OECD publishing

HARNESSING "NEW SPACE" FOR SUSTAINABLE GROWTH OF THE SPACE ECONOMY

Report prepared for 4th edition of the G20 Space Leaders' Meeting under India's G20 Presidency

BENGALURU, INDIA
6-7 JULY 2023

OECD
BETTER POLICIES FOR BETTER LIVES

This document was prepared by the Organisation for Economic Co-operation and Development's Space Forum (the OECD Space Forum) in the Directorate for Science, Technology and Innovation.

It represents an input for discussions at the fourth edition of the G20 Space Economy Leaders' Meeting (SELM), organised on 6-7 July 2023 in Bengaluru, India. The document benefited from comments and original inputs from Steering Group Members of the OECD Space Forum.

The OECD Space Forum's aim is to improve the measurement of the space economy and its broader impacts, in order to help countries formulate better evidence-based policy analysis. The Secretariat wishes to acknowledge the sustained support provided by the organisations forming the OECD Space Forum's Steering Group: The Canadian Space Agency (CSA), Canada; Centre national d'études spatiales (CNES), France; Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany; Agenzia Spaziale Italiana (ASI), Italy; the Korea Aerospace Research Institute (KARI), Korea; the Netherlands Space Office, the Netherlands; the Norwegian Space Agency and the Ministry of Trade, Industry and Fisheries, Norway; the Swiss Space Office, Switzerland; the UK Space Agency, United Kingdom; the National Aeronautics and Space Administration (NASA), United States; and the European Space Agency (ESA).

The arguments employed herein do not necessarily represent the official views of the member countries of the OECD or the G20.

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Photo credits: Cover © Anton Balazh/Shutterstock.

© OECD 2023

The use of this work, whether digital or print, is governed by the Terms and Conditions to be found at http://www.oecd.org/termsandconditions.

Key findings

- The space sector is undergoing a transformation known as “new space”. This phenomenon began about 15 years ago, but it has gained significant momentum in the last couple of years. This major shift is due to several factors: the emergence of new space technologies such as small satellites, lean manufacturing processes, billionaires from tech companies investing in space projects and paving the way for more private investment, advances in computing power and digitalisation leading to new space applications, and eventually key policy decisions to support the development of a new ecosystem of commercial space actors.
- “New space” is characterised by new commercial actors who are introducing innovative industrial practices and funding strategies to the space sector. This has led to a reduction in the cost of access to space technologies and has fostered further space innovation. In just over a decade, “new space” actors have had a major impact on the global space sector, providing disruptive new offerings in space manufacturing and operations, launch services, as well as in specific applications such as earth observation and satellite communications. Following suit, long-term industrial incumbents involved in space activities for decades have also taken up many of the “new space” innovation models.
- This has led to a more intensive use of orbital resources, with higher launch activity and many more operational satellites on orbit. It has also democratised space access around the world with many governments supporting the development of national space capabilities, better distributing the benefits of space technologies and further improving conditions for innovation.
- But increasingly, there are concerns about the sustainability of this growth. Increases in launch activity are associated with a worrying increase in orbital debris, which could (in a worst-case scenario), disrupt orbits of high socio-economic value. Furthermore, the vitality of the “new space” ecosystem is fragile to economic shocks and market entrenchment.
- To sustain the positive aspects of the “new space” ecosystem, governments are encouraged to assess their regulatory and procurement systems to facilitate market entry, as well as their support systems for young and small actors, which are more heavily affected by economic shocks than established firms. Finally, multi-actor collaboration and partnerships are needed to solve mutual challenges such as the long-term stability of a crowded orbital environment.

Table of contents

A tentative definition of “new space” 6
What is “new space”? 6
The growth of the “new space” ecosystem 7
Policy implications of “new space” 8
Increased demand for orbital slots and other space resources 8
Better distribution of the benefits of space exploitation 9
Challenges to future growth 11
Growing concerns about the environmental sustainability of space activities 11
The vitality of the “new space” ecosystem is at risk 11
“New space” business models face multiple technological, market and regulatory risks 12
Policy options for sustained and sustainable growth 13
Levelling the playing field 13
Supporting young and small space actors 13
Building partnerships to address mutual challenges 14
Ensuring long-term sustainability of space activities 14
References 16

Figures

Figure 1. Defining the main segments of the space economy 7
Figure 2. Orbital launch history 8
Figure 3. Commercial operators of space infrastructure dominate in low earth orbits 9
Figure 4. Almost 90 countries with a satellite in orbit 10

Figure 5. Investment in commercial space ventures 11

Figure 6. Monthly number of objects in Earth's orbits by object type 12

A tentative definition of "new space"

In the last 15 years, "new space" actors have provided disruptive new offerings in launch services, space manufacturing and operations, as well as in specific applications such as earth observation and satellite communications. This, combined with significant advances in data processing and computing, has lowered the cost of access to space and expanded the range space applications, paving the way for new entrants into the sector, with considerable socio-economic implications.

What is "new space"?

