POLITECNICO DI TORINO

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Analysis of space patents: classification of companies and citation flows in technical application sectors

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“Stay hungry. Stay foolish.”

Steve Jobs

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Abstract

The objective of this thesis is to identify and characterize space-related patents by classifying them as belonging to the upstream or downstream sector of space. In addition, it aims to create a patent repository and conduct a citation flow analysis to determine when an invention developed in the space context is subsequently used in civil domains, and vice versa.
The research is based on the identification and analysis of patents related to companies active in the space sector, considering both patents filed by them (root patents) and those that cite them (citing patents). Using tools and methodologies, such as the use of Power Query Editor for data extraction and citation flow analysis or the navigation on Dealroom.co and Derwent.co platforms, the aim is to trace citation paths and identify interactions between space and civil patents.

The scope is to understand the technologies behind that space-related patents and their applications in the civil context by analyzing the technical sectors identified by the International Patent Classification. In this way citation flows and interconnections between space and civil patents could provide valuable information on knowledge transfer between sectors and the impact of space innovations on civil society.

The creation of a patent repository and the analysis of citation flows represent a significant contribution to the literature on intellectual property in the space sector and to the insights of the links between space innovation and civil progress.

Introduction

The space industry has generated new business opportunities and contributed to the development of advanced technologies, especially satellite communication, which has revolutionized telecommunications by enabling global connectivity and a wide range of services, such as data transmission and mobile telecommunications. Earth observation from satellites has opened new possibilities not only in the purely space sector but also in the non-space sector, for example in environmental monitoring, agriculture, natural resource management and weather forecasting. In addition, space activities have stimulated innovation and involvement by other stakeholders in the fields of engineering, materials technology, and scientific research.

It is relevant to protect space innovations through intellectual property such as patents that offer companies and inventors the possibility of obtaining exclusivity and exploitation rights on their creations, encouraging innovation and knowledge dissemination. Intellectual property protection in the space sector encourages investment and stimulates competitiveness between companies so that all their inventions can speed up time to market and benefit economically.

Citation flows between upstream and downstream companies in the space context play an important role in knowledge and technology transfer. The upstream firms are involved in developing advanced space technologies such as satellites, rockets and space instrumentation, and can cite other companies' patents as the basis for their innovations. On the other hand, downstream companies use space technologies to provide services or develop applications and may cite patents from upstream companies as a reference to improve their own products or services.

Analyzing these citation flows is the main aim of this thesis work, to understand whether there is a form of collaboration and interaction between different entities in the space and non-space industry. In addition, citation streams can help identify major trends and directions of innovation in the space sector, enabling companies to adapt to new challenges and opportunities.

By analyzing which patents are most frequently cited, it is possible to identify key technologies and key players in each sector. This can help companies make strategic decisions, such as identifying potential collaborations, monitoring competitors, or identifying new business opportunities.

The research conducted is divided into three macro chapters, each one detailed according to the needs of the topics to be analyzed, starting with chapter 1 in which it is highlighted the importance of intellectual property, focusing in particular on patents, providing a general overview of the space sector in its transition from a traditional system to a new level called "New Space", focusing on the space economy that involves many companies (in particular startups, scaleups) whose economic contribution with continuous investment allows the progress of innovative developments in the sector.
The latter will be classified into upstream and downstream based on research conducted on the *Dealroom.co* platform whose methodology is described in the second chapter. While the third chapter will statistically examine them with interesting numbers on their worldwide distribution and patent ranges.
In this last macro chapter, the focus will also be on the relationships that exist between the various technological fields of application of these companies by studying the citation flows between patents on the *Derwent.co* platform.
Finally, conclusions with the main expected results close the paper.

1. Theoretical foundations and context

1.1 Key concepts related to intellectual property and patents

Intellectual properties are relevant in today's economy based on creativity and innovation, as for start-ups they do not allow the replication of certain products that are launched to the market, while for larger companies they are useful for generating profit from their investments. Therefore, a new product or service is considered an invention if it guarantees the opportunity to generate income by attracting funding. If intellectual properties were not available, not only numerous innovative projects would not be financially viable, as anyone could freely replicate the outcomes, but also all other competitors would make use of the same product invention by placing it at a lower price on the market, generating a price war, since they have not incurred R&D costs.

The different types of intellectual property include patents, utility models, copyrights, trademarks, registered/unregistered designs, trade secrets and other forms of IPs.

The focus in this work of thesis is on patents, which represent intellectual property rights that offer protection for an invention within specific jurisdictions.

Patents are often regarded as a 'limited monopoly' as they can prevent competitors from entering the market or using a patented technology. Obtaining a patent can be an expensive undertaking, especially for more complex applications and if it covers several jurisdictions, that indicates a strong interest and potential significant investment by the organization in the specific field (Trippe, 2015).

An invention is patentable if it meets the following requirements:

- Novelty
- Inventiveness
- Industrial applicability
- Not contrary to morality or public order (e.g., all inventions related to human cloning processes, or the commercial use of human embryos are excluded)

Ideas, concepts, discoveries, PC programs, business methods, or teaching methods cannot be patented. However, if a computer program is used to achieve a technical result, such as in an electronic control device, it may be eligible for a patent (IPTK basics, 2018).

A patent contains three different macro sections that appear in almost every document regardless of jurisdiction: a first page with **bibliographic data**, a **description** (Disclosure), and a **claim** section. Each of these is then structured into several sub-sections, which are divided into different fields when these documents are used to create databases. One can also find a graphic section with a visual representation of what the patented tool is. The various sub-sections include:

Applicant/Assignee: this refers to the individual or entity that applies to obtain an industrial property right (such as a patent application) at an industrial property office. Typically, the applicant is the actual inventor, but it can also be an employee or someone to whom the inventor has transferred their rights to the invention (assignee). Usually, the applicant is a company or organization, but in cases where the rights to the invention are not transferred to another entity, the applicant can be the inventors themselves (Trippe, 2015).

Inventor: this is the individual who is responsible for creating an invention in terms of intellectual effort associated with it, so that he has the right to be acknowledged as the creator of the invention in the patent. Compared to assignee or applicant, the name of the inventor does not change over the life of a patent application (Trippe, 2015).

Priority, filing and publication date: They are the main dates in the life cycle of a patent. The filing date depends on the patent authority receiving the request, the priority date relates to the filing of an earlier application if the applicant claims the priority of the latter, and finally the actual publication date of the patent (usually 18 months after the filing date or earliest priority date) (Trippe, 2015).

Classifications: It is organized in a system which subdivides the technology into different units by assigning a symbol inherent to the technical nature of the invention under consideration. Sometimes, the classification relates not only to the claimed technology but also to other disclosures contained in the patent document. The system used to classify an invention is based on the International Patent Classification (IPC) that is currently used by most jurisdictions and patenting authorities in the world (Trippe, 2015).
This classification method identifies different sections, each corresponding to a letter from A to H as follows in the *Table 2.1* below:

A	Human necessities
B	Performing operations; transporting
C	Chemistry; metallurgy
D	Textiles; paper
E	Fixed constructions
F	Mechanical engineering; lighting; heating; weapons; blastings
G	Physics
H	Electricity

Table 1.1 IPC technical application sectors

An example of a classification for a technology is reporting in the *Table 2.2* below:

Section	G	Physics
Class	G01	Measuring; Testing
Subclass	G01S	Radio direction-finding; radio navigation; determining distance or velocity by use of radio waves
Class Group	G01S0019	Satellite radio beacon positioning systems; determining position, velocity or attitude by using signals transmitted by such systems
Subgroup	G01S001948	By combining or switching between position solutions derived from the satellite radio beacon positioning system and position solutions derived from a further system

Table 1.2 IPC framework

Citations: During the examination process of a patent application, an examiner reviews prior art relevant to the novelty, obviousness, or inventiveness of the invention. When such references are found, they are cited within the document at various stages of publication, typically in a search report accompanying the document. Citations are associated with references that may pertain to a similar subject matter as the proposed application. By citing these references, it indicates a technological connection shared between two documents (Trippe, 2015).

Granting of licenses

Generally, it is permissible for the owner of the intellectual property to license it to third parties who can use that service. They are granted in exchange for the disclosure of the invention itself. A granted patent confers the exclusive right to produce and market what is associated with the invention.

A practical application spinoff is involving NASA (National Aeronautics and Space Administration) through the commercialization of its technologies by incorporated companies. As soon as the company starts selling the product, NASA collects royalties.
To mainstream its inventions, NASA created a Tech Transfer program in 1962 and since then, it has granted 1600 licenses. Currently there are about 450 active licenses for NASA-patented technologies, with 100 new licenses roughly being executed each year. In 2016, 2600 software usage agreement were issued. NASA makes these technologies available to academia and industry, as well as state and local governments, through their patent licensing program (Nakahodo and Gonzalez, 2020).

Among the technologies patented by NASA, one example that can be classified as a non-space one, is a method and apparatus for detecting deception, high stress, or internal conflicts in responses of a subject, contained in the description of **Patent No. 8,337,208**.
The use of this technology occurs during criminal interrogations or for an employment screening in which the interrogated subject is interviewed to check his reaction to the questions posed in terms of internal conflicts in the oral and written responses. It can have different fields of application, from interrogations of criminal defendants to employment screenings, or in medical psychology for mental health assessment. In concrete terms, it is a fully computerized and automated method that detects the presence of internal conflicts in the reaction of an interrogated subject to questions put to him/her. For example, if the answers are unclear, not complete with information, not truthful, or even this instrument is able to detect if one is purposely creating totally false discourses to distract from the evidence or facts that really happened.
These inconsistencies are more challenging to be identified and less immediate compared to identifying factual inconsistencies for a human being by manual techniques. Therefore, this equipment uses supporting algorithms that based on the answers obtained sets up three stages of statistical analysis that examine, for example, the order of the words provided by the subject both in writing and orally, when stating his country of origin or his job. After which a heat map comes into play that associates each word with an emotion or state of mind.
This subset of dimensions is closely scrutinized to identify responses in which the subject exhibits strong stress, emotional volatility, and internal conflict, each of which may indicate deceptive responses.

Another example of technology patented by NASA relevant to the engineering management field is described in **Patent No. 8,224,472**, which describes a system for organizing, analyzing, and presenting periodic progress reports on certain tasks and the next steps of projects in a project portfolio.

When an individual is facing with a project of medium to long duration (e.g., 6 months) in which it is very likely to be necessary to manage and monitor the progress of many tasks, sub-tasks, and the allocation of resources pertaining to that task, it is then necessary at scheduled times to have certain checkpoints or meetings to assess the progress of the work. During the resource allocation phase, the managers who will follow that project must carefully determine which resources will be part of the team, both in terms of preserving collaboration during the performance of activities, especially in interpersonal relationships, but also in terms of the suitability of skills to be able to perform that particular task, so as to avoid the risk of suffering delays in product development or worse, not completing the project due to the mismatch of technical characteristics of the same.

The produced reports are accessible to all those involved in the project and others, except for more sensitive information that only a small number can consult.

Concretely, it is needed a system that based on the user's request guarantees the automatic provision of monthly reports on budget, workforce utilization, spreadsheet analysis, calendar management, risk allocation, classes of projects, a benchmark analysis of project performance. To do this, the system needs a link to external resources so that it can integrate information internally, such as the name of a company's employees and the related skills, so that when a new project is about to start and the team that will follow the work has to be determined, then the system itself will return the correct allocation after having gone to the skills module.

Clearly this is a customizable solution, in the sense that each user can focus only on the reports that interest him or her.

Among the benefits of such a Project Management Tool there is the ability to store previous versions of a current report, so that comparative analyses can be performed in the future by retrieving that numerical data.

Finally, the system is also able to provide the Schedule Index and Cost Index by analyzing the Earned Value of a project, starting from its Budgeted Value and Actual Cost.

1.2 Overview of the space sector and companies involved

The space sector is expanding so much globally that many both public and private investments are being made, interest in space exploration activities has also grown, with more than 80 countries registering satellites in orbit (see next histogram in *Figure 1.1* to observe the trend of satellite launches from 1957 to the present day). Important players such as NASA, ESA (European Space Agency) or SpaceX, which are committed to promoting entrepreneurship, increase investments as part of their goal to support a global space society (Moranta and Donati, 2020), fit into this context.
SpaceX for instance in 2018 launched 15 rockets and a satellite used by NATO to announce its willingness to reinvent the concept of space, or another space giant like Blue Origin in 2019 launched the first tourists into space (ESC, 2018).

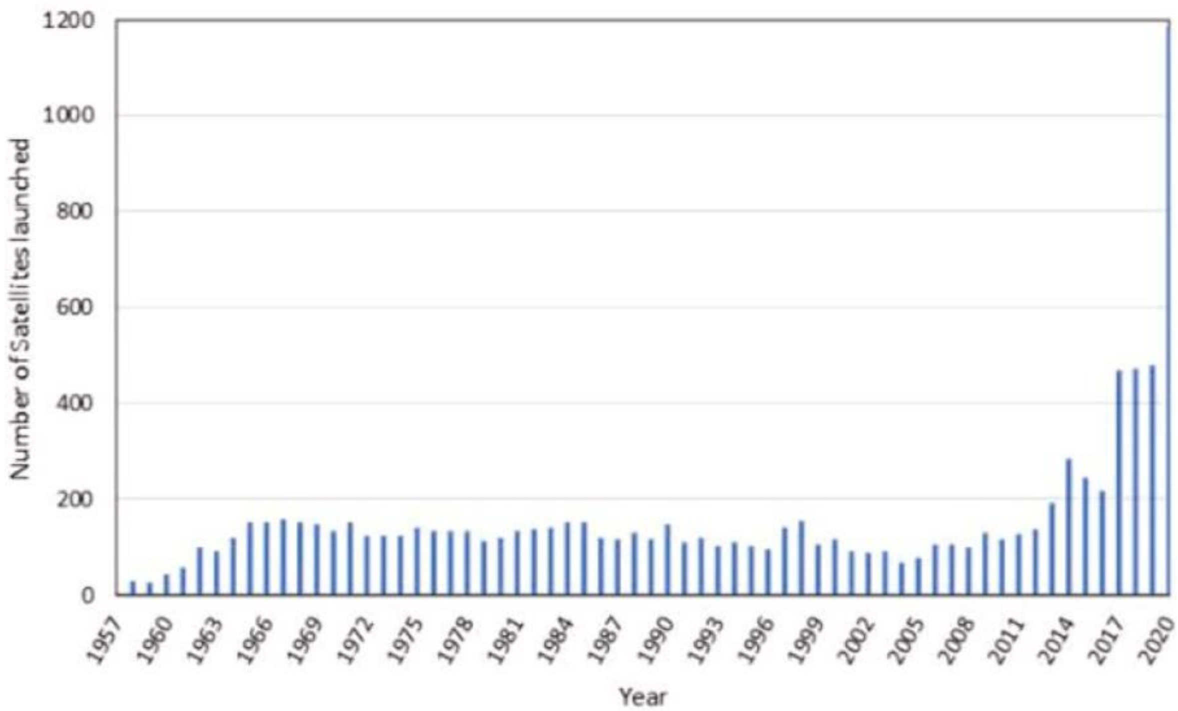


Figure 1.1 Satellites launched per year from 1957 up to date

Since these are miniaturized satellites, there have been major improvements in the reduction of launch costs compared to traditional spacecraft by 70%, one of the biggest factors in this revolution has been reusability. For example, SpaceX has landed 69 boosters on planet Earth since 2020, many of which have been reused again for a second and third mission, even reaching a record of being used six times on the same booster. China's Mars trips and the Prometheus project are also targeting this type of cost reduction and 30% launch price savings if reusability is exploited (Nicola Garzaniti, 2021).

Apart from the USA, to facilitate the emergence of a dense, dynamic network of investor-backed companies for the benefit of European stakeholders both public and private, it is necessary the awareness by every actor involved in about the state of affairs. The European Space Policy Institute (ESPI) is working in this direction by conducting a study with the aim of collecting and consolidating relevant data to assess private investment in European space start-ups and to examine the trend and future perspectives of entrepreneurship in the European space sector in comparison, for example, to that in the US (Moranta and Donati, 2020).

