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# The Impact of Space Economy in Creating Value to the Spacefaring Nations' Economies

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**Abstract:** The Space Economy could be defined as, the full range of activities and the use of resources by human beings in the course of exploring space, to make new applications in economic areas, such as meteorology, energy, telecommunications, insurance, transport, maritime, aviation and urban development, leading to additional socio-economic benefits. Some analysts argued that the ongoing emerging space industry could mushroom grow and become a trillion-dollar industry by 2040.

## INTRODUCTION

The Space Economy could be defined as, the full range of activities and the use of resources by human beings in the course of exploring space, to make new applications in economic areas, such as meteorology, energy, telecommunications, insurance, transport, maritime, aviation and urban development, leading to additional socio-economic benefits. Some analysts argued that the ongoing emerging space industry could mushroom grow and become a trillion-dollar industry by 2040.

The main current trends, impacting the Space Economy growth and development comprise:

- The worldwide increase in public interest to invest in space activities.
- The high level of private investment in space ventures,

  The expected profitability, and the growing Venture Capital market.
- The continuing growth of space industry revenues.
- The ongoing worldwide development of commercial activities in new areas, like micro-launchers and space flights.
- The outstanding integration of space into the society and economy leading to more value creation and more socio-economic benefits.

The most effective business trends of the European space sector's position within the international space landscape, showed a mushroom growth in satellite constellation, in-orbit operation technologies, the ongoing rise of space tourism and the development of commercial space stations. As for the space policy developments impacting the future space sector, they include:

- Shifts in international cooperation in human space flights & explorations.
- Governments' focus on enhancing and strengthening the commercial space sector.
- Space being on high-level of developed countries' political agendas, namely, in G7 & G20 summits' agenda.

- Worldwide adoption of new national space laws.
- Countries' ambitions and longings for independent access to space.

Credible recent reports revealed that,144 orbital launches were successfully carried out in 2021, registering a 26% noticeable increase over 2020. This was accompanied by a record number of 1,843 satellites and spaceships being launched.

The space exploration provides applications for achieving the Sustainable Development Goals, including ensuring food security, reducing the risk of disasters, preventing humanitarian crises, monitoring natural resources, improving health, and reducing poverty.

## SPACE ECONOMIC PLATFORM

### The Mechanics of Space Economy

One of the crucial elements of space anti sustainability, is the problem of human-generated space debris in orbit around the Earth and the risk it poses to orbiting satellites and spacecrafts. The sustainable use of the earth orbit outer space, emerged as a hot public policy issue among the spacefaring nations since 2010. However, in the United States it was emphasized as an integral goal in the National Space Policy, as well as the National Security Space Strategy. However, the possibility of maintaining future sustainable space economic development, looks rather blurring and gloomy, due to the risks posed to active satellites, by the human-generated space debris in orbit around the Earth. Moreover, although classical microeconomic policy mechanisms have been proposed over the last two decades to deal with space debris, none of them materialized and gained ground in the policy-making arena. Thus, this problem will be hanging around, for yet come years.

The overall picture shows that there are about 1,000 active satellites currently orbiting around Earth. The vast majority of these active satellites exist in two distinct regions in the atmosphere, namely the Low Earth Orbit (LEO) and the Geosynchronous Earth Orbit (GEO). About 470 of these active satellites are in former orbiting between 200 and 2,000 kilometers in altitude, and about 419 active satellites are in the latter, approximately 36,000 kilometers above the Equator. These satellites are providing a wide range of social, public, and private benefits, including enhanced national and international security, more efficient use and management of natural resources, improved disaster early warning and response, and reliable global communications and navigation.

This space debris resulting from the human use of space, consists of dead satellites, spent rocket stages, and fragments associated with the humanity's six decades of activity in space. In addition to this 1,000 active satellites, the US military is currently tracking about 21,000 pieces of human-generated debris in Earth orbit, that are larger than 10 centimeters, each of which could destroy an active satellite in a collision. Also, scientists and space agencies indicated that there is a huge population of other 500,000 pieces of space debris sized between 1 and 10 centimeters, each of which could severely damage an active satellite in a collision.

It is noteworthy that all of this humanly generated debris is concentrated in the most actively used regions of Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO), thus increasing the risks of collisions with orbiting active spacecrafts and satellites. These increased risks will in return, raise the costs of operating satellites, through increased production costs in designing and maintaining satellites. Thus, in a nutshell, these rising costs may make it economically unfeasible to perform certain types of space missions in the future, leading to a hug loss of space socio-economic benefits. In this regard, some economists focusing on space debris, suggested the imposing of a deposit on launch of a spacecraft, which would be returned in case the spacecraft is de-orbited. Failing to do so, the deposit could be transferred to a fund for cleaning up legacy debris or be assigned to compensate owners of spacecraft hit by debris.

**The Sustainability of Space Economy**

In a little more than a decade, the space sector has experienced considerable development throughout the world, with greater impacts on larger economy backed by digitalization and globalization. The growing importance of space activities for the economy, for the social wellbeing, and for science, is becoming more notable. The ongoing transformation of the global space sector could be viewed from three different standpoints, namely assessing institutional and private investment trends, examining evolutions of the space economy, confronting current market realities, and finally focusing on global space innovation activities. However, space activities are expanding globally, with a record number of spacefaring countries and commercial firms investing in space programmes.

