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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Faculty of Business Administration and Management

Sustainability Analysis of Companies in the Space Economy: An ESG Approach

Master's Thesis

Master's Degree in Business, Product and Service Management

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CFP	Corporate Financial Performance
CSR	Corporate Social Responsibility
EGNOS	Geostationary Navigation Overlay Service
EO	Earth Observation
ESA	European Space Agency
ESG	Environmental, Social, Governance
GNSS	Global navigation satellite systems
GOOS	Global Ocean Observing System
GRI	Global Reporting Initiative
LEO	Low Earth Orbit
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
ROA	Return on assets
SDG	Sustainable Development Goal
UN	United Nations
UNOOSA	United Nations Office for Outer Space Affairs

ABSTRACT

The space sector has proven to create value for the benefit of humanity, but sustainability has become imperative for a solid economy and fast-growing industries, and now more than ever business should be done without negatively impacting the environment, our communities, and our society from a global point of view. Therefore, this sector needs to keep growing from both an ethical and financial perspective to avoid compromising the needs of the future.

Addressing the challenges companies are facing in terms of sustainability is key to identifying strategies to overcome them. This research was conceptualized to analyze the various aspects of the rapidly growing space economy and its intersection with the high relevance of sustainability challenges in today's world by conducting a qualitative content analysis of the environmental, social, and governance (ESG) aspects of the sustainability strategies of leading corporate and startup companies in the space industry.

1. INTRODUCTION

1.1. Justification

It is certain that the space sector has a significant role to play in the context of severe environmental, social, and economic issues depicted by the dangers of climate change, pollution, and natural resource depletion. Therefore, space-related initiatives and corporate innovations have the potential to boost the world's economy and encourage more sustainable and responsible economic growth. Although, if not diligently regulated in terms of its social and environmental impact, the commercial activities of space could also potentially represent a major risk to both the space and Earth environments.

Over the course of many decades, there has been a substantial evolution in the variety of activities in the global space sector. Today, space capabilities are crucial to many commercial digital applications as well as critical infrastructures like telecommunications.

Beyond a shadow of a doubt, three stages of the space economy's development have been established, with distinct public and private stakeholders participating in each stage. The initial stage around the latter half of the twentieth century started with governmental along with military space initiatives mainly performed by two cold war rivals, the United States of America (US) and the United Socialist Soviet Republic (USSR), in the so-called "Space Race" that claimed to have scientific purposes, such as studying Earth and the solar system and gaining military and strategic advantages over rival nations.

Developments like the first satellite, first outer space flights, and first human outer space flights, ultimately resulted in space technology entering society on a global scale, opening the doors for the involvement of private actors.

The decade of the 1970s marked the second stage of a new era, where the commercial use of space was encouraged by changes in government regulations and significant developments in the field of technology, this included several satellites launches for managing fax, phone, and television broadcasts, as well as Earth observation satellites

utilized to improve forecasting for both public and private interests, significantly improving meteorology throughout the world.

The participation of private actors had an exponential growth accelerating the extensive range of space-based services and products, signifying the beginning of the third and current stage, kicking off in the early 2000s and known as the New Space movement.

According to the Bank of America in 2019, 79% of the world's space economy was produced by commercial operations. This has taken the space economy to its present moment, where nearly every human being has interaction with space-based applications in their day-to-day lives, starting with digital maps and navigation systems, weather forecasts, all the way to satellite television, and instant credit card transactions.

The space economy is surely known by the public eye for its disruptive innovations, contributing to the creation of new business models and revenue streams, and as reported by investment bank firm Morgan Stanley, is aiming to become the next trillion-dollar industry by 2040, this will be possible with an estimated significant reduction of cost in launch system, as well as lower costs of operating in space and the development of artificial intelligence; which will also potentially allow private space travel for tourism purposes become commercially available.

Financial gains are not everything and one thing that should be seriously discussed is the space economy's contribution to sustainability where it is expected that this sector takes on a more vital role to mitigate the critical global priorities of our times. The defining of space programs and the design of space systems must urgently take environmental factors into account in addition to technical and economic evaluations (Miraux, Wilson, and Dominguez, 2022). The Sustainable Development Goals can only be accomplished with the help of space activities. For that reason, the long-term sustainability of outer space activities is of interest and importance for current and emerging actors in this industry, especially for developing countries (Paulino & Pulsiri, 2022).

The space sector certainly has the capabilities and funding to support the sustainable development goals (SDG, 2030-2050), but a regulatory framework for outer space

activities is necessary to promote principles of behavior and policies that support the idea of minimizing the impacts of human activities on Earth as well as on the outer space environment. The main players in the industry should be encouraged to plan their activities based on the SDGs, their main national requirements, and international considerations for the sustainability of space and the Earth (Paulino, and Pulsiri, 2022).

In our current times, amid the 29,000 tracked objects in orbit, only 16% are intact, operational satellites. The rest is made up of spacecraft in very poor conditions as a result of disuse and neglect and fragmentation debris caused by explosions, collisions, etc. (Miraux, 2022).

Many people in the space community are concerned about the issue of space debris. Most forecasting analyses seek to determine how severe debris densities and flows would grow in particular orbit settings hundreds of years from now. Contrariwise, space operators do not yet view space debris as a significant mission possibility of harm (Schaub et al., 2015).

Anther critical consideration is that the launch of rockets and satellites, among other space-related activities, are linked to air pollution and climate change, rocket launches can produce significant amounts of carbon dioxide (CO2), nitrogen oxides (NOx), and water vapor, all of which can help form greenhouse gases and add to ozone depletion (Maloney et al., 2022).

This outlook demands for the current governmental leaders and global organizations to put their efforts into the development of a scheme of regularization of all activities occurring throughout the entire surface of the Earth and beyond, to prevent damage being done under the mere chase of profit.

This master thesis is intended to offer a contribution to the research field that encompasses business with sustainability by means of qualitative analysis of the ESG reporting of companies in the space sector.

1.2. Objectives

1.2.1. General Objective

The general objective of this master's thesis is to analyze the sustainability of the space sector through an ESG approach.

1.2.2. Specific Objectives

To achieve the general objective proposed, the following specific objectives have been set:

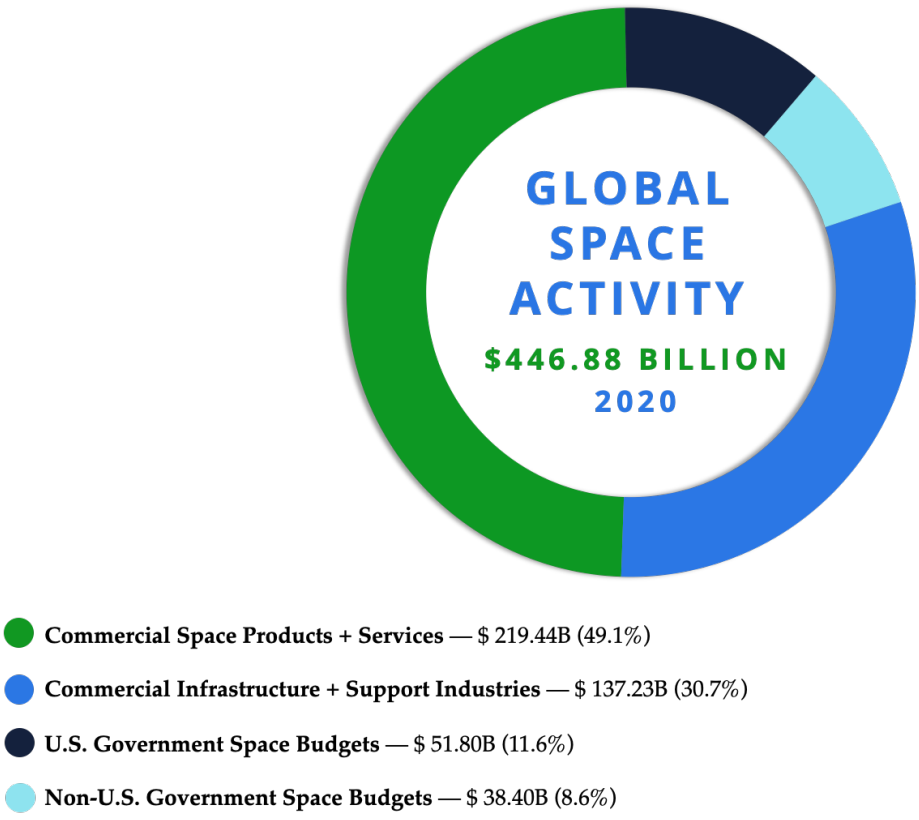
- To analyze and understand the space sector and its current composition.
- To conduct a literature review on the fundamental aspects of ESG reporting.
- Analyze the ESG reports of selected companies in the space sector.
- Determine the main future challenges related to sustainability for the space industry.

2. UNDERSTANDING THE SPACE ECONOMY

2.1. Space Economy

The term space economy refers to "the full range of activities and the use of resources that create value and benefits to human beings in the course of exploring, researching, understanding, managing, and utilizing space" (OECD, 2022). The space industry has seen rapid expansion in recent years, with a forecasted global space economy value of $447 billion in 2020 (Space Foundation, 2021). Several variables, such as the rising demand for satellite technology, the development of reusable launch vehicles, and the introduction of new space applications like space travel and asteroid mining, all contribute to this growth (Deloitte, 2022).

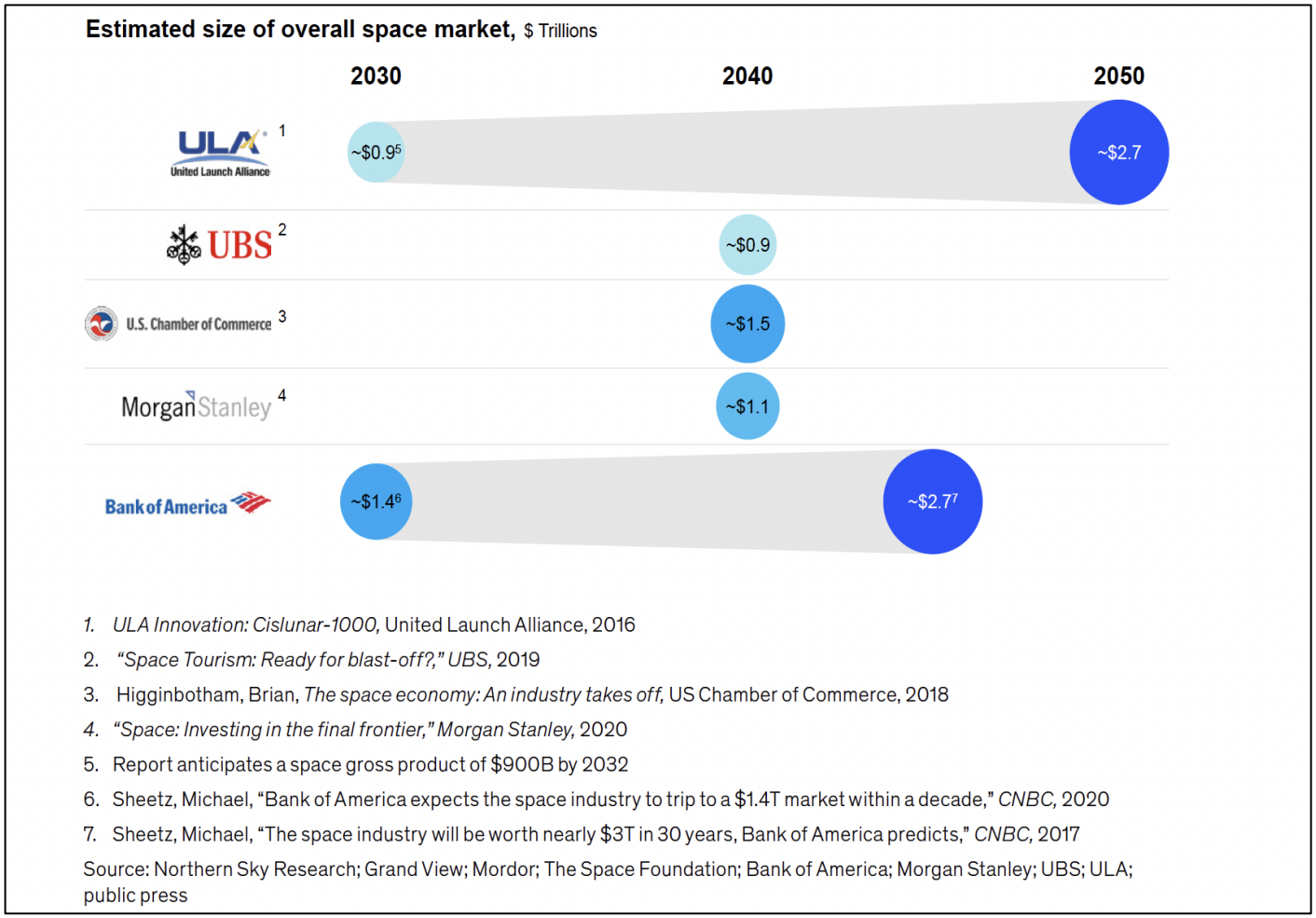
Figure 1. Global Space Activity



Source: Space Foundation Annual Report (2021)

It is anticipated that the space economy will expand during the upcoming years, with some projections calling for a worldwide space economy worth over $1 trillion by 2040 (Morgan Stanley, 2021).

Figure 2. Estimated Size of Overall Space Market



Source: McKinsey and Company (2022)

The global space industry currently has a very strong industrial foundation. Subsequently, the infrastructure and skills inside the industry are developed sufficiently to serve as an entrepreneurial base for new ventures and innovative concepts. Commercial space activity has the ability to develop self-sustaining value generation for society (McElroy, 2022).

The fact that many organizations, reaching much beyond simply prosperous governments, are now able to create value in space is one of the fascinating consequences of this development. The benefits of free-market capitalism, such as innovation, efficiency, and creativity, have been fully realized. In this way, humanity will continue to gain ever-increasing benefits from space in the future.

The space industry has experienced sustained expansion throughout the decades in a variety of sectors, including launch vehicles, small satellites, navigation services, telecommunications, tourism, remote sensing, research, and more.

Because there was no shared infrastructure to support entrepreneurial activities in the past, space entrepreneurship was constrained. With accessible launch services, new opportunities are now available. The vast majority of the benefits and economic activity that will come after will not be conceptualized and carried out by the launch providers themselves, but rather by other businesspeople who later use their goods and services. There is no coincidence in the commercial space industry's expansion. It is the outcome of the government handing over some of its space-related duties to industry.

2.2. Business Operations in the Space Sector

With new businesses and technologies stepping into the market on a regular basis, the space industry is consistently developing. This sector is composed by a wide range of business operations, here follows a non-exhaustive overview of some of the many commercial activities of the space sector including:

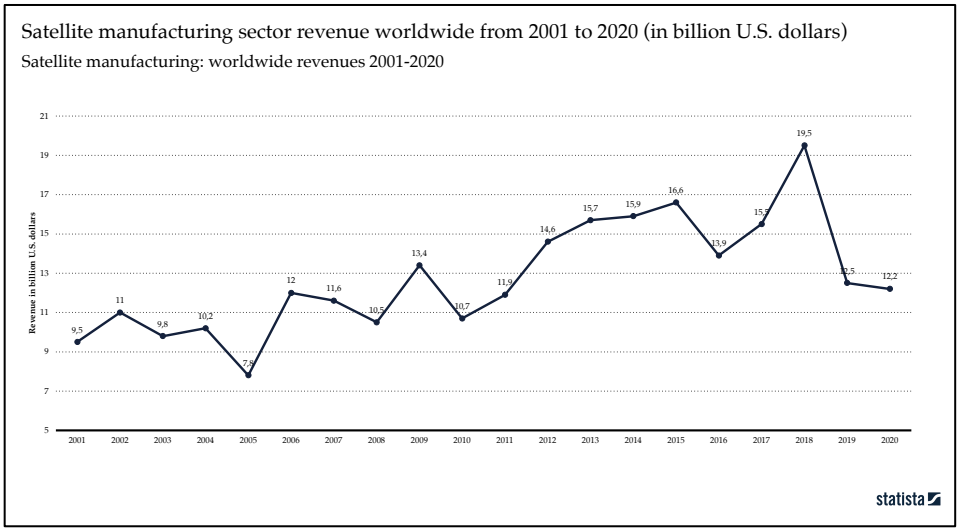
- Satellite Manufacturing and Operations
- Launch Services
- Space Tourism

- Space Mining
- Space Debris Removal
- Space Agriculture
- Space Research and Development
- Space Insurance

2.2.1. Satellite Manufacturing and Operations

With multiple uses covering everything from communication and navigation to scientific research and earth observation, satellites are a crucial part of space-based technology. Companies that manufacture and operate satellites for numerous purposes oversee developing, constructing, launching, and maintaining satellites (Hein, 2020).

Figure 3. Satellite Manufacturing Sector Revenue Worldwide 2001-2020



Source: Statista (2023)

The fabrication of the satellite's component parts, assembly and integration, testing, and launch all fall under the manufacturing process. Companies manage the satellite's

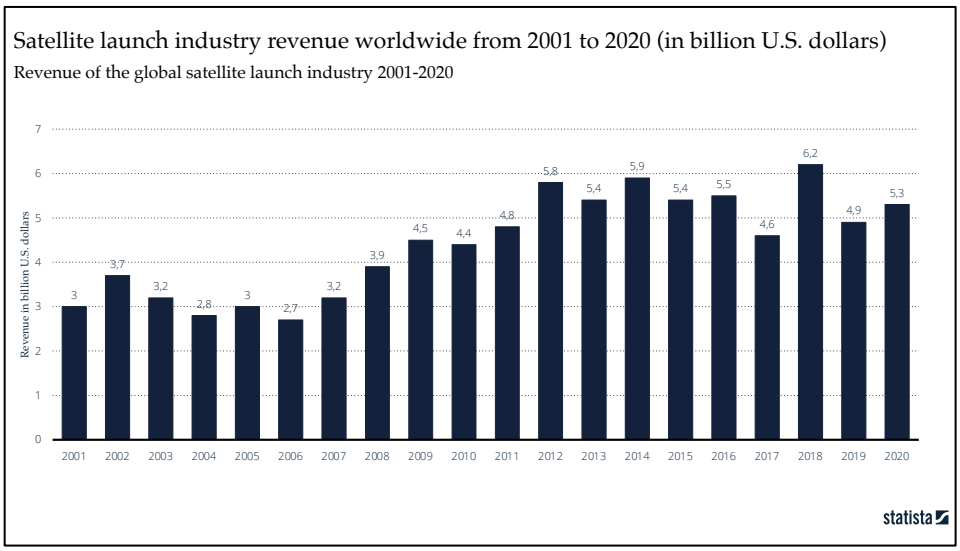
operations once it is in orbit, including directing its movement, coordinating communications with ground stations, and gathering data. As the need for satellite technology increases, businesses are looking at more economical and environmentally friendly ways to create and run satellites (Bhuiyan, 2020).

2.2.2. Launch Services

Companies that provide services to send payloads into space using rockets or other launch vehicles, including satellites, make up the launch services sector. Various activities, including communication, earth observation, navigation, scientific research, and more, may be the focus of the payloads. Launch service companies handle every step of the payload launch process, including getting the rocket and payload ready for flight, carrying out the launch, and putting the payload in the desired orbit (Deloitte, 2022).

The rising demand for satellite technology and the expansion of the space industry have both contributed to the market for launch services experiencing significant development in recent years. According to a Morgan Stanley analysis, the market for launch services worldwide was estimated to be worth $7 billion in 2020 and is expected to reach $20 billion by 2030 (Morgan Stanley, 2021).

Figure 4. Satellite Launch Industry Revenue Worldwide From 2001-2020

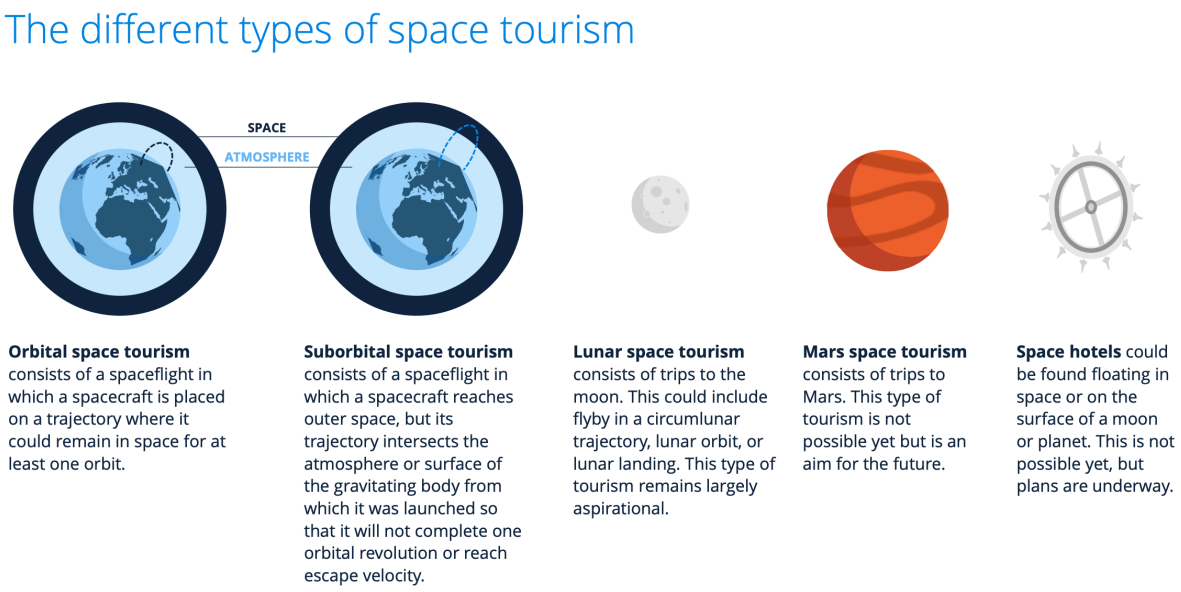


Source: Statista (2023)

2.2.3. Space Tourism

To enable people to travel to space for pleasure, adventure, or scientific research, businesses provide space tourism services. In order to send visitors to space, experience zero gravity, view Earth from orbit, and engage in other activities like spacewalks and experiments, spaceships and other vehicles are used. Although the space tourism sector is still relatively young, a number of businesses have developed recently with the aim of increasing public accessibility, including Virgin Galactic, Blue Origin, and SpaceX (Deloitte, 2020).

Figure 5. The Different Types Of Space Tourism



Source: Statista (2022)

According to some estimations, the space tourism sector might contribute significantly to the space economy and reach a value of $3 billion by 2030(Morgan Stanley, 2021). On the other hand, there are still important obstacles to overcome, such as the exorbitant costs of space travel and the dangers involved with spaceflight. Furthermore, as the sector grows, it is important to carefully assess the environmental impact of space travel since it is still mostly unknown (Bhuiyan, 2020).

2.2.4. Space Mining

Several companies are looking at ways to mine celestial bodies, such as asteroids and the moon, with the purpose of obtaining valuable resources including minerals, water, and metals.

A forecast by Goldman Sachs revealed that by 2040, the global space economy could produce sales of $1 trillion or more, with space mining playing a significant role in that expansion (Wang & Choi, 2017). In accordance to this analysis, it is possible that the value of all space resources is able to reach $700 quintillion, with mining of asteroids being the commercial activity generating the majority of that value.

Planetary Resources is one of the companies of ConsenSys, a blockchain technology business currently engaged in space mining, designing, and implementing asteroid mining methods to increase the availability of natural resources on Earth. They estimated that merely 1% of the asteroids in our solar system could be mined for a $1 trillion profit, and that one asteroid may contain up to $50 billion worth of platinum (ConsenSys, n.d.).

Regarding the viability of space mining, NASA research has discovered that a single 500-meter asteroid may contain 1.5 times as much nickel and 174 times the world's yearly production of platinum (NASA, 2012). In addition, this research showed that mining a single 1-kilometer asteroid could produce enough resources to support the global economy for several decades.

Table 1. Asteroids with the highest mineral and element value

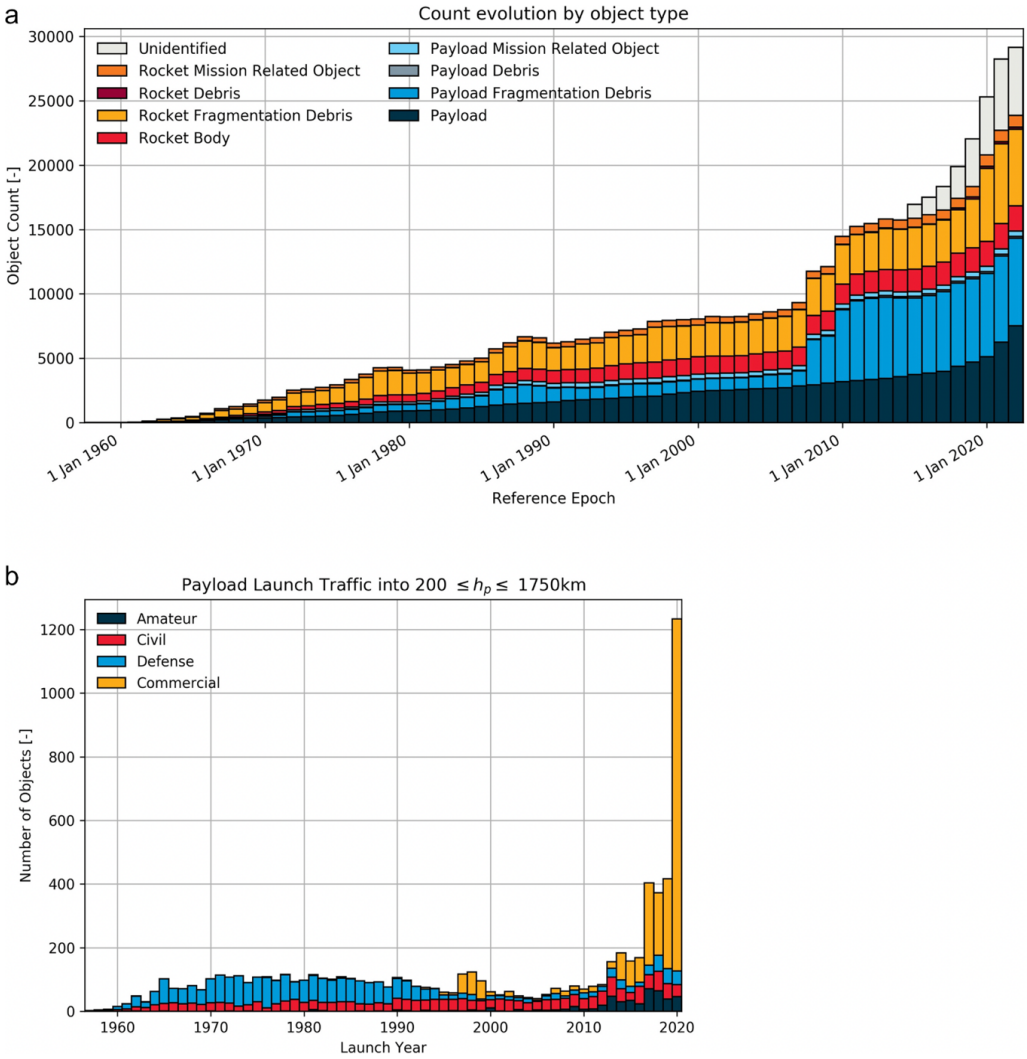
Asteroids with the Highest Mineral and Element Value	
Asteroid name	Value in quintillion U.S. dollars
Davida	26,99
Diotima	7,09
Alauda	5,73
Palma	5,21
Lachesis	4,11
Winchester	3,94
Stereoskopia	3,7
Chiron	3,56
Siegena	3,5
Gyptis	3,38
Chicago	3,1
Hispania	3,05
Berbericia	2,69
Kreusa	2,63
Nemausa	2,52

Source: Statista (2016).

2.2.5. Space Debris Removal

Another commercial activity consists of companies developing technologies to minimize the chance of space collisions by removing space waste such as damaged satellites, rocket stages, and other debris. As the European Space Agency (ESA) published, over 34,000 objects larger than 10 cm are now in orbit around Earth, along with millions more untraceable objects of smaller size. (ESA, n.d.). Some examples of these item are old satellites, rocket stages, and other pieces from space missions. Space debris can become a serious threat to operational satellites and other spacecraft over time, and if it breaks free of its orbit and re-enters Earth's atmosphere, it might even endanger human life.

Figure 6. Evolution of the number of objects and payload launch traffic in LEO



Source: Miraux (2022)

There are several strategies being executed to remove space debris, for instance, using nets, harpoons. Another approach to eliminate all this waste is through robotic spacecraft that can hook onto the junk and either de-orbit it or relocate it to a safer location.

2.2.6. Space Agriculture

The ability to reliably provide the metabolic requirements of a crew (oxygen, water, and food) with a minimum amount of resupply from Earth will be crucial to the colonization of space.

Ways to grow crops and produce food in space are being researched, this is tremendously important since astronauts require a sustainable source of nourishment for long-term missions like manned Mars missions. In order to find ways to cultivate crops and produce food in space, SpaceX and Boeing are funding research in this area. A United Nations research claims that by offering fresh methods for cultivating crops in regions with little arable land, space-based food production can also assist in resolving issues with food security and hunger on Earth (UNOOSA, 2017).

The need to give plants enough nutrients, light, and water in the conditions of microgravity is one of the major difficulties in space agriculture. The potential advantages exceed the negative aspects, as the ability to grow food in space could eliminate the need for replenishment missions and allow longer missions to succeed. The International Space Station has been used by astronauts to successfully cultivate plants and vegetables, but NASA scientists at the Kennedy Space Center in Florida are working with a university team to develop long-term strategies that may support explorers working in deep space (NASA, 2017).

