SPACE GOV

SPACE SUSTAINABILITY AND GOVERNANCE
Mitigating Compounded Risks
through Foresight and Futures Methods

Policy Brief

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SPACE-Gov: Space Sustainability and Governance - Mitigating Compounded Risks through Foresight and Futures Methods Policy Brief 2023
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Abbreviations

ADR	Active Debris Removal
BPA	Bisphenol A
COPUOS	Committee on the Peaceful Uses of Outer Space
EO	Earth observations
ESA	European Space Agency
ESRIN	ESA Centre for Earth Observation
EVA	Extra-vehicular Activities
GHG	Greenhouse gases
ISS	International Space Station
LEO	Low Earth Orbit
OST	Outer Space Treaty
PCB	Printed Circuit Board
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RPO	Rendezvous and Proximity Operation
TRL	Technology Readiness Level
UNOOSA	United Nations Office for Outer Space Affairs
UN SDG	United Nations Sustainable Development Goals

Introduction

Our daily socio-economic activities are heavily reliant on the smooth and invisible functioning of the space infrastructure. While societies regularly turn to space solutions for navigation, communication, weather forecast, and climate modeling, there is a lack of awareness and discussions over the challenges and risks that the rapid growth of the space sector may bring. Several years ago, there were only around 2,000 operational satellites in orbit. Now, mega-constellations consisting of satellites in the thousands are regularly proposed. Additionally, over 50% of essential climate variables can only be measured from space.[1] In other words, until existing functions of space technologies can be fully replaced by new or future technologies, there is not a future where space technologies do not play a part.

The space sector is at a crossroads. In recent years, geopolitical conflicts, tensions and disagreements have ended some longstanding space partnerships. Surviving international co-operation, such as the International Space Station (ISS) – often seen as a beacon of hope transcending divide among humankind – faces growing uncertainty. With multilateralism under enormous pressure, new binding international instruments become increasingly difficult to conclude. At the same time, a shared understanding of rules and regulations are desperately needed in view of the exponential growth of space activities. Recent launch incidents, including those in Tanegashima, Cornwall, and French Guiana, put further pressure on the overall supply chain, reflecting Europe's reliance on commercial US launchers. These developments also show UK's and Europe's limited access to space after halting co-operation with Russia. Moreover, growing environmental demands stand in tension with space ambitions to diversify local and national economies by capturing shares of the growing space market, set to expand further with the Artemis programme led by the US.

Against the backdrop of the convergence of mounting political and institutional uncertainty, the SPACE-Gov project brought together technology and policy experts to explore potential risks, anticipate changes, and envision the long-term sustainable growth of the space sector. Built on research and intersectoral discussions, this policy brief captures key elements aimed to inform ongoing debates.

To explore further findings from SPACE-Gov, readers may find more materials complementary to this report at sites.exeter.ac.uk/spacegov

1 World Economic Forum, *Global Future Council on Space – Space for Net Zero White Paper,* September 2021. <https://www3.weforum.org/docs/WEF_Space_and_Net_Zero_2021.pdf>

Key Recommendations

Global Space Supply Chain

Major risks/ challenges explored:

The project identified vulnerabilities in the European space supply chain (e.g. materials) as a result of compounded risks caused by the pandemic and the recent war. Delays and recent launch incidents also put significant demand pressure on the European launch segment, leaving UK/European space actors with limited options to gain access to space.

Policy Recommendations:

At the local/ national/ European level

Expand recycling of metals and rare earth materials to ease regional demand.

Further support urban mining.

At the European level

Explore the potential of consolidating co-operation within the European space industry to reduce redundant efforts.

Conduct further research on the potential of interoperability in mission design to open up access to space options.

Space Sustainability

Major risks/ challenges explored:

Diverse approaches towards achieving (space) sustainability had led to policy ambiguity and complexity, preventing the consolidation of global, national and regional policy efforts. At the same time, the emergence of unintended policy externalities compounded risks faced by the space sector. A focus on incremental/"bolt-on" policy change left structural questions about the sustainability of major space business models underexamined.

Policy Recommendations:

General recommendation

Gradually unpack the concept of sustainability in major intersectoral forums. For example, by inviting speakers on a space sustainability panel to define the term before commencing discussions.

At the national/ European level:

Avoid policy silos. Equip staff with the ability to anticipate and assess (un)intended policy consequences, strengthen cross-sectoral and cross-disciplinary exchanges between policy and technology stakeholders, and between academia, industry, and governments.

Advance a more co-ordinated policy approach across cognate fields/ related issue-domains. At the national level, actionable measures could include dedicated hours set aside for short-term secondment, and/or attendance at meetings/ conferences in related/ cognate fields.

Support a diversity of R&D activities towards making the space industry more sustainable. (e.g. satellites constructed with non-toxic substances)

Explore the potential of creating a repairing/ recycling/refuelling segment to complement existing space sustainability efforts (e.g. ADR). At the national level, pilot funding mechanism similar to ESA Open Space Innovation Platform to encourage ambitious research aimed to address structural sustainability challenges. Engage external reviewers (e.g. experts from ESA, JAXA, NASA) to ensure bold and fresh ideas are not disadvantaged in the review process.