Never before has there been so much interest in the space sector, with orbiting registered satellites of over 80 countries and increasing growing public and private investments. Public space budgets reached about USD 75 billion in 2017 and is expected to jump further in the following years, with the United States leading with the highest budget, accounting for more than half of the total, followed by China, Japan and France respectively. The innovations and new space technology systems are attracting much attention and increased public and private capital. Digitalisation is creating new opportunities in industry, as well as assembly lines for the mass production of small satellites. Thus, the space economy is projected to grow, but at a slower pace, as markets expand, and activities become more interconnected with terrestrial systems and consumer products. Start-ups in all segments of the space sector continue to emerge with over 500 small companies, not only in the United States, but also in Europe, Japan, China, and India. Some of these start-ups aim to provide new launch capabilities, innovative internet services via small satellites. Digitalisation is increasingly impacting the entire space sector, namely science, manufacturing, production processes, and research, and development (R&D).

In view of accelerated digitalisation trends, shake-ups are expected in the space sector affecting all parts of the economy, as the structure of the space industry itself seems to be on the verge of a shake-up, with new challenges to overcome. Changes in customers' appetites for digital products, from satellite television to geospatial services, could have strong impacts on many of the existing commercial space services providers. Stronger competition across the sector may lead to increased concentration and multiple exits in certain segments of the value chain, creating both winners and losers. Finally, one crucial unknown in the near future, for all space activities, is linked to the accumulation of debris in orbit, representing millions of objects, where a single accident caused by one of them, could be of catastrophic blow for the entire space economy.

## NECESSARY ACTIONS FOR SPACE SECTOR

Continued digitalization led to the transformation of the space sector, which in turn urged policymakers to play important roles in enabling the transition for existing firms, together with fostering innovation and entrepreneurship. However, to harvest the full gains and benefits of current and coming space activities and to secure sustainable and balanced growth, the following necessary and sufficient policy actions are advised for developing countries:

- Increase of use of commercial services by governments, through procurement and co-funding mechanisms, together with institutional space budgets which represent key elements for commercial space activities, with the concerned entities acting as internal stakeholders of many commercial space services.
- To take advantage of the opportunity to participate and harvest benefits from the space sector’s value chains, and rigorously and persistently track who is doing what in the space industry, by carrying out regular periodic field surveys and analysis of their collected data.
- Address the space sector needs of human resources, in the light of current digitalisation trends that will increase competition among its internal and external stakeholders, for talent in space-related activities and employment.
- Identify solutions to mitigate space debris, through international cooperation, regulation, and technology development, as the coming years could see more than a tripling in the number of satellites in orbit.

## THE TRANSFORMATION OF THE SPACE SECTOR

Institutional and private investments are generally on the rise around the world. However, Governments remain the main investors in space activities, via procurements and grant mechanisms, but long-term civil space research and development budgets show signs of slowing in some countries.

Worldwide, governments are the main investors in space activities, via procurement and grants mechanisms to public agencies, research institutes, universities, and the private sector. But in only 5 years the global landscape for space activities has evolved, with new countries investing in space research and development, and getting involved in global value chains. Private funding of commercial projects has also grown, with unprecedented private capital flows in the space sector from angel and venture capital investments.

Public investments represent the bulk of funding in space activities, reaching almost USD 75 billion in 2017, and kept growing in 2018, as compared to an estimated USD 52 billion in 2008. Governments invest in space capabilities to support national security and governance objectives, by being able to map and monitor resources on earth from space, broaden socio-economic motivations, and develop scientific capacities.

Countries with space programmes have moved from being a very exclusive club, to a much wider group of developed and developing countries, with very diverse capabilities.

In only a decade, the number of countries with a satellite in orbit have increased from 50 in 2008 to 82 in 2018. The satellites considered are of course very different in their specificities and may involve very little national technical expertise, ranging from large multi-ton telecommunication satellites purchased on the international market to very small cubesats built in local universities. But the possibility to have one's satellite in orbit, registered with one's own national administration, has never before been so affordable (OECD, 2016).

Since 2007, some 20 new countries have also started investing in original space programmes and supporting private endeavours, with distinctive and symbolic projects. These countries included, the United Arab Emirates, which recently landed on Mars, New Zealand's successful small launcher, Luxembourg's asteroid mining programme, and Israel's lunar mission. Most of these programmes were not starting from scratch, as Luxembourg has been a member of the European Space Agency since 2005 and is the home of the second largest commercial satellite communications operator. This has even led to a renewed interest amongst diverse legal expert groups to consider the international implications of space mining. The United Kingdom has also recently modified its regulatory framewor for commercial space activities, to enable small satellite and suborbital activities to launch directly from UK territory.

## THE SPACE POOL RESOURCES

The outer space around Earth, is considered a public good and global commons, by the 1967 Outer Space Treaty, which stated that: "Outer space is free for exploration and access by all countries and is not subject to national takeover by claim of sovereignty, by means of use or occupation, or by any other means". Thus, it is deemed free for exploration and access by all countries and is not subject to national takeover by claim of sovereignty, by means of use or occupation, or by any other means. The voluminous outer space trillions of cubic kilometers, means that the placement of a satellite into orbit by one country does not stop in anyway the placement of satellites into orbit by other countries. Space debris experts argued for implementing regulations that include mandatory de-orbiting of spent rockets and satellites at the end of their operational lifespan, together with imposing tax or fees to limit the amount of space debris produced.