The term "new space" (or "newspace", "start-up space", "entrepreneurial space", "space 4.0", etc.) was coined in the early 2000s to distinguish commercial activities and actors distinguished from traditional space activities and sector incumbents. "Old space" actors were often affiliated with defence and aerospace industries, closely linked with government agencies on year-long projects and reliant on government procurement and R&D support.

In contrast, "new space" actors, big and small, brought with them funding and innovation strategies from other industries and typically still have one or several of the following characteristics:

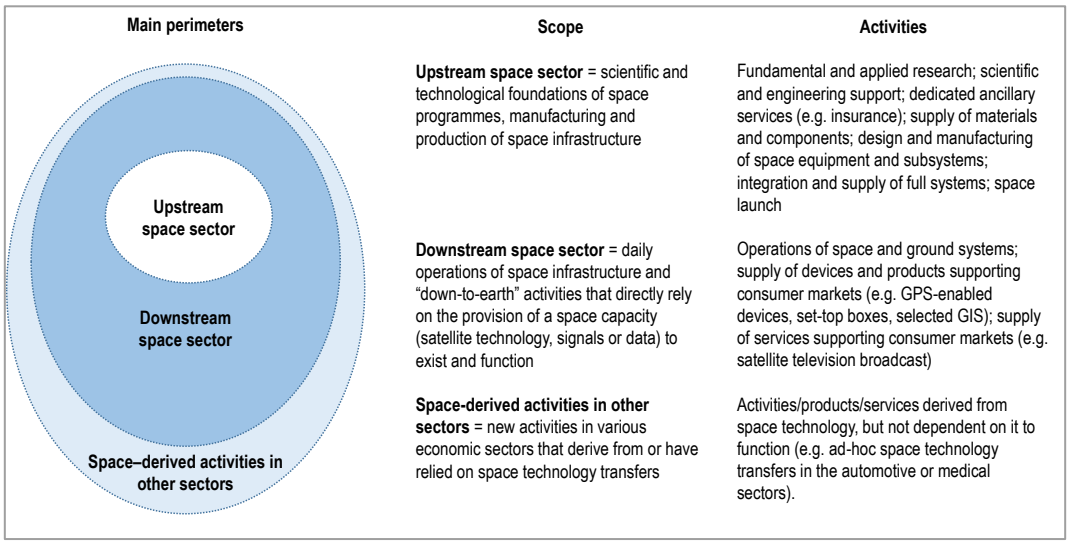
- having a high dependence on private capital (third-party or otherwise), including equity finance in many cases, with some of the proponents of "new space" being digital economy billionaires
- making maximal use of lean production processes (standardisation, using off-the-shelf components, additive manufacturing) and digital business models ("space-as-a-service", etc.)
- putting on the market new products and services born from the convergence of digital and space technologies: miniaturised satellites, satellite constellations, data analytics combining location-based and satellite data.

The lines between "old" and "new" space actors were unclear from the beginning and are increasingly blurred, as incumbents innovate to adapt to disruptions and recent market entrants become more set in their ways (e.g. benefiting themselves from large government contracts). Still, the term "new space" can be useful for identifying market entrants that, one way or the other, have overcome the (often considerable) cultural, regulatory, and financial barriers to conduct space activities.

In terms of economic activities, "new space" activities can be found in both the upstream and downstream segments of the space economy, as defined in the *OECD Handbook on Measuring the Space Economy* (OECD, 2022[1]) (shown in Figure 1). The upstream segment covers fundamental space activities such as manufacture and launch, while downstream activities exploit data and signals from space-based infrastructure. Within these categories "new space" actors aim to:

- pursue and disrupt existing space activities, which notably include space launch, planned and deploying constellations for satellite broadband in the low-earth orbit (LEO); multiple constellations of miniaturised satellites and their applications; as well as space and ground services tailored to these activities
- develop completely new commercial activities, e.g. space resource extraction, space tourism, on-orbit services, and so on.

Figure 1. Defining the main segments of the space economy



Source: OECD (2022[1]), *OECD Handbook on Measuring the Space Economy, 2nd Edition,* http://doi.org/10.1787/8bfef437-en.

The growth of the "new space" ecosystem

"New space" activities were fuelled by the favourable conjunction of technological developments, policy decisions and macro-economic events in the early 2000s.

This includes a radical reduction in the size of space systems and instruments (sometimes by several orders of magnitude) and innovative solutions for launching multiple satellites into orbit, as well as advances in storage, processing, and analysis of data (OECD, 2019[2]). Not restricted to the space sector but significant nonetheless, was the influx of money to the equity finance sector in the 2010s, opening new avenues of funding for space ventures over the next decade. And finally, the US government made a strategic shift to support more direct service buys with the Commercial Orbital Transportation (COTS) programme, for transporting cargo to the International Space Station.