The first American-built fresh food growth experiment aboard the station was NASA's Veggie Plant Growth System. It supported ongoing research into the creation of systems for long-duration exploration missions' food production. This activity is a component of Kennedy's efforts, as mandated by the Human Research Project and the Space Life Physical Science Division, to conduct plant research and produce sustenance for exploration missions.

Figure 7. Prototype Lunar/Mars Greenhouse

Through the design and construction of an innovative hydroponic plant growth chamber, the Prototype Lunar Greenhouse is designed to sustain a continuous vegetarian diet for astronauts on distant locations such as the moon or Mars. It employs plants and crop production designed to provide not only food, but air revitalization, water recycling and waste recycling.
Credits: University of Arizona

At the University of Arizona's Controlled Environment Agriculture Center, an 18 foot long, 7 foot, 3 inch diameter lunar greenhouse chamber is equipped as a prototype bioregenerative life support system.
Credits: University of Arizona

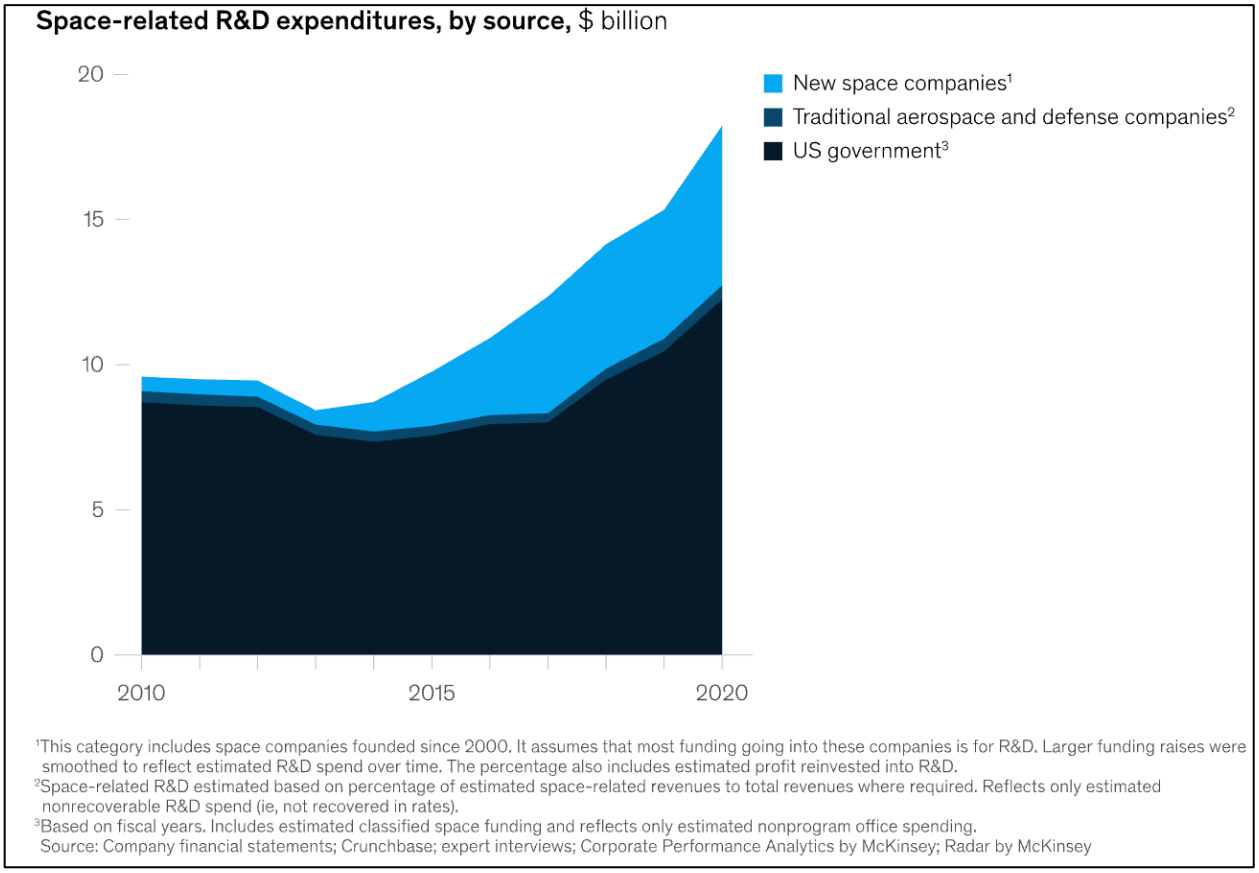
Aboard the International Space Station, astronauts have been gaining experience in growing crops in space. Expedition 50 commander Shane Kimbrough of NASA harvests lettuce from the Veggie experiment on Dec. 2, 2016. The Veggie Plant Growth System is a deployable plant growth unit capable of producing salad-type crops to provide the crew with a palatable, nutritious and safe source of fresh food.
Credits: NASA

Source: NASA (2017)

2.2.7. Space Research and Development

Research and development is being conducted in a variety of fields, including robotics, artificial intelligence, materials science, and energy systems for space exploration and utilization. Despite the US federal government continues to provide the majority of funding for space R&D, industry participation has increased significantly. The estimated $5–6 billion per year in space R&D funding today comes from investments in new space enterprises, up from less than $1 billion only ten years ago. While some of these businesses are backed by affluent founders, others are funded by investment firms (private equity or venture capital). Any profits, if any, might be used to fund additional R&D (McKinsey, 2021).

Figure 8. Space R&D Investments by Source



Source: McKinsey (2021)

The challenges of space research and development, such as high investment costs and complex technological needs, must also be addressed. Despite these challenges, it is critical to continue exploring and developing space technology in order to further human understanding and advance a number of industries.

2.2.8. Space Insurance

Insurance services are being widely offered promising to guard against loss or damage of space assets including satellites and launchers. Considering the large investments being made in space-related activities, insurance companies are becoming more interested in the expanding space insurance sector. A handful of insurance business, including Lloyds of London and AIG, are currently the leaders of the industry.

In 2019 the global market for space insurance reported a worth of $700 million (Euroconsult, 2020). The market leader in the area of satellite insurance, covers the risk involved in developing and operating satellites. The major threats are launch problems, in-orbit failures, and crashes with other space junk.

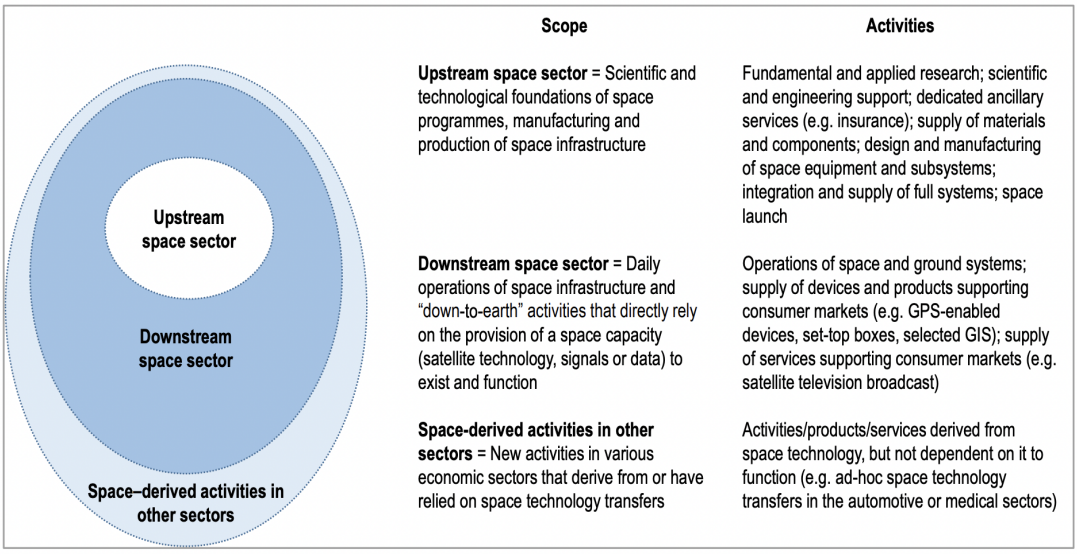
Additional kinds of space insurance include third-party liability insurance, which covers losses caused by space activities to third parties, and launch vehicle insurance, which covers the risks connected with launching rockets. As more companies and lawmakers invest in space-related projects, the market for space insurance is anticipated to expand.

2.3. Categorization of Sectors in the Space Economy

The main sectors of the space industry are divided into three categories:

- Upstream (e.g., satellite manufacturing, provision of technology, research and development, supply of raw materials for space infrastructure)
- Downstream (e.g., satellite transmission services, Earth observation, navigation and satellite communication)
- Space-derived activities in other sectors (e.g., applications of space technology generating value in the automotive and medical industry).

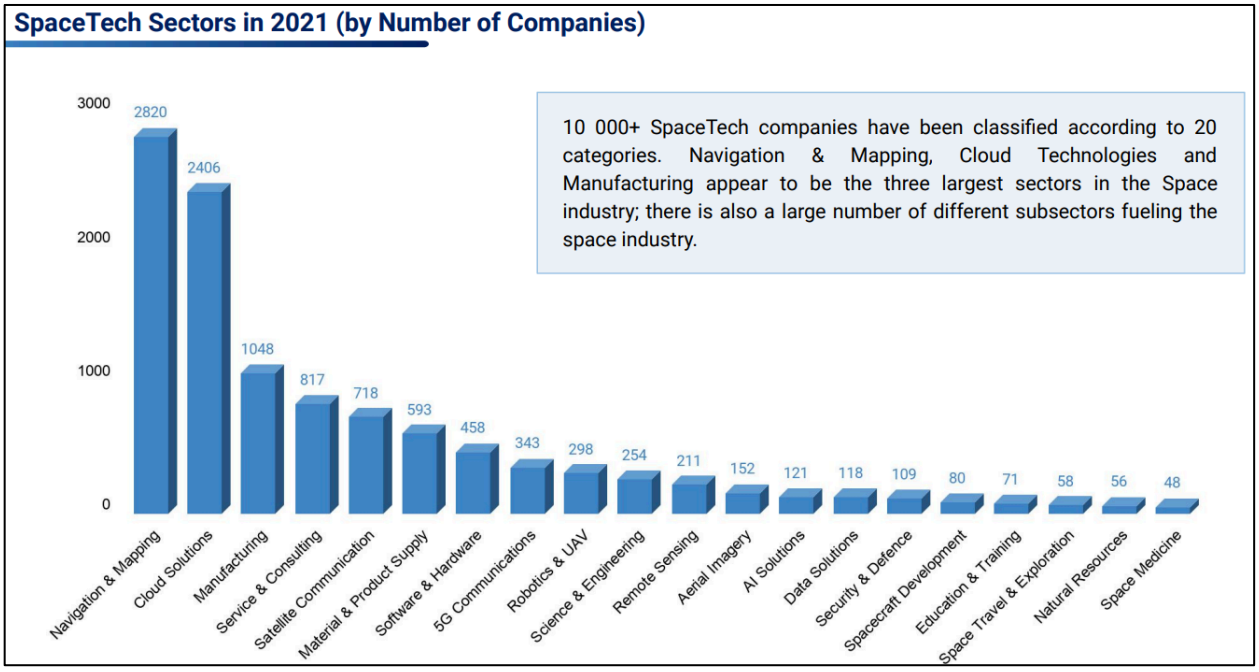
Figure 9. Main Sectors in the Space Economy



Source: OECD (2022)

Despite sharing a common industrial foundation and infrastructure, each sector has its own strategic goals and resources and as space technology grows more integrated into the systems and services utilized in everyday activities, there is a steady evolution of the many uses or applications of space activities.

Figure 10. SpaceTech Sectors in 2021



Source: SpaceTech Analytics (2021)

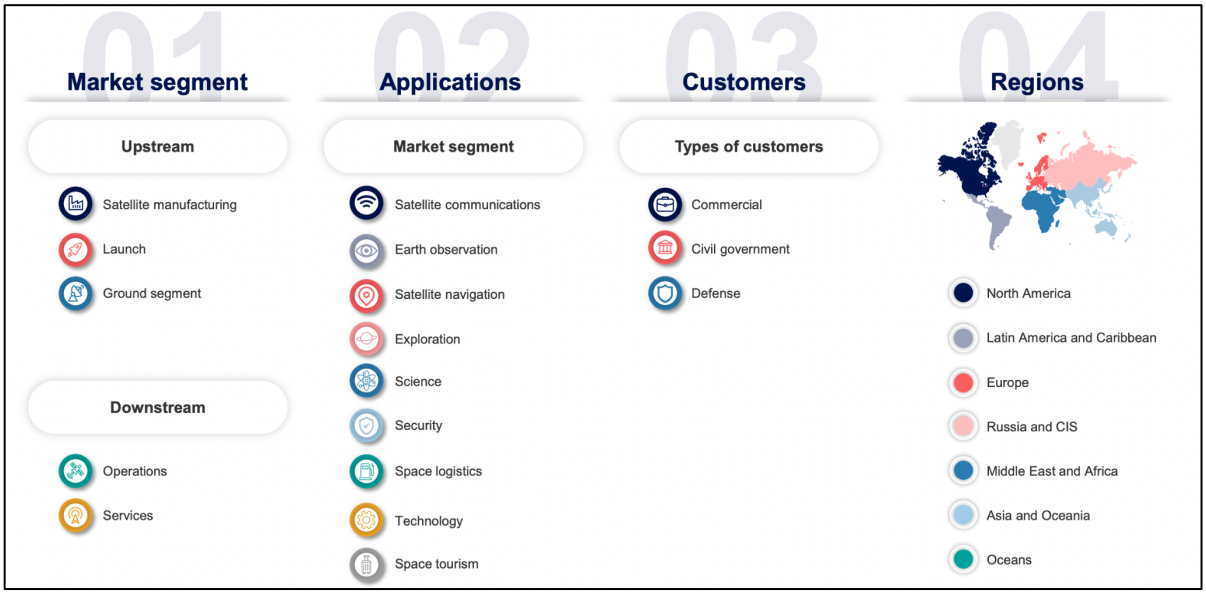
North America, Europe, and Asia account for the majority of market revenue. In comparison to the more vibrant Asian area, which has seen growth of 7% over the past five years, Europe is gradually falling behind. The market for space is dominated by the other three regions, which together account for 21% of the market. Additionally, such regions are less dynamic than the others and are mostly motivated by national aspirations (Euroconsult, 2022).

The downstream market is more evenly distributed due to its "mass market" nature and does not require significant upfront financial efforts and/or government contracts to be sustainable, whereas the upstream market consistently requires government initiatives

to thrive. In contrast to the upstream market, it addresses a demand for connection or location-based services and produces a steady source of income.

The evolution of the regional standard of living and the evolution of the demographics are two key elements that influence the growth of the downstream market. The need for connectivity and navigation services is driven by these two elements. The desire of the various governments to close the digital divide by funding satellite communication through development projects (RDOF) is another factor driving the need for broadband access.

Figure 11. Market Segments of the Space Sector



Source: Euroconsult (2022)

3. SUSTAINABILITY IN THE SPACE ECONOMY

3.1. Sustainability and its Importance in Business

The United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."(UN, 1987). Sustainability in business refers to methods that are long-term economically feasible, socially just, and environmentally responsible. It necessitates a dedication to avoiding detrimental effects while promoting beneficial effects on the environment, society, and economy (Sheth & Parvatiyar, 2021).

A survey conducted by Harvard Business Review Analytic Services showed that 56% of executives believe that using sustainable business practices can help organizations lower risk and boost their reputation (Whelan & Fink, (2016). Cost reductions for businesses are another benefit of using sustainable business strategies.

Sustainability has also proven to drive innovation, as published by the United Nations Global Compact, 87% of executives believe that sustainability is crucial for driving innovation (UN Global Compact, 2017). The goal is to ensure that new, environmentally and socially responsible goods, services, and business models can be developed as a result of sustainability challenges.

It is safe to say that companies are capable of gaining long-term viability by implementing sustainable practices, this was shown in a 2017 MIT Sloan Management Review publication titled "corporate sustainability at a crossroads" which explained how companies that integrate sustainability into their business strategy are more likely to be successful in the long term (Kiron et al., 2017). This is so that enterprises may provide beneficial outcomes for society, mitigate the effect they have on the environment, and foster collaborative environments with stakeholders.

Figure 12. Benefits of Sustainable Business Practices

Source: Personal elaboration

Businesses that want to succeed in the long run must be sustainable. It has proven to aid businesses in minimizing risk, saving money, engaging with their staff members, fostering creativity, and accomplishing long-term viability.

3.2. Intersection of Space Economy and Sustainability

With the expansion of the commercial space industry and growing environmental concerns, the convergence of sustainability and space economics is becoming increasingly important. While there are many possible advantages for civilization from space activities, such as better navigation, communication, and earth observation, there are also potential drawbacks for the environment, such as space debris and launch activity pollution.

The growing number of satellites and other space objects in orbit, which raises the risk of accidents and produces contaminants that can harm other satellites and spacecraft, intersects with the space economy and sustainability. For the space environment to be sustained, the problem of space trash must be addressed (Foreman et al., 2017).

Earth observation, which offers vital information on climate change, resource management, and environmental monitoring, is one of the principal operations carried out in space. (Anderson et al., 2017). The creation of sustainable policies and decision-making can benefit from this data.

Finally, Space tourism is an emerging market that is now under development, and it will be crucial to make sure that it is carried out in a sustainable and responsible manner, limiting adverse effects on the environment and society.

3.3. Space Supporting the UN Sustainable Development Goals

The space sector along with The United Nations have collaborated in the creation of The United Nations Office for Outer Space Affairs (UNOOSA). It was first founded as a small, focused unit inside the UN Secretariat to support the ad hoc Committee on the Peaceful Uses of Outer Space, which the General Assembly established in its resolution 1348 (XIII) of December 13, 1958. (UNOOSA, n.d.).

From the start of the space era, the UN foresaw how the space industry was going to impact Earth and human beings on a completely new level and they wanted to make sure space exploration benefits were for the prosperity of global society.

In 2015 all United Nations Member States accepted a unifying framework for peace and prosperity for people and the planet, both now and in the future, provided by the 2030 Agenda for Sustainable Development. The 17 Sustainable Development Goals (SDGs), which are an urgent call to action for all nations—developed and developing—in a global partnership, are at the center of it. They understand that fighting poverty and other forms of deprivation requires policies that enhance health and education, lessen inequality, promote economic growth, combat climate change, and fight to protect our oceans and forests. (United Nations, n.d).

Table 2. UN Sustainable Development Goals

Sustainable Development Goals	Goal description
Goal 1: No poverty	End poverty in all its forms everywhere
Goal 2: Zero hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3: Good health and well-being	Ensure healthy lives and promote well-being for all at all ages
Goal 4: Quality education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5: Gender equality	Achieve gender equality and empower all women and girls
Goal 6: Clear water and sanitation	Ensure availability and sustainable management of water and sanitation for all
Goal 7: Affordable and clean energy	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8: Decent work and economic growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9: Industry, innovation and infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10: Reduced inequality	Reduce inequality within and among countries
Goal 11: Sustainable cities and communities	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12: Responsible consumption and production	Ensure sustainable consumption and production patterns
Goal 13: Climate action	Take urgent action to combat climate change and its impacts
Goal 14: Life below water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15: Life and land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16: Peace, justice and strong institution	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17: Partnership for the goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: Adapted from United Nations (2015)

Space technology has been seen as essential to achieving SDGs and can be used to contribute to all the goals, for this reason, UNOOSA created "SPACE4SDGS", a program that highlights how space technologies can directly and specifically support each SDG.

Figure 13. Space Supporting the Sustainable Development Goals

Source: UNOOSA (n.d.)

Earth observation (EO) and global navigation satellite systems (GNSS) are two examples of space initiatives that can significantly improve the forecasting of natural disasters, the monitoring of air and water quality, the emergency response process, search, and rescue operations, and more (UNOOSA, 2018).

Additionally, the utilization of data helps bridge the space segregation by strengthening alliances and coordinating efforts for peaceful applications of outer space.

There are two noticeable European flagship programs directly linked to the support of the SDGs not only in Europe but worldwide. First is the European GNSS European Geostationary Navigation Overlay Service (EGNOS) and Galileo, and the European EO program Copernicus. The operational services for EGNOS, Galileo, and Copernicus have been launched as a result of the European Union's efforts in infrastructure development and market adoption. Numerous market application domains, including those related to transportation (such as aviation, road, maritime, and rail) as well as consumer and business applications (such as monitoring infrastructure, agriculture, and construction) are supported by these services on a continuous basis.

Figure 14. ESA Projects Supporting SDGs

Source: UNOOSA (2017)

It is feasible to navigate safely and effectively by designating a place on a map where EO data provide details on safe routes, distances to danger, and static and, whenever possible, dynamic environmental factors.

3.4. Corporate Sustainability

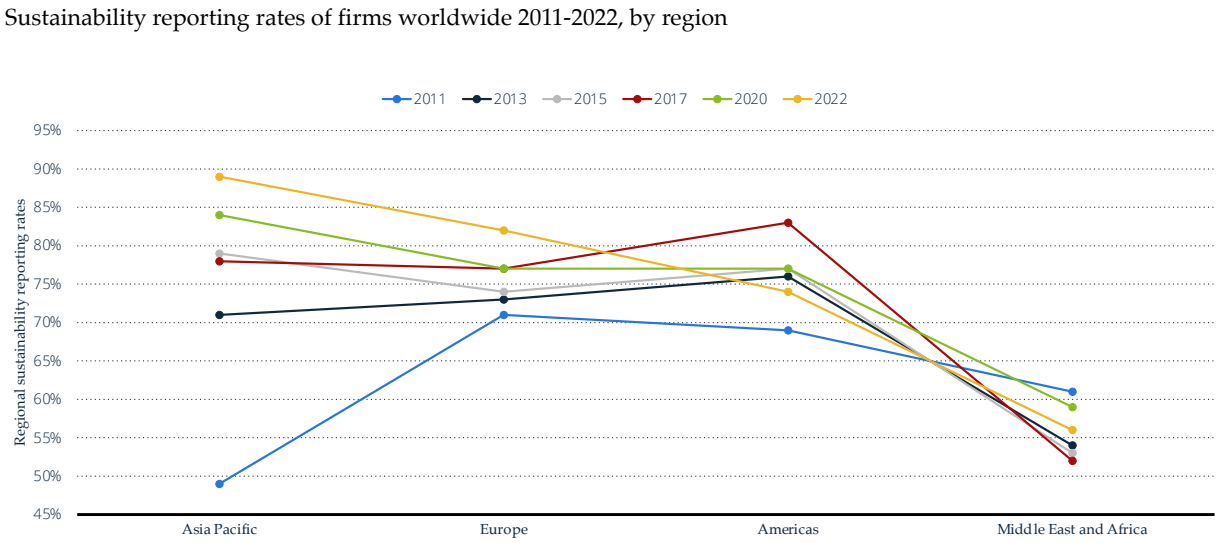
Holding corporations accountable for the societal repercussions of their activities has become a skill for governments, campaigners, and the media. As a result, business leaders in every nation now view corporate social responsibility as an obligatory cause for concern. Corporate attention to sustainability has increased, although not entirely voluntarily. Many businesses only became aware of it after being shocked by how the public reacted to issues, they had not previously considered to be part of their corporate obligations (Roca & Searcy, 2012).

Broad external variables, including firm size or industry affiliation, may not truly reflect the motivations behind sustainability reporting. For instance, stakeholder-, legitimacy-, and signaling theory can be used to explain why larger corporations tend to have more in-depth sustainability reports than smaller ones. In other words, external causes do not stand out enough to rule out other theoretical interpretations (Thijssens, 2016).

The most well-known set of voluntary standards for reporting on corporate sustainability is the GRI. The GRI's mission is to establish disclosure on environmental, social, and governance performance, this also includes sharing best practices for how businesses communicate and show accountability for their effects on the environment, the economy, and people, as well as, providing the most commonly used sustainability reporting guidelines in the world, which encompass everything from waste management to emissions reporting, health and safety to diversity and equality. As a result, GRI reporting facilitates communication and transparency between businesses and their stakeholders (GRI, 2021).

The Asia-Pacific region experienced the fastest growth in the number of businesses reporting on sustainability, going from around 50% of firms to about 90% of businesses reporting on sustainability. The only regions to see a decline in participation in sustainability reporting were the Middle East and Africa, where it fell by 5% between 2011 and 2022 (Statista, 2022).

Figure 15. Sustainability Reporting Rates per Region 2011-2022



Source: Statista (2022)

3.5. ESG Reporting

The way forward in meeting the many stakeholder expectations of the environmental, social, and governance (ESG) implications of businesses around the world is thought to be through the incorporation of sustainability concerns into business strategy (De Silva & Heenetigala, 2016). Choosing which indicators to use to communicate ESG data and how to handle ESG reporting varies in different companies and different sectors. Despite this, how a business manages its social responsibility and partnerships with stakeholders, often dictates the corporate strategy for reporting and publicly publishing the ESG performance.

Businesses must be deeply committed to gathering and disclosing specific information on governance and social issues in order to be transparent in their ESG reporting (Tamimi & Sebastianelli, 2017). Studies have concentrated their research on topics related to corporate governance, social and environmental disclosure, and voluntary disclosure.

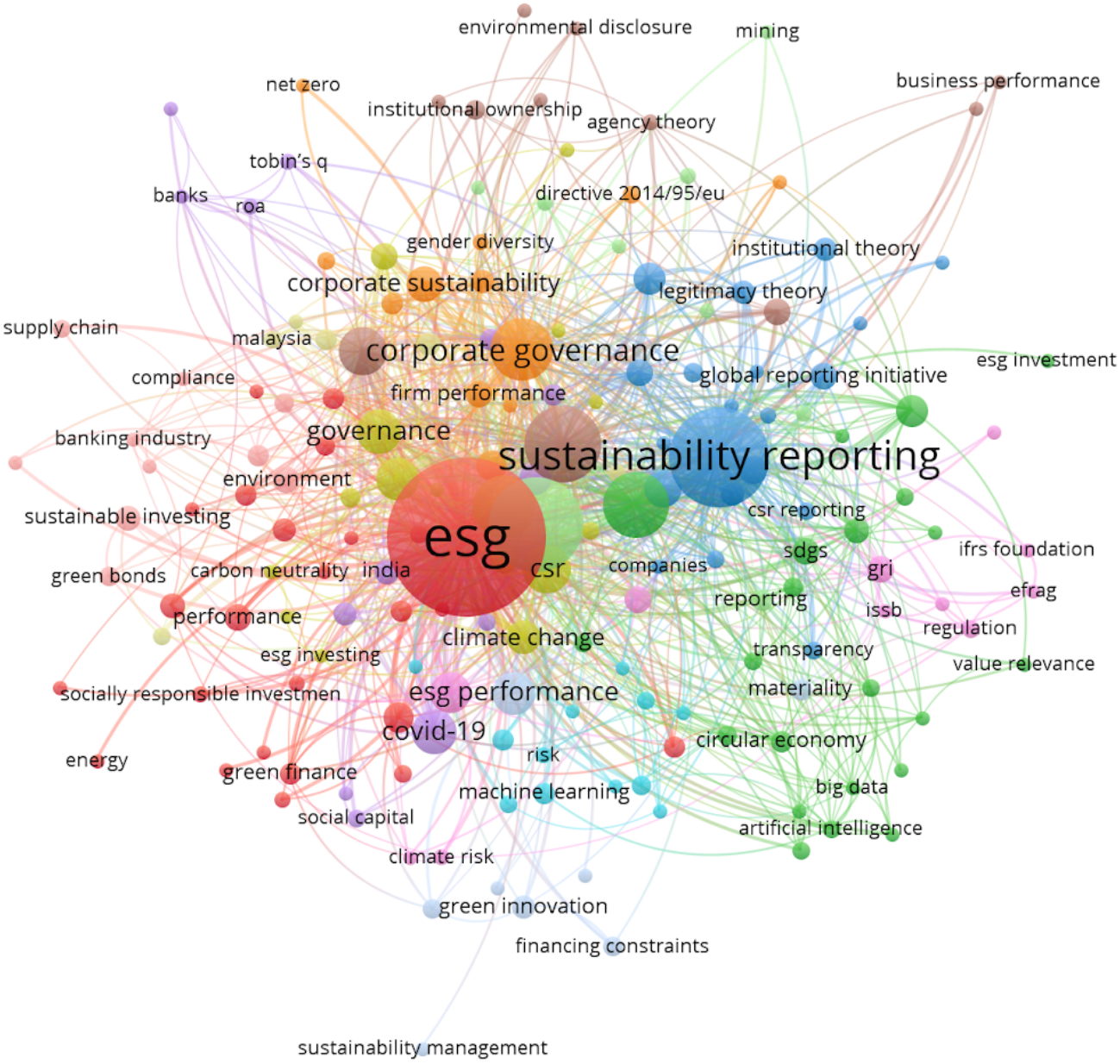
The incorporation of ESG indicators is arguably the greatest approach to enhance the market share of socially responsible investments. ESG disclosure is quickly becoming a crucial performance standard for investors. To increase a company's competitive position, non-financial performance must correlate with its financial performance (Cucari et al., 2018).

During their research article Jun Xie (2019) concluded that numerous CSR initiatives have been launched to improve company sustainability in relation to ESG concerns and, evidence from multinational corporations established that the majority of ESG activities had positive associations with company effectiveness, ROA, and market value (Xie at al. 2019). Policies that are cost-effective in terms of environmental activities, such as green building policies, sustainable packaging, environmentally friendly supply chains, or the implementation of independent assessment, are positively correlated with CFP.