Global Space Governance

Major risks/ challenges explored:

SPACE-Gov identified the gradual but escalating tensions in the space domain. The deterioriation of relationships among major space powers bring extra risks to past and ongoing space activities (e.g. ISS, co-ordination of moon-bound efforts). Rapid commercialisation of space activities outpaced the formation of international guiding rules, norms, and practices. Moreover, the inspirational element of space ambition is increasingly being questioned given recent deterioriation in previously established space partnerships. The sector also has much to improve with regard to inclusivity and diversity. All of these converge to weaken the appeal of future space endeavours against the backdrop of competing global priorities (e.g. climate change, extreme weather, inequality, etc)

Policy Recommendations:

General recommendations

Effectively communicate space-derived benefits.

Further utilise existing international mechanisms and avenues to discuss differences between mmajor space powers along with non-state and non-spacefaring stakeholders. If regional/group-based norms and rules are being advanced, ensure that relevant space stakeholders are informed, or consulted.

Integrate a multi-sensorial approach to enhance safety of space missions, strengthen space science and activities, and to engage and enthuse a community of individuals of diverse abilities and backgrounds.

I
The Global Space Supply Chain

Strengthening Supply Chain Resilience through European Co-operation

The space sector spans multiple areas of technological, industrial, and commercial developments. From raw materials to manufacturing; commissioning the development of products to launch; and from ground-control and maintenance to the processing of space data, the sector has seen increasing uncertainty and volatility in every step of the space asset's life cycle.

In the European context, there is a hope that more resilience could be built to strengthen the space supply chain. This would include more robust supplies *from sourcing materials to launch capability.*

Space Materials

The European space sector relies considerably on specific raw and processed materials which may not be easily sourced regionally. Following the pandemic, some materials sourced from outside the European Union (EU) (e.g. specialist adhesive such as low outgassing silicone used for PCBs[2]) suffered an increase in lead time of up to a year, which could not be anticipated by industry when the procurement was planned. This results in either prolonged delays or costly verification of the suitability of other candidates under time pressure. Moreover, metals, such as titanium and aluminum, and rare earth materials face increasing international demands as the global space industry expands. Demands are further compounded as other sectors and infrastructure (e.g. telecommunications) also rely on some of these materials. As global geopolitical tensions deteriorate, Europe needs to rely on an "alliance-based" supply chain. This means that instead of sourcing internationally, Europe could only procure from a limited pool of suppliers (e.g. cannot source from sanctioned countries). This adds another layer of pressure given ongoing disruptions caused by the pandemic and the war in Ukraine.[3]

Two recommendations can be identified to relieve the stress on the supply chain. First, recycling initiatives for sought-after materials (e.g. aluminum) could be expanded. Here, urban mining could potentially play a key role in easing pressure on supply. For example, recycling aluminum consumes only 5% of the energy needed to produce it from raw materials.[4] Second, co-operation within the European space industry could be strengthened to ensure the sector's demands are met and to reduce redundant efforts. The latter is a more difficult proposition to advance. As an established industry, the balance between competition and co-operation, including those internal to a regional market (i.e. within Europe or North America), could be a delicate one to strike. While redundant efforts put further pressure on the supply chain, a lack of competition could also significantly hinder innovation. Taking into account competition with other established and emerging space actors (e.g. US, China, India) for resources, a healthy balance of competition and co-operation within Europe could ease pressure on limited and sought-after materials. In specific instances, there is the recognition that more *collaborations within the European space industry could potentially yield a more desirable result than competition between European suppliers.* A consolidation of necessary knowledge-sharing across Europe could help strengthen robustness of the European supply chain, avoiding unnecessary redundant efforts. It could add to enhanced knowledge continuity within European companies and institutions, reducing cost and over-reliance on foreign supplies (e.g. US).

Discussions on space supply chain often focus on physical/hardware supplies.

2 Printed Circuit Board

3 Lilia Alaieva, "The war led to a shortage of Rare Earth Elements for the space industry," *Universe Space Tech*, 28 August 2022. <https://universemagazine.com/en/the-war-led-to-a-shortage-of-rare-earth-elements-for-the-space-industry/>

4 Subodh K. Das and Weimin Yin, "The Worldwide Aluminum Economy: The Current State of the Industry," *JOM: The Journal of The Minerals, Metals & Materials Society*, 59, 57-63, 2007. <https://doi.org/10.1007/s11837-007-0142-0>

Existing practices seem to be able to absorb significant delays in these segments, with the understanding that satellite missions could often be delayed for years.[5] However, deliberation at SPACE-Gov identified that the digital/ downstream segments could also face vulnerability not often explored. Disruptions to storing, archiving, processing, and co-ordinating downlinked space data could also present significant risk to the delivery of space-based services/ products. With the main hub of Earth Observation (EO) interface – ESRIN – located in Southern Italy, it was pointed out that the surrounding regions had in the past experienced earthquakes (e.g. Montagano in 2023[6], Croatia in 2020). Although these incidents were not catastrophic-level event (e.g. Fukushima), they nevertheless warrant further examination to identify potential mitigation measures. To mitigate such risk, it was pointed out that other ESA centres could be prepared to serve as redundancy centres to manage and co-ordinate EO-related activities.

