Klecha & Co.

With the kind contribution of **Raffaele Mauro**, Co-founder and General Partner of Primo Space, the first continental EU venture capital fund focused on space technology.

Insights Report

Space Economy:

Lift-off into the final frontier

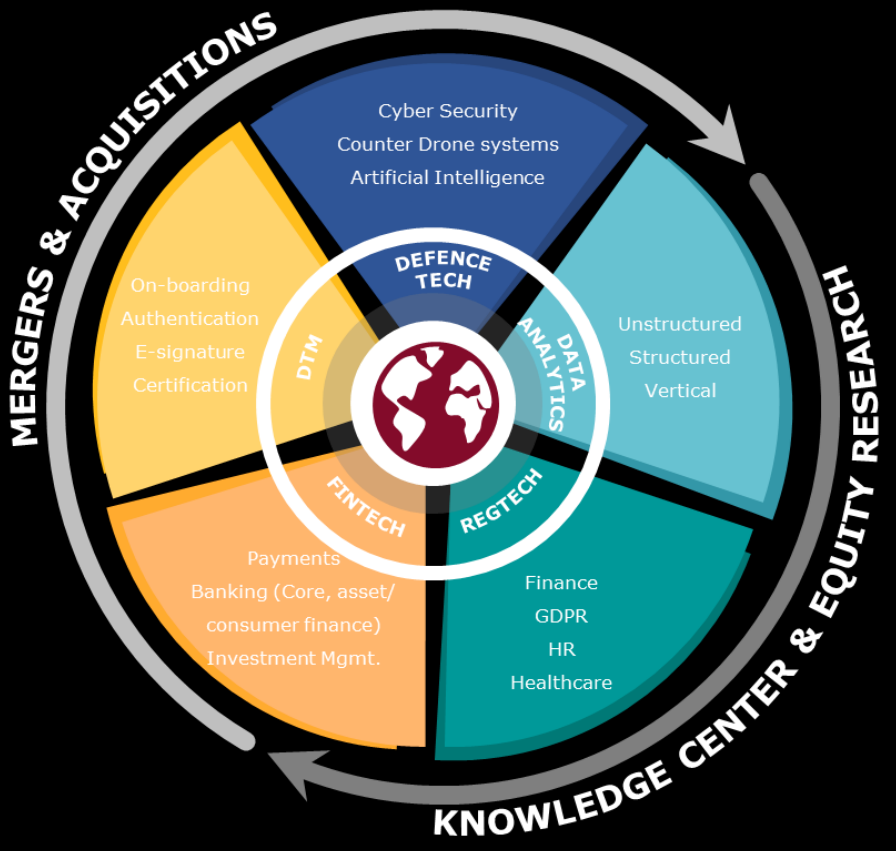
November 2022

ABOUT US

Klecha & Co.

Klecha & Co. is a private investment bank focused on Technology, including Software, IT Services, Hardware and IoT. Our clients are private sector companies, active contributors to the data revolution or solution providers to the opportunities and challenges arising from the digitalization of business processes. We support our clients from the definition of their strategy through to post M&A integration.

The depth of our industry expertise, sector focus and M&A experience make us truly unique in the market.



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Stats on the Space Economy[1]

$ 1 trillion

The economic potential of space commerce for businesses by 2040

US$ 264 billion

Of equity investments across 1,727 companies focused on the space economy, since 2013

31,156

Number of objects in Earth's orbit, almost doubling from 2016 (18,485)

1,022

Spacecrafts(*) placed in orbit during the first six months of 2022; 958 were commercial

US$ 6.1 billion

In investments received by companies focused on the space economy in Q2 2022

US$ 30 / KG

Estimated cost to launch payloads into space by 2040, down from US$ 1,500 / KG

US$ 700 quintillion

Value of minerals present in the asteroid belt between Mars and Jupiter

US$ 1 billion / day

Economic costs to the US if the GPS systems are under a cyber-attack

(*) The term *Spacecrafts*, as intended in the present report, mainly refers to low-earth-orbiting satellites

Key Considerations

Human activities in space will grow more widespread during the next decade. Unlike the prior century's space race, the great powers will not be the only major actors. Along with less powerful countries, non-state actors and the business sector will play important roles. Technologies will emerge to improve both crewed and un-crewed space operations. Space technology will also help to better collect and manage data on human activity around the planet, improving a variety of commercial and national security operations – all of which will contribute to building a flourishing space economy.

According to Euroconsult, the global space industry reached an astounding US$ 370 billion in 2021[2]. For context, that equates to approximately 0.6 percent of gross domestic product for any G20 country. According to a Morgan Stanley report, the global space industry's revenue might exceed US$ 1 trillion by 2040[3]. Already, the space sector contributes significantly to economic growth. It is critical for everything from weather prediction to GPS systems to geospatial sensors and data collection. Furthermore, a Harvard Business School study estimated that every dollar spent in the space economy generates roughly $50 in societal benefit[4].

The increasing importance of the private sector is the most significant trend in the space economy. Commercial work contributed for about 80% of the space economy[4]. This progression is spawning a new generation of "Silicon Valleys," or clusters of space invention and productivity. Many of these innovation hubs are progressively connecting through joint initiatives and acquisitions of companies in the United States, Japan, South Korea, the United Kingdom, Israel, and elsewhere.

Reduced launch costs will let even smaller, developing states to participate in space operations, which is essential for the growth of the space industry. The commercial sector will increasingly include offering services in space. This will cover tasks like satellite refueling and repairs, including the replacement of parts and systems, as well as maintenance work on solar panels. Crewed space missions, in contrast to other areas of the space economy, may likely be driven by geopolitical rivalry, with great countries utilizing space deployment to highlight their technological superiority and adventurous spirit.

The space economy encompasses more than just technology and research. The global space industry is advancing sustainable development and driving economic growth thanks to its numerous positive side effects. Space-related endeavors foster innovation and will have the largest impact on terrestrial activities in the next years. They generate new industrial capabilities and markets, offer employment prospects, and heavily rely on scholarly research and development.

The Space Economy: An Overview

In 2020, the United Nations Office of Outer Space Affairs (UNOOSA) launched the Space Economy Initiative, a new UN platform charged with bringing together emerging and non-spacefaring countries to strengthen their space economies. The space economy is expected to equalize the power struggle and foster global economic competition. On one hand, commercial space capabilities will become ubiquitous, and on the other, even militaries will find it increasingly difficult to surprise their enemies. Meanwhile, the rules, competitive practices and norms that have developed around the internet could serve as models for how the governance of space could emerge in the future.

Few things spur innovation more than competing billionaires with flexible budgets and a tenacious ambition to make history. This is absolutely true of the modern-day space race. Elon Musk's SpaceX became the first private business to transport humans into orbit in 2020. Soon after, Richard Branson's Virgin Galactic and Jeff Bezos' Blue Origin ventured into zero gravity. Their efforts have reduced prices and heralded a new era of space activity, making the universe more accessible than ever before.

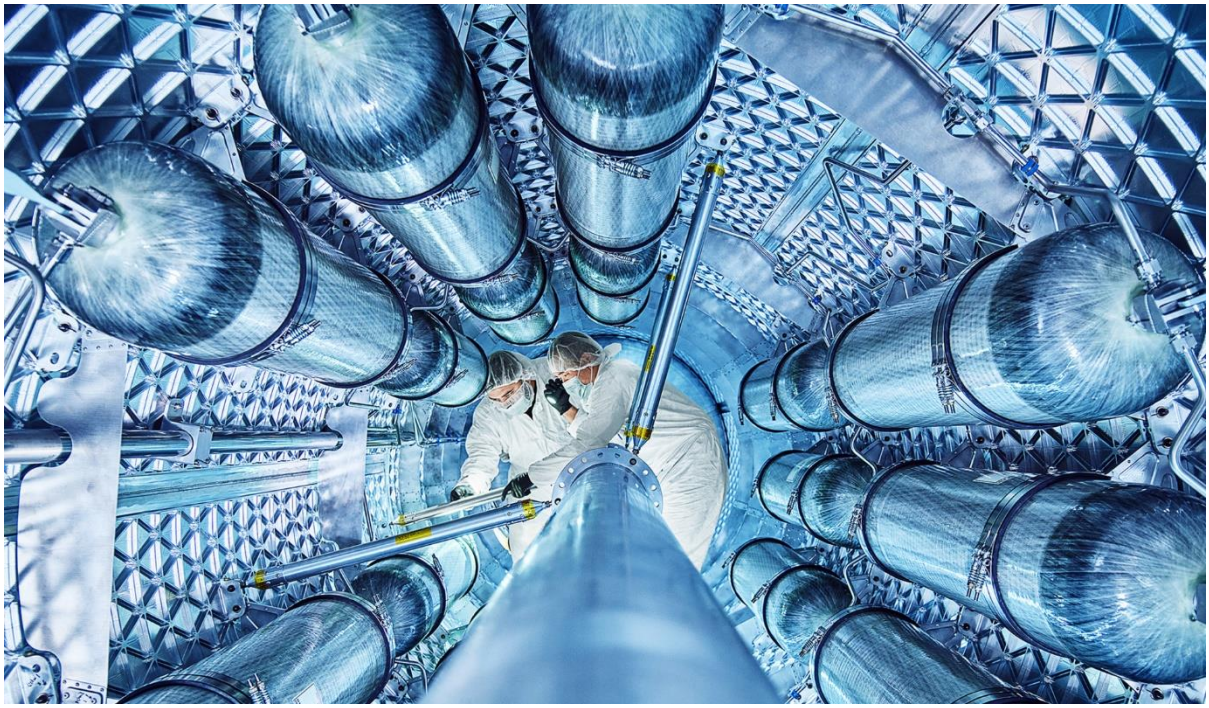
Explorers and scientists have always found inspiration in space. The pursuit of space has created new technologies and substantially expanded humankind's scientific understanding in fields ranging from physics to chemistry, material sciences to engineering. It has also enhanced our daily lives in numerous ways – the European Space Agency believes that for every Euro spent in the industry, society gains six Euros[5] (slightly lower than that estimated by another a Harvard study). Until recently, space was synonymous with government spending: the tremendous costs and dangers involved rendered the field unavailable to commercial participants. Today, significant technological advances and a new entrepreneurial spirit are fast developing a new space economy. Because of frontier technologies and the data revolution, the industry is seeing the emergence of new private actors who see unrivaled business prospects in space exploration and exploitation.

The Space Economy is defined by OECD as the full range of activities and the use of resources that create value and benefits to human beings in the course of exploring, researching, understanding, managing, and utilizing space[6].

Picture 1: A launch system undergoing testing in the Mojave Desert[7]

The early space industry was highly organized, national, and bureaucratic. It was primarily restricted to state-run initiatives with a small number of public-private collaborations. The New Space economy

is global, entrepreneurial, and open to the public. It is becoming more diverse and expanding with private companies in a range of sub-sectors. NASA, the US Air Force, and even the European Space Agency (ESA) have long worked with private enterprises to enhance space technology. The Commercial Space Launch Act of 1984 went much farther, forcing NASA to "explore and encourage, to the greatest extent practicable, the widest commercial use of space." By 2010, roughly one-third of all space launches worldwide were commercial, and NASA announced the end of the space shuttle program. The ESA too in 2015[8] set up a process for strategic partnerships with the private sector to facilitate the implementation of exploration ambitions, and to foster growth and competitiveness of the European space and non-space industrial base.



Picture 2: Technicians complete final checks on the metallic first stage rocket [9]

For a long time, companies in this field sold the satellite or the technology, and clients did not understand how this related to their needs. As a result, several industry providers, realizing that it was not about the satellite, began talking about data. However, the customer was unable to intuitively understand or consume that as well. Now, more and more industry providers are discovering that it's not about the data at all, but rather about meeting the client where they are and providing solutions. As a result of this better customer-centric mindset, investors are taking notice, and the industry is becoming more investable for the first time. Investors are finally witnessing acquisitions that correspond to their investment criteria, such as genuine organic growth, economies of scale, and paths to profitability. From 2001 to 2008, outside investments in space economy start-ups increased from less than US$ 500 million per year to around US$ 2.5 billion per year in 2015 and 2016. According to Bryce Tech's Start-Up Space 2022 report, investment in space economy start-ups reached a new high of US$ 15 billion in 2021, breaking the previous record of US$ 7.7 billion the year before[10]. With more funding, there will be more players bringing new technology to the market. All of this correlates to lower costs, lower entry barriers, shorter launch schedules, and more customer-centric services.

Today's space economy is nearly exclusively devoted to Earth-for-space applications. However, as this sector expands at an unprecedented rate, it may give birth to the space-for-space industry.

The space economy value chain

The modern space economy depends on both an industry for space infrastructure and one for space services, very much in the same way as the digital economy depends on both digital infrastructures and digital services. The latter is induced and enabled by the former. As two components of the so-called "space value chain," the series of value-adding activities that begins with the research and manufacturing of space systems and ends with the provision of/sale of space-based solutions to end-users/customers, these two businesses cannot be separated in this regard. The space services industry is referred to as the "downstream," which corresponds with all the subsequent economic activities related to the operation and exploitation of this satellite system for providing space-based goods and services to end users, on a simplified linear space value chain. The space infrastructure industry is referred to as the "upstream," which corresponds with the sequence of economic activities leading to an operational satellite system in orbit. The traditional upstream-driven technical push in the generic space value chain is continuously giving way to a market-demand pull (upstream develops assets that the downstream market can use) (downstream drives space systems development with needs for new services). Over the past few decades, space has drawn a significant number of new players, with both space and non-space enterprises entering the various value chain streams.