There are conflicting findings in the literature on the effects of ESG reporting, with some finding it valuable and others not. This is understandable given the differences in institutional settings, how non-financial disclosures are measured, or how firms view non-financial information given that some companies are unsure of how this type of disclosures will affect their performance in the financial markets (Cordazzo, 2020). Another perspective is laid-out by Schiehll and Kolahgar (2021) where they showed that revealing significant ESG information improves stock price informativeness on the basis of the value relevance of information and the criterion of financial materiality. They also shown that financial materiality in ESG disclosure results in more insightful stock pricing and that ESG information is truly value important for investors (Schiehll & Kolahgar, 2021).

Emerging from this systematic literature search on “ESG reporting”, studies implementing an ESG approach and qualitative assessment in the field of business management amidst different industries, was used to extract a series of keywords containing state-of-the-art terms for the creation of labels or codes to categorize the content of the information obtained from each studied business in three groups (Environmental, Social and Governance). This will later contribute to the identification of relations and themes amongst the studied companies.

Figure 16. Network Visualization "ESG Reporting"



Source: Personal elaboration with VOS viewer

The following tables illustrate a summary containing indicators used in the previous literature on ESG reporting analyses.

Table 3. Variables in the Literature to measure Environment

Environmental Indicator	Authors
Direct greenhouse gas emissions	*Tamimi & Sebastianelli (2017)*
Electricity usage	*Tamimi & Sebastianelli (2017)*
Renewable energy usage	*Tamimi & Sebastianelli (2017)*
Water usage	*Tamimi & Sebastianelli (2017)*
Waste discarded	*Tamimi & Sebastianelli (2017)*
Waste recycled	*Tamimi & Sebastianelli (2017)*
Waste sent to landfills	*Tamimi & Sebastianelli (2017)*
ISO 14000 certification	*Tamimi & Sebastianelli (2017)*
Energy efficiency policy	*Tamimi & Sebastianelli (2017)*
Environmental supply chain management	*Tamimi & Sebastianelli (2017)*
Green building policy	*Tamimi & Sebastianelli (2017)*
Sustainable packaging	*Tamimi & Sebastianelli (2017)*
Presence of environmental quality management policies	*Tamimi & Sebastianelli (2017)*
Protection of biodiversity (e.g. protection of trees,vegetation, and wild life)	*Tamimi & Sebastianelli (2017)*
Climate change policies	*Tamimi & Sebastianelli (2017)*
Non-renewable material used	*De Silva Lokuwaduge & Heenetigala (2017)*
Renewable material used	*De Silva Lokuwaduge & Heenetigala (2017)*
Total fuel consumption	*De Silva Lokuwaduge & Heenetigala (2017)*
Total reduction/increase of energy consumption	*De Silva Lokuwaduge & Heenetigala (2017)*
Total volume of water recycled and reused by the organization	*De Silva Lokuwaduge & Heenetigala (2017)*
Direct GHG emission	*De Silva Lokuwaduge & Heenetigala (2017)*
Biodiversity value of water source affected by water withdrawal	*De Silva Lokuwaduge & Heenetigala (2017)*
Verification type	*Xie et al. (2019)*
Green building policy	*Xie et al. (2019)*
Sustainable packaging	*Xie et al. (2019)*
Environmental quality management policy	*Xie et al. (2019)*
Climate change policy	*Xie et al. (2019)*
Risks of climate change discussed	*Xie et al. (2019)*
Emissions reduction initiatives	*Xie et al. (2019)*
New products—climate change	*Xie et al. (2019)*
Energy efficiency policy	*Xie et al. (2019)*

Source: Personal Elaboration

(Cont)

Environmental Indicator	Authors
Material	*Cordazzo et al. (2020)*
Energy	*Cordazzo et al. (2020)*
Water	*Cordazzo et al. (2020)*
Biodiversity	*Cordazzo et al. (2020)*
Emissions	*Cordazzo et al. (2020)*
Effluents and waste	*Cordazzo et al. (2020)*
Environmental compliance	*Cordazzo et al. (2020)*
Supplier environmental assessment	*Cordazzo et al. (2020)*
Product and services	*Cordazzo et al. (2020)*
Transports	*Cordazzo et al. (2020)*
Environmental grievance mechanisms	*Cordazzo et al. (2020)*
GHG emissions	*Schiehll & Kolahgar (2021)*
Air quality	*Schiehll & Kolahgar (2021)*
Energy management	*Schiehll & Kolahgar (2021)*
Water and wastewater management	*Schiehll & Kolahgar (2021)*
Waste management	*Schiehll & Kolahgar (2021)*
Waste and hazardous materials management	*Schiehll & Kolahgar (2021)*
Climate change policy and target	*Schiehll & Kolahgar (2021)*
Carbon emissions	*Cucari et al. (2018)*
Climate change effects	*Cucari et al. (2018)*
Pollution	*Cucari et al. (2018)*
Waste disposal	*Cucari et al. (2018)*
Renewable energy	*Cucari et al. (2018)*
Resource depletion Community relations Independent directors	*Cucari et al. (2018)*

Table 4.Variables in the literature to measure Social

Social Indicator	Authors
Presence of labour unions	*Tamimi & Sebastianelli (2017)*
Women employed	*Tamimi & Sebastianelli (2017)*
Women employed in managerial positions	*Tamimi & Sebastianelli (2017)*
Percentage of minority employees	*Tamimi & Sebastianelli (2017)*
Number of accidents reported	*Tamimi & Sebastianelli (2017)*
Number of fatalities reported as a result of operations	*Tamimi & Sebastianelli (2017)*
Initiatives employed to reduce social risks in the supply chain	*Tamimi & Sebastianelli (2017)*
Number of suppliers audited	*Tamimi & Sebastianelli (2017)*
Community spending	*Tamimi & Sebastianelli (2017)*
Fair remuneration policy	*Tamimi & Sebastianelli (2017)*
Training initiatives	*Tamimi & Sebastianelli (2017)*
Commitment to equal opportunity policies	*Tamimi & Sebastianelli (2017)*
Child labor prevention policies	*Tamimi & Sebastianelli (2017)*
Ethical policies	*Tamimi & Sebastianelli (2017)*
Whistle blower policies	*Tamimi & Sebastianelli (2017)*
Signatory of the United Nations Global Compact (UNGC)	*Tamimi & Sebastianelli (2017)*
Employment of new employees	*De Silva Lokuwaduge & Heenetigala (2017)*
Employment of new employees by reporting type	*De Silva Lokuwaduge & Heenetigala (2017)*
Total employees by reporting type	*De Silva Lokuwaduge & Heenetigala (2017)*
No of indigenous people	*De Silva Lokuwaduge & Heenetigala (2017)*
Employee turnover	*De Silva Lokuwaduge & Heenetigala (2017)*
Number of strikes exceeding one week duration	*De Silva Lokuwaduge & Heenetigala (2017)*
Number of lockouts exceeding one week duration	*De Silva Lokuwaduge & Heenetigala (2017)*
Overall injury rate	*De Silva Lokuwaduge & Heenetigala (2017)*
Occupational disease rate	*De Silva Lokuwaduge & Heenetigala (2017)*
Lost day rate denominator	*De Silva Lokuwaduge & Heenetigala (2017)*
Absenteeism rate	*De Silva Lokuwaduge & Heenetigala (2017)*
Average hours of training	*De Silva Lokuwaduge & Heenetigala (2017)*
Fatalities	*De Silva Lokuwaduge & Heenetigala (2017)*
Incidents of discrimination during the reporting period	*De Silva Lokuwaduge & Heenetigala (2017)*
Total number and percentage of operations that have been subject to human rights reviews	*De Silva Lokuwaduge & Heenetigala (2017)*
Grievances about human rights – addressed	*De Silva Lokuwaduge & Heenetigala (2017)*
Total number of confirmed incidents of corruption	*De Silva Lokuwaduge & Heenetigala (2017)*
Total number of non-monetary sanctions	*De Silva Lokuwaduge & Heenetigala (2017)*
Product Stewardship Programme	*De Silva Lokuwaduge & Heenetigala (2017)*

Source: Personal Elaboration

(Cont)

Social Indicator	Authors
Equal opportunity policy	*Xie et al. (2019)*
Human rights policy	*Xie et al. (2019)*
Employee CSR training Discloses	*Xie et al. (2019)*
Health and Safety Policy	*Xie et al. (2019)*
Fair remuneration policy	*Xie et al. (2019)*
Local communities	*Cordazzo et al. (2020)*
Supplier social assessment	*Cordazzo et al. (2020)*
Public policy	*Cordazzo et al. (2020)*
Customer health and safety	*Cordazzo et al. (2020)*
Marketing and labelling	*Cordazzo et al. (2020)*
Customer privacy	*Cordazzo et al. (2020)*
Socio-economic compliance	*Cordazzo et al. (2020)*
Grievance mechanisms for impacts on society	*Cordazzo et al. (2020)*
Employment	*Cordazzo et al. (2020)*
Labour/management relations	*Cordazzo et al. (2020)*
Occupational health and safety	*Cordazzo et al. (2020)*
Training and education	*Cordazzo et al. (2020)*
Diversity and equal opportunity	*Cordazzo et al. (2020)*
Labour practices grievance mechanisms	*Cordazzo et al. (2020)*
Protection of human rights	*Cordazzo et al. (2020)*
Non-discrimination	*Cordazzo et al. (2020)*
Freedom of association and collective bargaining	*Cordazzo et al. (2020)*
Child labour	*Cordazzo et al. (2020)*
Forced or compulsory labour	*Cordazzo et al. (2020)*
Security practices	*Cordazzo et al. (2020)*
Rights of indigenous peoples	*Cordazzo et al. (2020)*
Human rights assessment	*Cordazzo et al. (2020)*
Human rights grievance mechanisms	*Cordazzo et al. (2020)*
Human rights and community relations	*Schiehll & Kolahgar (2021)*
Customer privacy	*Schiehll & Kolahgar (2021)*
Data security	*Schiehll & Kolahgar (2021)*
Access and affordability	*Schiehll & Kolahgar (2021)*
Product quality and safety	*Schiehll & Kolahgar (2021)*
Customer welfare	*Schiehll & Kolahgar (2021)*
Selling practices and product labeling	*Schiehll & Kolahgar (2021)*
Human capital	*Schiehll & Kolahgar (2021)*
Labor practices	*Schiehll & Kolahgar (2021)*
Employee health and safety	*Schiehll & Kolahgar (2021)*
Employee engagement, diversity, and inclusion	*Schiehll & Kolahgar (2021)*
Supply chain	*Cucari et al. (2018)*
Discrimination	*Cucari et al. (2018)*
Political contributions	*Cucari et al. (2018)*
Diversity	*Cucari et al. (2018)*
Human rights	*Cucari et al. (2018)*
Community relations	*Cucari et al. (2018)*

Table 5. Variables in the literature to measure Governance

Governance Indicator	Authors
Number of female directors on company board	*Tamimi & Sebastianelli (2017)*
CEO gender	*Tamimi & Sebastianelli (2017)*
Number of board meetings for the year	*Tamimi & Sebastianelli (2017)*
Percentage of members in attendance at board meetings	*Tamimi & Sebastianelli (2017)*
Number of meetings of the board's audit committee	*Tamimi & Sebastianelli (2017)*
Number of directors on the company's compensation committee	*Tamimi & Sebastianelli (2017)*
Executive compensation is based on ESG disclosure scores	*Tamimi & Sebastianelli (2017)*
Structure of the governance board	*De Silva Lokuwaduge & Heenetigala (2017)*
Committees of the board	*De Silva Lokuwaduge & Heenetigala (2017)*
Any committees responsible for decision-making on economic, environmental and social impacts	*De Silva Lokuwaduge & Heenetigala (2017)*
Number of executives on the board of directors and its committees	*De Silva Lokuwaduge & Heenetigala (2017)*
Number of non-executives on the board of directors and its committees	*De Silva Lokuwaduge & Heenetigala (2017)*
Number of independent directors on the board of directors and its committees	*De Silva Lokuwaduge & Heenetigala (2017)*
Tenure on the board of directors (years)	*De Silva Lokuwaduge & Heenetigala (2017)*
Female directors on the board	*De Silva Lokuwaduge & Heenetigala (2017)*
Competences relating to economic, environmental and social impacts	*De Silva Lokuwaduge & Heenetigala (2017)*
Stakeholder representation	*De Silva Lokuwaduge & Heenetigala (2017)*
Nomination and selection processes for board of directors – whether and how diversity is considered	*De Silva Lokuwaduge & Heenetigala (2017)*
Frequency of the board of directors' review of economic, environmental, and social impacts, risks and opportunities	*De Silva Lokuwaduge & Heenetigala (2017)*
UN Global Compact Signatory	*Xie et al. (2019)*
GRI Criteria Compliance	*Xie et al. (2019)*
Global Reporting Initiatives Checked	*Xie et al. (2019)*
Percentage of independent directors	*Xie et al. (2019)*
CEO duality	*Xie et al. (2019)*
Audit committee meetings	*Xie et al. (2019)*
Percentage of women on board	*Xie et al. (2019)*
Executive compensation linked to ESG	*Xie et al. (2019)*
Business ethics policy	*Xie et al. (2019)*
Organizational profile	*Cordazzo et al. (2020)*
Strategy	*Cordazzo et al. (2020)*
Ethics and integrity	*Cordazzo et al. (2020)*
Governance	*Cordazzo et al. (2020)*
Stakeholder engagement	*Cordazzo et al. (2020)*
Reporting practice	*Cordazzo et al. (2020)*
Economic performance	*Cordazzo et al. (2020)*
Market presence	*Cordazzo et al. (2020)*
Indirect economic impacts	*Cordazzo et al. (2020)*
Procurement practices	*Cordazzo et al. (2020)*
Anti-competitive behaviour	*Cordazzo et al. (2020)*
Anti-corruption and bribery	*Cordazzo et al. (2020)*
Business ethics	*Schiehll & Kolahgar (2021)*
Competitive behavior	*Schiehll & Kolahgar (2021)*
Management of the legal and regulatory environment	*Schiehll & Kolahgar (2021)*
Critical incident risk management	*Schiehll & Kolahgar (2021)*
Systemic risk management	*Schiehll & Kolahgar (2021)*
Cumulative voting	*Cucari et al. (2018)*
Executive compensation	*Cucari et al. (2018)*
Shareholders' rights	*Cucari et al. (2018)*
Takeover defense	*Cucari et al. (2018)*
Staggered boards	*Cucari et al. (2018)*
Independent directors	*Cucari et al. (2018)*

Source: Personal elaboration

4. METHODOLOGY

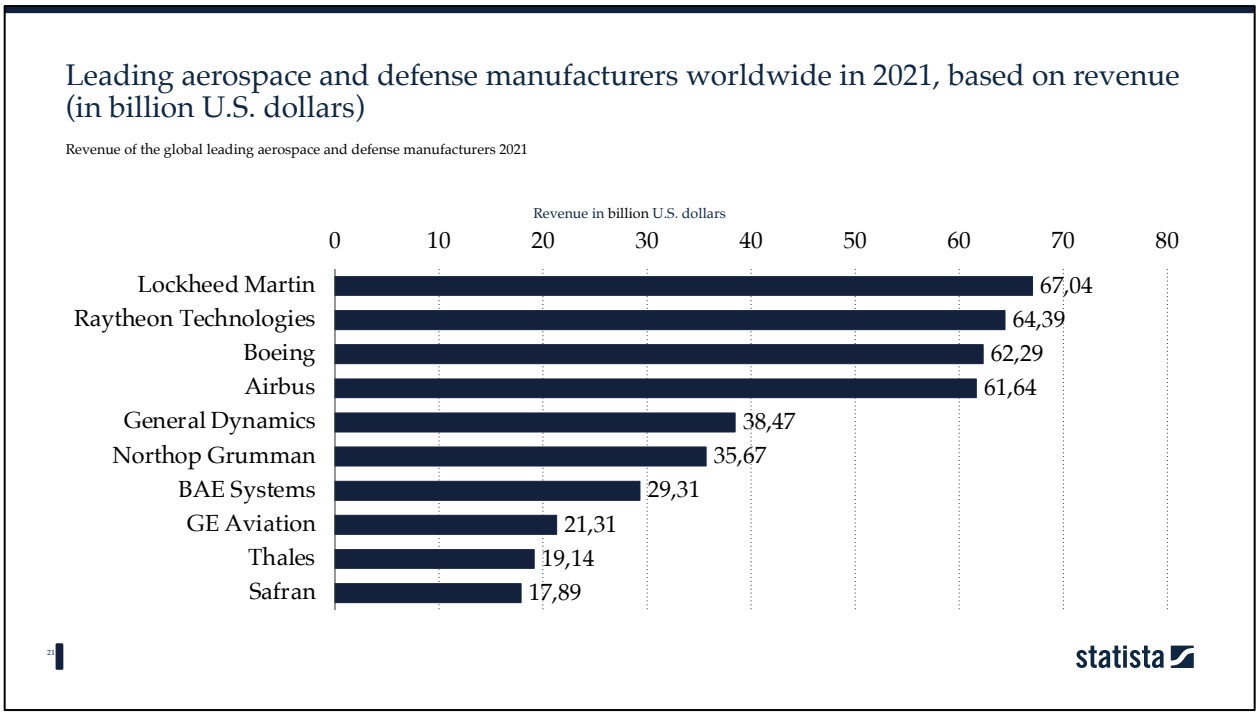
4.1. Research Design

The first step consisted of performing a revision of the available statistical studies in reference to companies in the space economy to determine the selection criteria of the group of companies to be evaluated, continuing with the collection of information related to sustainability from each selected company.

4.2. Data Collection

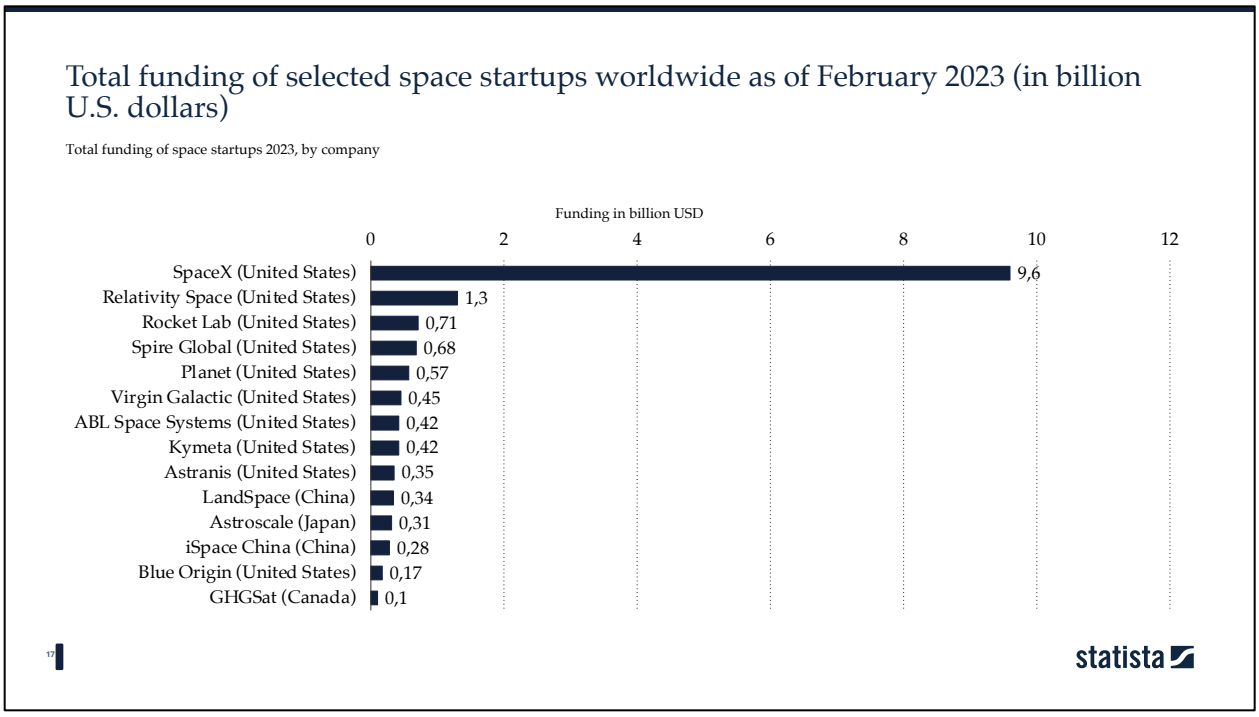
To identify a series of companies that were relevant to the space economy, a close examination of the studies and reports published on "Statista" related to this field was executed. The final selection was based on the studies included in figure 17 and figure 18.

Figure 17. Leading Aerospace Manufacturers Worldwide in 2021



Source: Statista (2021)

Figure 18. Funding of Space Startups Worldwide 2023



Source: Statista (2023)

These studies were selected because they both encompass companies that are currently leading space-related commercial activities in terms of revenue and funding; therefore, it is necessary to evaluate the actions they are taking concerning sustainable development. Thereupon a sample of 15 companies shown in Table 6 was selected for the sustainability analysis, an interesting consideration is that the majority of companies, more precisely 13 out of the 15 analyzed companies are located in the upstream section of the chain of value.

Table 6. List of selected companies from the space sector

No.	Company	Type	Chain of Value
1	Airbus	Corporate	Upstream
2	BAE Systems	Corporate	Downstream
3	Boeing	Corporate	Upstream
4	General Dynamics	Corporate	Upstream
5	General Electric	Corporate	Upstream
6	Lockheed Martin	Corporate	Upstream
7	Northop Grumman	Corporate	Upstream
8	Raytheon Technologies	Corporate	Upstream
9	Safran	Corporate	Upstream
10	Thales	Corporate	Upstream
11	Blue Origin	Start-Up	Upstream
12	Planet Labs	Start-Up	Downstream
13	Rocket Lab	Start-Up	Upstream
14	Space X	Start-Up	Upstream
15	Virgin Galactic	Start-Up	Upstream

Source: Personal Elaboration

An individual file for each company was created containing all the sustainability information gathered from their non-financial reports, official company websites, ESG reports, sustainability reports, annual reports, and social media accounts, to be further analyzed and interpreted.

Table 7 and Table 8 offer a brief summary of the space sustainability operations of the selected companies.

Table 7. Summary of Space Sustainability - Corporates

Selected Company	Summary of Space Sustainability - Corporates
Airbus	Airbus actively contributes to environmentally friendly satellite technologies and sustainable space operations. They concentrate on minimizing the environmental impact of satellites at every stage of their lifecycle, from design to production to disposal. To maintain the long-term viability of space activities, Airbus actively promotes responsible space debris mitigation techniques and incorporates energy-efficient parts and materials into their satellite systems.
BAE Systems	BAE Systems contributes to sustainability in space operations through responsible satellite manufacturing and design practices. They emphasize the use of energy-efficient components and materials, as well as waste reduction and recycling efforts. BAE Systems is committed to promoting sustainable supply chain practices and collaborating with partners to develop innovative solutions for space exploration and satellite technology that minimize environmental impacts.
Boeing	Boeing's sustainability initiatives extend to space activities, where they concentrate on lessening the impact of satellite systems and launchers on the environment. In their space programs, they place a high priority on fuel economy, waste reduction, and emissions management. Boeing actively engages in international programs to promote responsible space activities and debris reduction, investing in research and development to create sustainable solutions for space exploration.
General Electric	Through its cutting-edge technology and solutions, General Electric (GE) contributes to environmentally friendly space operations. By creating propulsion systems for satellites and spacecraft that are energy-efficient, they contribute to the sustainability of space. In order to increase the effectiveness and sustainability of space-based technologies, GE actively conducts research and development. It also prioritizes the use of renewable energy sources in space missions.
General Dynamics	By creating satellite systems and launch vehicles that respect the environment, General Dynamics places a strong emphasis on sustainability in their space activities. Throughout all of their space programs, they put a strong emphasis on energy conservation, minimizing waste, and emissions management. Through sustainable supply chain management and cooperation, General Dynamics supports sustainable practices in the space industry and actively engages in projects to reduce space debris.
Lockheed Martin	They put their attention on four main things: lowering carbon emissions, saving resources, promoting sustainability in space, and involving stakeholders. By improving energy efficiency, employing renewable energy sources, and implementing sustainable manufacturing practices, they seek to lessen their carbon impact. To encourage sustainability and preservation of the environment in space activities, they collaborate with industry partners, customers, and communities to involve stakeholders.
Northop Grumman	Northrop Grumman creates environmentally friendly satellite systems and launch vehicles as part of their integration of sustainability into their space operations. Throughout the lifecycle of their space goods, they put an emphasis on energy efficiency, waste reduction, and responsible resource management. Through partnerships and collaborations, Northrop Grumman supports sustainable space sector practices and actively contributes to efforts to reduce space debris.
Raytheon Technologies	By creating reliable spacecraft designs, installing effective propulsion systems, and abiding by global standards for space operations, Raytheon Technologies seeks to secure the long-term viability of space activities. This company is making investments in the development of sustainable space technology, such as cutting-edge materials and energy-efficient systems.
Safran	They emphasize esponsible design, eco-efficient manufacturing and ethical end-of-life management.By maximizing resource usage, waste minimization, and emissions control, they give industrial processes that are environmentally friendly top priority. Safran also places an extreme value on managing space systems end-of-life responsibly, which includes encouraging recycling, reusability, and safe disposal techniques.
Thales	Thales is a global space manufacturer delivering high-tech solutions for telecommunications, navigation, Earth Observation, environmental management, exploration, science and orbital infrastructures. Governments, organizations, and businesses depend on Thales to develop, manage, and provide satellite-based solutions that enable them to link and position anything or anybody everywhere, watch our planet, and make the best use of its and our solar system's resources.

Source: Personal Elaboration

Table 8. Summary of Space Sustainability - Startups

Selected Company	Summary of Space Sustainability - Corporates
Blue Origin	Blue Origin, a space tourism company founded by Jeff Bezos, has committed to using renewable energy to power its facilities and operations. The company has installed solar panels at its headquarters and is exploring other renewable energy sources for its operations.
Planet Labs	Planet Labs is a satellite imaging company that uses small, low-cost satellites to collect data on Earth's environment and resources. The company's satellites use less power and produce less waste than traditional imaging satellites, making them more sustainable.
Rocket Lab	Rocket Lab incorporates environmental risk reduction and sustainable practices through mission planning and execution. They use sustainable sources of enery like solar power, they study advanced concepts or orbital debris removal to better protect our space environment. Rocket Lab is commited to the sustainability of their capabilities in the space economy, including satellite design and manufacture, spacecraft software and components, and reliable launch ervices.
Space X	By creating reusable rockets and spacecraft, SpaceX hopes to increase the sustainability of space travel. The cost and environmental impact of launching payloads into orbit have been reduced by the company's many successful landings and reusing of its Falcon 9 rockets.
Virgin Galactic	Virgin Galactic is a space tourism company that has implemented sustainable practices. The company uses 100% renewable energy to power its operations, and its spacecraft are designed to use low-emission fuels.

Source: Personal Elaboration

Afterward, using keywords from the literature review on "ESG reporting" with Scopus database, a list of codes was established for the qualitative content analysis of the data gathered from each company.

4.3. Data Analysis Techniques

Two steps were followed in the process of defining the codes, first deductive coding and second inductive coding. An initial set of codes was established from the literature review for deductive coding. Then, information in sustainability reports, ESG reports and companies' web pages were used for the inductive coding.

The qualitative software Atlas.ti was used for the content analysis. The sustainability data from the companies was reviewed line-by-line as the codes were assigned. Each code was given a color for a total of 14 codes divided into the three groups that resulted from the ESG concepts.

Table 9. ESG Codes

Code Group	Code Name	Code Color	Code Description
Environmental	Carbon footprint	Carbon footprint	Information related to the carbon emissions of the company and their efforts to reduce them
Environmental	Net-zero		Aimin to reduce emissions by 45% by 2030 and reach net zero by 2050 as set by the UN
Environmental	Water Management		Identify information related to the company's water usage and management practices
Environmental	Waste Management		Information related to the company's waste management practices
Environmental	Recycling		Implementation of recycling, waste reduction and reusability practices
Environmental	Sustainable development Goals		Direct reference to the UN 2030 Agenda for Sustainable Development in order to address the 17 Sustainable Development Goals (SDGs)
Environmental	Climate change		Assessing the company's strategies and actions to address climate change
Environmental	Space Sustainability		Sustainability practices directly related to space operations and space-derived products and/or services
Social	Employee Health and Safety		Information related to the company's policies and practices related to employee health and safety
Social	Supply Chain Sustainability		Information related to the company's sustainable supply chain management practices
Social	Social Impact		Analyze the company's initiatives to support local communities and efforts to create positive social impact through CSR programs
Social	Inclusion & Diversity		Promotion of inclusion and diversity within their workforce
Governance	Business Ethics		Outline of the company's ethical principles and mechanisms in place to promote a culture of integrity and prevent misconduct
Governance	Anti-Corruption and Bribery		Commitment to combating corruption and bribery and implementation of anti-corruption policies, training programs, and internal controls

Source: Personal elaboration

After obtaining codes, an individual analysis is conducted for each code to measure, first its presence and absence in the companies analyzed. Then, the count of codes is analyzed to evaluate the degree of importance of every code for each company.

