prominent example would be the need for new mission oriented Space policies. While studies show that Space agencies in recent years have increasingly adopted a decentralized innovation policy approach to enable rapid commercialization of the Space sector (Mazzucato & Robinson, 2018; Robinson & Mazzucato, 2019), the role of the state remains pertinent in steering the directionality of future Space activities. More specifically, the core challenge lies in more proactively shaping the sector's selection environment inspired by explicit sustainability informed visioning considering competing interests. This is very much along the lines of the emerging "third kind" of innovation policies identified by (Schot & Steinmüller, 2018). Since mission-oriented innovation policy frameworks have recently gained increasing attention in the field of transition studies (Hekkert, Janssen, Wesseling, & Negro, 2020; Wanzenböck, Wesseling, Frenken, Hekkert, & Weber, 2020), the Space sector could thus become an emblematic field in which these mission oriented research will be further developed.

To ensure sustainability of the orbital environment and socially just development of the sector, transition studies could more explicitly address the issue of governance by integrating perspectives from studies concerning broader sustainability issues. In particular, an engagement with environmental governance studies like the field of Earth System governance might potentially yield fruitful conceptual synergies (Patterson et al., 2017). This literature could complement transition studies with its explicit take on different architectural forms of (top-down but also bottom-up) governance in dealing with multi-dimensional environmental concerns (Biermann & Kim, 2020). In so doing, it provides a closer scrutiny to the role of formal and informal institutional arrangements in steering directionality. This literature furthermore adopts a more holistic view in dealing with different challenges of the Earth system, which is therefore more attentive to issues of 'problem shifting' (Biermann & Kim, 2020) – a challenge increasingly reckoned in the transitions community (Kim & van Asselt, 2016; Van Den Bergh, Folke, Polasky, Scheffer, & Steffen, 2015). This is especially relevant when dealing with the negative consequences of developments in the Space sector. Moreover, transition studies could extend its territorial boundary of analysis and derive new insights by drawing from existing environmental governance studies on 'areas beyond national jurisdiction' (Young, 2020). This line of work might bring high generalizability to other environmental and sustainability issues including, amongst others, obvious examples such as the deep seabed, Polar Regions, and the virtual world of Internet (Young, 2020).

Finally, the rapidly changing Space sector could inspire to push the research frontier of transition studies. The increasing role of large technological companies (e.g. Google and Amazon) in managing next-generation Space-based infrastructures might be reinforcing – if not exacerbating – distributional tensions in the capitalist economy (Mazzucato, 2021).[10] After five-decades, the old debate of 'the moon versus the ghetto' in innovation policy (R. Nelson, 1977, 2011) has recently been revived, but often only in a similar vein questioning why social and environmental challenges face more hurdles than 'moonshots'.[11] Given the recent unfolding of new dynamics in the Space sector, this article may therefore provide some inroads to innovation and transition studies for engaging with the emerging topic of Earth-Space sustainability.

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