As a result, space systems and services could be produced and launched faster and more cheaply than before, with government procurement expanding (or creating) the market. Satellite data and signals could also be more easily exploited. This caught the interest of venture capitalists, which had money to invest in new technologies, and it also attracted new actors from outside the space sector, often the information and communication technology sector. Below is a list of selected effects of the market entry of "new space" actors:

- disruption of the launch market with more affordable and reusable launch services
- disruptive and new applications from micro- and nanosatellite constellations (weighing less than 100kg and 10kg, respectively) in the low-earth orbit, for geospatial and signal intelligence (e.g. imagery, radio-frequency monitoring), weather and emissions monitoring, Internet-of-Things, etc.
- deployment of constellations with thousands of satellites for satellite broadband in the low-earth orbit (with satellites weighing some 150-200kg, which is still "small" compared to traditional satellite design)
- commercial development and/or introduction of "new" services, such as space tourism, on-orbit servicing, in-space manufacturing, etc.

Policy implications of "new space"

The long-term effects of "new space" are driving several developments that have implications for policy makers.

- a better distribution of the benefits of space technologies, thanks to a more diverse population of space actors (countries, stakeholders, operators), contributing to a growing pool of actors and potential partners for co-operation and trade
- a more intensive use of orbital natural resources (e.g. orbital slots, electromagnetic spectrum), with higher launch activity and many more operational satellites on orbit
- rising concerns about the sustainability of this growth. It is associated with a worrying increase in orbital debris, and recent years' succession of economic shocks threaten the vitality of the innovation ecosystem.

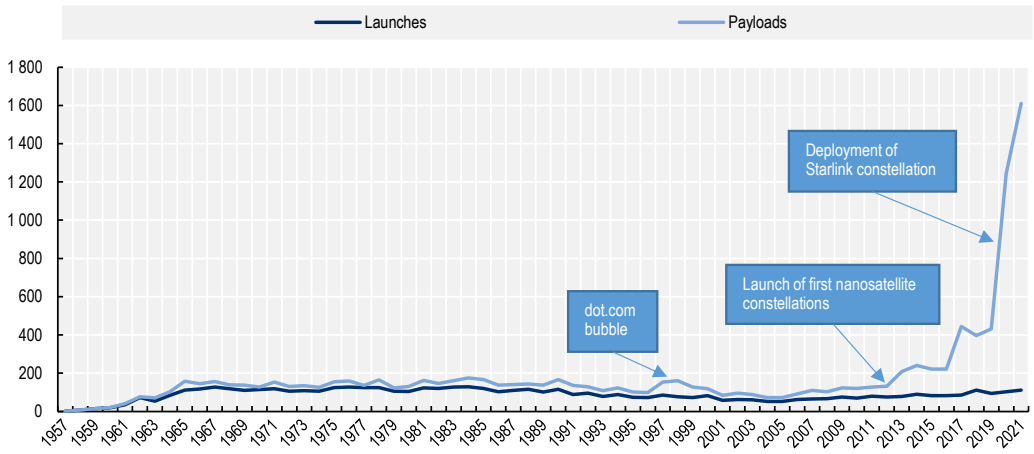
From a policy perspective, this creates multiple challenges in terms of sustainable and secure use and equitable access to technologies and orbital resources, which will require close collaboration between stakeholders at both the domestic and international level.

Increased demand for orbital slots and other space resources

The lowering of production and launch costs and improved access to finance has led to an explosive growth in satellites launched into orbit in the last decade, mainly by "new space" actors.

Figure 2. Orbital launch history

Number of launches and payloads (until 23 November 2021)



Note: Payloads refer to space objects (e.g. satellites, space probes) designed to perform a specific function in space, excluding launch functionality. It is worth to note that the number of launches remains stable over the period, with an increased number of satellites per launch starting around 2012.
Source: US Space Force (2021[4]), cited in Undseth and Jolly (2022[5]), "A new landscape for space applications", http://doi.org/10.1787/866856be-en.

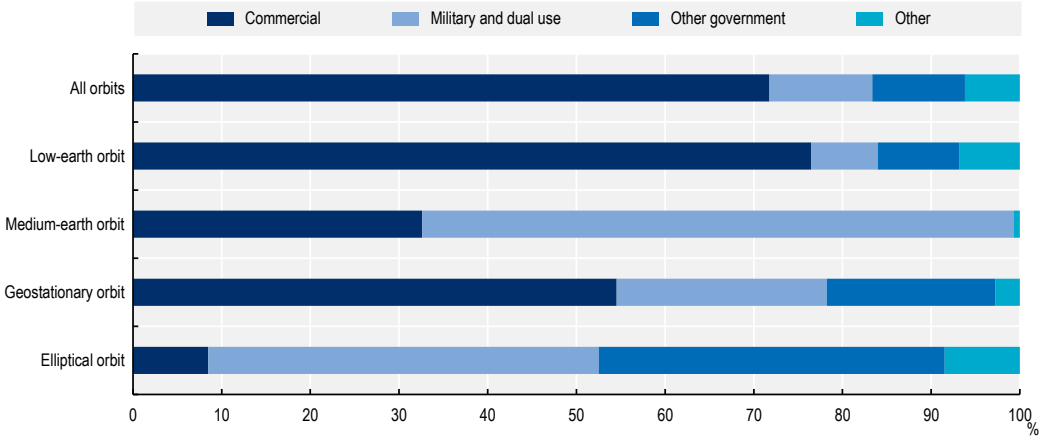
Figure 2 shows how launch activity picked up from 2011 onwards, with the launch of the first nanosatellite constellations for earth observation, (OECD, 2014[3]). Commercial missions in the low-earth orbit are often deployed in multi-satellite constellations to improve geographic coverage and shorten revisit times, leading to a notable increase in the number of launched satellites or payloads. Starting from 2019, the bulk of

global launch activity is dedicated to the deployment of satellite broadband constellations in the low-earth orbit.