Finally, an ESG index is calculated with three components:

- The Environment index: sum of presence/absence of codes related to environment.

$$Ei = \sum Environment\ codes$$

- The Social index: sum of presence/absence of codes related to social.

$$Si = \sum Social\ codes$$

- The Governance index: sum of presence/absence of codes related to governance.

$$Gi = \sum Government\ codes$$

- The ESG index: sum of Environmental index, Social index and Governance index.

$$ESGi = Ei + Si + Gi$$

5. RESULTS

5.1. Analysis Results of ESG Reporting of Companies in the Space Sector

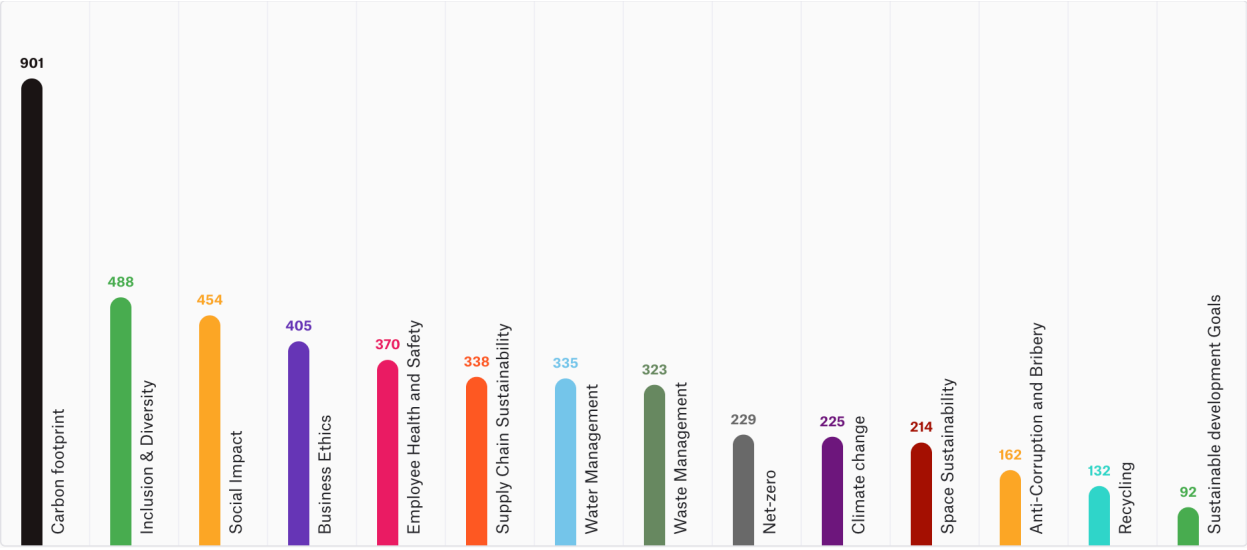
In this section, the final number of citations for the codes defined in the content analysis is presented in descending order.

Figure 20 shows a significant predominance of the citations related to the carbon footprint of the companies, more accurately this is the code with the highest number of citations; this same phenomenon can be observed in Figure 21 where a cloud of concepts from the citations was created. Based on this evidence it is possible to conclude that companies in the space sector are prioritizing the reduction of their carbon footprint.

One valuable observation is that for authors Lokuwaduge & Heenetigala (2017) in their study "Integrating Environmental, Social and Governance (ESG) Disclosure for a Sustainable Development: An Australian Study", 76 percent of the companies they analyze reported on Direct GHG emission, being the indicator, most used by the companies in their sample. It is then possible to infer that carbon emissions remain a relevant indicator for the ESG disclosure of companies.

Such results are consistent with the findings of Tamini and Sebastianelli (2017) with about 58 percent of their analyzed firms reporting that they have emission reduction policies in their journal "Transparency among S&P 500 companies: an analysis of ESG disclosure scores".

Figure 19. Final Count of Codes



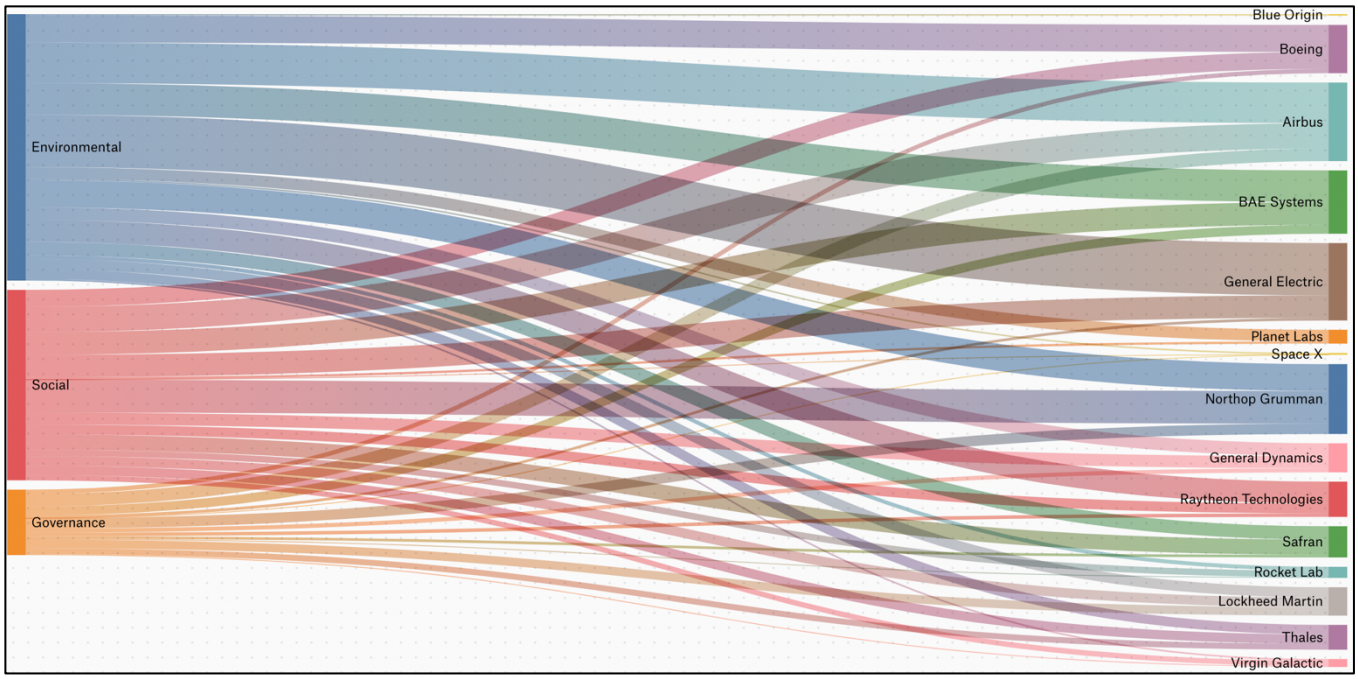
Source: Personal Elaboration with Atlas.ti

Figure 20. Cloud of Concepts from ESG citations

Source: Personal Elaboration with Atlas.ti

In Figure 21 a Sankey diagram is portrayed to offer a visualization of the flow between the three groups of codes (Environmental, Social, and Governance) on the left to the group of analyzed companies on the right; this particularly shows that the links represent the magnitude of the presence of each code that was found in the collected data. It is also very noticeable that some companies disclose more ESG data than others, for instance, Airbus, BAE Systems, General Electric, and Northop Grumman disclosed a larger amount of information in contrast with SpaceX, Blue Origin, and Virgin Galactic.

Figure 21. Sankey Chart: Groups vs Companies



Source: Personal Elaboration with Atlas.ti.

In the next subheading, the results for the citations of each individual code are depicted in terms of the presence of the code and count of the code.

5.2. Results of the Environmental Concept

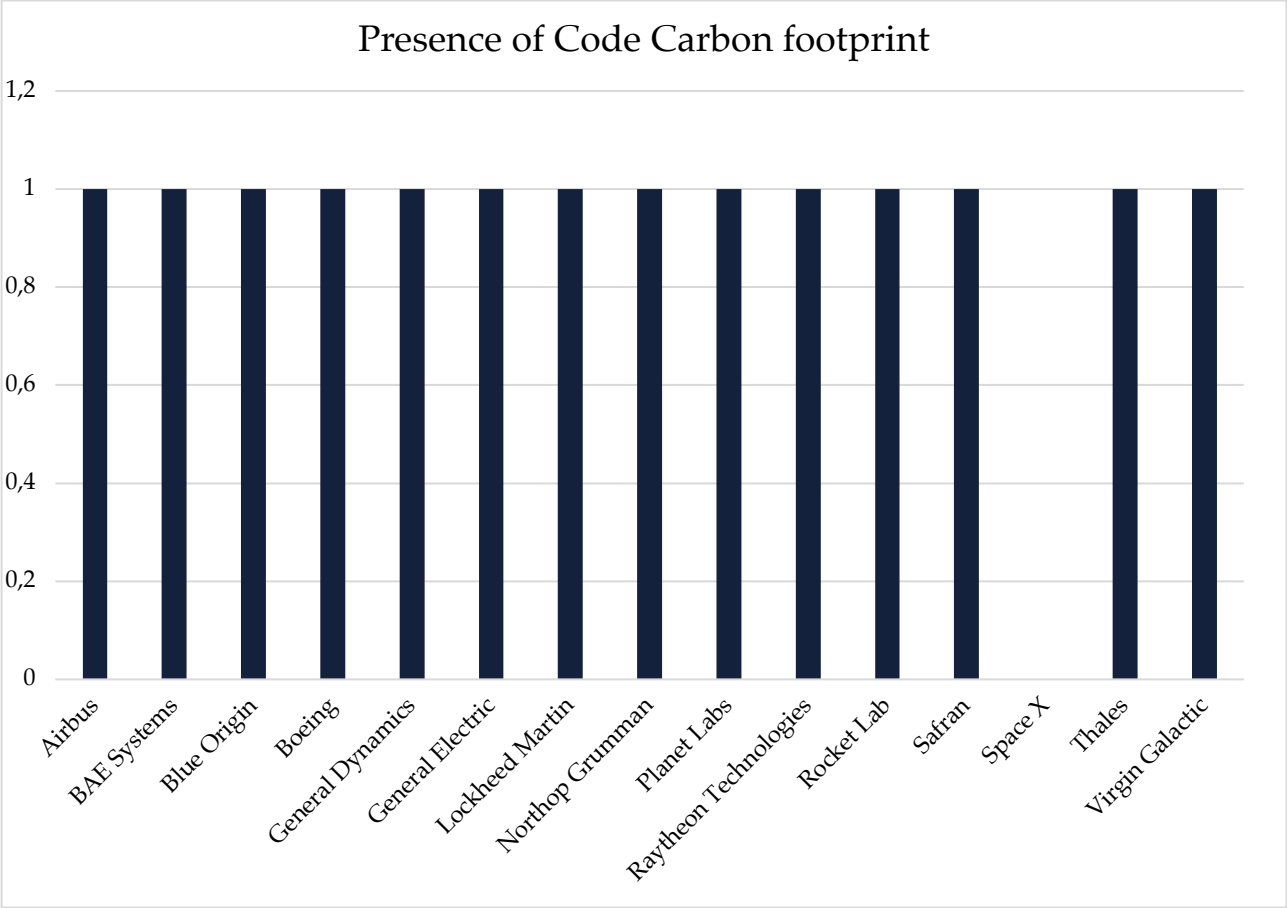
Nine codes were analyzed in the Environmental concept:

1) Carbon footprint
2) Climate change
3) Net-zero
4) Recycling
5) Space Sustainability
6) Supply Chain Sustainability
7) Sustainable development Goals
8) Waste Management
9) Water Management

5.2.1. Results for the code Carbon Footprint

Figure 23 shows whether the code is present or not in the data collected from the company. This ESG concept associated with the environment is present in all of the companies except for startup SpaceX, where information directly related to their carbon footprint and their efforts to reduce it was not particularly addressed in their official communication channels.

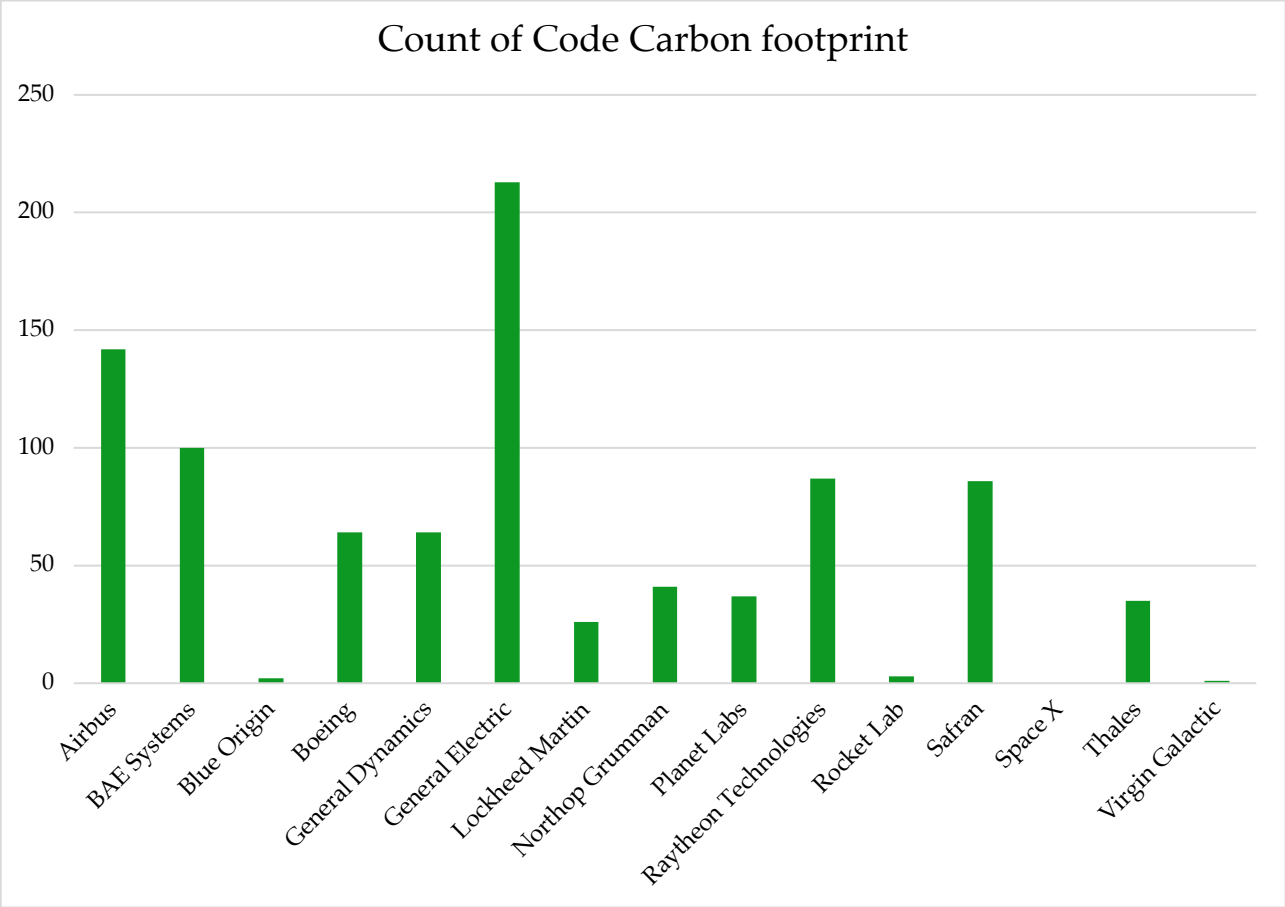
Figure 22. Presence of Code Carbon footprint



Source: Personal Elaboration

Then in Figure 24 it is possible to visualize that corporation General Electric is by far the company with the highest number of citations for the carbon footprint code, this shows that this company is openly disclosing information regarding its carbon emissions and how they are planning to reduce it. As for the startups Planet Labs is the one with the leading number of citations for this code, contrasting with the rest of the startups that are sharing little to no information on this aspect.

Figure 23. Count of code Carbon Footprint

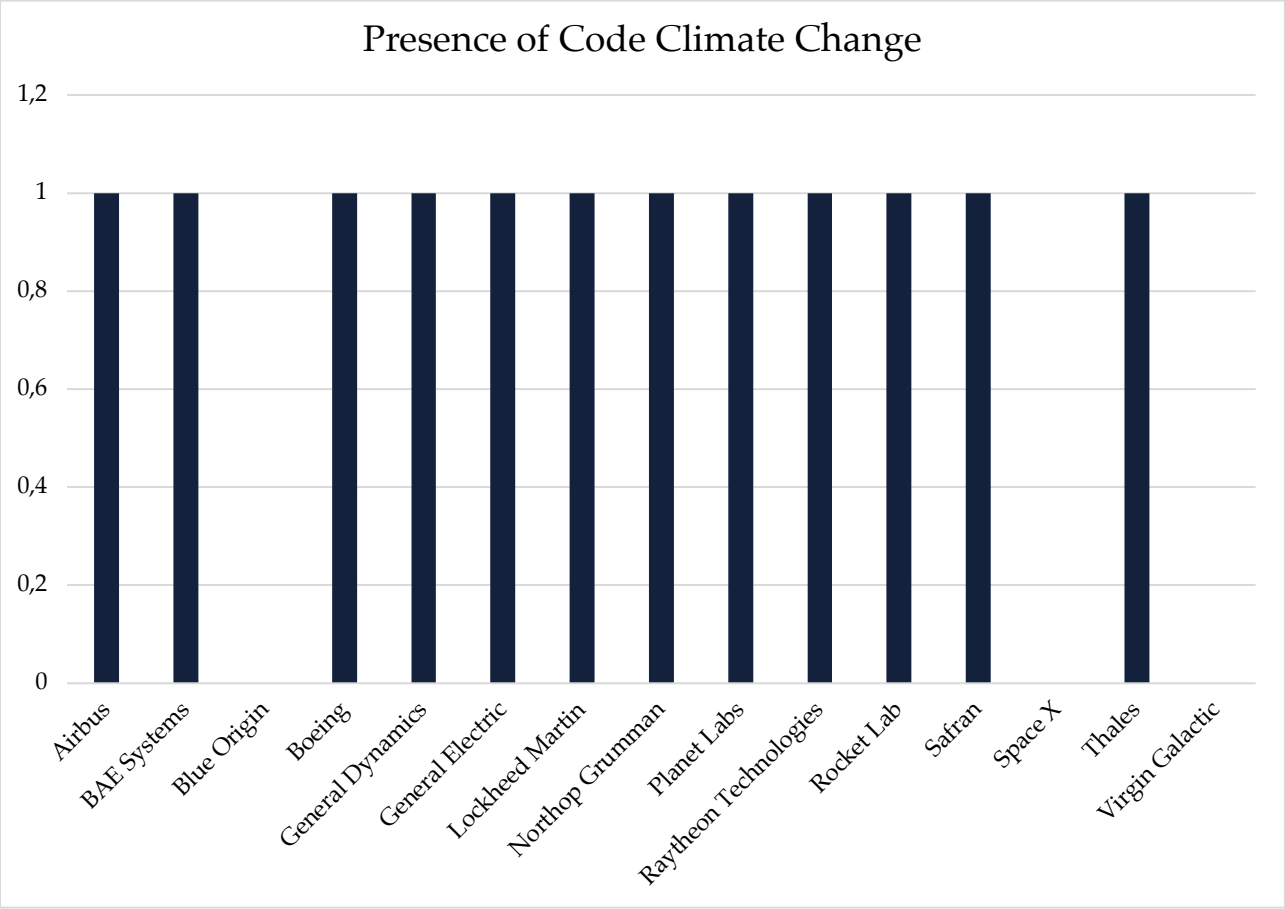


Source: Personal Elaboration

5.2.2. Results for the code Climate Change

The second analyzed code is climate change, on Figure 25 it is shown that only startups SpaceX and Blue Origin are not acknowledging climate change on their platforms. Therefore, 13 out of 15 companies analyzed are outlining their strategies against climate change.

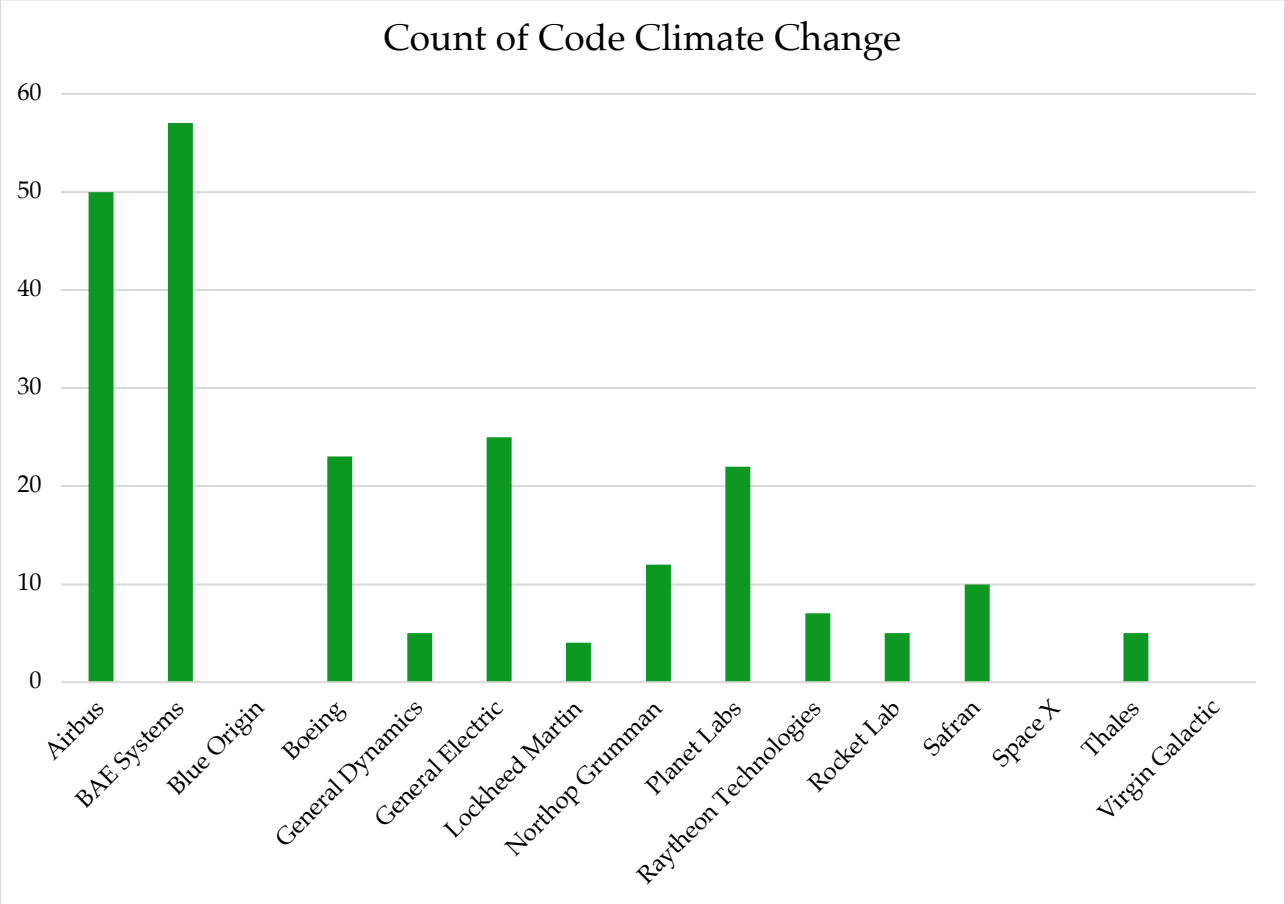
Figure 24. Presence of Code Climate Change



Source: Personal Elaboration

Continuing with the number of citations of the code climate change, it is clear that corporates Airbus and BAE Systems are the ones making moves against climate change due to having the topmost number of citations on this aspect, compared to this, corporates General Dynamics, Thales, Raytheon Technologies, and Lockheed Martin are significantly low, surpassed by startup Planet Labs.

Figure 25. Count of Code Climate Change

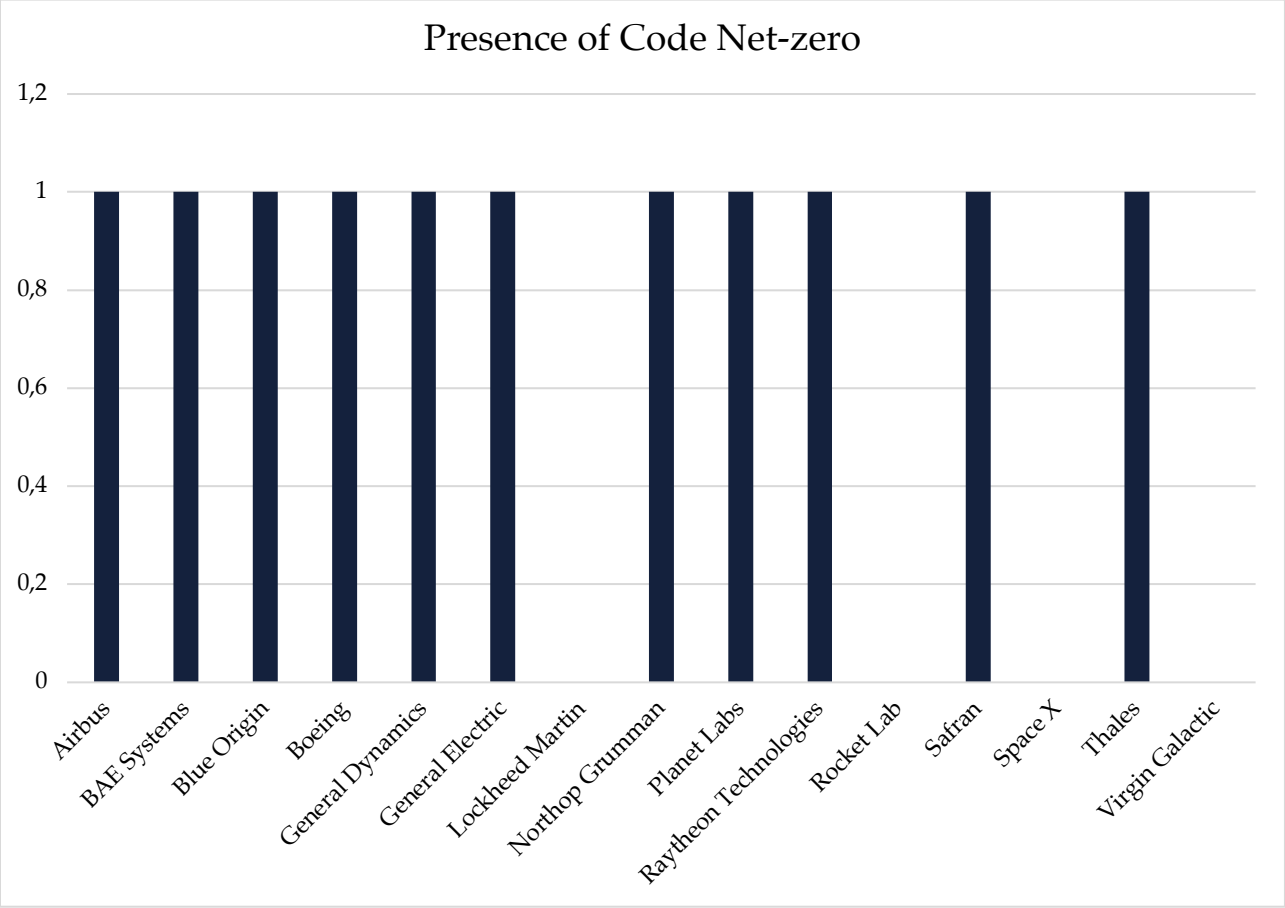


Source: Personal Elaboration

5.2.3. Results for the code Net-zero

Heading on to code Net-zero, the only corporate has no presence of this aspect is Lockheed Martin, making a total of 9 out of 10 corporates with the presence of this code. Once again for the startups Planet Labs is present and it is joined by Blue Origin, this means that only 2 out of 5 startups are showing their initiatives on reaching Net-zero target for their emissions.

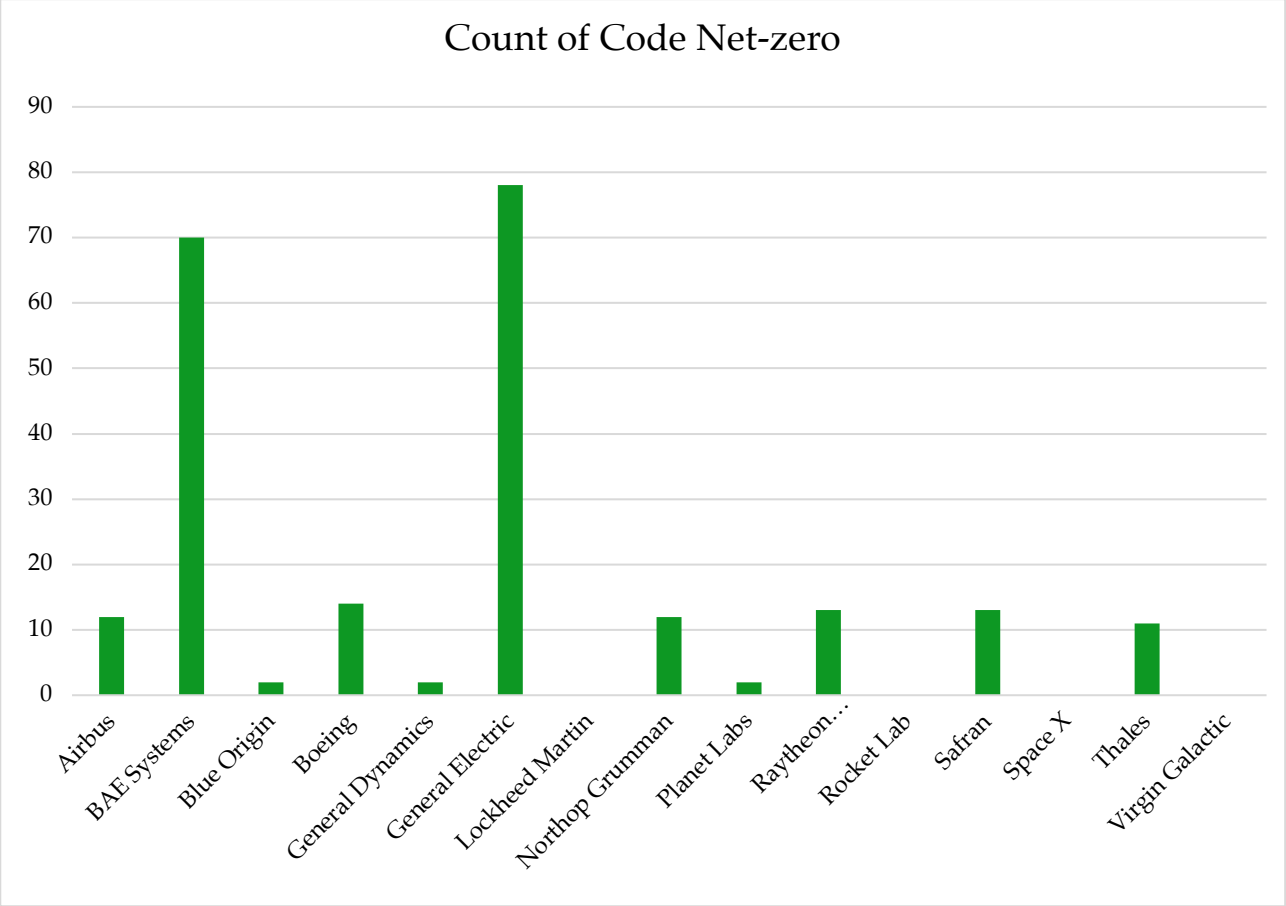
Figure 26. Presence of code Net-zero



Source: Personal Elaboration

Now for the count of citations, General Electric is broadly disclosing their strategies to reach Net-zero target, followed closely by BAE Systems for the corporate group, other corporates like Boeing, Northrop Grumman, Raytheon Technologies, Safran, and Thales are positioned on a close average number of citations for this code. Then Planet Labs continues to consistently address environmental aspects like Net-zero efforts, as well as, Blue Origin, for the startups group.

