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Italy plays a leading role in the global aerospace industry. Our businesses, expertise and technologies and our astronauts are renowned for their outstanding excellence.

A status that carries great responsibility and the duty to follow and explore every aspect of an ever-changing environment.

In a world of increasingly global challenges, from climate change to the impacts of demographic trends, space research opens up a world of as yet unexplored possibilities for humans while encouraging a more sustainable and inclusive approach.

This report by Intesa Sanpaolo Innovation Center and Fondazione Links offers a snapshot of the state of the art, especially in terms of its impacts in other industrial sectors where new technologies can act as a catalyst for growth and a driver of the economy.
Understanding where we are today is essential to identify the challenges of tomorrow.

Enjoy the read.

Maurizio Montagnese
Chair of Intesa Sanpaolo Innovation Center

Marco Mezzalama
Chair of Fondazione Links

Preface

The New Space Economy is booming, driven by the commercialisation of the traditional and institutional space sector. Underlying this paradigm shift is, on the one hand, technology, both upstream and downstream, and on the other, new business models and public-private partnerships.

This report provides a broad overview of the Italian space industry in this changing scenario, with emphasis on emerging innovations and applications and new industrial and commercial enterprises. Summarising an industry that is rapidly evolving day-by-day is not easy and attempting to establish which solutions will be the most successful is even harder. What is certain is that Italy is one of the few countries in the world to have an industrial supply chain and a research system that is able to ensure the technological advancements and the development of applications needed to face the challenges of our times, space-related or not.

The first part of the report describes the Italian aerospace ecosystem, placing it in the context of the European and international market, and provides essential elements for understanding its complexity and value. The second part analyses the six typical technology and application domains of the space industry: from the strategic sector of access to space to human and robotic exploration of space, and from satellite technologies to their applications in the field of telecommunications, navigation and Earth observation. The advent of small satellites (and miniaturization technologies) and improved data management and processing capabilities (increasingly automated, on-board and from the ground) are perhaps the most distinctive aspects of the small space revolution that is already underway. Looking (a little) beyond the "here and now": building, transporting and operating a habitat on the Moon, or a lander on Mars, means developing know-how and technology that creates value for Italy and cements its already recognised position as a global player. The third and final part of the report describes the synergies with other industrial sectors, both in terms of direct technology transfer (spin-offs and spin-ins) and by type of transversal services and applications enabled by space infrastructure. Exploring and operating in space does pose many challenges but undoubtedly comes with many advantages, which can now be immediately exploited in a wide range of applications: precision agriculture, telemedicine, energy system monitoring, supporting transport systems and mobility, land and cultural heritage monitoring, and so on.

What emerges from the report is a complex and dynamic scenario that represents an essential basis for the development of Italy, from a perspective of economic and environmental sustainability. Italy has an enviable tradition to build on and an aptitude for innovation to use as a springboard: we can make this a winning combination.

I would like to end this preface with a quote by Douglas Adams from The Hitchhiker's Guide to the Galaxy: *"Space, it says, is big. Really big. You just won't believe how vastly hugely mind-bogglingly big it is*".
My first reason for choosing this quote is that Space has never been as big as it is today, yet, and above all, never so close as it is now, to people on Earth, people in Italy. The second reason is that sometimes reality surpasses science fiction, and what we could only imagine just a few decades ago is now already a part of our everyday lives.
Thanks to all who followed their dreams and made them come true, continuing to work towards a future in space. Hope you enjoy the read.

Sabrina Corpino
Associate Professor at Politecnico di Torino

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02 Technology Clusters

03 Target Industries and Sectors

01/

The Italian aerospace ecosystem

1.1 The market context

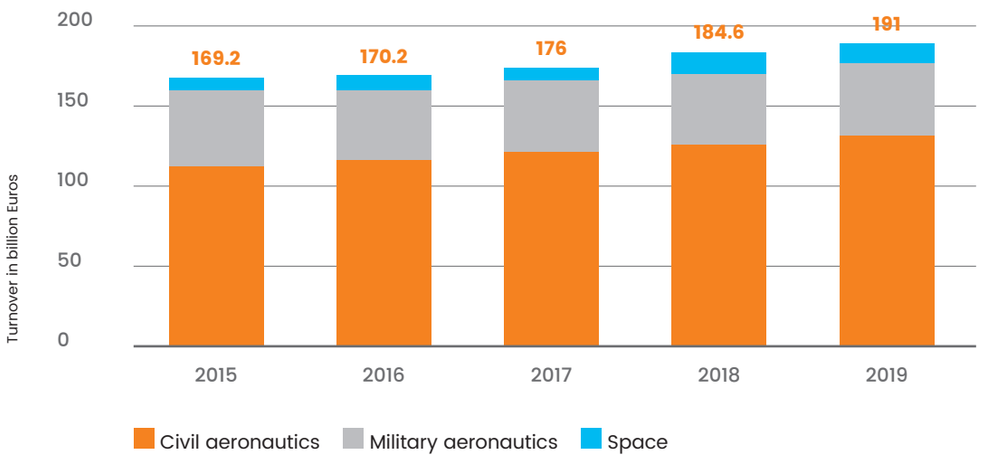
The OECD recognises Space Economy as a strategic sector for economic development. Generally speaking, aerospace activities can accelerate the technological and industrial progress of an area as they enable innovations that have impacts in multiple areas of industry, bringing significant social benefits. The importance of the aerospace sector is further evidenced by the increase in the allocation of resources by governments and institutions, and the world of finance and venture capital.

The aerospace sector manages all activities linked to the development and operation of flight vehicles, from aircraft to spacecraft, and satellites. According to Statista, the aerospace sector, including the defence segment, employs around 890,000 people in Europe alone and offer a very high return on investment: every euro invested in aerospace yields 11 euro in the broader economy. This benefit, coupled with the sector's pivotal role in ensuring technological and scientific progress and its strategic implications also in military terms, have historically justified the strong political and financial support received from public decision-makers, also due to the need to support long development cycles.

The turnover of the European aerospace industry stood at approx. 191 billion euro in 2019, marking an increase of 12% vs 2016. In terms of the breakdown by segment, while the performance of the military aeronautics segment remained relatively constant over the period, the turnover of the civil aeronautics and space segments increased. In detail, the civil aeronautics segment grew by 11%, from 117 billion euro to 130 billion euro, while the space segment grew by 59%, from 8.2 billion euro to 13 billion euro.

Turnover of the European aerospace and defence industry, 2016-2019

Source: Fondazione LINKS calculations based on Statista data -
Turnover of the European aerospace and defense industry from 2015 to 2019



The space segment includes all activities concerned with the exploration, research, understanding, management and utilisation of space, as well as the exploitation of the resulting resources.[1] Already from the early 2000s, the growth of the Space Economy was driven by a combination of diverse factors, such as the lower cost of space technologies and the possibility to exploit these further by developing new ground-based applications, the interconnection with the Internet economy, the use of smart manufacturing techniques and the emergence of new geopolitical dynamics. The maturation of the segment in the second half of the 2010s changed the financing dynamics of the sector: traditional institutional backing was flanked by growing and ambitious investments by private investors, redefining the relationship between public and private and opening up a new phase that goes by the name of "**New Space Economy**".

1 OECD, "The Space Economy at a Glance", 2014

The OECD identifies three distinct Space Economy segments:

1. The **Upstream** segment, relating to the activities, technologies and the science at the basis of space programmes, i.e. the development of the enabling space infrastructure and the production of space equipment such as satellites and launchers;
2. The **Downstream** segment, relating to "down-to-earth" products and services that directly rely on satellite data and signals to operate and function, i.e. telecommunications, navigation and positioning services, and those related to earth observation;
3. **Activities that are derived** or induced from space activities but are not dependent on it to function (e.g. technology transfer from the space sector to the automotive or medical sectors).

DEFINITION OF SPACE ECONOMY ACCORDING TO THE OECD

Definition translated and reworked on the basis of the OECD 2022 *Handbook On Measuring The Space Economy*

UPSTREAM

Scientific and technological foundations of space programmes, production and manufacturing of space infrastructure.

Fundamental and applied research; scientific and engineering support; dedicated ancillary services (e.g. insurance); supply of materials and components; design and manufacturing of space equipment and subsystems; integration and supply of full systems; space launch

DOWNSTREAM

Daily operations related to space infrastructure and ground-based activities that directly rely on space products/services (satellite technology, signals or data) to exist and function

Operations on space and ground infrastructure; supply of devices, products and services supporting consumer markets (e.g. GPS-enabled devices, set-top boxes, selected GIS, satellite television broadcast)

SPACE-DERIVED

or induced activities in other sectors

New activities in various economic sectors that derive from or have relied on space technology transfers

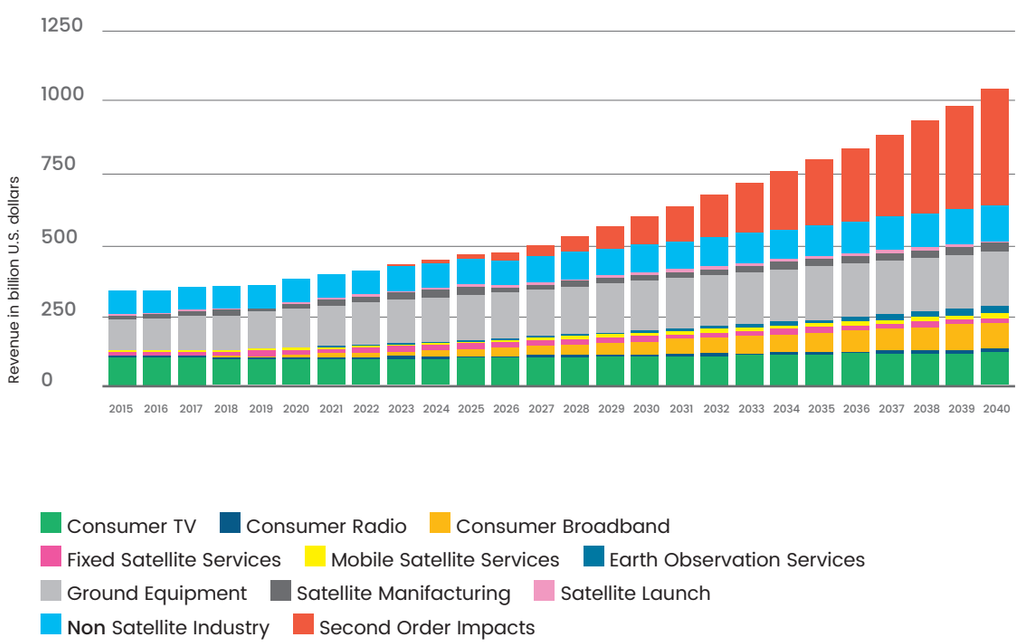
Activities/products/services derived from space technology, but not dependent on it to function (e.g. ad-hoc space technology transfers in the automotive or medical sectors)

OECD Handbook on Measuring the Space Economy, 2nd Edition

The space economy was valued at around 378 billion dollars in 2020, up 12% from 337 billion dollars in 2016.

Growth projections indicate that global revenue will increase to 600 billion dollars by 2030 and exceed 1 trillion dollars by 2040

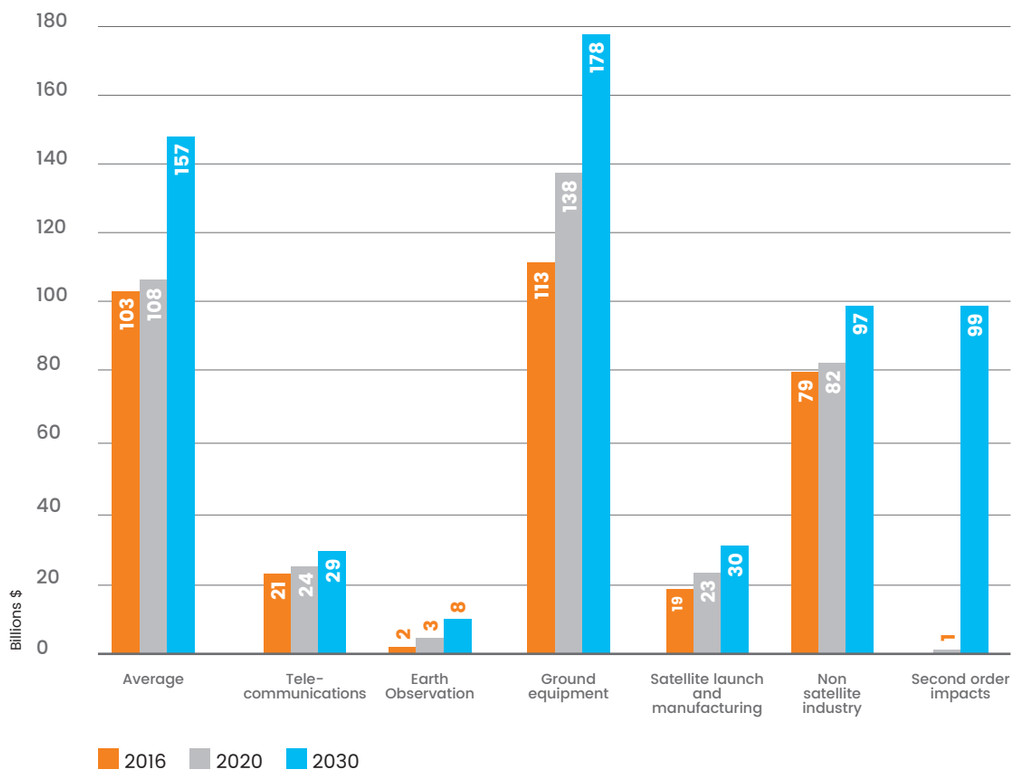
Global space economy revenue, 2015-2040
Source: Statista



All Space Economy segments grew between 2016 and 2020 and will continue to grow in line with projections up to 2030.
Interestingly, according to Morgan Stanley's analysis published by Statista, second-order impacts (i.e., additional turnover generated in other sectors from the use of space technology or services) are expected to reach 100 billion dollars in 2030 and 411 billion dollars by 2040, accounting for about 40% of the value of the entire Space Economy.

By 2030, the largest segments of the Space Economy will continue to be, in order, ground equipment and media communications, while the non-satellite segment (which includes government spending budgets for space missions and commercial travel) will be overtaken in value by second-order impacts.
The Earth observation segment, in which Italy excels, will see its value double by 2030 (8 billion dollars), reaching 25 billion dollars by 2040.

Change in Space Economy segments, 2016, 2020 and 2030
Source: Fondazione LINKS calculations based on Statista data - Global space economy revenue, 2015-2040.



While the market outlook for the space sector is positive overall, some business segments and business models remain reliant on public funding because they are significantly riskier due to high upfront investments, immaturity of the market and/or high levels of technological and regulatory uncertainty.
At the other end of the spectrum, less capital-intensive value-added services represent the most attractive business segments as they offer the best market opportunities and the lowest risk levels: it is precisely in these segments that there is growing commercial interest given that private actors generally prefer activities that can be structured on a business-to-consumer (B2C) model and that involve shorter implementation time spans for delivery of the product or service.

The most attractive segments for commercial investors include:

- The Ground Equipment segment, which includes, for example, the development of hardware and software for mission control centres, telemetry and remote control systems, GNSS receivers and communication terminals;
- Satellite services related to telecommunications, Earth observation and satellite navigation;
- Part of the space tourism segment.

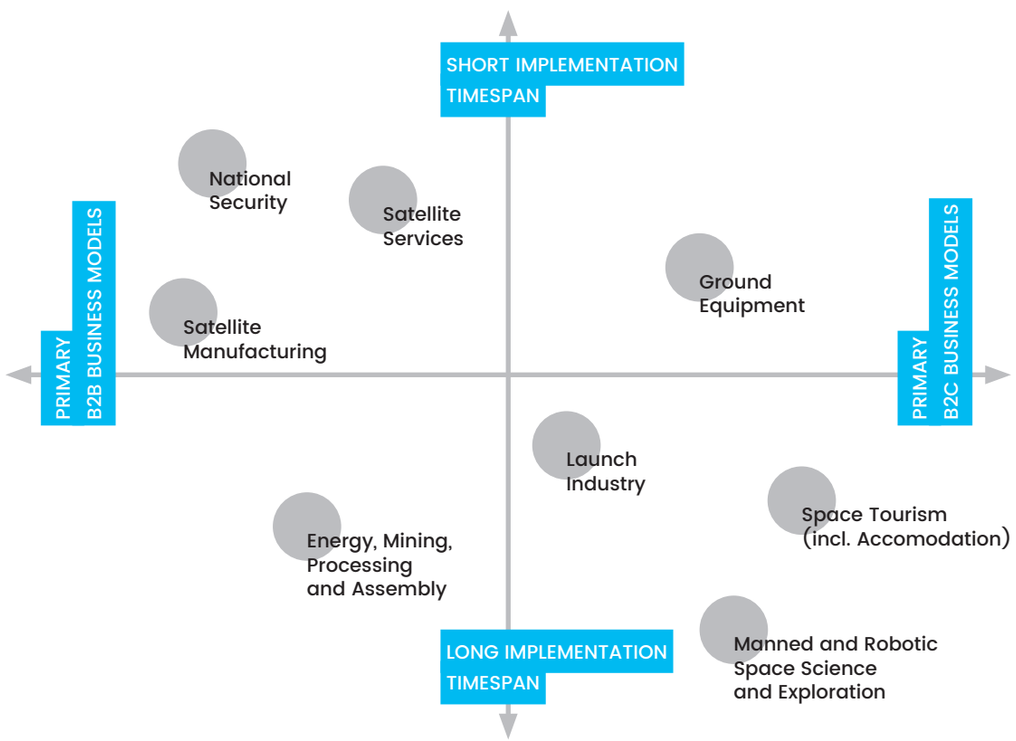
By contrast, mining and manufacturing in microgravity, deep space exploration and the construction of large satellites are segments of lower interest to commercial investors.

Of the 378 billion dollars of global revenue generated by the space segment in 2020, 78% is attributable to commercial activities and the remaining 22% to government spending.
Commercial space activities grew by 7.6% between 2016 and 2020, from 275 billion dollars to 296 billion dollars. Aggregate space spending by governments worldwide also grew over the same period, from 62.2 billion to 82.5 billion dollars in 2020.

In 2021, the United States allocated a total space budget of 54.6 billion dollars, accounting for almost 60% of the total budget of 92.4 billion dollars allocated by all governments worldwide.

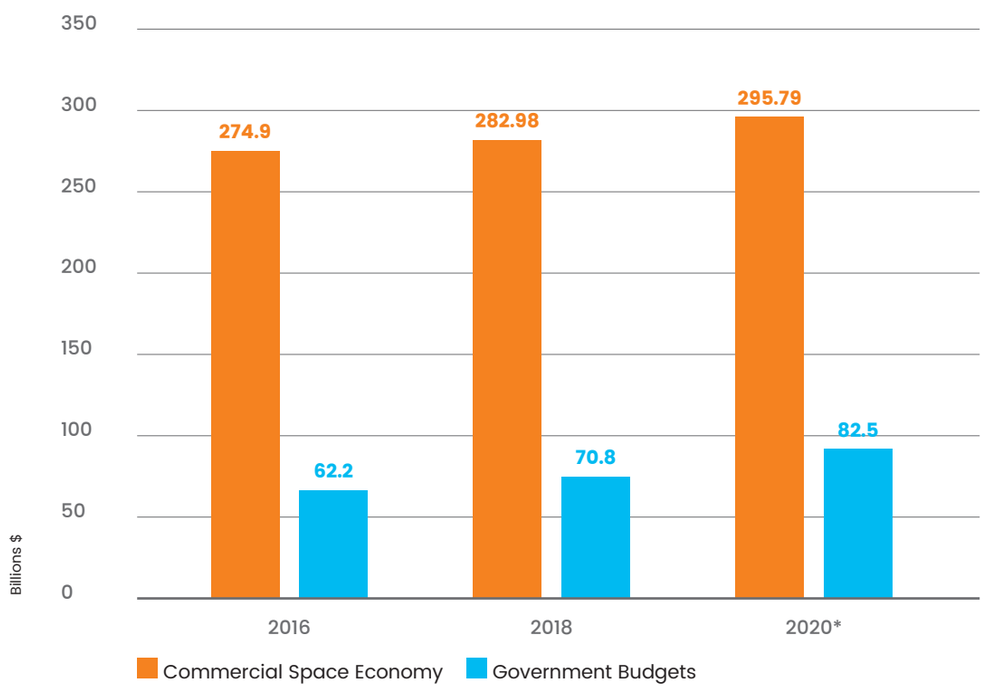
Time frames and references of the different lines of activity in the Space Economy sector

Source: Intesa Sanpaolo Innovation Center calculation based on EIB data



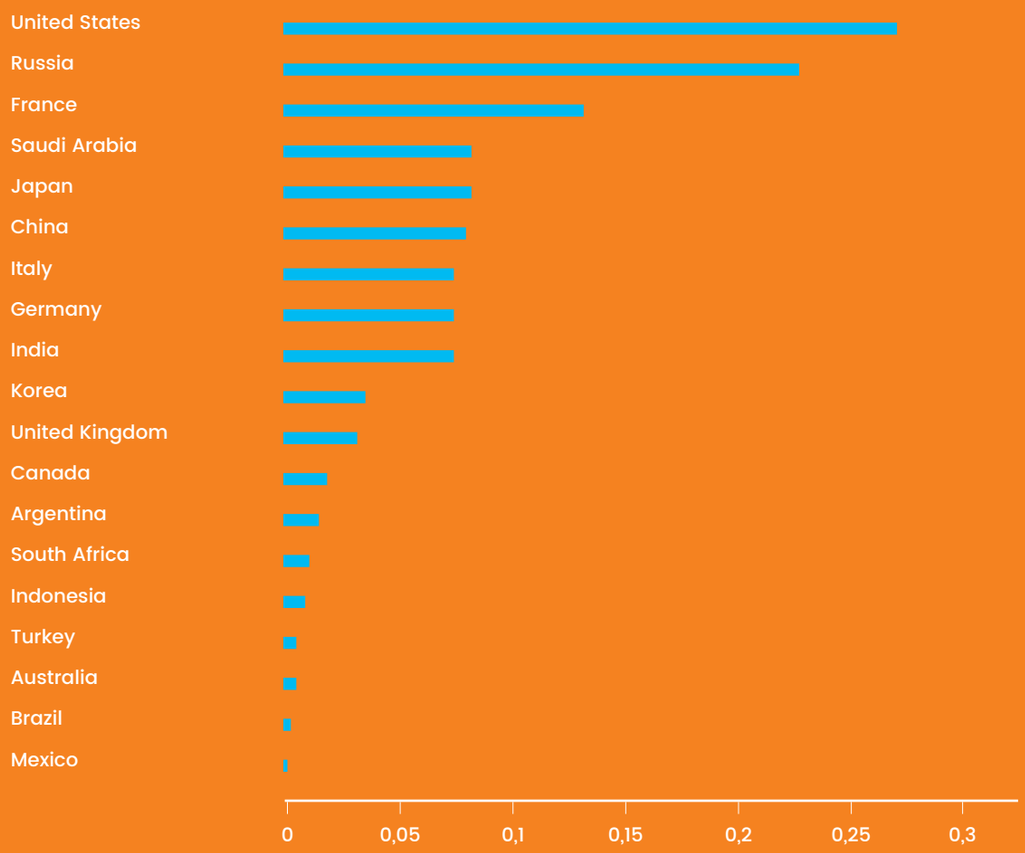
Value of the commercial space economy and aggregate government budgets at global level from 2016 to 2020

Source: Fondazione LINKS calculation based on Statista data



* The value of the commercial space economy is an estimate

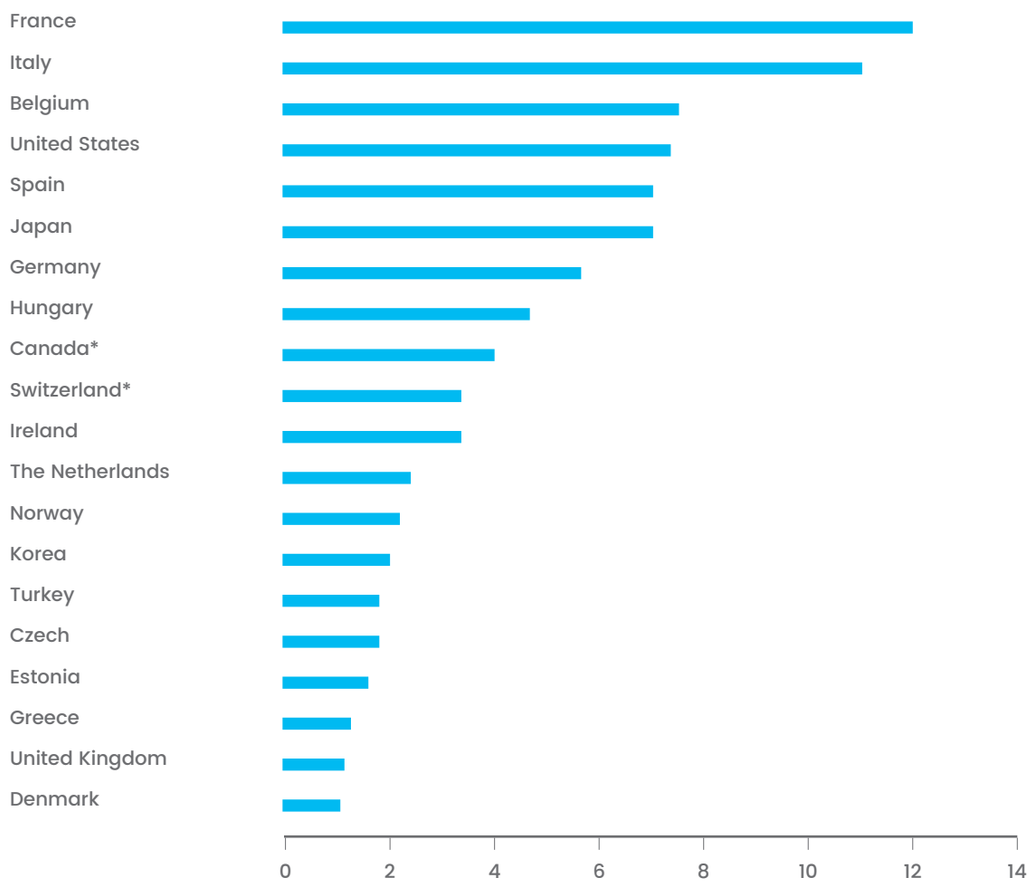
Annual expenditure for national space programmes in 2020
Source: Intesa Sanpaolo - "Spazio: nuova frontiera per economia e ricerca", 2021



In 2020, the average ratio of government space budgets to GDP in the G20 countries was 0.05%, with the United States and the Russian Federation leading the way with 0.2%, while Italy invested 0.069% of GDP

Another interesting indicator of the weight that a State attaches to the sector is what share of **the government budget for research and development is spent on space activities**.
According to the OECD, Italy ranks second on the international scene right after France (11.7%), with an average share 10.9% in the two-year period 2018-2019, higher than Belgium and the United States.
Although the numbers highlight that the Space Economy is geographically concentrated in developed economies, there are initial signs of partial democratisation in some areas of activity: in 2021 around 90 countries had at least one owned satellite in orbit, highlighting an evident growth from 2013 onwards (Source: OECD).

