Innovation within Mearth: Beyond-Earth innovations and their impact on Earth's progress

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Abstract

This contribution delves into the analysis of beyond-Earth innovations and their profound impact on human life and Earth's progress. The paper first examines the literature on innovation, highlighting that innovation, which represents the primary source of progress, is complex, uncertain, and somewhat disorderly, requiring various types of knowledge, capabilities, skills, and resources. The development of innovations also necessitates collaboration among various actors and diverse ways of thinking. It is often the result of the cross-pollination of ideas that break down barriers between functions, industries, sectors, nations, and geographic distances. Furthermore, the paper underscores that ecosystems play a central role in innovation, as exemplified by the Mearth Ecosystem. Mearth consists of a geographic space representing the interconnectedness of Earth and its satellite, the Moon. Additionally, the strategic importance of the innovative activities that are and will be developed in the future beyond Earth, particularly within Mearth, is explained and emphasized. Finally, the important new role of private organizations and startups is highlighted in the exploration and commercialization of activities beyond Earth and their strategic contributions to innovations.

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INTRODUCTION

Space represents a challenging frontier for research in our time. It is not simply a new industry; rather, it serves as the source of numerous solutions to Earth-related challenges. Beyond-Earth activities influence various aspects of life on our planet, ranging from technological innovations to reshaping the foundations of physics and even influencing geopolitics. Innovation is fundamental to the development of new technologies, providing solutions to the problems that beset us and forming the basis of productivity growth. Beyond-Earth innovation, in particular, is invaluable in today's landscape, profoundly impacting our lives alongside evolving technologies. Indeed, beyond-Earth technologies deeply influence diverse fields, including cancer research, the development of new materials, semiconductors, electronics, and fiber optics. Furthermore, technologies developed beyond Earth can take advantage of other emerging technologies, such as quantum computing, to enhance security in communication and computing power. As a result, comprehensive space research is going to become increasingly dependent on quantum technology.

Additionally, ecosystems play a key role in innovation. An innovation ecosystem is a network of relationships that captures the cross-industry and cross-country complexity of the innovation process. 'Mearth'—a term representing the interconnectedness of Earth and its satellite, the Moon—is the geographic space where innovations and an innovation ecosystem can be developed to meet the challenges of life on Earth. The geography of Mearth, represented by a radius of 297,000 miles (478,499 kilometers), is in fact characterized by its proximity to Earth.

This contribution first analyzes the topic of innovation in the literature, then examines innovations developed beyond Earth, exploring their multifaceted impact on our planet. In this regard, it highlights the importance of innovative activities that can be developed within 'Mearth'. Additionally, the work analyzes the topics of commercialization and investment in beyond-Earth innovations, highlighting the important new role of private organizations and startups.

Innovation in the literature

Innovation refers to the process of creating and implementing new ideas, products, services, or production processes that result in either groundbreaking advancements that revolutionize entire industries or simpler improvements. Essentially, innovation involves applying creativity to devise better or more efficient solutions to existing problems or to identify entirely new opportunities. It is a complex phenomenon that unfolds through various phases, starting from the inception of a scientific idea through to its commercialization. Moreover, innovation is a pervasive phenomenon that encompasses all organizations. Throughout the history of mankind, one innovation has often built upon another or completely displaced it (Goldsmith, 2012).