Figure 27. Count of Code Net-zero

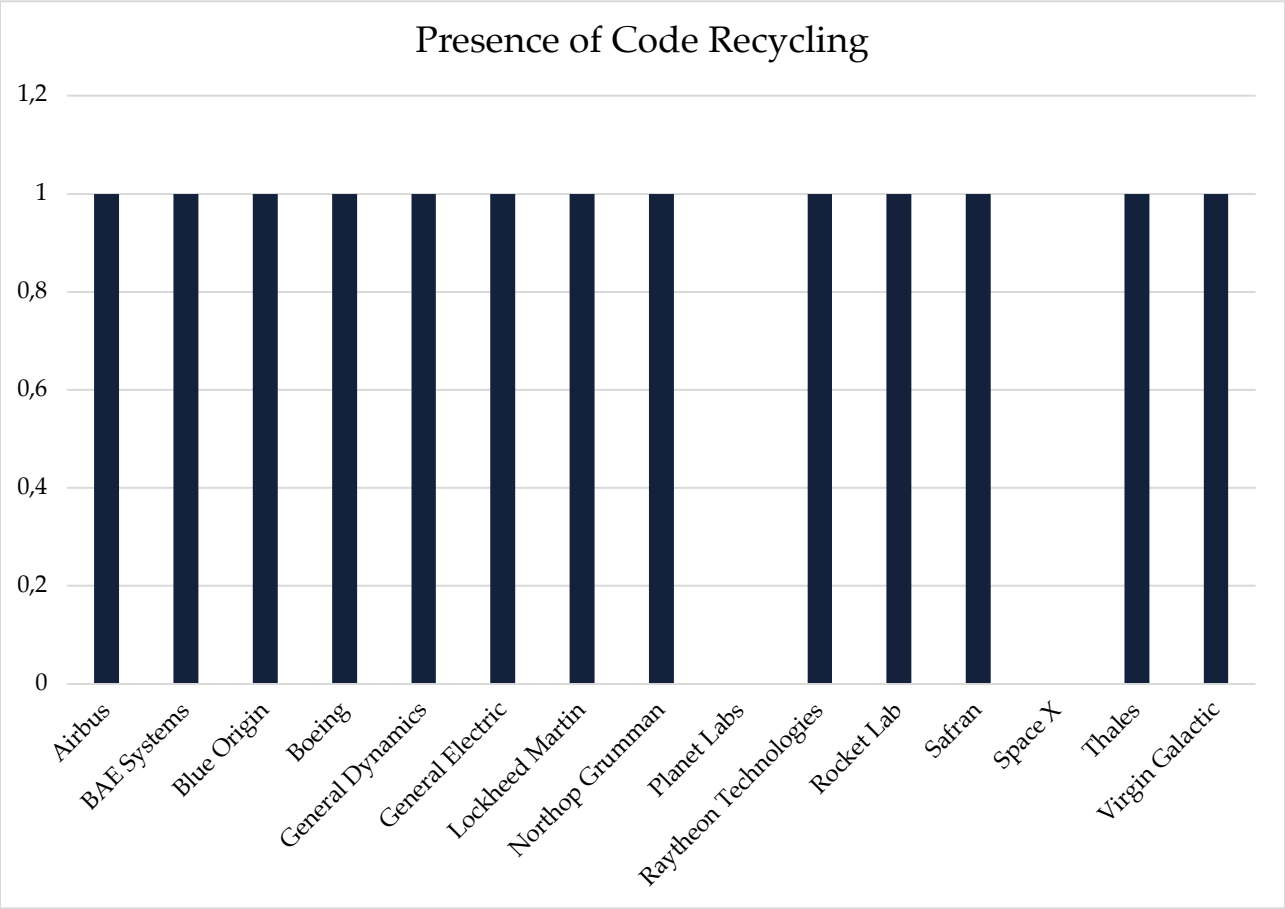


Source: Personal Elaboration

5.2.4. Results for the code Recycling

For the recycling code, all 10 of the corporate companies are able to successfully meet the citation criteria, this means they are actively promoting their recycling practices. As to the startups, 3 out of 5 are found to meet the criteria of the recycling code.

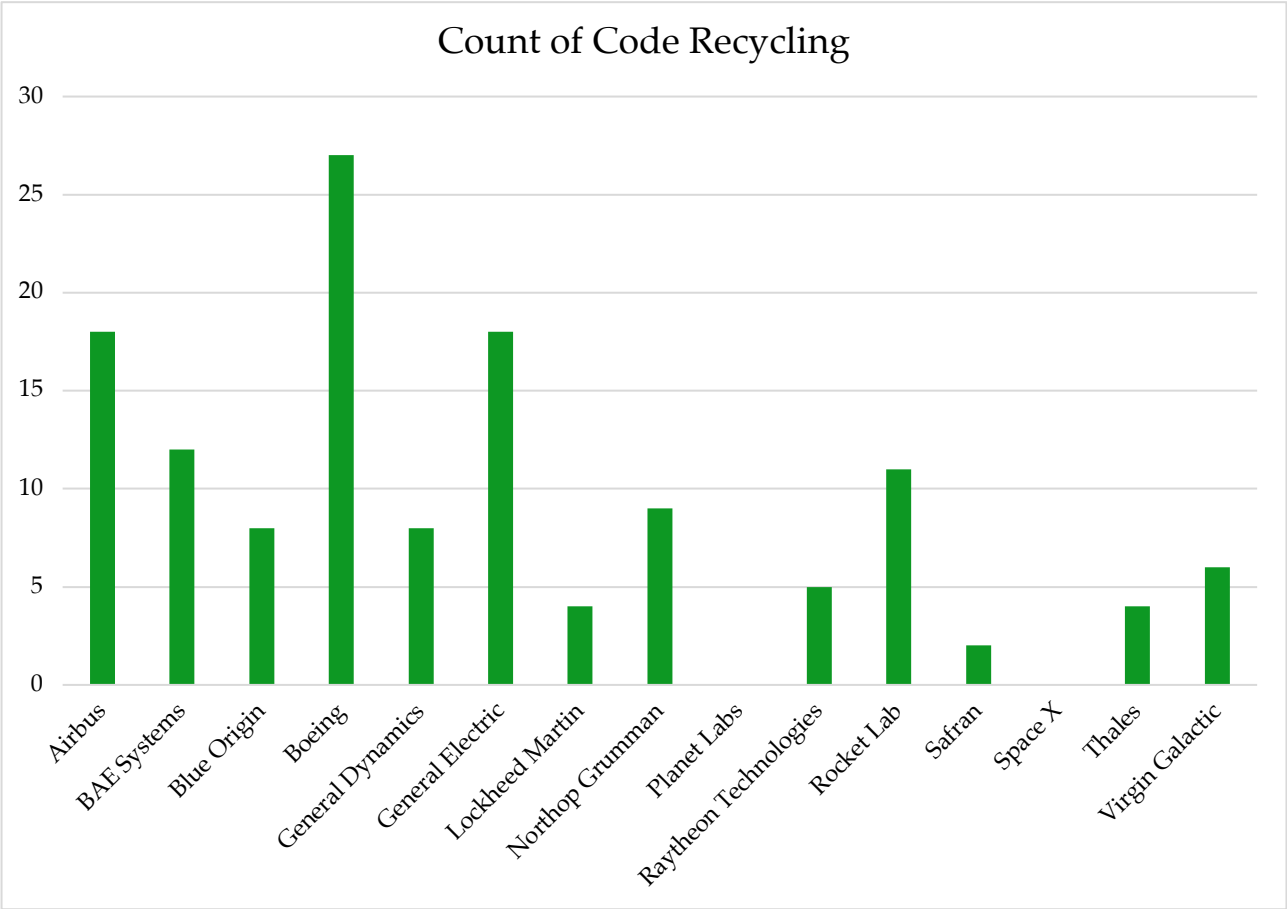
Figure 28. Presence of Code Recycling



Source: Personal Elaboration

As a group, all the corporations demonstrate practicing recycling as part of their sustainability strategies. Going into detail it can be seen that the final count of citations for the recycling code shows Boeing with the highest number of initiatives related to this aspect, continuing with Airbus and General Electric with a similar final count. For the startups, Rocket Lab is making a significant appearance but 2 of 5 companies from this group have no explicit information on this element.

Figure 29. Count of Code Recycling

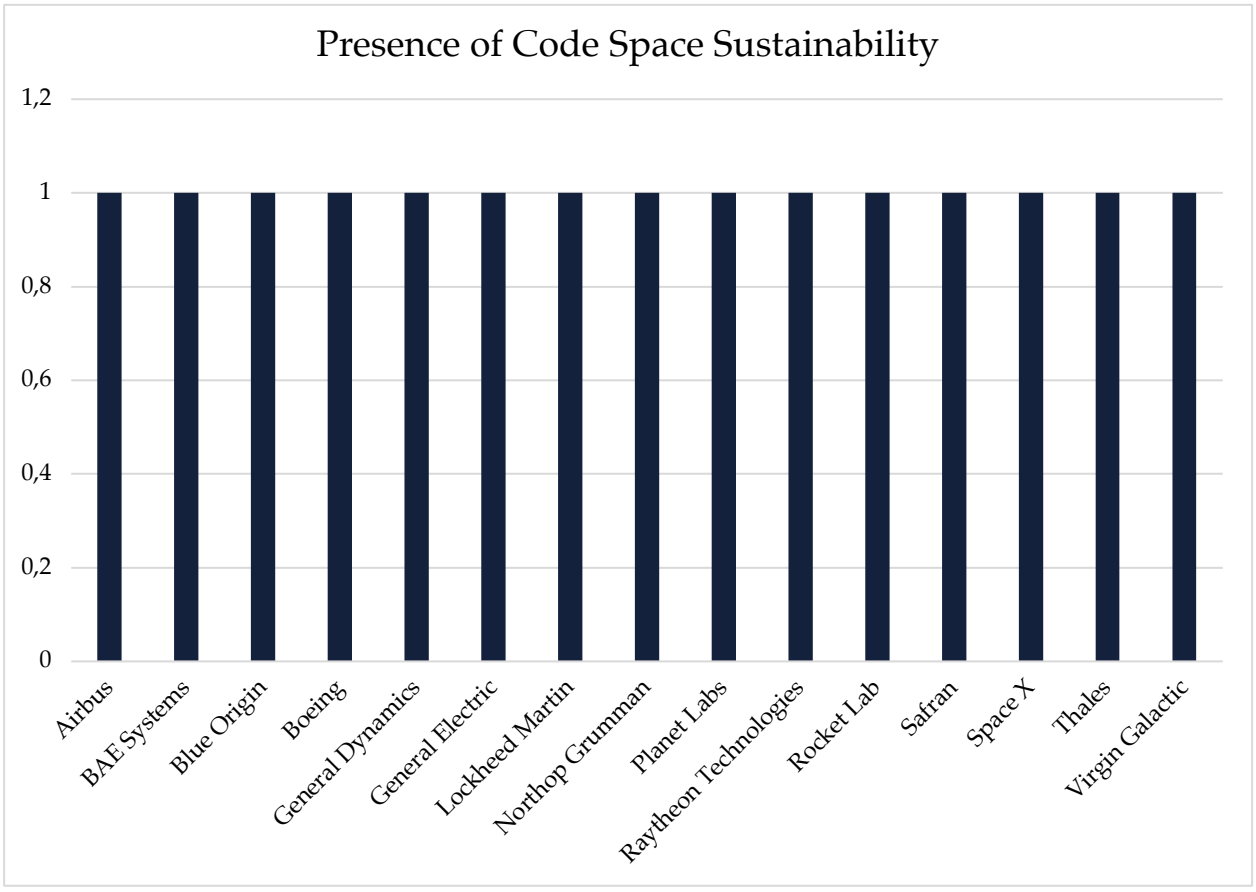


Source: Personal Elaboration

5.2.5. Results for the code Space Sustainability

All 15 analyzed companies have the presence of code space sustainability. This indicates that these companies are taking action to be sustainable in their specific space operations and space-based products and services.

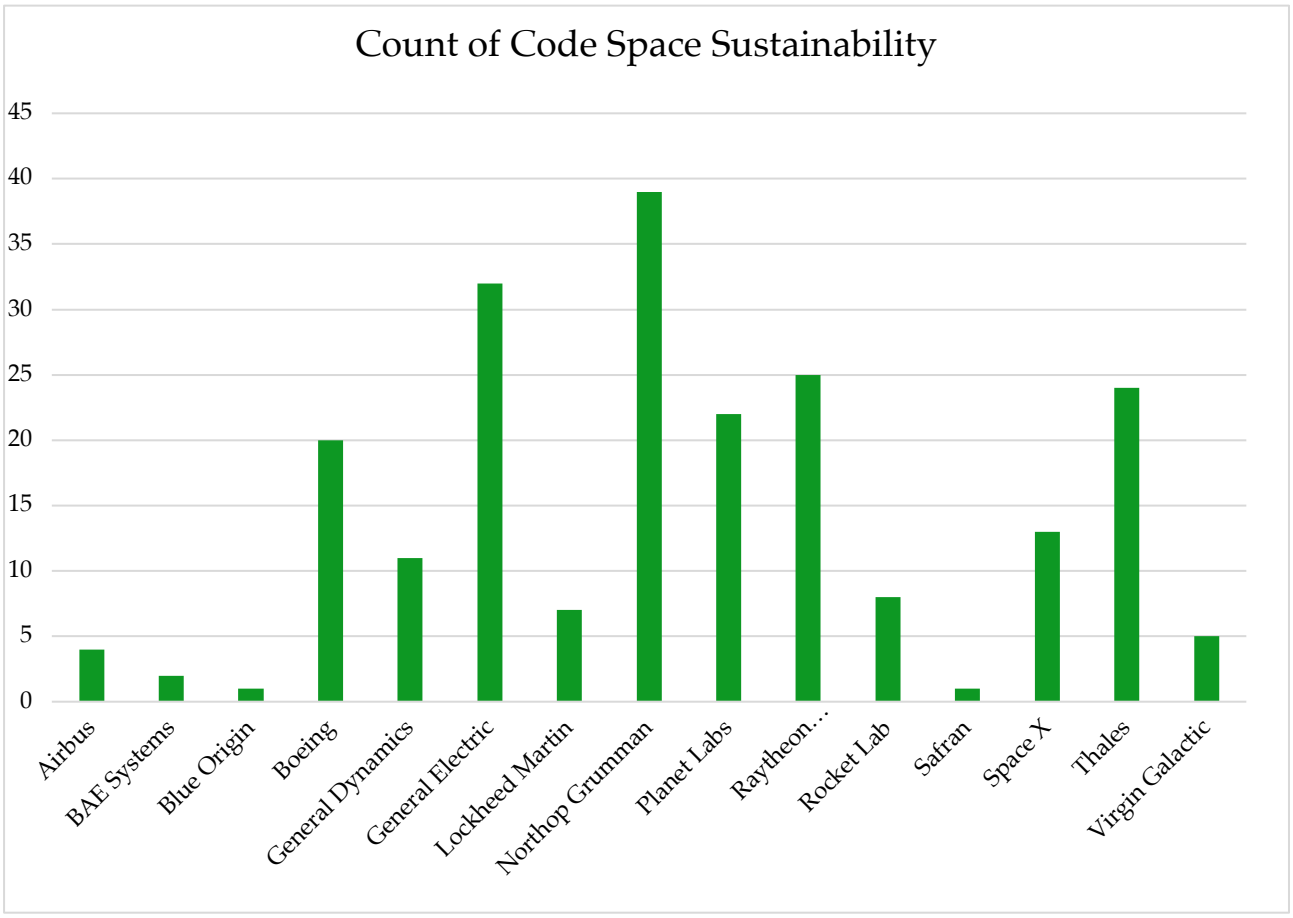
Figure 30. Presence of Code Space Sustainability



Source: Personal Elaboration

From the corporate companies, the top one for code space sustainability is Northop Grumman, and coming in second is General Electric, from this group the lowest number of citations was Safran. As for the startups, the lead is taken by Planet Labs which also surpasses 7 out of 10 corporates.

Figure 31. Count of Code Space Sustainability

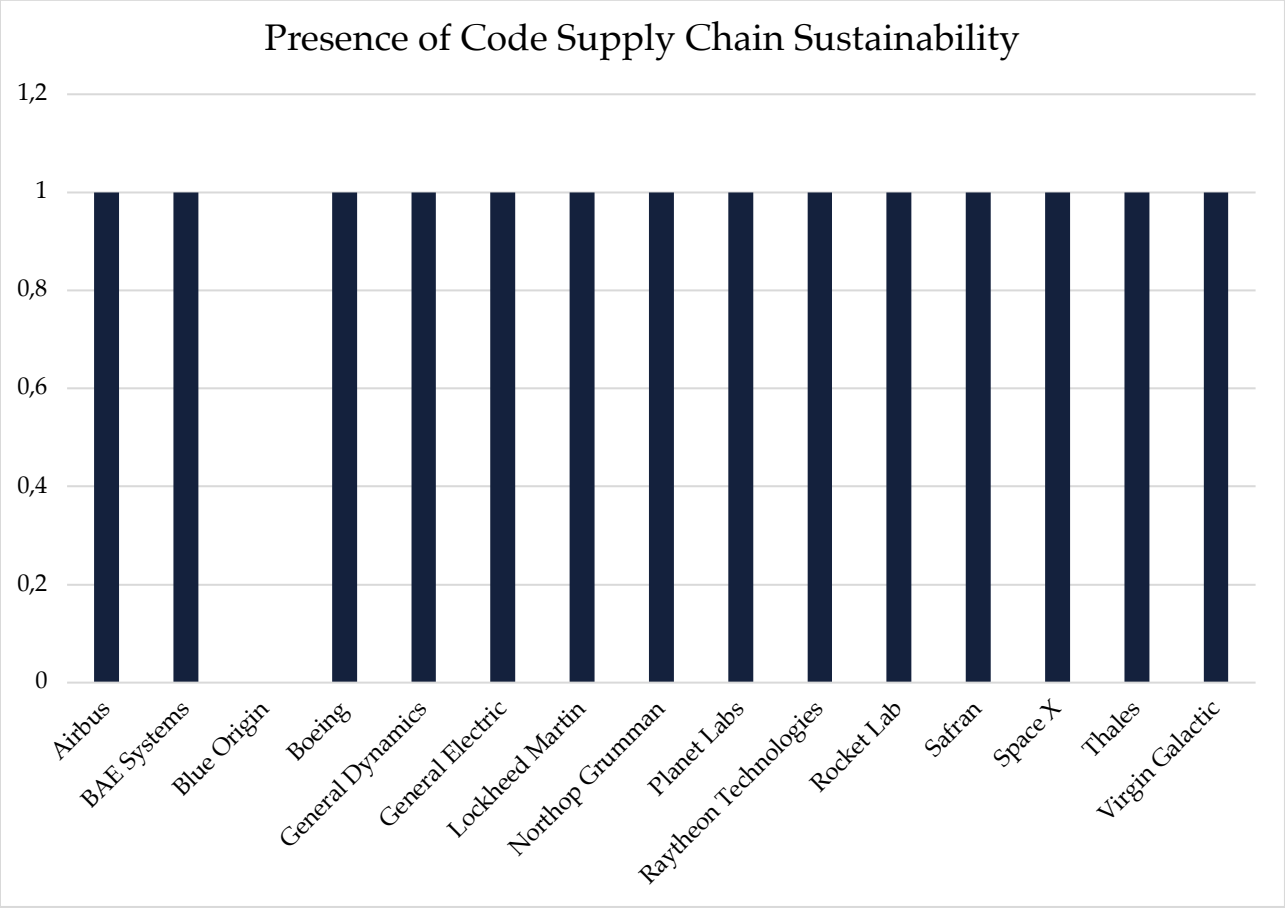


Source: Personal Elaboration

5.2.6. Results for the code Supply Chain Sustainability

The code Supply Chain Sustainability is present in all of the 10 analyzed corporate companies. When looking specifically into the startup's group 4 out of 5 companies also have the presence of this code which demonstrates a high level of presence for both corporate and startup companies.

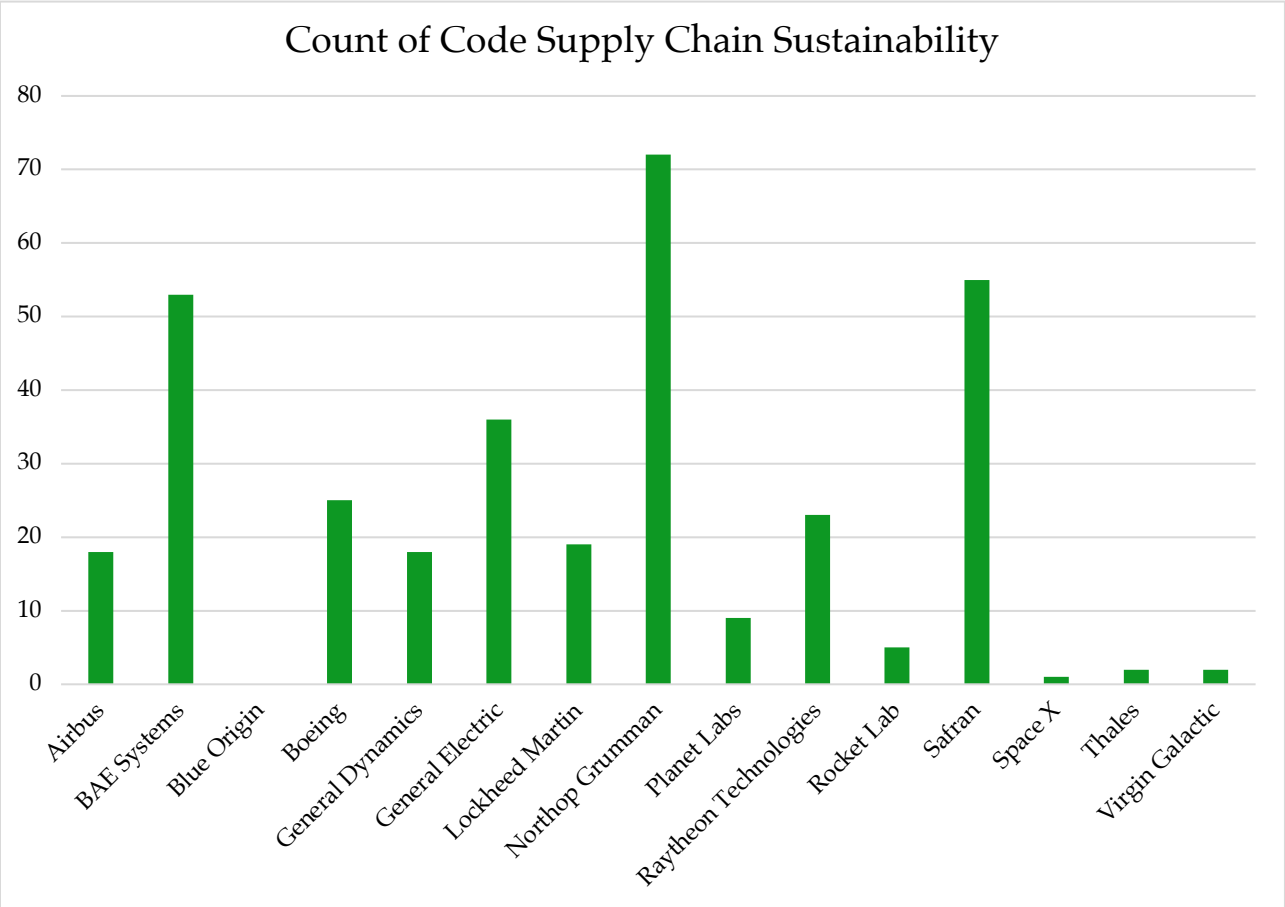
Figure 32. Presence of Code Supply Chain Sustainability



Source: Personal Elaboration

When it comes to the final number of citations 3 companies have a clear advantage, in the first place is Northop Grumman, second would be Safran and third BAE Syste, these 3 are from the corporate group whereas the remaining 7 have presence of citations regarding Supply Chain Sustainability but it is noticeable that Thales has a significantly lower count. To continue with the startups Planet Labs and Rocket Lab has the highest results and Blue Origin does not have any citation for this code.

Figure 33. Count of Code Supply Chain Sustainability

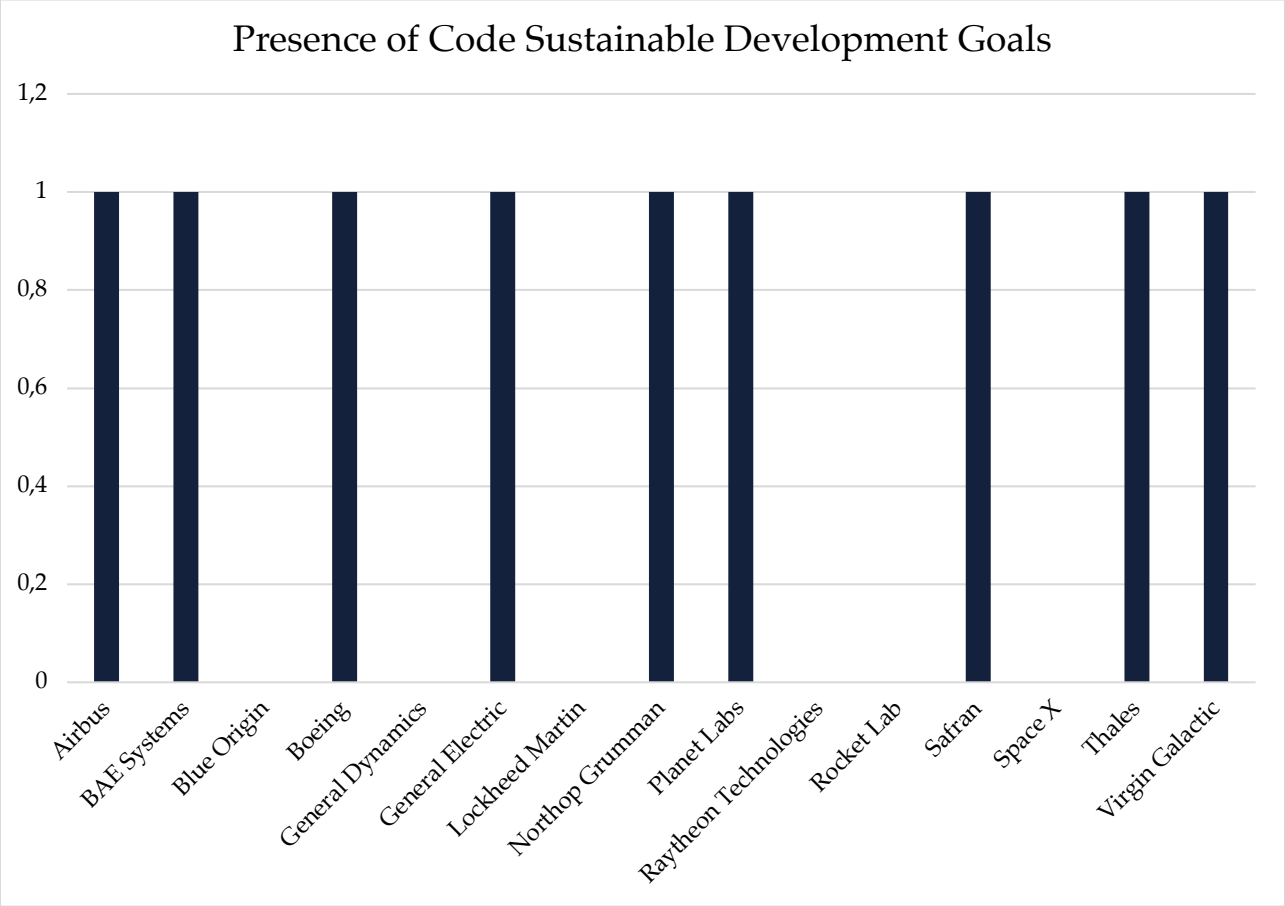


Source: Personal Elaboration

5.2.7. Results for the code Sustainable Development Goals

This code refers to initiatives in supporting the UN Sustainable Development Goals and 7 out of 10 corporates explicitly disclose in what ways they are working to attain these goals. On the other hand, only 2 of 5 startups present information related to their efforts into upholding the UN 2030 and 2050 agenda.