Government spending on research and development in the space sector 2018-2019
Source: Intesa Sanpaolo - "Spazio: nuova frontiera per economia e ricerca", 2021



* Figures for Canada and Switzerland are the latest available (2016 and 2015 respectively)

1.2 Italy's positioning

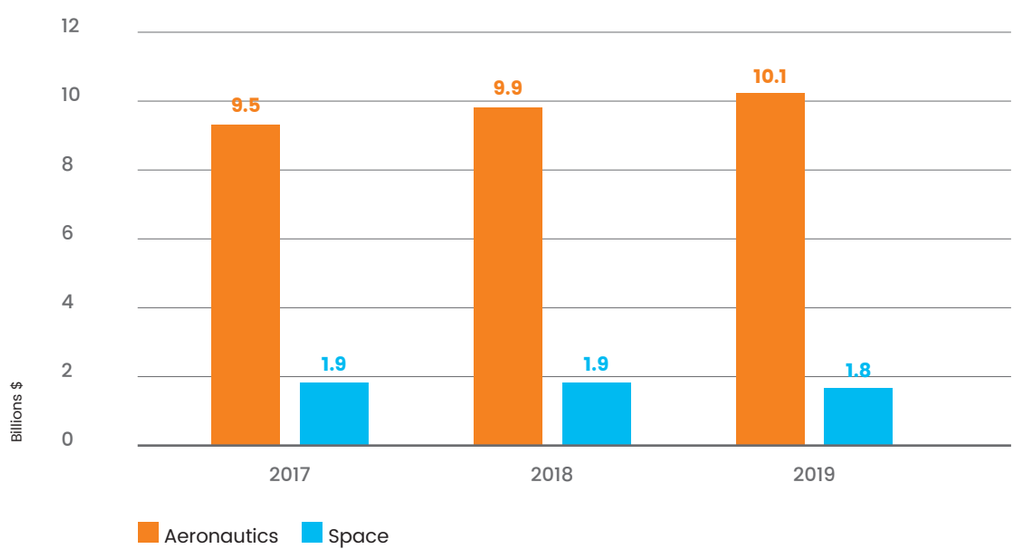
The Italian aerospace ecosystem is characterised by a very heterogeneous set of players who work in close cooperation with one another: this is due to the fact that historically, the government was both the entity that funded organisations in the aerospace sector, and their main customer.

Since the beginning of the new century, the digital industrial revolution and the advent of the New Space Economy have opened up the whole of the aerospace sector to the market, in which a growing number of private players are bringing fresh capital for commercial ventures, enabling public decision-makers (through public funds) to take on a role that is less operational and more of guidance.

The Italian aerospace industry ranks seventh in the world and fourth in Europe in terms of turnover, with revenues totalling 11.9 billion euro in 2019. The sector's 500 or so companies employ around 47,000 people and invest heavily in research and development

Italian aerospace industry

Source: Fondazione LINKS analysis based on Italian Trade Agency / Invitalia figures



The companies of the sector focus highly on innovation as a strategic and competitive lever: on average, around 11% of the annual turnover is invested in research and development, for a total of almost 1.4 billion euro. Although aerospace companies employ only 0.21% of the Italian workforce, they account for around 8.4% of the total R&D expenditure of the totality of Italian companies (16.6 billion euro). In addition to investments in innovation, aerospace companies work in an integrated way with academia and the scientific community, utilising the related infrastructure and services and assisted by regulatory bodies.

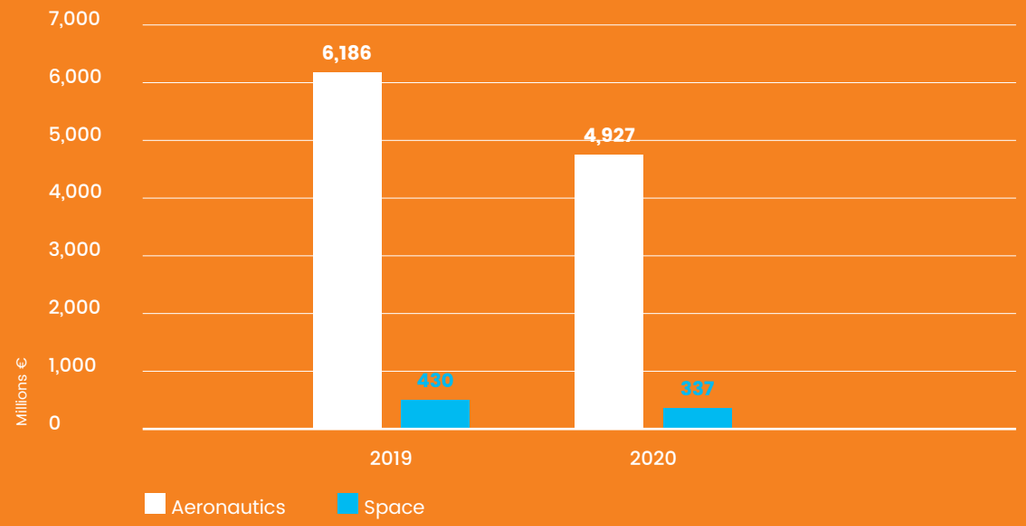
Approx. 50% of the sector is made up of manufacturers of aircraft, spacecraft and related devices, and about 20% of companies specialising in repair work. The remaining share of around 30% is made up of developers of flight equipment, software and instruments. Of the 500 companies active in this sector, about half (53%) are micro enterprises with an annual turnover of less than 2 million euro and fewer than ten workers. Considering the employment aspect alone, the number of companies employing fewer than five people rises to above 66% and only approx. 6% of companies employ more than one hundred workers.
In the fixed-wing aircraft segment, the national landscape is made up of a large number of companies that play an important role as suppliers of Boeing and Airbus - the giants in the sector of large commercial aircraft.
In the regional aircraft segment, ATR (a 50/50 joint venture between Leonardo and Airbus) dominates the regional turboprop aircraft market. In the engine segment, the main national player is Avio Aero - the main European branch of GE Aviation for the design and development of propulsion systems and a major supplier of turbine modules, mechanical transmissions and engine combustors for aircraft.

In the market of rotary-wing aircraft used in civil aviation, the Italian industry competes only with Airbus for world leadership

The Italian offering includes a full range of helicopters, from light single-engine to large three-engine models, and the world's only civil tilt-rotor aircraft. The industry has independent and comprehensive design capability, coupled with a global commercial presence, making it possible to cover all segments of aircraft use, from quarrying support and emergency medical services, to VIP and corporate transport services.
Overall, the aerospace industry generates a turnover of 13.5 billion euro, through a supply chain of around 4,000 companies, employing 160,000 people.
The space segment alone includes approximately 200 Italian companies, 80% of which are small and medium-sized businesses. This segment employs a total of around 7,000 people (the larger companies alone, Avio, Selex ES, Telespazio and Thales Alenia Space Italia, employ approx. 80% of the workforce), generating an annual turnover of about 2 billion euro.
According to a more inclusive logic, there are 286 active companies in the Italian space industry. Of these, as many as 17% focus on R&D activities and services, including

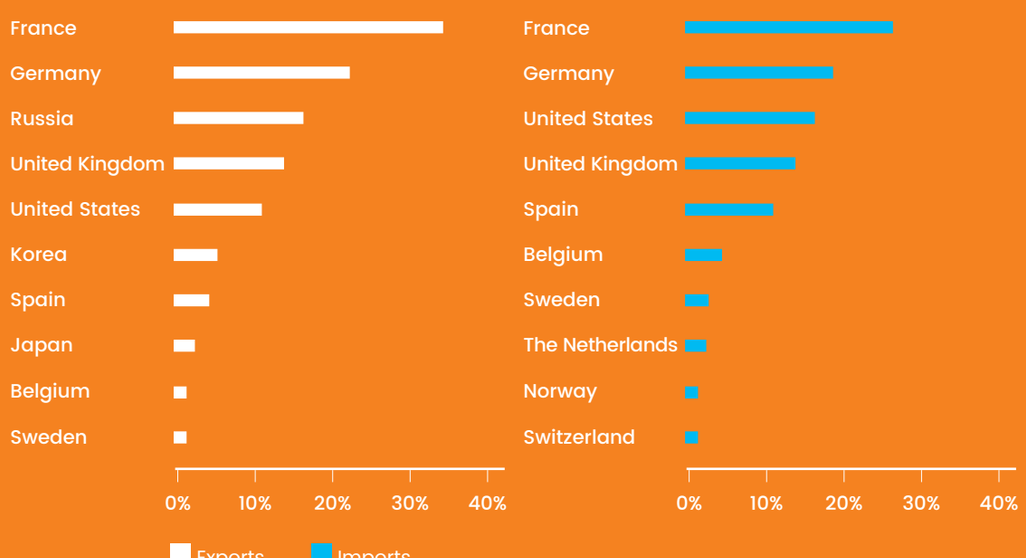
Italian Aerospace Exports 2019-2020

Source: Fondazione LINKS analysis based on data of the economic observatory of Italian Ministry of Foreign Affairs, November 2021.



Exports and imports in the Italian space sector 2018-2020

Source: Intesa Sanpaolo - "Spazio: nuova frontiera per economia e ricerca", 2021



manufacturers of satellites and/or complex engineering systems and companies specialising in Earth observation. 14% of the companies operate in the electronics sector, with a predominance of manufacturers of telecommunications equipment and navigation and measuring instruments, and 12% supply engineering studies. There is also no shortage of companies in the mechanical engineering sector, both in metalworking (8%) to develop special materials suitable for use in space and in the production of machinery and components (3.5%).

The space industry has a strong employment multiplier effect, whereby every new job in the sector creates four more jobs in the supply chain [2]

These numbers confirm the important role of the national space industry, through which Italy is able to support an influential international policy, make a significant contribution to the balance of trade and consolidate its presence in the field of technological development with highly skilled jobs.
Italian exports in the aerospace sector totalled 4.9 billion euro in 2020, down by around 20% vs 2019 (6.1 billion euro). In 2020, the largest share of the sector's exports went to Europe (41.2%). An important share of exports went to the United States (30%), while Asia received 17% of exports (of which 10% for East Asia).

Similar performance also for exports in the space segment considered alone, which fell by about 20%, from 430 million euro in 2019 to 337 million euro in 2020. Products traded in the space sector mainly consisted of satellite components for communications, both on the export and import side. Europe is the main trade destination, with France and Germany accounting for 51.6% of Italian exports in the sector (31.7% and 19.9% respectively in the three-year period 2018-2020). Next in line are Russia with 16.1%, the United Kingdom with 14.2% and the United States with 10%. The analysis of the export markets for Italian spacecraft and satellites shows that trade flows are highly concentrated.

The strategic nature of the aerospace sector, in particular of the space segment, is confirmed by the governance choice made in 2018 by the Italian Parliament, which directly entrusted the overall responsibility for space and aerospace policies to the Prime Minister, assisted by an inter-ministerial committee. The guidelines for space policy are outlined in a strategic vision document of the Italian space agency ASI, which guides the allocation of financial resources: Italy allocated around 837 million euro for space activities in 2017 and increased the allocation to 1,121 million euro in 2019, up by 34%. The projections for 2020 indicate a further increase to 1,527 million euro.
In terms of public funding for R&D, Space is the second largest recipient after universities.
Of the allocated funding, 66% went to ESA and 30% was earmarked for national and bilateral projects. The key priorities of the programme include Earth observation

2 L'industria italiana dello spazio: ieri, oggi e domani www.mise.gov.it

(30%), launchers and space transport (26%), human spaceflight and microgravity (20%) (see section 1.2 below).

In 2021, Mario Draghi's government included the space industry in the 2021 National Recovery and Resilience Plan as an economic enabler and approved the allocation of an additional 4.7 billion euro, half to be funded by the private sector, divided into five policy orientations consistent with the initiatives carried out at European level, also with a view to maximising their impact at the national level:

1. Satellite telecommunications (Mirror GovSatCom)
2. Support for national participation in GALILEO (Mirror Galileo)
3. Galileo PRS infrastructure
4. Support for Copernicus (Mirror Copernicus)
5. Space exploration and the related technological developments.

These orientations will be pursued by the entire Italian space ecosystem, which includes large companies, SMEs, start-ups, Aerospace Clusters, research centres, universities and national and supranational institutions (ASI and ESA), leveraging the extensive skills that have historically enabled Italy to preside over the entire space value chain, particularly in the upstream segment: from the production of satellites, launchers and orbital systems to the supply of subsystems, components, equipment, high-tech instruments and advanced services.

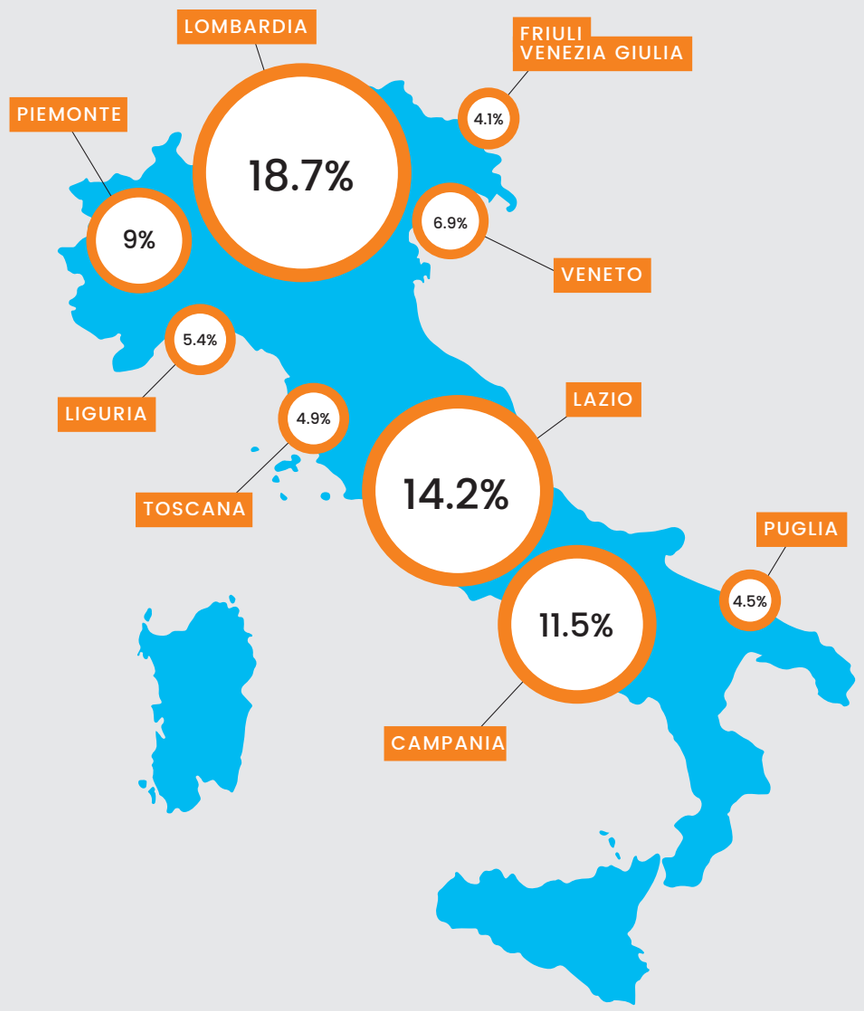
Considering the aerospace sector as a whole, the market success of large players is the result of synergies and the support received from a large number of smaller companies and research centres, which make up a value chain that is able to transfer expertise to and from other industrial sectors. Moreover, the growing number of innovative start-ups and promising academic spin-offs can help to preserve the sustainability of the industry, and national leadership in the future.

The geographic distribution of aerospace companies is highly concentrated in the North-West, where just under a third of a total of approximately 500 companies are based, while the North-East, Centre and South account for 20.9%, 23.4% and 19.5% respectively (the remaining 3.1% being based in the Islands).

The regional distribution is dominated by Lombardy with 18.7% of companies, followed by Lazio (14.2%), Campania (11.5%), Piedmont (9%) and Emilia-Romagna (8.5%).

MAIN ITALIAN AEROSPACE COMPANIES

Source: iCRIBIS



In addition to the geographical distribution of aerospace companies, it is interesting to understand the domains of excellence and the established expertise of each regional cluster. The analysis conducted by the CTNA (Cluster Tecnologico Nazionale Aerospazio), proposes a classification of the main domains of the sector according to three levels of density of expertise. For example, for propulsion and energy management (engines, power generation and distribution systems, fluid systems, electrical systems) Piedmont is the reference region, followed by Puglia and Lazio, while for expertise in air traffic management, Campania ranks first, followed by Puglia and Lazio.

Cluster Tecnologico Nazionale Aerospazio - 2020

Similarly to the regional distribution of the broader aerospace sector, the space sector is also spread over most of the national territory, with a higher density in Lazio and the North-West areas of Lombardy and Piedmont. Important levels of expertise can also be found in Campania and Apulia.

Main Italian aerospace companies

Among the large companies established internationally, **Avio**, a space operator based in Colleferro in the province of Rome, develops launchers of the Vega family, which due to their lightness and other features, are widely used in European commercial missions. Avio is a predominantly Italian enterprise of excellence that has already carried out several successful missions since 2012 and will continue with other missions in the future with the advancements of the Vega C and Vega E programme.

Through the company **Thales Alenia Space**, a joint venture between France's Thales (67%) and Leonardo (33%), satellites for telecommunications, remote sensing and Earth observation are manufactured in Lazio and Piedmont. With around 2,300 employees, Thales Alenia Space Italia makes a major contribution to the construction of the pressurized modules for the International Space Station (ISS), mainly at its Turin site, as well as its Milan and L'Aquila sites. The company is also the main contractor for the construction of the Cosmo-SkyMed system, the first Earth observation satellite system designed for both civilian and military use. This system of satellites will have the capability to scan the Earth from space with a resolution of one square metre, day and night, in all weather conditions.

Also supporting the project is **Telespazio**, a subsidiary of Leonardo and Thales and one of the world's leading players in satellite services, geo-information and network navigation systems. Telespazio has built the entire ground segment for Cosmo-SkyMed and has set up a Control Centre for the entire constellation at the Fucino "teleport", for both first- and second-generation satellites. Also based in the Fucino area is Telespazio's control centre for the Galileo programme, a joint initiative launched by the European Union and the European Space Agency to improve Europe's technological independence and to define international standards for Global Navigation Satellite Systems (GNSS). The control centre manages and plans image acquisition requests and handles processing and archiving and the distribution of services for numerous market applications, from transport to agriculture. The Fucino centre also manages signal carrier and distribution services for major national and international broadcasters, as well as direct satellite broadcasting of radio and television signals.

The above holdings (Thales Alenia Space and Telespazio) make Italy's **Leonardo** a global player in the space and defence industry, with a presence in 15 Italian regions, covering everything from the design and development of satellite systems and the management of launch services and in-orbit control of satellites, to Earth observation and satellite navigation systems. These products are used in the main European space missions, not only Galileo but also Rosetta (mission to study comets, concluded in 2016 with the landing of the probe on comet 67P/Churyumov-Gerasimenko), ExoMars (mission to study Mars, with the landing of a Rover on the surface) and Copernicus (Earth Observation for environmental and security purposes).

In Lombardy, **OHB Italia** (formerly Carlo Gavazzi Space) is a medium-sized company that can count on the expertise of 180 engineers and physicists to develop innovative solutions for low-cost access to space, providing resources and consolidated facilities to carry out manufacturing, integration, qualification and flight certification

MAIN ITALIAN AEROSPACE COMPANIES

Source: Intesa Sanpaolo Innovation Center calculation based on Italian Trade Agency data

activities. The company became part of the German OHB group in 2017.

The public-private company **ALTEC** (63.75% owned by Thales Alenia Space Italia S.p.A. and 36.25% by the Italian Space Agency) is based in Turin, Piedmont. Altec is a centre of excellence for the provision of engineering and logistics services to support operations and use of the International Space Station and other orbiting infrastructure, as well as for space exploration missions.

Sitael is one of the largest wholly privately owned space companies in Italy, mainly focussed on the development and production of small satellites. With over 380 employees, mainly based in Puglia, Sitael covers all processes involved in the design, development and production of small satellites, as well as activities linked to advanced propulsion systems, instrumentation and avionics. This is made possible through the use of critical facilities such as clean rooms, space-qualified assembly lines, vacuum and thermo-vacuum plants, mechanical test facilities and test facilities for rocket motors. To build its own spacecraft, Virgin Galactic entered into an agreement with Sitael in 2018. Under the agreement, the vehicle will be built with Sitael's technological contribution and assembled in Puglia, to be used at the Grottaglie spaceport.

Alongside these larger, better-known companies, a **multitude of SMEs** play an important role both in covering specific competencies to support the Upstream segment (i.e., what is sent into space, to make up the space infrastructure) and in exploiting the data generated to develop a wide range of applications, i.e., the Downstream segment.

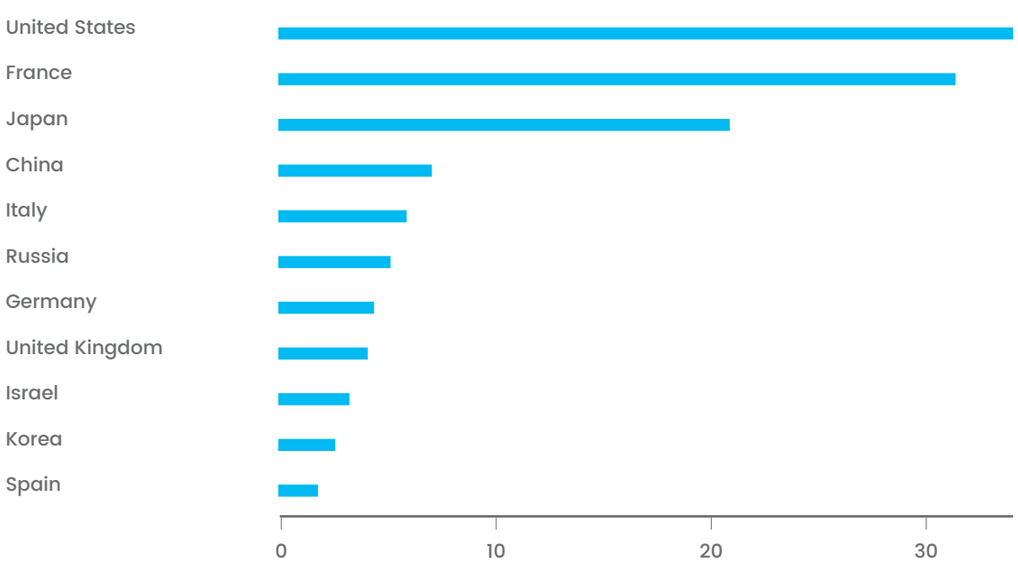
40% of the SME community is made up of small and medium-sized companies and the remaining 60% of micro enterprises with fewer than 10 employees and a turnover under 2 million euro. Given the strong integration of the supply chain and the availability of significant public incentives, there is a strong sense of belonging among the companies of this sector, which often form alliances and take part in the initiatives of technology clusters and dedicated skills centres. This form of alliance enables coordination and consultation activities and is effective in encouraging the best talent to emerge and bringing the sector's needs to the attention of major public decision-makers.

Led by the National Aerospace Technology Cluster - CTNA (**Cluster Tecnologico Nazionale Aerospazio**), Italy has 12 regional aerospace clusters:

- Cluster Lucano dell'Aerospazio (CLAS) in Basilicata
- Comitato Distretto Aerospaziale Piemonte in Piedmont
- Distretto Advanced Manufacturing 4.0 in Tuscany
- Distretto Tecnologico Aerospaziale (DAC) in Campania
- Distretto Aerospaziale Sardegna (DASS) in Sardinia
- Distretto Aerospazio in Abruzzo
- Cluster Tecnologico Aerospaziale in Emilia-Romagna
- Aerospace Cluster in Lombardy, and that in Umbria
- Distretto Tecnologico Ligure sui Sistemi Intelligenti Integrati in Liguria
- Distretto Aerospaziale del Lazio, at Lazio Innova, and the DTA
- Distretto Tecnologico Aerospaziale in Puglia

Over time, the national CTNA cluster and the regional aerospace clusters, which formed due to the presence of large-scale space industries in the specific areas, have attracted and involved SMEs operating in the aerospace supply chain. With the advent of the New Space Economy, university start-ups and spin-offs are also joining these clusters, having recognised the important role that community and network initiatives play in a sector that is fast-growing but made up of a relatively low number of companies compared to other Italian industrial sectors.
Clusters also represent an opportunity for companies of other industrial sectors, whose innovative applications and solutions have high potential for use in the aerospace sector: think for example of additive manufacturing or the Internet of Things. In addition to companies, the involvement and contribution of universities and research centres is also fundamental to provide the skills needed in the industry. **Italy's system of basic scientific research in the aerospace sector** is one of the best in the world, ranking sixth globally, comparable to France and Japan, with a scientific output that has remained constant at around 5% of the total since the 2000s. Considerable progress has also been made in **technology transfer**, where, compared to the early 2000s, Italy has doubled the **number of patents** in the aerospace sector, significantly improving the applied research phase. Between 2013 and 2018, Italy ranked fifth in terms of the number of patents filed in the field of space technology.

Main patenting countries in the field of space technology 2013-2018
Source: Intesa Sanpaolo - "Spazio: nuova frontiera per economia e ricerca", 2021



Among the main actors playing a significant role in research and technology transfer is the Italian Aerospace Research Centre **CIRA** (**Centro Italiano di Ricerche Aerospaziali**), headquartered in Campania, which has supported Italian companies competing in the international space market since 1984. Aligned with the national strategies and having the CNR (Italy's National Research Council) as one of its shareholders, CIRA has cutting-edge aerospace research infrastructure equipped with unique testing facilities and state of the art laboratories.

Its most innovative infrastructures include the **latest-generation wind tunnels**, such as the Plasma Wind Tunnel complex (equipped with two hypersonic arc-jet systems), the PT1 transonic/supersonic wind tunnel and the Icing Wind Tunnel (IWT) for low-temperature tests. In cooperation with companies and other institutions, CIRA tackles the most advanced aerospace research topics: the study of aeronautical craft and spacecraft capable of flying autonomously and at very high speeds (7.5 km per second, or 27 times the speed of sound), the development of innovative systems to reduce the environmental impact of aircraft, increase flight safety and improve the efficiency of air traffic management, and the development of enabling technologies for the space transport systems of tomorrow. With 350 employees, mainly active in research and development, CIRA is a member of the major European and international research programmes and collaborates with the leading universities and aerospace companies. CIRA is also responsible for implementing the National Aerospace Research Programme - PRORA.

#in depth
NRRP support to Space Economy

Italy has chosen to also back the space sector as a tool for economic recovery and sustainable development under the National Recovery and Resilience Plan (NRRP). The Plan has earmarked additional investments amounting to 2.3 billion euro for the plan of activities currently being pursued at national level, split between direct funds and additional funds, to be allocated to space projects to be completed by 2026.
Under the NRRP, the National Space Economy Plan (PNES) includes 4 investment lines:

1. **SatCom**
2. **Earth observation**
3. **Space Factory 4.0**
4. **In-orbit economy**

Summary of funding allocated through the NRRP and additional funds
Source: ASI

Investment lines	**Total investment (M€)** *(RRF-compatible)*	**Total public funding (M€)**	**RRF amount (M€)**	**Law Decree 59/2021 amount (M€)**
SatCom	320	320	210	110
Earth Observation	1,255	1,230	797	430
Space Factory	340	280	180	100
In-Orbit Economy	460	460	300	160
TOTAL M€	**2,375 M€**	**2,290 M€**	**1,487 M€**	**800 M€**

SatCom

Telecommunications use national infrastructures whose operation must be guaranteed even in emergency conditions. The **SatCom** initiative, regarding the future satellite system for government telecommunications, aims to provide innovative and secure telecommunications services, to be implemented in three areas:

1. **Development of small satellites for connectivity of IoT devices.**
   The development prospects of the IoT market suggest the existence of opportunities for the development of a dedicated infrastructure on the national territory, as well as on foreign sites of national interest. Such infrastructure, which can be built with low-cost, small-sized satellites, would integrate the terrestrial network in places that are difficult to reach, thus ensuring the operational continuity of the IoT nodes of institutional interest.

2. **Creation of a secure and autonomous satellite infrastructure for connectivity.**
   Quantum Key Distribution (QKD) technology can be deployed to increase operational efficiency, implement new functionalities and improve the security performance of SatCom systems. This will enable the development of enabling technologies to ensure the robustness and resilience of communications. The mission is intended to be Italy's contribution to the European "Secure Connectivity" initiative.