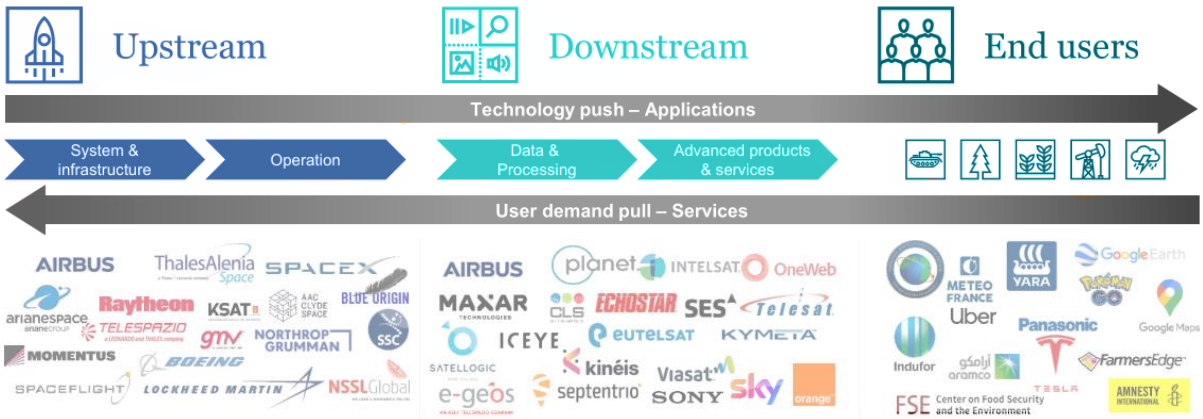


Chart 1: The space economy value chain, encompassing different domains and the various players operating within the value chain[11]

Some of the key stakeholders in various parts of the value chain include:

Upstream: Launch systems and vehicles, satellite manufacturing, ground segment systems and network equipment, launch service provision, satellite and ground segment operations (that are also denoted as midstream). Major players include governmental agencies (that fund space technology R&D for both their own use and dual uses), public partnerships and players that design, manufacture space vehicles and other hardware / software to ground stations.

Downstream: Data and satellite (direct to home, broadband, navigation, etc.), value added services, user equipment (satellite navigation devices, chipsets, TV dishes, radio receivers, etc.) Major players include owners of satellite systems, service providers and governmental or civilian agencies that use the services across communication, navigation, etc.

End users: Consumer, industry, governments, non-profit organizations across sectors such as: energy, infrastructure, agriculture, marine, defense, security, location-based services, etc.

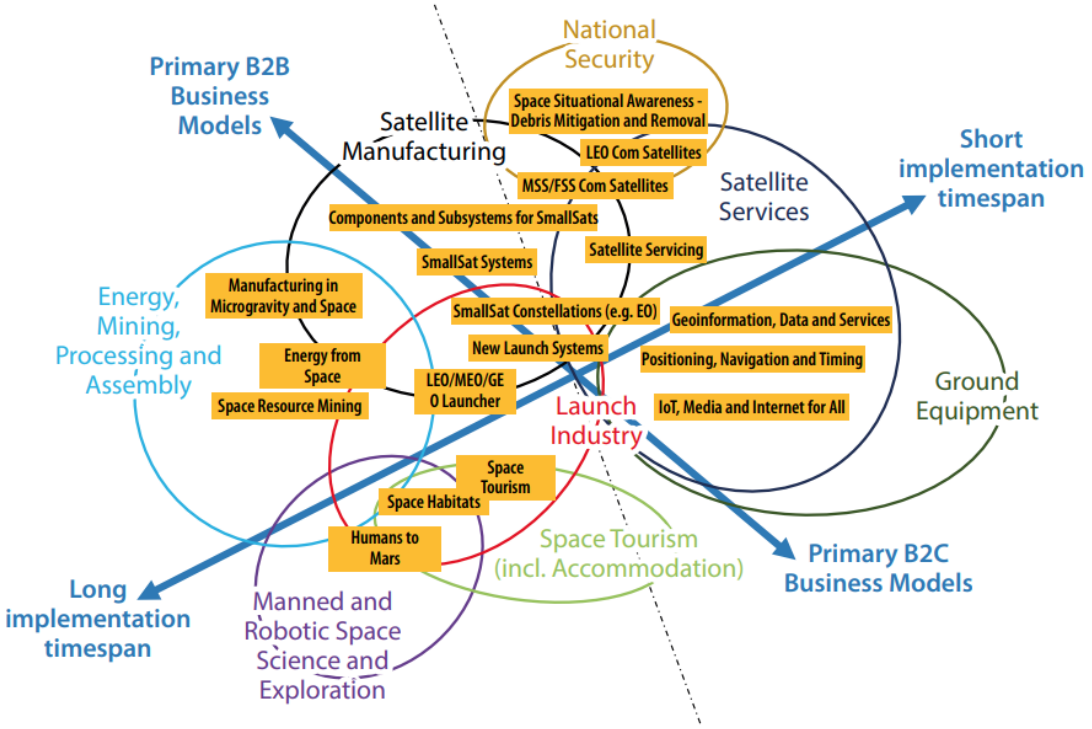


Chart 2: The landscape of space business services, business models and segments[12]

This value chain also caters to the broader space economy that can be broadly described (and is covered in more detail in later sections) as space domains, which include: Space access, Earth Observation (EO), Satellite communication (satcom), Satellite navigation (satnav), Space situational awareness (space safety) and an In Orbit Economy for space exploration.

Technology and macro factors that are influencing the space economy

The past year has seen significant advancements in space science. SpaceX, Blue Origin, and Virgin Galactic all completed their inaugural missions with a touristic objective. Days before the new year, NASA's rover on Mars made a successful landing, and the James Webb Space Telescope, the most potent of its kind in the world, launched into orbit. Apart from technology, there are other space-industry specific trends that are influencing the industry as we move ahead. Space technology can be a crucial enabler of digitization while also benefiting from digital breakthroughs. Below is a list of technological innovations that are being widely used in the domain of space, and form the backbone of the space economy:

Digital Twins: Digital twins for modeling change optimization strategies for IoT, AI, and analytics, which are gaining widespread use in the data value chain.

Sensor platforms for mobile devices: Miniaturization results in new mobile sensors, which expands data collection possibilities from many sources (e.g., smallsats, HAPS, UAV)

Artificial Intelligence and Automation: To extract insights from space data, AI creates new analytics paradigms by merging machine learning, data mining, and high-speed computing.

Technological advancements in space: Miniaturization, micro launchers, reusable launchers, and ridesharing all help to expand access to space. This, for example, allows for additional Earth Observation (EO) crafts to gather high-quality pictures with high revisit and cheap costs, as well as Low Earth Orbit (LEO) based networking and IOT.

Computing and storage on the cloud: Cloud computing advancements allow low-cost access to increased power and storage, enabling new digital business models for data and services.

Connectivity and mass digitization: Connected devices and small sensors combined with big data digitization technology resulted in an increase in available data. This heterogeneous data, for example, can be combined with space data to enable new applications.

IoT and 5G: 5G is projected to accelerate IoT, promote Industry 4.0, and enable faster data transmission rates, boosting the amount of data available for big data analytics.

Additive Manufacturing & 3D Printing: AM and 3D Printing, with the unique geometries of their productions, allow the creation of lighter, cheaper and more efficient components for various application in aerospace, particularly for space exploration.

However, space specific factors that are themselves guided by these technologies, are seen to be as key drivers that all stakeholders in the space ecosystem consider to be key in realizing the full potential of the space economy.

1. Cyber security in space

While space operations promote the United Nations' developmental goals, provide weather forecasts, and innovate to address climate change, they also offer security dangers that must be managed. Historically, space and terrestrial systems served different users and requirements. This concept has evolved as Earth-Space networks have become increasingly sophisticated. Future smartphones may incorporate satellite messaging for emergency communication in areas without terrestrial connectivity. Digital transformation has led to system interfaces crossing traditional trust boundaries (partners, customers, etc.). Large satellite constellations increase the number and complexity of ground control and service support infrastructures, increasing the attack surface. Space services provide important services such as military, utilities, aviation, and emergency communications. This makes them desirable for cyberattacks, especially during geopolitical upheaval. In February 2022, as the Russian invasion of Ukraine began, a huge number of satellite modems in Ukraine and Europe were disabled by a cyberattack, prompting global operator Viasat to execute a hard reset to continue delivering crucial communication, especially to Ukrainian refugees in Slovakia. SpaceX supplied thousands of Starlink satellite internet terminals to Ukraine in 2022. To mention another case in point, a significant contribution to the reportage of Russian military activity in Ukraine, from the moment of invasion to subsequent attacks, came from high-resolution images of Maxar Technologies satellite. Given the importance of this trend, a separate section is dedicated to cyber security in space in the following sections of this report.

2. Space as a service

There are emerging new business models that use infrastructure that is leased rather than owned and are built on space-as-a-service. The two major branches of such services include:

Ground Segment as a Service (GSaaS): To help satellite operators reduce the burden of their ground segment operations, the concept of "ground segment as a service" was developed. Ground station operation, data storage, and other infrastructures are abstracted by GSaaS and mutualized for usage by numerous users. Providers of GSaaS rely on a single ground station network that can support numerous satellite operators. GSaaS is more suited to New Space needs than standard end to end offerings since it provides greater flexibility, cost-effectiveness, and simplicity. The GSaaS market has enormous development potential as a result of the dramatic expansion in satellites. The market is

expanding enough to accommodate new entrants despite the fact that competition has increased as a result of the wide scope (and demand) that this sector offers for incumbents and new entrants.

Picture 3: Providers of GSaaS are able to roll out movable satellite dishes[13]

Satellite and Payload as a Service: Targeting consumers that want to access space assets without incurring the expenditures of acquiring their own satellite or constellation, a number of Satellite and Payload-as-a-Service models have evolved. Operators rent out capacity to public or commercial organizations, giving them authority over direct or indirect tasking or just delivering data. By having an anchor client, financial risk associated to asset expansion for operators is frequently decreased. In the area of Earth Observation, the model is beginning to gain some momentum. This model also includes hosted payload proposals for in orbit testing or other missions. Customers can purchase entire end-to-end services that include payload development or supply their own payload. Offered through third-party platforms and adaptable, "plug & play" hardware and software interfaces by satellite makers or intermediaries (e.g., Loft Orbital)

3. Regionalization of space

Numerous space activities are being impacted by recent geopolitical events, which are also driving to regionalize the industry. Space has not been exempted from the geopolitical repercussions and restrictions brought on by the conflict between Russia and Ukraine. The impact is felt in a variety of areas of the space industry, including science, satellite communications, and other fields, highlighting the strategic relevance of space on the international arena. Additionally, this is a major factor in the regionalization of space activities and the localized push for greater independence and autonomy in space. Due to the current geopolitical situation, several missions have been suspended or postponed, which include: ESA is presently looking for a replacement landing system and other important technologies to replace Russian contributions to ExoMars, the Russian Spektr-RG satellite's German eROSITA black-hole telescope has been turned off, a potential US-Russia collaboration on the Venera-D Venus mission has been canceled, and ESA and Roscomos collaboration on the Luna-25, 26 and 27 missions has ended, with other institutional and commercial flight prospects identified.

Picture 4: Ongoing geopolitical events may jeopardize US-Russia space agreements[14]

Additionally, there is a considerable disruption in space access, which has an influence on a number of institutional and commercial missions slated for launch on Russian rockets. There is concern regarding upcoming launches, particularly the launch of the following generation of Galileo satellites, as a result of the absence of Russian backing for Soyuz launches from the European spaceport in Kourou. The ExoMars mission has been put on hold until it can be modified for a different rocket and a launch window is available because the Russian Proton rocket is no longer an option. As customers look for new launch providers and demand for SpaceX launch services increases, a backlog of delayed launches is anticipated.

4. Militarization of space

The Outer Space Treaty of 1967[15] prohibits the deployment of nuclear weapons and other Weapons of Mass Destruction (WMDs) in space. Additionally, it forbids military operations on celestial bodies while allowing for enforceable regulations governing space exploration and peaceful use. The pact makes no mention of "weapons of mass devastation" and makes no mention of the launch of ballistic missiles, which may be fitted with any kind of warhead. The use of transitory vehicles equipped with nuclear weapons, WMD, electronic systems, energy platforms, or kinetic systems is made possible by this gap or omission. During the flight phase, these movable vehicles can transform into weapon platforms. Many countries have already hiked up their defense and military space budgets for the upcoming years. For example, the 2023 US Government budget requested for space included US$ 24.5 billion for its newly formed Space Force, up from US$ 5 billion from prior years. China and Russia are following stead with similar increased allocations towards the militarization of space.

Picture 5: Logos of the US Space Force, the French Space Command and China's Strategic Support Forces, all of which are national space programs for different governments

Growing dangers are driving people away from traditional, large-scale systems and toward quick-to-market, low-cost solutions, such as commercial and "connected" options. Early warning systems for ballistic and hypersonic missiles; multilayer constellations from the Space Development Agency; resilient communications; Situational Awareness in Space, both on Earth and in Space are under development. Amazon's Kuiper and SpaceX's Starlink, among other commercial EO and SATCOM disruptions, result in a merging of military and commercial systems for the warfighter. Programs like the Joint Enterprises Defense Infrastructure Cloud Contract (JEDI) and the Joint All-Domain Command and Control (JADC2) are developing the idea of "Space as a Node," putting more value on data than on conventional networks.

Space has always been a battleground for intelligence operations, from the American spy satellite series *Corona*, used for photographic surveillance of the Soviet Union, to the latest *NROL-91* launched in September 2022. Reconnaissance satellite nowadays are mainly used for imaging surveillance through synthetic-aperture radar (radar imaging surveillance) and electromagnetic spectrum (optical imaging surveillance) and for signal reception. Signals intelligence intercepts encrypted radio waves to detect messages between people and/or machines, while other spy satellites are able to detect nuclear detonation and ballistic missile launches. The stratosphere is a true open square to gather

information on governments and organizations, therefore becoming a key asset in espionage activities.

5. New opportunities for downstream space applications

There are more chances for downstream space applications in a variety of terrestrial industries. With the use of space data in industries like agriculture and insurance, there are an increasing number of downstream solutions for terrestrial applications. A number of new industries are starting to look for space solutions, especially for applications involving better connection or environmental monitoring. Due to a low level of awareness, there may be issues connecting with terrestrial sectors, difficulty integrating space data into current platforms and solutions, and the high cost of adopting space-based solutions.