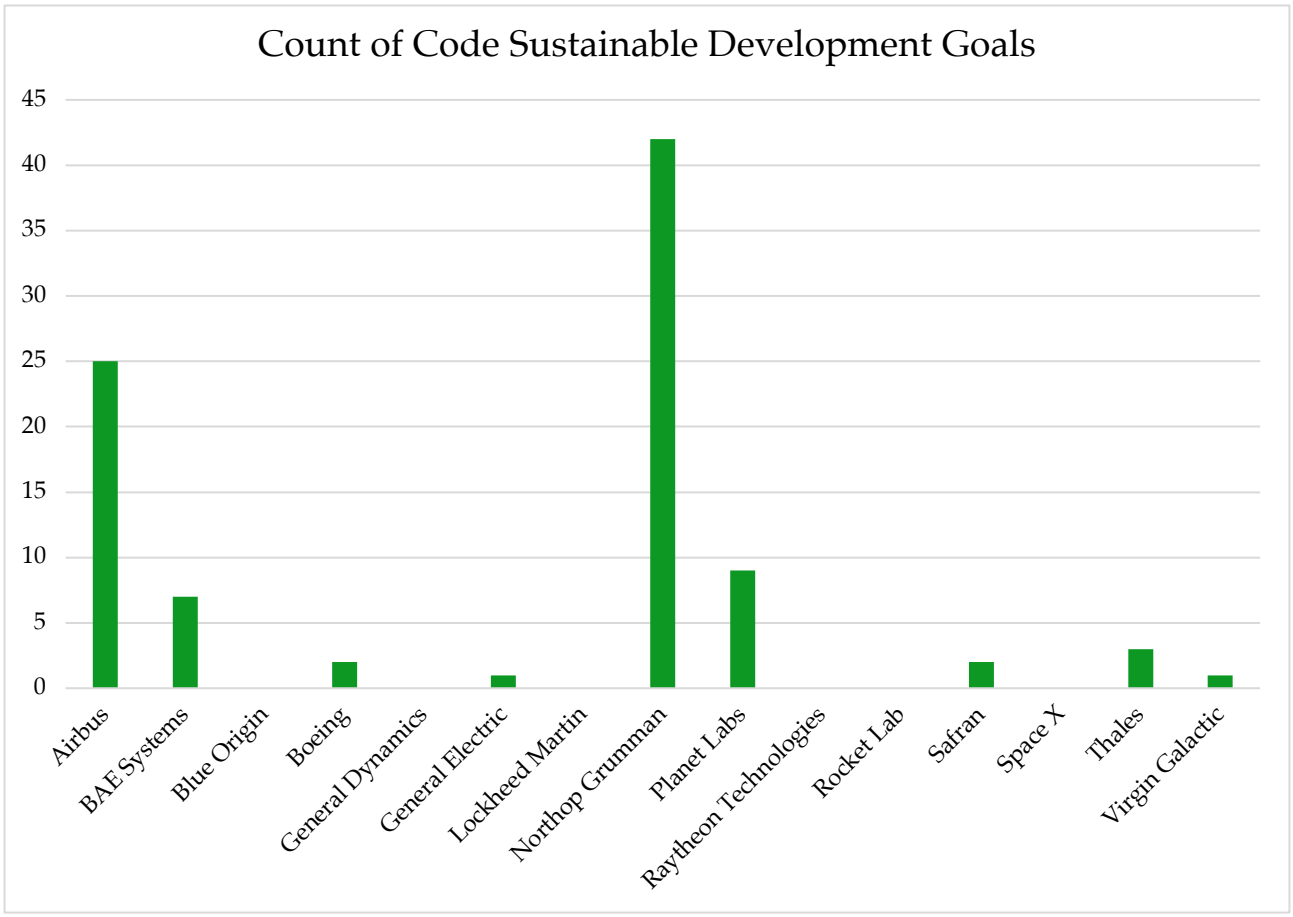
Figure 34. Presence of Code Sustainable Development Goals



Source: Personal Elaboration

By observing the number of citations, it can be promptly seen that corporation Northop Grumman is making the Sustainable Development Goals part of their sustainability strategies in a very specific manner, Airbus also had a significant level of presence. Continuing with the startups Planet Labs continues to consistently take the lead in sharing information concerning their sustainable practices, Virgin Galactic also accumulates citations, therefore it seems that they are also taking part in the UN agenda.

Figure 35. Count of Code Sustainable Development Goals

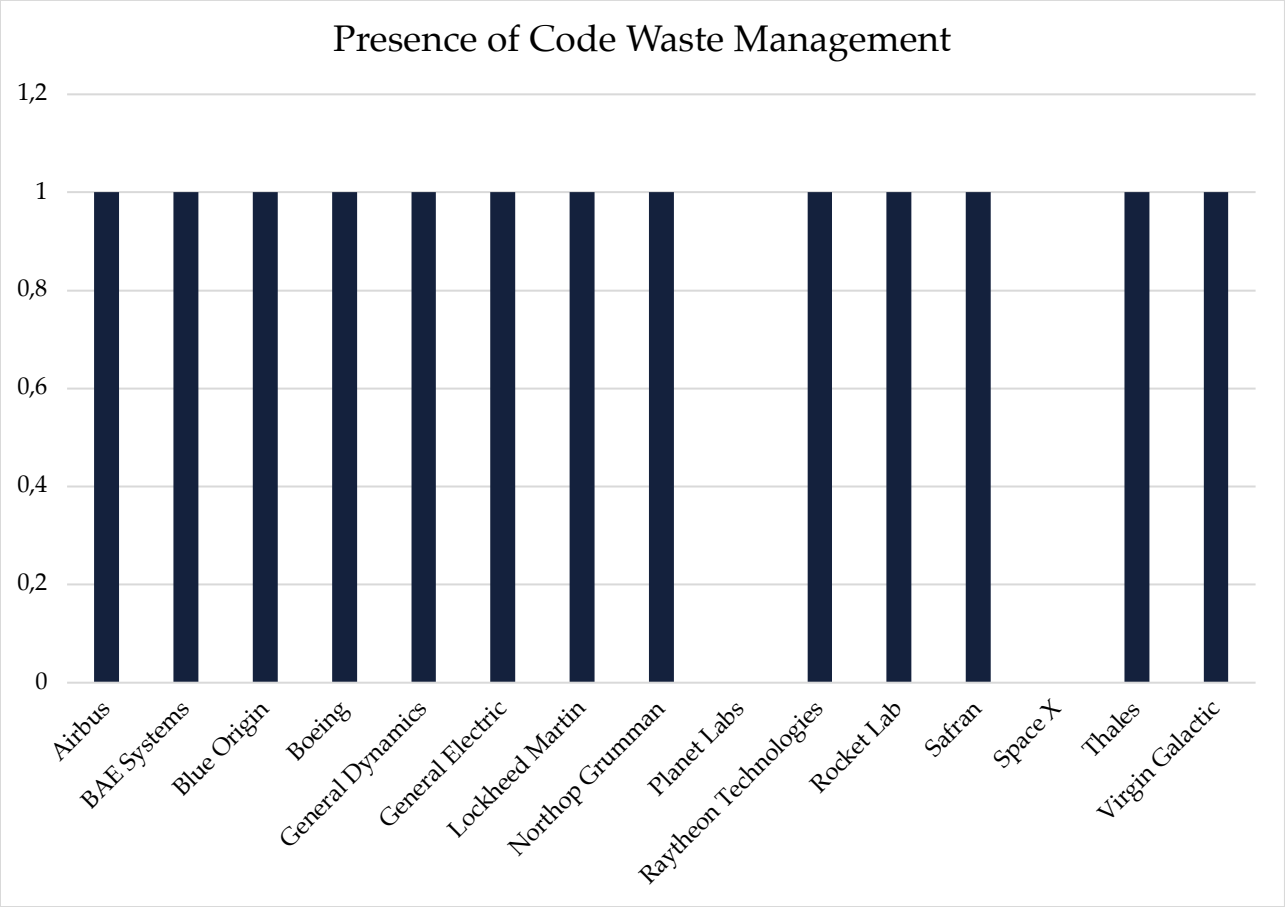


Source: Personal Elaboration

5.2.8. Results for the code Waste Management

For the code waste management, 2 out of the 15 analyzed companies fail to provide information on this aspect. More precisely, the two companies not having citations of this code are startups, which means that all the corporates have evidence related to the management of waste.

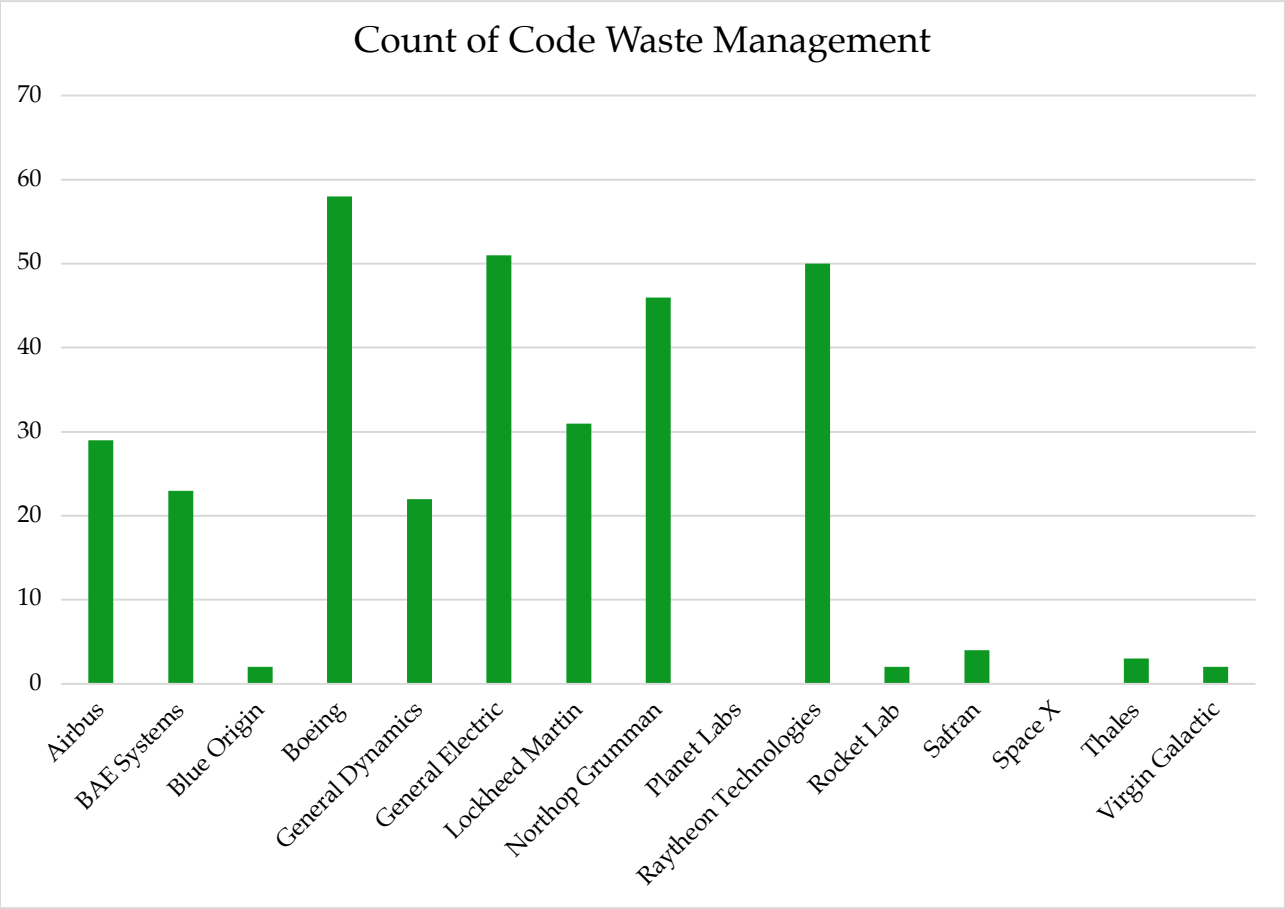
Figure 36. Presence of Code Waste Management



Source: Personal Elaboration

Visualizing the count of codes for this environmental aspect, 4 out of 10 corporates stand out: Boeing, General Electric, Northop Grumman, and Raytheon Technologies with fairly similar behavior on the final number of citations for waste management.

Figure 37. Count of Code Waste Management

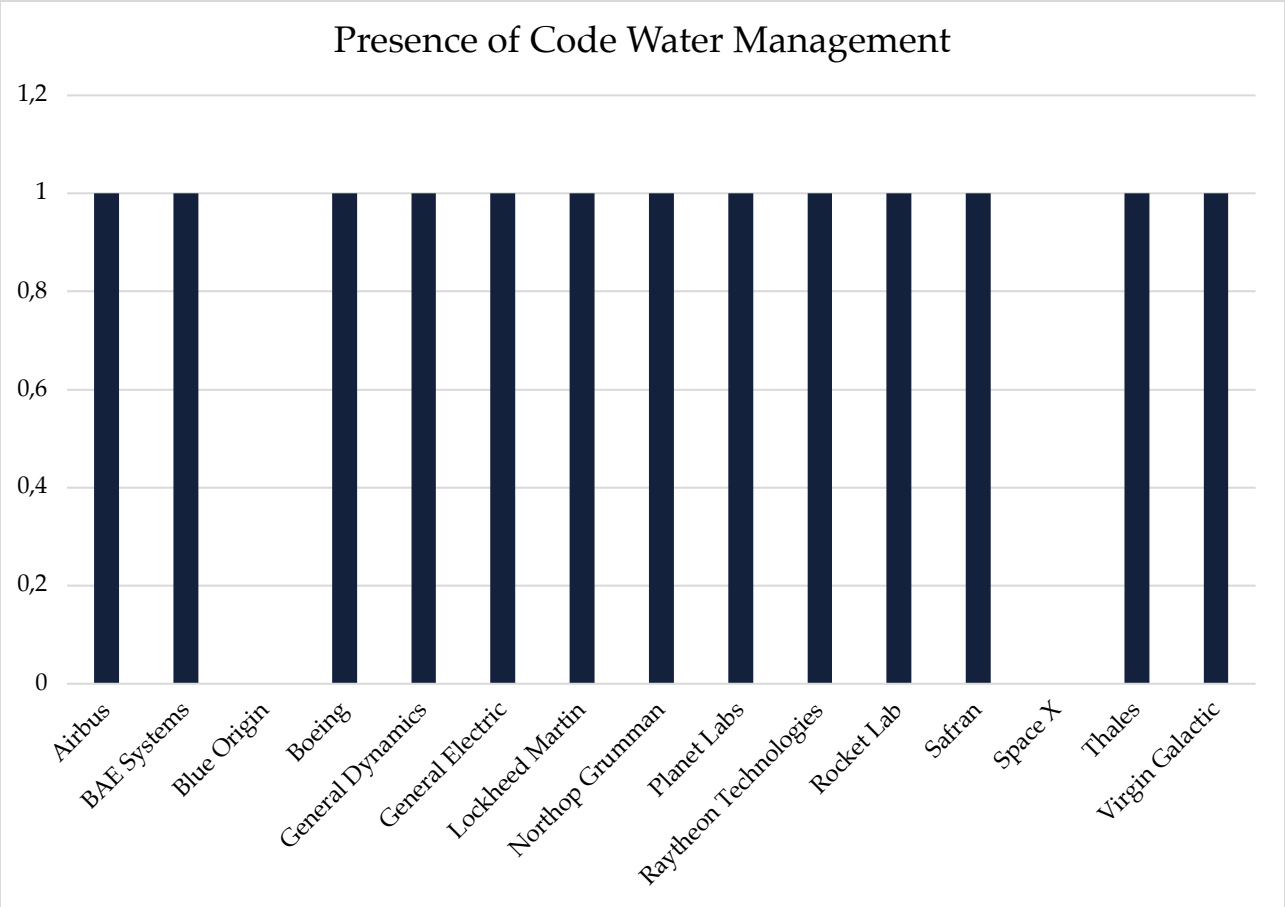


Source: Personal Elaboration

5.2.9. Results for the code Water Management

A key environmental aspect of this study is water management and from the analyzed companies only 2 startups do not have official relevant information available to the public in their media outlets. In this case, 3 out of 5 startups have the presence of this code and all corporate companies as well.

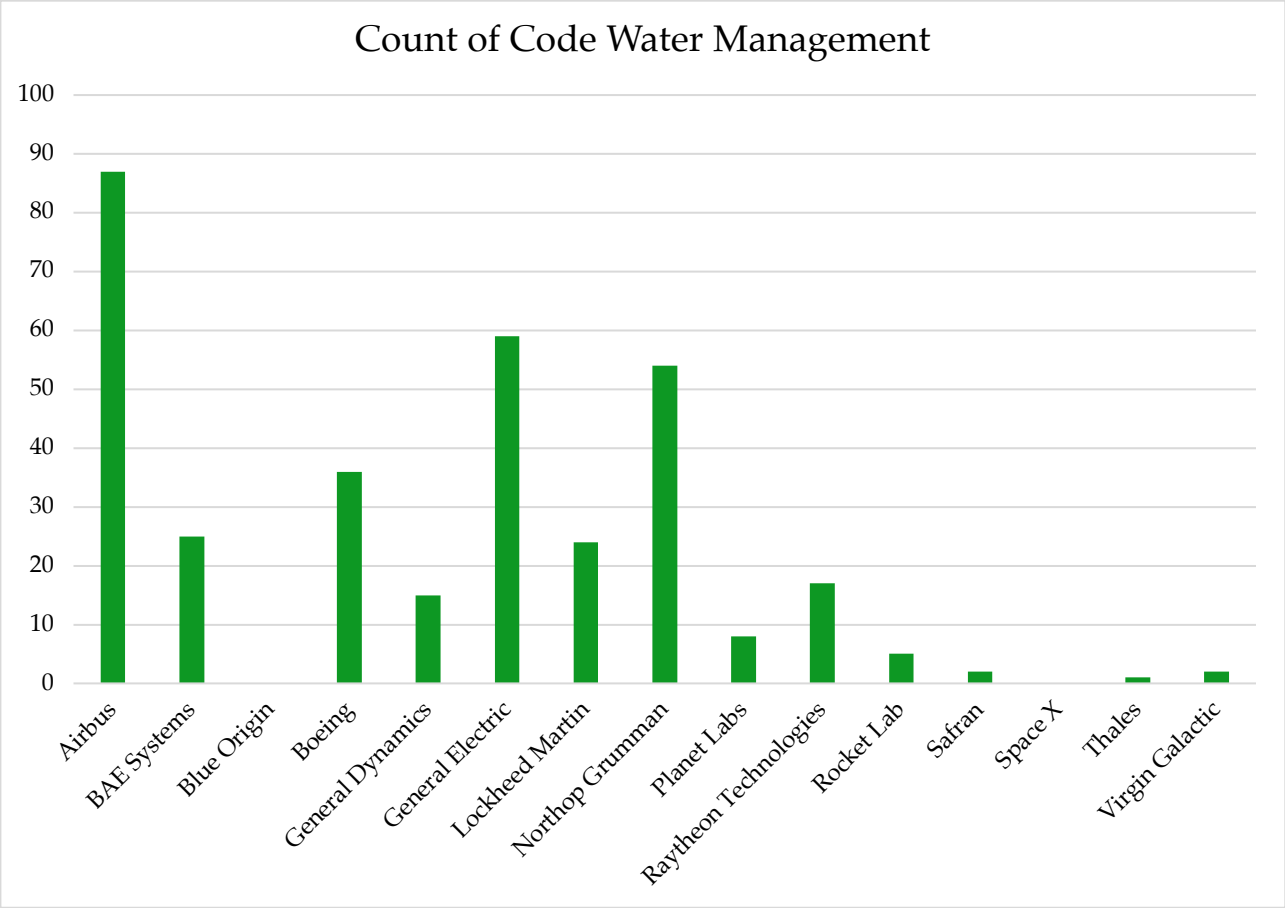
Figure 38. Presence of Code Water Management



Source: Personal Elaboration

As for the count results the highest number of citations is the corporate company Airbus, continuing with General Electric and Northop Grumman. Then Planet Labs once again takes the lead for the startups followed by Rocket Lab and Virgin Galactic.

Figure 39. Count of Code Water Management



Source: Personal Elaboration

5.2.10. Summary of Environment Index

After analyzing each individual code from the ESG reporting of the selected companies, a list ranking the businesses based on the environmental aspects of their sustainability information shows corporate companies positioned on top of startups. This could be an indicator that firm size is dependent on the level of disclosure of ESG reporting (Tamini & Sebastianelli, 2017).

Table 10.Summary of Environment Index

Company Type	Company Name	Carbon footprint	Net-zero	Waste Management	Supply Chain Sustainability	Recycling	Sustainable development Goals	Climate change	Space Sustainability	Water Management	Ei =∑ Environment codes
Corporate	Airbus	1	1	1	1	1	1	1	1	1	9
Corporate	BAE Systems	1	1	1	1	1	1	1	1	1	9
Corporate	Boeing	1	1	1	1	1	1	1	1	1	9
Corporate	General Electric	1	1	1	1	1	1	1	1	1	9
Corporate	Northop Grumman	1	1	1	1	1	1	1	1	1	9
Corporate	Safran	1	1	1	1	1	1	1	1	1	9
Corporate	Thales	1	1	1	1	1	1	1	1	1	9
Corporate	General Dynamics	1	1	1	1	1	0	1	1	1	8
Corporate	Raytheon Technologies	1	1	1	1	1	0	1	1	1	8
Corporate	Lockheed Martin	1	0	1	1	1	0	1	1	1	7
Startup	Planet Labs	1	1	0	1	0	1	1	1	1	7
Startup	Rocket Lab	1	0	1	1	1	0	1	1	1	7
Startup	Virgin Galactic	1	0	1	1	1	0	0	1	1	6
Startup	Blue Origin	1	1	1	0	1	0	0	1	0	5
Startup	SpaceX	0	0	0	1	0	0	0	1	0	2

Source: Personal Elaboration

A Mann Whitney test is conducted to compare the result based on the type of company. The null hypothesis is that Ei does not differ between Corporate and Startup companies. The result, however is that there exist a significant difference in the Ei between the two groups ($z = 3.114$, $p=0.0018$; exact $p=0.0020$)($P\{Ei(Corporate) > Ei(Startup)\} = 0.980$).

5.3.Results of the Concept of Social

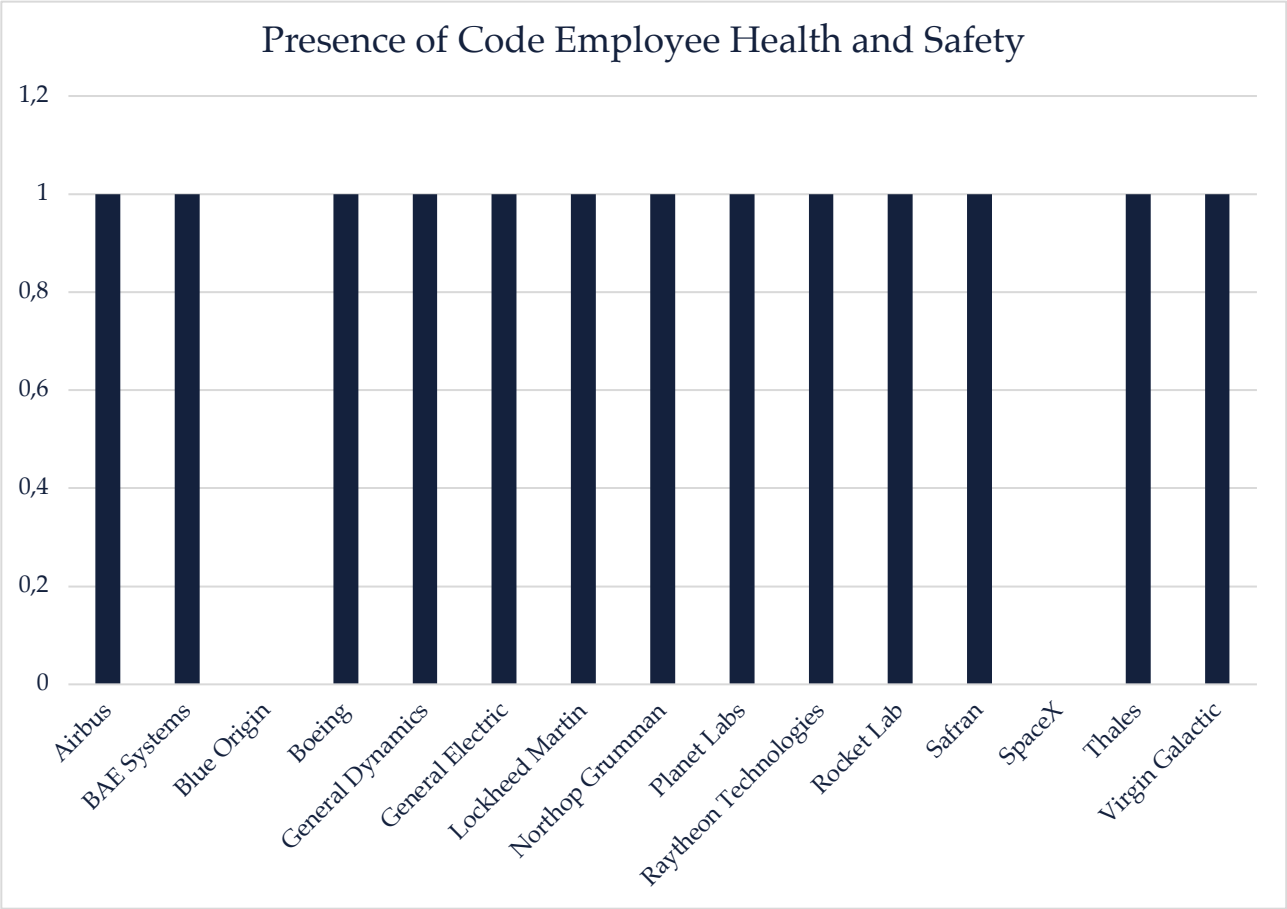
Three codes were analyzed in the social concept:

1) Employee Health and Safety
2) Social Impact
3) Inclusion & Diversity

5.3.1. Results for the code Employee Health and Safety

To start with the social group the code to analyze is employee health and safety. The presence of this code was detected in all of the 10 corporates and for the startups in 3 out 5 companies which include Planet Labs, Rocket Lab, and Virgin Galactic.

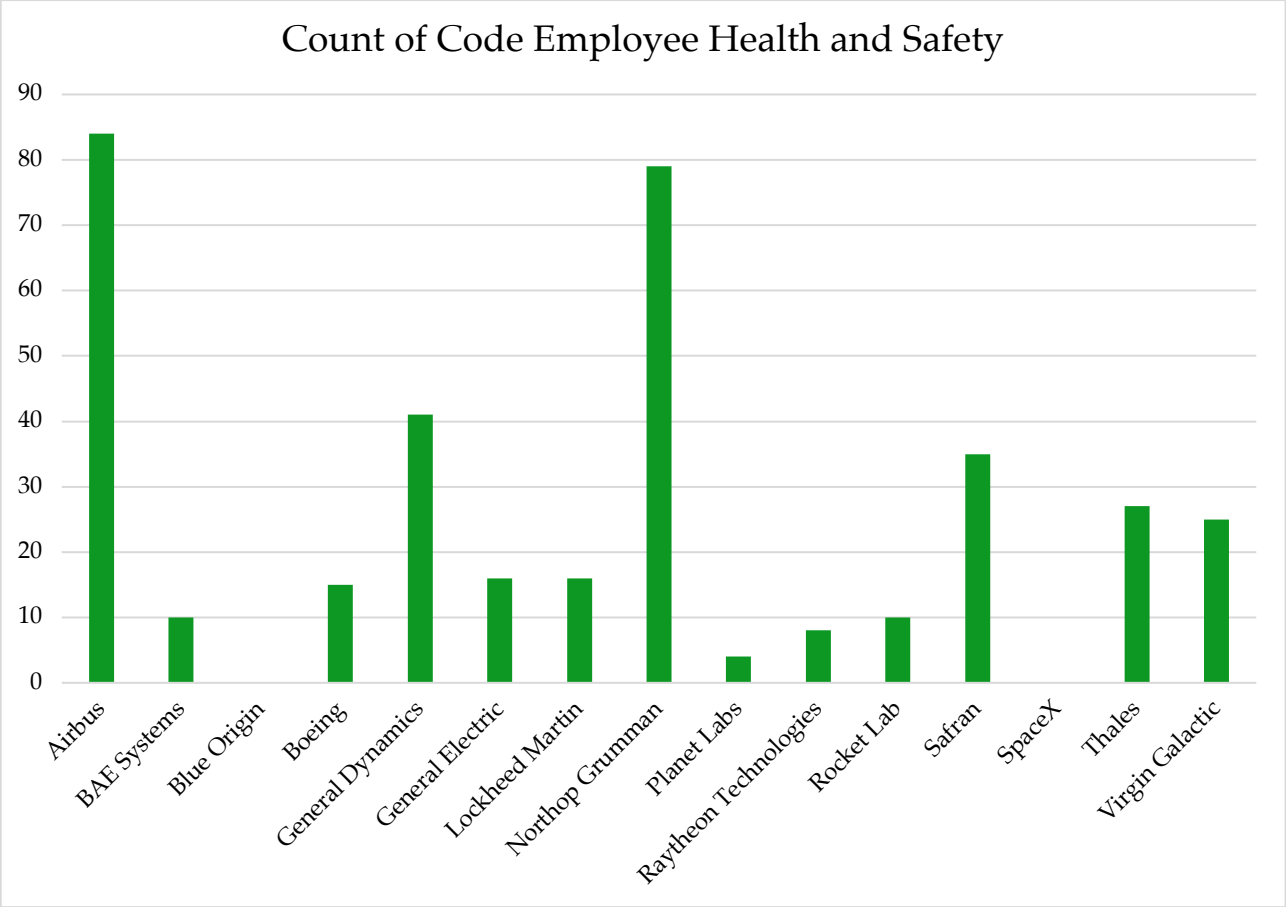
Figure 40. Presence of Code Employee Health and Safety



Source: Personal Elaboration

Observing the number of citations obtained by each company there is an evident dominance by corporate companies Airbus and Northop Grumman regarding information linked to practices and policies for the benefit of their employee's health and safety. In the case of the startup group, the head in line is Virgin Galactic.