In this regard, Bradley and Wein , developed a model of space debris dynamics, to estimate various fees and costs for regulating space debris. They estimated damage to operational spacecraft from debris, by choosing an average cost of a destroyed satellite and a discount rate. The model calculates the fee to be implemented to ensure a tolerable level of risk. For a discount rate of 5% and a satellite replacement cost of $500 million, Bradley and Wein calculate a launch fee of $980 to offset future expected damage of a satellite that will be deorbited at the end of its mission (Bradley and Wein 2009). Unfortunately, no serious national or international efforts were exerted to regulate space debris as an environmental pollutant. Moreover, this issue is currently absent from any of the serious national or international policy discussions. The two main reasons for this comprise the true nature of the most commonly used regions of outer space together with the lack of private actors using these regions who would be responsive to market incentives.

According to the physical characteristics of the space environment and the physics of orbital mechanics, a satellite placed into orbit does not occupy a fixed location. It moves in an elliptical path, of which size, shape, altitude, and exact dimensions are the result of the forward velocity of the object and the gravitational pull of the Earth.

Out of the voluminous wide-open deep space, the region of LEO and GEO are the most heavily-used and congested regions, thus standing as Common-Pool Resources (CPRs) within the larger global commons of outer space, like fisheries and oil fields within the commons of the oceans. The orbital mechanics of these two congested regions of space provide economic benefits to most of space actors, thus resulting in a clustering of satellites at the same altitude in both LEO and GEO, and an increasing number of countries placing their satellites in the same regions, leading to problems stemming from competitors responding to marginal private costs instead of marginal social costs, as commonly found in Common-Pool Resources on earth. The congestion in GEO region is extremely acute due to its small size, high demand by competitors, and the need for all satellites in the region to use the same or similar portions of the radiofrequency spectrum. This congestion made it economically feasible to create appropriate mechanisms in the form of international and national legal forms to fairly regulate and allocate the spectrum used by GEO satellites.

Although there has been deep concern of developing fair regulatory mechanisms for the highly congested parts of LEO, these concerns have yet to materialize. This is largely due to the high cost of putting such mechanisms in the right place and the lack of measurable economic benefits from LEO, that would justify the resulting expenditures.

Although it is true that space in totality is very worthy for humans and much benefit could be driven from its use, an economic analysis revealed that very little private actors benefited from the current use of LEO. The most recent estimates valued the total space economy at $290 billion in 2011. However, very little of this figure comes from private benefits as follows: $107 billion is from commercial ground infrastructure and support industries and another $73 billion from government space budgets. Moreover, of the $111 billion in commercial space products and services, almost all of it is provided by satellites operating in GEO.

In LEO the single biggest source of private benefit is the Earth observation sector, with an estimated total value in 2011 of $2.2 billion. However, this revenue stems largely from civil government and military customers, and governments are expected to fund development of most Earth observation satellites during the next 10 years. Aside from Earth observation, the only other meaningful revenue from satellites in LEO comes from three communications satellite constellations, namely: Globalstar (46 satellites), ORBCOMM (26 satellites), and Iridium (71 satellites). Collectively, the annual earnings of these firms total about $100 million. Data from the insurance industry support this, as follow: only 24 satellites in LEO are currently carrying commercial insurance, for a total insured value of about $1.4 billion, out of a total satellite insurance market of $20 billion.

Thus, the vast majority of economic value currently derived from LEO is either from satellites owned and operated by governments, or governments providing the bulk of demand for services provided by privately owned satellites. This value is almost entirely in the form of social benefits such as national security, science, climate and weather monitoring, management of natural resources, disaster response, and space exploration. As the public sector is traditionally much less responsive to prices and markets, LEO is thus a poor candidate for microeconomic policy mechanisms aimed at incentivizing behavior.

There have been many ideas and proposals for ways of making money in LEO and growing the space economy, such as orbital manufacturing, tether-based launch systems, space elevators, propellant depots, and space habitats. However, while some of these ideas are promising, the chances are extremely slim of developing a thriving space economy in LEO, that will provide a free market solution to its space debris.

## SPACE INVESTMENTS AND GLOBAL ECONOMY

Space science is one of the important economic sectors in which creativity is a vital part of investing large sums of money, with returns in billions of dollars for the investing countries. In fact, space represents the heart of the information society, as there are now thousands of operational satellites, orbiting around the world, many of them are in the low and fixed Earth orbits. The expected size of the economy is estimated to exceed 1 trillion dollars in 2040. However, the main revenues will come from the revenues of satellite and missile services, in anticipation of the high demand for “satellite internet” and the delivery of ambitious packages, such as space tourism, mining and mines in space, housing, agriculture, and the like.