Access to Space

Aiming for Normalised and Regular Access to Space for All

There have also been repeated references to the importance of normalised access to space – often interpreted as having access to delivering and installing payloads in orbits via launches.

The launcher segment is considered a crucial part of the broader space supply chain, and it is believed that normalising access to space could open up more business opportunities, enable new markets, bringing more space-derived benefits to societies.

In recent years, there have been considerable advances in both vertical and horizontal launch technologies. SpaceX's Starship, once tested and successful, is envisioned to significantly bring down the cost of installing satellites in orbits.[7] In spite of these advances, however, the UK and European space sectors currently have very limited options to launch a payload. This is due to the unlikely convergence of several unfavourable scenarios, including a frosting relationship with Russia, and recent delays and launch incidents with ESA's new launchers.

Innovation is particularly challenging for space segments such as launchers and manufacturing – segments that are traditionally built on redundancy and heritage. This segment employs only the most tried-and-tested technologies with the highest Technology Readiness Level (TRL). Most recently, successive incidents with Europe's new micro-launchers - Vega-C - had significantly delayed ESA's launch schedule. This development occurred in an ill-opportune time, coming after the delayed delivery of Ariane 6 - ESA's next generation of heavy-lift launcher - and after co-operation with Russia to launch Soyuz from French Guiana had halted.[8] [9]

This has left Europe with no short-term launch solutions but to turn to US-based launchers (i.e. SpaceX). While efforts to gain regular access to space are evident in the original plan of combining Soyuz, Vega and Ariane models to launch at French Guiana, recent incidents and the ongoing war still rendered Europe with limited immediate launch options.

The growing backlog of payloads waiting to be launched raises other concerns. Satellites due to launch may not be designed to endure a long period of storage. The storage premises would need to be maintained to a high standard to avoid payload contamination and degradation, incurring considerable

5 For example, the launch of James Webb Space Telescope has been delayed for over 7 years. See U.S. Government Accountability Office, "James Webb Space Telescope: Project Nearing Completion, but Work to Resolve Challenges Continues," *GAO Reports & Testimonies,* 13 May 2021. <https://www.gao.gov/products/gao-21-406>

6 See Reuters, "Magnitude 4.6 quake strikes Southern Italy region," *Reuters Environment*, 29 March 2023. <https://www.reuters.com/business/environment/magnitude-54-earthquake-strikes-southern-italy-region-emsc-2023-03-28/ >

7 Adam Mann, "Despite test failure, Starships posied to transform space science," *Science*, 20 April 2023. <https://www.science.org/content/article/despite-test-flight-failure-starship-poised-transform-space-science>

8 Guillaume Reuge, Mathieu Rabechault, and Juliette Collen, "Vega-C rocket lost after lift-off in Europe space setback," *PHYS.org*, 21 December 2022. <https://phys.org/news/2022-12-vega-c-rocket-lost-shortly-lift-off.html>

9 Leonardo David, "Russia's War in Ukraine Threatens Joint Missions to Mars, Venus and the Moon – Interplanetary voyages are among several space science collaborations delayed or doomed by the ongoing conflict," *Scientific American*, 11 March 2022. <https://www.scientificamerican.com/article/russias-war-in-ukraine-threatens-joint-missions-to-mars-venus-and-the-moon/>

costs. Payload designed for deep space[10] destinations are additionally constrained by launch windows. Such launches would need to take into account orbital alignment. In the case of ExoMars - designed to explore Mars - missing a launch window means years of delay before the next launch window opens.[11] In the meantime, in addition to payload degradation/ contamination, technologies employed could become obsolete as more recent innovation emerge.

If launch options are not diversified soon as global geopolitical tensions worsen, there are concerns over the emergent risk of access to space becoming *de facto* monopolised by a limited number of actors.

Risky Business?

Various initiatives to achieve launch capability in Europe (e.g. Cornwall, Shetland, and ESA Boost) echo the broader ambition in Europe to diversify and establish normalised access to space. While the earlier launch from Cornwall did not reach the altitude it envisioned, the launch demonstrated the potential that horizontal launch could bring. Virgin Orbit's launch also prompted reflections on our broader attitude towards risks. The company was unable to secure further investors and had to cease operations shortly after the January launch. Actors in dominant space economies like the US, however, are able to absorb a significant amount of risk. Consider the case of SpaceX, which was able to secure further funding despite three initial failures.[12] In the case of Virgin Orbit, however, neither institutional nor private investment seemed to be ready to absorb the amount of risks associated with the early stages of launch activities. Locally and nationally in the UK, it is difficult for institutional entities to take on the level of risk that launch initiatives usually require.