3. **Enhancement of existing telecommunications infrastructure.**
   Given the current availability in Italy of satellites for institutional communications, the PNES proposes to strengthen the related user segment together with the development of technologies for secure communications with integration to 5G/6G networks. This line of action also proposes to develop, on the basis of existing infrastructure, a national HUB for integrated satellite and terrestrial services for various users (institutional and for emergency management applications). The national HUB could also be put forward as Italy's contribution to the planned future European GovSatCom/Secure Connectivity HUB.

Earth observation

Through the NRRP funds, in this area the PNES proposes intervention along three lines that complement the ASI projects already in the incubation or technological development phase:

1. **Enhancement of the ASI Space Centre of Excellence at the Matera Base,** already the site for satellite operations of the national remote sensing systems and an international centre of excellence for geodesy activities, so as to enable coordination among all institutions interested in Earth observation data. This will be achieved through a further expansion of the site, the launch of an incubator for Earth observation applications and services and a programme dedicated to Southern Italy, aimed at integrated applications. The initiatives promoted through the Matera Centre aim to significantly increase opportunities for the development of new applications and services that will also include the themes identified by the Copernicus User Forum:

- Coastal service and maritime-coastal monitoring;
- Air quality monitoring services;
- Ground motion monitoring services;
- Monitoring service coverage and land use (Land Cover/Use);
- Hydro-meteorological monitoring services;
- Water resources monitoring services;
- Emergency service;
- Security service.

2. **Development of an Earth Observation (EO) satellite constellation.**
The new constellation will consist of small satellites positioned in low Earth orbit (LEO). This constellation will integrate and enhance the existing systems and also provide a service that will compliment the service provided by the European Copernicus Earth Observation constellation. In May 2022, the Italian ESA astronaut Samantha Cristoforetti announced live from the International Space Station that the constellation will be called IRIDE (see Section 2.6.5).

3. **Launch of the CyberItaly project**, an initiative that through artificial intelligence, a wide range of sensors and a higher frequency of satellite data updates (OT Constellation) extends and enhances the Map Italy 1 project to create a dynamic digital replica of Italy that accurately imitates change in its physical parameters. This replica is continuously fed with data from national, European (Copernicus Earth Explorer) and international missions (where available), combined with in situ measurements. CyberItaly will provide a precise representation of changes in our country, helping to monitor and predict the impacts of natural phenomena and human activities on the territory. Operationally accessible at European level, the system will support sustainable development policies, transforming Italy into a huge European laboratory for monitoring and simulation of environmental models to produce useful analyses to meet the challenges and objectives outlined in the Green Deal.

Space Factory 4.0

The objective of this line of action is to **increase competitiveness through two programmes dedicated** to products that have greater strategic weight for upstream activities, able to determine a flywheel effect for the entire national supply chain:

1. **The Space Factory 4.0 programme, dedicated to the development of smart factories for the production of small satellites.**
The programme envisages the creation of integrated lines manufacturing, assembly, integration and testing of small satellites in Italy, to be developed in an innovative, open and digitalised logic (Industry 4.0). The implementation of platforms based on the operational and architectural principles of Cyber Physical Systems for Production (CPSP) is planned, operating the digital transformation and digitisation of manufacturing processes, in line with what is suggested in the National Plan for Industry 4.0 Transition. The development of design methodologies through digital twins, rapid prototyping and the use of virtual reality and automated testing and check-out techniques will allow the integration of the design, development, production, and testing phases, optimising time and resources and increasing the competitiveness of operators in the sector. The initiative is in complete synergy with the developments of the national and European programmes in the telecommunications and Earth observation sectors, which are characterised by a demand for complex infrastructures (mega-constellations) and/or rapid time to orbit, and with the proposal to strengthen the national upstream with the SAR X and Optical Earth Observation Constellation. In this sense, the Space Factory will be designed to be incrementally available for the production of the OT constellation.

2. **The access to space programme, dedicated to the development of green technologies for future generations of propulsion systems and launchers.**
This line of action is in total synergy with the projects developed in Italy within the scope of national and ESA programmes, and can therefore be launched very quickly. The programme is dedicated to the development of Green technologies for future generations of propulsion systems and launchers through the launch of a technological roadmap supported by in-orbit demonstrations of the new launcher architectures and new propulsion systems currently being developed under the national and international programmes of Italian industry. The programme will be structured in phases as follows:

- Launch of a programme dedicated to the in-orbit testing of the most promising innovative propulsion technologies;
- Initiation of the development of the high-thrust green engine for future generations of launchers, to be optimised with a roadmap of technology demonstrators. This project also includes:
  - the optimisation, upgrading and digitalisation of production lines, production processes, integration and testing for new generations of launchers;
  - training of specialised personnel to complement the currently existing teams and ensure the transition to the new technological concepts.

The measure concerns the entire Italian production chain and involves the sector's leading research centres.

In-orbit economy

The investment includes building expertise to develop and strengthen national capability in **Space Situational Awareness** (**SSA**) and **Space Traffic Management** (**STM**), as well as investments in **In-Orbit Servicing technologies**.
These areas are becoming increasingly relevant considering the increase in the number of satellite launches in recent years and the expected future growth.

The capabilities to provide **In-Orbit Servicing**, i.e. to locate and reach orbiting objects and perform an intervention on them, manipulating or removing them, are particularly important because they can enable STM services but also commercial applications, including lifetime extension and intervention in case of failure of a spacecraft. The technologies and operational capabilities involved in such applications represent a strategic asset for Europe, where Italy has strong expertise in the design, development and qualification of in-orbit services and de-orbiting systems, which can contribute to European capabilities.

Another important segment is the capability to acquire, process and use data for SSA, an application area that is attracting increasing interest from global institutional and commercial players. Italy has developed an important capability in the SSA/SST sector with the construction, under the ESA programmes, of an important telescope for the **observation of Near-Earth Objects**, which can also be used, with appropriate modifications, for the **identification and tracking of space debris (SST)**.
The first telescope for SST applications is already envisaged in the national plans and will be installed at the ASI Base in Matera with the creation of a national centre of competence for the observation and tracking of space debris.
The realisation of further telescopes appropriately located in other geographical areas of the globe would guarantee an almost complete coverage, giving Italy a leading role in the field of observation of these phenomena from the ground and ensuring a strategic role for a space centre located in southern Italy in the field of space traffic management.

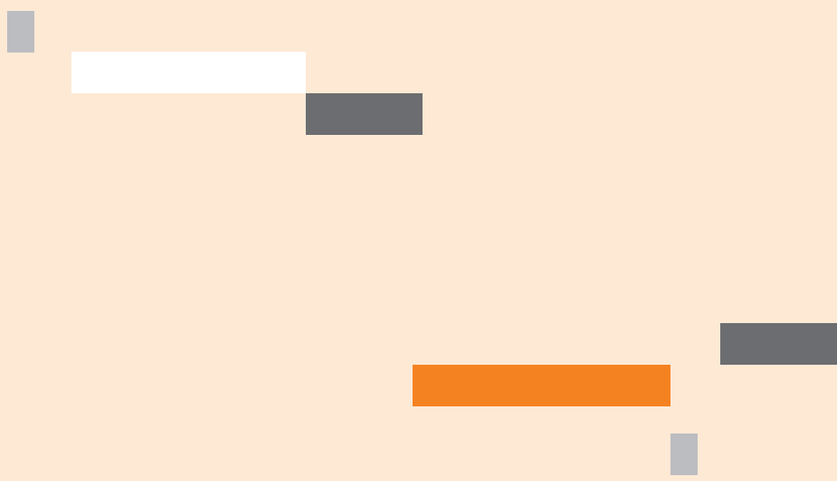
In particular, the PNES provides for the following activities:

1. **A programme dedicated to the development of new orbital service** and interoperability capabilities in the various programmatic areas, through remote-controlled and autonomous robotics projects and artificial intelligence (AI) techniques and with "In Orbit Demonstration" missions for the management of integration, implementation and reconfiguration of space assets and for the future maintenance of constellations and other orbital infrastructure:
   - Implementation of a demonstrator;
   - Development of critical enabling technologies: the demonstration must include the execution of approach and handling manoeuvres on a target.

2. **Construction of three additional telescopes** to create a space debris observation and tracking network, with the control centre located at the ASI base in Matera.

It is also proposed to define a space debris catalogue and to launch specific projects to study and manage space debris and NEO objects in MEO orbit, of great interest for critical space infrastructures (Galileo), and projects to study and develop systems for application on other critical orbits. These activities will be developed at the ASI control centre in Matera and the ISOC control centre in Pratica di Mare.
Through an amendment to the NRRP 2 decree of 30 June 2022, the Ministry of Technological Innovation and Digital Transition, which is responsible for space economy policies, has been authorised to subscribe, between 2022 and 2025, up to 90 million euro of quotas or shares in the funds managed by CDP Venture Capital - the asset management company that directs the National Innovation Fund - to support Italian start-ups that develop space technologies or products.

These resources will be channelled into the "Italia Space Venture" fund, which will be increased by an additional 90 million euro made available by CDP Venture Capital and through other co-investments from private entities, bringing to an estimated total endowment of 250 million euro. The "Italia Space Venture" fund will finance both private venture capital funds dedicated to space and innovative business ventures in the space and aerospace sectors, including university spin-offs, start-ups and innovative companies in the growth stage. The fund will rely on the expertise of ASI and ESA experts to assess the technological potential of the target initiatives.



1.3 Role of the Space Agencies

The role of space agencies has always been of vital importance for the development of aerospace technologies and activities. In particular, the development of technologies that enable space exploration requires a long-term vision and huge investments over several years. The Italian Space Agency plays a leading role in directing the national aerospace activities, with regard both to scientific research and the industrialisation of components and technologies.

The Italian Space Agency (ASI) was established in 1988 to coordinate all the space activities pursued by Italy. ASI operates in line with the decisions of the **Italian Government**, which guides its activities through **COMINT** (**Comitato Interministeriale per le Politiche relative allo Spazio e all'Aerospazio**). The Agency is supervised by the Ministry of Universities and Research, with which it actively collaborates to promote pure and applied research activities in the aerospace sector. ASI's guidelines are enshrined in two operational documents, *the* **Strategic National Space Policy Document** (**DSPSN**) and the **Strategic Vision for Space Document** - (**DVSS**).

L'Agenzia Spaziale Italiana in breve: profilo e attività

ASI is tasked with coordinating, guiding and managing Italian aerospace activities, and, in particular, it supports and promotes:

- Research and Development activities in the sector, in cooperation with other public bodies, universities, research centres and private players. Particular attention is paid to the inclusion of highly innovative SMEs;
- The implementation of new high-tech missions, products and services, working closely with the European Space Agency and other space agencies;
- Technology transfer, also in sectors not directly related to aerospace;
- Public-private industrial collaborations to increase the industrial, economic and technological competitiveness of the entire country.

Italian Space Industry Online Catalogue

The Agency plays a central role in the development of the entire Italian aerospace ecosystem thanks to its long-term investments in both national projects and those managed with ESA and other space agencies like NASA (US) and JAXA (Japan). In particular, the relationship with ESA is fundamental for the management and implementation of all those projects in which supranational critical mass enables access to economic and scientific resources of primary importance at global level.

The **Strategic Vision for Space Document** (**DVSS 2020-2029**) identifies eight programmatic areas and five enabling sectors.

Agenzia Spaziale Italiana, "DOCUMENTO DI VISIONE STRATEGICA PER LO SPAZIO 2020 - 2029"

The eight programmatic areas in which the ASI is committed to promoting the activities are:

1. **Telecommunications, Earth observation, Navigation**. This area includes all activities linked to the Copernicus and Galileo systems, for example, and their use for the benefit of citizens and the national economy.
2. **Study of the universe**. This area includes research activities, in particular those carried out with ESA and NASA.
3. **Access to space**. This area includes, for example, activities linked to the development of the Vega launcher.
4. **Sub-orbital flight and stratospheric platforms**. The activities also include the creation and promotion of spaceports and the associated services.
5. **In-orbit servicing**. This area also includes the de-orbiting of satellites and their maintenance.
6. **Robotic exploration of space** and of asteroids and planets through international cooperation programmes.
7. **Human space exploration** through cooperation with NASA and ESA, and maintaining Italy's leadership role.
8. **SSA - Space Situational Awareness**. A new approach that aims to protect both space infrastructures - as infrastructure of critical economic and military importance - and the civilian population from potential threats from space or space assets.

In order to promote Italian technology and the national interests, ASI has become directly involved, through **equity investments**, in companies and entities that are considered strategic for their contribution to the scientific community and industrial fabric. ASI also has three minority stakes in Italy's largest private aerospace groups, which have a major impact on many long-term industrial projects:

- a 20% stake in **e-GEOS,** in joint venture with **Telespazio,** for the exclusive management of the ground segment and the data collected from the dual-use (civilian-military) COSMO-SkyMed satellite constellation for **Earth observation** (see Chapter 2.6). The **COSMO-SkyMed** constellation provides data that complements those of the European Copernicus constellation and is controlled through the ASI centres in Matera and in Malindi, Kenya.
- a 36.25% stake in **Aerospace Logistics Technology Engineering Company** (**ALTEC**) based in Turin. The private industrial majority shareholder is **Thales Alenia Space Italia**. ALTEC specialises in the provision of **engineering and logistics services for the International Space Station** (**ISS**) and for the planning and implementation of space exploration missions. The company is working on projects linked to the exploration of the Moon and Mars.
- a 30% stake in **Spacelab**, formerly ELV S.p.A., with the remaining 70% held by **AVIO**. The company develops innovative technologies and products for access to space in the launcher sector (see Chapter 2.1).

ASI is also an entity that promotes the Space Economy as a whole, through a series of concrete initiatives concerning:

- technology transfer;
- support for deep tech spinoffs and start-ups;
- support for "start-up competitions";
- potential promotion of investments;
- knowledge intelligence and management/exploitation of patents;
- agreements with universities and research centres in Italy and abroad.

ASI - New Space Economy

In 2017, ASI set up **Fondazione Amaldi** in collaboration with the **Consorzio di Ricerca Hypatia**. The Foundation was set up promote and implement, in the most agile way possible, the technological transfer of know-how from ASI's own aerospace sector to the manufacturing sector, also with a view to **encouraging cross-fertilisation** with non-aerospace industrial sectors. The Amaldi Foundation hosts the **ESA Business Applications Ambassador Platform for Italy** (AP-IT), whose role is to stimulate the ecosystem of space applications and support business ventures in the sector.

ASI is also a member of many other associations with the aim of fostering the competitiveness of the Italian scientific and industrial system through participation in industrial projects or projects at the frontier of research. These associations include CTNA, ESPI (European Space Policy Institute) - which provides European policy makers with an informed view on European space-related issues - and NETVAL (Network for the Enhancement of University Research).

Technical expertise combined with strong coordination with the Italian government enables ASI to act as the main point of contact for national **Space Diplomacy**. This is achieved both through participation in the programmes of ESA and other space agencies, and through international cooperation with the **United Nations Office for Outer Space Affairs**. The high level of innovation pursued through these activities and the involvement of various industries with a view to promoting technological and scientific advancement, even outside the aerospace sector, gives rise to the concept of **Space Innovation Diplomacy**[3].

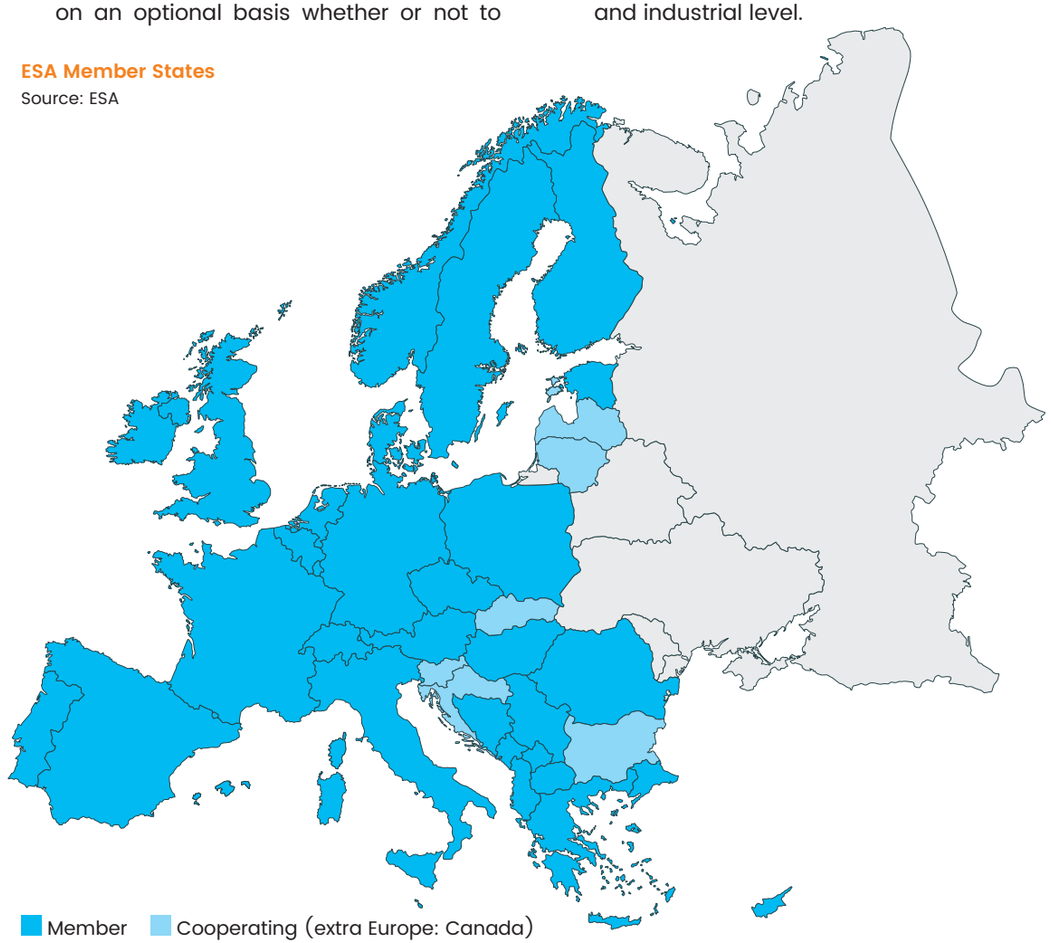
Italy has been an active member of the European Space Agency (ESA) since it was established in 1975.
ESA is an international agency tasked with coordinating the space activities of its European member countries. The initial idea was to create a new actor with the technological, financial and long-term planning capabilities needed to be able to advance **Europe as a space power**.
It is important to emphasise that **the agency is not part of the European Union. It is an independent entity**, also financially.
ESA's 22 members include European countries that are not part of the EU, such as Norway and Switzerland, and even Canada, which is geographically located in North America. ESA and the EU do however work in close coordination, especially with regard to space infrastructures that are part of the EU space programme, i.e. the **Galileo** satellite navigation system and the **Copernicus** Earth observation satellite constellation.

3 Start-up / Spin-off / Incubatori, Risk Finance www.asi.it

ESA is financed by the member states through two main funding sources:

- The **mandatory programme**. All member countries contribute to this programme, which finances ESA's scientific activities as well as general services that are considered essential, without which the Agency would not be able to perform its tasks. Contributions for the mandatory programme are based on the Gross Domestic Product of each Member State.
- **Optional programmes**, which are more flexible. Each Member State can choose on an optional basis whether or not to finance them. Funding an optional programme opens up the possibility for entities from the contributing nation to take part in ESA's calls for proposals. Activities funded by optional contributions include telecommunications, Earth observation, space navigation, space transport and even part of ESA's management of the International Space Station and microgravity experiments. Optional programmes also include the GSTP (General Support Technology Programme), aimed at stimulating national space research at both academic and industrial level.

ESA Member States
Source: ESA



ESA's budget varies from year to year and agreements between the member states are discussed every four years or so. The latest 2019 agreement established to increase the ESA budget in order to address new technological and scientific challenges, from the study of new launchers to the exploration of the Moon and Mars.
ESA's 2022 budget has increased to 7.2 billion euro, from 6.49 billion euro in 2021.

ESA invests in industrial contracts in the Member States, with geographic allocation of the funding in proportion to each country's economic contribution

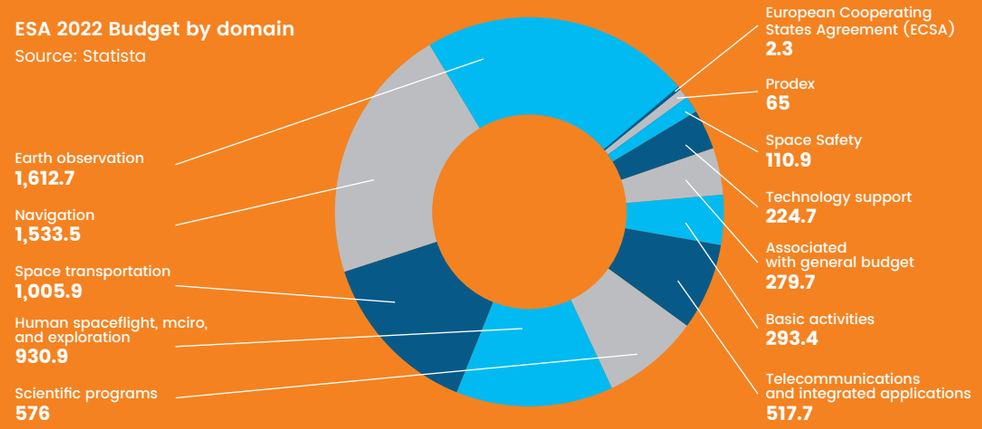
This mechanism is designed to increase the scientific and industrial involvement of the Member States. For every euro of contribution, the minimum guaranteed return for each country totals 0.94 euro, while for individual programmes the return varies from a minimum of 0.84 euro. Italy is the Agency's third net contributor, with a share of 13% in 2021 (589.9 million euro), preceded by France and Germany. Italy's contribution to ESA commits between 55% and 65% of the ASI budget.

The geographical distribution of investments makes **ESA one of the most important investors in the entire Italian aerospace ecosystem**. The international character and absolute scientific excellence of ESA's projects and programmes have made it possible for numerous innovative Italian SMEs to access to prestigious opportunities. Moreover, Italy's growing contribution to the optional programmes has enabled numerous university research groups and private research centres to take part in projects that will enable the **development of new know-how** in high-growth areas such as telecommunications, space exploration, Earth observation and satellite navigation.

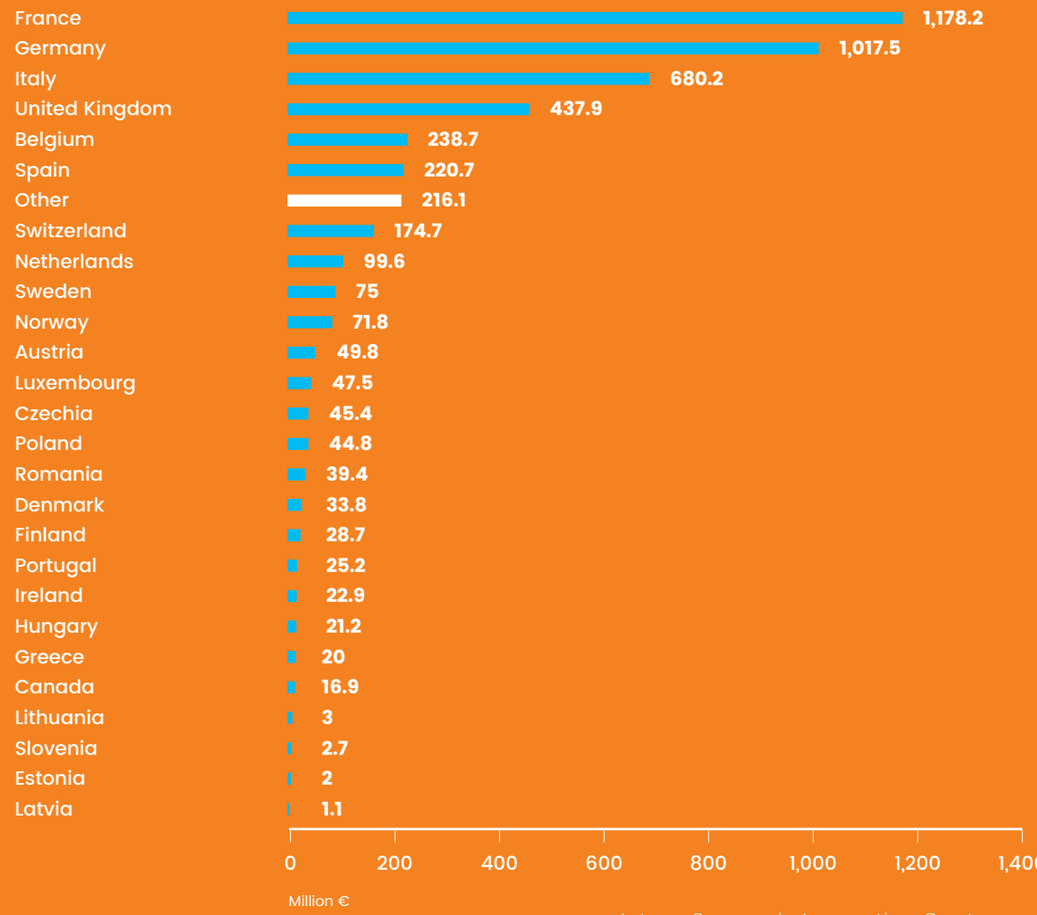
ESA also plays a crucial role at continental level in **promoting start-ups and deep tech spinoffs**, through targeted initiatives dedicated to specific technologies or through locally structured incubation programmes, such as those pursued by the **ESA Business Innovation Centres** (**BICs**). Italy has two ESA BICs, one in Rome since 2009 and the other in Turin since 2021.
ESA's headquarters are located in Paris, France. The Agency has a number of sites located in Member States, each specialised in a specific area:

EAC European Astronauts Centre in Cologne, Germany;
ESAC European Space Astronomy Centre in Villanueva de la Canada in Spain;
ESOC European Space Operations Centre in Darmstadt, Germany;
ESRIN ESA centre for Earth Observation in Frascati, Italy;
ESTEC European Space Research and Technology Centre in Noordwijk in the Netherlands;
ECSAT European Centre for Space Applications and Telecommunications in Harwell, United Kingdom;
ESEC European Space Security and Education Centre in Redu, Belgium.

ESA 2022 Budget by domain
Source: Statista



Contributors to ESA Budget for 2022
Source: Statista



1.4 Open Innovation and Technology Transfer

Space economy is recognised as a driver of the economy because its development also has positive impacts in other industrial sectors that are not, strictly speaking, part of the space sector. This is first and foremost due to the sector's ability to innovate to meet the major technological challenges posed by space missions and programmes, involving the huge deployment of resources that would be difficult for companies in the sector to access on their own.

The technological challenges to be overcome to reach and control the space environment require the use of **highly skilled personnel**, **robust equipment of high quality and manufacture** and **rigorous testing, especially when considering the activities of the upstream segment**. These quality requirements need to be met due to the particular conditions in space, which are notoriously hostile to life: meteorological phenomena, the presence of micrometeoroids, microgravity, exposure to radiation and the vacuum of space pose risks that can compromise both the success of space missions and the safety of astronauts. Given that these extreme factors cannot be fully replicated on Earth, it is impossible to fully test systems and hardware under space conditions and it is therefore essential that they satisfy the requirements of extreme resilience and reliability.

Due to the long testing periods needed to ensure the high **reliability** of aerospace systems, the time factor is also crucial: the management of processes that aim to increase the Technology Readiness Level (TRL) of a technology has significant impacts on the product's time-to-market, resulting in innovation cycles that tend to be long and complex. For this reason, many aerospace companies tend to be highly specialised and choose to focus on a micro-sector, so as to be able to manage its complexities more easily.

In addition to these factors, there are other specific aspects that characterise aerospace research and development and influence how technology transfer takes place:

- Some space activities are closely linked to military programmes, where the transfer of technology and knowledge is highly controlled and regulated;
- Aerospace research and development projects are often of long duration and based on extensive collaboration networks involving a number of public and private actors, even from different countries;
- In addition to being an important part of aerospace technology development, testing is also a key element of technology transfer. In many cases, test facilities such as wind tunnels, vacuum chambers and cryogenic chambers are government-owned and made available to the industry.