The balance in costs between the satellite system, that is the satellites and their supplements, and the terrestrial system, that is, the electronic systems and facilities, is the most important factor in the future of communications satellites, of which there are now more than 35,650 satellite television channels, which are expected to exceed 47,000 channels in 10 years’ time. The effective satellites in the space system, recorded 1235 satellites in 2014, estimated at about 1.4 billion US dollars. As for the terrestrial system, its economic dimensions ae estimated at 5 billion US dollars for facilities, 100 billion US dollars for the services and 10 billion US dollars for applications. The communications services provided by half of these satellites worth billions of dollars, as in 2013, the global economy related to outer space generated income of about 250 billion dollars.

While developing ground observation, it is usually the first step for countries wishing to enter space activity to follow, because the required structure for ground observation is less than what is required by communications and navigation activities.

Earth observation can also be developed rapidly to provide satisfactory services using the available space information. As for navigation, it is considered the other side of the activity which is expensive, because of the requirements for establishing its internal structure, and that its economic resources are not guaranteed. Both activities, surveillance, and navigation, have to respond to regulations that differ in different countries, creating obstacles to the globalization of the two activities.

The argument that the enthusiastic team of space economics presents today that we need to build the infrastructure, and then imagination will follow in its role in the employment of money and people, because necessity is the mother of invention and it makes the impossible out of opportunity. However, there are those who believe that what is happening today is nothing but a new form of “colonialism” and “imperialism” and is a violation of “the international law.” In 1967, ten years after the first “Sputnik” missile, the Outer Space Agreement was activated, which stipulated that all outer space flights are in the interest of all countries, regardless of their economic or scientific status, and it will be in the interest of mankind as a whole, avoiding the cold war and aiming at curbing the nuclear race.

The Convention prohibited the use of all weapons of mass destruction, together with the claim of sovereignty and made the member states of this agreement bear the responsibility of the non-state actors on their lands. After the multiple “Apollo” flights, the United Nations drafted a more ideal agreement, the Moon Agreement in 1979, and only 18 countries joined it and is still not activated due to America’s withdrawal from it, for its objection to the clause that the Moon And its resources are a common heritage of mankind, claiming that this will create a global socialist system that will hinder the commercial use of the American private sector. Moreover, there is lack of private actors deriving private benefits, to enhance the economics of space sustainability, by the new approach of information economics and common-pool resources.

In 2007, several national space agencies published a set of voluntary guidelines for minimizing the creation of space debris, which were endorsed by the United Nations in 2008. and many countries around the world are in the process of implementing them into national regulation.

In 2011, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) initiated a Working Group on the long-term sustainability of space activities with the goal of developing a set of voluntary best practice guidelines to promote the sustainable use of space. And in 2012, the United States declared it would work with the European Union and other spacefaring states to develop an International Code of Conduct for Space Activities. However, these initiatives do take on new meaning when viewed through the lens of more recent developments in economics such as information and game theory.

## THE SWELLING OF SPACE ECONOMY

The fifty years of human activities in space, designed to study the space environment and test initial capabilities in Earth orbit, produced socio-economic benefits that improved mankind quality of life on Earth. Besides, they contributed critical knowledge and capabilities for developing satellite telecommunications, global positioning, advances in weather forecasting, early warning system and delivering high returns for invested funds. They also sparked new scientific and technological knowledge of inherent value to mankind, that led to better understanding of the Universe, the surroundings, and the solar system at large, together with knowledge, coupled with ingenuity, that provides people around the globe with solutions as well as with useful products and services.

Future space exploration goals target sending humans and robots beyond Low Earth Orbit and establishing sustained access to inspirational destinations such as the Moon, Asteroids, and Mars. Space agencies participating in the space exploration are employing the complementary capabilities of both humans and robotic systems to enable mankind to meet the most ambitious space exploration challenge, and to increase benefits for society in three fundamental areas, namely innovation, culture, and inspiration, thus contributing to many diverse aspects of everyday life, from solar panels to implantable heart monitors, from cancer therapy to light-weight materials, and from water-purification systems to improved computing systems and to a global search-and-rescue system. Achieving these ambitious future exploration goals, will in turn further expand the economic relevance of space. Space exploration will continue to be an essential driver for opening up new domains and avenues in knowledge, science, and technology, triggering other sectors to engage with the space sector for joint research and development. This will return immediate benefits back to Earth in areas such as materials, power generation and energy.

## SPACE EXPLORATION BENEFITS DELIVERY

Generally, meeting the challenges of working in space has led to many technological and scientific advances that have provided benefits to society on Earth in areas including health, medicine, transportation, public safety, consumer goods, energy, environment, information technology, and industrial productivity.

However, the space exploration benefits include among others:

- fuelling future discoveries.
- addressing global challenges in space and on Earth through the use of innovative technology.
- creating global partnerships by sharing challenging and peaceful goals.
- inspiring society and especially the younger generations through collective and individual efforts.
- and enabling economic expansion and opening new business opportunities.

However, the benefits of space can be categorized as either direct or indirect. The direct benefits of exploration include the generation of scientific knowledge, the diffusion of innovation and creation of markets, the inspiration of people around the world, and agreements signed between the countries engaged in exploration. The indirect benefits that result over time include tangible enhancements to the quality of life such as improved economic prosperity, health, environmental quality, safety, and security. They also include intangible philosophical benefits such as a deepened understanding and new perspectives on humankind's individual and collective place in the Universe.