By the end of 2022, the constellations from two commercial operators, US' SpaceX and UK's OneWeb (3 000 and 500 satellites respectively) represented more than half of *all* operational satellites on orbit (Union of Concerned Scientists, 2022[6]). Commercial operators and their infrastructure now dominate in low-earth orbits and in geostationary orbits, as shown in Figure 3.

Figure 3. Commercial operators of space infrastructure dominate in low earth orbits

Operators as a share of operational satellites on orbit. Data as of 1 January 2022



Note: Military and dual use include defence-related missions, as well as military-civil, government, military-commercial, or a combination of the three.
Source: Undseth and Jolly (2022[5]), "A new landscape for space applications", http://doi.org/10.1787/866856be-en.

This is just the beginning. The US Kuiper constellation, backed by Amazon, is set to start deployment in 2023 and has booked up to 83 launches on various rockets in coming years to place their planned 3 000+ satellites on orbit (Amazon, 2022[7]). Other G20 economies have their own projects. The Canadian government is supporting the commercial Telesat Lightspeed constellation, projects in the People's Republic of China [hereafter China] (Guo Wang) and Korea (Hanwha Systems) were announced in 2021; and in 2022, the European Union introduced its IRIS^2 constellation for secure communications, expected to be fully operational in 2027. This comes in addition to multiple fully commercial projects.

Even if they do not all come to fruition, these initiatives increase the demand for space manufacturing and launch services, as well as orbital resources such as orbital occupancy and radio spectrum and fuel the creation of additional activities. There are now projects for commercial spaceports across the globe, from Norway to New Zealand.

There is also increased commercial interest for other space resources. By 2022, the United States, Luxembourg, the United Arab Emirates and Japan had voted laws concerning resources extracted commercially from celestial objects.

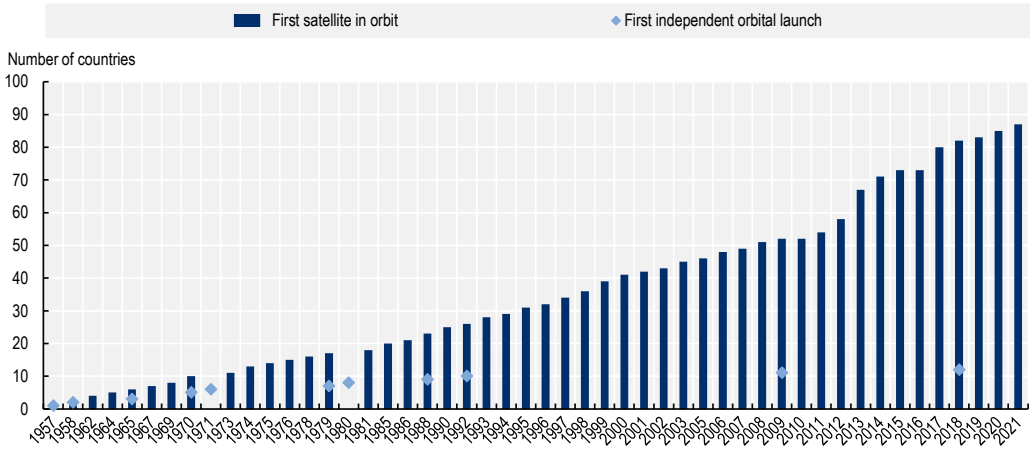
Better distribution of the benefits of space exploitation

One of the key legacies of "new space" is the "democratisation" of space technologies and resource exploitation, both in the geographic sense and from a user perspective, thus maximising the potential gains of space exploitation.

Geographic diversity on orbit has never been higher. By 2022, operators in almost 90 countries on four continents had operated a satellite at some point in time, with a distinct jump after 2012 (Figure 4). Among G20 economies, half had demonstrated this ability by 1970, with Korea, Türkiye and South Africa added to the list by 2000. Lower-income countries are also better represented than before, with 12 new lower-middle and two low-income countries having operated their first satellite in the last ten years (Union of Concerned Scientists, 2022[6]).

Figure 4. Almost 90 countries with a satellite in orbit

Number of countries having had a satellite in orbit (launched between 1957 and October 2021)



Source: OECD (2022[1]), *OECD Handbook on Measuring the Space Economy, 2nd Edition,* http://doi.org/10.1787/8bfef437-en.