Public investments in space give rise to the development of new space products and services in an emerging market of innovative business models in which space-related competencies are exploited as core competencies in such a way as to reap economic, social and environmental benefits.
In contrast to public, private actors in these circumstances conduct space business differently from governments, thus coining a new development called 'New Space' in which various tangible, business- and service-oriented trends intersect (Moranta and Donati, 2020). New Space refers to all those space activities that develop lower-cost solutions compared to traditional space systems, product development processes (e.g., agile) and innovative business models, less structured organizations for instance by the presence of departments, much faster time to market, the ability and willingness to take risks with a spirit of enterprise, and expectations of doing profits from such technological development (Nicola Garzaniti, 2021).
This transformation is characterized, among other things, by an increasing investment and involvement of private actors, including new entrants and start-ups to the extent that they become more attractive to other investors. The Bank of America Merrill Lynch has estimated that the value of the space sector could reach **USD 2.7 trillion in 30 years** (Moranta and Donati, 2020).

The most important factors driving financial market interest in the space sector are summarized in the *figure 1.2* below:

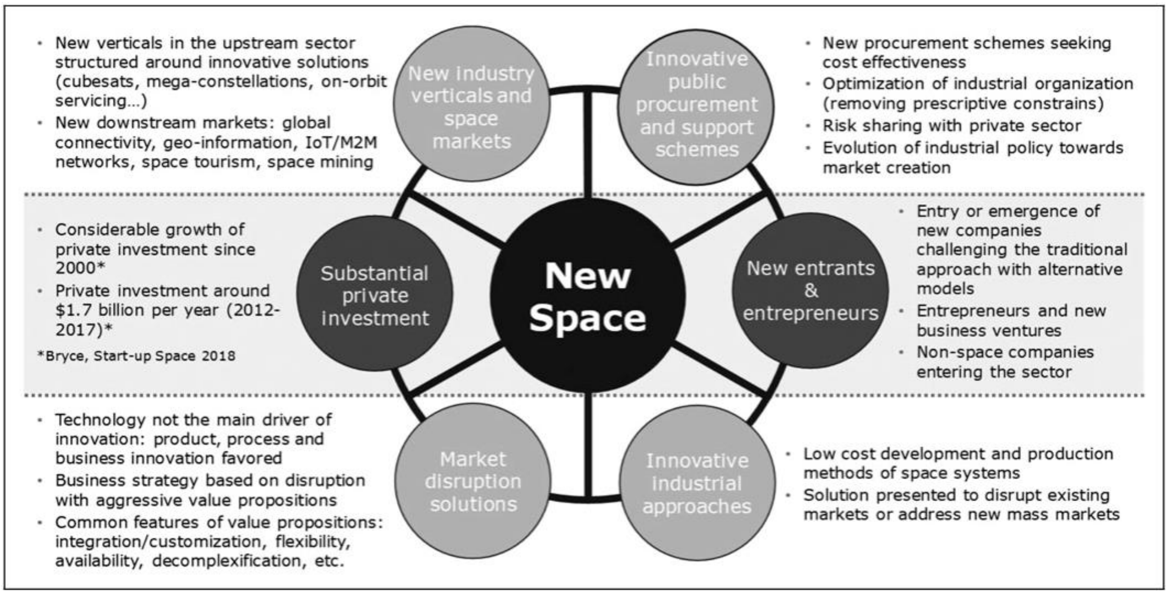


Figure 1.2 Factors driving the New Space

According to a study on technology trends based on a commercially available patent analytical tool, there are more than 200 New Space missions throughout the framework.

The application areas involved in the development of new products and services of these missions' concern, for example, "remote sensing and imaging, launch systems, flight systems, telecommunication systems, constellation management, digital processing architectures, image analysis, manufacturing process and materials, feature recognition and extraction, antenna systems and space platforms" (Nicola Garzaniti, 2021).

Since most of the stakeholders conducted in New Space are all private, one very often runs into the problem of not being able to see their latest progress because it has not been published in papers for fear of lack of commercial development of a deposited solution, or even lack of interest. This is why the analytical study of patents is of fundamental importance in being able to supplement the lack of such information, in order to draw conclusions on how New Space is evolving and to be able to delineate a perimeter around it composed of relevant actors, products and technologies (Nicola Garzaniti, 2021).

In these terms, a patent is designed to identify emerging, disruptive, or promising technologies and to monitor technology trends in general. Positive results have been found in areas such as telecommunications or battery technologies for electric mobility, or in the sector of production technologies like the Additive Manufacturing.

However, most New Space companies are start-ups or otherwise small companies, which by nature prefer to develop a single technology or focus on a niche market through their own resources. Along the New Space supply chain, there are upstream companies that protect their intellectual property (e.g., through trade secrets), as opposed to downstream companies that could have a much higher patenting activity.

New Space vs Traditional Space

The life cycle of a technological innovation is described by a S-curve which initially defines a slow growth phase of the innovation, with a starting initial adoption. In this stage the technology is immature and needs investment to become an emerging one. Subsequently, when the innovation reaches a critical mass of adoption and awareness, growth accelerates rapidly, forming the ascending part of the S-curve and there is a positive a positive return to the initial investment.
Finally, the curve declines and flattens out when the innovation reaches market saturation and adoption stabilizes.
This path is represented in the *figure 1.3* below for the traditional space industry, where the product development phase of a space tech s-curve can be so long (from 5 to 15 years) that there is need of a great effort in terms of investment, otherwise the risk of deterring is high. Once this phase will be overcome, the space company would benefit of a longer period of positive return (10-15 years) during the commercial adoption and harvesting stage.

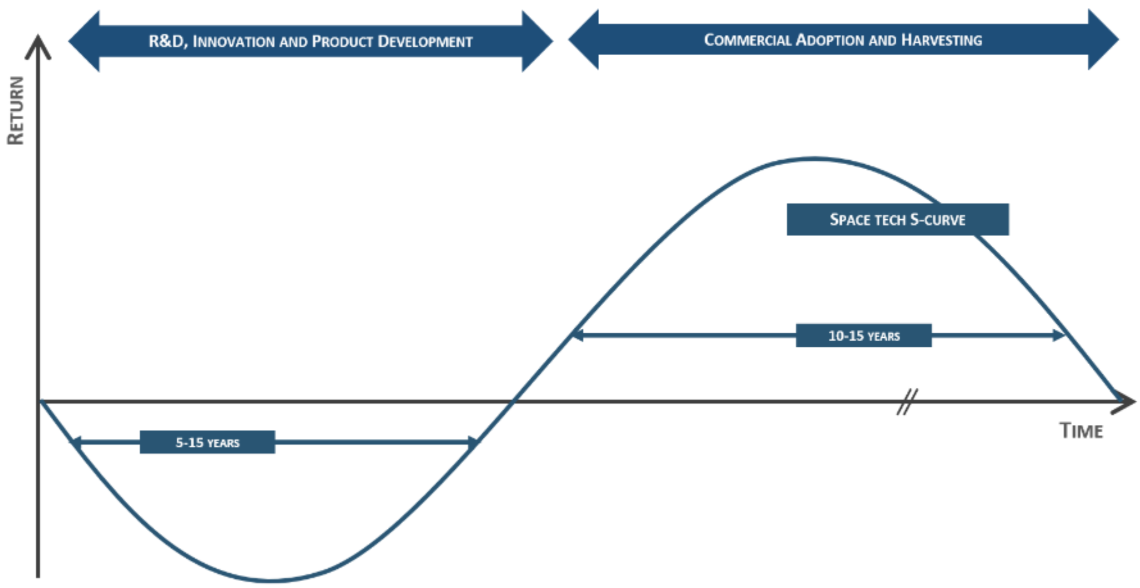


Figure 1.3 S-curve of a traditional space technology

With the advent of the New Space, business models and technologies in the industry have undergone major improvements, radically changing what was the traditional model's idea of innovation. Improvements in costs, complementary assets, and design processes have reduced the product development phase, thus requiring less investment than previously necessary. For example, the enhancement for satellites and spacecraft relies on the concept of miniaturization, which refers to the trend of reducing the size and weight of instruments, devices, and components to optimize the limited resources available during space missions and to enhance overall efficiency, flexibility, and performance of space systems

In parallel, these changes have accelerated the adoption and commercialization of technology. The repercussion on the S-curve of such radical changes is a shift towards the left as reported in *figure 1.4* below.

The future expectation is for a further reduction in the timeframe of the product development phase dictated by continuous advances and discoveries in the field of manufacturing technologies, including components, electronics, and digital transformation.

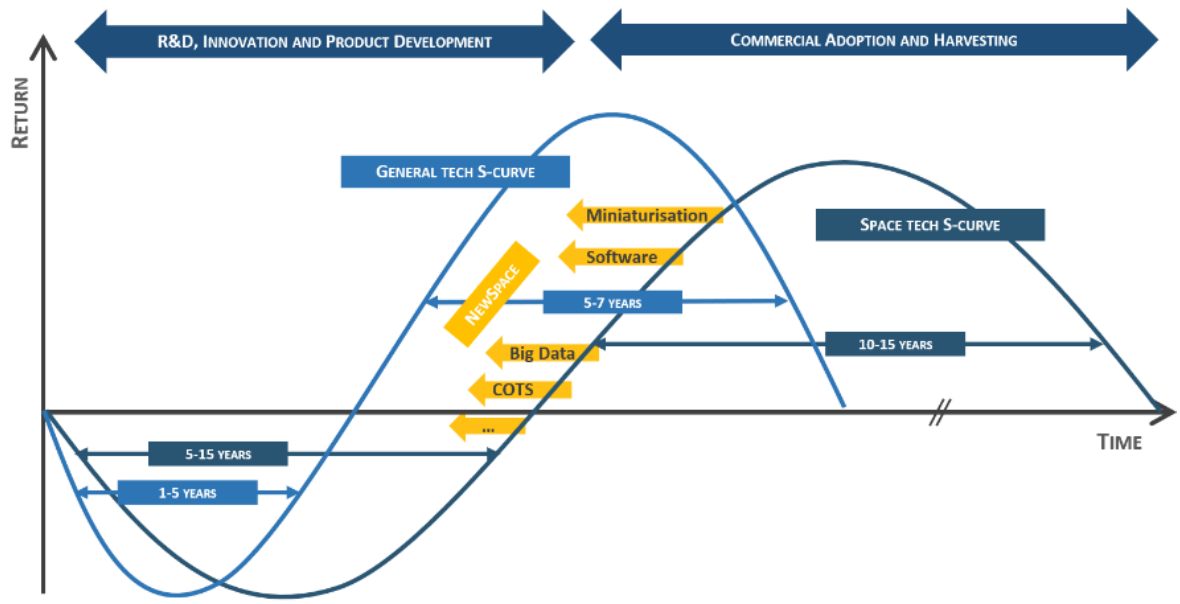


Figure 1.4 S-curve shifts to the left with the New Space age

In the same figure above, it can be observed an overlap with another curve for information and communication technologies, which differ from space technologies both in the initial product development phase and in the positive return of investment phase. Such investment requires an initial effort for only 1-5 years in ICT technologies, compared to 5-15 years in the space sector. This substantial difference highlights the need for larger investments and high capital requirements in the space sector.

Patents can influence the S-curve of innovation, as inventors who protect themselves through an intellectual property want to gain a competitive advantage over other companies in the market, compared to which they want to accelerate the growth and diffusion phase of innovation, facilitating technology transfer.
Once the patent expires, the slowing down phase of the innovation begins, and it becomes of public domain and accessible to all without restriction.

Space Economy

The space economy can be defined as "the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilizing space" (OECD, 2020).
This encompasses a wide range of sectors of space applications, activities and resources that contribute social value (*digitization*) and benefits to humanity through satellite communications (e.g., commercial geographic information systems), positioning (e.g., Global Positioning System based products), navigation and timing, Earth observation, space transportation, space exploration, science, space technologies (OECD, 2012).

The challenge is converting space and non-space activities, fueling a great deal of investment interest from various stakeholders: angel investors, venture capital firms, private equity firms, banks, corporations, accelerators, and incubators. These actors generate a considerable optimism about market prospects together with the involvement of major information and communication technology companies in the sector. A concrete example of such a venture is the collaboration between NASA (National Aeronautics and Space Administration) and start-ups, launched by NYSA (New York Space Alliance). In this partnership born to bridge the gap between the two parties, NASA commits to licensing its technologies for both space and non-space commercial applications, while start-ups commit to supporting NASA's space missions (See *Figure 1.5* below).

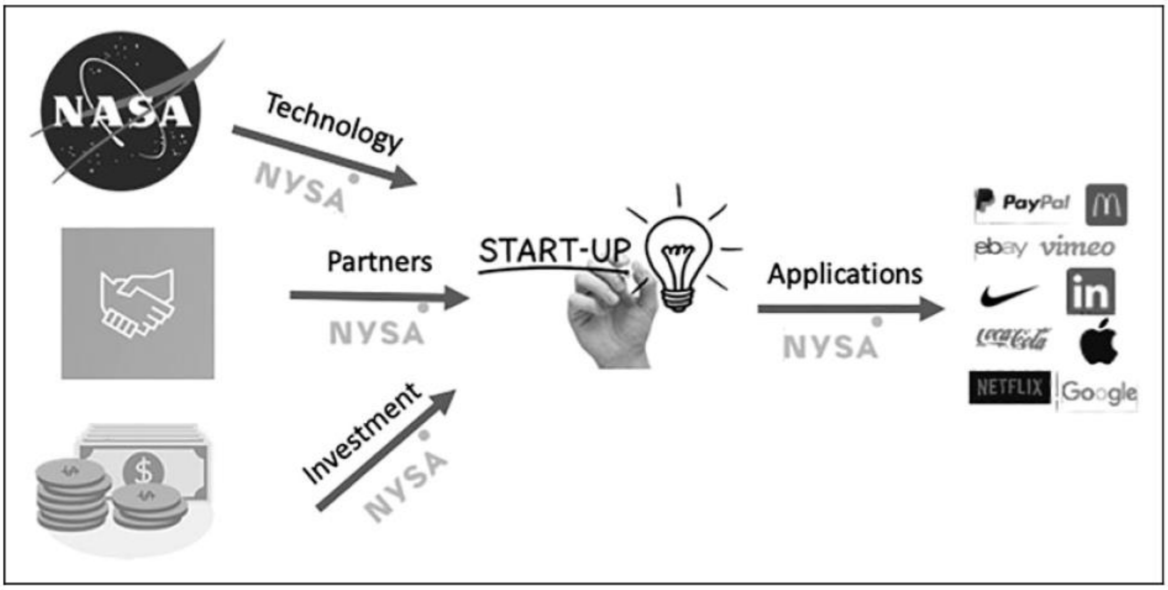


Figure 1.5 Organizational framework of the program

This would nurture both the entire aerospace ecosystem and the economic level of both parties involved in this co-operation: NASA would exploit the capabilities of the non-space related sectors and the commercial space market by gaining economic benefits for its research activities, while the start-ups would benefit mainly in the early launch phase with access to capital and Intellectual Property Rights protection. Empowering non-aerospace sectors (engineers, scientists, inventors, entrepreneurs) to come in and support NASA serves to complement solutions already considered by the agency, or even to find new ones.
Factors which are raising the interest of financial markets in the space sector can be identified in the dynamism of new concepts brought about by strong innovation, the entry of high-profile firms and entrepreneurs, lower barriers to entry and quicker time to market (Moranta and Donati, 2020).

G20 countries account for most of the government funding for space activities and are leaders in space research and innovation. Investments amount to approximately **USD 79 billion in 2019**. The focus of governments is on protecting socio-economic purposes and the development and innovation of scientific capabilities, without ever diverting attention from national security and country governance (OECD, 2020).
In a more traditional system, countries with space programs relied internally on their own specialized industries to provide both defense and aerospace support, whereas there is now a larger group of developed countries with different capabilities that can be asked for support (OECD, 2020).
One of the most useful indicators to measure the intensity of space funding is the ratio of space budgets to GDP as can be seen in *Figure 1.6* below. In 2019, the

budgets of the United States and the Russian Federation were the most relevant ones, accounting for around 0.2% of national GDP among all 20 countries, followed by France and Saudi Arabia with 0.1%. The last announced a budget of USD 1 billion in 2019, becoming the top institutional investors in the space in terms of GDP share (OECD, 2020).