Possibilities for benefit creation increase rapidly when the products of space exploration become tangible. The media and communications industries play an important role in interpreting exploration data, so that citizens may understand and appreciate their significance. To maximize societal impact, space agencies share space exploration results and collaborate with the society in terms of its research institutions, businesses, universities, schools, museums, and other organizations.

However, the primary benefits of Space Exploration are basicly reflected by the new knowledge generated during space systems development to meet challenges facing space missions.

Technological knowledge, generated to address the extreme challenges of space missions, yields many innovations that benefit the public. Scientific knowledge acquired from space expands the understanding of nature for society. Generally, the benefits from space exploration are rooted in the generation of new knowledge, which has inherent value to mankind.

## SPACE HUMANS' INVESTMENT VENTURES

The human Investments in the field of space have shown a very huge jump during the recent years, in a clear indication that humanity has begun a crazy race to leave the blue planet, looking for an alternative in deep space. To this end, there is a belief that the future will be for investments in the fields of space and astronomy, which will achieve huge profits.

According to observers, it was found that global investments in the field of space, have multiplied five times in the past five years, compared to what they had been before. But most importantly than that, it has multiplied about 16 times, compared to what it was in the first five years of the current millennium. These figures reveal that the total global investments in the field of space during the period 2000 to 2004, amounted to only 1.1 billion US dollars, but this number increased during the years 2005 to 2009 to reach 1.5 billion US dollars, and in the years 2010 to 2014 it jumped to $3.4 billion.

Space activities are expanding globally, with a record number of countries and commercial firms investing in space programmes. Never before has there been so much interest in the space economy, with satellites in orbit, registering a record of over 80 countries and growing public and private investments in utilities. Huge activities are derived from satellite data and signals, contributing to new economic activities in space infrastructure. Space activities also provide some of the most successful illustrations of international co-operation, such as the co-operation between 17 space agencies to provide free satellite data to those affected by disasters. Likewise, as the use of the Earth's orbits accelerates with deployment of mega-constellations for satellite broadband, a new and pressing challenge to the long-term sustainability of space operations will be the accumulation of space debris.

## SPACE INDUSTRY INVESTMENT AND FUNDING

### Space Orbital Investment Shifts

Private-sector funding in space-related companies topped $10 billion in 2021—an all-time high and about a tenfold increase over the past decade. But this surging investment, which has fueled a wave of innovation, is just one factor transforming the space sector. In another big shift, investors are now directing more funds to projects involving lunar and beyond orbital regimes, which have traditionally attracted less attention than regimes at lower altitudes, and all signs point to continued growth.

To understand what's happening around, just begin by looking at the evolution of space investment. Historically, much of the private funding—as well as government activities, have focused on satellite communications, including GPS and television coverage. Initially, these ventures involved satellites in Medium-Earth Orbit (MEO) or Geosynchronous Equatorial Orbit (GEO). Satellites in GEO appear to be stationary, since their 24-hour orbital cycle is the same as the Earth's, and their coverage is limited to specific geographic regions.

Over the past five to ten years, more space investment has been flowing to ventures in Low-Earth Orbit (LEO)—both for satellite communications and other objectives. Satellites in LEO, which sit closer to the Earth than their MEO and GEO counterparts, are ideal for enabling high-speed, low-latency communications. They are also typically smaller and much less expensive. Overall, about 60 to 70 % of space-company funding is now directed at LEO endeavors. The growing popularity of LEO is easy to understand. Launch costs are lower for this orbit than for GEO or MEO, giving more companies and nations access to space, and LEO can also accommodate smaller, cheaper spacecraft. What's more, NASA has been encouraging commercial activity in LEO. In fact, there has also been interest in suborbital ventures because of the expected growth in space tourism and as a means of later advancing to higher orbits.

**Space R&D Funding**

While LEO ventures still lead in funding, it is suggested that the space industry is on the tip of another shift. Over the past few years, investment in lunar and beyond initiatives has been on a steady upward trend, driven by both government missions and commercial interests. These initiatives now account for about 10 to 15% of total private investment in space-related companies, around $1 billion, up from well under 5% only a decade ago. In 2021, private funding for lunar and beyond regimes exceeded funding for suborbital ventures for the first time.

However, a wide range of companies are pursuing missions in lunar and beyond orbits. Their areas of focus included spacecraft components and technologies, propulsion, mission services, launch vehicles, in-space transportation, communications, mining, infrastructure, and robotics. Some of these ventures involve budding areas, such as mining rare materials in space, while others focus on developing advanced technologies, such as propulsion methods, that are critical to expanding the use of lunar and beyond orbits.

It is critical to address these issues quickly because this is the inflection point, where new orbits and opportunities are within reach. Prompt attention, combined with the continued development of technologies and business models, will set the stage for future missions, and help shape and model the evolving activities in space.

**Space Activities' Private Sector Funding**

Commercial satellite telecommunications stand as the core for private financing, due to their high profitability over the past 15 years. This successful trend in financing satellite telecommunications has led to similar, lower scale, experiences in other domains of space activities. For example, in the past 10 years, several companies launched initial public offerings of stocks, using the proceeds to build their next generation of earth observation satellites.