10 Usually considered as missions set for the moon and beyond.

11 Jamie Carter, "Mars Alert: Why Three Spacecraft Must Leave For The Red Planet Within Weeks or Miss Their Chance," *Forbes*, 8 July 2020. <https://www.forbes.com/sites/jamiecartereurope/2020/07/08/mars-alert-why-three-spacecraft-must-leave-for-the-red-planet-within-days-or-miss-their-chance/ >

12 Tom Huddleston Jr., "Elon Musk has worried about SpaceX bankruptcy before – early on he thought it would be 'worth $0," *CNBC Power Players*, 30 November 2021. <https://www.cnbc.com/2021/11/30/elon-musk-warning-not-first-time-spacex-has-risked-bankruptcy.html>

Space is Different, Space is Hard

Space as a sector above disagreements

Two recommendations could potentially address the above challenge. First, given the demanding task of launching into orbit, there was the suggestion for the international community to consider setting aside space as a topic that allows for international co-operation regardless of political differences. The ISS and past launch co-operation between the US, Europe, and Russia have long been considered examples of shared space ambition trumping political rivalry. One possibility is to isolate space endeavours from other geopolitical disagreements, to detach it from potential issue-linkage in negotiations. At the same time, it is critically important to signal a firm stance against behaviours that jeopardise global peace and security. While there is recognition that the ongoing war rendered it extremely difficult to engage in collaborative dialogue, there is also the longer-term hope that the next major international space endeavour should be truly international in nature, involving all major and emerging spacefaring powers. There is the general hope that space remains a collaborative and peaceful domain, rather than a confrontational one, and that future political disagreements are not escalated into the militarisation/ weaponization of space activities.

Second, establishing interoperability and payload standards could potentially help mitigate risks in securing more access to space options. Currently, larger satellites are usually designed to fit specifically into a designated launch vehicle. Significant cost will be incurred if the payload needs to be adapted to the specification of another launcher. Given the higher risk nature of launch activities, developing standards and interoperability from the conceptual stage of satellite design could potentially open up more launch and commercialisation options.

Section summary

Risks explored

Mounting pressures on sourcing raw and processed materials.

Access to space becomes limited/ restricted/ nationalised/ monopolised.

Causes

Increased global competitions for raw and processed materials.

Limited pool of “alliance-based” suppliers due to the deterioration of geopolitical tensions. Recent launch incidents created a backlog of payload to be launched.

Geopolitical developments removed access to space options (e.g. via Soyuz).

Limitations in risk-taking of institutional and private investment further restrict the prospect of diversifying and experimenting new launch solutions.

Recommendations
Expand recycling, reclamation and urban mining initiatives.

Strengthen co-operation in the European space industry.

Balance competition with co-operation to avoid unnecessary redundant efforts that add to supply chain pressure.

Conduct further research on the potential of interoperability in mission design to open up access to space options.

II
Space Sustainability at a Crossroads

Coinciding with the gradual momentum that the UN Sustainable Development Goals (SDGs) garnered, there have been increasing references to sustainability in the space sector. In the space context, definitions of sustainability vary. Discussions at SPACE-Gov revealed concerns over how diverse interpretations on space sustainability could lead to policy ambiguity and complexity, adding to unintended impact on the space economy.

Surveying ongoing debates, major interpretations on space sustainability include but are not limited to the following:

1. Space for Sustainability
Using space technologies to ensure environmental sustainability on Earth, limiting the negative impact that human activities have on the environment. For example, using EO data for climate modeling and the monitoring of deforestation.

2. Sustainable Sharing of Common Pool of Resources/ Global Commons
Ensuring the sustainable use of finite, depletable space resources such as orbital slots and radio frequency, as well as co-ordinating *space traffic* and limiting the impact of *space debris*.

3. Sustaining the Space Economy
Sustaining commerical and economic activities in the space industry, such as creating economic opportunities to pursue moon-bound endeavours, avoiding decades-long hiatus of under-development/ under-investment in certain segments of the space economy[13].

4. Life Cycle Assessment and Sustainable Space Business Models
Evaluating the impact and implications of the full life cycle of planning, developing, launching, using, and disposing of satellites, including assessing the impact of new space sustainability practices, which will see an exponential number of satellites deorbited by burning up in the atmosphere.[14] Developing alternative satellite models, such as wooden satellites, and building models whereby future satellites can be repairable, refuellable, recyclable, and removable.

5. Space for UN SDGs
Using space technologies to deliver and implement the 17 UN Sustainable Development Goals (SDGs), which include promoting gender equality, climate action, reducing inequality, and more.