Joseph A. Schumpeter has been a pioneer in the theory of innovation; in fact, innovation is a central concept in Schumpeter's economic theory (Schumpeter, 1934)[1]. He made the important distinction between invention and innovation. Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out in practice. An innovation requires the combination of several different types of knowledge, capabilities, skills, and resources. For instance, Fagerberg (2013) emphasizes that a combination of factors, including production knowledge, skills, facilities, market knowledge, a well-functioning distribution system, and sufficient financial resources, may be required.
According to Schumpeter, innovation is the primary source of progress and long-term economic growth, despite his concerns about the social challenges and collateral effects of innovation, such as its potential to increase inequality. He further argues that capitalism is an evolving system that continually progresses through the process of innovation. Schumpeter uses the notion of "creative destruction" to characterize the process through which innovation "revolutionizes the structure from within, incessantly destroying the old and incessantly creating the new" (Schumpeter 1942, p. 83). Creative destruction is, therefore, a fundamental element of the innovation process, representing the cyclical and dynamic nature inherent in economic development.
Moreover, a single innovation is the result of a lengthy process involving many interrelated innovations. Usually, an innovation is not a well-defined, homogeneous entity that can be identified at a precise date or become available at a specific point in time (Kline and Rosenberg, 1986). Additionally, Fagerberg (2013) highlights the existence of time lags between invention and innovation.
"Such lags reflect the different requirements for working out ideas and implementing them. Lags between invention and innovation may also be related to the fact that some or all the conditions for commercialization may be lacking. There may not yet be sufficient demand, or it may be impossible to produce and/or market the innovation because some vital inputs or complementary factors are not (yet) available" (2013, p.8).
An important distinction to consider in innovation is between incremental, radical, and disruptive innovations. Radical innovations represent significant and transformative breakthroughs in technology, production processes, products, and business models, creating a substantial shift in an industry or the entire economy. Therefore, they usually stem from the creation of new knowledge and the commercialization of completely novel ideas or products.
Disruptive innovation is a term coined by Clayton Christensen (1977) and represents a phenomenon in which an innovation transforms an existing market or sector. In his theory of disruptive innovation, Christensen (1977) describes a process by which a product or service takes root initially in simple applications at the bottom of a market and then relentlessly moves up the market, eventually displacing established competitors. In Christensen's view, disruptive innovations, more than breakthrough technologies that create better products, are innovations that make products and services more accessible and affordable, thereby making them available to a much larger population. In other words, disruptive innovation represents something new that changes the *status quo*. Of course, not all innovation is disruptive. There is a considerable amount of incremental innovation. Indeed, the cumulative impact of incremental innovations may be significant and relevant. Moreover, realizing economic benefits from radical innovations often requires a series of incremental improvements.
Today, digital technologies are assuming a disruptive role. In the new digital ecosystem, platforms are an example of strategic tool for any innovative activity. Thus, scientific specialties and innovative technology platforms converge, becoming interconnected with the entrepreneurial spirit, seeking to enact positive change and overcome boundaries and barriers to enable the development of new products and processes to benefit mankind in ways not previously seen.
Another important aspect studied in the literature on innovation is how innovations spread or diffuse. Experience shows that many innovations require a lengthy period, often spanning several years, from the time when they become available to when they are widely adopted. Rogers in his *Diffusion of Innovations* (2003, p.5)[2] defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system". Roger's definition of innovation contains a novel concept and method. Rogers (2003) suggests that four main elements influence the spread of a new idea: the innovation itself, communication channels, time, and a social system. Thus, his theory identifies a five–step decision-making process of diffusion: awareness, interest, evaluation, trial, and adoption. However, a common concern regarding innovation is its rate of adoption. According to Rogers (2003, p.177), the adoption of innovation "is a decision of full use of an innovation as the best course of action available". Rogers (2003) defines the rate of adoption as the relative speed at which participants adopt an innovation, where the rate is usually measured by the length of time required for a certain percentage of the members of a social system to adopt an innovation.[3]

[1] This is the English version translated from the 1911 original German, *Theorie der wirtschaftlichen Entwicklung*.
[2] The first edition of *Diffusion of Innovation* by Rogers was published in 1962.
[3] Time, therefore, is an important measure when determining an innovation's rate of adoption (i.e., the number of adopters for an innovation in a given period). In Roger's view, within the rate of adoption, there is a point at which an innovation reaches critical mass.

Another interesting view of innovation diffusion, as highlighted by Goldsmith (2012), is that innovation today is not as geographically isolated as it was in the past. In fact, nowadays, a person in any part of the world could introduce an innovation that displaces existing innovations and organizations globally. In addition, Goldsmith (2012, p. 428) shows that as the number of competing innovations increases, their life cycles become shorter. Time compression is intensifying, forcing entrepreneurs and leaders to make quicker and more precise decisions. Today, they have only a few months to bring a new product from inception to launch.
While Takahashi et al. (2024) introduce a multidimensional approach to the diffusion of a single innovation. In this regard, they collectively examine the diffusion of public interest in a specific innovation through search trends, the diffusion of technological advances as evidenced in patent records, and the diffusion of innovation within academic publications. Additionally, these authors consider the role of national context in the diffusion of innovations. Their results indicate that interest in a specific innovation occurs before the takeoff diffusion of patent innovation, which in turn precedes the dissemination of innovation in academic publications.
However, as Dearing and Cox (2018) point out, most innovations fail to diffuse. For innovation to sustain itself, it must be widely adopted.
Thus, as indicated in the literature, the diffusion of innovations is related to processes of dissemination and implementation, sustainability, improvement activities, rapid decision-making, and scaling up.
Furthermore, experience shows that innovation is a non-linear, stochastic process that thrives on the cumulative nature of knowledge and is also the result of creativity.
Kline (1985) already emphasizes that innovation is not a linear process. The nonlinear model of innovation is rooted in the observation that success rarely emerges from constant progress. Most outcomes include setbacks, mistakes, and sometimes failures. Therefore, achieving innovation goals is marked by uncertainty and diversity, essentially constituting a stochastic process. Malerba (2000) underscores that the dynamic of innovation is influenced by the level of uncertainty and the characteristics of innovative technology.
Furthermore, economic literature has highlighted that innovative capacity depends on the wealth of knowledge; that is, the introduction of innovation occurs when a certain level of knowledge or experience is reached. Thus, innovation has a cumulative effect. However, in the literature on innovation, some argue (Reinganum, 1989) that when there is a high degree of uncertainty, new businesses (e.g., startups) have greater incentives to invest in research activities, thereby making innovative activities more dynamic.
In addition to nurturing innovation, it is essential to establish an environment that fosters it. This entails creating an ecosystem that favors innovation.[4] Today, competition is increasingly moving away from the level of single firms to the collective level of innovation ecosystems, due to greater interconnectedness of value creation in the contemporary business environment (Adner and Kapoor, 2010; Dedehayir, Mäkinen, and Ortt, 2022). An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors (Granstrand and Holgersson, 2020). Innovation ecosystems prioritize technology-focused R&D, investment, and a strong technology infrastructure, and they aim for growth (Davies et al., 2023). An innovation ecosystem involves the successful agglomeration of firms extending on a global level, successful ICT platforms, new industries, entrepreneurs, and investors. It is characterized by the Internet, mobile, and ICT systems' platform dimension, and more recently by Web 3.0. Any entrepreneur or startup with a good idea can, irrespective of geographical location, launch a business application for any platform and be successful.
Moreover, rules and regulations undeniably influence innovation. Yet, at times, rules crafted in the past may impede creativity and the generation of new ideas. Thus, reconsidering and adjusting these rules to meet evolving needs is a crucial factor in enhancing innovative activity. Only through such adjustments can companies carve out more room for experimentation and innovation. Furthermore, governments should incentivize collaborations and work with private commercial enterprises so that fully developed ecosystems can thrive independently, rather than exclusively securing contracts with government agencies and controlling and limiting the winners in the beyond-Earth arena. This is because exclusive government guidance in this strategic sector tends to be permeated by bureaucracy and inefficiency, with the risk of never being on the cutting edge of change.