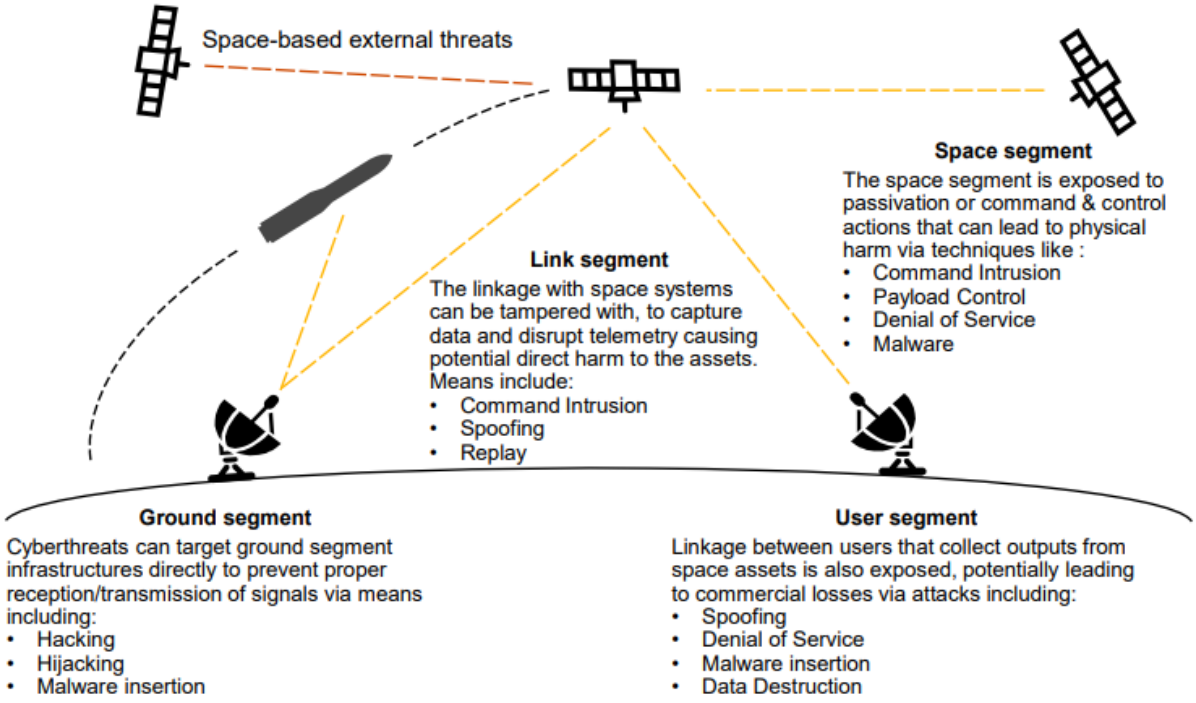
- **Finance:** The sector is looking for quantitative space data for ESG variables due to the sector's increased interest in sustainable finance and regulatory constraints. Commodity merchants and investors are also interested in using satellite data to gain competitive insights from space.
- **Offshore wind energy:** satellite data could help judicial and administrative permits linked to environmental impact standards or animal monitoring. The wind energy sector already relies on meteorological data. Additionally, communication is required as offshore installations are constructed in deeper waters.
- **Tourism:** In addition to space tourism, there is significant interest in applying space solutions for destination management and sustainable tourism, including assessing climate change effects and biodiversity. Connectivity is particularly important for cruise ships and remote tourism activities.
- **Virtual reality:** Players are looking for more sophisticated and realism-based elements in videogames, especially those with space themes and the ability to use high-resolution satellite imagery. The experience for gaming events can be improved and AR games can be enabled.
- **Internet of Things:** IoT analytics is a major trend in several industries, including smart cities, agriculture, and urban planning, where satellite data may be incorporated to produce improved insights and solutions. Additionally, satellite communications (satcom) can offer IoT connectivity in remote places, on ships, or during long distance travel.
- **Environmental protection and fight against climate change:** Space technology and satellite services can make a difference in mitigating climate change. With weather satellites it is possible to monitor and predict the power output of photovoltaic power plants, thus gaining useful information to improve systems and identify faults that reduce energy production by more than 10% a year. Via miniaturized ceramic gas sensors also heating combustion can be managed and controlled through particular technologies that allow the reduction of fuel consumption by 10-15%. Additional fuel saving of 15-25% could be reached combining satellite information and cars' satnav systems to optimize the operation of auxiliary devices basing on locations and road conditions.
- **Infrastructure monitoring in key sectors (Oil & Gas, Mining):** Radar imagery taken by satellites can revolutionize the way infrastructures are measured and monitored. Data collection and interpretation through millimetric scale make it possible to notice very small changes and run more efficient analysis and predictions about infrastructural damages and failures. Space sensor technology can also be used in offshore drilling tools and in exploration activities, from floor mapping to inspection of installations, proposing a great advantage for the oil and gas industry.

- **Archaeology and cultural heritage protection:** Through the process of remote sensing also satellites are valuable tools in archaeological discoveries, since all the images taken from aerial or space platforms can be analyzed and investigated by professionals anywhere in the world.

Cyber security in space

The reality that there are numerous entry points for cyber attackers in the ground systems and network equipment needed to control space systems is something that satellite operators and other stakeholders in the space economy must cope with. Cyber and malware attacks are quite easy to carry out, making them significantly more affordable than missiles or lasers in the domain of space, and having the tendency to cause much more debilitating effects. It is for these reasons that the space economy must be well equipped to deal with such cyber-attacks in order to ensure the safety of the wider ecosystem.

The space industry and technology share a lot of similarities with our terrestrial digital world's infrastructure and perform many of the same tasks. However, size, distance, and the importance of systems and equipment operation pose the most problems. For instance, if a hacker infiltrated earth-based system and supplied a satellite with false information, it might result in an interstellar collision and possibly bring down important communications networks worldwide. Second, more governments and corporate groups than ever before are getting involved in space programs. The number of potential access sites for hackers grows even as the entry barrier is dropped, encouraging creativity and discovery. The primary player that needs to be protected is no longer NASA. Malicious actors now have a much wider range of potential targets, including other governments and equipment suppliers. The development of sophisticated technology that can be used for hacking, such quantum computers, also poses a serious cybersecurity risk to the ecosystem located in space. As industries like space travel and militarization advance, hackers who are aware of the potential financial benefit of ransomware and other assaults will turn their attention to these developments. The significant lack of international cybersecurity collaboration combined with space technology creates several challenges that must be overcome in the coming decades.



Picture 6: The exposure of the different segments within the space economy exposed to cyber threats[16]

By creating uncertainty in revenue and cost models, cyberthreats can weaken business models. Insurance against cyberthreats will be more and more necessary, raising the cost of satellite programs and operations. Data dependability, particularly in defense and intelligence, might deteriorate, which makes decisions more difficult. Future risks, such as attacks on commercial HSF and space stations, could escalate in severity.

Attacks on space infrastructure are no longer confined to nations with space-capable satellites; the proliferation of low-cost satellites has considerably increased the possibilities for hackers. The potential of cyber-attacks on satellites is increasing as the number of satellites launched and reliance on satellite-dependent technologies grows. Some of the more prominent types of attacks include:

Ground control system compromise: Obtaining cryptographic keys to gain control of the satellite. Subversion of ground system capabilities by utilizing the ground system to maliciously interact with a satellite

Attacks on the satellite-to-ground communication link: Injecting malware into communications, spying on the link, interfering with signals. Communications hacking on systems via command link injection, replay attacks, or electronic attacks like jamming and spoofing

Attacks on the satellite itself: Malicious features embedded during hardware development, including hardware-based trojans. Design vulnerability exploitation, where designed-in features of the system are used for malicious purposes, i.e., direct memory writes to a satellite. Destroying the satellite in space, interfering with satellite capabilities in space (e.g., altering or "blinding" satellite sensors to deny surveillance or the capacity to monitor and track armed forces), incorporating backdoors into satellite software or firmware during the design process. The economic costs associated are also of very high magnitudes. A cyber-attack on the Global Positioning System alone could cost the US $ 1 billion a day.

In addition, there are also threats such as software defined radio compromise, insider threats and bringing down satellites as space to earth weapons. The workflow below showcases the value chain that contributes to the space economy, and space sector in general, during which there is scope for the different types of cyber-attacks, and the work around in ensuring cyber safety.

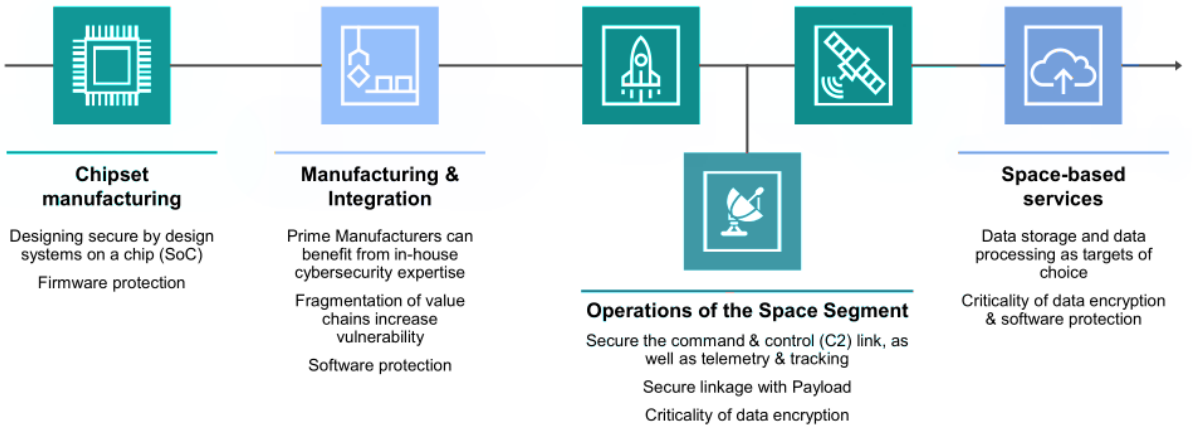
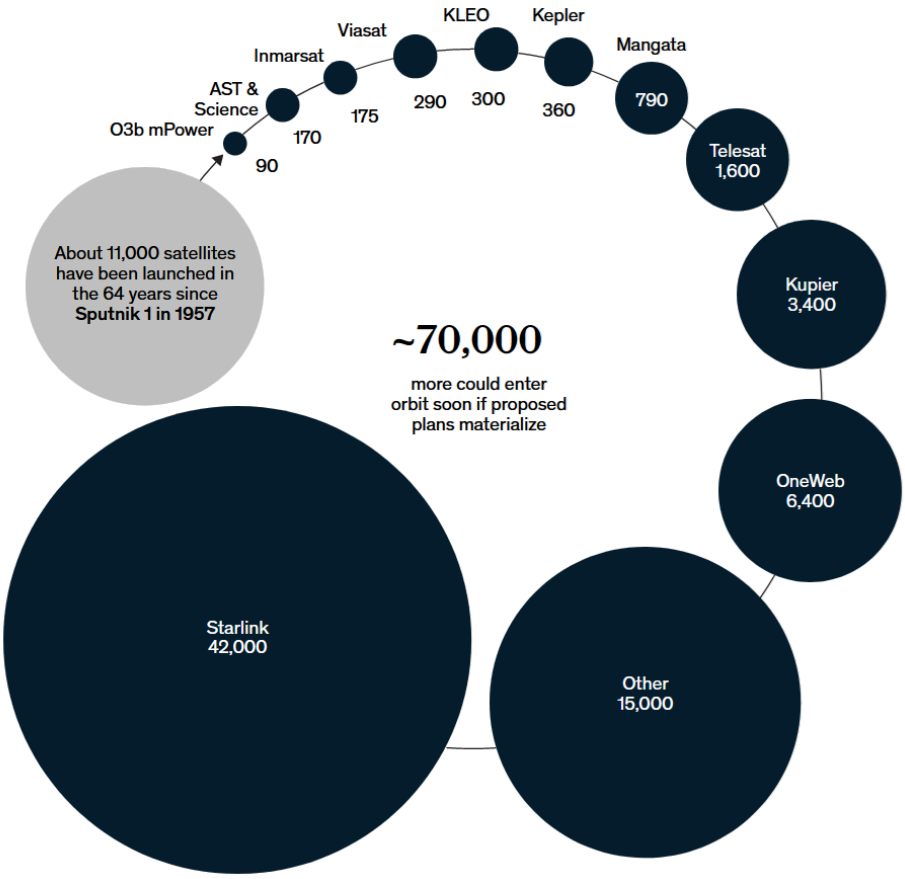


Chart 3: The value chain across the space economy that is vulnerable to cyber-attacks and accompanying cyber protection measures that can be used[16]

Government and business parties saw the necessity for the development of new defenses as nation-state actors began to pose cyber threats in space. However, the development of space-centric

cybersecurity standards and regulation has lagged behind the expansion of the cyber threat. To make sure systems are resistant to cyber compromise, government, business, and the international community must implement defense-in-depth strategies for space system safety. Increased collaboration between various disciplines is one possible solution, and it calls for a combination of policy, standards, and technology solutions.



Picture 7: More than 70,000 satellites could enter orbit in the near future, leaving a large security concern for potential targets by hackers and other industry agents[17]

It is important to distinguish between cybersecurity concerns for systems that are in active design or development and those that are currently functioning, such as those in orbit. Due to the limitations and potential solution space provided to mission owners, guidance may vary dramatically between these two stages. Addressing cybersecurity concerns for systems that are already in use is primarily limited to ground segment updates. While it is possible to update software while in orbit, doing so can be risky and is typically avoided to prevent mission failure. Knowledge and funding are the major obstacles for ground-based defenses. Budgeting, standards/requirements development, and knowledge transfer are important since ground systems replicate more conventional IT systems. The major obstacles to satellite defense are raising awareness of the risks and creating on-board cyber equipment that complies with the satellite's physical, electrical, and computing constraints. It will need a shift to adopt "security on-board" since satellite engineers have a strong motivation to use what has previously worked, due to which there are not many choices for deploying security systems on board a satellite. In order to build and mature security solutions that can operate within a satellite's field of view and have the intended effect of cyber resiliency to protect, detect, recover, and respond, more investment is required from both government and commercial groups.

Ongoing developments in space cyber security: Threats and initiatives

A useful starting point for more general cyber rules for the whole space industry as it develops and adopts commercial software would be Germany's security guidelines for satellites[18]. The Federal Office for Information Security in Germany, which just released the guidelines, is aiming to use them as the foundation for any future global or European cybersecurity regulations pertaining to the space sector. Businesses would benefit from having similar words they can use to with partners and suppliers in various nations. The document lays out minimal cyber safeguards to help satellite enterprises ensure their supply chains handle specific vulnerabilities. The German standards outline precautions to be taken to protect satellites at various stages, including when they are being transported, tested, and once they are in orbit.