Everything, Everywhere, All at Once

Solving Legacy, Present and Future problems with Policies

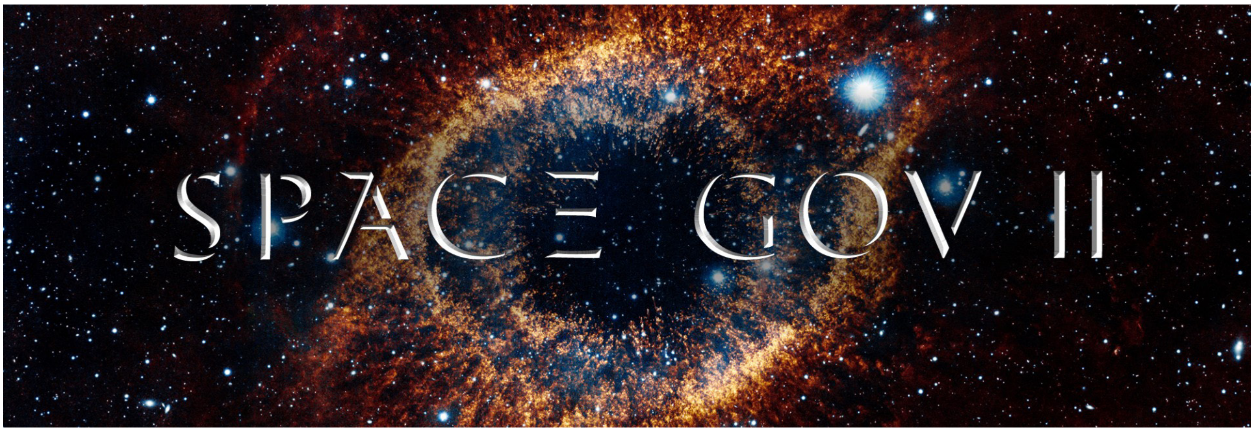
While many of these interpretations overlap (e.g. climate modeling efforts could be included in the broader UN SDGs initiative), they all have a different focus. However, many of these diverging understandings of space sustainability share a common consideration for developments that go beyond the present and stretch into future horizon. Some take into account the benefits of future generations, while others describe aspirations that go beyond decades (e.g. the UN SDG has the ambition to see its goals implemented by 2030). Some interpretations focus on solving legacy problems (e.g. existing space debris, climate change, plastics in the ocean), while others are forward-looking and anticipate imminent developments (e.g. space traffic congestion, the need for advances in collision avoidance manoeuvres). These point to some tensions in driving policies at multiple governance levels to advance overall space sustainability.

13 Panel discussion on "Bringing Connectivity to the Moon and Beyond," *ESA SPACE2Connect Conference*, Matera, Italy. 7 June 2023. <https://space2connect.esa.int/#content-speakers>

14 The burn-up process could release toxic and other substances that could induce ozone depletion and modify the radiative balance of the atmosphere. See ESA, "On the atmospheric impact of spacecraft demise upon reentry," *ESA Cleanspace blog*, 11 August 2022. <https://blogs.esa.int/cleanspace/2022/08/11/on-the-atmospheric-impact-of-spacecraft-demise-upon-reentry/>


SPACE GOV


SPACE GOV I


SPACE GOV II


SPACE GOV III

Scenario

Unexpected Regulatory Externalities

The Many Roads to Space Sustainability

It is often difficult to simultaneously evaluate intended and unintended consequences of policies developed to solve a specific problem.[15] Given numerous global, national, and local priorities that need to be addressed at the same time, it was pointed out that regulations targeting non-space domains (mainly on regulating commercial industries to protect consumers and citizens) could have major implications for the space sector. For example, according to the World Economic Forum, over 50% of climate variables essential for climate modeling can only be measured from space.[16] This suggests that there are currently no alternatives that can fully replace space data in the course of moving towards net zero. At the same time, the immediate need to combat climate change by reducing carbon and greenhouse gas (GHG) emission at times stands at odds with space activities, including activities designed to ensure sustainability on Earth, such as utilising EO data for climate monitoring and for early warning for disasters. With increasing regulations and legislations introduced at multiple governance levels to advance green futures, these developments could put further compounded pressure on the space sector – a sector already subjected to long design lead time and vulnerable to numerous risks.

One specific example on chemical regulations highlights potential unexpected consequences that legislations in seemingly non-related areas could bring. Recently proprosed chemical regulations in Europe (i.e. REACH) puts further limits on using substances such as BPA[17] and PFAS[18]. While it is recognised that some of these substances can be harmful for people or the environment, and would need to be regulated/banned, they are often present in specialist materials (e.g. PCBs, insulation, thermal control materials, adhesives, etc) essential for the space sector. These legislations may be beneficial for the community in the long run. Nevertheless, they may inadvertently affect the competitiveness of the European space industry, which heavily relies on previous heritage, requiring very specific materials and processes that can withstand the harsh environments in outer space.