All these factors and characteristics specific to the sector naturally lead to highly **innovation-intensive** firms and a greater propensity to collaborate, even between very different players within the supply chain and even between companies that are more or less in direct competition.

The need to allocate resources more efficiently due to previous space budget cuts and the increasing complexity of the technological challenges to be overcome have pushed the sector to explore and consistently apply the Open Innovation paradigm, i.e. the process of strategically managing the sharing of ideas and resources between entities to co-create value.

Through this approach, the knowledge of tools and infrastructure developed through investments made by the industry's main players can be exploited to search for new solutions and applications in other sectors, consequently reducing the high cost of space programmes and further stimulating the development of a supply chain of firms that are highly specialised in specific technological micro-environments. This is particularly the case for SMEs, which are able to gain access to the resources and know-how of larger companies and agencies that would otherwise have been too costly to develop internally.

The exploitation of technologies generated by space programmes represent examples of Spin-Outs, i.e. solutions and technologies initially developed to meet space challenges and subsequently transferred to the industrial and commercial sectors. From smoke detectors and water filters to cordless electric tools and special materials, many inventions of the past are derived from space challenges.

In the space field, there are generally three different types of technology and knowledge transfer:

- **Spin-in**, i.e. the spill-over of industrial or commercial technologies, products and services to the space sector;
- **Spin-out**, i.e. the spill-over of technologies, products and services designed for use in space to the commercial and industrial sectors;
- **Spin-x**, i.e. technologies, products and services developed from scratch by merging space and terrestrial concepts.

This last category (Spin-x) is the effect of the fourth industrial revolution that took place with the advent of digital technology, which led to more rapid evolution of technology and, consequently, a greater **convergence of terrestrial and space-based technology sectors**. This has enabled synergistic development, in which highly innovative elements characterise both Space-Related products (space-enhanced products/services) and Space-Enabled products/services.

The possibility that the results of research and innovation processes can be exploited by the outside world and the gradual entry of private players into the aerospace industry make this field and even more attractive proposition for the finance sector. This trend has been intercepted and encouraged by European institutions, which, over time have put together a range of initiatives aimed at creating **financial entities** of both a public and mixed nature (through so-called blended finance, i.e. a mix of both public and private capital) that are able to support aerospace companies in the early stages, which are notoriously too risky to fund with private capital alone. This aspect has also increased the involvement and interest of private financial players in the later stages of growth and scalability.

The European Space Economy has also become attractive for venture capital operations

At European level, this vision lead to big shift in the number of venture capital initiatives launched to fund the space sector between 2020 and 2021, first in the UK and then in Italy and France. As early as 2006, one of the forerunner was the UK-based Seraphim Capital fund, specialising in funding the growth of space-technology firms, in synergy with the leading companies in the sector and the national space agencies.
In France, the CosmiCapital Venture fund was launched in 2021, born from a partnership between CNES (the French space agency) and ESA and managed by Venture Capital Karista with the objective of investing exclusively in private companies in the space sector. The fund targets diversified but early-stage ventures, providing resources to support the growth of innovative space companies in all stages of the industrial value chain.

In 2021, the European Commission further strengthened and structured its support programmes for the space economy. In cooperation with the European Investment Bank (EIB), 100 million euro was allocated to support the **InnovFin Space Equity Pilot**, a programme specifically dedicated to supporting the innovation and growth of European SMEs in the space technology sector. The programme invests in venture capital funds across the EU, such as **Orbital Ventures** and **Primo Space**, with the aim of supporting firms that market new products and services in the space sector.
Orbital Ventures is a Luxembourg-based early-stage fund, focused on space technologies in the downstream segment (communications, cryptography, data storage and processing, geolocation, earth observation) and the upstream segment (space hardware, materials, electronics, robotics, rockets, satellites). The fund is managed by Promus Ventures, which, in addition to the 40 million euro committed by the EIF (European Investment Fund), has raised a further 80 million euro from international companies and institutional and private investors, as well as public players, including the Luxembourg government.

Italy too saw the launch in 2020 of the first Italian technology venture capital fund specialising in investments in space sector projects - the Primo Space Fund. Managed by Primomiglio Sgr, the fund has received 30 million euro in funding from the EIF, 21 million euro from Cassa Depositi e Prestiti and a further 7 million euro from other investors (including Compagnia di San Paolo and Banca Sella). The fund invests in tech spin-offs, start-ups and SMEs, in collaboration with the world of academia and research and ASI, the aim being to identify and support the best technologies and entrepreneurial teams to bring to the market. Primo Space Fund has allocated a significant part of its investments to national aerospace start-ups, including 1.5 million euro to Aiko Space in 2020, 1.5 million euro to Sidereus Space Dynamics and 3.5 million euro to the start-up Caracol in 2021.

For advisory and scouting activities, the fund will be able to count on the support of the Fondazione E. Amaldi (see section 1.2), a technology accelerator that works to enable technology transfers from the space sector to other economic and industrial sectors, established in 2017 by the Italian Space Agency and Consorzio Ricerca Ipazia. The Foundation's mission is to discover areas of technological excellence, develop synergies between space and non-space actors and provide innovative financing tools.

In view of the success of the InnovFin Space Equity Pilot in attracting private capital, the European Commission has launched the Competitive Space Start-up for Innovation (CASSINI) initiative that will lead to the establishment of a 1 billion euro European Space Fund.

Some of the main European VC initiatives in the space sector
Source: Fondazione LINKS analysis

NAME	COUNTRY	TYPE OF INVESTOR	Investment stage
Alpine Space Ventures	Germany	Venture Capital	n/a
E2MC	France	Venture Capital	Early-stage
Karista CosmiCapital Venture	France	Venture Capital	Early-stage
Orbital Ventures	Luxembourg	Venture Capital	Early-stage
Primo Space Fund	Italy	Venture Capital	Seed ed early-stage
Seraphim Space Capital	United Kingdom	Venture Capital	Any investment stage
Space Ventures Investors	United Kingdom	Venture Capital	Early-stage e growth-stage

The fund will be financed by the European Commission and the EIB Group and will cover actions across the entire innovation cycle, from the business idea to industrialisation, the aim being to stimulate private investment in space companies through venture capital funds and to increase the number of start-ups in the sector (also by connecting them with the ICT and digital worlds) and improve their market penetration throughout the entire business cycle.

Companies in the initial stage of their life (seed phase) are also supported by the EIC Accelerator, a programme designed to finance and support organisations that implement deep tech solutions, proposing high-potential and high-risk projects within the EU that are well suited to the aerospace sector.

In addition to finance, a number of other actions promoted by European institutions offer support through acceleration programmes designed to provide and consolidate the skills needed to get to market.
As early as 2003, ESA's Technology Transfer and Business Incubation Office set up the aforementioned Business Incubation Centres (ESA BICs) to help technology transfer to and from the space sector to reach the market. By 2021, more than twenty ESA BICs had been established with additional branches in another 40 cities, covering a total of 17 European countries. Together with their national partners and ESA, the centres have provided all the necessary technical expertise to develop the business venture (as well as initial grant funding) to over 300 start-ups currently being incubated.

Cassini initiative
Source: Cassini initiative

© NASA, ESA, A. James (STScI)

The success of the initiative is evidenced by the more than 700 start-ups promoted across Europe, creating thousands of new high value-added jobs through the applications of space systems, the exploitation of ESA intellectual property and the transfer of space technologies.
Some of these initiatives have been extraordinarily successful: the ESA BIC Bavaria, established in 2009, incubated a total of 130 start-ups in 2018, creating 1,800 jobs and generating an annual turnover 150 million euro; since 2016, the ESA BIC Switzerland has supported 40 start-ups and invested a total of more than 6 million euro (from ESA), which has made it possible to raise more than 170 million euro in third-party funding and to create more than 300 jobs. Each year, more than 180 new start-ups are included in the programmes of the ESA BICs.

ESA BIC Lazio, Italy, has been active since 2006, through Lazio Innova and in collaboration with the European Space Agency (ESA) and the Italian Space Agency (ASI). Since 2016 it has supported more than 40 business projects that apply space-derived knowledge and technologies in other business sectors. The second national ESA BIC was established in Turin in November 2021: start-ups admitted to the incubation programme will receive a financial contribution of 50,000 euro to cover both product development and intellectual property management.

Table of ESA BIC initiatives
Source: ESA

COUNTRY	ESA BIC
GERMANY	4
ITALY	2
FRANCE	2
PORTUGAL	1
UK	1
IRLELAND	1
SWITZERLAND	1
AUSTRIA	1
BELGIUM	1
GREECE	1
ROMANIA	1
POLAND	1
HUNGARY	1
LUXEMBOURG	1
CZECH REPUBLIC	1
DENMARK	1
ESTONIA	1
NORWAY	1
FINLAND	1
SWEDEN	1

#in depth
ESA BIC Turin

ESA BIC Turin

The **ESA Business Incubation Centre Turin** is the space-related incubator supported by ESA and ASI, born from the synergy between the **I3P Incubator of the Politecnico di Torino**, the **Politecnico di Torino** and **Fondazione LINKS** (applied research centre) with the aim of supporting the technological and business development of new innovative enterprises in the field of aerospace technology, with both Upstream and Downstream applications.

The centre's activities kicked off in October 2021 with the launch of an open call for start-ups and entrepreneurial projects. Three annual selections are planned **with the aim of supporting the launch and development of at least 65 space economy start-ups over the next 7 years**.

The I3P Incubator manages the entire incubation programme, from scouting for innovative projects and start-ups to providing strategic support, drawing on legal consultancy services for aspects relating to the protection of intellectual property rights and helping the companies access the capital needed to grow and integrate into the Italian and European industrial systems, in coordination with ESA and ASI. In view of their expertise in the field of space, the Politecnico di Torino and Fondazione LINKS provide technological support to the start-ups selected for the programme.
Turin's candidature for the ESA BIC leveraged I3P's experience in the world of innovative start-ups, the strong scientific and technological expertise of its technical partners and the involvement of a wide range of actors from the institutional, industrial and financial sectors.
In fact, under the ESA BIC Turin project, the Piedmont Region provides grants to new local start-ups or start-ups attracted to the area, while the Turin Chamber of Commerce provides financial support for the management activities and the Fondazione Compagnia di San Paolo acts as the main support entity for the centre's activities, both through a multi-year contribution to cover the ESA BIC programme's operating expenses and by activating innovative investment instruments to support the technological development and growth phase of start-ups.

The centre also sees the involvement of numerous financial operators active in different stages of start-up development, the aim being to offer investment opportunities from the initial seed phase to the growth and internationalisation phases.
The Club degli Investitori Club, LIFTT, RedSeed, the aerospace fund Primo Space, NEVA Sgr, RIF-T, Finpiemonte Partecipazioni, CDP Venture Capital and Intesa Sanpaolo have also joined the project.

In particular, the Intesa Sanpaolo group provides specific credit lines for new companies incubated at the centre and Finpiemonte Partecipazioni will offer investment opportunities through equity and quasi-equity instruments.

Industrial development opportunities for aerospace start-ups are also dependent on the ability to ensure that they are able to integrate into international value chains. On this front, the centre can count on numerous affiliated partners who have chosen to support I3P's project: the **Distretto Aerospaziale del Piemonte**, a large cluster of leading Italian aerospace companies like Leonardo, Thales Alenia Space Italia, Altec, Avio, Macaer, and numerous innovative industrial companies such as Tyvak International, Teseo, APR, Argotec, D-Orbit, Ithaca, Nanoracks, Aiko and GV Filtri.
The ESA Business Incubation Centre Turin plays an important role in the Piedmont aerospace industry, which will also see the launch of a new aggregation hub in Turin, called "**Aerospace City**". The wide range of public and private players that have supported the initiative testifies to the strategic importance of aerospace technologies as a lever of economic development at local and national level: in fact, there is also the possibility to expand the operational activities of the ESA BIC centre by setting up additional branches in other Italian regions.

The first round of selection was concluded in May 2022, with 8 start-ups admitted to the incubation programme:

- **ADAPTRONICS**
  A spin-off of the University of Bologna, winner of the 2021 National Innovation Award in the area of industrial applications. The start-up has developed a solution based on a multifunctional electrostatic membrane to enable the gripping and manipulation of objects. In space, this solution will enable the refuelling and maintenance of satellites.

- **ASTRADYNE**
  The start-up has developed an innovative technology for the production of flexible printed circuit boards that can be applied to a variety of deployable space systems such as antennas, housing modules and solar panels. The first application developed by the company consists of an origami-inspired solar panel, which can reduce the limitations of the conventional panels used in space applications.

- **HIPPARCOS**
  A start-up specialising in the development and production of innovative satellite positioning systems based on cameras that measure relative position with respect to the stars.

- **KURS ORBITAL**
  Born from a corresponding Ukrainian enterprise, the start-up develops a space logistics solution based on proprietary technology for docking satellites in orbit, enabling the provision of inspection and maintenance services.

- **MESPAC**
  A Turin-based start-up that uses proprietary algorithms to process metoceanic data obtained by combining satellite data with data collected by surface sensors, enabling the characterisation of marine environments and supporting the construction of off-shore facilities.

- **SPACE-V**
  A spin-off of the University of Genoa, the start-up develops innovative greenhouses for growing plants at orbital stations and future settlements on the Moon and Mars.

- **SYNCHROPAL**
  Using proprietary technology, the start-up has developed an innovative system for timing synchronisation based on satellite data that guarantees the protection of digital terrestrial infrastructure from hacker attacks.

- **VOLTA STRUCTURAL ENERGY**
  The start-up develops satellite-integrated batteries based on aluminium ions to achieve significant weight reduction and high energy efficiency.

The last round of selection for access to the incubation programme ended on 9 September 2022.

#in depth
ESA BIC Lazio

ESA BIC Lazio

ESA BIC Lazio was one of the first three ESA BICs to be launched by the European Space Agency in **2009**.
Lazio is home to the high-tech production facilities of Italy's leading aerospace companies, the headquarters of the Italian Space Agency and one of the European Space Agency's branches - the European Space Research Institute (ESRIN), located in Frascati. Italy's first ESA BIC was established in Lazio to exploit the synergies of an area that is strongly oriented towards aerospace research and production: in fact the Lazio Technology Cluster - **Distretto Tecnologico dell'Aerospazio laziale - generates an annual turnover of more EUR 5 billion.**

ESA BIC Lazio is hosted and managed by Lazio Innova, an in-house company of the Lazio Region that is active in promoting and developing the entrepreneurial and manufacturing ecosystem by fostering research and innovation, quality and entrepreneurial culture. ESA BIC Lazio is co-financed by the Lazio Region and ASI under the generic programme line of ESA Business Applications and Space Solutions programme. ESA BIC Lazio covers an area of 3,500 square metres. The start-ups are housed at the **Spazio Attivo Roma Tecnopolo** technology park near ESA's ESRIN centre, which is equipped with offices, meeting rooms, training classrooms and laboratories. **Specialists from ASI and ESA provide technical support to the entrepreneurs and Lazio Innova takes care of the business management side of the project.**

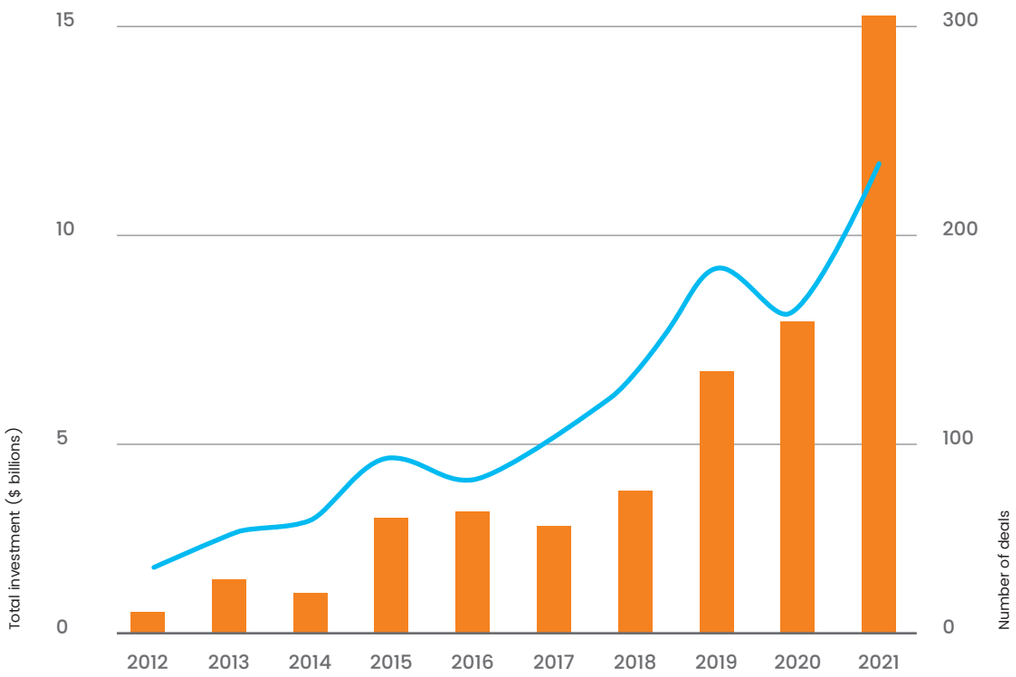
In the initial period of activity, from 2009 to 2016, ESA BIC Lazio contributed to open innovation and awareness actions in relation to the incubation and business development opportunities offered by ESA at regional and national level. From 2016 to 2021, the Lazio centre allocated 500,000 euro of funding for each two-year period and incubated 41 business projects that turned into 21 active companies. The revenues of these companies amounted to approximately 7 million euro in 2019.

In line with the national and European intention to increase investments in this crucial sector for the economy, the funding for 2021-2023 has been doubled to 1 million euro. The new programme will support up to 20 new business projects with up to 50,000 euro per project.

The growing interest of private finance in space-related ventures is confirmed by the increase in the number of investors that finance space start-ups and the resulting increase in the amount raised. Globally, as many as 596 private investors funded space start-ups in 2021, up by more than 59% on 2020, while the total amount funded increased from 7.6 billion dollars to more than 15.4 billion dollars, up by more than 102% on 2020.

In 2021, the volume of private investments in European space start-ups reached 611.5 million euro, increasing by almost 22% from 502 million euro in 2020

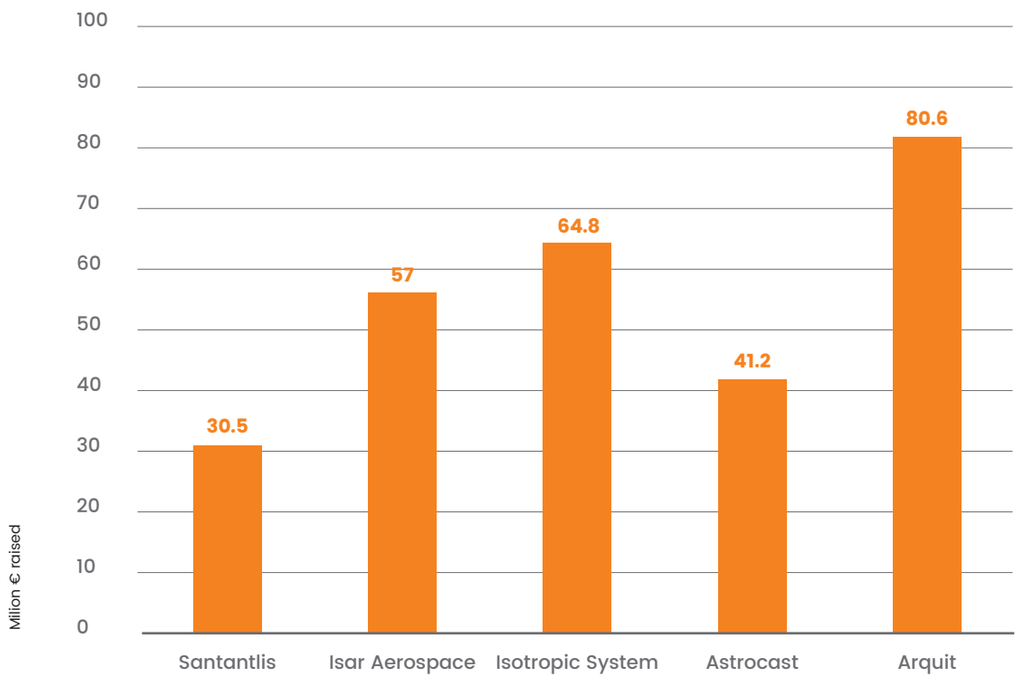
Global investments and deals in space economy start-ups
Source: Bryce Tech



This amount was spread over a total of 86 deals, marking a sharp increase compared to previous years, thus confirming, despite resulting in a slight decrease in the average value per deal compared to the previous year (7.11 million euro vs 8.8 million euro in 2020), the general upside trend compared to 2019 (when the average value per deal was 3.36 million euro).

In 2021, 67 of the 86 total investments referred to Venture Capital deals totalling 420 million euro, accounting for 69% of the total investments. Interestingly, 11% of the total investments in 2021 were made by raising private equity, for a total of 67.2 million euro. This amount refers to two deals only (referring to the start-ups Astrocast and Hiber). Another significant deal in terms of the amount financed was the merger through SPAC of the start-up Arqit, through which approximately 80 million euro was raised. These figures confirm the increasing maturity of the sector, evidenced by its attractiveness for private equity investors, which come on board at later stages of maturity compared to VCs, and by the increasing variety of funding sources used. Another notable observation when considering the longer period is the growth in the average

Highest investments in European space start-ups in 2021
Source: ESPI

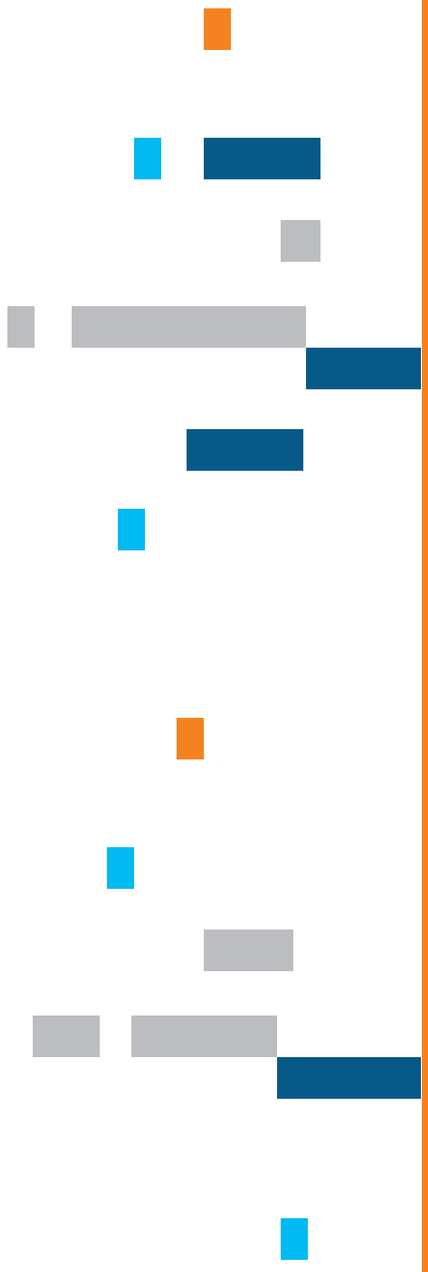


value of seed rounds, which increased every year in the period 2014-2021, from 700,000 euro in 2014 to 2.6 million euro in 2021.

Regarding the **geographic distribution of investments in space start-ups**, although these remain widespread across European countries, in 2021 the majority of deals and investment volumes were concentrated in countries that have historically invested heavily in the space sector (66% of the total investment volume referred to the UK, France, Germany, Italy and Spain).

The top five European deals in terms of value accounted for 44% of the total volume invested in 2021, totalling around 270 million euro.

With regard to Italy, there were 8 extraordinary transactions in the aeronautics and space sector in 2021. Of these, 2 concerned start-ups operating purely in the space sector, 5 related to the aeronautical sector and 1 (Caracol) referred to both sectors. While no financial amounts have been disclosed for almost all of the transactions in the aeronautical sector (with the exception of the 9.4 million euro of SICAMB), the space and aerospace sector raised a cumulative amount of 10 million euro during the year, with the Primo Ventures fund being involved in all 3 transactions.



Company	Sector	Transaction amount	Date of transaction	Investors
Aeromerchs	Aeronautics	n.a.	01/02/2021	Newchip
Caracol	Aerospace	€3,5M	14/09/2021	Eureka! Ventures, Primo Ventures and Angel Investors
Enginia	Aeronautics	n.a.	18/06/2021	Carel Industries
GEM elettronica	Aeronautics	n.a.	21/04/2021	Leonardo
Leaf Space	Space	€5M	13/01/2021	Primo Ventures, RedSeed Ventures, Whysol Investments
Mecaer Group	Aeronautics	n.a.	02/12/2021	Fondo Italiano di Investimento, Stellex Capital Management
SICAMB	Aeronautics	€9,4M	13/12/2021	Deltagroup Uruguay, Invitalia, Killinchy Aerospace Holdings, ST Engeneering
Sidereus Space Dynamics	Space	€1,5M	12/10/2021	CDP Venture Capital SGR, Primo Ventures

02/

Technology Clusters

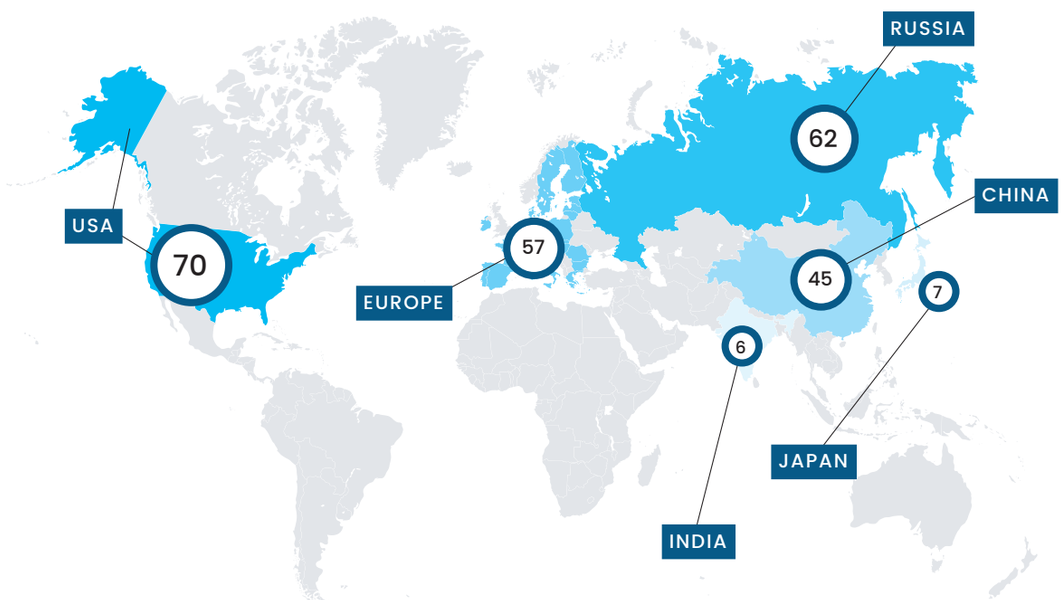
2.1 Access to Space

Access to space is enabled by a set of strategic activities that many States preside over in order to guarantee their own independence in what the United Nations defines as Outer Space, an axis of delicate geopolitical balances due to the importance of the sector, not only in scientific and industrial terms but also from a military and economic standpoint.

There is no doubt that economic growth, particularly in field of digital technology, has benefited from the availability of services derived from space technology applications. Access to Outer Space is therefore crucial for the industrial and economic development of a nation and ensuring that its citizens have access to modern and secure infrastructure.