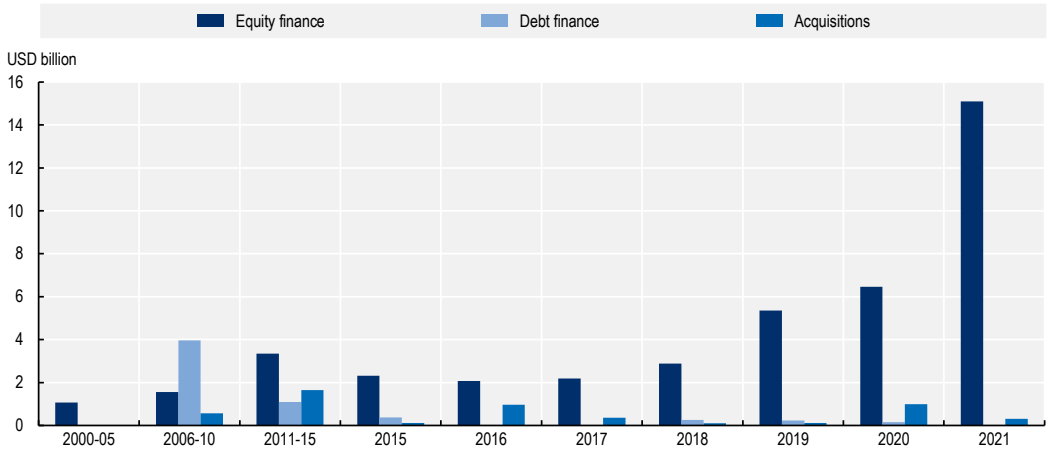
Furthermore, there are also more opportunities for innovative actors, such as universities and start-ups. For instance, government agencies are offering more services specifically targeting emerging actors, such as testing and flight opportunities (e.g. the European Space Agency's General Support Technology Programme (GSTP), or the Korean STAR-Exploration programme) (Olivari, Jolly and Undseth, 2021[8]). In China, private capital was allowed to enter the aerospace field in 2014 and the State Council encouraged the development of commercial space in the 2016 China Aerospace White Paper (Zhang, 2018[9]). The Indian Space Research Organisation (ISRO) is in a similar process of promoting more commercialisation and entrepreneurship (IspA-EY, 2022[10]).

Countries also make satellite data available to stimulate innovation and entrepreneurship, for example the Earth Explorer portal of the US Geological Survey for Landsat data, Digital Earth in Australia, satellittdata.no in Norway, or Satellite Data Portal in the Netherlands (OECD, 2020[11]).

The last decade also saw a change in the access to and nature of finance. While traditionally dominated by government support or private debt finance, the space sector's access to equity finance improved considerably between 2012 and 2021, as shown in Figure 5 (BryceTech, 2022[12]). This has given more opportunities to start-ups.

However, there is a still a long way to go. Venture capital funding rounds have so far mainly benefited a limited number of firms (notably SpaceX and OneWeb) and 65-75% of investments, depending on the data source, are in North America (BryceTech, 2022[12]; Seraphim Capital, 2022[14])). Future availability of finance is also an issue; private space investment activity has slowed down in 2022 and early 2023 (Seraphim Capital, 2022[14]). With the growth of inflation and interest rates in 2022, equity finance volumes to space ventures may have peaked.

Figure 5. Investment in commercial space ventures



Source: Based on BryceTech (2022[12]), cited in Undseth and Jolly (forthcoming[13]), "Does space investment need a boost?".

To improve access to equity finance, several space agencies and G20 economies have in the last years announced dedicated public space venture capital funds and similar initiatives, including Japan, Korea, France, Italy and the European Union (Undseth and Jolly, forthcoming[13]).

Challenges to future growth

The rapid growth of the space economy is raising concerns about the environmental sustainability of future activities. Furthermore, the current economic climate puts the continued vitality of the "new space" ecosystem at risk. Finally, there are doubts about the economic viability of several of the proposed projects for satellite broadband and other ambitious activities, such as in-space resources extraction.

Growing concerns about the environmental sustainability of space activities

The size of existing and planned constellations of several thousand satellites, raises concerns about the environmental sustainability of space activities (OECD, 2022[15]). Increased density on orbit, as shown in Figure 6, increases risk for collisions and debris generation, as well as light pollution disrupting astronomic observations. There is also pollution associated with manufacturing, launch and spacecrafts' re-entry into the atmosphere (Boley and Byers, 2021[16]).