One way to address this is to advance research to develop new materials without prohibited substances. However, this is expected to take time and resources, and cannot provide an immediate solution if there are no readily substitutable products. Alternatively, a derogation can be secured to continue using the restricted/ regulated substances in space activities, as has been done in the past. Nevertheless, a chemical ban can fundamentally change market supply and demand. In scenarios where the demand comes only or mainly from the space sector, the price of the product exempted for uses in space efforts could go up significantly. This could add to pressure on the supply chain, making it impossible or extremely difficult to source the specialist product in Europe (as suppliers may not be able to sustain production to provide for such a niche market). This in turn would mean further reliance on external import from a pool of alliance-based suppliers, leading to what is colloquially known as “the space price”. This would make space efforts more expensive, rendering it harder for space-derived benefits to justify the socio-economic and environmental cost of each satellite. While the above two options of diversifying R&D activities and seeking a derogation are not mutually exclusive, if the legislation outpaces breakthroughs in developing new non-toxic substitute materials, it could render the European space industry less competitive.

15 One example would be the heated debate on the potential ban of single-use plastic straws. It was argued that the ban policy neglected and failed to engage people with disabilities. A universal ban could disproportionately affect individuals who may benefit from the usage of plastic straws, products which often have no equivalent substitutes for individuals with special needs. While an exemption could be introduced, a ban could potentially change the economics of supply and demand, affecting the affordability of certain materials and products for those who genuinely need them.
See Erin Valley, “Grasping at Straws: The Ableism of the Straw Ban,” *Center for Disability Rights,* <https://cdrnys.org/blog/disability-dialogue/grasping-at-straws-the-ableism-of-the-straw-ban/>*;*
CBC, “Why banning plastic straws can be harmful for people with disabilities,” *CBC Radio, 18 July 2018.* <*https://www.cbc.ca/radio/asithappens/as-it-happens-wednesday-edition-1.4751691/why-banning-plastic-straws-can-be-harmful-for-people-with-disabilities-1.4751697*>

16 World Economic Forum, *Global Future Council on Space – Space for Net Zero White Paper*, September 2021. <https://www3.weforum.org/docs/WEF_Space_and_Net_Zero_2021.pdf>

17 Bisphenol A

18 Perfluoroalkyl and Polyfluoroalkyl Substances

The above case highlights the danger of regulatory silos, where issue-specific regulations are developed without due considerations for (unintended) consequences in other issue-domains. Often, a legislation relatively limited in scope could be interpreted differently when the definitions were not fully clarified across various issue-domains that it affects. Sustainability is one such term that could pose further challenges to the space sector.

A lack of co-ordination and comprehensive approach in policy-making at multiple governance levels could lead to major unintended consequences. An isolated problem would be identified, a narrow policy would then be introduced to address the problem, often without significant consideration for the policy's wider implications. This creates what may be described as the *"Bolt-On"* phenomenon in policy-making, with an increasing number of rules introduced to address various narrower aspects of a wider problem (e.g. carbon offsetting, chemical banning with potential derogation). These regulatory initiatives are necessary, and do lead to positive impact and behavioural changes. The concerns come when other more structural and systemic aspects of the problem remain underexplored. In the domain of space, while Active Debris Removal (ADR) has garnered considerable support in recent years, other more holistic approaches to advancing space sustainability remain behind in terms of research, funding and securing policy buy-in (e.g. universal docking and rendezvous standards[19], refuellable and repairable satellites by design).

Compared to other established technology industries, such as the aviation and automobile industries, the space sector is surprisingly behind in developing a servicing and maintenance segment. Most satellites today are still not designed to be refuellable, repairable, or recyclable. Major space sustainability/servicing initiatives today evolve around deorbiting activities, namely, moving the defunct satellite to a graveyard orbit, or to bring it down to be burned up in the atmosphere. This development may be in part linked to approaches that favour *sustaining* current space business models, either through commissioning new satellites, or through launching bigger constellations with cheaper satellites.

Instead of concentrating on more "bolt-on" measures (e.g. competing deorbiting designs which saw the proliferation of docking standards), exploration in turning the satellite industry into a circular economy warrants further support, research, and investigation. Given limited space resources (orbital slots, spectrum) and raw materials on Earth, ambitious research aimed at repairing, refuelling, and recycling satellites could provide longer-term answers to both supply-chain and space sustainability concerns.

Section summary

Risks identified

Diverging/ competing interpretations of sustainability led to policy ambiguity/ complexity.

Preferences for incremental/"bolt-on" approaches to problem-solving limit potential to create a sustainable space business model.

Causes

Policy silos mean intended and unintended consequences are not fully explored.

Lack of cross-departmental and cross-sectoral exchanges limit potential for a comprehensive and co-ordinated multi-level policy approach.

Recommendations

Clarify departmental/unit-based defintions of sustainability. Invite stakeholders to identify aspect(s) of sustainability they focus on at public or major forums.

Avoid policy silos by creating opportunities for cross-departmental/cross-sectoral knowledge transfer. For example, by setting aside certain hours to encourage staff/academics to attend events/ meetings in cognate fields/units.