As the cost and weight of satellites continue to fall, the conditions are ripe for many previously excluded emerging countries to join the space race and equip themselves with space infrastructures.
However, while the number of countries with at least one satellite in orbit increased to around 90 in 2021, approaching almost 50% of the total number of nations, this rise in the number of satellite owners and users has not coincided with a real democratisation of access to space. In fact, between 2009 and 2018, most countries relied on a very limited number of private or military operators to launch their satellites into space.

Average Annual Mass Launched in 2009-2018 (tonnes)
Source: HIE



The United States, Russia, Europe, China, Japan and India have launched more than 95% of the total mass of satellites in orbit

This confirms the strategic nature of the sector and the persistence of technological and financial barriers that prevent emerging countries from securing autonomous access to space. On the other hand, for the countries that already have the infrastructure needed to access space, this opens up the possibility to commercially exploit those assets.

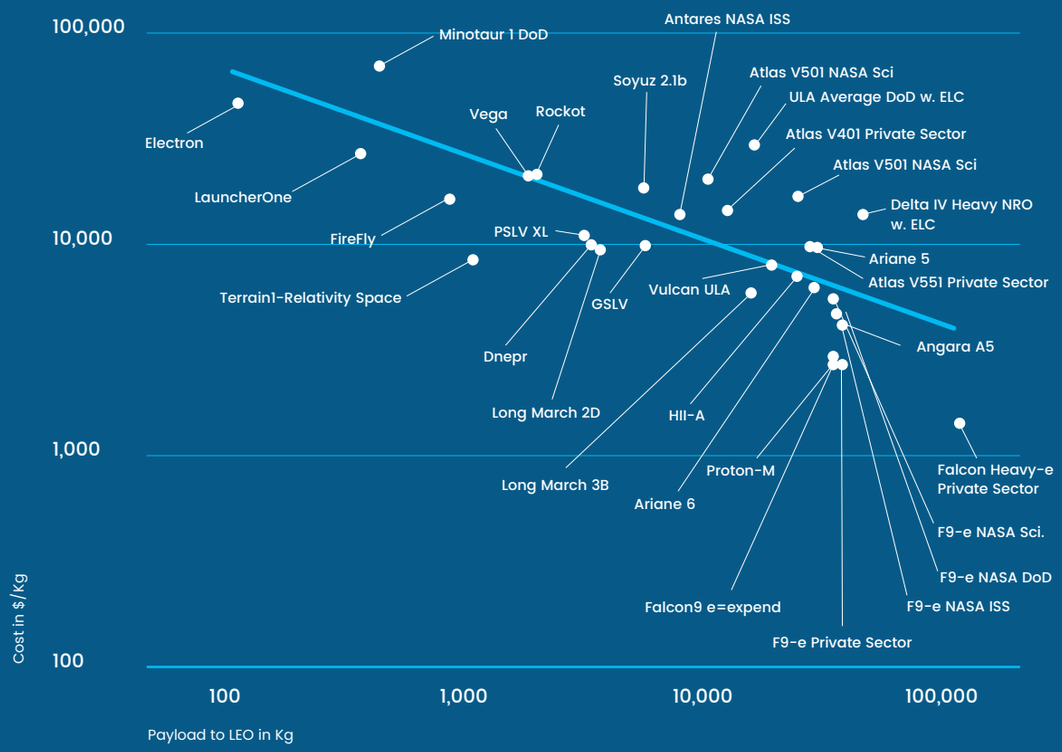
With the proliferation of launchers, missions and spacecraft, the related ground infrastructure now plays a key role in gaining access to space.
At present, most European and Italian industry players use the **Guiana Space Centre** (**GSC**), located in French Guiana, as a launch base. The GSC hosts the launch pad for the European Ariane and VEGA launchers because its location at 5 degrees north of the equator has two major advantages from a technical perspective: it enables direct launches to orbits with almost any inclination, reducing or eliminating the need for energy-intensive orbital plane changes and reducing the cost of sending material into orbit due to the higher tangential velocity of the Earth's surface relative to areas further away from the equator. The geographical location of the GSC does however come with some disadvantages, e.g. its location outside the European continent and the fact that it is accessible only by air or sea.

2.1.1 Cost of launches

Since the early 2000s, countries with more advanced space programmes are implementing projects to develop light launchers. This is notwithstanding the fact that this size of launcher cannot achieve the economies of scale of large launchers: in fact, the cost per kilogram of payload, i.e., the load transported, ranges between 10,000 and 20,000 dollars vs a **cost of 951 dollars per KG** achieved in 2020 by the Falcon Heavy, the first large launcher to break the $1000/kg load barrier. However, light and ultra-light launchers can offer greater flexibility in accessing space, allowing smaller and lighter satellites to be carried to the intended orbit. They also reduce the timescales and the issues involved in scheduling a launch into orbit of a satellite or small constellations.

Large launchers are used to transport satellites of all sizes, as well as to send astronauts and cargo to the **International Space Station** (**ISS**).
These launches involve complex procedures, enormous logistical efforts and the availability of spaceports located in specific geographical areas. These launchers are therefore unsuitable for placing smaller satellites in orbit, hence the development of light launchers for small- to medium-sized satellites (0.5 - 2 tonnes) and micro-launchers for microsatellites weighing less than 0.5 tonnes, which both provide very high flexibility at an affordable cost and are better suited to meet the needs of commercial missions.

Payload cost by different type of launcher
Source: Nasa



LAUNCHER CLASSIFICATION BY SIZE

Source: HIE

HEAVY-LIFT	MEDIUM-LIFT	LIGHT-LIFT	MICRO-LIFT
PAYLOAD TO LEO	**PAYLOAD TO LEO**	**PAYLOAD TO LEO**	**PAYLOAD TO LEO**
> 10,000 kg	4000 - 10,000 kg	500 - 4,000 kg	<= 500 kg
ESTIMATED LAUNCH PRIZE	**ESTIMATED LAUNCH PRIZE**	**ESTIMATED LAUNCH PRIZE**	**ESTIMATED LAUNCH PRIZE**
$45 - 400 M	$30 - 400 M	$5 - 50 M	$1 - 10 M

The space launch market analysis highlights a growth in the number of European and international projects and companies that deal with light launchers and micro-launchers.
Several new launch vehicles have been developed specifically to meet the growing demand from small satellite operators, particularly from those that manage mega-constellations of many small satellites (see Chapter 2.3), as it gives them greater control over the investments needed, based on the specific timing and orbit requirements to be met.

The size of the global space launch services market is set to reach 26.16 billion dollars by 2027

The launch services market comprises the entire chain of activities involved in carrying out a space launch, from design and engineering to component production, assembly, payload integration, test phases and the actual launch.
Market growth will be driven by the increasing efforts made by governments to strengthen their intelligence sources through space surveillance. Emerging players include the **Asia Pacific** region, whose market will account for about 1/3 of total revenues by 2026.

Regarding the costs involved in gaining access to space, these have historically been extremely high. However, factors such as the entry of private providers in the market and the continued adoption of new technologies have triggered a major evolution in the sector, resulting in a general reduction in costs. This trend is expected to continue in the coming decades, making space travel progressively more affordable.
Among the technological trajectories that are of help in achieving these goals, SpaceX has demonstrated the potential of reusable rockets to reduce the cost per kilogram carried into orbit, particularly in low Earth orbit - where the International Space Station is located and mega constellations for telecommunications are currently under construction (see Chapter 2.3). NASA has set the goal to reduce the cost of launches to a few tens of dollars per kilogram by 2040.

SpaceX

The following graph shows the downward trend of the cost of space launches over time. The figures are inflation-adjusted and refer to US launch vehicles carrying 1 kg (2.2 lbs) to **Low Earth Orbit** (**LEO**).

2.1.2
The Italian VEGA launcher

The European response in the launcher sector is based on two large families: the **Ariane** heavy launcher and the **VEGA** light launcher, both marketed by **ArianeSpace**.

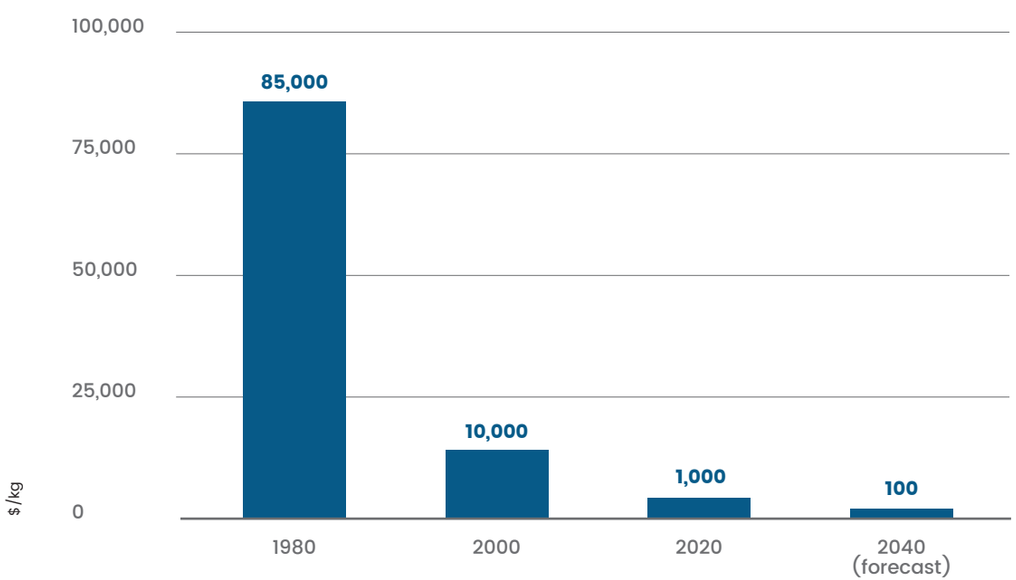
Arianespace

The Italian ecosystem has played a leading role in the development of **VEGA** - **Vettore Europeo di Generazione Avanzata** (Advanced Generation European Vehicle), providing 65% of the funding and ensuring a leading role for national companies. The VEGA launcher is available in different configurations and is designed to guarantee access to space at an affordable cost in the small- to medium-sized payload launch sector. VEGA has a payload launch capacity of up to 1.5 tonnes in low Earth orbit. The launcher has a four-stage modular structure, powered via various propulsion systems, in whose development the Italian company Avio has played a central role.
Thanks to its **Attitude and Vernier Upper Module** (**AVUM**) and its most recent evolution AVUM+, VEGA is able to perform up to 5 in-flight restarts and deliver multiple payloads to different orbits during the same launch, therefore allowing greater flexibility of use. The AVUM/AVUM+ is capable of handling simultaneous launches of satellites of various sizes, including nanosats and cubesats.

The upgraded version of VEGA - **VEGA-C** - came into service in July 2022 and is designed to deliver larger payloads (up to 2.3 tonnes) into orbit. VEGA-C optimises production costs by sharing the new first stage, the P120-C, with the **Ariane 6** boosters. The P120-C will in fact be used as a solid-state booster in the Ariane62 (2 boosters) and Ariane64 (4 boosters) models of the new European heavy launcher. Developed in collaboration with Airbus, the P120-C is the world's largest monolithic engine to use a solid-state propellant, made from carbon fibre with **Filament Winding technology**. This technology consists in winding resin-impregnated carbon fabric fibres around a rotating mould. Once the mould is removed, the end product is a cost-effective manufactured part with high structural rigidity. The P120-C contains the propellant grain and serves simultaneously as a combustion chamber. It is manufactured at **Avio**'s Colleferro plant near Rome.

The VEGA programme is subject to continuous development and upgrading. VEGA-C will be developed in a "light" version that will use a different engine from the P120-C. VEGA-C Light will complete the commercial offering of Avio and ArianeSpace with a launcher dedicated to light payloads, lower than the 2.3 tonnes of the standard VEGA-C.
Next to come into service, from 2025, will be **VEGA-E** (**Evolution**), consisting of three stages: the first two will be in common with VEGA-C and the third and final stage will use the new LM10-Mira propulsion system, powered by **liquid oxygen-methane** (LOX/CH4) with a cryogenic thrust of 10 tonnes. LM10-Mira is a state-of-the-art propulsion system in terms of performance, cost, and environmental impact and it places Italy among the few countries in the world able to use environmentally friendly fuels for launch vehicle propulsion (e.g., the Raptor family of thrusters developed by SpaceX also use oxygen-methane fuel).

Change in launch costs from 1980 to 2020 and forecast to 2040
Source: Intesa Sanpaolo Innovation Center calculation based on Futuretimeline data



2.1.3
Propulsion

In addition to the initial launch stage (**Escape Propulsion**), in the aerospace field, propulsion in space is divided into a further two stages that concern the mobility of spacecraft both in Earth orbit (**In-Space Propulsion**) and on interplanetary trajectories (**Deep Space Propulsion**).
In these two post-launch phases, the use of alternative technologies instead of chemical propulsion is beginning to emerge, including, for example, electric propulsion (already widely used for drift correction in geostationary orbit) and frontier technologies such as solar sails and tether propulsion.

Oxygen and methane are also emerging as fuels due to their availability and environmental compatibility, and because they do not release pollutant gases during combustion. Moreover, methane can be produced from renewable sources and can be easily stored (it liquefies at a temperature of -161.5 °C compared, for example, to -252 °C for hydrogen).

By contrast, solid-state propellants based on powdered aluminium, ammonium perchlorate and polyurethane have a high environmental impact, both in the production and launch phase. Solid-state propellants are nonetheless widely used for small and medium-sized launchers due to their chemical stability, which makes them more manageable.
Electric propulsion seems to be a viable and cost-effective alternative to chemical propulsion in space as it saves fuel and increases operational possibilities in orbit. Despite the thrust being generally lower by a few orders of magnitude and therefore inadequate for impulsive or instantaneous manoeuvres, electric propulsion allows acceleration over very long time periods, in the order of months or years.
The **lower weight and mass** achieved with electric propulsion systems also translate into a significant **reduction in the cost of delivery into orbit** and greater reliability. This technology seems to have great potential for further development: important applications are expected in the area of **interplanetary travel**.

Another areas of focus for the world of research concerns electric propulsion systems that draw energy from the Sun, e.g. systems that use solar or magnetic sails. In detail, solar sails exploit the radiation pressure exerted by a light source, while magnetic sails use a static magnetic field to deflect a plasma wind of charged particles radiated by the sun, thereby imparting momentum to accelerate a spacecraft. While the solar sail theory has been demonstrated by multiple effective applications in both probes and satellites, the magnetic sail emerges as the most futuristic propulsion system. An example is the mini-magnetospheric plasma propulsion system (M2P2), in which a magnetic sail uses the properties of plasma to create an enormous bubble-shaped magnetic field capable of harnessing solar wind, receiving constant thrust from it.
Among the most important players in this field is **Sitael**, a company specialising in Hall Effect Thrusters (HET).
With this technology, the ionised propellant is accelerated through the use of a magnetic field. This type of propulsion meets the needs of different types of satellites, from geostationary telecommunications satellites to low-orbit mega constellations. HET propulsion is also used in ESA's SMART-1 space exploration mission. In fact this type of propulsion system ensures satisfactory efficiency over a wide power range (from around 100 W up to tens of kW), allowing satellites to be maintained in orbit more efficiently and for longer than in the past.
Sitael is also working on a new-generation electric propulsion motor without on-board propellant: the **ram-EP**. The system is able to harvest particles in the upper atmosphere, at an altitude of around 200km, and use them as fuel.
This technology has the potential to play a major role in the near future in managing fleets of satellites in very low orbit. In fact, it can extend the life of satellites, whose life expectancy is currently determined by the availability of propellant on board. The use of molecules in the atmosphere instead of propellant will enable the development of a new class of satellites capable of operating in low Earth orbits for extended periods, or to use the rarefied atmosphere of other planets during missions within the solar system.

The idea behind the Sitael prototype has been validated under ESA's Technology Research Programme.

Sitael

T4i is a spin-off from the University of Padua that develops electric and hybrid propulsion systems for satellites and small satellite dispensers.
The REGULUS-50 motor is based on helicon technology and has an extremely simple structure, therefore reliable and robust: there are no electrodes and no neutralizer, grids or other components subject to wear. REGULUS was tested in space during the 2021 UNISAT-7 commercial mission in collaboration with GAUSS (see Chapter 2.3). The motor is designed to use solid-state iodine as a propellant but can be adapted to use other types of propellants such as xenon or argon gas. The thrust and reliability characteristics of the Regulus-50 make it suitable for missions with very high impulsive change in velocity (Delta-V).

T4i

2.1.4
The role of 3D printing

Additive manufacturing technology is poised to play a key role in this new generation of propulsion systems.
3D printing can be used to manufacture simpler and more reliable components by combining several secondary parts into a monolithic design, which, by minimising the need for screwed and welded joints, reduces the weight of the entire propulsion system and improves performance at overall level. In addition, as fewer components are needed, and from a more limited number of suppliers, this reduces the lead time for manufacturing the semi-finished products, thus improving the flexibility of the production process.
The Italian ecosystem has seen the emergence of a number of highly innovative SMEs that develop applications and technologies for additive manufacturing in the aerospace field.

BEAMIT specialises in manufacturing components for aeronautics and rocket engines using advanced 3D printing techniques.
The company specialises in the use metallic materials such as stainless steels, aluminium or titanium alloys, super alloys and pure copper. BEAMIT uses 250x250x200mm, 400x400x360mm and 280x500x360mm platforms with Powder Bed Fusion (PBF) technology, including multi-laser machines capable of handling four beams simultaneously. BEAMIT can also print components with the NanoParticle Jetting (NPJ) printing process, based on the use of ceramic nanopowders.
The company actively collaborates with numerous European and Italian aerospace companies, such as **Safran Aero Boosters**, **Avio SpA**, **Thales, Leonardo**, **SITAEL** and **Airbus Space**.

BEAMIT

CARACOL has developed advanced 3D printing solutions for the production of monolithic parts, even of large dimensions.
In particular, its proprietary robotic additive manufacturing system Scalprum 13800 features high production speed thanks to its 6-axis technology. The company has accumulated experience in the production of aeronautical parts printed with composite materials (polyamide, polypropylene, etc.) that can be enriched up to 40% with glass and carbon fibres. These parts have very high mechanical and thermal resistance properties. The development of proprietary technologies allows CARACOL to significantly reduce production times and the amount of scrap produced, thereby reducing costs for the end customer.

CARACOL

Roboze specialises in the production of components for the aerospace industry, with a high level of accuracy down to 0.01 mm.
This level of accuracy is achieved using a proprietary 3D printing technology based on a mechatronic movement with gears but without the use of belts - the Roboze Beltless System. This technology guarantees unparalleled repeatability of processes. The company has developed high-performance composite materials and polymers with high chemical, thermal and mechanical resistance. In particular, Roboze has developed a range of high-performance materials based on Peek matrix composites reinforced with ceramic-based short fibres. The use of these new materials, coupled with the Roboze Beltless System, makes it possible to mould components with very high strength, able to replace certain types of metal alloys.

Roboze

2.1.5
Reusable space vehicles: the Space Rider

The need to test technologies, materials and procedures for the atmospheric re-entry of a robotic space shuttle led to the development of the prototype **IXV** (**Intermediate eXperimental Vehicle**), an automated and reusable space vehicle developed entirely in Europe, capable of autonomous re-entry from space. The IXV atmospheric re-entry technology demonstrator was developed by Thales Alenia Space Italia, AVIO and SpaceLab, in collaboration with leading Italian space companies (inter alia, Altec, Selex, Telespazio and Cira). IXV was born out of the need to collect data to build a space vehicle capable of carrying loads of various types to low Earth orbit and returning autonomously to the ground, the aim being to strengthen Europe's capabilities in relation to scientific and space exploration missions but also in managing loads that need to be brought back to Earth (e.g. experiments and/or items produced in microgravity or to support missions linked to astronauts' stays in space). IXV is an ESA programme with approximately 40% of the funding provided by ASI.

SpaceLab

For the IXV prototype, **AVIO** managed the production of the ablative thermal protection systems designed to dissipate the heat produced during re-entry into the atmosphere, developed in collaboration with the Materials Science and Technology (STM) group of the University of Perugia, a centre of excellence in the development, production and advanced testing of traditional and nano-structured polymeric and composite materials. The collaboration made it possible to develop and test an elastomeric ablative compound with high resistance to ablation, including in thermo-vacuum conditions. The Italian ecosystem played a key role in the project and demonstrated its ability to manage all phases, from engineering to construction, and from the launch phase to flight control and subsequent re-entry.
The success of the IXV prototype gave way to the development of the **robotic** (uncrewed) **space shuttle Space Rider**, an Italian-led project funded by ESA to build Europe's first reusable platform for access to space. The vehicle has a payload capacity of up to 600 kg and is capable of placing itself in low orbit at an altitude of up to 400 km and remaining there for up to two months. **Space Rider is scheduled to be launched in 2024** on a VEGA-C rocket. Space Rider will open up new market opportunities: its load capacity will enable both the launch of payloads into orbit and experiments in microgravity thanks to a **robotic laboratory**.

#video
Space Rider Animation

To protect the data collected during experiments from the radiation and extreme temperatures typical of the space environment, Space Rider will use a specific reusable onboard memory (Mass Memory Unit) developed by three Italian companies **Sitael, Intelligentia** and **IngeniArs**. The system will be based on the CAN (Controller Area Network) communication protocol, which is already used in the automotive industry to connect different electronic control units, and is designed to operate smoothly even in environments subject to strong interference caused by electromagnetic waves.

Intelligentia

Space Rider will also use an **all-Italian thermal protection material**, the fruit of a collaboration between **CIRA** and **Petroceramics**, a Bergamo-based company specialising in the production of reinforced ceramic materials for the high-end automotive sector.
The new composite, called **ISiComp**, guarantees excellent mechanical and thermal performance and can be manufactured rapidly and cost-effectively. Thanks to tests carried out in CIRA's Scirocco Plasma Wind Tunnel, the long-fibre reinforced ceramic matrix composite (CMC) has demonstrated that it can effectively withstand the high temperatures of atmospheric re-entry, dissipating 1,500 degrees in just a few centimetres of thickness, and that it can be reused for multiple re-entry missions without being replaced.

2.1.6
The Near Future

The **miniaturisation** of satellites and satellite payloads has opened up new markets for companies capable of reaching low Earth orbit (LEO) at competitive costs.

The start-up **Sidereus** is developing an extremely compact launcher to deliver cubesats and small payloads (around 20kg) to LEO. The first prototype engine of the new launcher was tested in December 2020. The company received 1.5 million euro of funding in the seed round (led by the funds Primo Space and Fondo Italia Venture II - Fondo Imprese Sud of CDP Venture Capital SGR), which it is investing in development of the second generation of the launcher.

Sidereus

#video
EOS - The Personal Computer of Launch Vehicles

Space tourism became a reality in the early 2000s, with the possibility of short stays on the International Space Station. Three factors have so far limited this new business:

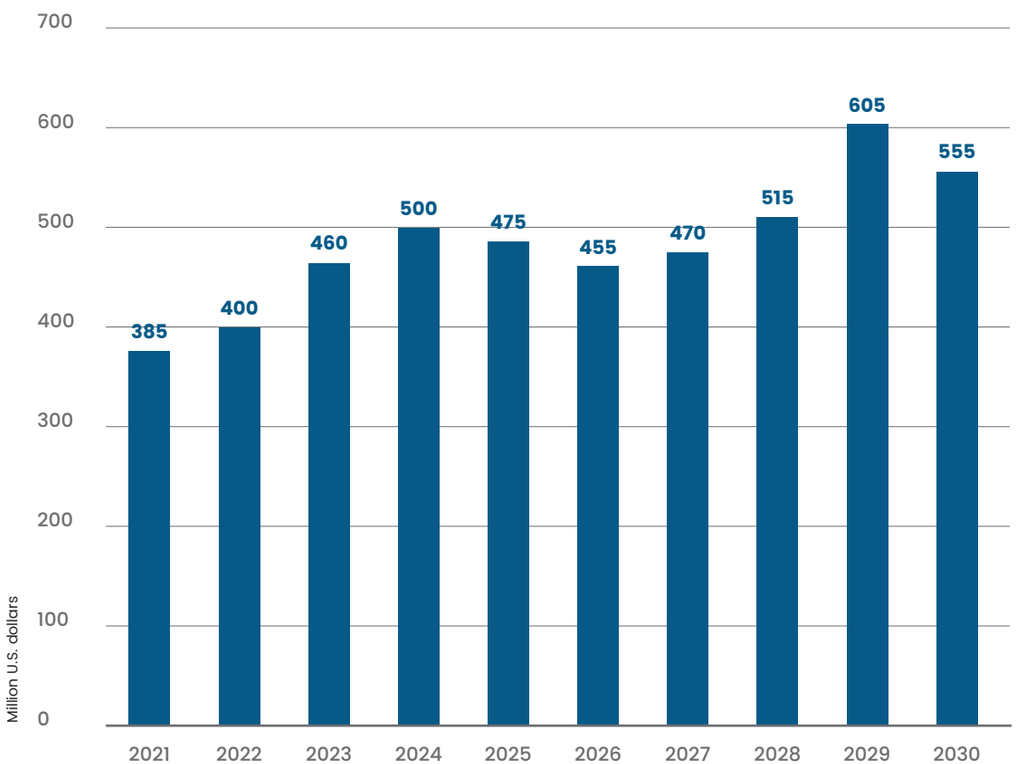
- the huge costs: each ticket costs between 20 and 60 million dollars per trip;
- the logistical difficulties: the launches used the same rockets used to transport civilian and military astronauts to the ISS, which therefore involved by very complex procedures;
- the structure of the ISS itself: the station is in actual fact an orbiting scientific laboratory, not suitable for tourists.

The situation changed radically in the summer of 2021, with the first flights organised by the US-based companies Virgin Space and Blue Origin.
The two companies have developed launchers designed specifically for space tourism, to carry passengers on sub-orbital flights. The journeys are of short duration but passengers are able to see the Earth from space through the large windows of the space vehicles and spend time in total weightlessness in relatively large spaces. SpaceX could possibly join this sector in the near future, with a shuttle dedicated to stays of a few days in Earth orbit.
The next step will be to build a space station in low Earth orbit specifically for tourism/commercial use, easily accessible to its users.
Axiom Space has a plan to build a number of modules that will initially be docked to the ISS, to successively become an autonomous, privately controlled station. The first two modules are at an advanced stage of design and construction at the Turin site of **Thales Alenia Space** (see Chapter 2.2).

Italy is entering the space tourism sector in a decisive way, both as a launch base with dedicated services and as an industrial ecosystem capable of building modules for space stations dedicated to tourism.

In October 2020, Italy officially announced the redevelopment of Bari Grottaglie airport as the first spaceport located in the continental part of the European Union

Forecast revenue of the orbital space travel and tourism market worldwide from 2021 to 2030
Source: Statista



Italy's National Aviation Authority - ENAC - has already published the first documents regarding the technical and legislative provisions needed to create the spaceport.

ENAC, "Regulation on construction and operations of spaceports"

Hangar Two, of approx. 9,000 square metres, has already been built and the new taxiways and runway upgrades are currently under development[1]. The Grottaglie spaceport will make it possible to cut costs and overcome the logistical constraints, particularly for SMEs, research centres and universities. Specific activities are planned in the fields of microgravity experiments, research and development and testing of innovative systems. The aim of the spaceport is to become the launch base for all **suborbital transport operations**, at an altitude between 10 and 100 km. Its location in Italy will make it possible to start training and coaching activities for specialised personnel at competitive costs.
Through its subsidiary **ALTEC**, the Italian Space Agency is partnering with **Virgin Galactic**[2] to launch the US company's **suborbital spaceplane for tourist flights**, marking the launch of a new tourism segment initially dedicated to high net worth individuals, which could possibly serve as a flywheel in the already broad and diverse Italian market.