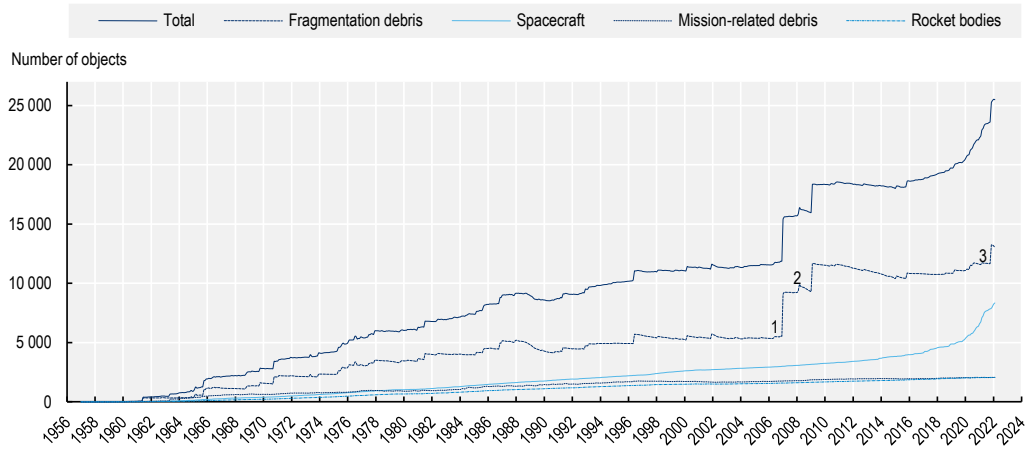
The vitality of the "new space" ecosystem is at risk

The health of the "new space" ecosystem relies on a steady influx of new, innovative actors, the continuation of which should not be taken for granted.

Costs to enter the market remain high, despite "new space" efforts to revamp production processes through standardisation, miniaturisation and reuse, and increased use of off-the-shelf products (Undseth and Jolly, forthcoming[13]; OECD, 2019[2]). Space manufacturing, space launch and more challenging activities (e.g. on-orbit manufacturing) continue to be extremely capital- and R&D-intensive, for which it may be difficult to raise funding. This puts effective limits on entrepreneurship and better explains the small but significant number of successful firms backed by billionaires (e.g. SpaceX (Elon Musk), Blue Origin (Jeff Bezos) and Virgin Galactic (Richard Branson)).

Figure 6. Monthly number of objects in Earth's orbits by object type

Historical increase of the catalogued objects based on data available on 1 March 2022



Notes: The three upward jumps in fragmentation debris correspond to: 1) the anti-satellite test conducted by the People's Republic of China in 2007; 2) the accidental collision between Iridium 33 and Cosmos 2251 in 2009; and 3) the anti-satellite test conducted by the Russian Federation in November 2021. More Cosmos 1408 fragments are expected to be added to the catalogue in the coming weeks and months of 2022.
Source: NASA (2022[17]), cited in OECD (2022[15]), *Earth's Orbits at Risk: The Economics of Space Sustainability*, https://doi.org/10.1787/16543990-en.

Furthermore, incumbents and "new space" actors alike are exposed to the structural weaknesses of the space sector value-chain that still exist in many segments (e.g. low production volumes and high levels of specialisation) making them vulnerable to economic shocks (OECD, 2020[18]). Young and small actors are particularly at risk. During the Covid-19 crisis a German survey specifically targeting space start-ups revealed that almost 40% of respondents described the impacts of COVID-19 as "dramatic" and threatening the very existence of their firm (BDI, 2020[19]).

Although certain space industry segments benefit from the current geopolitical climate with high counter-cyclical defence expenditure, there are growing concerns about medium and long-term access to private as well as public sources of funding, as the projected economic slowdown in 2023, high inflation and rising debt service burdens could negatively affect public R&D budgets (OECD, 2023[20]). Many industry actors anticipate significant funding cuts in future civilian institutional programmes. Government support and procurement continues to play a pivotal role, also for "new space" actors, as government agencies often fund early-stage R&D and facilitate access to private third-party funding by representing a viable market for products.

"New space" business models face multiple technological, market and regulatory risks

It can be argued that at least certain segments of the space economy are fuelled by expected high returns from satellite broadband activities. This has ripple effects on access to third-party finance, on the supply of satellites and launchers, as well as on the provision of launch services.

However, how robust are the underlying business models for these projects? There are multiple questions related to the actual performance of the space-based infrastructure, to the affordability and technological capabilities of the ground segment, to the overall pricing model of the service that will affect the size of the market, and ultimately, to the ability to transform this into a truly profitable activity for operators.

Other emerging activities, such as space tourism and resource extraction face similar challenges in terms of market risks. i.e. the question of whether there is enough commercial and government demand to ensure profitability. Regulatory risks can also be considerable in certain domains such as in-orbit resource utilisation and extraction, which are particularly capital- and research intensive, with long lead times, and which rely on the interpretation (and potential modification) of international treaties as well as formulation of national legislation.

Policy options for sustained and sustainable growth

"New space" and its actors, technologies and practices have transformed the space sector and created new opportunities for growth and societal wellbeing. However, policy action is needed to ensure that this growth is sustained, sustainable and equitable.

Levelling the playing field

An important contribution by "new space" to society is the multiplication of entrepreneurship and ensuing innovation in the global space sector. But this trend is fragile and could easily be reversed. The continuously high economic and regulatory barriers of certain space industry segments increase the risks of entrenchment. Furthermore, as the space sector becomes more digitised, the scalability of intangible digital assets makes "winner-takes-most" scenarios more probable (OECD, 2019[21]).