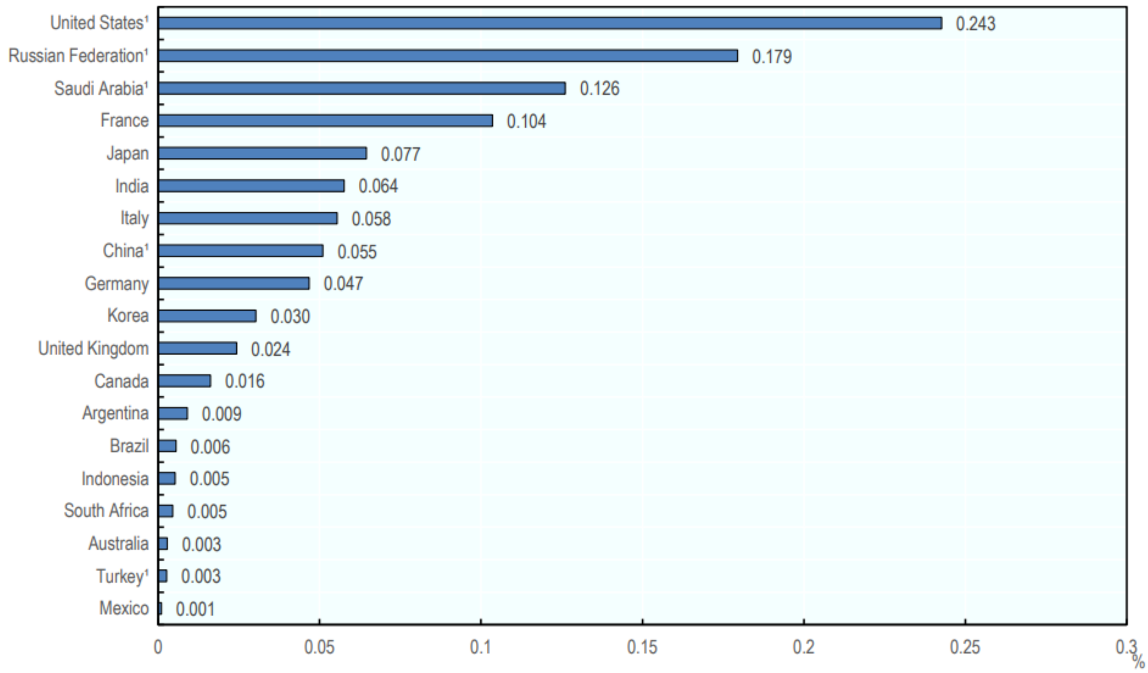


Figure 1.6 Government space budget (as a share % of GDP) for G20 countries in 2019

In the graph, from Japan onwards, the budgets provided by the governments of the top 20 economies are below 0.05%, which corresponds to a very low index, mainly dictated by the fact that it also includes civil and military space activities. Comparing with other sectors such as medicine, agriculture, and energy, the government tends to spend less on space R&D.

1.3 Insight into the classification of space companies as upstream and downstream

A company is considered a space company if the main business in revenue share is part of the space value chain. Space economy is divided into three segments:

The **upstream** segment encompasses the technological aspects of space programs including Manufacturing, Launch, Satellites, Science, R&D. The support received in carrying out these activities comes from engineering services such as design of space equipment and subsystems, electronic and mechanical equipment, software for space and ground systems, and systems for spacecraft guidance, propulsion, power, and communications. This segment serves also as supplier of materials and components for space and ground systems, including satellites or orbital systems, launch vehicles, and terrestrial systems like control centers and telemetry, tracking, and command stations. For instance, a space company classified upstream as being involved in antenna production is Taoglas.
The activities in scope within this category are conducted by the government sector, space business enterprises, and the scientific community at large (OECD, 2012).

The **downstream** segment consists of space infrastructure operations and products and services that rely directly on the analysis and storage of satellite data and signals for their operation and functionality. Generally, it includes various activities such as the communication between satellites and terrestrial infrastructures thanks to ground stations, data distribution services thanks to cloud computing-powered services that simplify access, use, and distribution of geospatial products, mainly in the field of geographic information systems (GIS). Also, this segment supplies devices for supporting customer markets: global innovation satellite services (GNSS) equipment and software development, direct-to-home provision of television, and radio, broadband, positioning, navigation, and timing services, as well as electro-optical imagery services for telemetry, tracking, surveillance, and security.
Examples of downstream companies are Deveryware employed in investigation services, G4S in security and consultancy services, POLE STAR for the realization of tracking apps.
Measuring the downstream segment of the space economy poses significant challenges as it can be difficult to accurately identify and quantify the specific space-related activities, leading to potential over- or underestimation (OECD, 2012).

The final segment of the space economy comprises **activities that are induced from space activities** but do not rely on them to function, such as technology transfers from the space sector to other industries like automotive or medical sectors whose products were originally fruits of investments done in the upstream space segment (OECD, 2012).

The investment in the upstream segment of the space sector is more than double the investment in the downstream segment. However, it is important to recognize that there is a significant challenge in tracking investments in the downstream sector because many companies have a diverse portfolio of services and products that are not solely focused on the space industry. Companies providing storage or processing capabilities, for example, rarely prioritize the space sector as their primary customer. Similarly, space capabilities or data are often just one aspect among many for companies delivering solutions to end users (Moranta and Donati, 2020).

A similar situation exists, although to a lesser extent, in the upstream segment, where companies offer equipment, components, or engineering services to customers in various industries. As a result, some private investments in European start-ups with space-related businesses may not be included in the analysis due to the difficulty of identifying these companies and establishing a clear link between the investment and the development of space products and services. This indicates that the space sector greatly benefits from investments in other sectors, particularly in the downstream segment (Moranta and Donati, 2020).

However, there is an increasing synergy between space and non-space industries due to the growing integration and interdependence between space and terrestrial technologies, the distinction between investments within and outside the space sector is becoming increasingly blurred (Moranta and Donati, 2020).

In *Figure 1.5* below, it is shown an overview of the main segments characterizing the space economy*:*

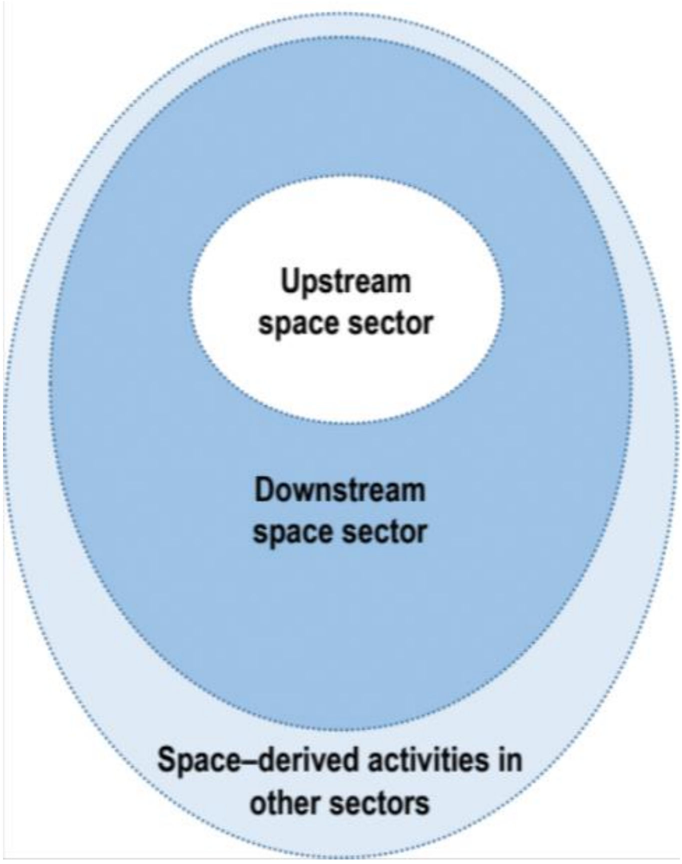


Figure 1.5 Main segments of space economy

Below the are some examples of companies with corresponding core technologies that can be applied not only in the space sector but also in other areas.

Regarding companies engaged in space activities on the upstream side, the renowned SpaceX with its core skill of developing reusable rockets and space launch systems has already been mentioned in sub-section 1.2, but equally important and noteworthy is the company Blue Origin, which focuses primarily on the commercialization of space travel and fits into the already discussed context of reducing the cost of launching into space. Among the latest innovations that this company is trying to focus on there is the new Bue Alchemist technology in the field of sustainability: i.e., the exploitation of the Moon's mineral, regolith, to make solar panels, thus producing sustainable energy from the Moon's soil.

Among the missions currently being conducted by NASA there is the Artemis one which aims to bring humans to the Moon after the Apollo programme, this time in a sustainable manner, and it is in this context that the company Blue Origin wants to insert itself through the release of this new technology.

On the other hand, analyzing the non-space upstream sector there will be found companies such as Intel, which is engaged in the production of processors and components for computers and electronic devices, and the mass production of these also includes Siemens and Samsung Electronics. These companies will be included later in the statistical analysis of the cluster of top patent assignees in these upstream sectors.

While, for the downstream category, in the space sector most companies develop technologies from the reception of countless satellite signals thanks to the installation of mega constellations of broadband satellites. These include, for example, Planet Labs, which collects images of the Earth to realize applications for environmental monitoring or in the agricultural sector, or Spire Global, which specializes in meteorological monitoring or maritime navigation.

In the field not directly related to the space sector, there are the giants Microsoft and Apple for example, which will also be found in the Assignees' extractions of downstream technology patents in Chapter 3 of the statistical analysis.

However, the top assignees or applicants respectively of the upstream and downstream category will be treated more in details with other examples in the sub paragraph 3.2.

2. Search methodology

In this chapter, the aim is to provide a high-level overview of how the experiment is prepared, utilizing various data sources (e.g., the online platforms *Derwent* and *Dealroom*) and techniques employed to construct the patent repository. The analysis of citation flows on the constructed repository is also discussed.

2.1 Description of the methods used to identify and characterize patents

The adopted method involved tracking within the database containing various space firms, including startups or scaleups, and using a query in the format "PA = (name of the space firm)" associated with interrogating the patent archive in the *Derwent* platform to retrieve the exact number of patents for each Patent Assignee or Applicant. The consideration to keep in mind when entering the query is to be sufficiently broad in choosing the assignee's name, for instance, removing the part that identifies the type of company (SRL, SPA, INC., or LTD.), but at the same time avoiding false positives (e.g., the query gives as result two companies with the same name, but one is completely unrelated to the space industry, so it is needed to refine the query by adding an element related to space).
This procedure is repeated for each company selected as ADVA optical Networking, an example of which is shown in *Figure 3.1* below:

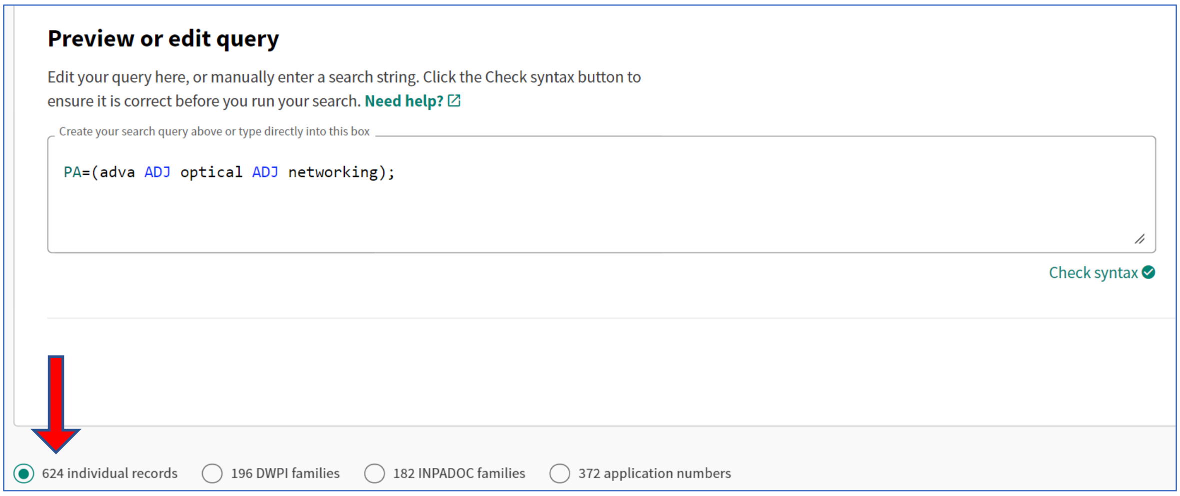


Figure 2.1 Example of a query for patents' identification from Derwent.co

The classification of a patent document consists of determining the subdivision of a classification system to which, because of its technical nature, the invention claimed in that document belongs, by associating a classification symbol to it (Trippe, 2015). Each patent is characterized by various attributes, such as the Publication Number,

Publication Date, the name of the Assignee or Applicant, IPC codes for Section, Class, Class Group, Subclass, and Subgroup. For statistical analyses it should be borne in mind that only the IPC is applied to all patent publications of almost all jurisdictions. Using a 4-digit IPC Subclass as a reference, a primary key "publication number - subclass IPC" is set up to assign a precise number of patents to each space firm.
It is important to note that this approach is necessary because the same patent could have different technical application sectors and can be associated with multiple IPC codes.

2.2 Explanation of the process of classifying space companies as upstream or downstream

The purpose of the classification by upstream or downstream space firms, the difference of which was previously explained in subsection 2.3, is to compare the distribution of patents in each category in terms of CPI and citation flows.
The main source to gather such distinction among categories of space firms is the *Dealroom* platform, where the research assumes the application of two defined filters for each company: "Has patents" because it is important to note that the thesis work focuses on the study of space company patents, and the second filter is related to the "space upstream" or "space downstream" tag. Once these parameters are set, the *Dealroom* website lists a series of potential startups or scale-ups to populate the company database, which will then be analyzed for their patents and related citation flows. For each assignee or applicant, the source link from which the classification information is obtained is provided, along with the founding year of the company and the country where it was founded or currently located.

Below there are two examples for the upstream category (*Figure 3.2* ABL Space Systems) and the downstream category (*Figure 3.3* 3D AEROSPACE):

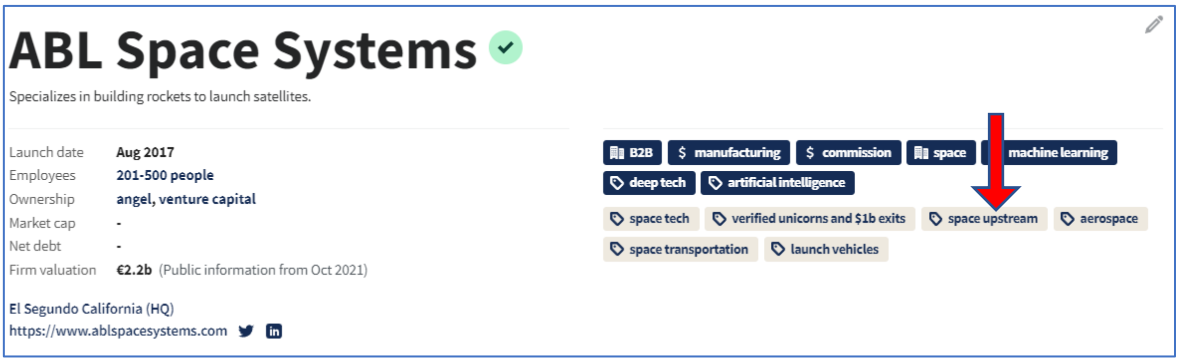


Figure 2.2 Example of an upstream firm from Dealroom.co

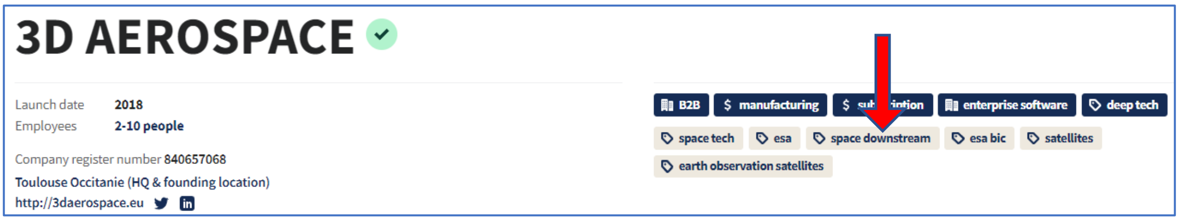


Figure 2.3 Example of a downstream firm from Dealroom.co

It is possible to have a scenario where a company has both the upstream and downstream tags simultaneously. Initially, these companies were considered, but when it came to building the patent repository, they were excluded from the sample.
In this regard, the process of filling the company list within an Excel file evolves in two phases: the first phase involves categorizing 200 companies as either upstream or downstream, which are previously identified in the *Dealroom* platform. This is done to quantify the distribution of the sample between the two types of assignees and to balance the number of upstream companies with downstream ones in the second phase, by searching for an additional 200 companies.