1 Grottaglie è il primo spazioporto italiano www.ilsole24ore.com

2 Anche l'Italia nel turismo spaziale www.adnkronos.com

Service / Product	Description	Application area	Company
Medium-size launchers	Launchers able to transport a payload of approx. 1.5 tonnes to LEO	**Access to low Earth orbit (LEO)**	**Avio**
Monolithic components for motors	Production of monolithic components for launcher motors using advanced 3D printing techniques based on metals and metal alloys.	**3D printing**	**BEAMIT**
Monolithic components	Production of large-scale monolithic components using advanced 3D printing techniques	**3D printing**	**Caracol**
Monolithic components	Production of ultra-high precision monolithic components using advanced 3D printing techniques based on polymers and composite materials	**3D printing**	**Roboze**
Electric motors for satellites	Hall Effect Thrusters (HET) for satellites	**Space propulsion**	**Sitael**

Service / Product	Description	Application area	Company
Electric motors for satellites	New generation electric motor for satellites without on-board propellant, based on ram-EP technology	**Space propulsion**	**Sitael**
Electric motors for satellites and satellite dispensers	Electric motor for small satellites and small satellite dispensers based on Magnetic Enhanced Plasma Thruster technology	**Space propulsion**	**T4i**
Reusable space shuttle for missions in LEO	Reusable uncrewed space vehicle able to launch payloads and conduct experiments in microgravity thanks to the integrated robotic laboratory	**Automated missions in low Earth orbit**	**Thales Alenia Space**
Thermal protection material	Thermal protection material for spacecraft capable of atmospheric re-entry	**Spacecraft components**	**CIRA, Petroceramics**
Spaceport for commercial and space tourism orbital and suborbital flights	Spaceport for managing and organising orbital and suborbital flights and transport operations in the commercial and space tourism sectors	**Launch base for orbital and suborbital flights**	**Spazioporto Bari le Grottaglie, ASI, Altec**

2.2 Space exploration

Space exploration is experiencing a resurgence, similar to the 1960s, in terms of the economic and technological efforts made by the great powers. But the main players have increased in number: alongside the two space superpowers, USA, and Russia, new entrants have joined the race, notably the European Union and China.

The race to space and to explore space has traditionally been funded by governments in view of the uncertain economic returns, mainly indirect and long-term.
Total spending on space exploration is set to reach 260 billion dollars by 2029.
Sectors linked to space transportation, such as launcher production and the exploration of the Moon and Mars, will see the highest growth. In these areas, space agencies take an extremely important leading role due to the very long planning time frames of up to ten or fifteen years, depending on the mission.
On the other hand, the cost of access to space has fallen sharply due to the entry of new private launchers, the miniaturisation of satellites and the electronics used in payloads, and the development of automated vehicles, factors that contribute to the rapid evolution in space exploration and activities in low Earth orbit. The development of technologies for the exploration, colonisation and commercial, scientific and industrial exploitation of low Earth orbit is therefore becoming essential to kick-start the subsequent activities in deep space. **Exploration missions of a scientific nature** focus on the inner and outer planets of the solar system or on deep space for the study of the cosmos.

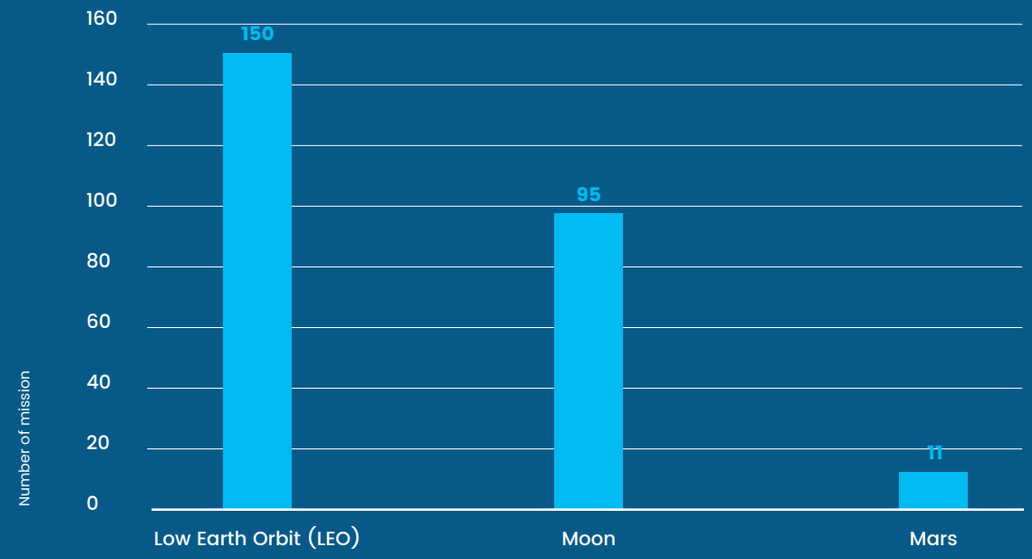
Since the 1980s, Italy has collaborated with NASA, ESA and other space agencies and has supplied scientific instrumentation for the international **missions to explore planets, stars and other celestial bodies**. By way of example, Italy contributed to the Mars Express, BepiColombo and ExoMars missions to study the inner planets of the solar system, and to the Cassini-Huygens, Rosetta, Cheops and Plato missions to study the outer solar system and the comets and exoplanets.

2.2.1 Low Earth Orbit, the Moon and Mars

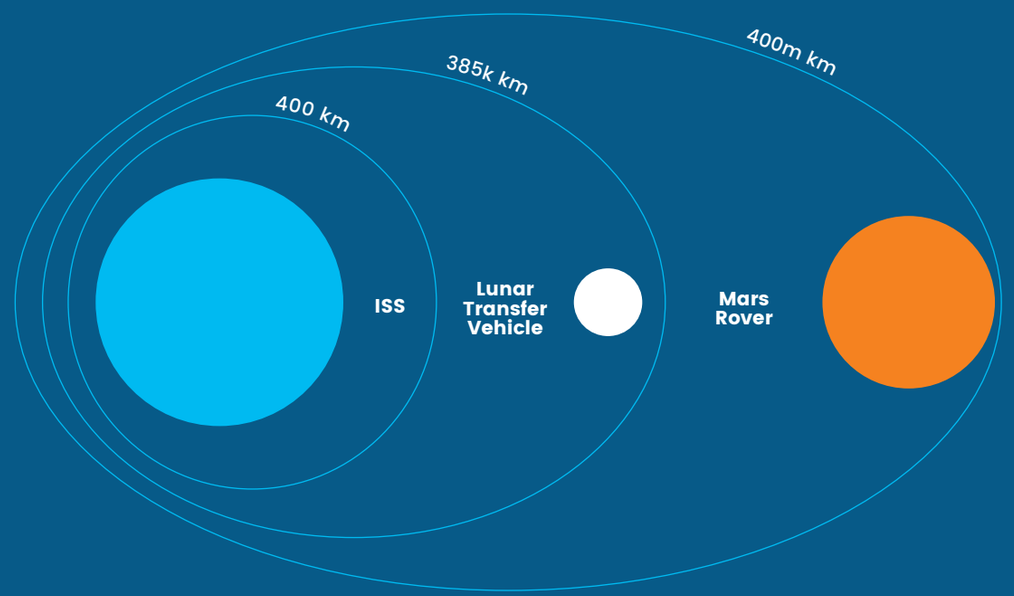
Today, space exploration has three main objectives: Low Earth Orbit, the Moon and Mars. Low Earth Orbit (LEO), where the International Space Station (ISS) is located, represents the first step towards space colonisation. The second objective is the Moon, the natural satellite of our planet, which is seen as an ideal place to test a variety of technologies and approaches and as a potential logistics base towards Mars and beyond.
The red planet is the third and most ambitious objective and is currently at the centre of many projects ranging from exploration to colonisation.

Low Earth orbit will attract the highest number of missions due to it being increasingly more easily accessible in terms of both logistics and the lower costs involved: in fact, as the distance from Earth increases, so does the cost of launching and managing a mission. In any event, this new decade will also see a significant increase in exploration missions to the Moon. Robotic and

Projected space explorations missions from 2020 to 2030, by type
Source: Statista



Human and Robotic Exploration destination
Source: ESA



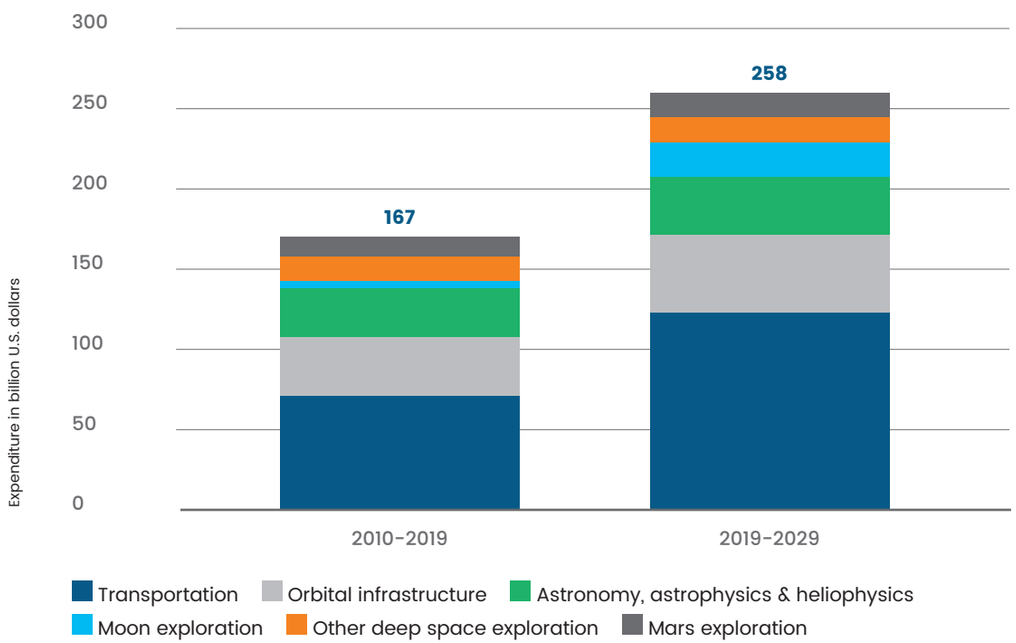
human missions to Mars are expected to be launched in the second half of the decade.

This three-step approach underpins the European Space Agency's strategy for planning its space exploration activities. ESA's approach and the related timelines, also called the European Exploration Envelope Programme (E3P), was defined in 2016. The ultimate goal of the programme, which involves and coordinates all other European space agencies as well as the European space ecosystem, is to take humans to Mars.

ESA - Terrae Novae: Europe's exploration vision

ESA's activities involve the combined use of highly automated robotic and human missions.
The use of automated probes, rovers and other types of robots will be essential to prepare the ground for human missions, especially for the exploration of Mars.

Government investment on space exploration worldwide from 2010 to 2029, by type (in billion U.S. dollars)
Source: Statista



Of particular relevance for the Italian ecosystem is **LICIACube** (Light Italian Cubesat for Imaging of Asteroids) (see Chapter 2.3), the first deep space mission entirely managed and developed by an Italian team composed of INAF, Politecnico di Milano, Università di Bologna, Università Parthenope, CNR and the company **Argotec**, which supplied the 6U platform. The aim of the mission is to witness the NASA-developed DART probe crash into the asteroid Dimorphos and acquire images of the target object in the post-impact phase. Argotec is also responsible for the integration and test phase.

2.2.2 Italy and the International Space Station

The Italian Space Agency has always invested in multilateral space exploration activities. The most important project, so far, is the International Space Station (ISS)[3].
The International Space Station is the largest project ever undertaken concerning the colonisation of low Earth orbit. Its construction began in 1998 and has never stopped: the station has been continuously modified and upgraded over time.

The ISS is a collaborative project involving numerous countries and companies. The European Space Agency leads the grouping of the ten European countries that finance and take part in the research activities at the station (Belgium, Denmark, France, Germany, Italy, Norway, the Netherlands, Spain, Sweden, and Switzerland). The station orbits the Earth at an altitude of 400 km. It measures 73 x 109 metres and has a total weight of 450 tonnes. The ISS travels at a speed of 28,000 km per hour, taking only 90 minutes to make one complete orbit of the Earth.

Italy was the third country in the world to orbit an element of the ISS, confirming the country's outstanding scientific and industrial excellence in the field of engineering and construction of space modules.

Around 40% of the habitable volume of the ISS was built in Italy

In 2001, ASI orbited, for the first time, one of the MultiPurpose Logistics Modules (MPLM) developed for NASA, via a Space Shuttle. In total, ASI has developed three logistics modules in Italy: Leonardo, Raffaello and Donatello, all three at the Turin site of **Thales Alenia Space Italy** (TASI).
The logistics modules are designed to have an operational life cycle of 10 years and to be used up to 25 times (25 launches). Each MPLM weighs 4,500 kg and measures 6.6 metres in length and 4.5 metres in diameter. The modules are protected by thermal blankets and shields against micrometeorites. The internal infrastructure, equipped with mobile racks capable of housing experiments and supplies, is modular and enables materials and the results of microgravity experiments in orbit to be brought back to Earth. After several launches, the Leonardo MPLM was then transformed into a Permanent Multipurpose Module (PMM) and permanently docked to the ISS in 2011.

3 Il contributo dell'Italia alla ISS
www.asi.it

The ASI-Thales Alenia Space Italia collaboration for the ISS programme included the design and construction of two modules designed to form part of the final structure of the ISS: the permanent module Harmony, or Node-2, and the permanent module Tranquility, or Node-3. Both modules were built at the TASI facilities in Turin, Italy, in collaboration with other major European groups. The Harmony module was launched in 2007, dramatically increasing the habitable space available to astronauts. The module has a total mass of 15,300 kg, a length of 7.2 m and a diameter of 4.4 m. The Tranquility module reached orbit in 2010 via a Space Shuttle. The module has a mass of 15,500kg, a length of 6.7m and a diameter of 4.4m. Tranquility introduced a number of important technical innovations to support life on orbiting stations and to prepare shuttles for future missions to the Moon or Mars:

- **Advanced protection against space debris and micrometeorites** thanks to a primary barrier made of Al-6061-T6 aluminium, and a secondary barrier made of Kevlar/resin panels.
- A **rowing machine and a treadmill for workouts**. This type of equipment is essential to protect the mental and physical wellbeing of astronauts who spend long periods in orbit in microgravity conditions, where loss of muscle mass and osteoporosis are much faster than on the Earth's surface.
- A **highly advanced air conditioning, filtering and management system, with elimination of carbon dioxide** and generation of oxygen. The module also takes care of water management. In particular, it is equipped with a **filtration and distillation system that transforms urine into drinking water**. This equipment is considered crucial for all long-duration missions, especially for those beyond LEO orbit.

Tranquility houses the famous **Cupola** (dome), which was also built in Turin by Thales Alenia Space Italia.
The Cupola weighs 1,800kg and has a height of 1.5 metres and a diameter of 2.95 metres. It has six side windows and one nadir-facing window. All windows are fitted with movable shutters.
Cupola was designed to enable observation of astronauts' activities outside the station and to monitor spacecraft docking and operations of the robotic arm of the ISS. The Cupola soon became very popular in the international media thanks to the spectacular views of the Earth, especially from the nadir-facing window.

TASI's experience with the MPLMs has been incorporated into the new Cygnus spacecraft, designed to send supplies to the ISS and to collect waste that burns up with the craft on re-entry into the atmosphere. The Cygnus programme is operated by the US company Northrop Grumman. The space vehicle consists of a Service Module, made by Northrop Grumman, and a Pressurised Cargo Module (PCM), made by TASI. The collaboration between the two companies began in 2009 with a contract to supply nine PCMs and continued with a new contract signed in 2016 to supply a further nine PCMs (subsequently extended for the construction of two additional modules). The PCM-18, PCM-19 and PCM-20 modules are currently under construction at TASI's Turin site. For the pressurised modules built in 2015, TASI opted to use the Friction Stir Welding process instead of the Variable Polarity Plasma Arc Welding process. Through this new technology, TASI is able to reduce manufacturing time and costs, while increasing machining precision and mechanical strength. A second production line equipped with friction welding machinery will become operational in Turin in 2021.

Thales Alenia Space invests in advanced technology for human space flight

The ISS project is now nearing the end of its life: the station is due to be decommissioned within 2030. However, an announcement has already been made that a part of its structure will be reused as the nucleus of the first private space station to be built under a collaboration between **NASA** and Texas-based Axiom. In an initial phase, Axiom's modules will be attached to the existing station. At a later stage, the Axiom sections will be separated from the ISS being decommissioned to form an autonomous station.

Thales Alenia Space has entered into an agreement with **Axiom Space** to build the first two modules of the future Axiom Space Station. The two modules, Axiom Hub 1 (**AxH1**) and Axiom Hub 2 (**AxH2**) will be delivered in 2024 and 2025. Each module will accommodate up to four people simultaneously, effectively doubling the theoretical number of passengers on board the ISS. The Axiom Hub modules will be pressurised and will use Thales technology for air and water management and protection from space debris and micrometeorites. The first sections of the modules are under construction at the Turin site in Italy. The agreement between Thales and Axiom is the first ever to be signed for the design and development of an entirely private space station.

Thales Alenia Space to provide the first two pressurized modules for Axiom Space Station

2.2.3
Microgravity

The ISS is the first human outpost in space. It serves as an orbiting laboratory where experiments are conducted to prepare for the future human colonisation of space and beyond. The activities carried out have important spin-off effects for applications and technologies used in other sectors not directly related to space, from the production of drugs and molecules to the development of austenitic alloys and the testing of new materials and equipment.
Microgravity experiments are conducted on the ISS with a view to better understanding the effects that the space environment has on living organisms and on materials and production processes. Italy is involved in researching and documenting the microgravity environment, having contributed to almost 20 space missions since 1992 with hardware, astronauts and scientific and technological experiments.

Around 40 Italian microgravity experiments have been conducted in the fields of physics, biology, biotechnology, human research and technological development

The complete list containing a description of the Italian experiments is available on the ASI website, which also contains a database with information on the experiments financed by the national space agency, including, in particular, technical-scientific publications and data collected during experiments conducted on the ISS

ASI - Experiments

One example of the experiments conducted, which also received national press coverage, is ISSpresso developed in collaboration with **Lavazza** and **Argotec**. ISSpresso is a machine used to prepare hot beverages (tea, coffee but also broth), specifically adapted to work in microgravity condition in order to improve the quality and variety of food available to astronauts on board the ISS. The results of the experiment have also had beneficial effects for products destined for consumption on Earth, making it possible to improve brewing techniques and methods.

#video
ISSpresso by Argotec e Lavazza ITA

The subject matters of the experiments range from sleep monitoring to the effect of ionising radiation on the body and in particular on visual function, and from the behaviour of shape-memory polymers to the benefits of using Augmented Reality in space station maintenance operations.

Also important and of great impact is the use of know-how acquired through microgravity experiments for applications in the medical field.
In fact, working in an environment that isn't affected by the Earth's gravitational pull has made it possible for researchers to investigate the mechanisms of progression of neurodegenerative diseases, in particular, Alzheimer's and Parkinson's, as well as the growth of endothelial cells, the end aim being to develop new cancer treatments.

#video
Angiex Cancer Therapy in Space

2.2.4
The Near Future

The Italian ecosystem is moving fast to develop products and solutions related to space exploration. At this stage, both national and regional authorities are pursuing specific dedicated initiatives. Supported by the European Regional Development Fund and Lazio's Regional Operational Programme, the **LAerospaZIO** programme was launched to finance technological and scientific projects with space-related themes. In addition to the scientific projects involving the **Istituto Nazionale di Fisica Nucleare** (**INFN**) and the **Istituto Nazionale di Astrofisica** (**INAF**), in collaboration with universities and national research centres, a number of technological projects have enabled Italian companies to advance their products and production processes.

One example is the **SOLE project**, in collaboration with **G & A Engineering**, for the development of a **demonstrator for the soilless cultivation of plants**, equipped with automated health and growth monitoring systems. The system could be used to grow fresh produce on board spacecraft, satellites and the ISS. The demonstrator also makes it possible to quantify the resources needed to produce fresh food, thus reducing the operating time for operators on board the vehicle. It could also have spin-off effects for cultivation on Earth, e.g. for growing crops in extreme environments (arid and polar regions, etc.) or in densely built-up areas.

Another example is the **MAGIC** project - **Enabling Technologies for Additive Manufacturing, Jointing and Control of Aerospace Thrusters -** in which **AVIO** and **Comeb srl** are involved in the industrialisation of additive manufacturing processes (Additive Layer Manufacturing) of nickel and copper alloys to make aerospace components such as parts for combustion chambers and cooling channels. The project is developing both industrial inventions and process patents that will enable the players involved to offer new production methods for aerospace thrusters, even in microgravity.

MAGIC Project

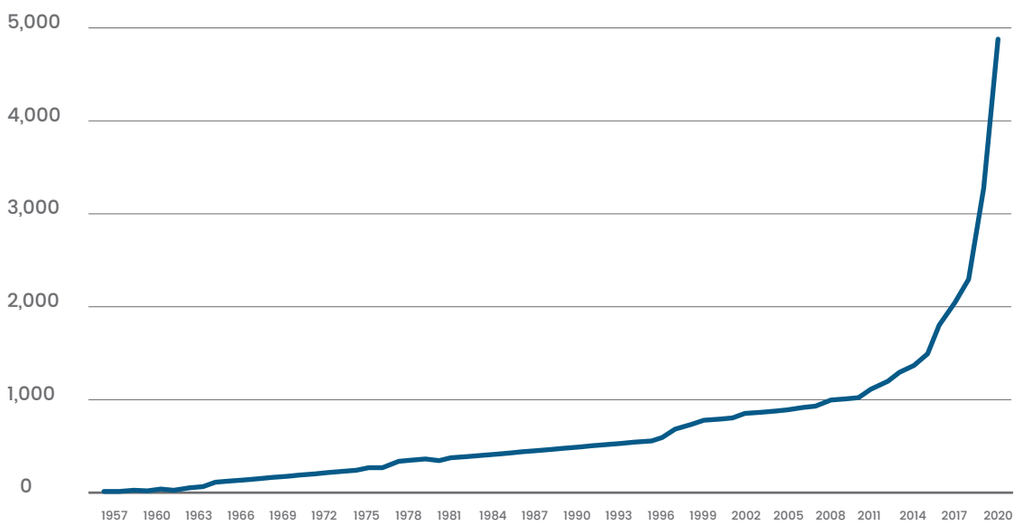
Service / Product	Description	Application area	Company
Mini satellites for missions in deep space	Mini satellites to collect images and to document deep space missions of long duration	**Deep space exploration**	**Argotec**
ISS Modules	Pressurised modules for logistics activities and habitation purposes on the International Space Station (ISS). MPLM modules and the Cupola	**Construction of the ISS**	**Thales Alenia Space Italia**
Modules for private space stations	Pressurised modules for production activities in microgravity, space tourism and research activities on private space stations	**Construction of privately-controlled space stations**	**Thales Alenia Space Italia**
Espresso coffee machine	Espresso coffee machines designed to work in microgravity conditions	**Supply of food and beverages in microgravity**	**Argotec e Lavazza**
Soilless cultivation of plants	Demonstrator for the soilless cultivation of plants to grow fresh produce in microgravity conditions on space vehicles	**Food growing in microgravity**	**G & A Engineering srl**
Additive manufacturing using nickel and copper alloys	Industrialisation of additive manufacturing processes using nickel and copper alloys to make aerospace components	**Additive manufacturing using new materials, and in microgravity**	**AVIO, Comeb**

2.3 Satellites and Satellite Constellations

Satellite manufacturing has been a key area of the aerospace industry from the very beginning. Satellites are the enabling infrastructure for all sectors that need a space segment, such as Earth observation, satellite navigation or telecommunications. The satellite market is experiencing strong growth across the board, from government and military to commercial satellites, and the Italian ecosystem is playing a leading role across the entire production chain.

Since the Soviet Union's launch of the first artificial satellite, Sputnik, in 1957, the number of satellites in orbit has continued to grow steadily. In particular, thanks to the advent of new private launchers and technological innovations that have made it possible to build smaller, high-performance satellites, the number of satellites in orbit has increased dramatically since 2011. According to the latest available data (source: Statista), there were almost 5,000 active satellites in orbit at the beginning of 2022, up sharply from around 3,300 at the end of 2020.

Number of active satellites from 1957 to 2021
Source: Statista



2.3.1 Satellite types: Telecommunications, Navigation, Earth observation

Italy has always had strong capabilities in the field of satellite design and development. The Italian Space Agency, ASI, has supported Italian industries by encouraging the development of innovative systems.

In the field of **telecommunications**, the first satellite, **SIRIO** (**Satellite Italiano di Ricerca Industriale e Operativa**), was launched into geostationary orbit in 1977 with the mission of conducting high-frequency propagation experiments up to 18 GHz, which continued until 1985.

In the 1990s, ASI launched the **ITALSAT** programme, which included two experimental telecommunications satellites launched in 1991 and 1996. The two satellites operated in Ka-band (20-30 GHz) and were designed to be able to switch traffic directly on board and also relay it to mobile users. The two satellites ceased operations in the early 2000s.

In 2001, Alenia Spazio signed a contract with ESA to develop ARTEMIS (Advanced Relay and Technology Mission Satellite) - ESA's first telecommunications satellite in GEO orbit.
ARTEMIS capitalised on Italy's experience with ITALSAT, from which it inherited the 3-axis bus structure. ARTEMIS was also the first satellite in history whose mission was saved thanks to electric propulsion provided by the two experimental propulsion systems mounted on the satellite. Due to a problem in the last stage of the Ariane-5 launcher, the satellite was placed below the intended orbit. The manoeuvres to return ARTEMIS to the correct altitude were carried out at the Fucino control centre with the help of a team from Alenia Spazio S.p.A, ESA and EADS Astrium GmbH.

With reference to **dual-use telecommunications systems**, the **ATHENA-FIDUS** satellite (Access on THeatres and European Nations for Allied Forces - French Italian Dual Use Satellite) was launched into geostationary orbit in 2014, under a collaboration between ASI and the French space agency CNES. The system was developed by Thales Alenia Space and Telespazio, the latter being responsible for the LEOP (Launch and Early Orbit Phase) and the IOT (in Orbit Test) services.

In the field of **satellite navigation**, Italy has been involved in **Galileo** since the early stages, specifically in the development of the space segment (see Chapter 2.5).
In the In Orbit Validation (IOV) phase, Thales Alenia Space played a leading role in building the GIOVE-B (Galileo In Orbit Validation Experiment) satellite, whose mission was to secure use of Galileo frequencies with the ITU (International Telecommunication Union), to test the main technologies to be employed by future Galileo satellites, such as atomic clocks and signal generators, and to characterise the Medium Earth Orbit (MEO) environment, where ESA had never operated before. For the consortium, **Thales Alenia Space Italia** built most of the satellite's structure and managed the assembly, integration and validation (AIV) phases.

ESA - eoPortal

During the in-orbit phase following its launch in April 2008, GIOVE-B was controlled by the Fucino Mission Control Centre operated by **Telespazio**, the first nucleus of the current Galileo Control Centre.
The GIOVE-B payload was the first to transmit the CBOC signal on the E1 band. This signal was defined by an agreement between the US and the EU to reduce interference on GPS signals and, at the same time, to improve the receiving capabilities of Galileo receivers.
GIOVE-B was also the first satellite navigation system to be equipped with a passive hydrogen maser clock, developed by Italy's **Leonardo** (formerly Galileo Avionica), with contributions from the Neuchatel Observatory and the company Temex TNT (Neuchatel, Switzerland). GIOVE-B ceased operations and was placed in "decommissioned" status on 23 July 2012.

In light of the quality of the work performed during the IOV phase, Thales Alenia Space secured the contract for AIV operations for all active satellites of the Galileo 1st Generation constellation.

In March 2021, TASI signed a contract with ESA, worth 772 million euro, to design and build six of the twelve satellites of the second version of Galileo - Galileo 2nd Generation (G2G).

The G2G satellites will take into orbit a number of innovative technological solutions such as:

- electric propulsion: this type of propulsion enables satellites to perform orbit corrections and movements more efficiently and for longer (see Chapter 2.1). It has also increased the life expectancy of this class of satellites to 15 years;
- a more powerful navigation antenna;
- a fully digital payload that can be reconfigured in orbit;
- advanced jamming and spoofing protection mechanisms against intentional interference, including the use of quantum encryption technologies.