2. BEYOND-EARTH INNOVATION

As emphasized by Schilirò (2023), innovation serves as a global catalyst for progress and change; it constitutes a strategic tool beyond Earth.
Working in the beyond-Earth space offers several potential advantages, such as a purified zero atmosphere, radiation, microgravity, unlimited solar energy, abundant resources, no climate environment (air, water, oceans, rain, snow, wind, etc.), lower pressure, and extreme temperatures.

[4] An ecosystem is the network of diverse stakeholders and activities involved in the delivery of a specific product or service through both competition and cooperation (Schilirò, 2023). The crucial idea is that each entity in the ecosystem affects and is affected by the others, creating a constantly evolving relationship.

Today, within this geographic space, autonomous systems, automation, remote control, artificial intelligence, zero-gravity manufacturing, biotechnology, and interplanetary Internet connectivity are all functioning to benefit Earth and its inhabitants. Of course, these innovations are conceived on Earth and developed beyond Earth.
The industry that revolves around the geographic space beyond Earth is using emerging technologies, including 5G, advanced satellite systems, 3D printing, big data and quantum computing, to upgrade and scale operations in that geographic space. Furthermore, many services, such as weather forecasting, remote sensing, global positioning system (GPS) navigation, satellite television, and long-distance communication,[5] rely on beyond-Earth infrastructure.
As a result, significant innovations are emerging from our planet's orbit to the moon's surface, presenting unprecedented opportunities on Earth. New industry trends, like smart propulsion, and space traffic management, are gaining traction. Examples of innovations in the beyond-Earth domain, such as robotic arms, miniature cameras, and other sophisticated technologies, not only enhance our ability to seize new opportunities in space but can also prove valuable on our planet. Opportunities, like harnessing solar radiation for lithography in semiconductor manufacturing, for instance, can emerge since all the essential technologies for this already exist. Moreover, consider the innovative category of space-based solar power projects. There are many projects going on; for instance, Caltech is trying to develop a project that collects solar power in space and transmits energy wirelessly to Earth through microwaves.[6] This project envisions thousands of solar panels floating in space, unobstructed by clouds and unhindered by day-night cycles, wirelessly transmitting massive amounts of energy to receivers on Earth. This innovative technology is poised to deliver clean, continuous energy to Earth from solar arrays in space. In other words, it ensures terrestrial power availability remains unaffected by weather or time of day, making solar power continuously accessible anywhere on Earth. ESA, the European Space Agency, is also involved in a similar project to develop a space-based solar power program.[7] In addition, small satellites, such as CubeSats[8], have become increasingly common in recent years. As reported by Deloitte Insights (2023), the development of Small Sats[9] and CubeSats have particularly increased the interest of investing in this field by private companies and government agencies. Small Sats and CubeSats allow for more affordable access to space and new business models, such as constellations[10].
Miniaturized satellites allow for cheaper designs; however, these small satellites also present challenges: they typically have less power and smaller capabilities. On the other hand, large satellites incur significantly higher costs, upwards of billions of dollars for a single satellite, but offer greater capabilities. In summary, we are presented with a range of possibilities, and our choices must be guided by our specific needs and a thorough evaluation of the associated costs.[11]
Furthermore, startups are developing small satellites that enable space companies to undertake missions that large satellites traditionally struggle with. Small satellites are particularly well-suited for use in proprietary wireless communications networks and for scientific observation, data gathering, and Earth monitoring through GPS technology. Additionally, advancements in industrial technologies enable the mass production of satellites. Together with increasing private investment in industry, startups are gaining momentum by developing technologies to ease movement, operations, and communications between our planet and the geographic space beyond Earth.
However, the potential for expanding innovation beyond Earth is sometimes underestimated. Orlova, Nogueira, and Chimenti (2020) highlight that industry leaders of the past have become irrelevant not due to their direct competitors, but because of new products and services emerging from other industries that have superseded the old ones. The same phenomenon can occur in the space sector. They demonstrate their thesis by offering a multi-industry analysis of the space sector's contemporary business environment, adopting an ecosystem approach to study it.
This is why we underscore the essential role of Mearth's Ecosystem, where Mearth represents a new geographic space that encompasses the interconnectedness of Earth and its satellite, the Moon. Innovations