The main sources of funding for new firms are usually the founders themselves, with investments from family circles, bank loans, equity capital and government support. A relatively new source of private capital comes from large aerospace and defence firms, which have all set up their own venture capital funds in the past five years, to invest in start-ups involved in software development, artificial intelligence, augmented reality, sensors, and autonomous vehicles in particular. The leading firms in this regard comprise, Boeing's HorizonX Ventures, Lockheed Martin Ventures, Airbus Ventures, Thales Corporate Ventures, and the Dassault System Venture Fund.

The space sector, start-up equity investments amounted to USD 3.25 billion in 2018, with the number of investment transactions also growing globally, from 200 investment deals in 2011 to over 1,400 in 2017. However, it is estimated that the 2018 total represented around 16% of all the equity capital invested in space companies since 2009. In China, almost 100 space start-ups have been launched since 2015, following a new national policy to foster space commercialization. In 2018, some 30 start-ups involved in rockets, satellite manufacturing and applications raised approximately USD 310 million in venture capital. When including publicly-listed space companies, total private investment amounted to USD 530 million in China, together with more than USD 50 billion invested in artificial intelligence start-ups during the period 2011-2018, with some USD 17 billion in 2017 alone.

## SPACE INVESTMENTS' SOCIO-ECONOMIC RETURNS

- Returns from investments in space are not quite evident, immediate, or sustained over time, as they depend on how a space programmes or projects are run. However, efficiency and productivity gains are becoming increasingly visible across sectors of the economy and society, from agriculture to energy, and from routine surveillance to timing of financial transactions.
- Socio-economic evaluations and impact assessments of space investments have been carried out over the years, and the demand for these studies has been growing, with Europe having the largest share of studies that focused on impacts 22%, followed by the United States 20%, where the global level stood at 19%, with very few developing countries included.
- In terms of the types of benefits that can be derived from investments in selected programmes, productivity and efficiency, gains can often be observed as follow:
    - at the firm level by processes and operations,
    - in the workforce by improvements in workers' skills and know-how.
    - and at the managerial level by organisational benefits such as cost avoidance, and commercial revenues.
- Beneficiary sectors that benefit from effects spurred by space activities, include agriculture; health; transport; urban planning; education; environmental management; climate monitoring, meteorology; energy; telecommunications; disaster management; finance and insurance; manufacturing, mining, and construction; high-tech industries; defence and security; tourism and leisure; research and development and science; and other generic services.

It is noteworthy to mention that the literature reveals that about 77 impact assessments and programme evaluations were published between 1972 and 2018. Thus, the benefits of space are not just confined to actors operating in the space sector, as many positive effects are available in non-space firms and at the broader societal level. This is the case of cost savings and cost avoidance, as around 57% of all cost savings and more than 75% of cost avoidance are realised beyond the space sector. Benefits in these categories are usually derived from the application of space technologies in other fields, resulting in the reduction of operating costs, as well as cost avoidance. On the other hand, positive impacts of space investments on commercial revenues and employment occur more frequently in space firms, as around 59% of effects on revenues and 71% of those on job creation have been quantified in the space sector.

The majority of efficiency and productivity gains appear at the level of operations and processes. About 55% involve better and more efficient production processes and operations that may eventually result in cost savings. The rest is almost equally distributed among gains, as 21% for the workforce, and 24% for management levels. Gains at the workforce level entail boosts of productivity and efficiency resulting from improvements in the workforce's skills and know-how. Gains at the management level comprise all types of improvements coming from better managerial decisions. Improvements include the introduction of more efficient organisational practices, better co-ordination among different business branches and increased external co-operation among firms.

## SPACE AND THE DEVELOPING WORLD

Terrifying challenges are facing the developing countries, because of the untapped space opportunities arising from advances in technology, science, and innovation. The relevance and take-up of many space applications in developing countries have been growing, due to the possibility of accessing many of these information-related technologies, more easily and more competitively. There is growing evidence of the role satellite technologies can play in supporting development objectives, through earth observation, satellite telecommunication and broadband, as well as global positioning and navigation technologies. However, satellite remote sensing has already provided epidemiology information to help contain malaria outbreaks in several sub-Saharan countries.

The OECD has been in charge of measuring resource flows to developing countries since 1961, providing new evidence on the intensifying links between development aid and space applications and identifying some 2,100 Official Development Assistance (ODA) projects over this period. This ODA can take place through transfers of resources, either in cash or in the form of commodities or services. They can be provided in many different ways, usually including privileged loans, grants, or even technical assistance. It can be provided from a donor to a specific recipient or channelled through the action of a development agency. However, the ODA amounts directed to space-related projects remain modest when compared with overall ODA funding. Total overall ODA commitments globally increased from USD 96 billion to USD 188 billion between 2000 and 2016. In comparison, the total committed amounts for space-related official development assistance projects between 2000-16 totalled USD 607.4 million. Top donor countries included countries with big space programmes, namely the United States, France, and Japan.