During the first phase, the first scenario that could arise is the absence of a company in the *Dealroom* archive: names of applicants and assignees can undergo changes throughout the lifespan of a patent application, particularly when the rights to the invention are transferred. Minor modifications may also occur in cases of corrections to resolve misspellings. An issue that commonly arises with names is the presence of variations resulting from the transcription of names from different scripts, such as Chinese, where different transcription rules are applied. As a result, the same individual may be represented by slightly different spellings of their name (Trippe, 2015). Another frequently appearing problem in search and analysis is that subsidiaries of corporations often use varying names in different countries. At this point, the procedure involves updating the name and *Dealroom* reference link in the Excel database while keeping track of the original name with a note. An example of this is the company Clyde Space, which has been acquired by the Swedish firm AAC Microtec AB, the previous name associated with this record.
Another common scenario occurred when the space upstream or downstream tag is not found on *Dealroom* during the search. Based on analysis and personal considerations after consulting the official website of the respective company, the upstream or downstream classification, or both tags, are deduced. An example of this is represented by Abeeway categorized downstream after consulting the sections into which the official website is divided.

For the search of additional companies in the second phase, the initial preference is to choose those located in Italy, Germany, UK, France, and once those are completed, fill the sample by selecting from other countries to reach approximately 200 in total. For each row entered in the Excel file per company, the corresponding query entered in *Derwent* with the respective number of patents assigned to each company is also included. What can happen during this parallel search in *Derwent* is that the query results in an excessive number of patents, or the ones indicated are related to a completely different field than the space sector. In such cases, the reference company is listed in the "Dropout" section of the Excel file, falling into one of the following lists:

- **Big corporation**: too big company which operates in many different industries
- **Disambiguity**: finding the right patent is too complex because the name is difficult to differentiate
- **Different core business**: core business is clearly different from aerospace
- **Other reasons**: absence of patents.

2.3 Details on the creation of the patent repository and citation flow analysis

This subchapter highlights the steps to create a proper dataset where all the patents, along with other information obtained from the *Derwent* platform, are compiled. Essentially, it involves gathering all the patents from upstream and downstream companies through two separate queries for each category, written in the following format: "PA = (name of the first downstream/upstream space firm) OR PA = (name of the second downstream/upstream space firm) OR etc.".
The Excel files obtained from the two queries are then extracted, and the data is cleaned and prepared using Power Query to examine the distribution of the two sets of patents across IPC codes and identify any differences.

The thesis's objective is to study the citation flows of patents, starting from those selected in the two distinct sets for the upstream or downstream categories, referred to as root patents. In this case as well, the citing patents are extracted from *Derwent* by conducting a search for forward patent citations using the publication numbers of the root ones. A statistical analysis is also performed on IPC codes to determine which assignees or applicants cite the collected space patents the most and to understand the industrial domains to which they belong.

3. Statistical analysis

Generally, in a patent repository the statistical measures revolve around analytics about the count of items in certain patent information fields. Methods for generating these statistics and consulting the results, include the use of lists for looking at one primary field at a time, and tables for working with two primary fields (Trippe, 2015).

3.1 Description of the companies' sample

The sample in question involves the collection of 418 space firms, with 204 belonging to the upstream category (accounting for 49% of the total) and 214 to the downstream category (accounting for 51% of the total).
As mentioned in subsection 3.2, alongside the search for new companies on the *Dealroom* platform to populate the database, certain companies are excluded based on the following reasons: 44 companies excluded because they are too big (e.g., Alstorm), 35 because the scope is ambiguous (e.g., Beeline), 10 for different core business (e.g., Autoliv), 18 for other reasons such as not having patents assigned (e.g., AG-Knowledge). The total of these excluded companies amounts to 107, which when added to the total number of 418 mentioned above, results in a starting sample of 525 space firms. The excluded part thus represents almost one fifth (precisely 20.4%) of the original sample.
Having discarded the previous companies, the focus is placed on the sample of 418 companies which presents a further as a restricted intersection between the upstream and the downstream category, consisting of 25 companies that have both the Dealroom tags, accounting for 6% of the total 418.
However, for the purpose of statistical analysis, this subset is excluded, finally reducing the total number of companies to 368, with 179 categorized as upstream (49% of total) and 189 as downstream (51% of total). The in-depth statistical analyses from now on will therefore focus on this sample of companies shown in *Table 3.1* below:

Category	Count	% of total
Upstream firms	179	49%
Downstream firms	189	51%
TOTAL	**368**	**100%**

Table 3.1 Sample in analisi

3.1.1 Analysis by age years

A first relevant statistical analysis pertains to the distribution of companies not only by category but also by age intervals, which are primarily identified in four ranges: from 1 to 5 years, there are 51 companies, with 55% being upstream and 45% downstream; from 6 to 10 years, there are 152 companies, with 45% being upstream and 55% downstream; from 11 to 20 years, there are 95 companies, with 51% being upstream and 49% downstream; and from 21 years and older, there are 70 companies, with 49% being upstream and 51% downstream. These figures are also summarized in the next bar chart in *Figure 3.1*.

The prevalence of companies found in this statistical analysis falls within the 6 to 10-year range, which coincides with a period of industry maturation and technology readiness, where many companies have successfully navigated the early challenges and are positioned for growth. It often takes several years for a space company to establish its operations, develop its technologies, and gain traction in the industry, as they initially go through the stages of research, development, and market validation, leading to their growth and expansion. Companies within the 6 to 10-year range may have successfully attracted significant investments from startups and entrepreneurs during their early stages, allowing them to develop their products, expand their operations, and reach a more mature stage. The entry of these actors is also driven by the emergence of new technologies and the reduced costs of access to space.

These reasons also explain why there is a slight prevalence of downstream companies (55%) compared to the upstream sector (45%) within this range, as the former responds to a broader market demand and is accessible (even in terms of costs) due to the easy adoption of the services offered without requiring significant investments in space infrastructure, as would be the case for the upstream sector. This enables downstream companies to expand more rapidly and gain a competitive advantage.

The space industry is dynamic and constantly evolving, but this age range may represent a period of strategic positioning and market penetration for these companies that want to gain a competitive advantage on specific market opportunities or niches.

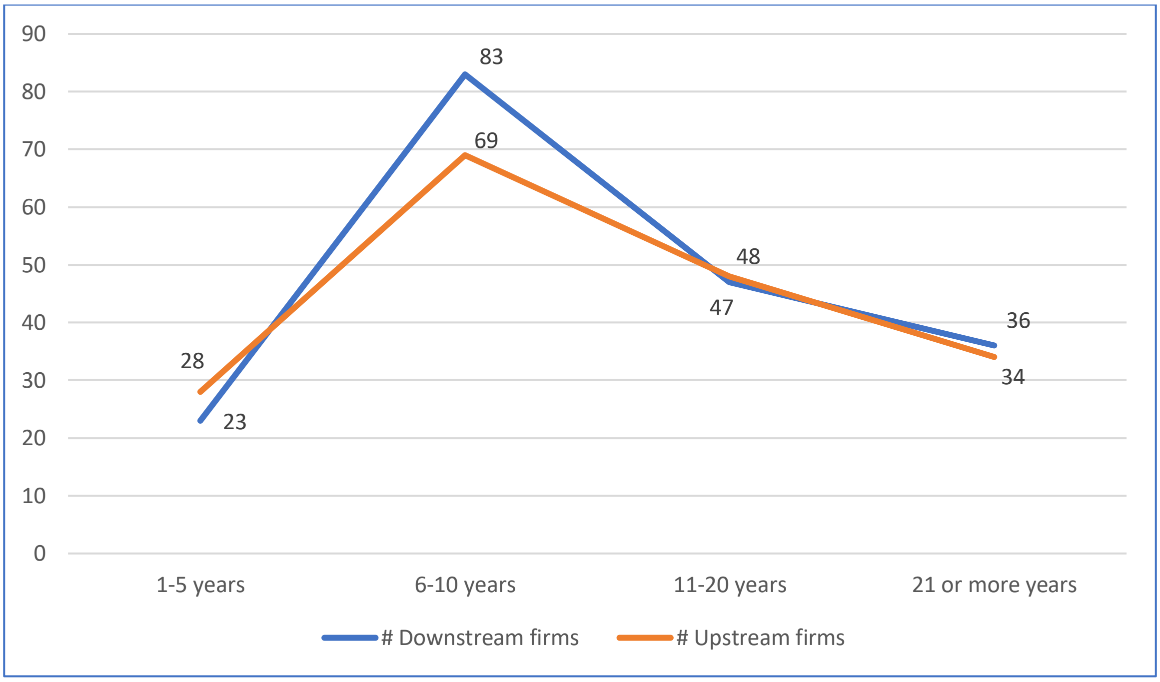


Figure 3.1 Distribution of space firms' categories by age interval

3.1.2 Analysis by Top 10 countries

Another important statistical analysis that emerged from the sample of companies is the distribution of these organizations across various countries worldwide. In particular, the main 10 nations are tracked based on the number of assignees in the following list, ordered in decreasing order:

- the United Kingdom with 65 companies: 30 upstream and 35 downstream
- the United States with 64 companies: 49 upstream and 15 downstream
- France with 60 companies: 23 upstream and 37 downstream
- Germany with 33 companies: 10 upstream and 23 downstream
- Italy with 22 companies: 8 upstream and 14 downstream
- Switzerland with 21 companies: 8 upstream and 13 downstream
- Sweden with 12 companies: 5 upstream and 7 downstream
- Belgium with 10 companies: 4 upstream and 6 downstream
- Finland with 9 companies: 4 upstream and 5 downstream
- Netherlands with 8 companies: 3 upstream and 5 downstream.

The other countries total 73 companies.

Before observing more detailed figures about this topic in *Table 3.2* below, it is important to clarify that the result of the higher number of companies in 9 out of 10 European countries is the outcome of a targeted research specifically focused on European states. Particularly during the second phase of populating the database with 200 companies in addition to those already present, it was decided to start with the states of Italy, the United Kingdom, Germany, and France.

Country	% tot firms	% upstream firms	% downstream firms
UK	18%	46%	54%
USA	17%	77%	23%
France	16%	38%	62%
Germany	9%	30%	70%
Italy	6%	36%	64%
Switzerland	6%	38%	62%
Sweden	3%	42%	58%
Belgium	3%	40%	60%
Finland	2%	44%	56%
Netherlands	2%	38%	62%
Other countries	20%	-	-

Table 3.3.2 Distribution of space firms' categories by Top 10 countries

Among the various countries, the United States stands out outside Europe, on a par with the United Kingdom in terms of total number of companies. The latter state enjoys a considerable number of space companies thanks to the strong support and investment from the British government in the development of the space industry, in fact the UK has established a national strategy for the space sector which includes the goal of increasing its global market share in the industry. This has led to significant investments in space infrastructure, R&D, as well as tax incentives for companies in the sector. In addition to this, the UK enjoys a strategic geographical position, making it an ideal hub for space activities and an attractive destination for its proximity to major European and international markets.
As far as the USA is concerned, however, it is not surprising that it is in the top 10 and at the top of this ranking for reasons that can be placed in a historical context, since the USA as a country has a long and rich history of space exploration and has been at the forefront of human space travel. It is sufficient to think about organizations like NASA which have played a central role in the development of space technologies and infrastructure, such that the US government has actively supported the space industry with significant public investments through NASA and the Department of Defense. In fact, the U.S. government is a significant customer in the space industry and requires advanced services and technologies for its missions. This has incentivized the development of private companies like SpaceX, Blue Origin, Rocket Lab that are specialized in providing upstream solutions such as: satellites, reusable spacecraft, space launches, advanced communication systems, and Earth observation services. For this reason, most space firms within this country belongs

to the upstream category (49 upstream space firms against 15 downstream space firms). Furthermore, the United States have adopted favorable regulations for commercial space activities, promoting innovation and competitiveness in the sector that include streamlining licensing and regulatory procedures for space launches and promoting policies that encourage public-private collaboration.

Country not in the top 10: Spain

It is worth noting that in the subset of the top 10 countries, Spain is not present solely because it does not have enough space companies. However, it would rank highly among the top 10 countries in terms of the number of granted patents (specifically, 683 patents, with the United Kingdom holding the record with 4383 granted patents as a reference).
Spain has made significant progress in the field of space innovation and has actively engaged in the development of space technologies and space exploration. There are several Spanish startups that are involved in the space sector and are contributing to innovation and the growth of the space industry in the country.
Among the startups in the initial sample of companies, **Zero 2 Infinity** is present, which is working on the development of innovative launch vehicles to deploy satellites and perform other activities in space. The main application associated with this company in the upstream sector is the launch vehicle called "Bloostar" (represented in the *Figure 3.2* below), a lightweight launch system based on an innovative concept that brings a high-altitude balloon to the stratosphere (20km altitude, 90min duration) where, thanks to a rocket engine from the first (80km altitude, 110s duration) to the third stage (600km altitude, 304s duration), satellites are deployed into orbit. This approach offers several advantages, including cost reduction and the ability to launch satellites from various locations worldwide.

Figure 3.2 Zero 2 Infinity upstream invention: "Bloostar"

3.1.3 Analysis by patent ranges

The latest statistical analysis closely related to the sample of companies is the one regarding the number of patents associated with each company. Given that it involves counting numerous occurrences, it was preferred to divide this distribution into four patent ranges for analysis: 1 patent, 2-5 patents, 6-50 patents, and 51 patents and above.
Table 3.3 below provides an overview of the total number of patents for each upstream and downstream category of companies. It also shows the average number of patents assigned to an assignee or applicant, respectively, for the upstream and downstream categories:

Tag	# Patents	Average # Patents
Upstream	9789	54,7
Downstream	9030	47,8
TOTAL	**18819**	**51,1**

Table 3.3 Sum and average value of patents per upstream and downstream category

One of the reasons why the total number of patents and the higher average number of patents per company belong to the upstream category, can be attributed to the nature of upstream activities, which often involve more complex and advanced technologies. These activities require significant research, development, and innovation efforts, leading to the creation of novel inventions and intellectual property. Companies engaged in upstream activities are at the forefront of technological advancements and may have a higher propensity to file patents to protect their innovations. As a result, upstream companies may have a higher propensity to file patents to protect their technological advancements with respect to the downstream categories.
Additionally, upstream companies may have a greater need to protect their intellectual property due to the competitive nature of the industry. Patents provide legal protection and exclusivity, allowing companies to gain a competitive advantage and secure their position in the market. As a result, upstream companies may be more proactive in filing patents to safeguard their innovations.

It is important to note that while the number of patents assigned to upstream companies may be higher, downstream companies also play a crucial role in the space industry. Downstream activities, such as satellite communications, Earth observation, and satellite services, often involve utilizing and applying technologies developed by upstream companies. These downstream companies may focus more on commercializing and providing services based on existing technologies rather than creating new inventions, which can result in a lower number of patent filings.

The distribution of space companies by category within each of the 4 patent ranges mentioned above shows 11 companies (4 downstream, 7 upstream) in the range for which only 1 patent was granted, 68 companies (32 downstream, 36 upstream) from 2 to 5 granted patents, 203 companies (98 downstream, 105 upstream) from 6 to 50 granted patents, and finally 86 companies (45 downstream, 41 upstream) from 51 granted patents onwards.
The graph below (*Table 3.4*) shows that as a percentage, the largest number of companies belong to the 6 to 50 patent allocation intervals, compared to the four intervals mentioned earlier (with a breakdown by category as usual).

Patent's range	% tot firms	% upstream firms	% downstream firms
1 patent	3%	36%	64%
2-5 patents	18%	47%	53%
6-50 patents	55%	48%	52%
51 or more	23%	52%	48%

Table 3.4 Distribution of space firms' categories by patents' range

Companies belonging to this range may have a high capacity to generate original and protectable solutions such that they need to obtain so many patents, because they make much more investments in research and development to create new ideas and technologies. For example, high-tech sectors like computer science, electronics, or biotechnology are highly competitive and may register a higher number of patents compared to other industries to maintain or achieve a competitive advantage by creating entry barriers for competitors.

3.2 Description of the patents' samples

In this paragraph, the set of distinct patents is examined for both upstream and downstream companies, with the usual statistical analysis focusing primarily on the IPC codes that refer to the industrial sector in which the company patents its innovation.

The analyzed datasets have been extracted from *Derwent.co*, as explained in paragraph 2.3 of the search methodology, by entering a single query that combines all the names of the Patent Assignees for each upstream and downstream category. It is important to note that each patent may have multiple application sectors identified by the 4-digit IPC subclass codes. For this reason, it is necessary to create a primary key that uniquely defines the patent through its Publication Number and the corresponding IPC subclass code. This is achieved by using Power Query editor, where the extraction records were processed to obtain the desired result.