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[5] See https://www.startus-insights.com/innovators-guide/top-10-spacetech-trends-innovations-2021/#:~:text=These%20trends%20include%20miniaturization%2C%20smart%20propulsion%2C%20data%20analytics%20%26%20more!&text=The%20space%20industry%20is%20utilizing,and%20scale%20operations%20in%20space.
[6] https://www.spacesolar.caltech.edu/
Caltech researchers proved that wireless power transfer in space was possible: Solar panels they had attached to a Caltech prototype in space successfully converted electricity into microwaves and beamed those microwaves to receivers about a foot away, lighting up two LEDs.
[7] The ESA project is aimed at addressing the future's clean energy needs and providing affordable energy. This initiative aligns with the goal that ESA aspires: to achieve Net Zero emissions by 2050. https://www.esa.int/Enabling_Support/Space_Engineering_Technology/SOLARIS/Space-Based_Solar_Power_overview
[8] CubeSats are a class of nanosatellites that use a standard size and form factor. The standard CubeSat size uses a “one unit” or “1U” measuring 10x10x10 cms and is extendable to larger sizes; 1.5, 2, 3, 6, and even 12U. Originally developed in 1999 by California Polytechnic State University at San Luis Obispo (Cal Poly) and Stanford University to provide a platform for education and space exploration. https://www.nasa.gov/what-are-smallsats-and-cubesats/
[9] SmallSats accounted for about 95% of spacecraft launched in 2022.
[10] Constellations refers to a group of satellites working together as a system with shared control.
[11] A typical weather satellite carries a price tag of $290 million, while a spy satellite might cost an additional $100 million (Global.com). Then there is the cost of maintaining and repairing satellites. Companies must pay for satellite bandwidth, similar to how cell phone owners must pay to transmit voices and data. In addition, small satellites might degrade in orbit.

born within limited yet expansive geographically beyond-Earth research activities, as will be the case in Mearth's Ecosystem and Mearth Economic System[12], have the potential to drive transformative changes across a wide range of industries and fields. These innovations can lead to strategic alliances with other entities and organizations, thus expanding their reach and impact. In fact, many other innovations have been developed by individuals who were thinking about beyond-Earth ventures. For instance, popular technologies like laptops and cloud computing emerged as products of needs originating beyond Earth's confines. Even the CAT scan and water purification systems originated because people asked different questions within the context of space exploration. Specifically, Mearth geography prompts the exploration of new types of questions that directly impact Earth (Goldsmith, 2023a).

As said above, the innovation activity in the geography of Mearth, given its proximity to Earth, is very important as it produces positive spillovers for innovation on Earth. Actually, Mearth expands visually to include Earth and extends just beyond the Moon, marked by a line known as the Mearth Line.[13] One potential positive spillover in activity beyond Earth occurs when, in the pursuit of innovation, the final mile is missing, and this mile can be completed later in a different context. In addition, several innovations come from space consultation, as historically occurred. These beyond-Earth innovations, like those resulting from the construction of Mearth, have the potential to foster the creation of jobs and career opportunities on Earth. Other important spillovers of these innovations include laying the foundations for new industries and addressing Earth's challenges for the survival of our species, as challenges and problems are created primarily by human actions on Earth rather than by our planet itself.

Therefore, such innovations developed beyond Earth can assist us in tackling some of our planet's most pressing issues, serving as steppingstones for further advancements. Additionally, they might redefine our daily lives by introducing products and services that enhance sustainability, efficiency, and connectivity in our world. In the case of innovations within Mearth, Mearth Space Industries, a design, build, manage, and lease construction company targeting a 4Phase development of the Moon over 40 years, could serve as a fertile ground for nurturing and developing these inventions. According to Schilirò (2023), the aim is to create an environment of ideation that can directly influence fundamental life functions (air/quality, food, water, health, reproduction) and advanced technological functions (energy, engineering, computing), and social interactions (society, science, education).

By investing in these innovations, the ventures within the Mearth Ecosystem could drive the progress needed to transform these ambitious ideas into practical, market-ready solutions. Furthermore, when these innovations are disseminated within the Mearth Ecosystem, they can ignite cross-pollination of ideas and potentially give birth to new technological offspring.

Today, more than ever, innovation relies on the cross-pollination of ideas, breaking down barriers between functions, industries, sectors, nations, and geographic distances. Innovation can also be generated from within organizations if managed and fostered in a safe, inclusive, and stimulating ecosystem. Moreover, high-impact innovation can only be achieved through collaboration and diversity in ways of thinking.

Game-changing inventions can also be licensed out to the wider marketplace, planting seeds of change, creating cross-pollination sharing, and catalyzing growth in unexpected places. Mearth's Discovery, a tech hub venture and a unit of Project Moon Hut[14], leverages the cross-pollination of ideas and inventions/innovations from one industry to an entirely different innovation in another industry, which is one of its defining benefits from the Mearth Ecosystem.