Attacks have been occurring for a while now, but recently they've been more frequent. In 2018, malicious software compromised American computers that manage satellites. In 2019, Iranian cyber gangs attempted to mislead satellite providers into installing malware. Additionally, one assessment found that Russia had hacked the GNSS and sent phony navigational data to thousands of ships, causing them to deviate from their intended path. The vulnerability of satellites was demonstrated by a cyberattack on Viasat Inc. on February 24, 2022, the day of Russia's invasion of Ukraine. The attack disrupted remote monitoring systems for German wind farms as well as internet connectivity for thousands of Europeans. According to the corporation at the time, the attackers had targeted modems and other devices in Ukraine that were connected to a Viasat satellite. The U.S. Cybersecurity and Infrastructure Security Agency issued a warning in March regarding potential dangers to satellites. The US, UK, and European Union (EU) attributed the Viasat incident to Russia in May. Russian officials have repeatedly denied conducting cyberattacks.

Through the non-profit Consultative Committee for Space Data Systems, government space agencies from the U.S., Japan, China, Canada, Germany, and Italy debate cybersecurity. The European Space Agency, which is a separate organization from the EU and includes non-EU nations like Switzerland and Norway, is another group member. The European agency on the other hand is looking into potential post-quantum encryption technologies and is keeping an eye on a global competition being sponsored by the American National Institute of Standards and Technology to find safe cryptographic algorithms. The EU launched the European Quantum Communication infrastructure initiative to build a secure infrastructure that will be robust especially against quantum computer threat. In the event that post-quantum computers develop that can defeat the degree of encryption used today, the group has examined ways to safeguard satellites that could remain in orbit for around ten years.

The EU also recently launched an initiative for a satellite-based connectivity system that will ensure worldwide uninterrupted access to secure and affordable satellite communication services for the protection of critical infrastructures, surveillance, external actions, and crisis management. On the other side of the globe, China is improving its ability to destroy satellites with directed energy weapons (DEWs), such as lasers and hyper microwaves.

Companies such as Cysec, SCASSI and Decentriq are some of the few that specialize in Audit & accreditation of the cybersecurity of space & ground systems, networks. They also provide technical evaluation and hacking of embedded components for cyber proofing.

The Global Space Economy is expected to reach US$ 642 billion by 2030

In its annual "Space Economy report" for 2021 that was released this year, Euroconsult, a space consulting and market intelligence firm, expects the space economy to reach US$ 642 billion by 2030, growing at a 6.3% CAGR during the forecast period, from its estimate of US$ 370 billion in 2021[19]. Estimates by Research And Markets pegs the size of the industry at a similar value of US$ 388.5 billion in 2021[20], with a similar forward CAGR. For a growing number of nations, space is becoming increasingly crucial. Space has evolved into a strategic domain for national defense and security, climate change, and connectivity, all of which are key drivers in the market's growth.

The space economy is primarily composed of the space market, which includes commercial space revenues and government procurement for space activities contracted to the private sector, and other spending (internal costs, research and development) from government organizations to conduct their space activities. The commercial space market occupies a giant's share at US$ 278 billion (or 75%) in 2021, followed by government procurement at US$ 59 billion (or 16%) and finally other government spending at US$ 33 billion (or 9%) in 2021. The space economy is anticipated to resume its robust growth trend after seeing a 4% decline in 2020 due to the impact of the COVID crisis on commercial space services, growing by 74% by 2030 to reach US$ 642 billion (at a 6.3% CAGR)[19].

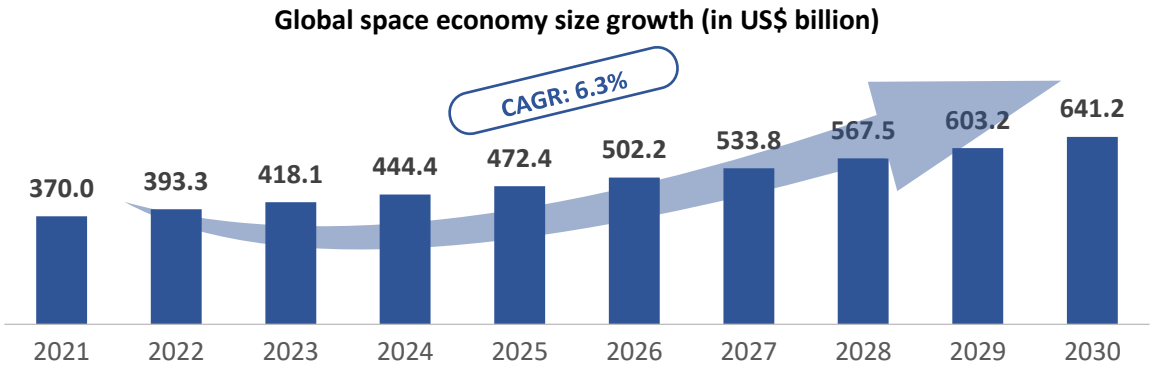


Chart 4: The global space economy is expected to grow at a CAGR of 6.3% till 2030[19].

The space industry is expanding globally, with a record number of nations and commercial businesses are running space initiatives. Currently, space infrastructure that has been deployed makes it possible to develop new services, which in turn enables it to develop new applications in fields like meteorology, energy, telecommunications, insurance, transport, maritime, aviation, and urban planning, all of which have positive effects on the economy and society. Deep space exploration and the proliferation of business entities in the sector are the main reasons why the space economy has been growing in popularity and size. For example, according to UBS, space tourism remains a small subsector of the larger space economy opportunity (estimated by them to be US$ 900 billion by 2030), which amounts to approximately US$ 4 billion by then, or 5% of the space economy market[21].

The COVID-19 pandemic had a negative impact on the global space economy. Due to the pandemic, there was a decrease in private sector investment, as evidenced by the cancellation of launches, the scaling back of operational missions, and the closure of several private businesses. With greater vigilance in the space economy for commercialization, sustainable space projects, and sanctuary of critical industrial assets in the space sector, the space economy is anticipated to rise dramatically in the next years.

Key market dynamics and future growth potential

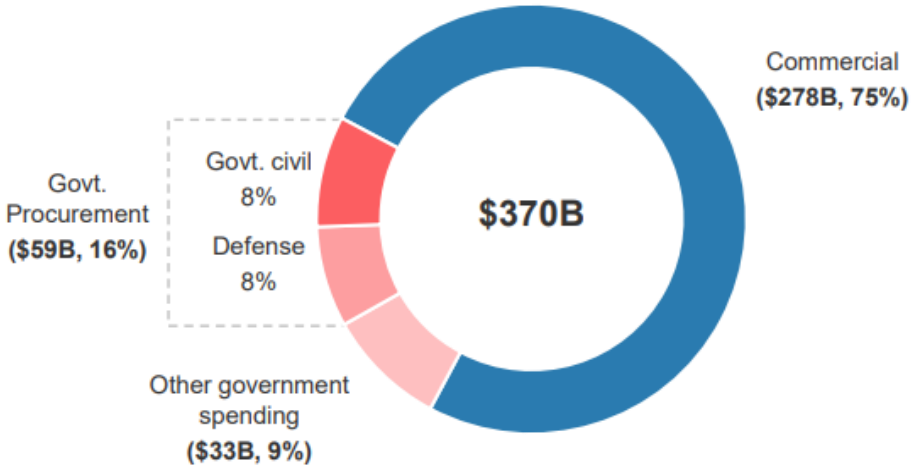


Chart 5: The segregation of the space economy by client type in 2021[19].

The global space economy is fragmented and divided between many players and stakeholders. There are many participants in the global market, including both public and private businesses. In the upcoming years, the market is likely to see new private startups. Private enterprises took involved in space activities to an ever-increasing extent, according to the space economy sector.

Growth Drivers: The proliferation of commercial actors in the industry, as private businesses have substituted various operations of government space agencies due to lower costs and quicker manufacturing times, is what propels the global space economy market. Additionally, the market has grown over the past few years as a result of a variety of factors, including increased government funding for space programs around the world, infrastructure development for the space economy, rising demand for cargo spacecraft, rising demand for satellite launches, and quick deep space exploration.

Challenges: The market has faced difficulties due to the growing amount of space debris, which poses a risk of harm to both active satellites and upcoming space launches. The market has also encountered significant difficulties, such as locating an acceptable regulatory framework.

Trends: As space science and exploration have progressed, the notion of space tourism has gained popularity, and numerous private companies are working to bring it to fruition in the near future. The space economy market is expected to expand due to a number of trends, such as the rising demand for uninterruptible internet, the introduction of space resource utilization (SRU), the sharp rise in small satellites and micro and small launch operations, the development of in-space manufacturing, the quick development of asteroid mining technology, the rising demand for payload & telemetry data, and the expanding connection between space and agriculture.

Large enough to contribute to nearly 0.6 percent of the global GDP[22] and also expected to growth at above GDP growth rates, the space economy has seen its size estimates in the future diverge across sources as shown in the graph below. This is primarily on account of using different methods of calculations and considerations of what should be included in calculating the size of the space economy.

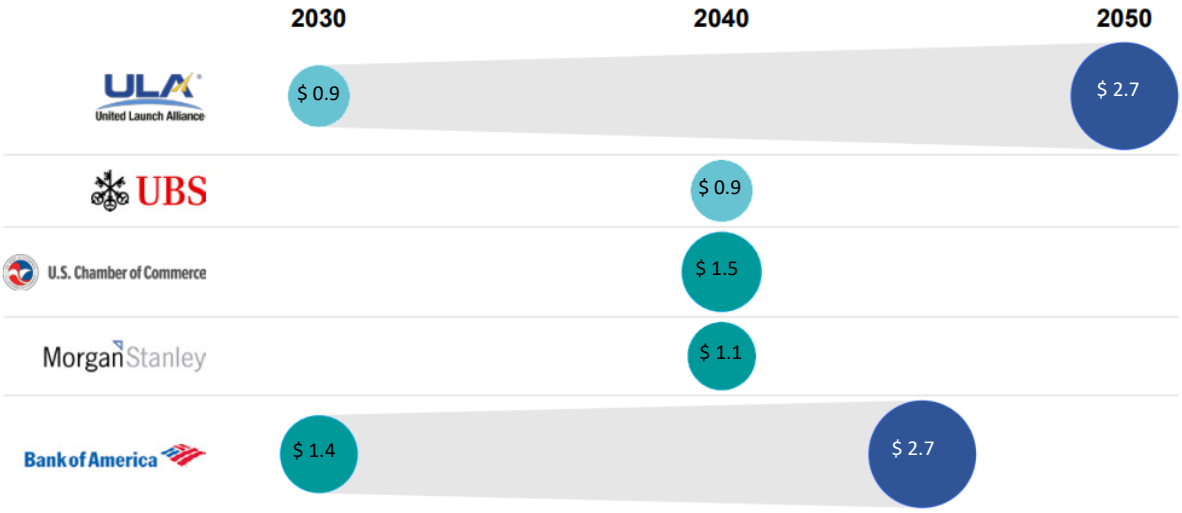


Table 1: The divergence in the estimated size of the space economy over the next 10 – 30 years (in trillions of US$)[22].

A closer look at the global space market

The global space market, which includes commercial activities and government procurement, was estimated at US$ 337 billion in 2021, an increase of 6% from 2020, making it equivalent to the market value of 2019 before the COVID-19 crisis, which impacted the revenues from satellite services in 2020. Satellite navigation and communications continue to be the biggest income generators, accounting for 50% and 41% of the overall market value, respectively, driven by B2C applications. Comparatively, Earth Observation (EO) still represents a meager 5% of the entire value, but with a far bigger upstream share. The growth of satellite navigation overtaking satellite communications, from roughly 37% of total revenues in 2016 to over 50% in 2021, is entirely attributable to the services made possible by GNSS services and the devices connected to them.

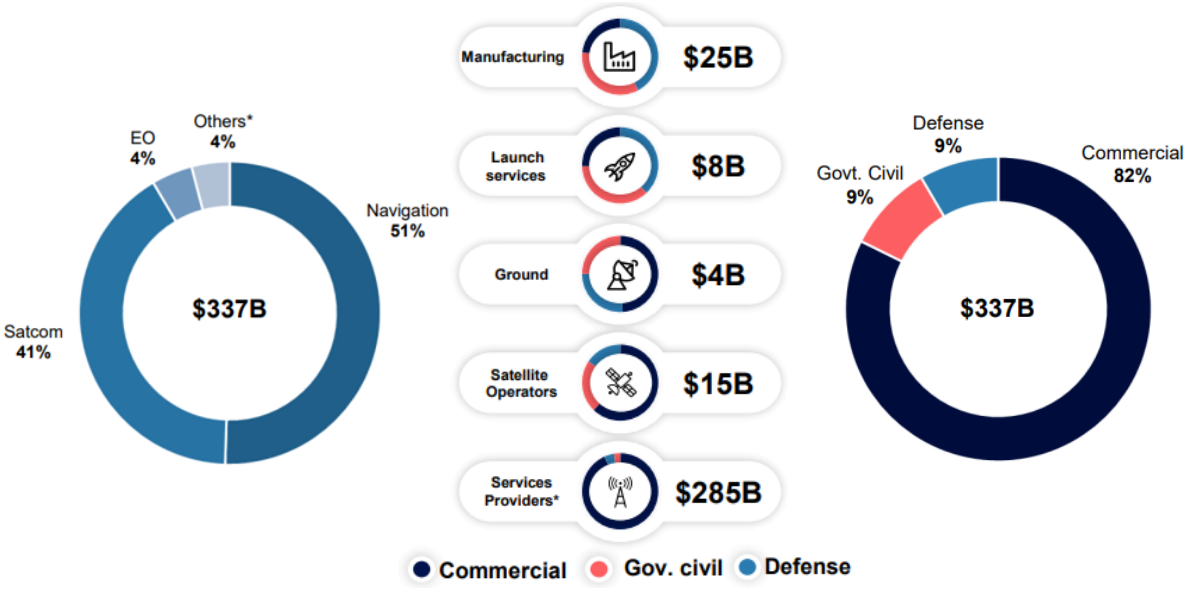


Chart 6: The split in the global space market by application and client type across the entire value chain for 2021[19].