The differences observed between the two sets are illustrated in the *Table 3.5* below for each analyzed company category:

Tag	# Primary Keys: *"Publication Number – IPC subclass"*	% Blank IPC subclass records
Upstream	16290	5%
Downstream	15367	3%

Table 3.5 Number of primary keys records: "Publication Number - IPC subclass" per category

The reason why there are blank records for IPC subclass codes, even if irrelevant with respect to the total number of records from both samples, is due to the unavailability of them in the Derwent platform for certain patents or companies. In this case, the cell will be returned as empty.

3.2.1 Downstream: analysis of IPC codes

The following paragraph analyzes the distribution of IPC subclass codes for the downstream category, based on the previously identified primary keys using Power Query editor. Specifically, the IPC subclass codes are separated from the publication number and counted to keep track of how many times the same patent can be associated with different IPC codes. Subsequently, a percentage value is derived for each denomination by calculating the ratio between the total records for that code and the total IPC subclass codes of the analyzed downstream firms' sample.
The following table (*Table 3.6*) presents the percentage distribution of each technical sector in the sample:

Downstream IPC subclass	Code's description	% out of total sample
H04W	Wireless communication networks	8%
H04L	Transmission of digital transformation (e.g., Telegraphic communication)	8%
H04B	Transmission	7%
G01S	Radio direction-finding, radio navigation	6%
G06F	Electric digital data processing	6%
H01Q	Antennas (i.e., Radio Aerials)	5%
H04J	Multiplex communication	3%
G06T	Image data processing or generation	2%
H04N	Pictorial communication (e.g., Television)	2%
G06Q	Information and communication technology	2%
Others	-	48%

Table 3.6 Distribution of IPC subclass codes for downstream category

Out of the 8 sections provided by the International Patent Classification, this table includes only 2 of them, Section G and Section H, highlighting the strong prevalence of these two technological sectors, accounting for 32% and 43% of the occurrences, respectively. These data are derived from an analysis in the subsequent *Table 3.7*, which provides a general overview of the percentage coverage of each section in the analyzed sample:

Downstream IPC section	Description	% out of total sample
A	Human necessities	5%
B	Performing operations; transporting	10%
C	Chemistry; metallurgy	3%
D	Textiles; paper	0%
E	Fixed constructions	2%
F	Mechanical Engineering; lighting; heating; weapons; blasting	3%
G	Physics	32%
H	Electricity	43%

Table 3.7 Distribution of IPC sections for downstream category

Section H is related to electricity technologies that cover all aspects of electricity, including generation, transmission, distribution, and utilization of electrical energy. From *Table 3.6*, it can be observed that the H04W subclass (8%) has a prevalence in the sample. This subclass pertains to wireless communication networks that establish links between users or between users and network equipment for information transfer. These networks have an infrastructure for managing the mobility of wireless users, such as cellular networks or WLAN (Wireless Local Area Network).

In general, this reflects the presence of downstream companies involved in the development of innovations such as devices like terminals, base stations, or access point devices adapted for wireless communication. They may also be engaged in mobility management, including geolocation of users and the development of traffic planning tools.

Similarly, the second highest occurrence of codes is the H04L subclass (8%), which is also dedicated to the transmission of digital information, such as signals and data traffic for communication monitoring (e.g., telegraphic communication).

Section G covers a wide range of subjects related to tools, machinery, and equipment used in various industries, as well as the processing and production of goods, generally referred to as "Physics" within this section. Specifically, there is a 6% occurrence of subclasses focused on radio wave detection through the emission of additional radio waves, capable of determining speed or distance (the latter being applicable to geolocation tools, for example, typical of downstream companies' activities). In general, these IPC subclasses related to downstream companies that have patented technologies typical of the downstream sector are particularly concerned with data traffic. An example is the subsequent IPC subclass G06F (also at 6%), which is focused on data processing.

These specific field application insights are derived from the archive website of all International Patent Classification codes.

3.2.2 Downstream: analysis of Applicants/Assignees

As already introduced in paragraph 1.1, the assignee or applicant is the entity of a startup or scaleup that applies to obtain an industrial property right (such as a patent application) at an industrial property office. In this case, the analysis focuses on the number of patent applicants within the downstream sector, whose identification is already present in the extraction of root patents. However, assigning a unique name to each assignee for every publication number proves to be challenging using Power Query Editor, as the names of companies are affected by variations that derive from transcriptions of names from other scriptures, such as Chinese, when varying transcription rules are applied. Consequently, one firm can be represented by slightly different spellings of its name, and another commonly encountered issue in search and analysis is that subsidiaries of corporations often use varying names in different countries (Trippe, 2015).
For example, from the examined extraction, the downstream company named **Basen** should ideally be referred to throughout the sample as "Basen Corporation" or at most "Basen Corp."; however, occurrences similar to "Basen Co. Ltd.,KR | 주식회사 바스엔,KR" are found.
The only way to address this issue is to perform manual data cleanup techniques, but it is a time-consuming procedure. For this reason, in this paragraph and also in the one of upstream analysis of Assignees/Applicants, it is decided to utilize the graph provided by Derwent for the top 10 downstream companies, as represented in *Figure 3.3* below.

The company with the highest number of assigned patents is **ADVA OPTICAL NETWORKING** with 539 patents, primarily focused on the development of technologies for long-distance optical transmission, enabling communication networks to handle large volumes of high-speed data. These products include optical transponders, multiplexers, and amplifiers that enhance the quality and reliability of optical communications. Additionally, ADVA provides solutions for extending Ethernet networks through optical infrastructures, allowing companies to expand and enhance their existing communication networks, supporting reliable and fast data transfer.
The specialization in these sectors perfectly aligns with the findings of statistical analyses on the IPC codes of downstream companies, which place H04W (Wireless

communication network), H04L, and H04B (Transmission of digital transformation) at the top.

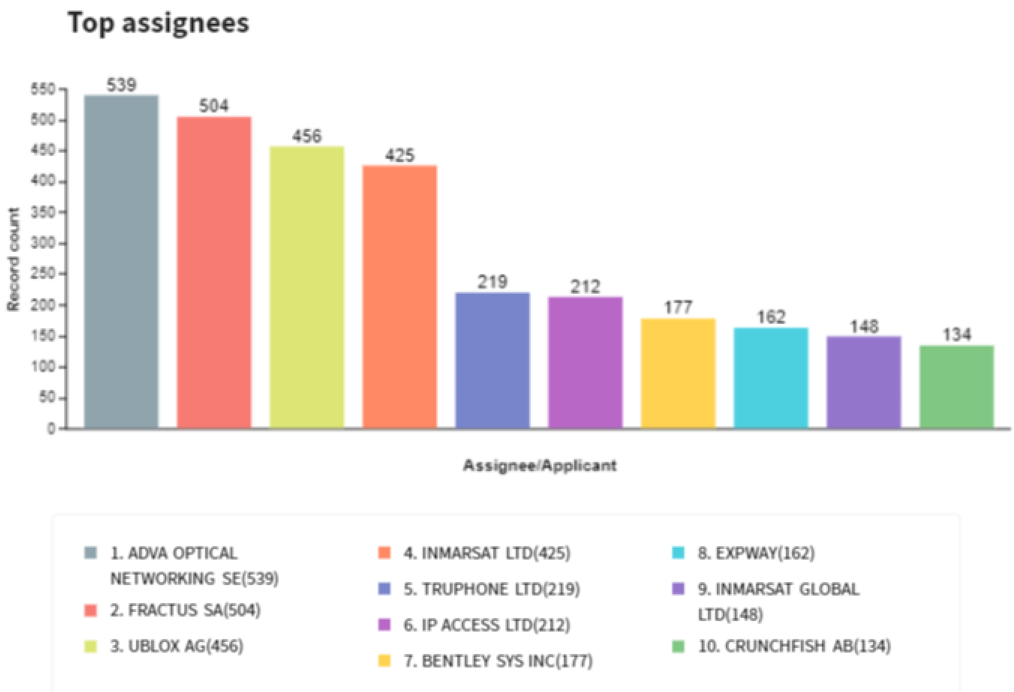


Figure 3.3 Downstream Assignees/Applicants

3.2.3 Upstream: analysis of IPC codes

The following paragraph analyzes the distribution of IPC subclass codes for the upstream category, particularly the *Table 3.8* below presents the percentage distribution of each technical sector in the sample:

Upstream IPC subclass	Code's description	% out of total sample
H01Q	Antennas (i.e., Radio Aerials)	11%
H01L	Semiconductor devices	5%
H04B	Transmission	5%
H04L	Transmission of digital transformation (e.g., Telegraphic communication)	5%
B64G	Cosmonautics; vehicles or equipment therefor	4%
G06F	Electric digital data processing	4%
B64C	Airplanes; helicopters	3%
B23K	Soldering or unsoldering; welding; cladding or plating by soldering or welding; cutting	3%
G02B	Optical elements, systems or apparatus	2%
G01S	Radio direction-finding; radio navigation	2%
Others	-	52%

Table 3.8 Distribution of IPC subclass codes for upstream category

Consistently with the definition of upstream companies, the most relevant IPC subclass code in this subset is H01Q (accounting for 11%) related to antennas as an application sector, such as Radio Aerials.

Antennas are used not only for transmitting radio signals but also satellite signals, to the extent that upstream companies may employ wide-ranging antennas for longer distances or directional antennas for specific areas of interest.

Parabolic antennas are utilized for satellite communications, enabling the reception and transmission of signals between orbiting satellites and ground stations.

The section B also prevails (accounting for 22% compared to other sections, see subsequent *table 3.9*) and refers to spacecraft or equipment therefor, but also to technologies related to chemical or physical processes for material processing, for example, to produce space suits. This is the case of the Subclass code B64G, which is present in the *table 3.8* for 4% of the occurrences.

Upstream IPC section	Description	% out of total sample
A	Human necessities	2%
B	Performing operations; transporting	22%
C	Chemistry; metallurgy	11%
D	Textiles; paper	0%
E	Fixed constructions	1%
F	Mechanical Engineering; lighting; heating; weapons; blasting	5%
G	Physics	16%
H	Electricity	38%

Table 3.9 Table Distribution of IPC sections for upstream category

3.2.4 Upstream: analysis of Applicants/Assignees

The main assignee of the examined sample is **Kymeta** with 557 patents, as depicted in the bar chart below in *Figure 3.4*. This company finds applications in various sectors, including transportation, defense, security, maritime industry, and other areas where robust and flexible connectivity is required. Kymeta is committed to harnessing the power of satellite communications to enable global connectivity and improve access to the Internet worldwide.

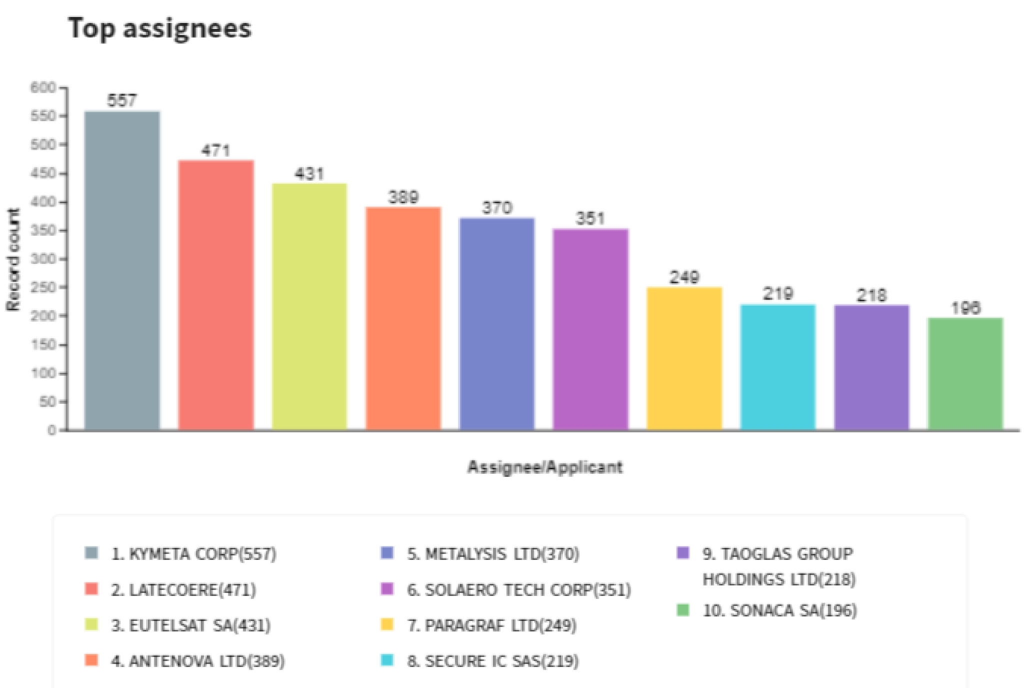


Figure 3.4 Upstream Assignees/Applicants

Consistent with the representation of the top 10 tech sectors related to upstream companies, Kymeta reflects the prevalence of the IPC subclass code H01Q (11%) in the top 10 analyzed in the previous *Table 3.8*, which pertains to the development of flat-panel antennas and innovative satellite communication solutions. These flat-panel antennas are integrated with electronic components in terminals such as the one shown in F*igure 3.5, and* are designed to be compact, lightweight, easy to install on vehicles, ships, aircraft, and other mobile platforms utilizing electronic bundle formation technology to communicate with orbiting satellites. Therefore, the company's primary goal is to provide high-speed and reliable connectivity in areas where traditional Internet access may be limited or unavailable.

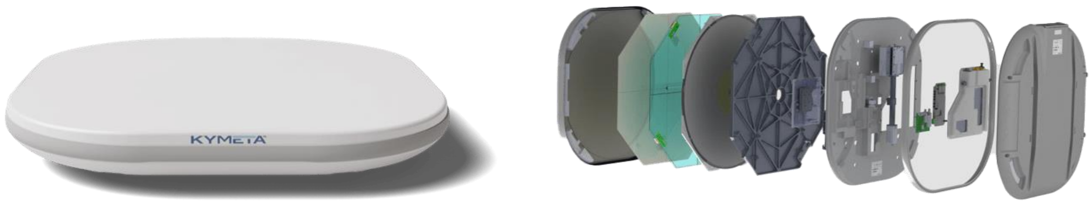


Figure 3.5 Kymeta "u8 Go" portable terminal

3.2.5 Comparison between the two categories

IPC analysis

For both categories, there is a prevalence of IPC subclass codes belonging to **section H** on electricity, with distinct applications based on the sector to which each company belongs. As mentioned, upstream companies are more focused on signal transmission and communication directly with space.

There is a strong presence of **section G** for downstream IPC subclass codes compared to the upstream category, as the processing and production of physical goods, machinery, or tools is particularly relevant in activities related to geolocation typical of the downstream sector.

Lastly, the two categories are distinguished by the significant attendance of **section B** for upstream IPC subclass codes, which are absent in the downstream category. This is because upstream companies are involved in the initial phase of the supply chain through the production of raw materials, which may involve patenting chemical or physical processes used for material transformation.

Application years analysis

The strictly increasing trend in the number of patent publication years is a common feature for both upstream and downstream companies. Among the reasons illustrated in *Figures 3.6* and *3.7*, which demonstrate the low number of patents issued by both upstream and downstream companies before the last 10 years.

Several factors can be identified such as economic conditions, industrial trends, and available investments that may have influenced research and development activities. Another possible explanation is that in the past, the importance of intellectual property protection through patents may not have been given the same emphasis as it is now, or the lack of accessibility of information in the past compared to when the internet and other digital technologies took over, which allowed the dissemination of knowledge about patents and the technical fields of their application, to the point that many companies were enticed to apply for patents.