However, skepticism towards the relevance of innovation beyond Earth to our daily lives is not uncommon. The harsh, alien conditions of the Moon or space, in general, seem to be ingrained in our thinking. Nevertheless, it is highly likely that every challenge solved for life on the Moon can provide a solution for Earth. For instance, the Helios space project[15], now focusing on the steel industry, yet it was a space innovation gone wrong to make refueling stations on the moon. The thinking it takes the innovation created a completely different innovation. Another example, scratch-resistant lenses in glasses are a product of an unintended outcome from a NASA project. The scientist was initially working on water filtration, and the creation of these lenses was a byproduct of that research. In fact, developing scratch-resistant lenses was not the primary focus of the project. At the same time, the water purification methods we use today were originally devised to provide astronauts with clean water (Goldsmith, 2023a). This is the case of innovation that has arisen because of other innovations.

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[12] The Mearth Economic System is the subset of the Mearth Ecosystem. Both the Mearth Ecosystem and Mearth Economic System are components of the Project Moon Hut (Goldsmith, 2023). It represents an innovation in itself.

[13] https://projectmoonhut.org/mearth/the-pmh-classification-system.php

[14] https://projectmoonhut.org/our-work/our-work

[15] Decarbonizing the steel industry. https://project-helios.space/

3. INNOVATION, BEYOND EARTH EXPLORATION AND ITS COMMERCIALIZATION

As stated in Miniaoui and Schilirò (2017), innovation is largely driven by entrepreneurs and the private sector, although government policy can play a strategic supportive role. In the previous section, we examined the complex, evolving, and expanding innovation beyond Earth and the innovative activities that can be developed within Mearth. These innovative activities are undoubtedly favored by exploration beyond Earth and its commercialization.

Beyond-Earth exploration is gaining more popularity than ever. An increasing direct participation of private companies in the space sector started in the early 2000s and became known as the New Space movement (Orlova, Nogueira, Chimenti, 2020).[16]

Although government agencies have traditionally dominated it, the new era is marked by the entrance of private companies into domains such as satellite launches, human spaceflight, and even the exploration of the Moon, Mars, and beyond. This has determined a significant shift toward the commercialization of space exploration beyond Earth, which also means "the cultural and philosophical shift toward greater private participation" (Orlova, Nogueira, Chimenti, 2020).

The market for geospatial technology, which uses satellite and drone imagery, GPS data, and mapping software to analyze and interpret data around the planet, is also experiencing extraordinary growth. New possibilities have emerged thanks to the proliferation of satellite launches — with SpaceX alone conducting a record 98 launches during 2023 — combined with the affordability of drones and advancements in imaging technologies.

A recent notable example of *private* space activity is 'Odysseus', which touched down on the Moon in February 2024. Launched by the Texas-based company Intuitive Machines, this marks an unprecedented milestone in the space age and signifies the return of an American vehicle to the Moon 52 years after the Apollo program's last mission.[17] However, although privately operated, Odysseus received partial funding from NASA's Commercial Lunar Payload Services program, initiated in 2018 to support commercial lunar flights. Like other missions, it carries six NASA instruments designed to gather data crucial for planning future Artemis program missions, which aim to return astronauts to the Moon (Hicklin-Coorey, 2022). The U.S. Artemis program, in fact, seeks to return astronauts to the moon with the first landing targeted for the program's third mission (Artemis III) in September 2026.[18]

Public–private relations in the space sector have contributed to foster beyond Earth exploration and innovation activity. The sector involves high-risk, capital-intensive activities and is influenced by significant strategic interests. Governments have traditionally played a crucial role in developing beyond-Earth technology. However, over the past few decades, there has been a noticeable shift towards the commercialization of beyond-Earth activities, with private companies increasingly becoming involved. In fact, commercialization trends are now accelerating in many countries, shifting from government-centric development to more decentralized approaches. The private sector is evolving beyond its traditional role as a contractor, taking on more development costs, financial risks, and responsibilities in selecting joint projects regarding beyond-Earth space. At the same time, within that context, public agencies assume three general (often complementary) roles: government acting as the lead developer[19], government serving as a customer by procuring finished goods and services, and government functioning as a partner in various schemes where the private sector co-funds projects (OECD, 2021). Public authorities are motivated by considerations such as technological transfer to launch new commercial activities or supporting private sector innovation in certain areas to fulfill government needs, as well as reduce the costs of space programs and increase returns on investments.

Beyond-Earth Investment not only represents part of the solution to some of our biggest challenges, but also offers commercial opportunity for businesses.

The commercialization of beyond-Earth exploration is driven by several factors. First of all, innovation has made it more cost-effective to develop new space systems and launch payloads into beyond-Earth space, which in turn has enabled a wider range of organizations to participate in the space sector (Deloitte Insights, 2023). Therefore, technological advancements, decreasing costs of launching payloads into space, and increasing interest from investors and the public have contributed to the growth of beyond-Earth activities.[20]

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[16] The U.S. SPACE (Spurring Private Aerospace Competitiveness and Entrepreneurship) Act of 2015 further opened the sky and encouraged greater commercialization, primarily for launch systems, space tourism, and resource exploitation in space. The law allows US industries to "engage in the commercial exploration and exploitation of space resources", including water and minerals, but it asserts that "the United States does not [by this Act] assert sovereignty, or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body." The right does not extend to extraterrestrial life, so anything that is alive may not be exploited commercially.