In the field of **Earth Observation** (**EO**) satellites (see Chapter 2.6), Italy has always played a key role at European level.
Over the years, ASI, together with Italian companies in the sector, has contributed to ESA and NASA missions and has developed national missions and missions in collaboration with other space agencies. These numerous missions include the ERS 1 and 2 missions and the successor mission **ENVISAT**, developed to monitor the Earth's resources and the dynamics of the Earth's crust and interior, and to support meteorological services at local, regional and global levels.
The ENVISAT satellite was equipped with nine instruments, including the **Advanced Along Track Scanning Radiometer** (**AATSR**) and the **Advanced Synthetic Aperture Radar** (**ASAR**).

In the field of passive remote sensing using hyperspectral sensors (bands: visible, NIR - near infrared range, SWIR - Short Wave Infrared and TIR - Thermal Infrared), the Italian Space Agency ASI funded the **PRISMA** (**PRecursore IperSpettrale della Missione Applicativa**) mission.
The mission was developed entirely by Italian organisations and companies, from the design and construction of the satellite to the launch and data management phases. ASI entrusted the development of PRISMA to a group of companies led by **OHB Italia** (formerly Carlo Gavazzi Space), which directed the mission and supplied the MITA platform for the satellite's structure.

Leonardo manufactured the hyperspectral instrumentation and other equipment (attitude sensors and the solar panel), AVIO manufactured the VEGA launch vehicle used to launch the satellite from the Kourou base and Telespazio managed the LEOP (Launch and Early Orbit Phase).
Mission control is handled by the Fucino Space Centre and X-band data is received and processed by the Space Geodesy Centre in Matera. The first PRISMA satellite enables the simultaneous acquisition of images in the Very NIR and SWIR frequency bands and in the entire visible spectrum (panchromatic images) (see Chapter 2.5). PRISMA mounts a highly innovative and **almost unique hyperspectral sensor** capable of detecting 240 bands between 400 and 2505 nm with an average spectral resolution of 10 nm and a spatial resolution of 30 m. Panchromatic images, on the other hand, have a spatial resolution of 5m. The second generation of the PRISMA satellite is in the planning stage and is scheduled to be launched in 2025.

In the field of active remote sensing via synthetic aperture radars (SARs), Italy has developed the **COSMO SkyMed** system (see Chapter 2.5), intended for dual-use, civilian and military.
The two generations of satellites are equipped with SAR sensors operating in the X-band, capable of observing the Earth even in conditions of cloud cover and in absence of sunlight.
The first generation of CosmoSkyMed consists of four satellites, the first launched in 2007, with completion of the constellation three years later. The first two satellites of the second generation were launched in 2019 and 2022 and will be followed by two more within 2025 to complete the constellation. The construction of the CosmoSkyMed satellites has seen the involvement of all major Italian companies in the sector, with TASI tasked with building the satellites and the end-to-end system, Leonardo in charge of the ground segment, logistics and operations and the supply of the on-board energy system and e-GEOS acting as the exclusive distributor of the end-products and services of the two generations of Cosmo-SkyMed.

In June 2020, ASI signed a commercial agreement with **Sitael**, the leader of a consortium comprising **Leonardo**, **Airbus Italia** and **Thales Alenia Space Italia**, for the industrialisation and commercialisation of the **PLATINO** programme, a high-tech mini-space platform, financed by ASI and the Italian government with an investment of over 100 million euro.
The agreement provides for the development of two missions (with X-band SAR payloads and TIR) whose launches are scheduled to take place in 2022 and 2023. Two additional satellites are also in the pipeline, the high-resolution PLATINO 3, scheduled for launch in 2024, and the hyperspectral PLATINO 4, to be launched the year after.
The plan is for PLATINO 1 satellite to fly in formation with the first- and second-generation CosmoSkyMed satellites during its first year in operation, orbiting at an altitude of at 619 km from Earth, before being moved to a lower orbit (around 410 km) to continue to operate autonomously.
ASI also has collaborations with the Argentine space agency for L-band SAR missions and with ROSCOSMOS, the Russian space agency, for a geosynchronous SAR mission.

2.3.2
Small satellites

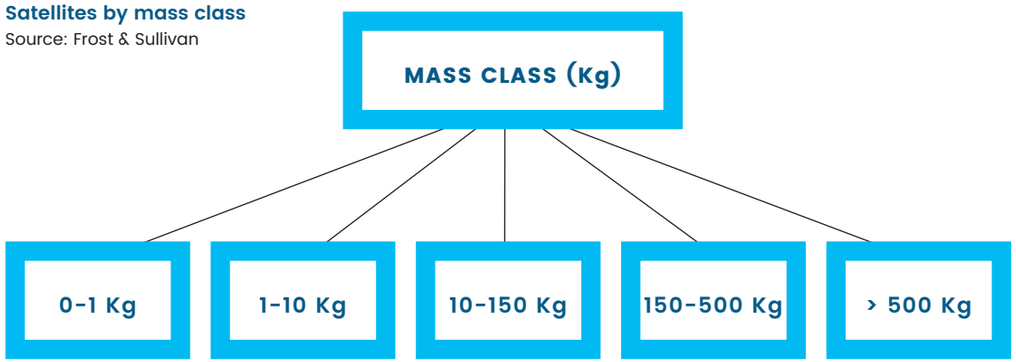
The Italian aerospace sector is also at the forefront of the development of small-sized satellites, which are transforming the satellite market.
In fact, new technologies enabling the miniaturisation and standardisation of onboard electronics, payloads and propulsion systems have now made it possible to build small, high-performance satellites.

The most important innovations for small satellites include **electric propulsion technology**, and the ever-increasing **on-board data storage and processing capacity** using artificial intelligence techniques that allow satellites to operate with increasing autonomy.
Electric propulsion technology is widely used in small satellites, particularly in mega-constellations of satellites in low Earth orbit (LEO). Electric thrusters are more compact and lighter than conventional thrusters, making it possible to reduce the weight, mass and cost of satellites.
The Italian ecosystem offers several alternatives in this segment. For example, **Sitael** (see Chapter 2.1) has extensive experience in the field of Hall effect electric propulsion (acceleration of the ionised propellant through the use of a magnetic field) for small satellites and **T4i** (see Chapter 2.1) has developed electric propulsion systems for satellites and small satellite dispensers.

Sitael

Standardisation has also made it possible to manufacture satellites in large series.
This fact, coupled with the significant fall in launch costs thanks to the arrival on the market of the first reusable launchers, has sparked a new space race among new satellite operators. This race has been accelerated by the ever-increasing availability of small, micro and nano satellites with low weight, low cost and high performance, which make it possible to create mega-constellations with tens, hundreds or thousands of satellites at a much lower cost than in the past.

Satellites by mass class
Source: Frost & Sullivan



In the Italian market, **Argotec** is one of the most dynamic players in the field of aerospace engineering for small satellites and the related applications.
The company develops and engineers small satellites (weighing less than 50 kg) with an 'all-in-house' process that follows the entire design, test, integration and validation phase.

Argotec has also collaborated with the Italian Space Agency on the **LICIACube** (**Light Italian Cubesat for Imaging of Asteroids**) mission.
The cubesat was selected by **NASA** to take part in the **DART** mission (**Double Asteroid Redirection Test**) with the aim of taking photo and video footage of the DART probe's attempt to change the orbit of the double asteroid Didymos. The LICIAcube cubesat was launched in 2021.
The collaboration with ASI also resulted in another extremely innovative cubesat, **ArgoMoon**.
The satellite has been sent to NASA in preparation for launch activities planned for late 2022. ArgoMoon is an integral part of **Artemis 1**, the first mission of the US Space Launch System (SLS) designed by NASA to return humans to the Moon. ArgoMoon is the mission's only European satellite. The cubesat will validate a number of optical technologies for deep space navigation and a new miniaturised propulsion system. Argotec's activities include training technicians and the team that manages space missions from the ground. Astronaut training activities are also carried out at the Cologne site of the European Space Agency - the European Astronaut Centre (EAC). Argotec also hosts a Mission Control Centre at its Turin headquarters, which has a direct connection with the International Space Station for the purpose of monitoring on-board experiments.

Argotec

The **nanosatellite** sector is presided over by **Tyvak International** (part of the Terran Orbital Corporation group), a European leader in this specific high-growth sector.
The company offers end-to-end and ready-to-fly nano-satellite solutions. The satellite development and test phase is based on an agile approach, thanks to which Tyvak can significantly reduce development time and, at the same time, increase payload management flexibility for customers.
Since its foundation, Tyvak has launched around 220 small satellites. The company collaborates with ASI and ESA on highly innovative missions. The management of the re-entry of satellites, and potentially their payload, has been tested through the **IPERDRONE** project, financed by ASI and implemented by **CIRA**, in collaboration with **Kayser Italia**. As part of the collaboration with ESA and ASI, Tyvak operated the **Federated Satellite Systems** - (**FSSCat**) mission, consisting of two cubesats with payloads dedicated to Earth Observation. Tyvak has also developed satellite deployers that can be adapted to different types of missions according to customers' requirements. In

particular, the 12U Deployer is a very lightweight system that enables the release of satellites in an efficient and controlled manner.

Tyvak International

Kayser Italia

EICAS Automazione has developed the **ARGO Star Tracker**, a low-cost, high-precision system for **determining the attitude of orbiting satellites and spacecraft**.
To perform the necessary calculations, the **ARGO Star Tracker** takes measurements using techniques based on proprietary algorithms that are able to compensate for the performance degradation of on-board instruments caused by the space environment. The ARGO Star Tracker was tested in orbit during the D-ORBIT ION SCV-2 mission in 2021.

#video
ARGO Start Tracker – The sky is the limit

In the field of communications between small satellites, **StellarProject** (see Chapter 2.4) has developed LaserCube, a payload that enables laser optical communication between small satellites, with very high performance relative to the size of the product.
GAUSS is a university spinoff, strongly specialised in the production of microsatellites (Cubesat and PocketQube) and in the launch and In Orbit Validation (IOV) phases.
GAUSS has developed small satellites that also function as launch platforms for the deployment of research nanosatellites made by universities, research centres and space industries. The UniSat Platform Technology is flexible and able to carry many different types of payloads so as to reduce launch costs. UniSat is therefore both a satellite with dedicated payloads and a platform for deploying other satellites (up to a weight of 40 kg).

GAUSS

Picosats develops communication components and structural solutions for small satellites. The company has developed RadioSat, a miniaturised solution for Ka-band communications (see Chapter 2.4) enabling data transmission at very high speeds. RadioSat is specifically designed to be integrated into small satellites placed in low earth orbit. In July 2022, Picosats raised 1 million euro from Progress Tech Transfer and LIFTT to test RadioSat in orbit with a view to speeding up its placement on the market.

PICOSATS

Picosats page on LIFTT

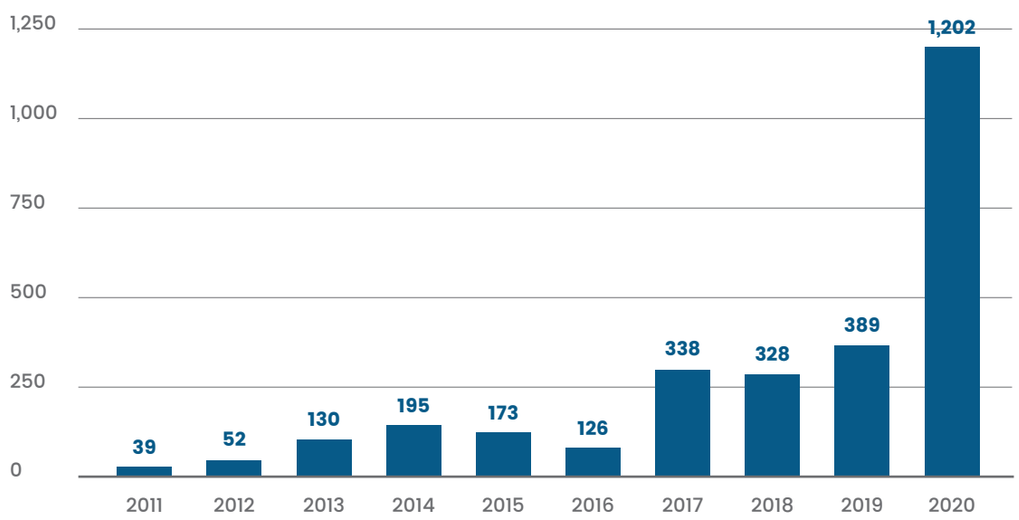
StellarProject (see Chapter 2.4.3) has created LaserCube, a miniaturised terminal for optical telecommunications based on laser technologies, designed specifically for small satellites and cubesats. The terminal features low power consumption whilst ensuring high performance.

2.3.3 Mega-constellations of small satellites

The number of satellites in orbit has risen dramatically due to mass launches carried out by several European and US companies to build their mega-constellations for telecommunications.
SpaceX is launching into orbit the largest constellation ever, Starlink. Once completed, the constellation will consist of 12,000 LEO satellites delivering broadband internet all over the world, with a latency similar to that of a wired broadband.

INTERNET STARLINK

Number of small satellites launched worldwide from 2011 to 2020
Source: Statista

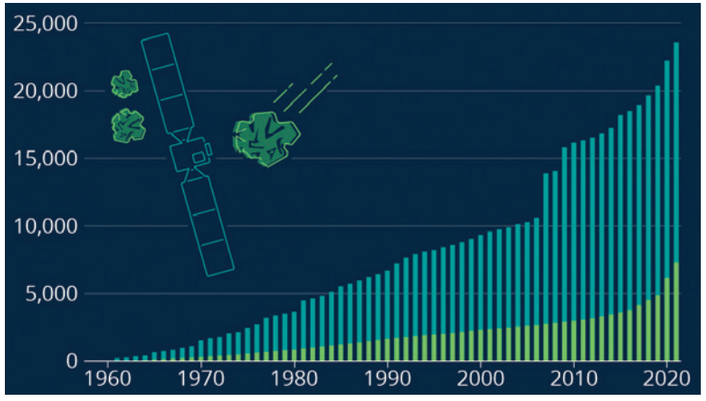


Thales Alenia Space has also joined this new race to build mega-constellations for telecommunications, in partnership with the telecommunications operator **TELSAT**.
Thales Alenia Space Italia and France will build the **298 Lightspeed satellites**, which aim to become the most advanced broadband telecommunications satellites available on the market. The satellites will weigh around 700kg and will be placed in LEO in order to guarantee very low signal latency for end users.
The satellites will communicate with each other thanks to an innovative architecture based on laser technology, which will use 1200 ultra-high-capacity optical links at full capacity. The signal will use the Ka-band and the transmission capacity for the entire network will be several Terabits per second (Tbps). In addition to building the space segment of the constellation, Thales Alenia Space is also involved in the construction phase of the entire system.

De-orbiting of satellites and space vehicles: the space debris issue

The large number of satellites currently in orbit and the awareness that the number of satellites and other objects in low Earth orbit will increase exponentially in the coming decades makes it necessary to address the problem of end-of-life management of satellites and all other objects in orbit. In fact, the Earth's orbit is full of active and decommissioned satellites with payloads, as well as a swarm of other objects that have been used, at some point, for various space activities. The majority of **space debris** consists of parts of launch vehicles left in orbit at the end of their operational mission. With the increase in launches and the **decommissioning** of old satellites without the possibility of re-entry into the atmosphere or moving them to parking orbits, the number of space debris objects is increasing dramatically, increasing the risk of collisions in low orbit.

Artificial objects in Earth's orbit by year of launch/separation
Source: Statista "Buchholz, K. (June 1, 2021). It's Getting Crowded up in Space



* Former transport good of a rocket (spaceship or more typically, a satellite)
** Space mission components, debris, rocket stages

Among the most prominent companies on the Italian and European space scene is **D-orbit**. The company has developed solutions to manage the entire lifecycle of satellites, with a particular focus on the positioning of small satellites and decommissioning. The company refers to itself as the first "**space logistics**" company. D-orbit is able to offer each client a customised service in relation to individual satellites or small constellations. Its ION Satellite Carrier can transport satellites of various sizes, up to a total volume of 64U, and release them into orbital slots. This approach can reduce the time required to bring the satellite into operation by up to 85%, and consequently reduce the launch cost of an entire constellation by up to 40%. D-orbit has developed and tested a next-generation payload for small satellites, designed to facilitate the atmospheric re-entry phase and the subsequent destruction of the satellite at the end of its life cycle. In 2017, the D-Sat mission launched a cubesat into a sun-synchronous orbit at an altitude of 500km to validate the D-Orbit Decommissioning Device (D3). D3 validated the emergency protocol MAMES (Multiple Alert Message Encapsulation) of the European Telecommunications Standards Institute (ETSI) .

D-orbit also adopts an innovative approach from a corporate point of view, being the first space company in the world to obtain the **B-Corporation certification**. In fact, the company aims is to develop technologies and new solutions for space in compliance with a series of environmental and social criteria.

D-orbit's D3 also tested the DeCAS system (Debris Collision Alerting System) developed by **Aviosonic Space**. The payload monitors the cloud of fragments created by the satellite's destruction during re-entry into the atmosphere (on-board debris tracking management). The DeCAS remains dormant until the satellite begins to disintegrate in the atmosphere and then begins to send data about the fragments generated, increasing the safety of the whole process of controlled re-entry into the atmosphere of an artificial satellite. This approach could play a key role in the near future, when thousands of satellites will need to be disposed of every year.

D-orbit

Debris Collision Alert System

ClearSpace, a spinoff of the École Polytechnique Fédérale de Lausanne (EPFL), is developing a new type of satellite for the removal of failed or end-of-life satellites, launchers and other types of space debris. ClearSpace's satellite is able to enter the orbit of the debris to be removed and identify it and lock onto it with its four robotic arms, even in the case of large pieces of debris. Once the debris has been secured, the ClearSpace satellite heads down to the atmosphere where it burns up together with the debris recovered. ESA purchased the ClearSpace removal service in 2020 for 86 million euro, kick-starting the world's first active space debris removal mission. The ClearSpace-1 mission will be launched in 2026 with a VEGA rocket (see Chapter 2.1.2) to attempt to remove the *Vespa - Vega* Secondary Payload Adapter upper stage of a VEGA rocket launched in 2013, weighing 112kg and located at an altitude of between 660 and 800km. The size and weight of the Vespa are ideal for testing this type of technology.

ClearSpace

#video
Earth's first space debris removal mission

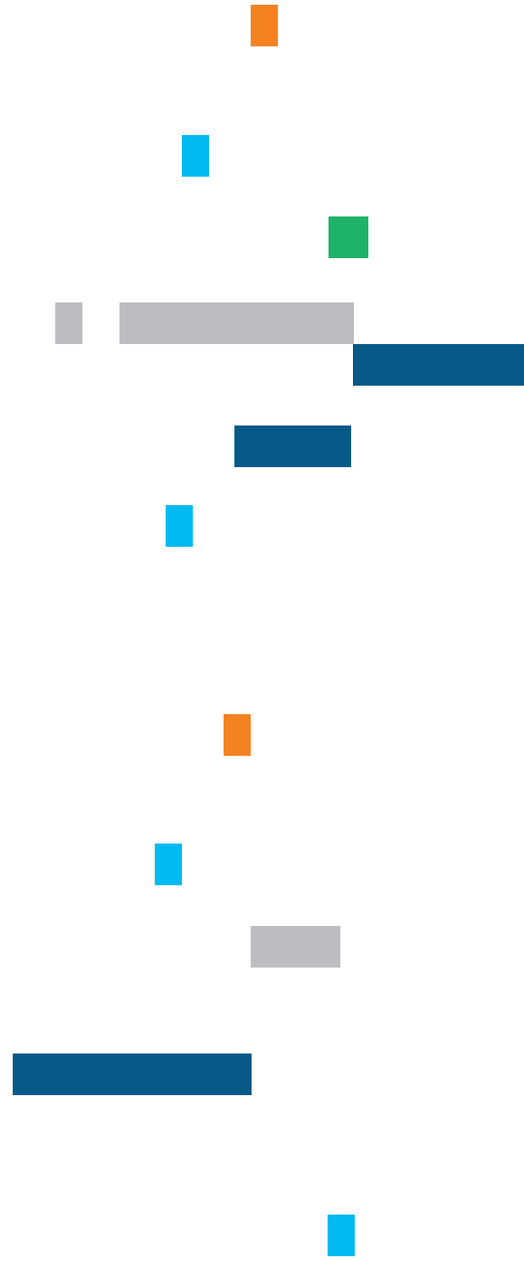
2.3.4 The Near Future

The Italian ecosystem is becoming increasingly specialised in the development of turnkey systems and platforms for small satellites and small satellite constellations. Many innovative start-ups and SMEs are involved in this process and are able to supply small satellites that can be easily configured and customised according to customers' needs.
Among the most interesting applications for the near future are satellites that have innovative payloads such as laser interlink communication systems (see Chapter 2.4), and electric propulsion systems based on technologies that significantly reduce the amount of propellant on board (see Chapter 2.1).

In the field of nanosatellites, Italy is securing a prominent position globally in the field of scientific missions in deep space.
One example is the **HERA** mission, for which **Tyvak** will manage the design, development and implementation phases, the launch services and the in-orbit operations of the **MILANI nanosatellite**. The satellite will photograph and analyse the surface of the **Didymos** binary asteroid system. The launch will take place in 2024.
The nanosatellite will be housed inside the HERA mother satellite, developed as the European contribution to the mission to defend the Earth from asteroids and other celestial bodies (Asteroid Impact & Deflection Assessment - AIDA). Another area where Italian industry is very active is in the space debris management sector.

D-orbit has already validated a specific payload for managing the atmospheric re-entry phase of satellites at the end of their life. ASI and the Italian Government are working to consolidate the national capabilities to monitor and manage objects in orbit, i.e. Space Situational Awareness (SSA) and Space Traffic Management (STM). These actions will be implemented by strengthening the existing infrastructures and building new dedicated telescopes in collaboration with ESA and the UN.

In continuity with the initiatives carried out over the last decade, the Italian Space Agency is funding several projects dedicated to the development of proximity operations, both for monitoring and observing space assets such as satellites or the ISS, and for space exploration or space debris removal activities (in particular through the use of automated space vehicles or dedicated satellites). For example, the **IPER-DRONE** project, led by CIRA in collaboration with Tyvak International and Kayser Italia, will design a drone capable of performing autonomous operations in the vicinity of the International Space Station. The drone will have inspection capabilities and the ability to return autonomously to the ISS. The **e.Inspector** project is developing a small satellite to acquire images and information relating to space debris and other orbiting objects so as to prepare the ground for future space missions to remove space debris or maintain objects in orbit. **SROC** (**Space Rider Observer Cube**) is a cubesat that will be part of the first cargo on board the reusable Space Rider shuttle. Once in orbit, the cubesat will be released to begin monitoring the activities on the Space Rider itself.



Service / Product	Description	Application area	Company
GNSS satellites	Design and production of prototypes and series of satellite navigation systems for the final Galileo constellation	**Production of GNSS satellites**	**Thales Alenia Space Italia**
EO satellites	Design and production of Earth observation satellites	**Production of EO satellites**	**OHB Italia, Leonardo, Thales Alenia Space Italia**
Small EO satellites	Design and production of satellites and constellations of small satellites to be placed in low Earth orbit (LEO) for Earth Observation	**Production of EO satellites**	**Sitael, Leonardo, Airbus Italia, Thales Alenia Space Italia**
Nanosatellites	Design, production, testing, integration and validation of nanosatellites for commercial and scientific applications	**Production of nanosatellites**	**Argotec, Tyvak International, Kayser Italia**
Platforms for the deployment of small satellites	Design and production of platforms and carriers for the deployment of small satellites	**Deployment of small satellites**	**D-Orbit, GAUSS**
Space logistics	Management of all phases of the life-cycle of small satellites: design, launch, deployment, in-orbit validation and decommissioning	**Deployment of small satellites**	**D-Orbit**

Service / Product	Description	Application area	Company
Small satellites with electric propulsion systems	Electric propulsion systems for small satellites, including with ram-EP technology	**Propulsion for small satellites**	**Sitael, T4i**
Decommissioning systems	System for managing the re-entry into the atmosphere of small satellites at the end of their life (decommissioning)	**Decommissioning of small satellites**	**D-Orbit**
Components for inter-satellite communications	Miniaturised solutions for Ka band radio communications between small satellites	**Inter-satellite communications**	**Picosats**
Decommissioning services	Services to monitor the cloud of fragments created by the destruction of satellites during atmospheric re-entry at the end of their life	**Decommissioning of satellites**	**Aviosonic Space**
Satellites used for decommissioning	Production of satellites equipped with robotic arms for the decommissioning of failed or end-of-life satellites, launcher parts and space debris, even of a large size.	**Decommissioning of satellites**	**ClearSpace**
Small scientific satellites	Production of small satellites for scientific missions in deep space	**Small scientific satellites for deep space missions**	**Tyvak International, Argotec**

2.4 Communications

The space communications sector is growing at a steady pace, in line with the number of artificial satellites in orbit and the demand for broadband services among users on Earth. The launch of constellations of satellites for telecommunications confirms the market demand for this type of solution and represents a technological challenge for both providers and the operators of these space infrastructures.

The very nature of this technological sector means that it is constantly and rapidly evolving.
On the one hand, technological innovation is opening up new prospects: the cost of launches is falling dramatically and the miniaturisation of data transmission/reception equipment makes it possible to create small satellites with very interesting levels of performance. On the other hand, at national and European level, there is a need to create telecommunications networks and earth-space communication systems that are better performing and more resilient to intentional and natural interference. Moreover, satellite communications represent the only possible alternative in the event of failure of the terrestrial infrastructures, due, for instance, to the orography of a specific territory or following natural or other types of disasters.

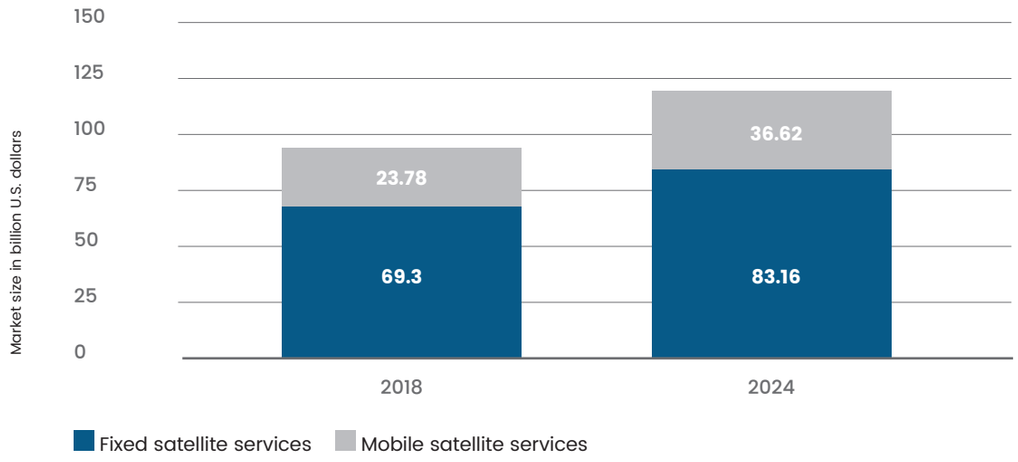
2.4.1 Satellite systems for telecommunications (Satcom)

The Italian aerospace industry has a long track record of designing, manufacturing and managing communication systems that exploit ground-based and in-orbit assets.
SATCOM systems are based on space infrastructure, usually a network of satellites whose payload is primarily made up of transponders (i.e. electronic instruments) capable of receiving a signal from Earth and relaying it back to Earth, thus creating a communication channel between the transmitting and receiving stations.