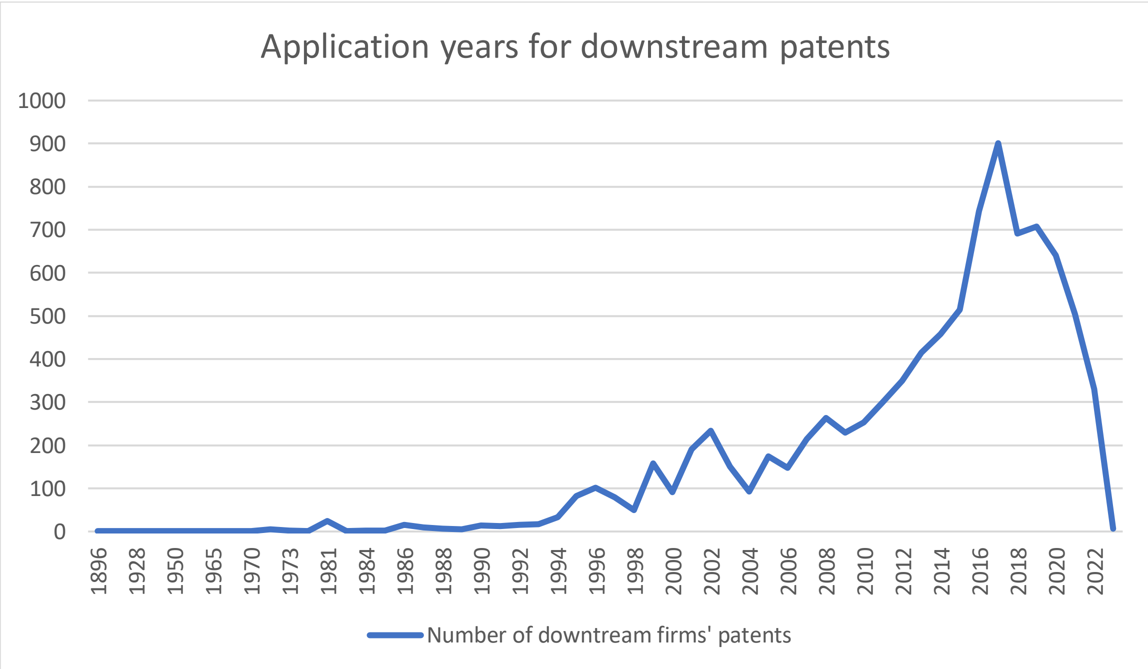


Figure 3.6 Application years for downstream patents

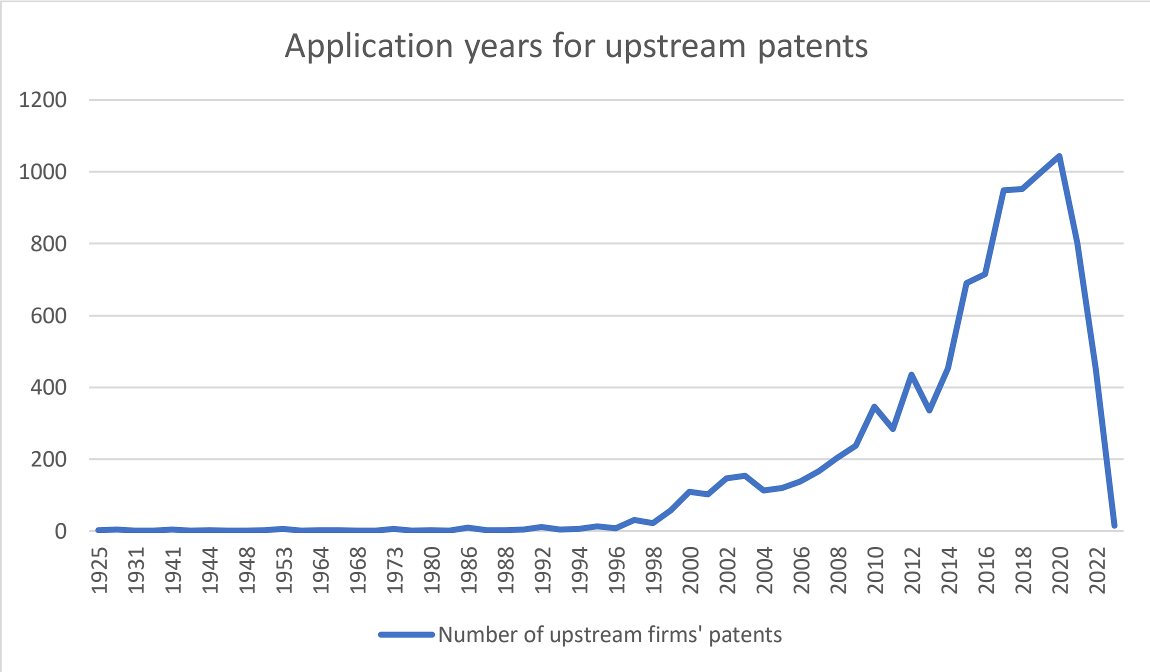


Figure 3.7 Application years for upstream patents

In the downstream sample analyzed, 2017 was the year with the highest number of patents applied for with 9.7% of the total sample.
While in the case of the upstream sector, the year with the highest number of patent registrations is 2020 with 10.3% of patents applied in the year out of the total sample analyzed.
This evidence is in line with a study reported by the European Space Agency (ESA) regarding the latest trends in space expansion, with a succession in the increase of patent applications and registrations at the world's various patent offices. Specifically, around 12,000 patent families have been filed worldwide over the past 30 years. This set has soared especially between 2017 and 2019, years in which an average of 470 spacecraft were launched in one year, four times the number corresponding to the early 2000s under analysis. At this point, as the number of satellites in space (especially the small CubeSats) increased disproportionately, research in the field of innovation on both the upstream and downstream sides, the latter with satellite data obtained from space, increased accordingly. In support of these activities, ESA again reports that these years have seen a sharp rise in investment, not only from the public sector but especially from the private sector.

Furthermore, one particularly significant observation from the graph in *Figure 3.6* is the decline in patent releases in the downstream sector in 2020. This decline can likely be attributed to the impact of the COVID-19 pandemic, which may have led to restrictions imposed to contain the spread of the virus and affected business operations across various sectors. Measures such as factory closures, resource reductions, and the need to adapt to new work models could have had a substantial impact. Downstream companies involved in production and distribution may have been more susceptible to disruptions in global supply chains caused by these restrictions. In contrast, upstream companies which focus more on research and development of new technologies and products such that they do not rely on supply chains, in fact they record a peak in that year as reported in the graph in Figure 3.7. Upstream companies in certain sectors may have even benefited from the pandemic. For example, those involved in the development of telemedicine, e-commerce, or remote solutions may have experienced increased demand and interest in their innovations during the pandemic. An interesting example in this regard is **Siemens Healthineers**, an upstream company included in the extracted sample of citing assignees. As a division of Siemens AG, Siemens Healthineers provides medical imaging solutions, laboratory diagnostics, and healthcare information systems. As expected, they are committed to research and development of cutting-edge technologies to improve disease diagnosis and treatment.

3.3 Description of the patent citation flows

This paragraph focuses on the main purpose of the thesis, which is to examine the citation flows of patents starting from specifically selected root patents in the upstream or downstream categories.
At the beginning, the research aims to determine the exact number of citing patents by creating a primary key consisting of the publication number of the root patent and the publication number of the citing patent (both derived from the root patents' sample), utilizing Power Query Editor. This approach excludes root patents that are not cited by any other patent, while keeping track of those that may have multiple citing patents associated. The count of citing patents for the upstream sector is about 10839 citing patents, while for the downstream sector there are 18380 patents.
Once the publication numbers of these citing patents are obtained from the sample of root patents, they are subsequently inserted into the Derwent platform, collecting **9534 citing patents** for the **downstream** segment and **14222 citing patents** for the **upstream** segment. At this point, the work can continue by performing analyses on the 4-digit IPC subclass codes, specifically the origin and destination of the technical sectors.
Like what has been already done for the IPC codes analysis phase of the root patents, a sample of primary keys identifying the citing patents is constructed as "publication number - IPC subclass", resulting in a breakdown per category shown in *Table 3.10*:

Tag	# Primary Keys: *"Publication Number – IPC subclass"*	% Blank IPC subclass records
Upstream	26326	1%
Downstream	16840	1%

Table 3.10 Number of primary keys records: "Publication Number - IPC subclass" per category

Furthermore, in the previous analysis of root patents carried out in Table 3.5 in Section 3.2 the upstream sector outperformed the downstream sector in terms of patent applications in the various technology sectors. Thus, there is no shift in citation patterns, but the same behavior is maintained with primary keys in root patents' sample which reported 16290 occurrences for the upstream sector and 15367 for the downstream sector but with a slightly higher number of empty cells.

For both the "root patent - citing patent" and "citing patent - IPC subclass" primary keys, empty cells are obviously found, and the reason is due to the unavailability of them in the Derwent platform for certain patents or companies.

3.3.1 Comparison between downstream citing and root tech sectors

After extracting the assignments of each publication number of the citing patents to the corresponding technical sector of application, a comparison is made between the top 10 IPC subclass codes of origin and those of destination, information highlighted in the last column of *Table 3.11* below:

Downstream citing patents' IPC subclass	Code's description	% out of total citing IPCs	Presence in top 10 root patents' IPC subclasses
H04W	Wireless communication networks	9%	X
H04L	Transmission of digital transformation (e.g., Telegraphic communication)	8%	X
H04B	Transmission	8%	X
G06F	Electric digital data processing	7%	X
H01Q	Antennas (i.e., Radio Aerials)	6%	X
G01S	Radio direction-finding, radio navigation	5%	X
G06T	Image data processing or generation	3%	X
H04J	Multiplex communication	2%	X
G06K	Graphical data reading; presentation of data; record carriers; handling record carriers	2%	
G06Q	Information and communication technology	2%	X

Table 3.11 Distribution of IPC subclass codes for downstream category

What emerges concerns a repetition of the same sectors of application of the technologies patented by the original companies, except for the sector identified by the code **G06K** which refers mainly to the data recognition and processing, dealing with technologies and systems for reading, recording, and managing data. An example could be technologies for the optical reading and interpretation of printed or handwritten texts to be converted into digital format, or tools for the automatic recognition of an individual through the acquisition and processing of fingerprints or voice. In this context, the company **Denso Wave** is derived directly from the cluster of citing patents (it is not present in the list of assignees of the source sample) belonging to the downstream category, not operating in the space sector. It is a Japanese company dedicated to the production of barcode encoding and reading equipment, famous for the introduction of the QR (Quick Response) code used to store any kind of content such as websites, passwords, telephone numbers, etc.

Among the cited assignees of Denso Wave, it can be recognized a company coming from the originating sample: **Fractus**, specialized in wireless communications sector by producing antennas useful for receiving and transmitting signals from and to the space, developing technologies or devices using automatic recognition or identification techniques within their field of activity.
If so, there could be cross-applications between Fractus' technologies, the G06K and H01Q IPC subclasses and Denso Wave, including the use of antennas designed by Fractus and integrated into tag RFID (Radio frequency identification) readers to ensure better radio waves reception and faster reading speeds. Antennas could also be used to enable wireless communication between the tag reader and other devices.
To obtain this information, the stream under consideration starts with:

- the citing patent JP05218251B2 associated with Denso Wave whose title is "*Radio frequency identification (RFID) tag reader has meander portions which are formed such that length of meander portion is longer in middle as meander portion is spaced apart from linear portion*"
- up to the cited patent JP2008113462A associated with Fractus, whose title is "*Antenna device for example for cellular telephone, has proximity region formed by non-contacting radiating arms in which distance between points in each arm is smaller than that of feeding point on one arm and any point on another arm*"

(Patents' information provided by *derwentinnovation.com*).
These two patents define the Rfid technology which works with radio frequency identification: i.e., a technology capable of autonomously storing data and information on objects, using Rfid (electronic tags that are inserted into the object) and fixed or portable devices (readers), which read the data in the Rfid and then automatically store them in memory.
In this sense, automatic product identification improves supply chain and business efficiency by eliminating out-of-stock and warehouse inefficiencies, because with this technology there is the possibility, for example, of keeping track of all goods leaving a warehouse if they are correctly labelled. An example is reported in the *figure 3.8* below.
In fact, one of the main areas of application for RFID today is in warehouse management and logistics.

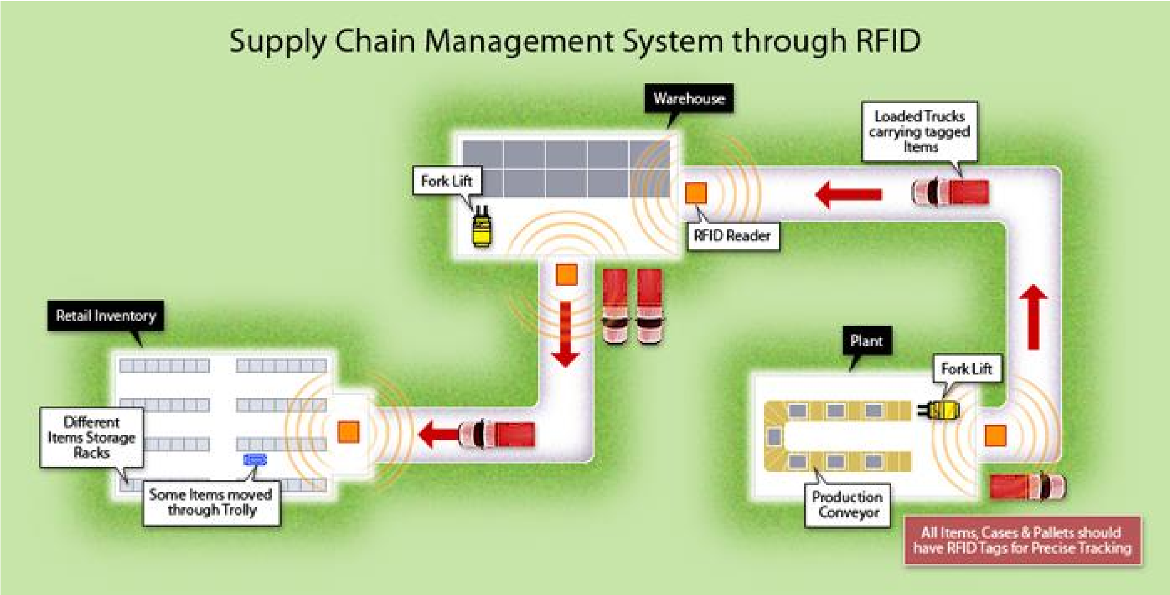


Figure 3.8 Application of G06K technical sector in the supply chain management

In this way, a flow between an assignee operating in the space sphere (Fractus) and one in the non-space (Densowave) sphere has just been demonstrated.

IPC Subclass code B64G analysis

The objective now is to study the patent citation flow within the IPC subclass code B64G, whose fields of application are briefly recalled according to the International Patent Classification website:

- B64G 1/00: Cosmonautic vehicles
- B64G 3/00: Observing or tracking cosmonautic vehicles (radio or other waves systems for navigation or tracking G01S)
- B64G 4/00: Tools specially adapted for use in space
- B64G 5/00: Ground equipment for vehicles (e.g., starting towers, fueling arrangements)
- B64G 6/00: Space suits
- B64G 7/00: Simulating cosmonautic conditions (e.g., for conditioning crews)
- B64G 99/00: Subject matter not provided for in other groups of this subclass

The others subclass codes of the B64 flow belong to the following technical applications:

- B64B: ground installation for aircraft
- B64C: airplanes, helicopters
- B64D: equipment for fitting in or to aircraft, flight suits, parachutes, arrangements or mounting of power plants or propulsion transmissions in aircraft

- B64F: ground or aircraft-carrier-deck installations specially adapted for use in connection with aircraft; designing, manufacturing, assembling, cleaning, maintaining or repairing aircraft; handling, transporting, testing or inspecting aircraft components
- B64U: unmanned aerial vehicles [uav]; equipment therefor

(Wipo, International Patent Classification website).