Figure 41. Count of Code Employee Health and Safety

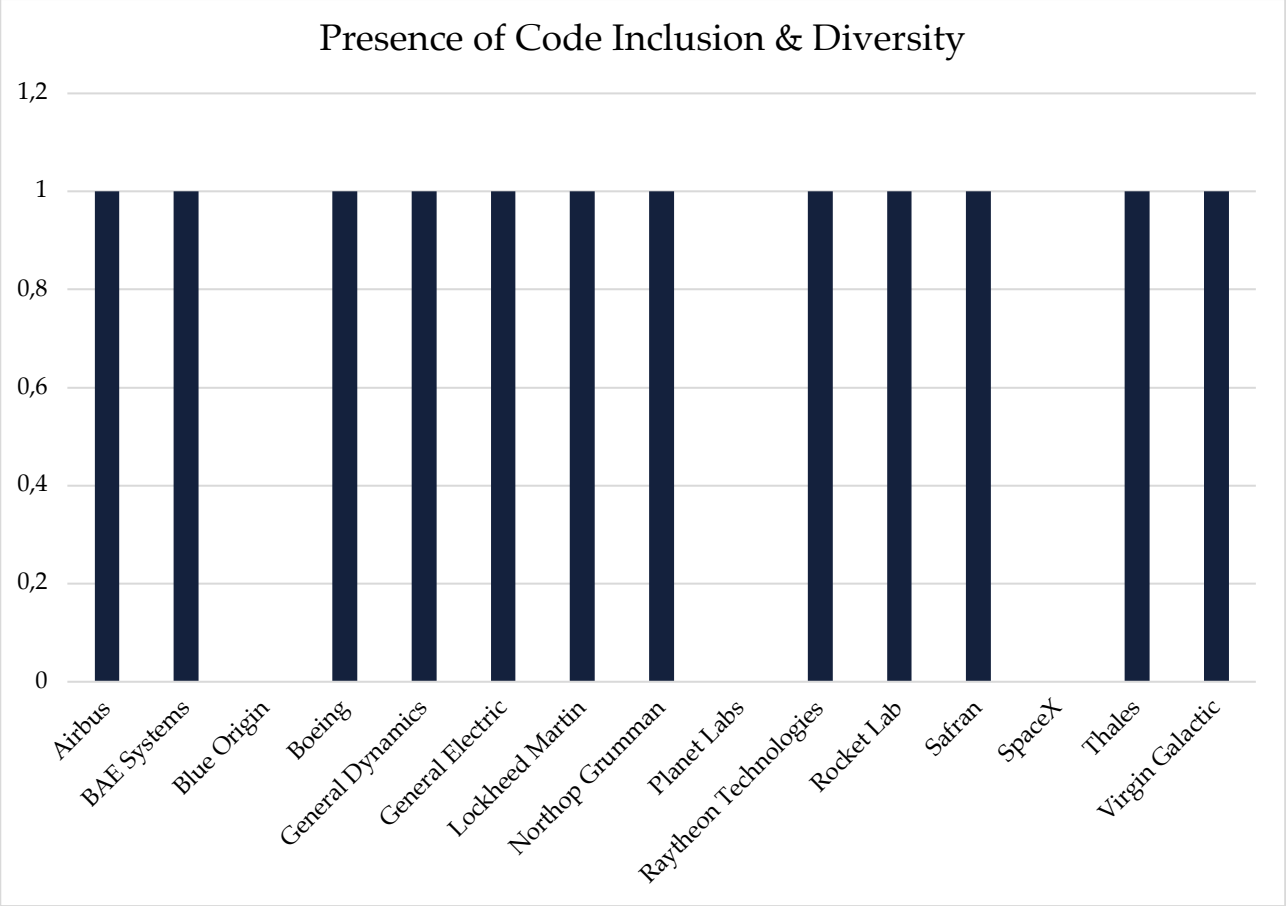


Source: Personal Elaboration

5.3.2. Results for the code Inclusion & Diversity

Inclusion and diversity is a code created for the identification of these two principles among the ESG reports of the selected companies. As shown in Figure 44 all of the corporate companies make reference to the promotion of these values but in the case of the startups 2 out of 5 companies refer to these aspects.

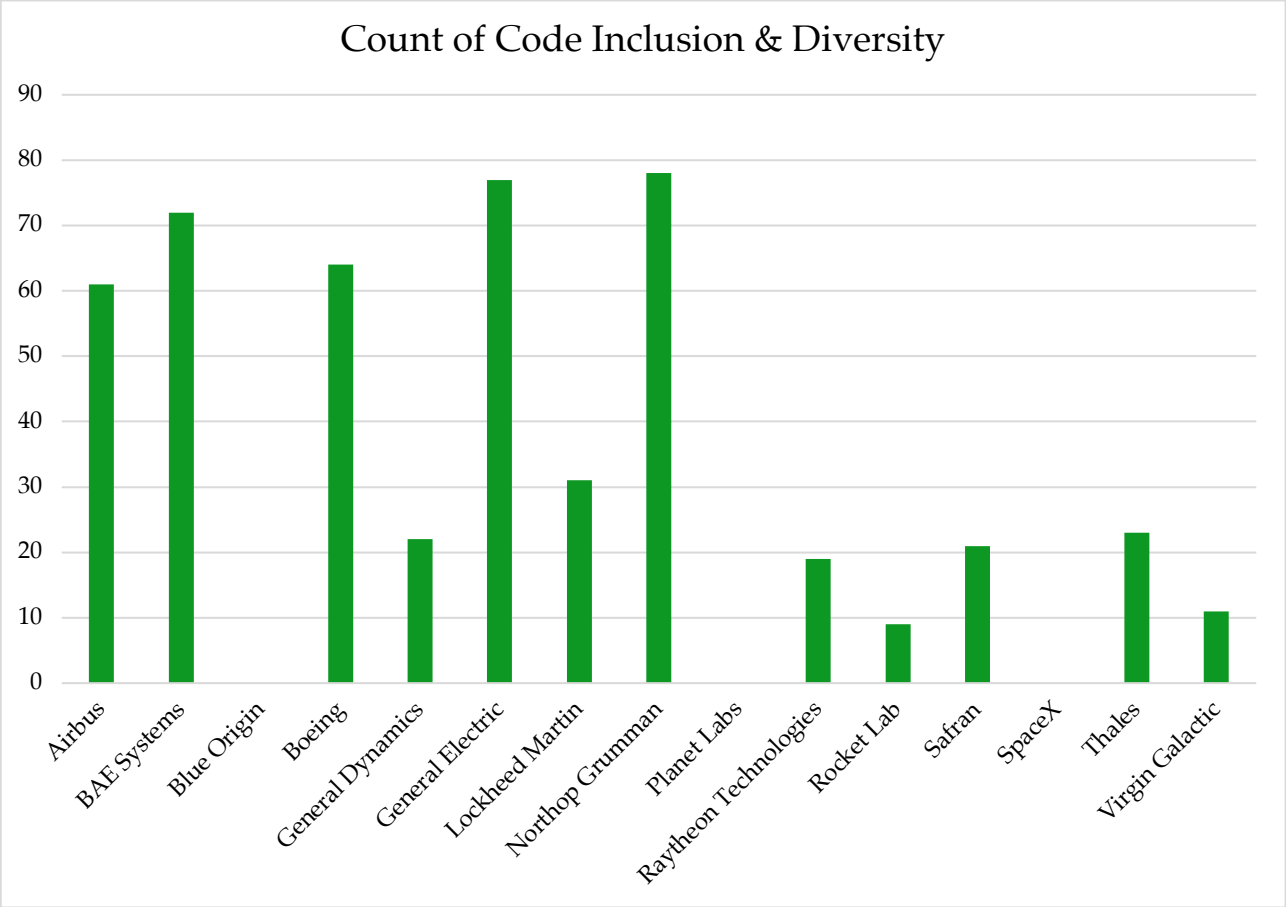
Figure 42. Presence of Code Inclusion & Diversity



Source: Personal Elaboration

For the count of codes of inclusion and diversity 5 out of 10 corporates have a fairly similar average of citations, these companies are: Northop Grumman, General Electric, BAE Systems, Boeing, and Airbus. In the startup group Virgin Galactic comes first and then Rocket Lab, the remaining 3 do not have citations for this code.

Figure 43. Count of Code Inclusion & Diversity

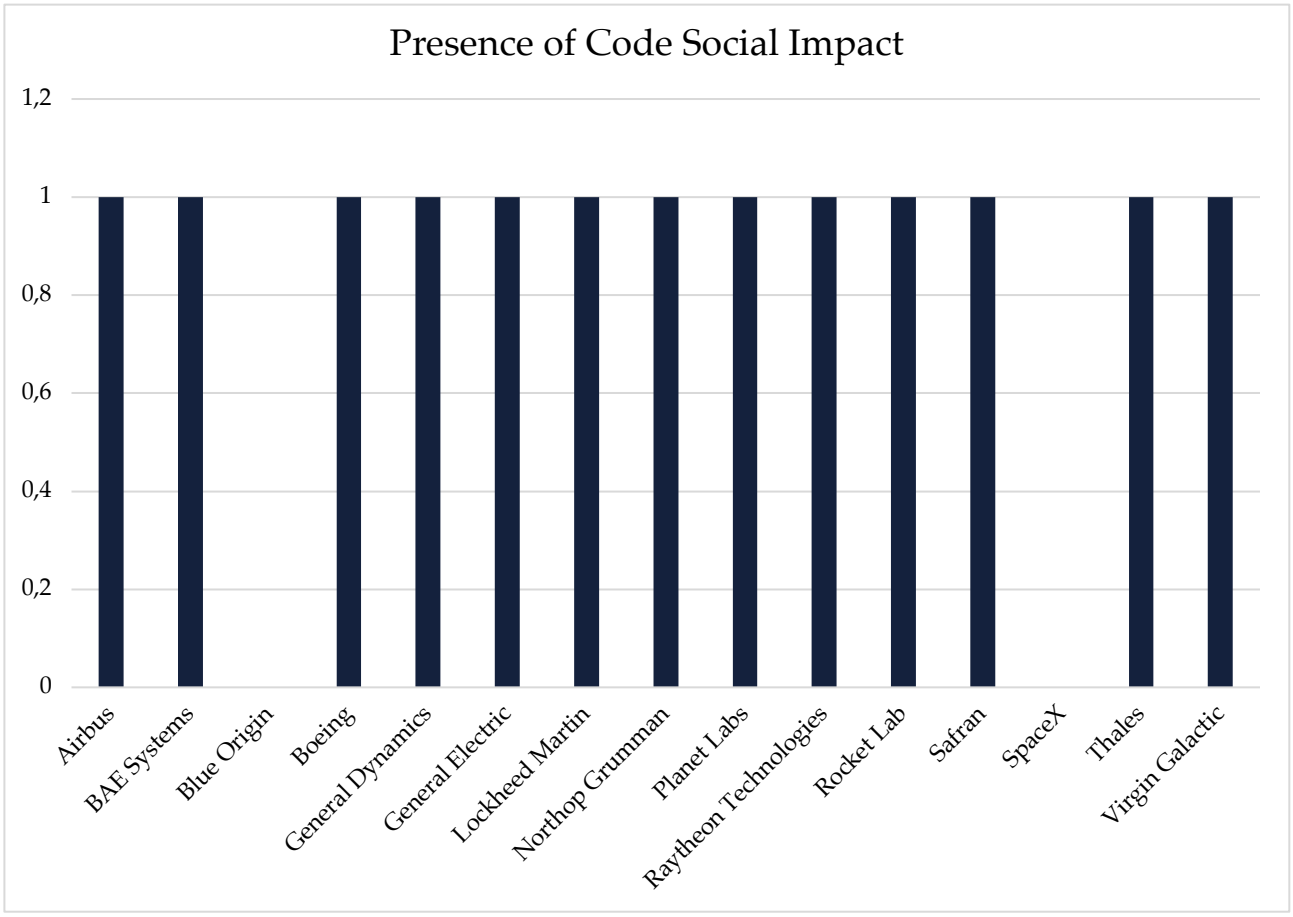


Source: Personal Elaboration

5.3.3. Results for the code Social Impact

The code social impact is associated with initiatives that impact the community for the betterment of society, all of the corporate companies disclose information on what are the actions they are implementing to positively impact society but in contrast only 3 out of 5 startups have the presence of this aspect.

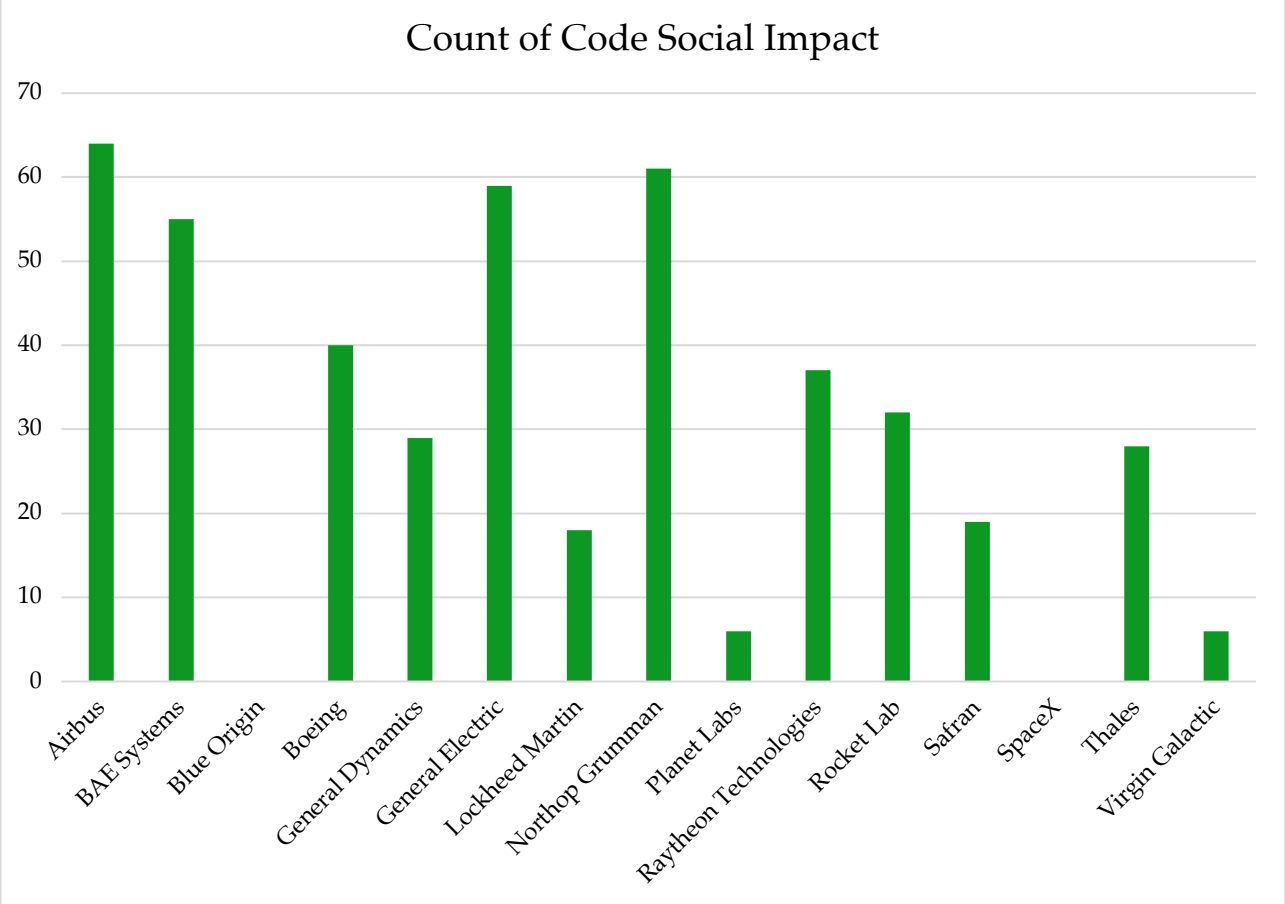
Figure 44. Presence of Code Social Impact



Source: Personal Elaboration

Reviewing the final number of citations for social impact corporate Airbus is positioned at the top of the list and Lockheed Martin placed last for this group. Then analyzing the startups Rocket Lab place first while SpaceX and Blue Origin have no citation associated with this code.

Figure 45. Count of Code Social Impact



Source: Personal Elaboration

5.3.4. Summary of Social Index

Corporate companies register no absences for the group of code of the social group. This demonstrates their involvement with the community, as well as the integrity of their employees and promoting values of inclusion and diversity. These results pose a contrast to the startup companies where 2 out of 5 companies have no presence of aspects from the social group.

Table 11. Summary of Social Index

Company Type	Company Name	Employee Health and Safety	Social Impact	Inclusion & Diversity	Si =∑ Social codes
Corporate	Airbus	1	1	1	3
Corporate	BAE Systems	1	1	1	3
Corporate	Boeing	1	1	1	3
Corporate	General Dynamics	1	1	1	3
Corporate	General Electric	1	1	1	3
Corporate	Lockheed Martin	1	1	1	3
Corporate	Northop Grumman	1	1	1	3
Corporate	Raytheon Technologies	1	1	1	3
Startup	Rocket Lab	1	1	1	3
Corporate	Safran	1	1	1	3
Corporate	Thales	1	1	1	3
Startup	Virgin Galactic	1	1	1	3
Startup	Planet Labs	1	1	0	2
Startup	Blue Origin	0	0	0	0
Startup	SpaceX	0	0	0	0

Source: Personal Elaboration

A Mann Whitney test is conducted to compare the result based on the type of company. The null hypothesis is that Si does not differ between Corporate and Startup companies. The result, however is that there exist a significant difference in the Si between the two groups ($z = 2.631$, $p=0.0085$; exact $p=0.0440$)($P\{Si(Corporate) > Si(Startup)\} = 0.800$).

5.4. Results of the Concept of Governance

Two codes were analyzed in the Governance concept:

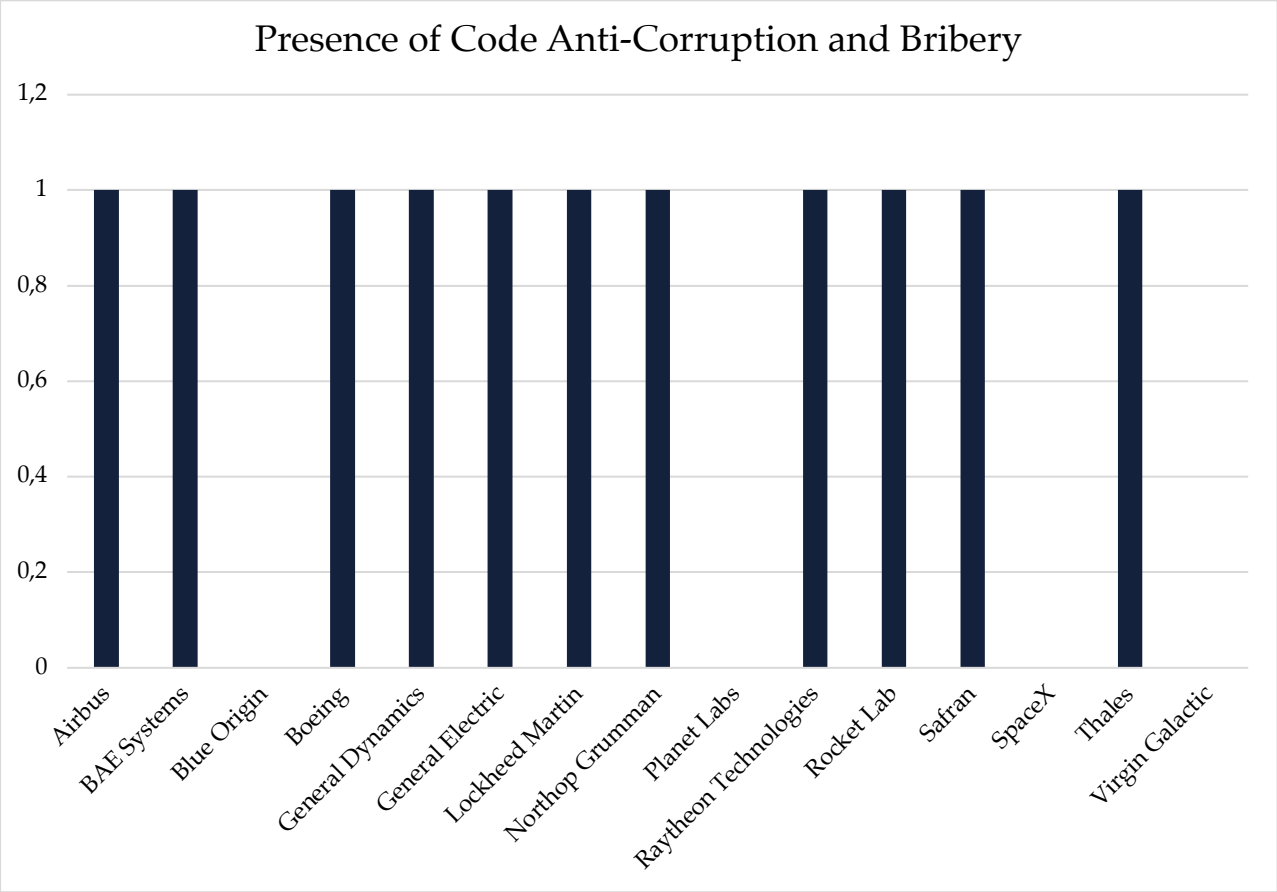
1) Anti-Corruption and Bribery

2) Business Ethics

5.4.1. Results for the code Anti-Corruption and Bribery

With respect to Anti-Corruption and Bribery, Figure 49 shows results for the presence and absence of the code Anti-Corruption and Bribery, which appears in 11 out of 15 companies. Moreover, three of the four companies for which the code is absent are start-ups.

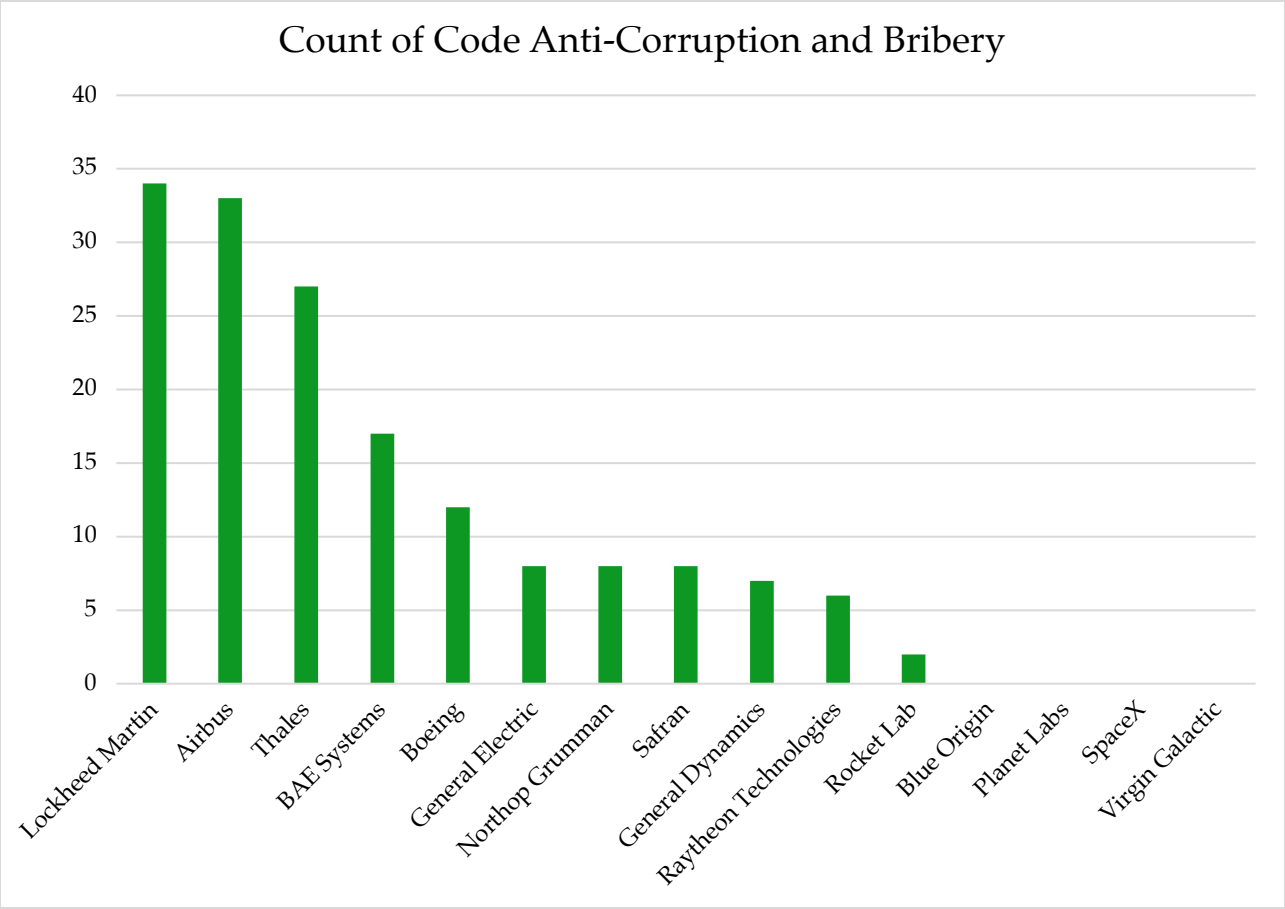
Figure 46. Presence of Code Anti-Corruption and Bribery



Source: Personal Elaboration

Figure 50 offers the results for the count of the code Anti-Corruption and Bribery, and it indicates the level of importance companies have for this code. It is considered that the number of citations of this code is directly proportional to the importance of this aspect to each company. This figure indicates that corporations are more concerned about this ESG concept since it is not found in the information available for start-ups.

Figure 47. Count of Code Anti-Corruption and Bribery

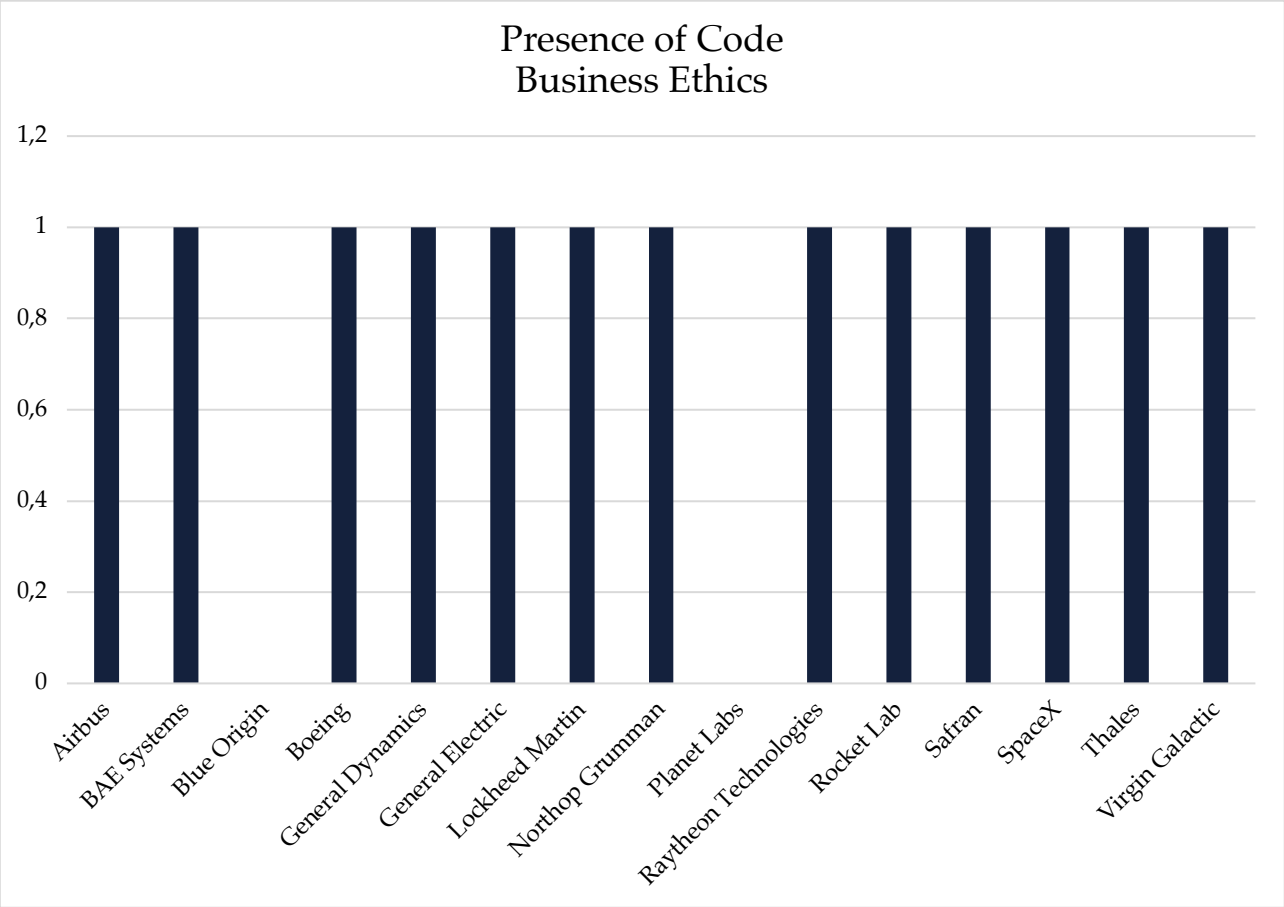


Source: Personal Elaboration

5.4.2. Results for the code Business Ethics

Business ethics is a critical aspect of Governance in timely businesses. All of the 10 corporates have the presence of this code but only 3 out of 5 startups disclose information on this code.