Policy makers are encouraged to review national regulatory regimes and procurement processes through a "competition lens", to ensure conditions are favourable for market entrants. One example is the growing use of Other Transaction Authority agreements by US government agencies (such as Space Act Agreements used for the COTS programme), which are exempt from the administrative requirements of federal procurement laws and regulations and therefore potentially remove some of the "red tape" and possible comparative administrative advantages of larger organisations with more resources and experience than smaller and younger firms (Undseth, Jolly and Olivari, 2021[23]).

Supporting young and small space actors

The succession of economic shocks and investors' shift away from equity finance could accelerate the process of space industry concentration, as young and small firms are generally more strongly affected than established actors (Calvino, Criscuolo and Menon, 2016[23]). Governments have already taken steps to improve access to equity finance through the creation of public venture capital funds. Other measures include dedicated R&D funding, technology testing and flight opportunities. However, more targeted measures may be needed for the smallest and most vulnerable actors. Policy makers may consider some of the following options:

- as major institutional customers to the space industry in most G20 countries, space agencies and other public space administrations need to consider the role of start-ups and other small actors in their space programmes, simplifying procedures and adapting eligibility criteria for R&D and procurement programmes, to facilitate access to public and private funding
- reinforce existing measures such as business incubation centres and product testing and demonstration schemes, addressing particularly the needs of small firms and entrepreneurs (e.g. encouraging reduced or no access fee to access testing facilities)
- keep track of the "new space" ecosystem. Overall, more high-quality data is needed about the space industrial base to inform policy decisions.

Building partnerships to address mutual challenges

Faced with mounting fiscal pressures and global challenges, governments are invited to build partnerships at both the national and international level. Government agencies have a broad range of procurement mechanisms and instruments at their disposal to make use of private sector capabilities and commercial interests (Undseth, Jolly and Olivari, 2021[22]).

- With revamped public procurement practices and more service buys, new partnerships are being set up with the space industry throughout OECD countries. Space agencies and other procurement agencies will need to have adequate and sustained skills and resources to negotiate contracts and carry out oversight.
- As the space ecosystem grows bigger and more diverse, space agencies and administrations need to identify and consider the complementary strengths of big and small actors and design policy instruments that address the different needs of these actors, clarifying issues such as asymmetric relationships in collaborative projects, intellectual property rights, etc.
- Agencies need to consider the impact of their policies on the incentives of other space actors. Privately funded projects are generally much easier to finance when there is an anchor customer assuring a secure line of revenues.

At the international level, space is already characterised by high levels of collaboration, as international organisations and committees co-ordinate activities in space exploration, space science, earth observation, space-based meteorological observations, space debris, radio frequencies, disaster management, space education, etc. Still, more efforts will be needed to muster the necessary economic, technological, and human resources to sustain and expand existing and new missions in earth and space exploration, or in other challenging domains. Several important lessons from managing internationally the Covid-19 crisis for science, technology, and innovation communities (OECD, 2023[24]) are also applicable future space developments and their sustainability challenges:

- Decision makers need to recognise the role of research infrastructures as unique resources for training and capacity-building; as intermediaries and brokers vis-à-vis other disciplines and sectors; and in international collaboration, by sharing data and analysis. For space, they include physical and virtual space infrastructures, such as the internationally co-ordinated meteorological satellites and future joint space stations for examples.
- The pandemic further showed how only globally inclusive responses can provide the necessary level of protection. The same applies to efforts to address space debris, which is a truly global challenge. Establishing or better employing existing international funding mechanisms, trusted relationships and scientific networks could contribute to making society more resilient.

Ensuring long-term sustainability of space activities

As space capacities become increasingly important for society, it is crucial to ensure the long-term sustainability of space activities and addressing negative externalities of space activities.

Stabilising the orbital environment will require concerted action at both national and international levels and new thinking, such as the “Sustainable Space Rating”, jointly developed by private and public actors and led by the Federal Institute of Technology in Lausanne, Switzerland. A long-term strategic view on the role and capabilities of both public and private actors is also needed.

- The OECD has published several reports on the economics of space sustainability, identifying some of the shorter and longer-term costs associated with space debris (Undseth, Jolly and Olivari, 2020[24]; OECD, 2022[15])

- The OECD Space Forum and its partnering space administrations have also launched an original project on the economics of space sustainability, collaborating with universities and research organisations to assess the costs of space debris and value of space applications.