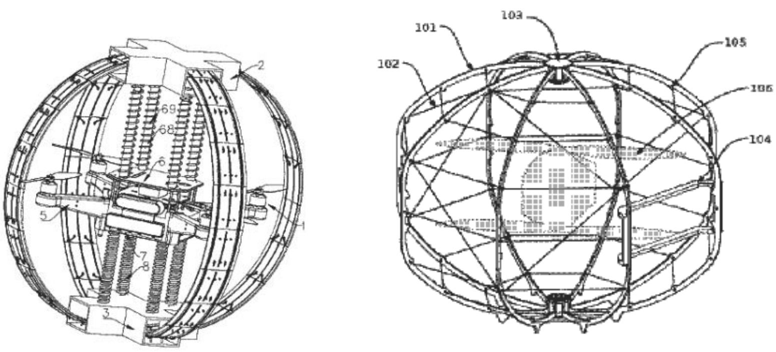
Below (*table 3.12*) technical sectors' weights, belonging to the citing patents' sample, are represented for the downstream category as percentage value out of the total 16840 records of primary keys "publication number - IPC subclass" (see table 3.10 above):

IPC Subclass	% out of total IPC subclass codes
B64B	0%
B64C	1%
B64D	0,6%
B64F	0,1%
B64G	0,1%
B64U	0%

Table 3.12 B64 tech sector for downstream category

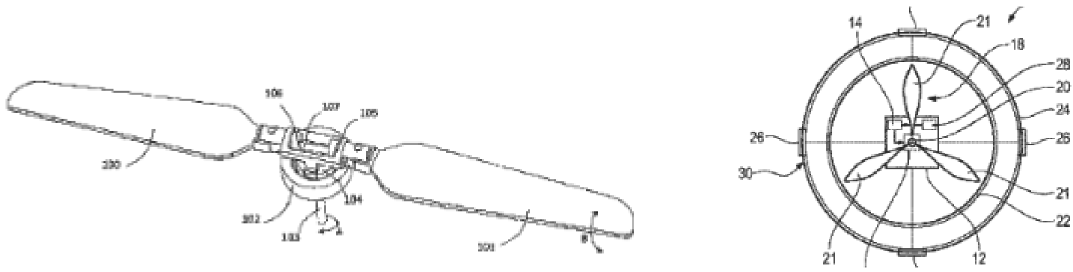
As can be seen, the presence of patents with this code is very low, however, it is of particular interest to study some interesting flows such as the following.
For the subclass code **B64D**:

- WO2021260497A1 for Flybotix from the source sample: "*Protective cage for unmanned aerial vehicle (UAV), has locking unit that is selected among cap and closing portion adapted to maintain ribs at predetermined relative angular positions, once fully deployed*"
- CN116101526A for Yanshi Space Information Technology from the citing patent assignees sample: *"Unmanned aerial vehicle device with spherical anti-falling protective frame, has upper and lower protective devices that are symmetrically set with respect to central plane of unmanned aerial vehicle main portion"*



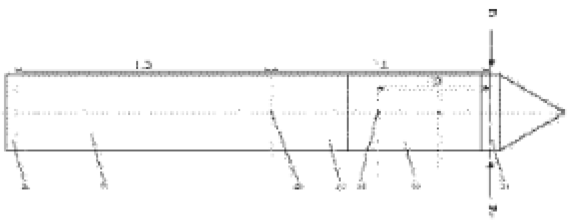
Unmanned aerial vehicle and protective cage

For the subclass code **B64C**:
US20220250744A1 for Rohde & Schwarz from the citing sample: “*Unmanned aerial vehicle for direction finding and/or spectrum monitoring, has rotor having rotational axis that coincidences with center axis of unmanned aerial vehicle, which runs through center of main portion”*
US20200298971A1 for Flybotix from the source sample: “*Two-degree-of-freedom actuator for use in two-bladed rotor of helicopter, has magnet diametrically-magnetized and able to rotate around secondary axis by leading rotation of secondary rotating parts around secondary axis”*



Rotors for helicopter blades

For the subclass code **B64G**:
CN105836161A for Beijing One Space Technology from the citing sample: “*Attitude control system for multiple-stage aircraft of rocket, has aircraft head part arranged with stage posture control device, and attitude controller fixed in aircraft head part, where stage posture control device controls yaw angle”*
US20200298971A1 for Inmarsat from the source sample: “*Inmarsat 2 F3 satellite, for use in geosynchronous orbit controlled by ground station telemetry, tracking and control station, has propellant line whose capacity is sufficient to propel satellite into disposal trajectoryTwo”*


Control systems for rockets

3.3.2 Comparison between downstream citing and root assignees

The research is now more detailed focusing on differences between the original and destination application sectors through the recognition of citing patents' assignees, understanding whether they are the same companies as in the original sample, or whether they change, and in which sectors they operate.

A first analysis can be conducted on how many citing patents are still assigned to the space companies of the source sample for the downstream category. Ideally, to conduct this study it is necessary to compare the number of times the assignees of the downstream citing patents extraction are the same of the extraction of the source patents of the same category.

However, as already discussed in section 3.2.2, the names of companies are affected by variations that derive from transcriptions of names from other scriptures, such as Chinese, so that one firm can be represented by slightly different spellings of its name, and another commonly encountered issue in search and analysis is that subsidiaries of corporations often use varying names in different countries (Trippe, 2015).

For this reason, since the difficulties of dealing with so many records coming from 9534 citing patents' assignees affected by this peculiarity, it is assumed to proceed with a restricted sample containing the top 100 assignees of citing patents and the other top 100 of root ones, both provided by the Derwent platform which instead converts to a much clearer and comparable assignees' names between two samples, with respect to what can be done with Excel through manual techniques that are time-consuming and subject to errors in dealing with thousands of rows. The only limit of this analysis is only looking at the top 100 companies and not all those really contained in the sample.

The restricted sample of the top 100 assignees of the citing patents weighs **3,7%** of patents (365 out of a total of 9534 within the sample) referring to the same assignees of the source sample used for benchmarking.

A company owning the citing patent could also be the assignee of the root patent, meaning that it holds the rights to both the citing and the root patent.

See *Table 3.13* below for more details:

Downstream assignees found in both samples	% of citing patents out of total sample	% of citing patents out of total source sample
FRACTUS	1,2%	6%
UBLOX AG	0,6%	6,2%
ADVA OPTICAL NETWORKING SE	0,6%	5,8%
BENTLEY SYS INC	0,4%	1,9%
REACTIVE ROBOTICS GMBH	0,3%	1,4%
BLICKFELD GMBH	0,2%	1,3%
FOCAL POINT POSITIONING LTD	0,2%	1%
ULTRA SAFE NUCLEAR CORP	0,1%	1,3%
PETROCERAMICS S P A	0,1%	1%
TOT	**3,7%**	**25,9%**

Table 3.13 Assignees of downstream citing patents found in the root patents' sample too

Although in this case the companies found in both samples have an almost negligible number of patents (3,7%) compared to the total analyzed, it can be deducted that if a company has more root patents (25,9%) than citing patents assigned, then it could indicate that the company has made important discoveries or innovations in a certain field and that their inventions have been recognized and cited by other patents, or that it has a strong position in the industry and a solid knowledge base and intellectual property. This is the case for all the Assignees under review, even more so in the case of Fractus and UBLOX, for which the number of root patents is almost 500 times larger than the number of citing patents.

The next analysis instead focuses on the remaining discarded assignees of the 100 within the restricted dataset, from which to select the top 11 companies that are not part of the source sample and proceed with further statistics, to highlight differences in technical fields of application between source and destination samples through the study of a few patents taken as examples for each assignee in the flow.
They are shown in the table 3.14:

Downstream citing Assignee/Applicant	Count of patents	% out of tot patents (9534)
Qualcomm Inc	178	1,9%
Samsung electronics Co. Ltd	158	1,7%
Huawei tech Co. Ltd	153	1,6%
IBM	107	1,1%
Ericsson Telefon AB	80	0,8%
Apple Inc	57	0,6%
ZTE Corporation	53	0,6%
Intel Corporation	47	0,5%
Alcatel Lucent (the new Nokia)	39	0,4%
Siemens	33	0,3%
Masonite	30	0,3%

Table 3.14 Top 11 Assignees of downstream citing patents' different from original ones

Of the top 11 just seen, the companies that are directly involved in the space sector are 3 out of 11, namely Qualcomm Inc, IBM, Intel Corporation, while for all the others it is necessary to consult the related patents and the type of relationship they have with the cited assignee and its reference patent for the citing one technology.

First in descending order is Qualcomm Inc which for example mentions the ANRA Technologies patent in the stream below eight times for different citing patents. The fields of application are diverse, identified by 6 IPC subclass codes (G05D, B64C, G08G, H04B, H04L, H04W), it follows a reference to unmanned aircraft and the development of a collision avoidance system:

- Qualcomm's patent US10719705B2 from the citing sample: "*Method for operating robotic vehicle, involves adjusting proximity threshold used in collision avoidance system consistent with effect on control or navigation of robotic vehicle of environmental or other conditions*"
- ANRA Technologies patent US9927807B1 from the source sample: "*Unmanned vehicle for example fixed-wing unmanned aircraft, for example for military applications, has data processing apparatus receiving navigation commands from control station and utilizing navigation commands to control movement of vehicle*"

(Patents' information provided by *derwentinnovation.com*).

In fact, this flow includes sector G05D for the development of control systems in connection with G08G which specifically deals with traffic control systems, B64C for aircraft in general such as helicopters or airplanes on which such implementations would take place.

Regarding the IBM citing company which offers satellite data management systems, space data analysis and general services for the aerospace sector, while the space company in the sample of origin, relevant to make a citation flow analysis, is founded in Italy called Octo Telematics, a pioneer in the insurtech sector through the provision of Big Data to insurance companies by transforming traffic information into analytics. It is famous because it created the world's first telematics information database in support of insurance.
The two are related to the IPC subclass code B60W, sector of conjoint control of vehicle sub-units of different type or different function, control systems specially adapted for hybrid vehicles, road vehicle drive control systems (information gathered by the International Patent Classification website).
IBM and Octo are linked through the following patents:

- US11001273B2 for IBM: "*Method for providing notification based on deviation from driving behaviour of vehicle, involves detecting that driver is deviated from driving behaviour, and transmitting notification indicating that driver is deviated from behaviour*"
- US20170166217A1 for Octo Telematics: "*Control system for dynamically controlling sensor-based data acquisition in vehicles, has processor that detects occurrence of event by comparing event score based on set of filtered signals with event threshold*"

  (Patents' information provided by *derwentinnovation.com*).

It is therefore clear that IBM's application area which is focused on monitoring traffic and driving in cars, but also could be used for supporting security during space missions in spacecraft.

Furthermore, within the sample there is Intel Corporation which is famous for electronic components such as high-performance microprocessors that can be used for satellites or on-board embedded systems.

In short, these three companies just described (IBM, Qualcomm, Intel) would perfectly mirror the analysis provided by the IPC subclass codes in *Table 3.11* for downstream citing patents, with the prevalence of patents used in wireless communication networks (H04W) and transmission of digital transformation (IPC subclass codes H04L and H04B). However, it is just seen how they are also applied in sectors with different IPC subclass codes.

On the other hand, it is interesting the presence of the other firms apparently related to non-space domains like Huawei and Ericsson Telefon.

In fact, although Huawei can be famous to be employed in the telecommunications and network infrastructure manufacturing sector (field of 5G networks worldwide), it can also be assigned to the space environment thanks to the relationship found with its cited assignee Ublox within the patents' sample. In fact, Huawei could supply network and communication equipment for satellite infrastructures, mission control systems, and ground stations related to the technical sector H04L (i.e., transmission of digital transformation). While Ublox produces global positioning systems (e.g., GPS) and wireless communication solutions.
The following two patents support this possible relationship:

- CN102565830A applied by Ublox with the following title: "*Method for estimating position of electronic device e.g., portable device, involves estimating position of electronic device based on detected matches between observation and record and determined indications of source of records*"
- CN107111641B applied by Huawei with the following title: "*Method of updating database of positioning data, involves processing stored measurement data to calculate revised estimate of respective position and processing revised estimate to update database of positioning data*"

(Patents' information provided by *derwentinnovation.com*).
So, although Huawei is specialized in the development of mobile devices, network infrastructure, telecommunications equipment, cloud computing solutions, it offers can also have a major impact in space solutions.

The same process of evaluating the citation flow can also be taken for Ericsson Telefon, purely focused on the development of electronic devices in the field of telecommunications but involved in space activities from another assignee involved in the space sector such as Inmarsat.
In particular, the two patents that are analyzed are the following:

- CN109328452A applied by Ericsson with the following title: "*Adaptive signal-detection mode selection method used in wireless communications, involves identifying combination to time offset and frequency offset results in largest second correlation result generated based on synchronization signal*"
- CN1802796A applied by Inmarsat with the following title: "*Transmission timing estimation method used for multi-user detection and decoding, involves estimating updated transmission estimate by canceling acquired current transmission estimate from combined signal*"

(Patents' information provided by *derwentinnovation.com*).
Ericsson could be involved in the development of communication infrastructures and wireless networks used for communication between satellites, ground stations

or during space missions, which is the same core sector in which Inmarsat is engaged.

Furthermore, an interesting flow in this sub-section concerns Siemens Healthcare (subsidiary of Siemens AG) and ADVA Optical Networking, which leads to the deployment of technologies used in the medical field, so a space-to-non-space flow would be analyzed through the following patents:

- US20210286659A1 for Siemens Healthcare: "*Integrated chip-based communication system used in medical imaging device of medical imaging facility, has crossbar or interconnect which designs data transmission as function of determined readiness to receive*"
- US20210243129A1 for ADVA Optical Networking: "*Method for correcting packet delay variation of express traffic, involves applying additional delay to high-priority express packet according to calculated variation compensation delay value to compensate preemption delay*"

  (Patents' information provided by *derwentinnovation.com*).

Siemens Healthcare provides medical imaging solutions, laboratory diagnostics, and healthcare information systems. As already mentioned in section 3.2.5, this company had a significant impact during the covid-19 pandemic, in fact, in 2020 it invested more than EUR 1.3 billion in research, developing a wide range of covid-19 tests and digital solutions for results management. For example, AI-Rad Companion is a software solution that uses deep-learning-based algorithms, increasing diagnostic accuracy in the interpretation of medical images as illustrated in the *figure 3.9*.

Fig.3.9 AI systems to automate tasks in magnetic resonance imaging of the brain and prostate

Siemens Healthineers impacts more than 5 million patients around the world every day. The areas of interest are laboratory diagnostics, clinical imaging and digital solutions, which bring health data to medical personnel, healthcare professionals and citizens.

The last interesting flow concerns Masonite, which, being specialized in the manufacture of flat doors, would seem to be an outlier in this list of assignees. However, defined as IPC subclass E06B for this patent stream, it refers to a type of glass assembly for aircraft portholes and therefore also used for glass applied to flat doors. Below:

- US6546682B1 for ODL from original sample: "*Window assembly for use for example in residential buildings and aircraft, has transparent film with marginal portion extending beyond perimeter edges of glass panels laminated on film"*
- US7721501B2 for Masonite from destination sample: *"Door for use for example in commercial building, has lip portion with flexible sealant fins, where fins provide contact force against insert to prevent rattling of insert within door and core material is provided in cavity between skins"*

(Patents' information provided by *derwentinnovation.com*).

3.3.3 Comparison between upstream citing and root tech sectors

The following section proceeds in the same manner as done for the downstream category in section 3.3.1, comparing the industrial sectors of application of the technologies patented by upstream firms in the source sample with those in the destination sample. This benchmark is represented by the tick in the last column of *Table 3.15* below:

Upstream citing patents' IPC subclass	Code's description	% out of total citing IPCs	Presence in top 10 root patents' IPC subclasses
H01Q	Antennas (i.e., Radio Aerials)	8%	X
G06F	Electric digital data processing	6%	X
H04L	Transmission of digital transformation (e.g., Telegraphic communication)	6%	X
H04B	Transmission	5%	X
H01L	Semiconductor devices	4%	X
A61B	Diagnosis; surgery; identification	3%	
B64G	Cosmonautics; vehicles or equipment therefor	3%	X
H04W	Wireless communication networks	2%	
B64C	Airplanes; helicopters	2%	X
G06Q	Information and communication technology	2%	

Table 3.15 Distribution of IPC subclass codes for upstream category

Most of the sectors present in the root patents are also found in the citing ones, except for the tech sector H04W and G06Q, with the last one being of particular interest for information and communication technologies in administrative, commercial, financial, managerial or for supervisory purposes.
While an outlier with respect to space is the technical sector related to the IPC subclass code **A61B** which covers instruments, implements, and processes for diagnostic, surgical and person-identification purposes, including obstetrics, instruments for cutting corns, vaccination instruments, fingerprinting, psycho-physical tests. Specifically, the top 5 extended forms directly gathered by the International Classification Patents website are the following:

- A61B 1/00: instruments for performing medical examinations of the interior of cavities or tubes of the body by visual or photographical inspection (e.g., endoscopes)
- A61B 3/00: instruments for examining the eyes
- A61B 5/00: measuring for diagnostic purposes
- A61B 6/00: apparatus for radiation diagnosis
- A61B 7/00: instruments for auscultation

(Wipo, International Patent Classification website).