Advance R&D in technologies to complement ADR developments. For example, by supporting complementary R&D in advancing new type of servicing economy for the satellite industry.

19 Also known as standards for Rendezvous and Proximity Operation (RPO).

III
Global Space Governance

Towards A More Responsible and Inclusive Space Future

Many challenges identified above would require global concerted efforts to resolve. Some of the challenges can be solved through technical solutions, and could be resolved with technological advances and innovation. (e.g. space debris removal, in-orbit servicing, RPO technologies) Others, such as the co-ordination of satellite traffic and the sharing of spectrum and other space resources, require governmental commitments to develop and adhere to shared rules, guidelines, and policies. Equally important, for space to continue to inspire, enthuse, and to be a unifying ambition amidst a widening gap of differences in societies, a more inclusive approach is imperative in envisioning our space future. This section explores scenarios of crises, but also of opportunities, that could shape shared norms, practices, and rules to a better co-ordinated, more responsible and inclusive future for space activities.

The Outer Space Treaty & Overcoming Differences

At the global level, international agreements and other binding instruments can signal a strong commitment from the global community to adhere to shared rules of the game. At the peak of the Cold War, space was the topic that opened up discussions of common ground when there were disagreements over most other areas between rivaling states.[20] Over half a century old, the Outer Space Treaty (OST) has long been the cornerstone of past and ongoing global space governance efforts. The increase of commercial actors, particularly in the LEO constellations segment, has put the OST and associated international legal instruments to the test, with some calling for them to be amended, adjusted, or updated. There have also been new ideas to include commercial actors in international policy-making forums. However, it may be advisable for existing instruments to remain unchanged, as these machineries were forged through decades-long negotiations. Existing international forums, such as the Committee on the Peaceful Uses of Outer Space (COPUOS), continue to serve as an anchor for diplomatic dialogue in spite of political divergence. As global geopolitical tensions worsen and alliance-based endeavours such as the Artemis rapidly advance, UN forums remain one of the few, if not the only avenue where all voices, *including those from the Global South and non-spacefaring countries*, could be engaged.

New risks to space infrastructure could come from both intentional behaviours (e.g. anti-satellite tests, weaponisation), and unintentional incidents (e.g. accidental collisions that may be misinterpreted as malice). For the former, diplomatic dialogue could be key in de-escalating tensions, avoiding the inadvertent misinterpretation of intents, and in co-ordinating information sharing in less severe cases (e.g. in alerting others of the upcoming tests). This would be especially pertinent in instances when diplomatic relationships are frosted.

While decision-making at the UN remains with sovereign member states, it should be noted that there are mechanisms where civil society and industry could also be engaged. Additionally, there are also structures in place (e.g. working groups) which enable emerging topics and new guidelines to be discussed and explored (e.g. Long-term Sustainability of Outer Space Activities[21]).

Scenario
Crisis As Opportunity
Reassessing Spectrum Allocation

The exponential growth of space activities, particularly the deployment of LEO mega-constellations, not only increases the risks of collisions, it also puts unprecedented pressure on spectrum sharing. International co-ordination in spectrum sharing traces back to the early 20th century. However, recent developments saw more and more LEO

20 Nikita Chiu, “Orbis non sufficit – Co-operation and Discord in Global Space and Disarmament Governance,” *The Hague Journal of Diplomacy,* Vol. 18: Issue 2-3, 2023. <https://doi.org/10.1163/1871191x-bja10164>

21 United Nations Office for Outer Space Affairs, “Long-term Sustainability of Outer Space Activities,” *UNOOSA Capacity Building Activities.* <https://www.unoosa.org/oosa/en/ourwork/topics/long-term-sustainability-of-outer-space-activities.html>

constellations proposed, rendering the need to mitigate interference and spectrum competition all the more imminent. Furthermore, recent developments revealed the additional exposure to financial risk that new space actors face. New space actors are increasingly turning to a mixture of institutional and private investment for support (e.g. with some investments from venture capital). Space start-ups often face pressure to fulfil ongoing needs to raise funds. With recent examples of space ventures falling into administration/ bankruptcy, there was the concern that emerging mega-constellations could fail, not technically, but commercially or financially. A scenario was identified in which the financing risk outweighs the technological risk. In this scenario, it was envisioned that satellites already in orbit were able to gradually deorbit successfully, posing no threat to other satellites and constellations in operation. While this scenario may be seen as a major crisis to the constellation's investors and business stakeholders, it was pointed out that it could also present an opportunity to liberate the frequency spectrum, opening up opportunities for late comers to utilise the freed-up resources.

The above scenario sees the silver lining in a crisis situation. As multilateralism faces mounting pressure, there was the fear that it may take a catastrophic event for the international community to put aside their differences to work together constructively.

It should be noted, however, that some negative developments, such as the Kessler syndrome, are irreversible. To mitigate such irreversible risk, and to avoid the situation further deteriorates into a "Wild West" scenario, the space community would benefit from being proactive in shaping and developing responsible behaviours for present and future space activities. Ideally, this would be an inclusive process, involving all major and emerging space actors.