[17] So far, in addition to the United States, four other countries—Russia, China, India, and Japan—have successfully managed to land their vehicles on the Moon.

[18] To date, only 12 humans have landed on the moon as part of NASA's Apollo program, from 1969 to 1972.

[19] In the USA alone, more than 2000 innovations were developed for space by NASA (https://spinoff.nasa.gov/).These innovations are undoubtedly intended for space, excluding those that did not go to space.

[20] Over the past few years, the costs of manufacturing and operating satellites have significantly diminished. Additionally, thanks to reusable rocketry, launch costs are much lower today (Deloitte Insights, 2023).

Furthermore, commercial innovation in space industry makes it possible to do even more in beyond-Earth space with ever-smaller satellites (World Economic Forum and McKinsey & Company, 2024)[21].
Indeed, the increased private sector investment has been decisive for the development of beyond-Earth activities. A growing number of venture capital firms and private equity firms have been investing, and more private companies have entered the market to provide space-related products and services. However, despite the decreasing costs of rocket launches, space exploration is not exactly cheap.[22] It takes millions of dollars to send even a single robotic mission to space and billions of dollars to send astronauts to orbit (Williams, 2019).[23] After all, the U.S. SLS rocket will cost $4.2 billion to build and launch to reach the Moon, with one launch planned every two years. However, it has already experienced delays.
The question then becomes: Was beyond-Earth exploration worth all the money spent? Williams (2019) argues that the most obvious benefit was how it advanced humanity's knowledge of space. By putting satellites and crewed spacecraft into orbit, scientists learned a great deal about Earth's atmosphere and ecosystems, leading, for instance, to the development of Global Positioning Satellite (GPS) navigation. The deployment of satellites also revolutionized communications technology. Since Sputnik 1 was launched into orbit in 1957, about 8,100 satellites have been deployed by forty countries for telecommunications, television, radio broadcasting, navigation, and military operations. Hicklin-Coorey (2022) highlights that beyond-Earth exploration not only increases space capabilities and better equips humanity for problems at home, but also leads to higher productivity through a more technically educated labor force and encourages greater international cooperation. This justify investing in beyond Earth exploration. The rewards of increased investment in space exploration will spur innovation, strengthen economies, and move us towards a multiplanetary environment for human life.
According to experts at the Union of Concerned Scientists (UCS), in 2023 the Satellite Database is listing more than 7,560 operational satellites currently in orbit around Earth. (Union Concerned Scientists, 2023)[24]. By 2040, the Swedish Space Corporation estimates this number will probably increase to 100,000. Such crowding necessitates better regulation, given that the rapid increase in satellites has also led to the problem of space debris. As highlighted by Di Pippo et al. (2023), the current legal framework fails to specify who should be responsible for debris removal. Moreover, the increase in the number of satellites and the accompanying challenge of space debris in Earth orbit raise new questions about the expanding role of private entities in space activities and, more generally, the issue of space environmental sustainability. A primary concern is, therefore, to develop beyond-Earth innovations that must be eco-compatible (Schilirò, 2019). Energy, materials, and information systems adopted in space must not only be used efficiently but also be environmentally sustainable.
A report by OECD (2021) argues that although private sector participation is growing, government programs and procurement still account for the lion's share of investments and represent a significant market for private firms. At the same, in 2018 alone, commercial beyond-Earth activities accounted for around three-quarters of its revenues, whereas the rest came from both civil and military government programs. The main contributor to the commercial market has been the telecommunication industry, and in that, satellites that relay television signals from the Geostationary orbit to the viewers' locations (Orlova, Nogueira, Chimenti, 2020).
Asking whether space exploration is worth the investment is reasonable. However, it lacks precision as it fails to account for the direct and indirect innovations that have benefited humanity over the past 60 years. Hence, a more pertinent question might be: what innovations have emerged to advance humanity? For instance, just from NASA's spin-off site, we can identify over 2400 direct spin-offs. However, it is also important to consider the secondary, tertiary, or multiple generations of innovations and their subsequent benefits. Therefore, the answer is that without this complex and multi-layered flow of innovations, we likely wouldn't have witnessed the same revolutions in communications, computing, transportation, medicine, astronomy, astrophysics, and planetary sciences. Additionally, we would not have come to learn as much about our origins on this planet. We would not have understood just how interconnected life and ecosystems are today (Williams, 2019).
It is important to be aware that there are innovations exclusively utilized in space that we can define direct innovations. However, we must also consider innovations used beyond Earth that subsequently find applications on Earth. Take, for example, innovations designed for space but never deployed and instead repurposed for terrestrial use. For instance, in cases where multiple companies compete to develop