References

Amazon (2022), *Project Kuiper secures up to 83 new launches to deploy satellites*, 05 April, https://www.aboutamazon.eu/news/innovation/project-kuiper-secures-up-to-83-new-launches-to-deploy-satellites. [7]

BDI (2020), "Auswirkungen der Corona- Pandemie auf den New Space- Sektor Ergebnisse: BDI-Umfrage", 30 March, Federation of German Industries. [19]

Boley, A. and M. Byers (2021), "Satellite mega-constellations create risks in low earth orbit, the atmosphere and on Earth", *Scientific Reports*, Vol. 11/1, https://doi.org/10.1038/s41598-021-89909-7. [16]

BryceTech (2022), *Start-Up Space 2022: Update on investment in commercial space ventures*, https://brycetech.com/reports/report-documents/Bryce_Start_Up_Space_2022.pdf. [12]

Calvino, F., C. Criscuolo and C. Menon (2016), "No Country for Young Firms?: Start-up Dynamics and National Policies"*, OECD Science, Technology and Industry Policy Papers*, No. 29, OECD Publishing, Paris, https://doi.org/10.1787/5jm22p40c8mw-en. [23]

IspA-EY (2022), *Developing the Space Ecosystem in India: focussing on Inclusive Growth*, Report co-developed by the Indian Space Assocation and Ernst & Young, https://ispa.space/assets/pdf/EY-ISpA-report_Developing.pdf. [10]

NASA (2022), "Orbital Debris Quarterly News", Vol. 26/1, https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/ODQNv26i1.pdf (accessed on 17 February 2020). [17]

OECD (2023), "Mobilising science in times of crisis: Lessons learned from COVID-19", in *OECD Science, Technology and Innovation Outlook 2023: Enabling Transitions in Times of Disruption*, OECD Publishing, Paris, https://doi.org/10.1787/855c7889-en. [24]

OECD (2023), "Science, technology and innovation policy in times of global crises", in *OECD Science, Technology and Innovation Outlook 2023: Enabling Transitions in Times of Disruption*, OECD Publishing, Paris, https://doi.org/10.1787/d54e7884-en. [20]

OECD (2022), *Earth's Orbits at Risk: The Economics of Space Sustainability*, OECD Publishing, Paris, https://doi.org/10.1787/16543990-en. [15]

OECD (2022), *OECD Handbook on Measuring the Space Economy, 2nd Edition*, OECD Publishing, Paris, https://doi.org/10.1787/8bfef437-en. [1]

OECD (2020), "Space economy for people, planet and prosperity", background paper for the G20 Space Economy Leaders' Meeting, 20-21 September, Rome, Italy, https://www.oecd.org/sti/inno/space-forum/space-economy-for-people-planet-and-prosperity.pdf (accessed on 4 February 2022). [11]

OECD (2020), "The impacts of COVID-19 on the space industry", *OECD Policy Responses to Coronavirus (COVID-19)*, https://www.oecd.org/coronavirus/policy-responses/the-impacts-of-covid-19-on-the-space-industry-e727e36f/. [18]

OECD (2019), *Going Digital: Shaping Policies, Improving Lives*, OECD Publishing, Paris, https://doi.org/10.1787/9789264312012-en. [21]

OECD (2019), *The Space Economy in Figures: How Space Contributes to the Global Economy*, OECD Publishing, Paris, https://doi.org/10.1787/c5996201-en. [2]

OECD (2014), *The Space Economy at a Glance 2014*, OECD Publishing, Paris, https://doi.org/10.1787/9789264217294-en. [3]

Olivari, M., C. Jolly and M. Undseth (2021), "Space technology transfers and their commercialisation", *OECD Science, Technology and Industry Policy Papers*, No. 116, OECD Publishing, Paris, https://doi.org/10.1787/0e78ff9f-en. [8]

Seraphim Capital (2022), *Seraphim space index: Q4 2022*, https://seraphim.vc/wp-content/uploads/2023/02/seraphimspaceUK-q4-2022_v1.pdf. [14]

Undseth, M. and C. Jolly (2022), "A new landscape for space applications: Illustrations from Russia's war of aggression against Ukraine", *OECD Science, Technology and Industry Policy Papers*, No. 137, OECD Publishing, Paris, https://doi.org/10.1787/866856be-en. [5]

Undseth, M. and C. Jolly (forthcoming), *Does space investment need a boost? OECD perspectives on how to raise private sector funding*. [13]

Undseth, M., C. Jolly and M. Olivari (2021), "Evolving public-private relations in the space sector: Lessons learned for the post-COVID-19 era", *OECD Science, Technology and Industry Policy Papers*, No. 114, OECD Publishing, Paris, https://doi.org/10.1787/b4eea6d7-en. [22]

Undseth, M., C. Jolly and M. Olivari (2020), "Space sustainability: The economics of space debris in perspective", *OECD Science, Technology and Industry Policy Papers*, No. 87, OECD Publishing, Paris, https://doi.org/10.1787/a339de43-en. [25]

Union of Concerned Scientists (2022), "UCS Satellite Database: January 2022 update", Data as of 1 January, https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database (accessed on 20 March 2019). [6]

US Space Force (2021), *Space-Track.Org website*, 18th Space Control Squadron, update 23 November 2021, https://www.space-track.org (accessed on 23 November 2021). [4]

Zhang, E. (2018), "Emerging commercial launch vehicle activities in China: Policy, technology and business", presentation at the OECD Workshop Economic Models for the Low-Earth orbit and Beyond, 25 October, Paris. [9]