Within the global space market, the upstream and downstream markets show distinct structures and drivers as seen below, across geographies (North America being the clear leader in upstream), applications (navigation and sat com taking the most upstream share) and clients (commercial leading the downstream markets)

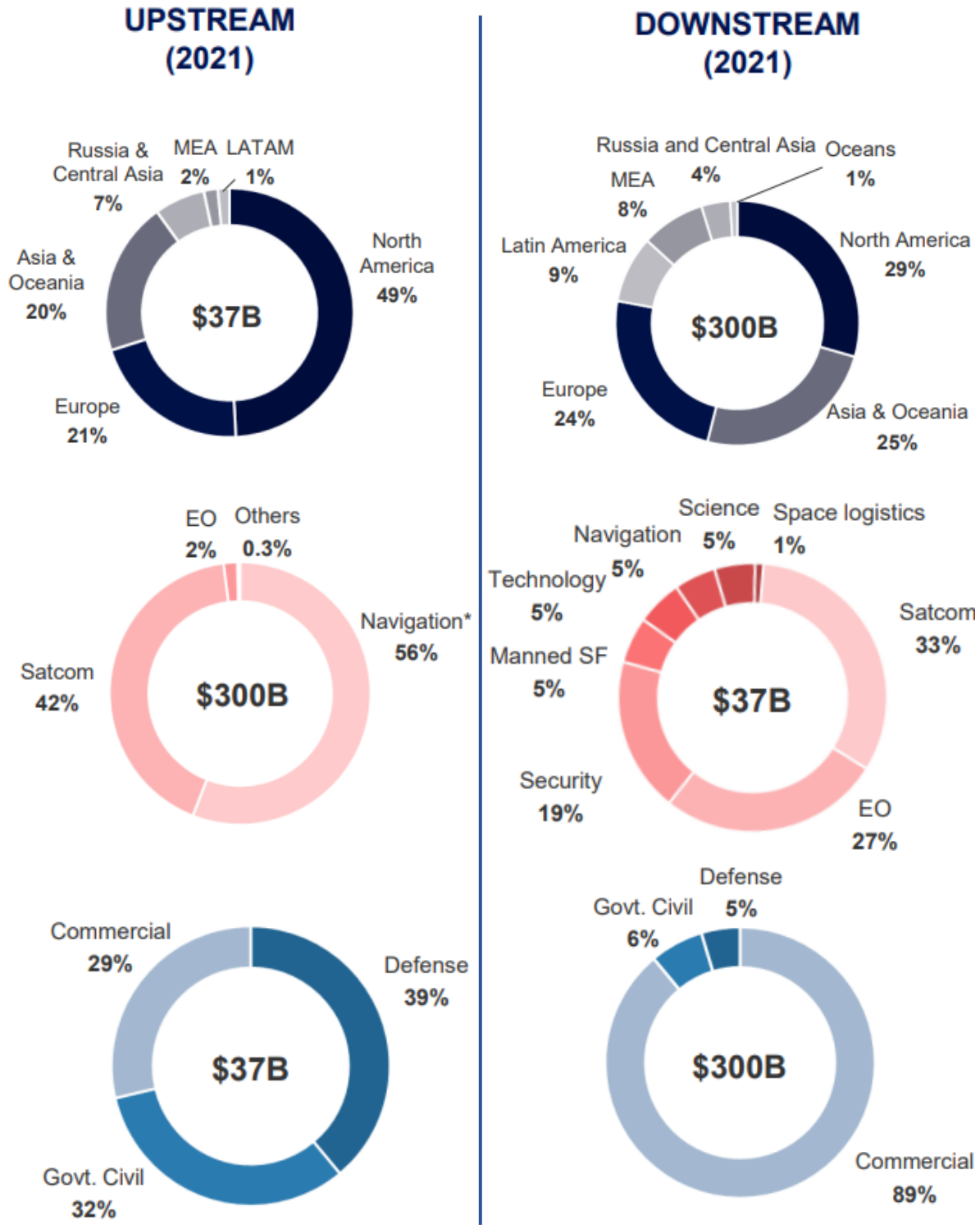


Chart 7: Segregation across upstream and downstream segments across geographies, applications and client types, for 2021[19].

Domain specific trends across the value chain that are shaping the space economy

Together, private sector business leaders and governmental organizations have turned the once-impossible ideal of space travel into an operational worldwide industry, establishing commercial aerospace firms, launching rockets and satellites, and even paving the way for space travel. In fact, 2021 saw 64 commercial space trips[23], which is more than twice as many as in previous years. The days of governments controlling markets and national interests alone guiding the evolution of the extraterrestrial environment are long gone. Going forward, there will be a conscious effort to concentrate on profitability, sustainability, and figuring out how much demand there is for space services from the viewpoint of specific citizens. In other words, business considerations must take precedence.

A wide range of economic opportunities, including new markets for firms and employment opportunities for people, are made possible by the expansion of space exploration and the private aerospace industry. The space economy is prepared for a growth trajectory akin to one of its rocket launches, with established players, business moguls building rockets to send themselves into space, and entrepreneurs starting businesses to gather orbital trash and make space travel more sustainable. The sections below highlight the trends relevant to each domain within the upstream and downstream sectors of the space economy, and the corresponding areas of focus driving growth for the future.

1. Evolution and increase in demand for the Earth Observation market

With hundreds of satellites planned to be launched in the upcoming years by both private enterprises and governmental organizations, the worldwide Earth Observation (EO) industry is expanding quickly. Factors such as the democratization of use of satellite data and information, interest in satellite imagery from a military interest (the war in Ukraine has heightened demand for the same) as well as environmental monitoring tools for tracking climate change and use for agricultural purposes, and finally the advancements made in the field of cloud computing, data analytics and machine learning towards analyzing satellite images.

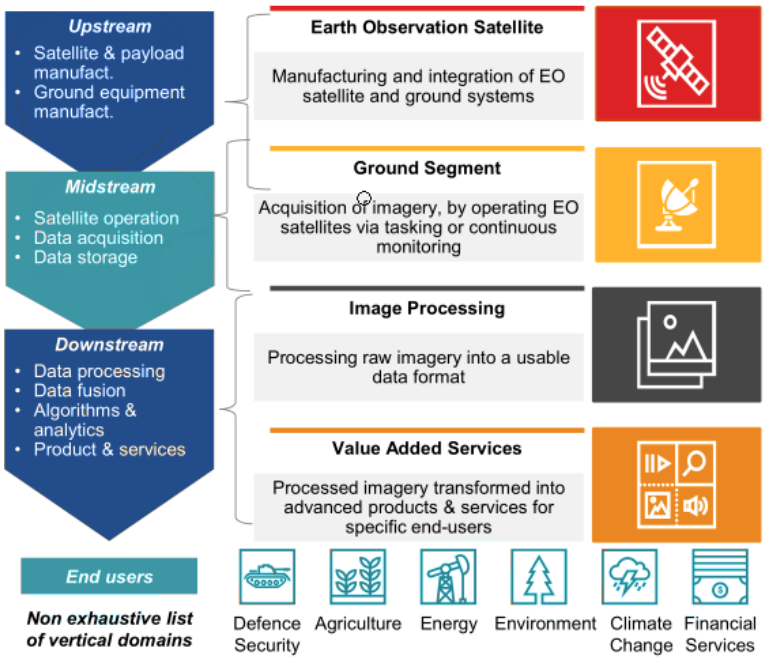


Chart 8: An overview of the Earth Observation value chain[24]

Several nations are investing in EO constellations as part of their national space strategies, taking advantage of advancements in the space industry, such as the reduction in the cost of access to space, the increase in the miniaturization of satellite systems and subsystems, and the introduction of innovative business models like "space-as-a-service." This includes plans from commercial EO firms to support their respective governments' Earth Observation data policies, such as LatConnect60 in Australia and Nara Space Technology in South Korea. Australia announced earlier this year that it would design, build, launch, and operate four new EO satellites. The UAE also announced plans for their SAR (Synthetic Aperture Radar) constellation.

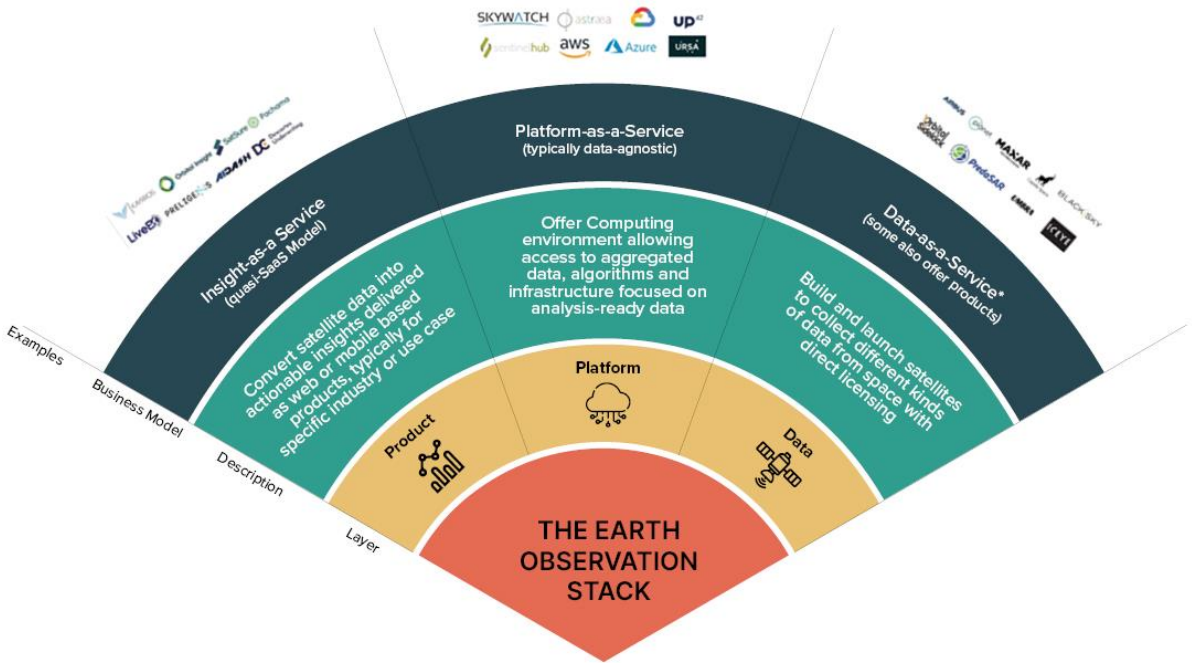


Chart 9: An overview of the Earth Observation value stack of services[25]

'Space-as-a-service' and satellite-as-a-service' make sovereign EO possible and easy to deploy. Space-as-a-service models allow governments to contribute to EO missions by supplying the critical payload and 'outsourcing' the remainder to commercial enterprises. Spire and Loft Orbital integrate, assemble, and test payloads, negotiate launch service agreements, and operate satellites. This concept allows the private sector to contribute to mission design and payload manufacturing, ensuring the mission's economic logic. With regards to 'satellite-as-a-service' concepts, ICEYE, a Finnish microsatellite SAR player, will provide fully operational SAR satellites in the following months. This arrangement allows countries and companies to buy turnkey satellites from ICEYE, assuring they own the assets.

From a financial perspective, this sector has seen interest from major insurers investing heavily in satellite data exploitation (e.g. AXA Climate, SwissRe, MunichRe, etc.). 4 recent SPAC IPO's (3 in 2021 and 1 in 2022) amounting to US$ 1.4 billion raised, and subsequent M&A by the listed players (Planent and Spire) of close to US$ 200 million indicate that this sector will see consolidation and a continued interest from financial investors and upcoming companies alike. Numerous EO systems are being developed, including Open Cosmos, Earth Blox, and Astraea, which were recently in the headlines, as well as by major IT firms like Google, Amazon, and Microsoft.

2. Increase in the accessibility to space through launchers

The space launch market has seen the use of different classes of orbital launchers by mainly six spacefaring nations.

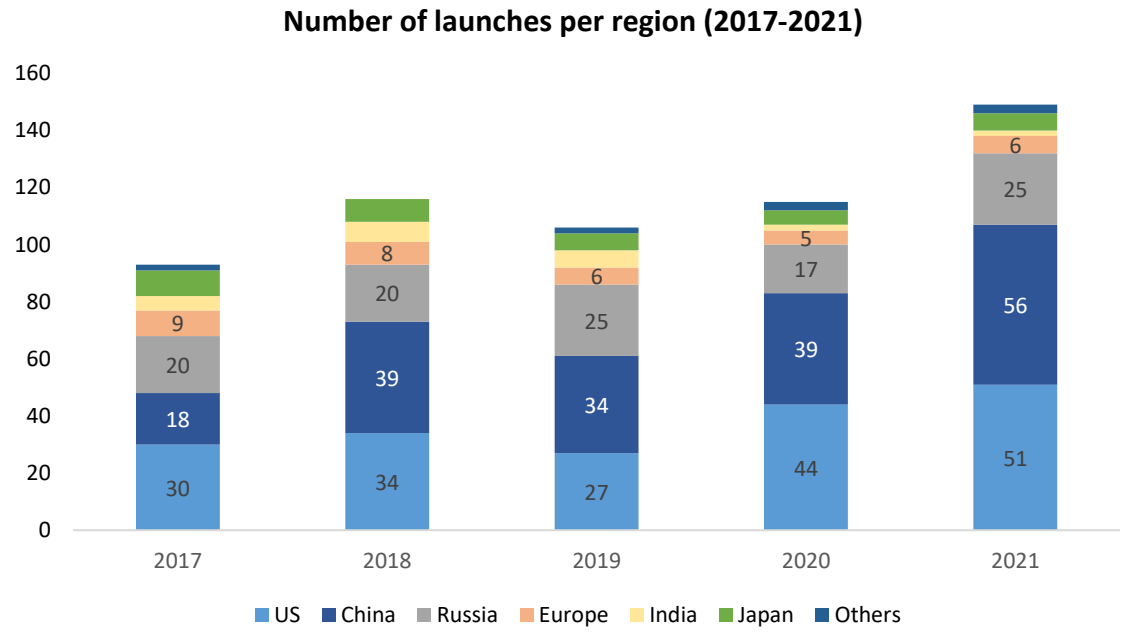


Chart 10: Distribution of launches per region over the last few years[24]

With the regional markets being largely captive and in the hands of a few regions / countries, countries such as China have recently outpaced the US in terms of launches made. The market is expected to be driven by medium-lift launchers, along with the new super-heavy launchers such as the BFR-Starship or New Glenn, that allow for the deployment of flocks of constellation satellites. Technology developments such as reusability, 3D printing or parts or even engines (provided by companies such as Orbex Prime, RocketLab) are expected to help in the increase in launches. The proliferation of space ports or dedicated launching pads or hubs for space activities are also seen as another growth driver. The increased use of motorized dispensers and micro launchers are seen as a way for other nations to rideshare or piggyback on payloads that are being sent to space, while also bringing down the overall cost. Green initiatives that subsidize renewable rocket fuel and re-using rockets are other factors that are expected to be seen as catalysts in the movement.