Regarding ODA commitments, the International Development Association (IDA) of the World Bank committed the largest amount of ODA in space projects, followed by France, the European Union (EU) and the United States. Over the period 2000-2016, the World Bank/IDA committed around USD 127 million, France committed some USD 111.4 million and the United States USD 50.6 million. As for Africa, the money was allocated at regional level, targeting more than one country at the same time. In terms of fields of application, most of the funding has been allocated to projects linked to environmental management objectives. Projects in this domain represented USD 225 million between 2000 and 2016. This is followed by forestry management (USD 59 million), telecommunications (USD 49 million) and agriculture and rural development (USD 48 million). The overall projects could be summarized as follow:

- Environmental management projects, often linked to climate change and not only aimed at promoting a better use of environmental resources, but also at making environmental monitoring more effective.
- The bulk of the initiatives are Forestry management projects focus on challenges linked to the sustainable use and conservation of forests. Remote sensing technologies are used to assess the conditions of forests, mapping, gathering data and building databases for monitoring purposes.
- Telecommunications projects deal with the development, or expansion, of regional/national telecommunication infrastructure, involving the provision of

satellite broadband and broadcast services, aiming to connect remotely located households and communities to the existing telecommunication networks.

Other relevant thematic clusters include agriculture and rural development, biodiversity and education, training, and research. Projects listed under ‘agriculture and rural development’ include all projects exploiting satellite images and data to inform agricultural practices, monitor agricultural resources and assess agricultural productivity. Several initiatives specifically aim at promoting food security as a direct consequence of greater crop production and better functioning of early warning systems and climate condition monitoring. Projects linked to biodiversity protection use remote sensing techniques for biosphere and animal protection. Several applications also include technologies to track species and their dislocation across different geographic areas. Finally, education, training and research projects and the distance-learning initiatives, focusing on the provision of tele-education services to populations living in remote areas.

A majority of countries with a space programme and private actors operatiing in the space sector have launched specific technical assistance projects promoting socio-economic development. They include applications aimed at improving the coverage of the medical system in remote areas, preventing the diffusion of diseases, providing classes, and training through tele-education channels and supporting policies for the management of resources and the prevention of natural disasters.

## SPACE POLICIES AND LEGAL FRAMEWORKS

Policies and legal frameworks play key roles in initiating, supporting, and boosting transfers from the space sector to other fields. Policymakers are encouraged to mitigate information asymmetries and ensure legal certainty, by defining clear property rights and legal frameworks; strengthening R&D networks using research grants, matching grants, and tax incentives, as well as other available policy instruments; promoting the role of technology transfer intermediaries, including innovation centres, incubators and technology parks. With their R&D and technologies, software and patents, facilities and expertise, space agencies are ready to support technology transfers and commercialisation.

As the space sector evolves, so does the role of space agencies and that of their technology transfer offices. There is an ever-growing focus on downstream activities and the transfer of space technologies to different sectors. Space agencies’ role in technology commercialisation and marketing has in some cases been upgraded from mere brokers to active “helpers” and market makers.

However, in developing regions characterised by scarce population density and complex urbanisation dynamics, satellite data can improve the implementation of a wide range of development policies at the local, regional, and national level. These include public service provision and investment strategies, as well as decentralisation policies. And satellite remote sensing has already covered several sub-Saharan countries for providing epidemiology information to help contain malaria outbreaks.

In this context, the role of space in Official Development Assistance (ODA) is examined, based on international data furnished by the OECD. ODA is today the key measure used in practically all aid targets and assessments of aid performance towards the developing world. The original OECD indicators provide new evidence on the intensifying links between development aid and space applications between 2000 and 2016. Space-related projects identified about 2,100 Official Development projects over the 2000-16 period.

The OECD has been in charge of measuring resource flows to developing countries since 1961, with particular attention given to the official and concessional part of this flow, defined as “official development assistance”, or ODA. The original dataset has been manually checked and cleaned, to identify and retain only the projects dealing with space-related initiatives. Some 2,100 ODA projects featuring satellite applications or technologies were identified over a 16-year period (2000-16).

ODA takes place through transfers of resources, either in cash or in the form of commodities or services. They can be provided in many different ways, usually including privileged loans, grants, or even technical assistance. ODA can be bilateral or multilateral, provided from a donor to a specific recipient or channelled through the action of a development agency. Bilateral aid represents the “flow from official (government) sources directly to official sources in the recipient country”. Multilateral aid represents “core contributions from official (government) sources to multilateral agencies, where it is then used to fund the multilateral agencies’ own programmes”. A donor can also decide to charge a multilateral agency with delivering a programme or project on its behalf in a recipient country. Although not negligible, the ODA amounts directed to space-related projects remain modest when compared with overall ODA funding, Total overall ODA commitments globally increased from USD 96 billion to USD 188 billion between 2000 and 2016. In comparison, the total committed amounts for space-related official development assistance projects between 2000-16 totalled USD 607.4 million.

Top donor countries generally include countries with big space programmes (United States, France, Japan). If focusing on ODA commitments, the International Development Association (IDA) of the World Bank committed the largest amount of ODA in space projects between 2000 and 2016, followed by France, the European Union (EU) and the United States. Over the period, the World Bank/IDA committed around USD 127 million, France committed some USD 111.4 million and the United States USD 50.6 million. The main regions receiving space-related ODA in the 2000-16 period, comprise countries in Far East Asia (East and Southeast Asia), receiving USD 240 million, and Sub-Saharan Africa receiving (USD 160 million). Several projects targeted more than one country, at which case funding was allocated at regional level. The African region has been the target of several such initiatives, receiving USD 43 million in commitments.