[21] Space-based Earth observation, for example, now enables identification of objects at a resolution of 15 centimeters (cm). And these images come at a more affordable price, as cost per pixel has continued to drop (World Economic Forum and McKinsey & Company, 2024).
[22] The single launch of the Space Launch System (SLS) rocket to send astronauts to the Moon for the Artemis program is estimated to cost $4.1 billion. However, others are looking to make this obsolete. NASA's spending on its Artemis program is projected to reach a total of $93 billion by 2025. https://www.space.com/nasa-artemis-moon-program-93-billion-2025
[23] In fact, despite the cost per kilogram has dropped from $18,500 to approximately $3,000, space transportation remains an expensive endeavor today. That's why the commitments of companies like Blue Origin and SpaceX are centered around reusable rockets.
[24] https://www.ucsusa.org/resources/satellite-database#:~:text=Assembled%20by%20experts%20at%20the%20Union%20of%20Concerned,7%2C560%20operational%20satellites%20currently%20in%20orbit%20around%20Earth.

innovations under contract, with only one emerging as the winner among 27 competitors, what becomes of the other 26 companies? Do they shut down, pivot, or repurpose their technology for other applications?
Moreover, during the innovation process, discoveries of new innovations sometimes emerge that are entirely unrelated to space (e.g., Helios). Innovations are related to processes and also concern materials. These processes can be utilized in other industries: the process is transferred, not the product. Innovation also arises from knowledge transition. For example, a person who works in the space sector and then gets hired by a new industry, transitioning and applying the knowledge to a different field. People contribute to innovation through knowledge diffusion, such as speaking at a conference or publishing a scientific paper, while others are inspired by these original insights and adapt them for use in their own innovative applications. Therefore, in the relationship between space and Earth, numerous avenues exist for the emergence and evolution of innovations.
Beyond-Earth exploration and addressing the many problems we face on Earth are not mutually exclusive; they are complementary. As a result, exploring beyond-Earth space will likely yield numerous benefits, although many of these benefits may be intangible. The new research approach transcends industry boundaries and, together with traditional space segments—launch, satellites, and ground equipment—addresses a much more complete set of industries, reaching all the way to the final users of voice, data, and content (Orlova, Nogueira, Chimenti, 2020).
Budd and Paladini (2023) have also emphasized the importance of the relationship between the Space Economy and the Earth Economy. They argue that this connection has been crucial in seizing opportunities for interplanetary activities, leveraging the advancements of Industry 4.0 and its associated cyber-physical systems technologies. These technologies include the Internet of Things, the Industrial Internet of Things, cloud computing, cognitive computing, and artificial intelligence.
Furthermore, as highlighted by Williams (2019), one of the greatest benefits of human spaceflight and beyond-Earth exploration has been the ability to study Earth from orbit. This has enabled us to learn an unprecedented amount about our planet's climate and weather systems, in addition to providing the means to measure these systems and assess the impact of human agency on them.
These advancements open opportunities for startups and incumbents, helping expand beyond-Earth capabilities across industries like agriculture, automotive, construction, defense and national security, insurance, manufacturing, mining, oil & gas, and more.
In the next future, the frontier of commercializing orbits closest to Earth—a cornerstone of the new Mearth economy—may align with the concept of orbital factories. The idea is to relocate factories within Mearth, utilizing increasingly advanced automation. This unprecedented scenario could envision, initially, the production of new materials, compounds, medicines, and, in the future, potentially planes, ships, cars, computers, or even furniture taking place in a gravity-free environment. Not to mention space tourism. This could likely occur with minimal costs and zero pollution in the future to our blue planet. However, today, this scenario remains a mere hypothesis, as it is based on a lot of overhyped claims in the industry, as seen in the case of AI.

A glance to space industry and market

According to Euroconsult (2022), the value of the space economy reached $464 billion in 2022, and the global space market grew by 8% over the same year. Of this sum, $100 billion is institutional spending,[25] while the remaining approximately $364 billion is related to commercial markets. Most of the sector's value (83%) is found in space-based end-user applications, an area of the space economy showing no signs of waning in the years ahead, covering telecommunications, Earth observation, and companies utilizing satellite navigation to deliver services to their customers. In 2022, global commercial downstream revenues amounted to $339 billion, with 96% generated from commercial service revenues.[26] Satellite navigation accounted for 67%, satellite communication for 32%, and Earth observation for 1%. Moreover, always in 2022, the number of satellites launched was 2,507, marking a 36% increase compared to the previous year. Among these, 95% were smallsats (<500kg), with 87% launched by commercial operators.
Various organizations are trying to forecast the growth of the space economy. For instance, Bank of America foresees that in 2040 the space economy will represent a business of $2.7 trillion, while Morgan Stanley is much less optimistic with an estimate of $1.1 trillion, an estimate not far from the one calculated by Euroconsult (non-official, authors' calculation) of $1.2 trillion (Varma, 2023).
Furthermore, the World Economic Forum and McKinsey & Company (2024) estimated that the space economy is forecasted to soar to $1.8 trillion by 2035 in an increasingly connected and mobile world. Space will be a larger part of the global economy by 2035 and its impact will increasingly go beyond space itself. The impact of the space economy will create value for nearly all industries on Earth and provide solutions to many of the world's greatest challenges.[27] Sectors such as supply chains and transportation, for instance, will become

[25] 60% of this expenditure consists of government defense contracts.
[26] Europe captures approximately 24% of the global commercial downstream market in 2022.
[27] As is also stated in Mearth's project.

increasingly dependent on satellites and other space technologies. In general, space will become more about connecting people and goods, and its return on investment will be more than financial, playing an increasingly crucial role in mitigating global challenges.