While there has been a rapid surge in the development of space ports globally, the demand for them is yet to be deemed to be sufficient. Governments have developed space ports with the intention to host operations for small / micro launcher vehicles, with subsequent ports being also opened for include space tourism. This relies heavily on inter-country co-operations (e.g. UK agreement with the US enabling US Virgin Orbit launch from Cornwall Spaceport, etc.). The US has over 12 commercial space ports, and another 16 under development. China has 2 space ports, in addition to 4 launch centers. The UK, Brazil, France and the UAE are each developing their space ports that are expected to be ready within the next decade, with the UK already completing a first series of tests. Smaller sub-sets of space ports are also under development in Norway, Sweden, Portugal and Germany – all of which are relatively smaller in size and expected scope to their global counterparts.

Space tourism has seen recent interest in the form of experimental and entertainment activities in the air and space environment. 2021 witnessed several successes in space tourism, which could be

marking the start of the space tourism era. The different types of flights and offers currently underway include:

Orbital spaceflights: A human spacecraft entering an orbital trajectory is referred to as an orbital spaceflight. Spacecraft in orbit must travel at orbital velocity, which is substantially faster than that needed for suborbital spacecraft. As a result, developing orbital spaceflights is more difficult and expensive, and it implies higher safety criteria.

Suborbital spaceflights: Suborbital spaceflight is described as a journey up to an extremely high altitude without putting the craft into orbit; the average altitude threshold is set at about 100 km. The primary developing market that sparked the commercial revival of space tourism is suborbital spaceflight. It can be pursued using balloons or rocket-powered vehicles (e.g. World View, Space Perspective).

Parabolic zero-g flights: During sets of 20 consecutive seconds, a certain aircraft (often an Airbus A300) conducts a parabola-shaped trajectory maneuver to simulate zero gravity. In addition to being employed for recreation and microgravity research, parabolic flights are also used for astronaut training.

Space facility visits: Space tourism also includes visits to space facilities and space centers open to the general public and conceived to foster public awareness on space matters.

While a lot of past activities focused on sub-orbital flights, orbital tourism remains targeted by private ventures building future plans. It was marked by SpaceX's successful orbital flight in 2021. Space tourism has led to some public backlash about its exclusivity to billionaires, environmental impacts, and its importance.

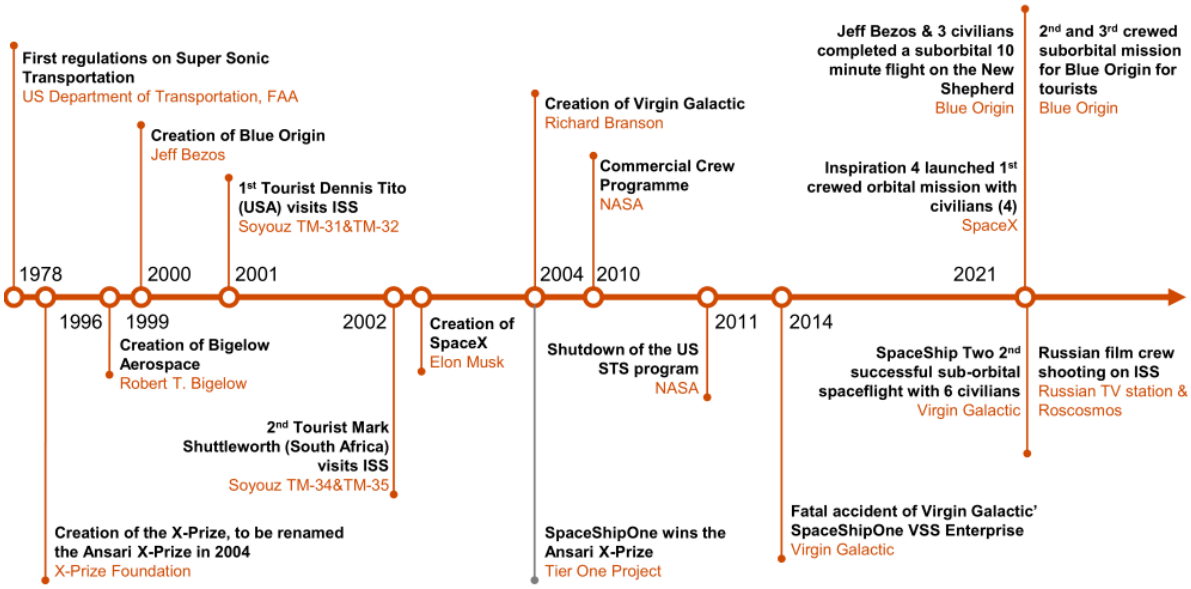


Chart 11: A timeline of the evolution of space tourism over the last decades[24]

3. Improvements in satellite communications (satcom) market driven by capacity & demand across existing business models

The view that that satellite technology is excessively expensive, has significant latency, and has limited capacity are beginning to change as it continues to penetrate the communication market. Some of the most crucial developments to keep an eye on include the rise in small satellites, the usage of Low Earth orbit (LEO), launches using reusable rocket launch vehicles, and new applications for 5G and the

Internet of Things (IoT). Satellite technology has the potential to play a significant role in Internet of Things (IoT) connectivity and "connect the unconnected" in regions of the world where there are currently no other viable options for communication. The sector has seen its share of evolution over the ages, with several satellite options available to satellite operations (HTS, VHTS, Flexible HTS, LEO HTS, Small GEO's etc.), who in turn are adopting a mix of these solutions. The pricing strategies for new players (Starlink) and the oversupply of capacity is putting pressure on pricing. The market also saw acquisitions in 2021, as an example, Viasat acquired Rignet, and then merged with Inmarsat to create a larger player in this space.

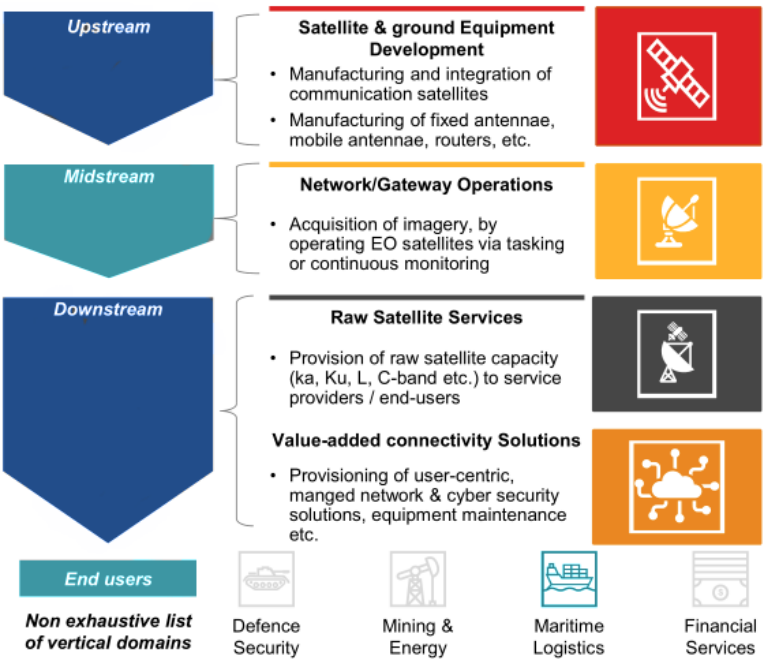


Chart 12: An overview of the satcom value chain[24]

Going forward, demand will continue to be driven by consumer broadband connectivity, anywhere connectivity (especially through aircraft carriers), and continued rise in Direct To Home (DTH) and Over The Top (OTT) streaming services. Military and governments will also continue to scout for high throughput and secure communications under multi-bank or multi-orbital networks. Existing demand is being met by mega-constellation operators such as Oneweb and Starlink which account today for close to 15% of total capacity. By 2025, it is expected that mega-constellation operators would account for over 80% of the total market supply.

According to EU Commissioner Thierry Breton, a fully (end-to-end) European constellation must be created within the EU, in order to compete with already-existing competitors like Oneweb, Starlink, Telesat, etc. Under the auspices of the "Guwang" or "national network," the Chinese government is attempting to create its own mega-constellation. As indicated by the EU Commissioner, the EU is initiating a satellite based secure connectivity system aimed at enhancing European sovereignty. This initiative was launched in 2021 for the development of a European satcom constellation, following which the Toulouse Agreement was signed in 2022 where EU states agreed on the need for an autonomous satcom constellation infrastructure. The plan envisages the building of a new infrastructure or "system of systems" on which feasibility studies have already been commissioned by the EC to incumbents and new space economy players.

Map 1: An overview of LEO satcom constellations being developed worldwide[24]

4. Increase adoption and improvement in satellite navigation (satnav)

Global Navigation Satellite Systems (GNSS) have historically been providing positing and timing data to an ever-expanding user base. Global navigation systems are being used by a very broad variety of people across all industries and provide information regarding positions, routes, speed, and timing. Public bodies are free to send navigation signals, and their use generates a sizable amount of economic activity. The creation of multi-constellation receivers (capable of receiving several GNSS signals) is anticipated to increase their adoption by end users and improve accuracy and integrity of performance. Additionally, navigation signals will need to fend off attacks like spoofing and jamming. The receiver market is being pushed to develop multi-frequency capabilities for its products by the growth of GNSS constellations and augmentation systems, as well as the increase in new signals that is linked with these developments. The functionality of the space components is being improved as GNSS adoption rises to keep up with changing user demands.

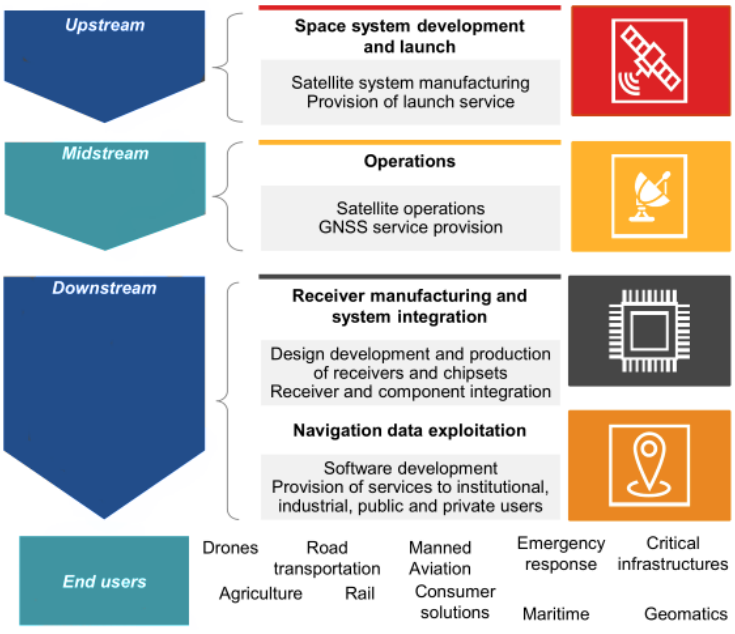
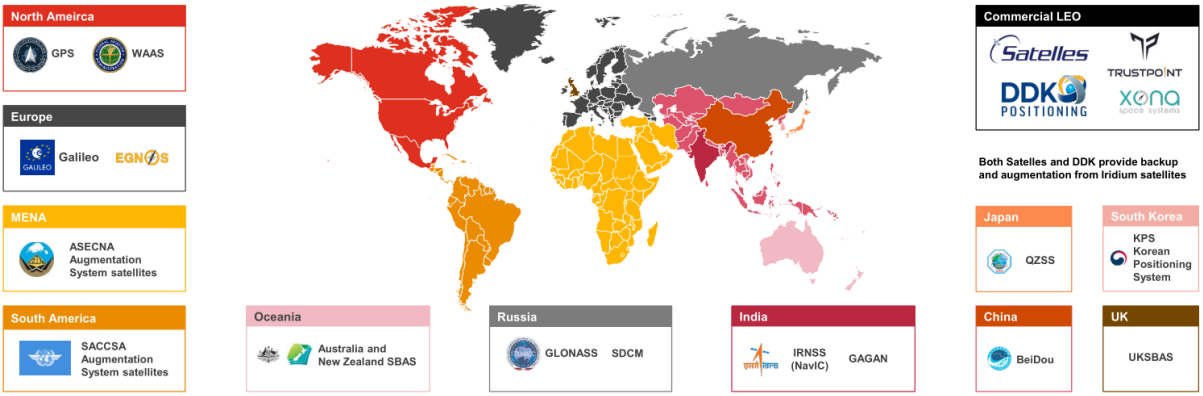


Chart 13: An overview of the satnav value chain[24]

The Galileo Programme, which is part of Europe's GNSS civil satnav service was aimed to be the first global navigation satellite system under civil control for private and public use by European and global entities. With an allocation of EUR 9.7 billion between 2021-2027, the program has over 30 satellites as part of the constellation, with 22 being active as of May 2022. There are furthermore over 2 billion Galileo enabled smartphones as of 2021. The main intention of this program was to be an open service that would be free of charge to users, providing positioning and synchronization to high-volume navigation applications. Security and regulations would be at the forefront of providing these services, along with a focus on enabling search and rescue services as part of the COSPAC-SARSAT program. Since early August 2022, new infrastructure was deployed as part of the Galileo Ground Control Segment (GCS) that has upgraded the infrastructure of the overall program[26].