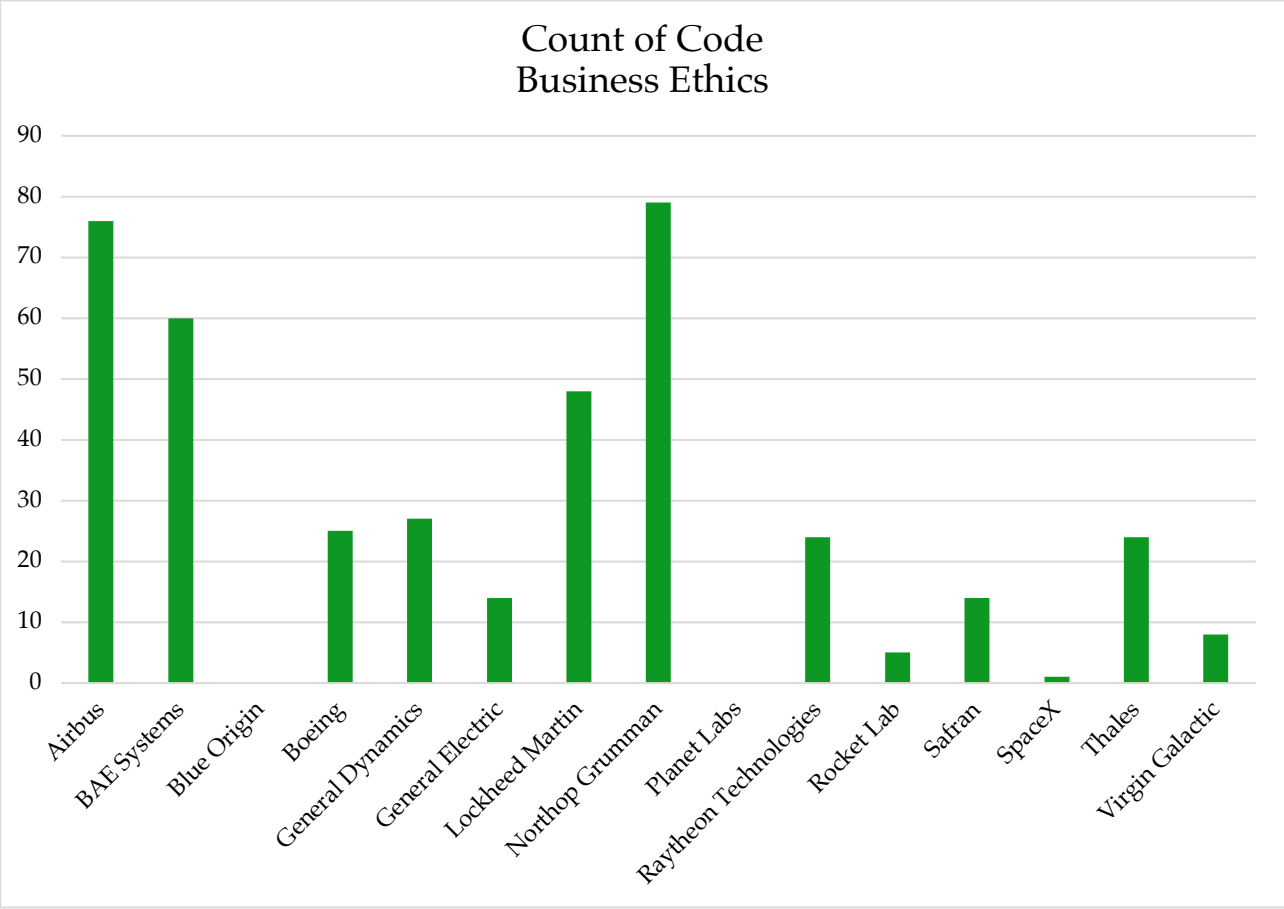
Figure 48. Presence of Code Business Ethics



Source: Personal Elaboration

Outlining the final results for business ethics Northop Grumman is at the top but very close follows Airbus, then for the startups Virgin Galactic is taking the first place, then goes Rocket Lab and in third place comes SpaceX. This is an indicator of the value business ethics pose for the selected companies.

Figure 49. Count of Code Business Ethics



Source: Personal Elaboration

5.4.3. Summary of Governance Index

For the governance index 2 out of 5 companies have no presence of data related to their strategies or policies concerning the 2 analyzed governance aspects. In this way, these two corporate companies are not prioritizing the exactitudes of the actions they are taking in this scope.

Table 12. Summary of Governance Index

Company Type	Company Name	Business Ethics	Anti-Corruption and Bribery	Gi =∑ Government codes
Corporate	Airbus	1	1	2
Corporate	BAE Systems	1	1	2
Corporate	Boeing	1	1	2
Corporate	General Dynamics	1	1	2
Corporate	General Electric	1	1	2
Corporate	Lockheed Martin	1	1	2
Corporate	Northop Grumman	1	1	2
Corporate	Raytheon Technologies	1	1	2
Startup	Rocket Lab	1	1	2
Corporate	Safran	1	1	2
Corporate	Thales	1	1	2
Startup	Virgin Galactic	1	1	2
Startup	SpaceX	1	0	1
Startup	Blue Origin	0	0	0
Startup	Planet Labs	0	0	0

Source: Personal Elaboration

A Mann Whitney test is conducted to compare the result based on the type of company. The null hypothesis is that Gi does not differ between Corporate and Startup companies. The result, however is that there exist a significant difference in the Gi between the two groups ($z = 2.631$, $p=0.0085$; exact $p=0.0440$)($P\{Gi(Corporate) > Gi(Startup)\} = 0.800$).

5.5. Summary of ESG Index

The summary of ESG index shows how robust the sustainability of each company is when considering the three ESG aspects as a whole. Obtaining a result below 14 indicates the absence of any of the ESG analyzed elements, this could imply a failure in communicating with transparency their ESG measures in the information available to the general public.

Table 13. Summary of ESG Index

Company Type	Company Name	Ei =∑ Environment codes	Si =∑ Social codes	Gi =∑ Government codes	ESGi =Ei +Si + Gi
Corporate	Airbus	9	3	2	14
Corporate	BAE Systems	9	3	2	14
Corporate	Boeing	9	3	2	14
Corporate	General Electric	9	3	2	14
Corporate	Northop Grumman	9	3	2	14
Corporate	Safran	9	3	2	14
Corporate	Thales	9	3	2	14
Corporate	General Dynamics	8	3	2	13
Corporate	Raytheon Technologies	8	3	2	13
Corporate	Lockheed Martin	7	3	2	12
Startup	Rocket Lab	7	3	2	12
Startup	Virgin Galactic	6	3	2	11
Startup	Planet Labs	7	2	0	9
Startup	Blue Origin	5	0	0	5
Startup	SpaceX	2	0	1	3

Source: Personal Elaboration

A Mann Whitney test is conducted to compare the result based on the type of company. The null hypothesis is that ESGi does not differ between Corporate and Startup companies. The result, however is that there exist a significant difference in the ESGi between the two groups ($z = 3.169$, $p=0.0015$; exact $p=0.0013$)($P\{ESGi(Corporate) > ESGi(Startup)\} = 0.990$).

5.6. Results for the Co-occurrence of Codes

For the assessment of the co-occurrence of codes, Table 14 shows a matrix depicting the number of companies where each combination of codes is present. Every raw indicates the co-occurrence between a code and the rest of codes. For example, the row for carbon footprint indicates that there are 11 companies for which both carbon footprint and Net-zero appears in their reports. As numbers are increases, it indicates that same codes tend to appear in various companies reports.

Table 14. Matrix of Co-occurrence of Codes

	Carbon footprint	Net-zero	Waste Management	Supply Chain Sustainability	Recycling	Sustainable development Goals	Climate change	Space Sustainability	Water Management	Employee Health and Safety	Social Impact	Inclusion & Diversity	Business Ethics	Anti-Corruption and Bribery
Carbon footprint	14	11	13	13	13	9	12	14	13	13	13	12	12	12
Net-zero	11	11	10	10	10	9	10	11	10	10	10	9	9	9
Waste Management	13	10	13	12	13	8	11	13	12	12	12	12	12	12
Supply Chain Sustainability	13	10	12	14	12	9	12	14	13	13	13	12	13	12
Recycling	13	10	13	12	13	8	11	13	12	12	12	12	12	12
Sustainable development Goals	9	9	8	9	8	9	9	9	9	9	9	8	8	8
Climate change	12	10	11	12	11	9	12	12	12	12	12	11	11	11
Space Sustainability	14	11	13	14	13	9	12	15	13	13	13	12	13	12
Water Management	13	10	12	13	12	9	12	13	13	13	13	12	12	12
Employee Health and Safety	13	10	12	13	12	9	12	13	13	13	13	12	12	12
Social Impact	13	10	12	13	12	9	12	13	13	13	13	12	12	12
Inclusion & Diversity	12	9	12	12	12	8	11	12	12	12	12	12	12	12
Business Ethics	12	9	12	13	12	8	11	13	12	12	12	12	13	12
Anti-Corruption and Bribery	12	9	12	12	12	8	11	12	12	12	12	12	12	12

Source: Personal Elaboration

5.7. Results for the Co-occurrence of Companies

For the assessment of the co-occurrence of codes, Table 15 shows a matrix depicting the number of companies where each combination of codes is present. Also, which are the companies using the same codes. Data in the table indicates high similarity in codes among corporate companies, and for a higher number of codes.

Table 15. Matrix of Co-occurrence of Companies

	Thales	Safra	General Dynamics	Northop Grumman	General Electric	Boeing	Lockheed Martin	Raytheon Technologies	Airbus	BAE Systems	SpaceX	Planet Lab	Virgin Galactic	Rocket Lab	Blue Origin
Thales	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
Safran	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
General Dynamics	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
Northop Grumman	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
General Electric	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
Boeing	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
Lockheed Martin	12	12	12	12	12	12	12	12	12	12	3	7	11	12	4
Raytheon Technolog	13	13	13	13	13	13	12	13	13	13	3	8	11	12	5
Airbus	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
BAE Systems	14	14	14	14	14	14	12	13	14	14	3	9	11	12	5
SpaceX	3	3	3	3	3	3	3	3	3	3	3	2	3	3	1
Planet Labs	9	9	9	9	9	9	7	8	9	9	2	9	6	7	3
Virgin Galactic	11	11	11	11	11	11	11	11	11	11	3	6	11	11	4
Rocket Lab	12	12	12	12	12	12	12	12	12	12	3	7	11	12	4
Blue Origin	5	5	5	5	5	5	4	5	5	5	1	3	4	4	5

Source: Personal Elaboration

5.8. Network of Companies and Codes

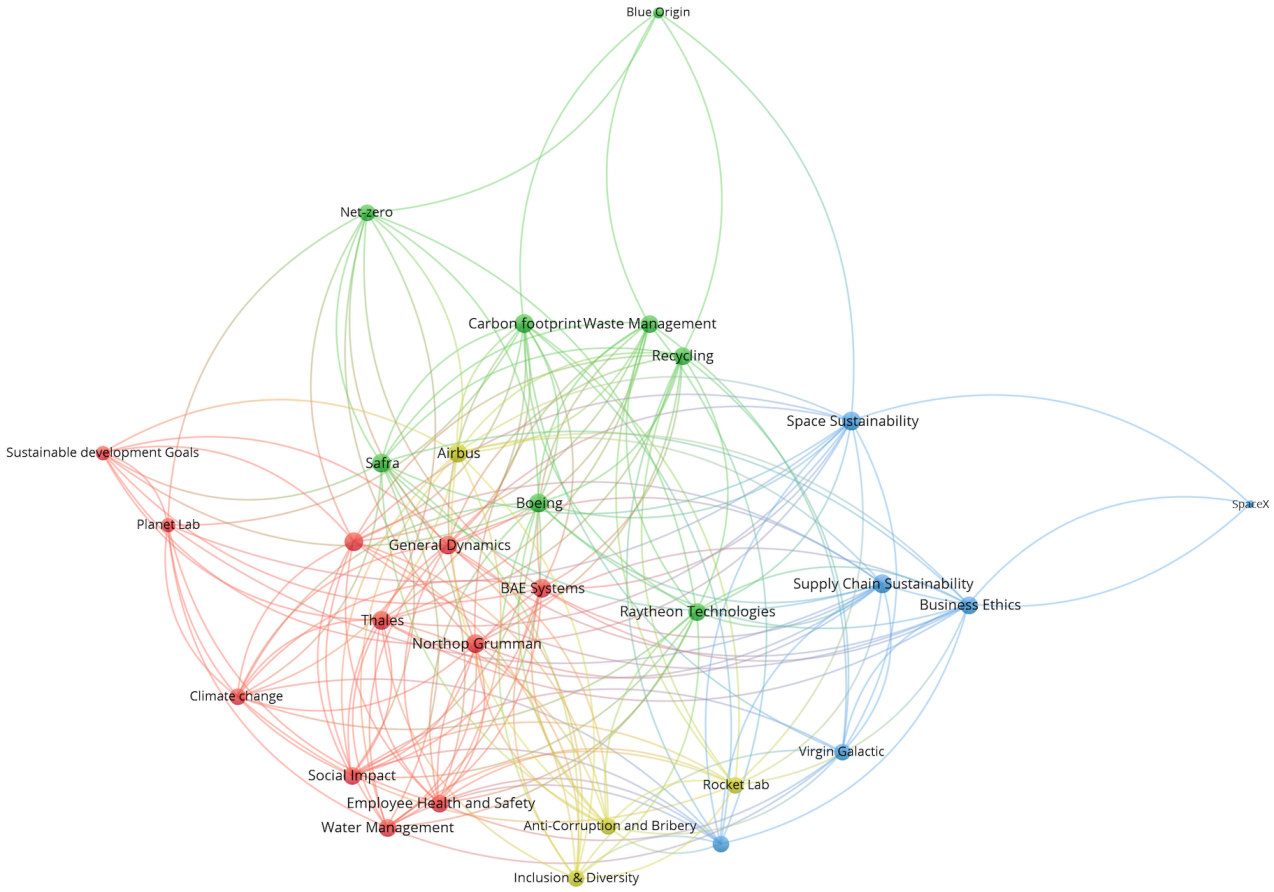
After analyzing the co-occurrence for companies and codes it is possible to integrate these two results in Table 16 to obtain different clusters resulting from the association of companies with similarities in the ESG aspects being addressed in the sustainability information gathered from each company. Then on Figure 55 there is a visual representation of these clusters.

Table 16. Network of Companies and Codes

ID	Label	X	Y	Cluster	Weight<Links>
6	Sustainable development Goals	-11.196	0.2802	**1**	9
7	Climate change	-0.7901	-0.3144	**1**	12
9	Water Management	-0.4252	-0.6329	**1**	13
10	Employee Health and Safety	-0.2978	-0.5718	**1**	13
11	Social Impact	-0.512	-0.5038	**1**	13
15	Thales	-0.4391	-0.1267	**1**	14
17	General Dynamics	-0.2767	0.0557	**1**	14
18	Northop Grumman	-0.2107	-0.1829	**1**	14
19	General Electric	-0.5061	0.0643	**1**	14
24	BAE Systems	-0.0478	-0.0497	**1**	14
26	Planet Lab	-0.959	0.1045	**1**	9
1	Carbon footprint	-0.0909	0.5971	**2**	14
2	Net-zero	-0.4728	0.8657	**2**	11
3	Waste Management	0.2151	0.5957	**2**	13
5	Recycling	0.294	0.5183	**2**	13
16	Safra	-0.4389	0.2552	**2**	14
20	Boeing	-0.056	0.1591	**2**	14
22	Raytheon Technologies	0.3299	-0.1061	**2**	13
29	Blue Origin	0.2371	13.552	**2**	5
4	Supply Chain Sustainability	0.7828	-0.0379	**3**	14
8	Space Sustainability	0.7071	0.3603	**3**	15
13	Business Ethics	0.9956	-0.0899	**3**	13
21	Lockheed Martin	0.3886	-0.6732	**3**	12
25	SpaceX	16.832	0.1575	**3**	3
27	Virgin Galactic	0.687	-0.4478	**3**	11
12	Inclusion & Diversity	0.0362	-0.756	**4**	12
14	Anti-Corruption and Bribery	0.1138	-0.628	**4**	12
23	Airbus	-0.2529	0.2801	**4**	14
28	Rocket Lab	0.4252	-0.5278	**4**	12

Source: Personal Elaboration with VOSviewer

Figure 50. Network of Companies and Codes



Source: Personal Elaboration with VOSviewer

Highly important environmental aspects like sustainable development goals, climate change, water management, employee health and safety, and social impact, are being undertaken by corporates Thales, General Dynamics, Northop Grumman, General Electric, BAE Systems along with startup Planet Labs, which are directly disclosing that they are working on improving in these areas. Other fundamental elements connected to the mitigation of negative environmental impacts are carbon footprint, net-zero, waste management, and recycling, these elements are being focused on startup Blue Origin and corporates Safran, Boeing, and Raytheon Technologies.

As far as being responsive to social and governance essential features functioning as, supply chain sustainability, space sustainability, and business ethics, the companies to be listed in the results of this study are corporate Lockheed Martin, next to startup SpaceX and Virgin Galactic. In this same manner but addressing factors such as inclusion & diversity, and Anti-corruption and Bribery the companies that appear to be aligned are corporate Airbus and startup Rocket Lab.

6. MAIN CHALLENGES FOR SUSTAINABILITY IN THE SPACE SECTOR

Through the realization of this master thesis, a clear focus on identifying the main challenges for the sustainability of the space sector was set from the beginning, this objective had the purpose of serving as a guideline for the prioritization of actions that contribute to a positive impact for Earth, space and for the benefit of humanity.

1. Development of an Effective Space Regulatory Framework

The international governance structure that is in place at the moment simply cannot keep up with the swift rate of evolution taking place in the space industry, and now that the Space industry is at a turning point due to its exponential growth, voluntary compliance to undertake actions for the mitigation of the collateral damage of the industry should no longer be acceptable. Instead, international collaboration between worldwide space agencies, governments, and leaders of the industry should take place for the establishment of an up-to-date governance system, because the current regime containing the regulations of operating in space is based on the Outer Space Treaties of the UN from the 1960s and 1970s which are not suitable to deal with present-day issues like space waste, moon rights of ownership, or extended revenue streams in LEO (Mckinsey, 2022). Moreover, as a result of space being a global asset, there must be a more rigorous legislation that ensures the maintenance of ethical and sustainable behavior in space.

2. *Value of the Return of Space Vehicles*

By establishing circular value flows and reducing waste, circular economy principles incorporate the environmental and social costs related to a specific item or service transaction (McElroy, 2022). The ultimate value recapture in the space sector can be achieved by product designs that incorporate attributes for durability, reusability, disassembly, utilization of versatile components, and recovery of materials. Recovery and reuse of launch hardware is a perfect example of a win-win situation in which what benefits the finances can also additionally improve the environment.

3. *Worldwide Launch activities control*

Despite the fact that greenhouse gas emissions from rocket launches are considerably low in comparison to other industries this is a matter that should not be neglected in consideration of the satellite launch contemporary demand forecasts for the long and the short term. It is crucial to keep in mind that if launch rates are greatly raised in the future, the repercussions might not be as minor as they are now and the main consequence in this situation would be ozone destruction. For the launch industry to remain viable, research into green technologies and propellants is crucial (ISU, 2010). As well as organizations engaged in the market development for rocket launches should prepare for a general limit on launches or for further technical mitigations that reduce ozone damage. (McElroy, 2022).

4. *Space Debris Mitigations*

The threat posed by space debris to the spacecraft of all nations is the most significant issue with regard to the safety, security, and long-term viability of outer space. The entire amount of space debris is increasing every year, and most of it is gathered in orbits where humans are active (Mahaseth et al., 2022). The demand for space and our growing reliance on it have highlighted the pressing requirement for regulatory and legal structures for managing the long-term risk that space debris raises.

This also calls for the increase of funding in space debris mitigation R&D that enables the advancement of technologies that remediates this harmful scene.

5. Space Economy in Support of SDGs

Amongst the goals of the current international space community, there should be an urgent claim for companies in the space sector to include the 2030 and 2050 agendas for sustainable development in their priorities and focusing on the solutions that space can offer for achieving the SDGs since this sector undoubtedly has the power to positively impact humanity on a global scale. Beyond seeking profit, the companies in the space economy should be seeking sustainability and the needs to be covered are found in the SDGs.

These challenges pose demands for cooperation across a wide range of stakeholders, government agencies, companies, educational organizations, shareholders, and the general public.

7. CONCLUSION

This exploratory research aimed to set focus on the sustainability of the space sector which is now undeniably going through a renaissance. This should not outweigh the sustainability of its operations and the appeal for a peaceful and thriving space industry that generates economic value and improves the sustainability, security, and responsibility of players on Earth may have long-term advantages (McKinsey, 2022).

Four main conclusions can be mentioned after the analyses conducted in this master thesis. The first is that over the past few decades, a significant number of actors have become involved in the space industry, with both new space enterprises and non-space companies entering the various value chain streams. Digital technologies are making it possible to produce goods more quickly, at lower costs, and with a variety of business models (PWC, 2020). This sector and its wide range of economic activities are composed of very diverse companies ranging from large corporations with profitable earnings to startups with multi-million-dollar investments.

Secondly, the benefits of space-based technologies to the environmental aspects of sustainability are not being questioned. However, a system of regulations and policies is required to support the commitment to reducing environmental impacts, in addition to the generation of encouragement to transform environmental and climate issues into business opportunities.

The third conclusion is that the economic growth of companies in the space economy has to go in hand with social development. This industry must increase its participation in activities targeting the reduction of inequalities with the promotion of inclusion and diversity across their workforces. It can also enhance the conditions of those who are in vulnerable positions through the support of local communities, not only limiting their contribution to space-related technologies but diligently setting in motion programs to mitigate current societal challenges.

In fourth place, this study has led to the conclusion that an effective governance structure is built on the basis of ethical principles. Companies in the space sector can only create a

safer world by prioritizing ethics and transparency, this will ensure a path to success sustained by values, accountability, and the desire to go ahead of what is necessary to meet global needs.

We are in a crucial period for guaranteeing that space is a secure, lasting, and accessible realm for everyone; without prompt and forceful action, beneficial results would not be attained (McKinsey, 2022). Space is already helping to advance important environmental and security goals. Available research demonstrates that it can contribute much more to the advancement of these universal goals if the international community adopts and develops critical space technology more quickly.

Nations must collaborate and work together in order to run a thriving global economy in space; international collaborations are essential for the space industry's value development and survival. (McElroy, 2022). Ultimately, the expectations for this sector rely on the creation of a feasible structure that achieves a balance between the beneficial effects of space activities and maintaining the integrity of the Earth's ecosystem.

Finally, As is the case of the majority of research studies, this one includes certain limitations, these limitations extend a series of opportunities for future research. For instance, international industrial classification rules do not recognize space as a category. As a result, there are differences in the definition, scope, and methodology of the studies on this global market. It is therefore challenging to compare the outcomes in general estimations for the actors of this sector (PWC, 2020). Further research could deepen the categorization of businesses in the space economy for a more accurate comparison among them. This study's data gathering and analysis methods are more theoretical than empirical. As a result, the outcomes may vary in other contexts based on different sustainability information disclosure guidelines, and different contexts would offer further insights into the intrinsic usefulness of ESG information.

In order to expand findings, enhance methodologies, and eventually deepen the understanding of the sustainability of companies in the space industry, it is hoped that this study will serve as a catalyst for future research.

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9. APPENDICES

9.1. Relationship of the Master's Thesis with the Sustainable Development Goals of the 2030 Agenda

As the space horizon broadens and more technological advancements are made, the advantages of space operations and services should be applied to eliminate inequality on Earth (Di Pippo, 2019). The SDGs can only be achieved by combining Earth-focused space research and technology with forward-looking space exploration. For this reason, UNOOSA has proclaimed space to be a vital resource for finding solutions to world issues. Partnerships are essential; despite disparities in politics, throughout the space age, the world has repeatedly demonstrated the marvelous results of joining forces through science and cooperating for the good of humanity.

This master thesis tackles the Sustainable Development Goals as part of the areas of discussion around the sustainability of the space sector. Insights on how the space industry is supporting the 2030 agenda are recounted in detail in section 3.3 Space Supporting the UN Sustainable Development Goals.

From the standpoint of business management, there are numerous ways that the space sector could generate intrinsic value for stakeholders in support of each SDG. For all of the SDGs, the space sector can either directly contribute to the SDG or has a higher duty to not cause damage (McElroy, 2022).

- SDG 07: Affordable and Clean Energy

The most efficient way to stop climate change will be to use clean energy more and reduce greenhouse gas emissions as a result, this is acknowledged in the challenges identified during the realization of this study.

Systems for remote sensing developed by the space sector can gather information on the amount of wind, sun, and clouds. In order to design and run power plants, this data can be utilized to forecast solar and wind activities.

ESA and their current programs in "SPACE4SDGS" detail how applications like infrastructure monitoring, power grid synchronization, seismic surveying, and solar and wind energy production forecasting represent a significant contribution to this SDG. More dependable, effective, and contemporary energy services can be achieved globally with the use of Copernicus and EGNSS (UNOOSA, 2018).

- SDG 09: Industry, Innovation, and Infrastructure

During the analysis of the contribution to the SDGs being made by companies in the space sector, it was clearly stated how companies like Thales with the presence of initiatives to engage in the pursuit of UN sustainable development goals, are for instance increasing their R&D investments and their private and public partnerships by having 40% of their employees working in R&D-related roles for the benefit of the space industry, innovation, and infrastructure.

Another aspect contained is this study worth highlighting is how the space industry with the development of technology enabling the ability to track goods and assets during their transfer is consequently increasing the efficiency and effectiveness of transportation activities. GNSS-based fleet management solutions are providing huge benefits to the transportation sector. Additionally, the use of GNSS greatly lowers the amount of fuel used in all forms of transportation by optimizing navigation routes, which in turn lowers CO2 emissions and lessens some of the effects of climate change.

- SDG 11: Sustainable Cities and Communities

Urban planning frequently utilizes satellite-based data to locate buildings and indicators for urban planning objectives. To manage growing populations and the demands they impose on transportation, metropolitan designs are going to require to evolve. The space

sector can improve this area with satellites that also offer data from the atmosphere monitoring service, which includes air quality, air pollution, and the state of the atmosphere above urban areas.

- SDG 12: Responsible Consumption and Production

The best way for space to promote responsible consumption and production is to work towards an efficient industry on Earth that as much as possible adheres to environmental aspects addressed in this research such as recycling, waste management, and pollution.

By creating reusable rockets and spacecraft, SpaceX hopes to increase the sustainability of space travel. The cost and environmental impact of launching payloads into orbit have been reduced by the company's many successful landings and reusing of its Falcon 9 rockets. Although has not mentioned that this is being done to support the SDGs it can be considered a significant contribution

The Defense and Space Division of the Airbus Company is working on a plastic-free supply chain initiative with the goal of reducing, reusing, and recycling single-use plastic trash and packaging throughout the Division's scope of activity by 2025. The project was initiated in 2019.

- SDG 13: Climate Action

Today, every nation on the globe is being impacted by climate change. National economies are being disrupted, lives are being affected, and today's costs will only increase in the future for individuals, communities, and nations (UNOOSA, 2018).

The utilization of satellite-based data is essential for understanding past, present, and potential future climate variability as well as for monitoring, reducing, adapting to, and attributing changes in climatic conditions.

EO services offered by startup Planet Labs have the potential to aid the development of sustainable solutions, monitor climate risk, and meet SDG 13.

- SDG 14: Life Below Water

The United Nations Educational, Scientific and Cultural Organization (UNESCO) launched the worldwide Ocean Observing System (GOOS), the largest and most extensive worldwide ocean observing system (Zong & Wang, 2022). Remote sensing and contemporary network technologies have recently boosted marine monitoring technology. The system is dependent on a network that has access to extensive and frequent monitoring data and consists of a satellite network, a coast-based autonomous observatory, and buoys.

The health of the ocean can be determined by measuring variables such as seagrass, coral reefs, water temperature, pH, salinity, and plankton from orbit by satellites. These variables also serve as indicators of biodiversity. Remote sensing devices also keep an eye on shipping activity in ports that may have an impact on SDG 14, for example, spillage of oil (Hedley et al., 2016). In this way, business operations in the space sector are greatly supporting SDG 14.

- SDG 15: Life on Land

It takes focused efforts to conserve, restore, and advocate the preservation and long-term utilization of agricultural and additional land ecosystems in order to preserve the variety of life forms found on Earth.

The migration of wildlife can be tracked using GNSS and remote sensing equipment, two of the main technologies provided by businesses in the space economy. A balance between farming, biodiversity, and urban infrastructure can be achieved by general land management practices that are informed by this kind of awareness into the ecosystem and habitat boundaries (Awange & Kiema, 2013).

- SDG 17: Partnership for the Goals

As mentioned in the priorities needing to be targeted for the space sector, cooperation between stakeholders, including businesses, shareholders, and organizations dedicated to education can aid the achievement of SDG 17, immediate action is required to organize, refocus, and unleash the transformative force of this soon to be trillion-dollar industry. Also, the development of an effective space regulatory framework has the power to ensure responsible space conduct in favor of this SDG.