The category “Africa (regional)” indicates that money was allocated at regional level, targeting more than one country at the same time. In terms of fields of application, most of the funding has been allocated to projects linked to environmental management objectives. Projects in this domain represent USD 225 million between 2000 and 2016. This is followed by forestry management (USD 59 million), telecommunications (USD 49 million) and agriculture and rural development (USD 48 million).

An overview of these projects includes the following:

- Environmental management projects typically adopt satellite technologies to improve the analysis and the use of the environment and related resources, often linked to climate change. Projects tend to be quite large, with a broad regional scope. Satellite remote sensing is used to support and improve decision-making. The bulk of the initiatives are not only aimed at promoting a better use of environmental resources, but also at making environmental monitoring more effective.

- Forestry management projects focus on challenges linked to the sustainable use and conservation of forests. Remote sensing technologies are used to assess the conditions of forests, mapping, gathering data and building databases for monitoring purposes.
- Telecommunications projects deal with the development, or expansion, of regional/national telecommunication infrastructure, involving the provision of satellite broadband and broadcast services. Projects are generally large, aiming to connect remotely located households and communities to the existing telecommunication networks.

Other relevant thematic clusters include agriculture and rural development, biodiversity and education, training, and research. Projects listed under 'agriculture and rural development' include all projects exploiting satellite images and data to inform agricultural practices, monitor agricultural resources and assess agricultural productivity. Several initiatives specifically aim at promoting food security as a direct consequence of greater crop production and better functioning of early warning systems and climate condition monitoring. Projects linked to biodiversity protection use remote sensing techniques for biosphere and animal protection. Several applications also include the adoption of GNSS technologies to track species and their dislocation across different geographic areas. Finally, education, training and research projects group the bulk of distance-learning initiatives focusing on the provision of tele-education services to populations living in remote areas.

A majority of countries with a space programme and private actors operative in the space sector have launched specific technical assistance projects promoting socio-economic development. They include applications aimed at improving the coverage of the medical system in remote areas, preventing the diffusion of diseases, providing classes, and training through tele-education channels and supporting policies for the management of resources and the prevention of natural disasters.

## CONCLUSION

The New Space Economy is a fast-growing market, driven by the commercialization of the historical institutional space sector. The space economy is expanding and becoming increasingly global, driven by the development of ever-more governmental space programmes around the world, the multiplication of commercial actors in value chains, durable digitalisation trends, and the new space systems. Future space exploration goals call for sending humans and robots beyond Low Earth Orbit (LEO) and establishing sustained access to space exploration destinations such as the Moon, asteroids, and Mars. The Everyday benefits of space exploration include:

- Improving health care. ...
- Protecting the blue planet and its environment. ...
- Creating scientific and technical jobs. ...

- Improving humans day-to-day lives. ...
- Enhancing safety on Earth. ...
- Making scientific discoveries. ...
- Sparking youth's interest in science. ...
- Mutual cooperating between countries around the world.

The Space economy grew to $469 billion in 2021, the fastest rate in years. The dollars spent for space exploration create jobs, jumpstart businesses, and grow the economy. Innovations improve daily life, advance medical research, support disaster response, and more. Humans are constantly evolving and finding new ways to add value.

Governments spending continues to grow, as there are over 90 countries operating in space now. However, the United States remains the biggest spender, with its $60 billion total space budget nearly quadruple of the next largest, China. Additionally, India and European countries each increased space spending by 30% or more in 2021, although those countries' budgets remain under $2 billion a year.

The commercial space sector is currently growing by leaps and bounds, and in the next three decades, human beings will enter the realm of space like never before, due in part to the way that public interest in space exploration has been revitalized and growing public engagement through social media. It's no longer a race between two superpowers, but a much more cooperative endeavor involving six major participants, the US, the European Union, Russia, China, Japan, and India along with commercial partners and many smaller agencies. By mid-century, things will progress further, as more nations will join the "space club," and more space agencies will send astronauts to space, and commercial entities will establish a permanent presence and will pursue many new kinds of space-related ventures.

However, in order to help local governments improve their response to natural disasters, tackle food security, safeguard human health, manage water and natural resources, an initiative was set up in 2004 by the National Aeronautics Space Administration (NASA) and the US Agency for International Development (USAID), to help improve environmental decision-making. The initiative now runs in more than 30 developing countries, in eastern and southern Africa, the Hindu-Kush region of the Himalayas, and the lower Mekong River Basin in Southeast Asia. In the Himalaya region, earth observation data are used to detect forest fires, monitor land-use and cover changes as well as water resources. In Africa, the main target of the initiative is flood forecasting, monitoring the impact of frost on regional agriculture and again assessing land cover and land-use change. Activities in the Mekong region focus instead on disaster risk reduction and response, together with water and food security, landscape management to reduce greenhouse gas emissions, and sustainability of the river basin.

Other space agencies and organisations are using earth observation for development purposes, often partnering with aid agencies and institutions in various parts of the world. The explicit goal is to use space expertise and knowledge to deliver socio-economic benefits to underdeveloped economies.

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