Using technology from the next generation of space crafts, GNSS systems are implementing enhanced spoofing / jamming resistance, search and rescue capabilities (Galileo and BDS Return Link) and precise point positioning (provided by Galileo). The durability of GNSS becomes more crucial as the economy, military, and individual depend more and more on it (especially in circumstances when safety and liability are at stake). Galileo uses an encrypted message to combat spoofing, and GPS III spacecraft are reputedly 8 times more immune to jamming. The geodetic community recently established the Open PNT Alliance with the goal of creating redundancy to institutional GNSS, and new satellites are being developed with greater resistance. Commercial LEO constellations have been suggested by a number of parties as a backup or alternative to institutional GNSS, including Xona and TrustPoint. From Iridium spacecraft, DDK Positioning and Satelles both provide PNT service. According to reports, Beidou (China) is also thinking about adding a supplemental LEO constellation to its MEO and GEO spacecraft, which may reduce PPP convergence times from 30 minutes to one minute.



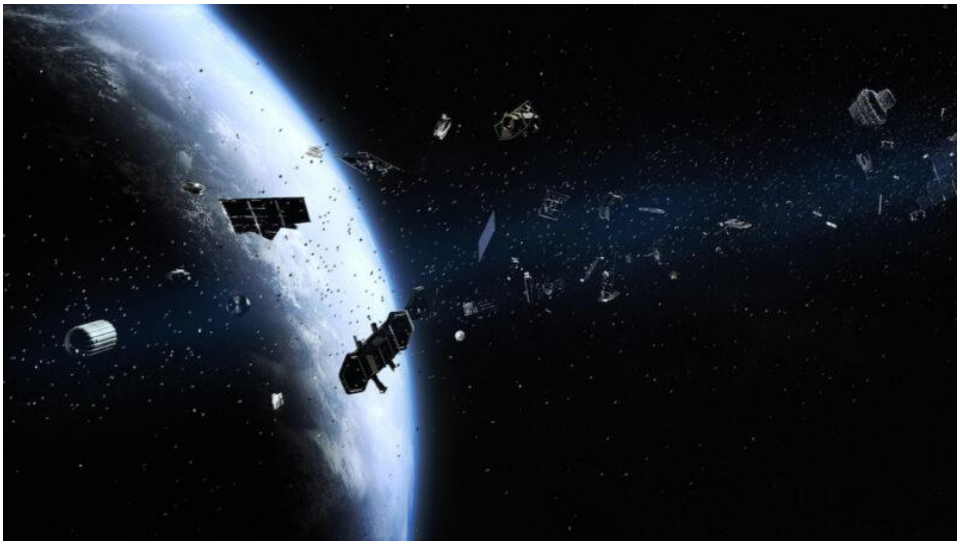
Map 2: An overview of the several GNSS constellations and satellite-based augmentation systems across the globe[24]

For the GNSS sector, roads continue to remain the largest market, with uptake expected to increase due to regulations and the increase in autonomous vehicles. GNSS road tolling is being used more frequently in place of physical or microwave-based toll booths as highways become more digitalized. In sectors such as aviation, rail and surveying, GNSS services are being used with enhanced precision catered towards accuracy, safety and information analysis. The low power consumption of devices using GNSS data (smartphones, wearables, trackers), combined with the relatively high precision that such devices can track are some of the other drivers with regards to the growth of this industry in the consumer segments.

5. Focus on space security: Space debris and sustainability

The safeguarding of space assets against dangers including artificial space objects, space weather phenomena, and near-Earth objects is essential to many industries and activities. The expanding use of space underscores the need of space safety initiatives.

In 2020, there were 10% as many space objects launched than there had been in all the years prior. Thus, there is now a significant possibility of unavoidable collisions between operating payloads and debris due to the continuing growth in the number of objects, their combined mass, and their combined area. This issue is further exacerbated by the growth of commercial spaceflight. For space debris, various estimates exist. The U.S. military recorded 23,000 objects in orbit with a diameter of at least 10 cm in 2018[27], while the ESA anticipates tracking 36,000 objects of the same size in 2021[28]. Additionally, it is anticipated that there are 50,000 debris items between 1 cm and 10 cm and 130 million objects smaller than 1 cm[29]. Every item poses a threat to satellites and spacecraft due to their high orbital speeds. According to a 2022 extrapolation, there will be a sharp rise in the number of catastrophic collisions between debris (and other objects) in the ensuing years, and even a fictitious halt would not stop it. Particularly at risk is the Lower Earth Orbit (LEO).



Picture 8: A rendition of space debris in Earth's orbit

Organizations including the World Economic Forum, MIT, and the European Space Agency have been creating mitigating strategies for years. Integrating their opinions into strategic decision-making will protect the space industry's self-interest and prevent cannibalization of the space enterprises. Several countries, including the US, Russia, China and the EU are putting in place Space Traffic Management (STM) frameworks to enforce regulations and mitigate debris in space. Such a market unlocks the potential for data providers and analytical software that can use machine learning methods to predict and identify space debris, while helping space assets navigate around them safely.

6. Creation of an in-orbit economy with the entry of space / non-space players

One of NASA's strategic goals is to "Lay the foundation for America to maintain a constant human presence in Low Earth orbit (LEO) enabled by a commercial market." Getting a lot of new firms and people into space will be necessary to build a strong LEO economy. It will necessitate the growth of both the demand for such capabilities and the provision of those services. The first private astronaut mission to the ISS occurred in April 2022, facilitated by SpaceX launcher and craft. Private astronaut missions are intended to support tourism, outreach, commercial research, and authorized commercial

and marketing operations on the space station. They will be dedicated, privately sponsored, entirely commercial spaceflights on commercial launch vehicles. By increasing the prospects for in-space manufacture, marketing, and promotion of commercial goods and services on the station, NASA and other organizations have also made the space station accessible for business. It is expected that as these organizations expand the commercial prospects on the space station, so will the number and variety of businesses utilizing those opportunities increase. That in turn will contribute to raising demand.

Picture 9: An illustration of the Origin NEO-1 space mining test spacecraft made by China[30]

A few initiatives that are underway, and will contribute to developing an in-orbit economy include:

- **In orbit servicing:** ESA's CleanSpace initiative is developing technologies and solutions for active debris removal. Several other companies (SSTL, S-orbit, Astroscale) are developing services to maintain and upgrade satellites already in orbit. Northrop Grumman and Space Logistics have already serviced Intelsat 901 satellites that ran out of fuel, providing them with an additional 5 years of life – while already in orbit.
- **Space stations and human spaceflight:** Countries have realized the importance of having a sustained presence in LEO to maintain R&D activities and also create a sustainable in-space economy. Emerging space nations (India, UAE) are actively seeking partnerships and collaboration programs to enable this. With Russia expected to quit the ISS due to ongoing global events, their space is looking to be filled and alternatively, competing space stations are expected to be launched. China for example, is progressing with its Tiangong space station, targeting operations by sometime next year. Russia announced its own national space station plan for 2025. Private companies are also expected to develop plans to provide commercial services to the ISS and future space stations.
- **Space tourism:** Commercial initiatives are moving forward for private space flights and the development of private space stations. The recent success of several space tourism companies have demonstrated the demand for such a market. Virgin Galactic, Blue Origin, and Zero-2-Infinity are anticipated to be significant players in the following ten years after overcoming difficult entry requirements and setbacks. Space tourists have been given flights by businesses like Space Adventures, some of which were aboard the ISS. They recently announced longer lunar or high-Earth orbital missions.

As countries across the globe build their roadmaps towards permanent human presence on the Lunar surface and Mars, private businesses from the space and non-space sectors are investing in the development of products, processes, or services for exploration. These plans are heavily impacted by

international partnerships, which have been largely affected by the war in Ukraine (e.g., ESA backed out of Lunar missions planned with Russia, Luxembourg abandons discussions on space mining with Russia etc.). There is a growing need for a regulatory framework to govern space exploration.

Some of the examples of non-space companies involved in space exploration include: Audi (lunar Rover), General Motors (automated robots), Rio Tinto (autonomous drilling and automated cars), Skyre (processing lunar resources), Foster Partners (lunar habitat) and Metalysis (refining space resources – metals), to name a few.

Picture 10: Examples of space companies that are developing commercial services for space exploration

Landscape & funding in the space economy ecosystem

As if the competition on Earth was not fierce enough, the conquest of space has recently accelerated. Most participants in the current space race are from the commercial sector. The worldwide space sector is said to be supported by 130 government agencies, 150 R&D hubs, 10,000 businesses, and more than 5,000 investors[31]. By investing the most in the private sector, the United States is in the lead, with growth also being seen in Asia and the Middle East.

Some of the key players in the space economy are:

Table 2: Major players that are playing a key role in the space economy[32]

Private market investments in the space economy

Despite receiving the majority of media attention, the launch and emerging (a subset of space infrastructure) industries have only received 10% and 1% of investments historically. Space technologies constitute the "invisible backbone" of our global economy and the next generation of digital infrastructure. 90% of current investments in the space economy are made on satellite technologies like GPS, Geospatial Intelligence, and Satellite Communications, which are already essential to most space economy companies. These space technologies also serve as crucial global infrastructure, offering perceptions and knowledge for navigating a world that is becoming more unpredictable and dynamic. The American National Reconnaissance Office (NRO) announced its largest-ever satellite imagery procurement contracts in Q2 2022, and several space economy companies noticed a rise in demand for their goods and services. The funding for such data startups will continue.

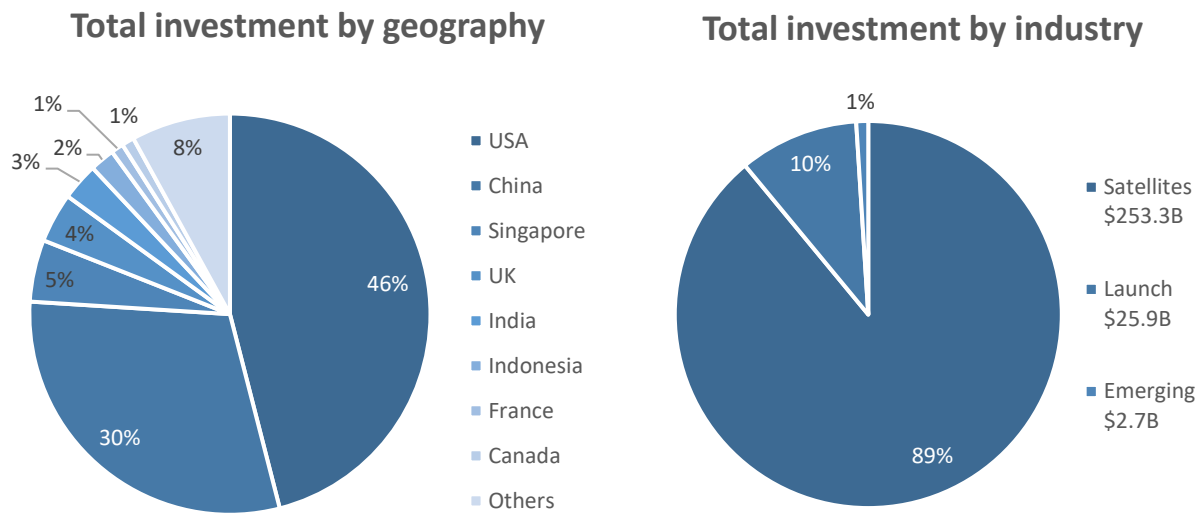


Chart 14: Cumulative private market equity investments from 2013 to present in the space economy[33]

Year to date, a total of US$ 13.8 billion in investments were made across 236 rounds. With US$9.5 billion invested in late-stage rounds through Q2 2022, they continued to steer funding in the space economy market. US$ 7.3 billion, or 53% of the total space investment made so far in 2022, was comprised amongst the top 10 funding rounds. 66% (or 155 in number) of all closed rounds to far were in early-stage companies, amounting to US$ 1.6 billion. Despite the weakening macro climate, the pipeline for growth projects remained has remained solid. A return to multi-year venture deployment plans and fewer corporate/hedge/mutual fund investors, after a record year in 2021, indicate that the pace of investments in early-stage space economy companies is moderating. Deal volume and investment both fell 35% and 38% quarter over quarter.

SpaceX continues to defy expectations and, despite the state of the market, having raised US$ 1.7 billion in Q2 2022 at a 25% higher valuation. The business secured a long-awaited environmental decision on the Starship program during the quarter, enabling them to test its next generation launch vehicle in space as early as Q3 2022. A new phase of infrastructure development has begun. Starship will significantly lower the cost to orbit, enable emerging Industries, and replace outdated infrastructure, much like the Falcon 9 did ten years ago.

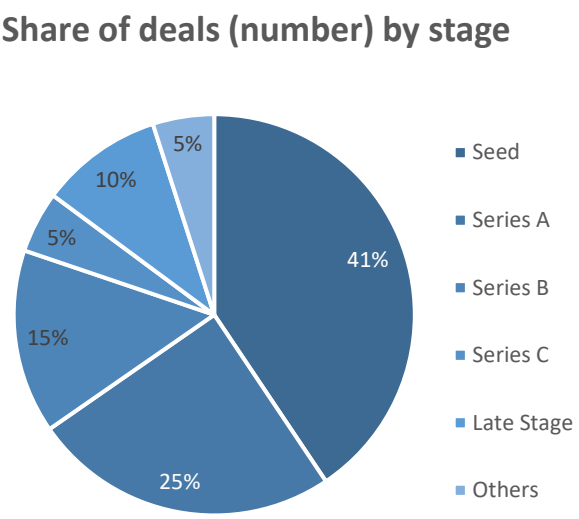


Chart 15: The quantity of deals in earlier stages continue to occupy a lion's share this year[33]

With an additional US$ 6.1 billion invested in 92 space enterprises in Q2 2022, the total equity investment in 1,727 different companies operating in the space economy over the previous ten years has reached US$ 264 billion. Six space firm exits in Q2 2022 brought investors almost US$ 4.3 billion in value, mostly as a result of purchases in the infrastructure and applications stack. In the last quarter, venture capital funds invested US$ 4.2 billion into 82 space firms. As we enter a new phase of infrastructure development with Starship set to be online later this year, investors and companies within the space economy are looking to work beyond the realm of our world's enclosures.

In addition, 12 SPAC IPOs have been announced in 2021/22 that were focused on the space economy with very ambitious growth plans over the upcoming years.