Of course, all these estimates and evaluations provided in the numerous reports represent values that likely do not take into account secondary, tertiary, and other indirect effects related to the beyond Earth economy. This is because it is almost impossible to conduct such exhaustive accounting. In fact, economic accounting does not measure the impact on the entire ecosystem. Moreover, apart from economic growth, employment, and others, the benefits of beyond Earth exploration and activities include cultural, educational, environmental, and social benefits that could be termed "community capital" (Budd and Paladini, 2023).

Regarding investment, in the U.S., the rise of SpaceX has attracted a significant amount of investment. Considering the situation up until 2023, the U.S. has dominated global infrastructure investment over the past 10 years, securing 68% of the total capital, with SpaceX alone accounting for 20% of the U.S. total. However, according to Space Capital's (2023) *space investment quarterly report*,[28] the top 5 countries receiving investment are now: USA, China, Singapore, India, and France.

Furthermore, considering production, the *Press Release* by Eurospace (2023) reveals that, between 2018 and 2022, the United States emerged as the leading country in spacecraft production, followed by China, Europe, Russia, India, and Japan. Specifically, Russia secured the fourth position, surpassing Japan, which experienced a notable decline in production over the years. Additionally, despite minimal production until 2021, India has shown growth and surpassed Japan in 2022.

In the US, SpaceX also emerged thanks to process improvements, transitioning from the clean rooms typically utilized by NASA to standard production lines. This significant step allowed for a decrease in production costs. By examining the market segments within the private and internal institutional sectors from 2018 to 2022, it becomes evident that SpaceX, with its satellite internet constellation Starlink, has been a significant game-changer in the United States. Even in Europe, China, and Russia, the private sector has assumed a certain role, although not as significant as in the US.

In the near future, and in line with the commercial development of activities beyond Earth, the frontier of commercializing orbits closest to Earth—a cornerstone of the new "Mearth" economy—may align with the concept of orbital factories.

The idea is to relocate factories within Mearth, utilizing increasingly advanced automation. This unprecedented scenario could help envision at first the production of new materials, compounds, medicines and in the future potentially planes, ships, cars, computers, or even furniture taking place in a gravity-free environment, likely with minimal costs and zero pollution to our blue planet. However, today, this scenario remains a hypothetical program.

CONCLUSION

This contribution delves into beyond-Earth innovations and analyzes their impact on Earth's progress, contributing to the solution of the major challenges humanity is facing. In fact, innovation serves as a global catalyst for progress and change.

The literature on innovation since Schumpeter suggests that innovation is the combination of entrepreneurial spirit and various different types of knowledge, capabilities, skills, and resources. As pointed out by Kline and Rosenberg (1986), innovation is complex, uncertain, somewhat disorderly, and subject to many types of changes. Additionally, innovation demands excellent market judgment to satisfy economic, technological, and other constraints simultaneously.

Innovations, especially high-impact ones, require collaboration among various actors and diverse ways of thinking. They are best developed within ecosystems, like the Mearth Ecosystem, where Mearth is a geographic space representing the interconnectedness of Earth and its satellite, the Moon. These developments are often the result of the cross-pollination of ideas that break down barriers between functions, industries, sectors, nations, and geographic distances.

Today, beyond-Earth space offers several potential advantages to benefit Earth's progress. This is because the industry revolving around beyond-Earth space uses emerging technologies to upgrade and scale its operations. In fact, many new technologies are used beyond Earth, and many services rely on beyond-Earth infrastructure. In particular, exploration beyond-Earth has resulted in significant innovations, contributing to the creation of GPS, solar panels, implantable heart monitors, cancer therapy, water-purification systems, improved computing, and more (Hicklin-Coorey, 2022). However, if innovation is the necessary condition for progress beyond Earth, and consequently for helping to solve the challenges humanity is facing, then, as underlined by Teece (2010), profiting from innovation requires a new and appropriate business model coupled with an effective business strategy. The introduction, for instance, of SmallSats and CubeSats allows for constellations—groups of satellites working together as a system with shared control—which represents a new business model.

[28] www.spacecapital.com/quarterly

As has been argued, the ventures within the Mearth Ecosystem are well-suited to drive innovation and the progress needed to transform ambitious ideas into practical, market-ready solutions.
Finally, the paper discusses and highlights the important new role of private organizations and startups in the exploration and commercialization of activities beyond Earth, emphasizing their strategic contributions to innovation.
The analysis just carried out leads to the conclusion that investing in activities beyond Earth, particularly in innovation and the development of new technologies, is not only economically beneficial but also brings long-term benefits to the environment and all the lives on Earth.

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