It would like to give an example of a company in the sample that is involved in the development of technologies in this non-space sector such as **Bausch & Lomb** which is a multinational company specializing in eye health technology. In particular, the company is involved in the design, development, production and marketing of eye care products and devices, including eyeglasses, contact lenses, lens care products, ophthalmic solutions and ophthalmic surgical instruments. During the search for a company in the sample of citing patents, several cases found that were in fact hospital facilities.

IPC Subclass code B64G analysis

Below (*table 3.12*) technical sectors' weights, belonging to the citing patents' sample, are represented for the upstream category as percentage value out of the total 26326 records of primary keys "publication number - IPC subclass" of the upstream category (see table 3.10 above):

IPC Subclass	% out of total IPC subclasses
B64B	0%
B64C	1%
B64D	0,6%
B64F	0,1%
B64G	0,1%
B64U	0%

Table 3.16 B64 tech sector for upstream category

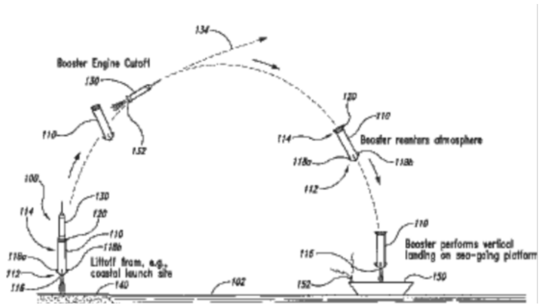
As can be seen, the presence of patents with this code is very low, however, it is of particular interest to study some interesting flows such as the following.

Regarding the subclass code **B64G**, it is identified a citation flow from a space to another space sector of application between the two space companies Boeing and Blue Origin:

US20110017872A1 for Blue Origin from the root patents' sample: "*Method for operating space launch vehicle, involves positioning landing structure in body of water so as to receive landing space launch vehicle*"

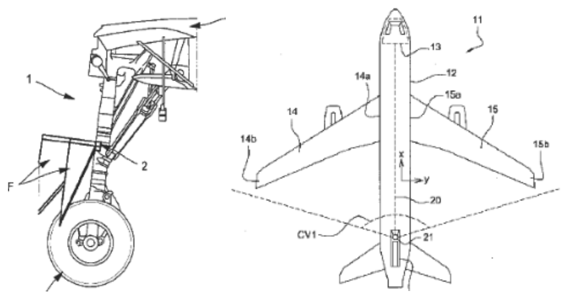
US20160368134A1 for Boeing from the citing patents' sample: *"Automated apparatus for moving end effector over surface of airfoil-shaped body in aircraft, has first and second rollers that are rotatably mounted to opposing ends of cross beam for rotation about axes respectively"*

(Patents' information provided by *derwentinnovation.com*).



Blue Origin patent illustration

For the subclass codes **B64C, B64D**:
US10000278B2 of Safran Electronics from the citing sample: *"Undercarriage for aircraft, has rod moved relative to box along longitudinal axis, and obstacle detector fixed on undercarriage, where obstacle detector is fixed in adjacent zone of end of box"*
WO2012131105A1 of Latecoere from the source sample: *"Aircraft such as helicopter, has observation system comprising cameras, which are positioned in wing of aircraft such that part of external environment of aircraft is located in panoramic field of view of cameras"*
(Patents' information provided by *derwentinnovation.com*).



Safran Electronics patent on the left, Latecoere one on the right

3.3.4 Comparison between upstream citing and root assignees

This section will proceed in the same manner as in section 3.3.2 for the downstream category, thus implementing the same search methodology and type of study: count of citing patents that are still assigned to the space companies of the source sample for the upstream category.
As usual, it is assumed to proceed with a sample of the top 100 assignees of citing patents and the other top 100 of root ones both provided by the Derwent platform. The first restricted sample of citing patents weighs **5,7%** of patents (814 out of a total of 14222 within the sample) referring to the same assignees of the source sample used for benchmarking.

A company owning the citing patent could also be the assignee of the root patent, meaning that it holds the rights to both the citing and the root patent.
See *Table 3.17* below for more details:

Upstream assignees found in both samples	% of citing patents out of total sample	% of citing patents out of total source sample
SOLAERO TECH CORP	0,9%	3,4%
KYMETA CORP	0,8%	5,5%
LATECOERE	0,6%	4,6%
SYNOVA SA	0,4%	1,7%
METALYSIS LTD	0,4%	3,6%
EUTELSAT SA	0,4%	4,2%
ANTENOVA LTD	0,4%	3,8%
TAOGLAS GROUP HOLDINGS	0,3%	2,1%
ASTRAPI CORP	0,3%	1%
CAILABS	0,3%	1%
PARAGRAF LTD	0,3%	2,4%
NORSK TITANIUM AS	0,2%	1,6%
CENTRE NAT RECH SCIENT	0,2%	0,8%
BLUE ORIGIN LLC	0,2%	1,1%
ARQIT LTD	0,2%	1,2%
TOT	**5,7%**	**38,3%**

Table 3.17 Assignees of upstream citing patents found in the root patents' sample too

Here again as already done for the downstream paragraph, although the companies found in both samples have an almost negligible number of patents (5,7%) compared to the total analyzed, it can be deducted that if a company has more root patents (38,3%) than citing patents assigned, then it could indicate that the company made important discoveries or innovations in a certain field and that their inventions have been recognized and cited by other patents, or that it has a strong position in the industry and a solid knowledge base and intellectual property. This is the case for all the Assignees under review, even more so in the case of Solaero and Kymeta.

The top 11 assignees or applicants reported in the *table 3.18* below are not present in the original sample of upstream firms, because the scope of this paragraph as done before for the downstream one, is to highlight differences in technical fields of application between source and destination samples.

Upstream citing Assignee/Applicant	Count of patents	% out of tot patents (14222)
AT & T	264	1,9%
ABBOT DIABETES CARE INC	252	1,7%
Boeing Co	186	1,3%
ADVANCED New Technologies Co LTD	112	0,8%
Airbus Operations	91	0,7%
ALIBABA Group Holding LTD	89	0,6%
Metalysis LTD	60	0,4%
Eutelsat	59	0,4%
Bosch GMBH Robert	59	0,4%
Mentor Acquisition One (acquired by Siemens)	58	0,4%
SKYBELL Technologies INC	48	0,3%

Table 3.18 Top 11 Assignees of upstream citing patents' different from original ones

Among the companies presented, two of them are most related to the space sector: Eutelsat and Boeing Co, the former deals with satellite telecommunications enabling broadband connectivity, the latter is an aerospace and defense company dedicated to the manufacture and sale of aircrafts, satellites, defense systems and other space technologies (e.g., rockets). It is renowned for its contribution to the space travel industry, having developed the Boeing CST-100 Starliner spacecraft to transport astronauts to the International Space Station.

Although ALIBABA Group operates mainly in the non-space field of e-commerce, Internet services, it has also patented a real-time satellite tracking method explained in the two patents of relationship with the space company Orbit Logic from the sample of origin, which refers to the technical sectors H04N (scanning of a picture), H04M (telephonic communication), H04W (wireless communication), G06Q for information and communication technology and G06F for regarding electrical digital data processing. The two patents follow:

- US20150257126A1 applied by Orbit Logic with the following title: "*Method for providing real-time imaging satellite opportunity notifications on electronic mobile device, involves calculating time periods during which satellites capture satellite imagery of user-defined location by mobile device"*
- CN107193847A applied by ALIBABA Group with the following title: "*Satellite real-time track information inquiry method, involves searching real-time track information of target satellite from information source based on first satellite identification"*

(Patents' information provided by *derwentinnovation.com*).

The real outlier in the Top 11 classification, however, is **Abbott Diabetes Care Inc** specialized in the design and marketing of diabetes management solutions such as medical devices, including blood glucose meters, sensors, and insulin pumps. Abbott's core innovation is the "FreeStyle Libre" system (*Figure 3.10*) for monitoring blood glucose based on sensors directly applied to the skin by communicating glucose data to the patient through a mobile application.

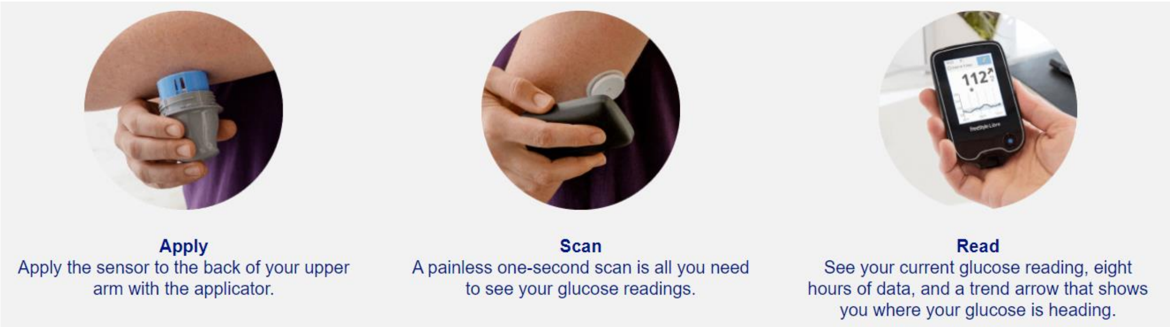


Figure 3.10 FreeStyle Libre: glucose readings technology released by Abbott Diabetes Care

In this way, an individual can monitor constantly without having to resort to traditional blood samples. It is interesting to understand the connection of such a company with its origin in the initial sample of upstream companies, thus analyzing the root patent of reference in this case which has as its assignee the M3 Systems company, which, being specialized in the development of sensors for environmental monitoring, navigation, spatial orientation and spacecraft control, may have released a technology in this field whose patent was later exploited by Abbott Diabetes Care for the "FreeStyle Libre" realization.

The following patent flow case between the two companies deviates from the sensor theme but focuses more on the sampling activity, as explained by the two patents:

- US10349874B2 applied by Abbott Diabetes Care Inc. whose title is: "*Analyte monitoring system for the blood glucose levels for the body cells, comprises an analyte sensor that is set in operative contact with an analyte, and generates multiple data points associated with a monitored analyte concentration"*
- US5284156A applied by M3 Systems whose title is: *Automatic tissue sampling device has first inner needle, second outer needle which both have handles and these are fitted into yokes of device"*

(Patents' information provided by *derwentinnovation.com*).

Finally, it is interesting to note the presence of Airbus in this list, a company that was discarded in the initial selection and classification phase of upstream or downstream startups or scaleups, as it is considered a big corporation operating in many different industries.

3.3.5 Comparison between countries of origin and destination

As a final analysis of the patent extraction samples, the top origin and destination countries of application of patents are compared, identifying for the downstream sector the relevant presence of the United States (977 patents) and the European Patent Office (776 patents) in the source patents, while almost the entire sample of citing patents sees application only in the United States (591 patents).
Mutually for the upstream category, the presence of the United States (885 patents) and the European Patent Office (523 patents) as source countries is once again consolidated, with the significant attendance of the United States alone this time with 1280 patents.
These numbers are not only in line with what this work of thesis starts with in chapter 3.1.2 of the analysis of companies in the top 10 countries, where there is evidence of the United States at the top of the list, confirming that it has a solid legal system for patent protection, is one of the largest and most developed economies in the world with a high propensity for innovation and technological development, and is a member of international intellectual property protection agreements such as the Patent Cooperation Treaty (PCT). These are all good reasons for a company or innovator to apply in this market.
The Patent Cooperation Treaty (PCT) assists applicants in seeking patent protection internationally for their inventions, helps patent offices with their patent granting decisions, and facilitates public access to a wealth of technical information relating to those inventions (WIPO, PCT website).
By filing one international patent application under the PCT, applicants can simultaneously seek protection for an invention in 157 countries out of 206 existing in the world (around 76%), as reported in the *Figure 3.11* below:

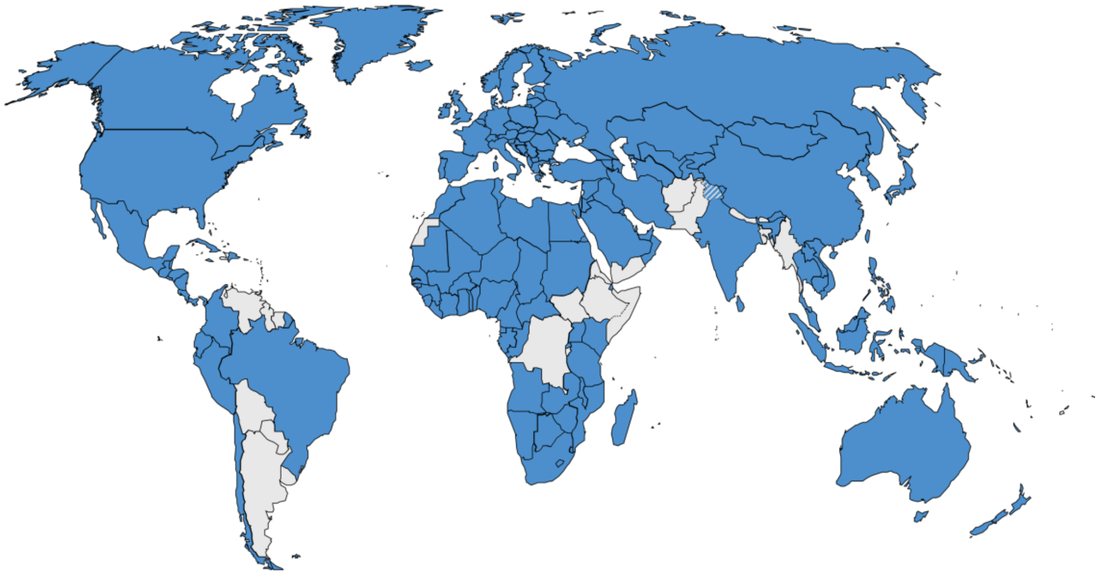


Figure 3.11 The 157 contracting States annexed to the PCT

Conclusions

From patent citation flow studies, it is possible to identify the key technologies in each sector, thus identifying emerging trends and areas of greatest interest for innovation.

In the last section of Chapter 3, patents are identified to explain the citation flows between companies from the source sample to companies in the citing sample. Such a method can help to trace the connections and interactions between actors in the field, such as companies and inventors, enabling a better understanding of knowledge diffusion and the dynamics of innovation networks. Many examples were found of companies from the citing sample (not present in the source one) that confirm their application in the non-space sector by nature, and others that while making a large contribution in non-space applications turn out to have patents in the space sector. A few examples of companies involved in flows of both one type and the other out of the 22 identified were given, i.e., Abbott, Densowave, Masonite and Siemens involved as non-space flow destinations, while Alibaba, Huawei, Ericsson as space flow destinations of citation flows although apparently not focused on space technologies by their nature. This demonstrates that citation does not depend so much on the characteristics of the company as on those of the patent. While all the patents studied for the B64G sector and other related streams find application in the space sector as expected by the nature of the IPC subclass code.

In the space-to-non-space flow, one of the key sectors analyzed in the destination was the medical field. Space has an impact through medical research carried out under ideal conditions to study the effects of gravity on the human body, thus developing new innovative therapies, drugs and understanding new diseases.
It is no coincidence that in Table 3.15 with the top 10 IPC subclass codes of the upstream category, 3% of the citing patents belong to the A61B sector on diagnosis and surgery.

The percentages of the top 10 IPC subclass codes for both the downstream and upstream categories are confirmed, i.e., most of the analyzed patents cover the subclass H01Q on antennas, H04W on wireless communication and H04L on transmission, G06F for electric digital data processing.
Furthermore, it can be attested thanks to the examples between patents an interesting result that a very space-centric root patent finds its corresponding citing patent equally addressed in space topics.

It was also seen that 3.7% and 5.6% of the assignees in the downstream and upstream categories, respectively, out of the total sample of the top 100 provided by Derwent, are found in both the source and the target sample, indicating that these companies hold the rights to both the citing and the root patent. It can be deducted that if a company has more root patents (25,9% up to the downstream category, 38,3% up to the upstream category) than citing patents assigned, then it could indicate that it made important discoveries or innovations in a certain field and that their inventions have been recognized and cited by other patents.
Although the samples analyzed in this thesis has more downstream companies than upstream companies, it is inversely proportional to the number of patents granted, as there are more for the upstream category. This is because upstream companies are involved in the research and development phase of new technologies that may require more patents to protect their discoveries. On the other hand, downstream companies may be more focused on the practical application of existing technologies, which may require fewer patents.

Overall, the analysis of patent citation flows provides an in-depth overview of technological developments, the relationships between inventions and the main players in the field. This information can be used to make strategic decisions, identify innovation opportunities, and assess the value of intellectual property.

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