	Satcom	Satellite Manu-facturing / Earth Observation	In-orbit Economy	In-orbit Economy	Access-to-space				Earth Observation			
	AST Space Mobile	Terran Orbital	Redwire	D-Orbit	Astra	Momentus	Rocket Lab	Virgin Orbit	Spire	BlackSky	Planet	Satellogic
Status	Active (NASDAQ)	Active (NYSE)	Active (NYSE)	Planned	Active (NASDAQ)	Active (NASDAQ)	Active (NASDAQ)	Active (NASDAQ)	Active (NYSE)	Active (NYSE)	Active (NYSE)	Active (NASDAQ)
Cumulated Revenues* (USD M)	N/A	3,209* (2021 – 25)	3,003* (2021 – 25)	1,482* (2021 – 25)	2,608* (2021 – 25)	3,929* (2021 – 25)	1,711* (2021 – 25)	2,884* (2021 – 25)	2,324* (2021 – 25)	1,315* (2021 – 25)	1,172* (2021 – 25)	1,331* (2021 – 25)
Raising (USD M)	*462*	*255*	*170*	*185**	*452*	*150*	*777*	*228*	*265*	*283*	*590*	*262*
Valuation (USD M)	1,400	1,800	675	1,280	2,535	567	4,800	3,800	1,600	1,500	2,800	1,100

Table 3: List of recent and planned SPAC IPOs indicating heightened level of interest in this domain[24]

Innovations in the space economy landscape: Innovative companies & initiatives in the EU

With constant innovations happening in the domain of space, various online sources track upcoming and innovative companies in this sector – some of which may already be established in their respective domains but would have "launched" new initiatives and innovations recently. While the shortlisting of these players is subjective and based on a ranking performed by Fast Company in 2022[34], these players nonetheless are at the forefront of technological innovation in the domain of space.

10 most innovative space companies in 2022 (as per Fast Company)

SPACEX

Space X: In 2021, SpaceX completed 31 successful launches of its Falcon 9 rocket, breaking its record for the number of missions completed in a year. In April, NASA selected SpaceX's Starship rocket to send humans to the moon, investing $2.9 billion in the vehicle.

Planet Labs: With its constellation of more than 200 satellites, the Earth imaging company Planet Labs provides high frequency data on our planet every day. From agriculture to sustainability, Planet's geospatial insights are used across industries to inform the decision making.

The John Hopkins University Applied Physics Lab: Launched the Double Asteroid Redirection Test (DART), the world's first full-scale planetary defense test to protect against asteroids. The mission, in collaboration with NASA, was a success and demonstrated new technologies designed and built by APL to change the direction of an asteroid's motion in space.

Relativity Space: In 2021, Relativity completed successful testing of its first rocket, the Terran 1, which is set to be the first 3D-printed rocket in space. The company has raised over $1 billion in funding to date and has secured launch deals with customers like NASA, Lockheed Martin, and Iridium.

Kymeta: Kymeta provides broadband communications worldwide, with its flat-panel satellite antenna and connectivity services. Through its antenna technology, Kymeta bring s on-the-go internet access to remote regions.

ABL Space Systems: Developed a transportable launch system model that can send a rocket to space anywhere there's a flat patch of concrete. ABL plans to launch its first rocket, the RS1, in 2022, and has already secured a list of major launch agreements over the next five years.

Astroscale: The Japanese startup Astroscale is the industry leader in orbital sustainability work. It debuted a new universal docking device in November, built to attach to satellites to help them be captured at the end of their missions.

Rocket Lab: Revealed plans for a new, reusable, midsize launcher called Neutron. The Neutron will operate with an industry-first design, with the rocket's second stage encapsulated within the first stage.

GHGSAT: Canadian company GHGSat claims to operate the world's only fleet of satellites that can detect greenhouse gas emissions from space and determine the exact facility from which the emissions have leaked.

Totum Labs: With its novel Doppler Multichannel Spread Spectrum (DMSS), the satellite connectivity startup, Totum Labs has introduced a global tracking chip that can monitor anything anywhere in the world both indoors and outdoors.

European funding schemes catering to the space economy

Several innovative funding schemes are in place in the EU, with specialized tools or financial features for the space sector. The following public institutions and their agencies are behind the funding schemes.

The European Commission manages the European Union Framework Programme for Research and Innovation (Horizon 2020) and the Competitiveness of Enterprises and Small and Medium-Sized Enterprises (COSME) program through its executive agencies, while it oversees the implementation of the European Structural and Investment Funds (ESIF) program through national and regional authorities across Europe.

The European Investment Bank Group (EIB) is made up of the EIB and the European Investment Fund (EIF). The European Investment Bank Group, for example, implements the European Fund for Strategic Investments (ESFI), a pillar of the European Investment Plan and a joint initiative of the European Commission and the EIB Group to stimulate the European economy through the mobilization of private finance for strategic investments.

National ministries, regional/local governments, and their agencies contribute to R&D financing in Europe. There are numerous funding schemes available, some based only on national money and others backed by European institutions.

The European Space Agency (ESA) is another key player in European space-related R&D spending. The ESA funds a variety of R&D programs aimed at fostering a high level of proficiency in the European space sector. Some of these programs are mandatory for its Member States and are funded through the general ESA budget, while others are optional and are funded through additional financial resources provided by participating Member States.

The EU's flagship Horizon 2020 research and innovation program is the largest of its type, with EUR 75 billion in financing available for innovative projects over a seven-year period (2014-2020). Horizon 2020 will invest approximately EUR 30 billion in research and innovation during its final three years (2018-2020). Horizon 2020 funding is mostly in the form of grants, but it is also available through procurement and prizes, as well as financial instruments such as loans, equity, quasi-equity, and guarantees. In addition, initiatives such as InnovFin, VentureEU, COSME & SME schemes are pathways that are expected to fund the developing space economy within Europe.

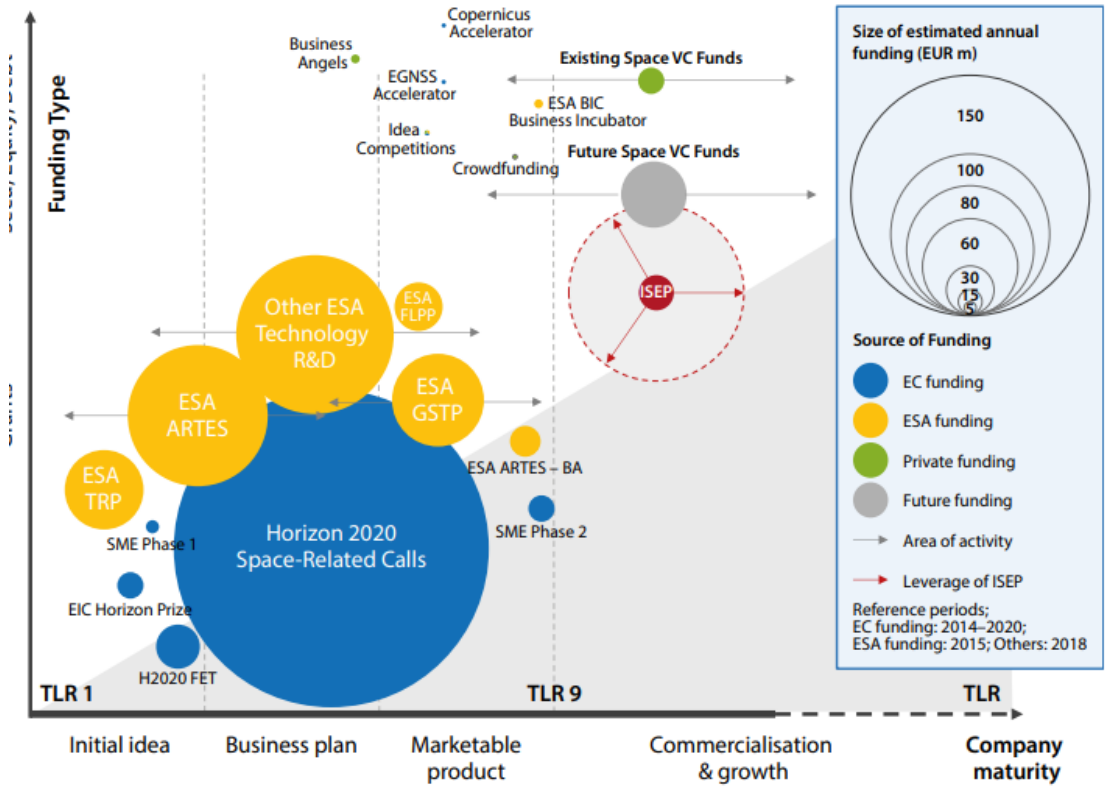


Chart 16: Overview of space-focused financial instruments in Europe and estimated annual funding volume (as of 2019)[35]

The figure above depicts an overview of the public funding schemes and instruments available in Europe that are directly or indirectly relevant for small and medium-sized companies (SMEs) in the space sector. The plan for the next EU multiannual financial framework (MFF) is to streamline the landscape of financing instruments under the unified umbrella of InvestEU.

Brexit has resulted in significant changes in the UK's participation in EU Space Programs, with the UK no longer participating in the satellite navigation programs Galileo and EGNOS (European Geostationary Navigation Overlay Service), the EU Space Surveillance and Tracking (EUSST) Programme, and the Governmental Satellite Communications (GovSatCom). Furthermore, the UK's involvement in the Copernicus Earth Observation Programme and Horizon Europe financing for UK space programs remains uncertain.

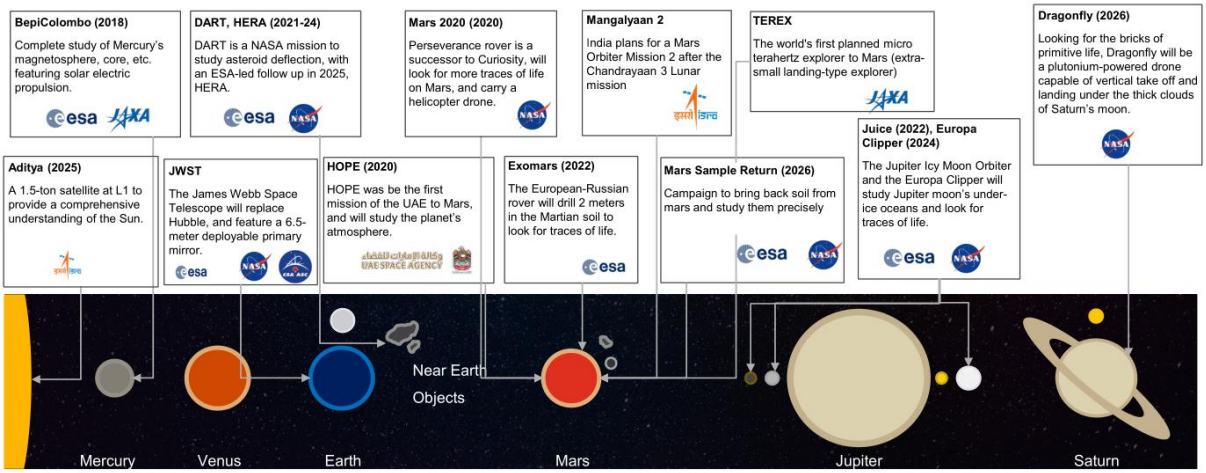
Appendix

An overview of relevant investors with space related portfolio companies in recent years[36]

Investor	Portfolio Companies
ACT Venture Capital	ferfics, Farran Technology, Arralis
ATOMICO	Mapillary, ONTRUCK, HAIL, LILIUM
BayBG	CargoGuard, NAVVIS
Bayern Kapital	TERRALOUPE, CORE DINATE, parcelLab
Caixa Capital	PLD SPACE, eat Tasty, fever, D-ORBIT
Capricorn VENTURE PARTNERS	sensolus
COMOVENTURE	D-ORBIT, LEAFSPACE
COPARION	VIMCAR, Libify, parcelLab, Reactive Robotics
Dendera HOLDING & VENTURE	ORBITAL SYSTEMS
DIGITAL+ PARTNERS	NAVVIS
DB Digital Ventures	Connected Signals, TALIXO, what3words
EARLYBIRD VENTURE CAPITAL	CARTÖDB, movinga, obilet
ForceOverMass	Hummingbird, zencargo, what3words
HAMBRO PERKS	what3words
heliad	Libify
HESSEN HessenKapital	MAPCASE
High-Tech Gründerfonds	CORE DINATE, cevotec, PARK TAG, IQ evolution, locr, blickfeld, enercast, Valispace, ORBEX, synaptican, Reactive Robotics
investiere venture capital	insolight, nezasa, astrocast, arviem, lunchgate
INVIUM PARTNERS	GOMSPACE
IQ CAPITAL	OXFORD SPACE SYSTEMS, Kisan Hub, FocalPoint
Jam Jar Investments	home run Grocery delivery in 1 hour!, what3words
KEYCAPITAL	LEAFSPACE, CABEO, Cesarine

Investor	Portfolio Companies
kibo ventures	CARTÖDB, minube, iContainers
kima ventures	ThrustMe, zenly
LIFE LINE VENTURES	ICEYE, MAPLET
Longwall Ventures	OXFORD SPACE SYSTEMS
MIG CAPITAL	NAVVIS
mustard seed	rapido, what3words
Notion Capital	FIVE AI, Kisan Hub, localz, shutl
OHB	BLUE HORIZON
Practica Capital	nano avionics, Trafi
PRIMO VENTURES	aiko, APOGEO SPACE, LEAFSPACE, PANGEA AEROSPACE, D-ORBIT, VECTION TECHNOLOGIES, astrocast, BRANDON
QUEST	sensolus
RedSeed VENTURES	LEAFSPACE
REDSTONE	TALIXO, what3words
ROSEN G>RD INVEST	ORBITAL SYSTEMS
SERAPHIM CAPITAL	spire, NIGHTINGALE SECURITY, TransRobotics, ICEYE, ALTITUDE ANGEL
Stena	ORBITAL SYSTEMS
TARGET PARTNERS	NAVVIS
Tengelmann Ventures	INTRANAV, blickfeld
TGFS	NAVENTIK, MAPCASE
TT venture	D-ORBIT
VenturesOne	
Vitamina venture capital	CARTÖDB
VITO ONE	HOMEDAY, building radar, CrateDB

Recent and expected space exploration missions beyond the moon[37]



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