With Artemis gathering increasing momentum, it was suggested that moon-bound efforts could be a major area of international co-operation, establishing shared norms, rules, regulations, and standards – all necessary in advancing the US-led endeavour. In a time when the next truly international space project (e.g. one which includes all major spacefaring countries) is unlikely to materialise in the near horizon, it was noted that an alliance-based collaborative initiative may be one of the few immediately feasible options to advance a more co-ordinated approach to space.

Keeping Space Inspirational

Advancing a multi-sensorial approach to strengthen space activities and research

Deliberation at SPACE-Gov also raised some challenging questions about the inspirational aspect of space. While many consider space to be a uniquely inspirational domain, with the potential to unify differences, this should not be taken for granted. As the space industry expands, it will draw more attention and vocal criticism. There is thus a need to more effectively communicate space-derived benefits, including providing connectiviity to remote regions, climate monitoring, and more. Additionally, it would also be important to be more transparent about the carbon footprint of the space sector.

With growing political divergence and tensions with other pressing global priorities, such as combating climate change and inequality, there has been mounting call for future space endeavours to be more inclusive to reflect the values that it seeks to inspire. Space exploration – one of the most expensive segments of the wider space ecosystem – is under mounting scrutiny to ensure greater representation of society.

To keep space inspirational, there was the recognition that future space activities need to be more inclusive. The recent announcement of John McFall as the world's first-ever parastronaut is a promising step. However, there remains significant room to improve in enhancing inclusivity and diversity in the space sector. Discussions at SPACE-Gov highlighted the importance of engaging individuals from different backgrounds and of diverse abilities to contribute to future uses and developments of space technologies and research. One desired future explored involves the full integration of a multi-sensorial approach to produce more detailed scientific discoveries, which will enable societies to engage in space-related activities and research through multiple sensory input/output, including but not limited to visual, sonic, and tactile elements. Current space science and technology relies heavily on a mono-sensorial approach (i.e. visual), neglecting the potential that other sensorial research (e.g. through analysing sonified space data) could bring to space science and the wider space economy. Multi-sensorial efforts have already contributed greatly to outreach and educational engagement, enthusing continuous public support to major space efforts (e.g. sonification of data from James Webb Telescope and Aeolus).[22 23] They could present great potential in propelling the space sector forward.

Experiences from past astronauts point to the potential benefits of employing a multi-sensorial approach. Given the harsh environment of outer space, human mobility and sensory reception are often reduced in a micro-gravity environment. Both Chris Hadfield and Luca Parmitano had reported that they had experienced temporary blindness at critical moments during extra-vehicular activities (EVA).[24 25] In both cases, they had to turn to utilise their other non-visual senses to return to safety. These incidents suggest that integrating a multi-sensorial approach could actually strengthen safety and security of major space activities. Thus, contributions from individuals with diverse abilities are not only important for a more diverse space workforce, they also have the potential to add significantly to space science, enhancing safety and mitigating risk for missions that are to be carried out in a high-risk environment.

Section summary

Risks explored

Growing geopolitical tensions led to heightened risks of conflicts and competitions escalated to the space domain.

Space ceases to unify or inspire.

Causes

Expansion of the space sector attracts more attention and public scrutiny.

Lack of progress in developing shared rules, norms, and practices led to the conclusion that constructive co-operation can only emerge after catastrophic events.

Lack of representation in the space sector, coupled with worsening space competition, rendered space no longer an inspirational topic.

Recommendations

Enhance transparency of the impact (e.g. carbon footprint) of the space sector, and ensure effective communication of space-derived benefits.

Prioritise multilateral avenues to engage diverging voices to resolve differences, including non-dominant space powers and non-state stakeholders. International dialogue needs to continue to prevent and avert irreversible catastrophic events. (e.g. orbital collapse)

Support and employ a multi-sensorial approach to enhance space science and to engage the wider community.

22 NASA, NASA Webb's First Full-Color Images, Data Are Set to Sound, *NASA Webb Telescope*, 31 August 2022. <https://www.nasa.gov/feature/goddard/2022/nasa-webb-s-first-full-color-images-data-are-set-to-sound>

23 ESA, "The sound of Aeolus will blow you away," *ESA Applications*, 14 July 2023. <https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Aeolus/The_sound_of_Aeolus_will_blow_you_away>

24 Jennifer Welsh, "Astronaut Chris Hadfield Describes Being Blinded During a Space Walk," *Business Insider,* 18 March 2014. <https://www.businessinsider.com/astronaut-chris-hadfield-ted-talk-blind-spacewalk-2014-3?r=US&IR=T>

25 Luca Parmitano, "EVA 23: Exploring the Frontier," *ESA blogs*, 20 August 2013. <https://blogs.esa.int/luca-parmitano/2013/08/20/eva-23-exploring-the-frontier/>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