Over the years, the Italian Space Agency, ASI, has launched a number of missions to deliver a mainly telecommunications payload. The first mission, **Sirio satellite**, was launched into geostationary orbit in 1977 with the aim of conducting experiments on high-frequency propagation up to 18 GHz and on the transmission of television signals. In the 1990s, ASI launched the **Italsat** satellites. In addition to operating in Ka-band (around 20-30 GHz) these satellites featured a payload with traffic-switching capabilities that made it possible to investigate broadband satellite communications, towards mobile users, and test pilot projects in the field of telemedicine and remote learning (see Chapter 2.6).
These missions enabled the Italian satcom industry to develop its know-how and present itself as a reliable partner for European and worldwide projects.
One example is the **Athena-Fidus** (**Access on THeatres and European Nations for Allied forces - French Italian Dual Use Satellite**) system, which enabled Italy, more than ten years since the deorbiting of the second Italsat satellite, to secure its own Ka-band telecommunications system for institutional and governmental users, such as organisations providing civil protection, health, education, territorial monitoring and e-government services. The system was developed by Thales Alenia Space Italia and Telespazio. The satellite was launched in 2014 and has an expected lifetime of fifteen years.
The Italian payload of the Athena-Fidus system includes repeaters and antennas for the institutional (civilian) and military missions. The satellite is equipped with two fixed and two steerable antennas to ensure broadband services throughout the whole of the territory visible from geostationary orbit, capable of supporting Italian missions abroad (dual service).
The architecture of the telecommunications network offers either mesh or star topology for both the civilian and military sections. This type of architecture provides a high degree of flexibility and is compatible with DVB-S2 and DVB-RCS standards for fixed and mobile telecommunications services.
In the communications sector, Italy's large aerospace companies have always played an important and predominant role for technical and financial reasons: projects to develop technologies and infrastructure for telecommunications are of long duration and extremely costly, and, for decades, the industry's customer base was institutional. In fact, the majority of the products and services were requested by space agencies, government agencies, large telecommunications companies or television broadcasters.

The advent of cheaper launchers and small satellites has lowered the threshold for entry into this sector. The increasing number of constellations of artificial satellites in orbit, i.e. the Space Segment (see Chapter 2.3) gives rise to the need for increasingly more efficient communications control centres on the ground, i.e. the **Ground Segment**.

Global space ground station equipment market size in 2018 and 2024, by type
Source: Statista



These centres are characterised by their ability to manage communications between ground and space infrastructure.
In the context of the evolution of the sector as a whole, the constant commitment of all stakeholders, from universities and private individuals to the Italian Space Agency, has enabled Italy to equip itself with communication technologies of excellence, starting from the ground-based infrastructure. In particular, the national ecosystem has very strong capabilities in the construction and management of these assets at both public and private levels.
The most important site at national level is the "Piero Fanti" Space Centre operated by **Telespazio** at Fucino (L'Aquila).

The Fucino Space Centre is considered the largest and best equipped commercial teleport facility in the world

The Centre was established in 1963 and can count on 170 antennas positioned over an area of 370,000 square metres. It hosts two control centres that are very important for Italy and the European Union: the Mission Planning and Control Centre of the COSMO-SkyMed constellation (see Chapter 2.6) and the Galileo Control Centre (GCC - see Chapter 2.5). The centre manages the **Launch and Early Orbit Phase** (**LEOP**) for one mission and the **Telemetry, Tracking and Command** (**TT&C**) function for multiple satellite operators:

- The LEOP runs from the time the satellite separates from the launcher to the time it reaches its final orbit. It is a highly complex phase that can last from a few days (about 10 for a satellite in geostationary orbit at an altitude of 36,000 km) up to several months. Telespazio is currently the only private company in Europe to have the technology and infrastructure required to manage the entire LEOP phase independently. It has managed the LEOP phase of more than 50 satellites since 1996. A new LEOP room was inaugurated in 2019 and has the capacity to handle the huge amount of telemetry data, up to fifty thousand, required to monitor a satellite in flight.
- The TT&C function manages and controls all activities of the satellite, including monitoring the payload, the health of the platform and its orbit.

The Galileo data dissemination network, comprising some fifty ground stations scattered around the globe, is also controlled from the Fucino Space Centre. The Fucino teleport facility also serves as the base for Telespazio's management of numerous television broadcasting services, integrated ground-satellite connectivity services and multimedia transmission networks for large corporate clients (e.g. ENAV and SNAM).

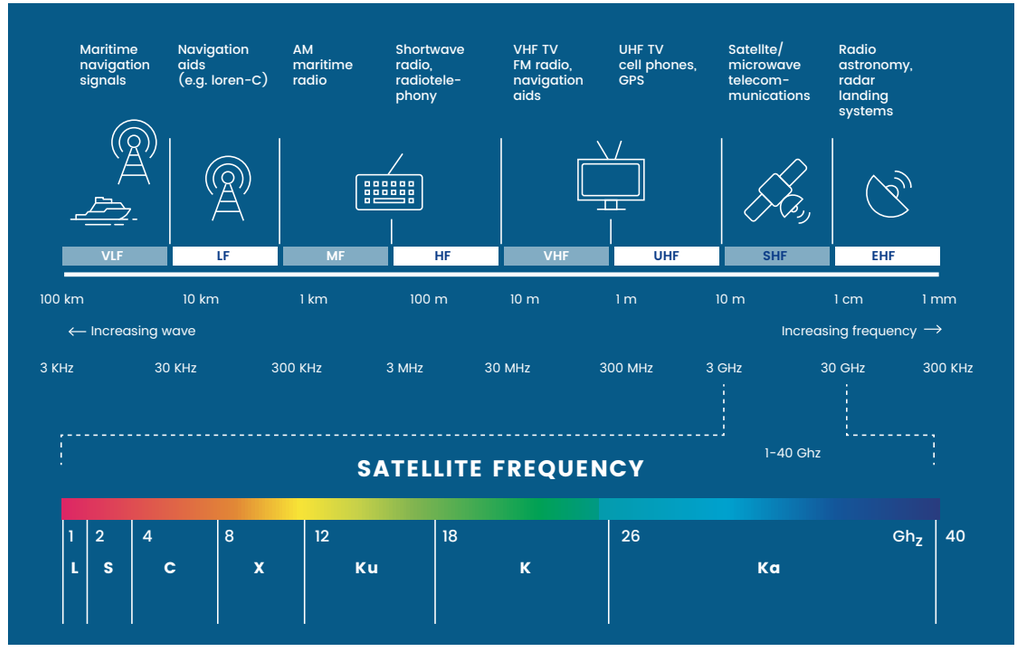
Fucino Space Centre

2.4.2 On-demand services

The ability to create constellations of small satellites at low cost is driving the market towards the development of new on-demand space asset management services.
Ground Segment as a Service (**GSaS**) exploits the same concept as other "as-a-service" models to provide all new space operators of various types with the services typical of a large teleport facility, as and when needed.
GSaS is based on the scalability of the service, which can grow in line with any increase in the user base or when new satellites are launched into orbit, depending on the customer's needs. This type of service is particularly appealing to companies, start-ups or research centres that are currently taking advantage of the new low cost launchers to send small satellites into space, given that these can be managed and monitored from the ground at competitive costs.

Satellite communications use specific bands, allocated through international agreements. The bands range from the 3 GHz of the SHF to the 300 GHz of the EHF. The **Ku, K and Ka bands** (12-40 GHz) are widely used in **satellite communications**. In particular, the Ka and Ku bands allow broadband and low latency transmission. On the other hand, communications between satellites and the control network (control centres, uplink stations) often use the **S, C, and X bands** (2-8 GHz).

Satellite communications frequency bands
Source: ESA



The entry of a giant like Amazon confirms the development potential of this particular sector where communications and cloud computing merge. Amazon has a division of its cloud sector dedicated to the provision of GSaS - the AWS Ground Station. Amazon's ground station network harnesses the enormous computational power of the company's servers for all activities dedicated to the collection and management of incoming data from satellites. The system operates in X- and S-band, narrowband and wide band frequencies. Data can be received in near real time through use of a EC2 Downlink instance.

In the Italian market, one of the leading players in this segment is the former start-up **LeafSpace**, founded in 2014 in the province of Como.
LeafSpace is currently one of the leading GSaS providers, offering Launch and Early Orbit Phase (LEOP) services and Telemetry, Tracking and Command (TT&C) services. Its ground infrastructure allows communications in several bands, including the S and X bands.
The company specialises in providing support to operators of constellations of small satellites and is involved in the engineering and design phase of satellite communication modules. LeafSpace also provides support to companies that already have an operational ground segment, helping them to increase the reliability of their systems and their geographical coverage. The company's ground infrastructure includes dishes from 3 to 3.7 metres for S-band and X-band transmission. Yagi antennas are used for communications in UHF and VHF bands.

LeafSpace has also developed a proprietary baseband processing software, which is used in conjunction with commercial high datarate receivers to ensure a high level of performance in handling individual satellites and small constellations.
The company has developed an "as-a-service" approach for the multi-mission ground segment, comprising a network of 12 ground stations and a proprietary software infrastructure. The solution is particularly effective thanks to a highly efficient planning algorithm that optimises the use of ground stations by various users.

LeafSpace

Another Italian operator in this sector is **ItalSpazio**, which specialises in satellite and space technologies and turnkey communication services between ground stations and the space segment, with an increasing specialisation in the management of small satellites and fleets of small satellites. ItalSpazio specialises in the construction of antenna systems and control stations.

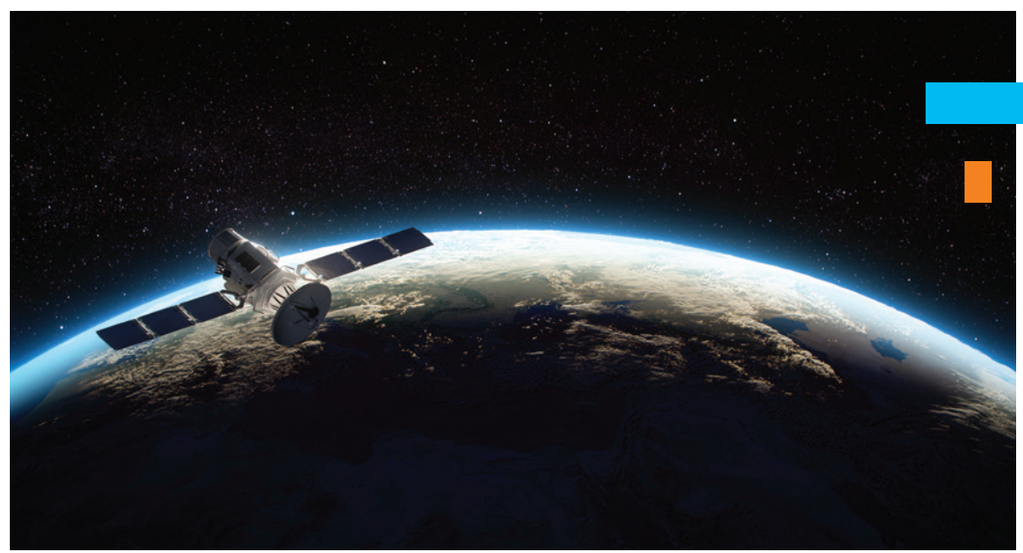
Italspazio

Market perspectives of Ground Segment as a Service (GSaaS)

TIM has announced a partnership with Eutelsat to offer satellite services in Italy, harnessing the opportunities offered by the new **Konnect** satellite built by Thales Alenia Space and operated by Telespazio from the Fucino Space Centre in Italy.
Konnect is an all-electric satellite: it was launched into orbit by electric propulsion, with an innovative LEOP phase lasting around six months. It is managed by Telespazio. Konnect offers broadband Internet plans for households (B2C) and businesses (B2B).

Konnect

The Eutelsat Konnect satellite operates in Ka-band, has a transmission capacity of 75 Gbps and provides end users with ultra-fast Internet access at up to 100 Mbps. The Konnect satellite's coverage in Italy excludes Sicily and Sardinia, which will instead be covered by Eutelsat's next satellite, Konnect VHTS. Eutelsat supplies services in Italy through its Satellite Teleports located in Turin and Cagliari.



2.4.3 Inter-Satellite Communication

Within satellite constellations, individual space vehicles are often equipped with inter-satellite communication tools. This allows satellites that are in "close proximity" to exchange data about their status and position. The GPS and Galileo satellite navigation systems (see Chapter 2.5) use an inter-satellite link to exchange information about their position and status. In this way, the navigation message sent to users can contain updated information for longer, even in the absence of contact with the ground segment control stations.
Optical communication between satellites via **laser interlink** represents a frontier technology that guarantees reliability and bandwidth.
Thales Alenia Space Italia and France will implement this technology in the **298 Lightspeed satellites** used to create a LEO constellation for ultra-high performance broadband telecommunications for the operator TELESAT. The satellites also mount a terminal for highly flexible space-to-ground telecommunications, featuring electronically steered antennas. Communication between the satellites of the constellation will use laser interlinks, with a cumulative transmission capacity of several Terabits (Tbps).
In this context, the company **StellarProject**, a deep-tech spinoff of the University of Padua, has created an innovative platform to enable the exchange of data between small satellites via optical laser technology. Laser communication between satellites has so far been the preserve of large satellites due to the size of the signal transmission and reception equipment and their energy consumption. StellarProject has developed a miniaturised terminal for optical telecommunications. The payload, designed for small satellites and cubesats, combines ultra-high performance with low power consumption, which is crucial for this class of satellite.

StellarProject technology enables optical-laser communication between satellites, including small-sized units

The product, called **LaserCube**, has a very high independent pointing capability that can increase the bit rate of communications between small satellites by more than ten times compared to devices based on traditional radio technologies.
LaserCube promises reduced signal latency coupled with increased security. LaserCube's optomechanical unit uses a dual-stage pointing system based on Stellar Project's patented technology. Thanks to these innovations, StellarProject enables operators of small satellites to access the performance levels and capabilities of larger and more expensive satellites.
LaserCube has been developed in two versions, one for the downlink of data from the satellite to a ground station and the other specifically designed for inter-satellite communications.
The second version will enable the development of satellite networks, including for Machine-to-Machine (M2M) applications, at low cost and with high efficiency.The terminal was developed and tested with the contribution of the European Space Agency's ARTES programme, supported by the Italian Space Agency. StellarProject is also working on integrating quantum communication technology into its products and is expanding its interest in data analysis for ground-based applications and space debris monitoring. For the LaserCube project, **Guizzo Space** built the payload electronics unit.
LaserCube was flight-tested in 2021. The payload was part of **D-Orbit's** WILD RIDE mission, and was integrated into its orbital ION Satellite Carrier vehicle, which was launched into orbit on 30 June 2021 aboard a Falcon 9 rocket developed by **SpaceX**.
ASI manages the test and validation phase of LaserCube's **Pointing, Acquisition and Tracking operations from the Matera Laser Ranging Observatory**.

ASI - Lasercube in orbita

Stellar Project Announces LaserCube Maiden Flight Mission

In addition to laser communications, the industry is seeing the emergence of miniaturised components for high-performance radio communications specifically designed for small satellites, such as the Radiosat transceiver developed by **Picosats** (see Chapter 2.3.2). The device is at an advanced stage of development.

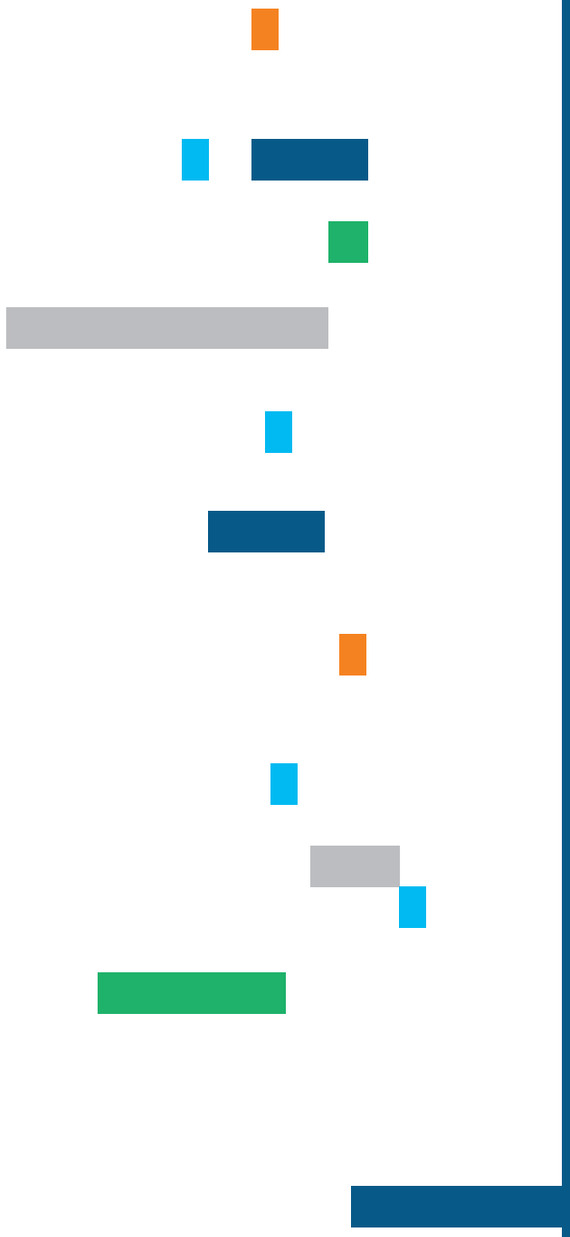
2.4.4 The Near Future

At national and European level there is a growing need to create telecommunications networks and ground/space communication systems that are more resilient to intentional and natural interference. The **security of communications** is always a strategic objective for any country, and is becoming more so today where connectivity to data networks is an essential requirement for every industry and for ensuring public security in the civil protection and military fields.
At national level, ASI has gathered information on the requirements of institutions and all national stakeholders. In 2019, ASI signed a contract with the Space Alliance (a joint venture between Thales Alenia Space and Leonardo) for the implementation of the first phase of the **Ital-GovSatCom** satellite system dedicated to institutional communications.
In this initial phase of the Ital-GovSatCom project, Thales has been tasked with the construction of the first satellite and its innovative payload and Leonardo will be in charge of the satellite launch and management phase. The project will be Italy's contribution to the broader European initiative called **GovSatCom**.
The European Commission officially launched the new space programme in 2021.
A key aim for the Union is to achieve technological independence in strategic sectors, including telecommunications. In fact the GovSatCom programme was launched to provide secure satellite communication services for governments and institutional users of the member states. GovSatCom is therefore the third and most recent European space programme, after Galileo and Copernicus, to come under the control of EUSPA (European Space Programmes Agency).

Another technology that is rapidly emerging in the communications sector is that based on quantum mechanics.
Quantum Communication is revolutionising the field of cryptographic protocols.
Quantum cryptography exploits the mechanisms of quantum mechanics to transmit cryptographic keys based on **Quantum Key Distribution** (**QKD**) technology with the end aim of increasing the robustness of terrestrial and satellite communications. The Italian Space Agency is engaged in a number of experiments in the field of quantum satellite communications, in collaboration with Italian universities and through participation in European projects.
The ASI Space Centre in Matera is using its MLRO (Matera Laser Ranging Observatory), which is normally used for high-precision geodesy applications and to constantly monitor satellite orbits, to study the behaviour of laser beams reflected by orbiting satellites carrying specific payloads[4].

The main ASI operation center, located in Matera

#video
ASI #SpaceTalk: Communications in the era of quanta



4 Interferenza quantistica di fotoni nello spazio
media.inaf.it

Service / Product	Description	Application area	Company
Teleport facilities	The "Piero Fanti" Space Centre is the largest and best equipped commercial teleport facility in the world. The Centre can count on 170 antennas positioned over an area of 370000 square metres	**Ground Segment - services for the management of the entire life cycle of satellites and constellations**	**Telespazio**
Ground Segment as a Service - GSaS	On-demand ground segment services for controlling and monitoring space assets, also for small operators and with the option of fast and efficient scale-up	**Ground Segment - services for the management of satellites and constellations**	**LeafSpace**
LEOP and TT&C services	Launch and Early Orbit Phase (LEOP) services and Telemetry, Tracking and Control (TT&C) services for single satellites and constellations. Turnkey services for the management of satellites and small constellations	**Services for the management of satellites and constellations**	**Telespazio, LeafSpace, Italspazio**
Transmission in K bands (KUI, K and KA)	Satellite communications with broad bandwidth and low latency in the Ku, K and Ka bands (12-40 Ghz)	**Broadband telecommunications**	**ItalSpazio, Telespazio, TIM**
Transmission in S and C bands	Communication services in S and C bands (2-8 Ghz) for satellite control and monitoring (uplink)	**Satellite communications**	**ItalSpazio, LeafSpace**
Broadband Internet	B2C and B2B satellite broadband services	**Satellite broadband internet service**	**TIM**
Inter-satellite laser link for small satellites	Design and development of laser interlink-based payloads for small satellites, with high bit rate and low latency transmission	**Satellite payloads for communications between satellites, Cybersecurity**	**StellarProject, Guizzo Space, Thales Alenia Space**

2.5 Satellite Navigation

Satellite navigation is considered in many industries as a commodity - now indispensable and globally available 24 hours a day. Applications of this technology include positioning and navigation services for means of transport, data encryption and communication security services and all timing-based applications.

The uninterrupted availability of signals make it a pervasive and enabling technology for a wide range of services, products and applications. The target market is therefore broad and multifaceted. EUSPA estimates that revenue of the downstream satellite navigation market will grow from around 199 billion euro in 2021 to **492 billion euro in 2031, with a CAGR of 9.2%**.

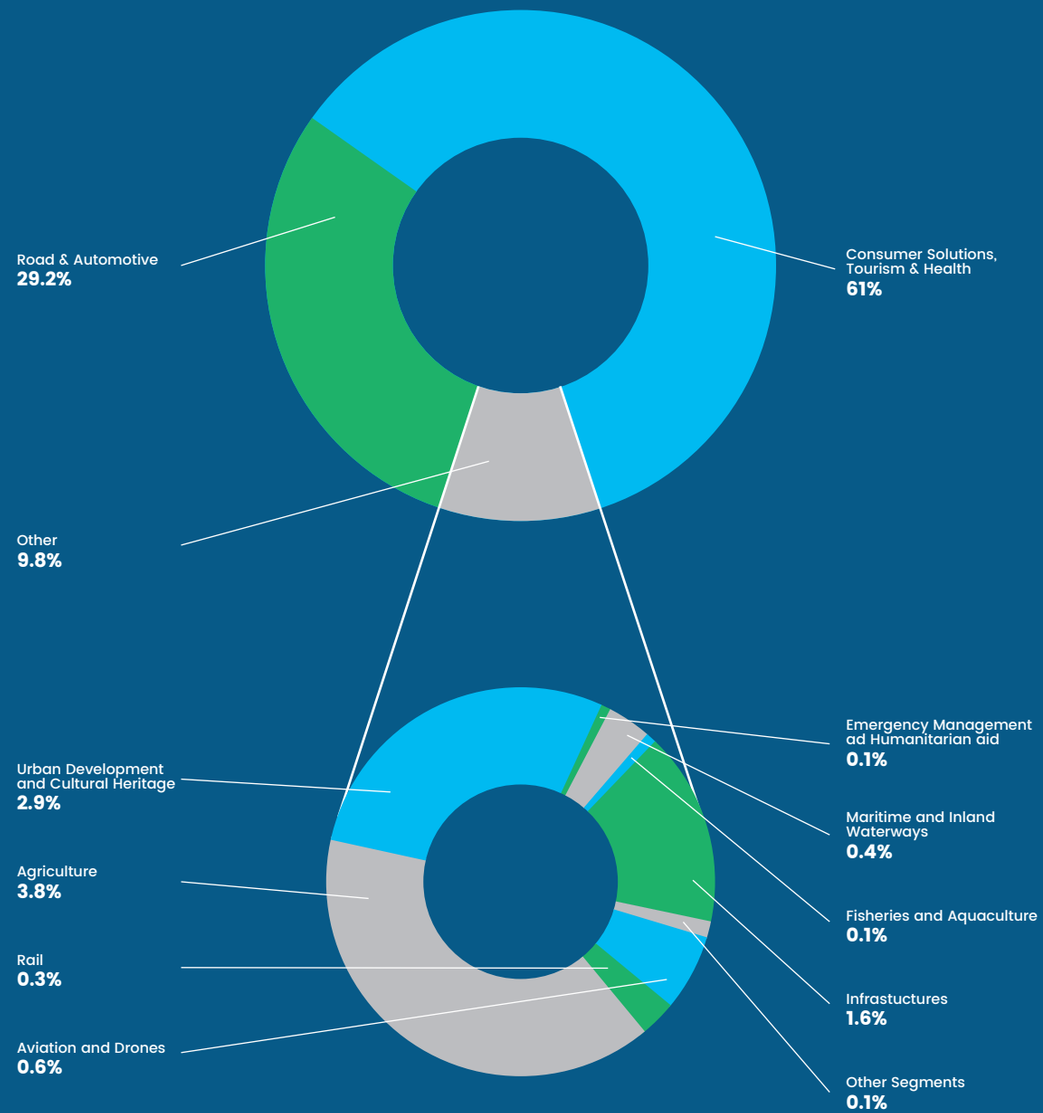
EUSPA EO and GNSS Market Report 2022

2.5.1 Global Navigation Satellite System – GNSS

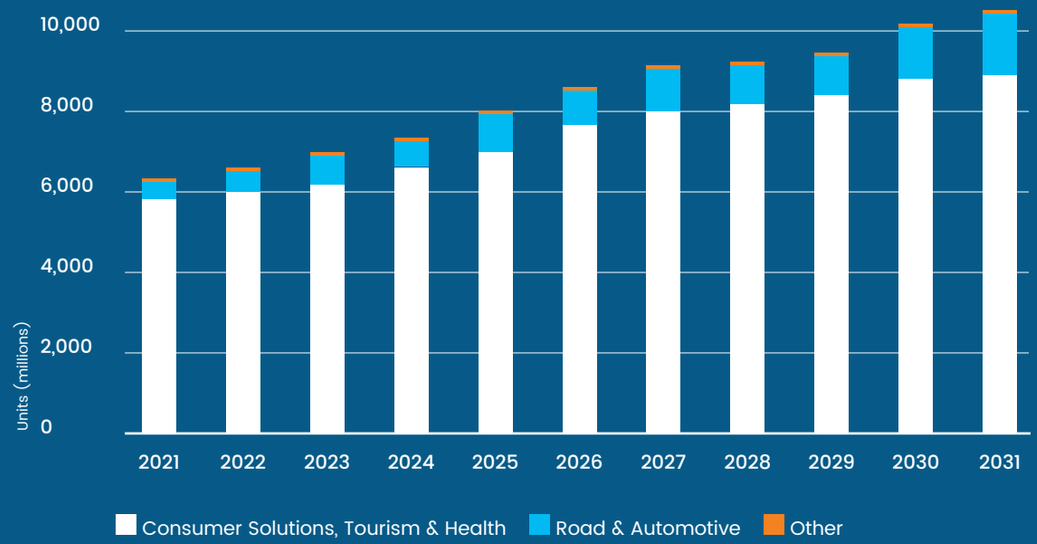
Global Navigation Satellite Systems (**GNSS**) are constellations of satellites capable of sending signals back to Earth so that users can identify their position. The satellite navigation sector is peculiar in the way in which it has developed in Italy and Europe.
Satellite navigation originated as a military technology in the United States and the former Soviet Union. The **GPS** and **GLONASS** systems are in fact considered dual-use infrastructures, born as military technology and now used also in the civilian sector. During the 1980s and 1990s, the use of GPS for civilian purposes became more prominent in the transport and logistics sector, giving GPS the role of an enabling technology.
The GNSS systems currently in operation with global coverage are the US GPS, the Russian GLONASS, the Chinese **COMPASS-Beidou** and the European **Galileo** system.

In terms of revenue, the market is dominated by the consumer and road segments, followed by applications and services in the geomatics and agriculture segments. The top three markets are the US (29% of global revenues), Europe (25%, including countries of the European Economic Area and the UK) and the Asia Pacific region (36%, generated by China, Japan and South Korea).

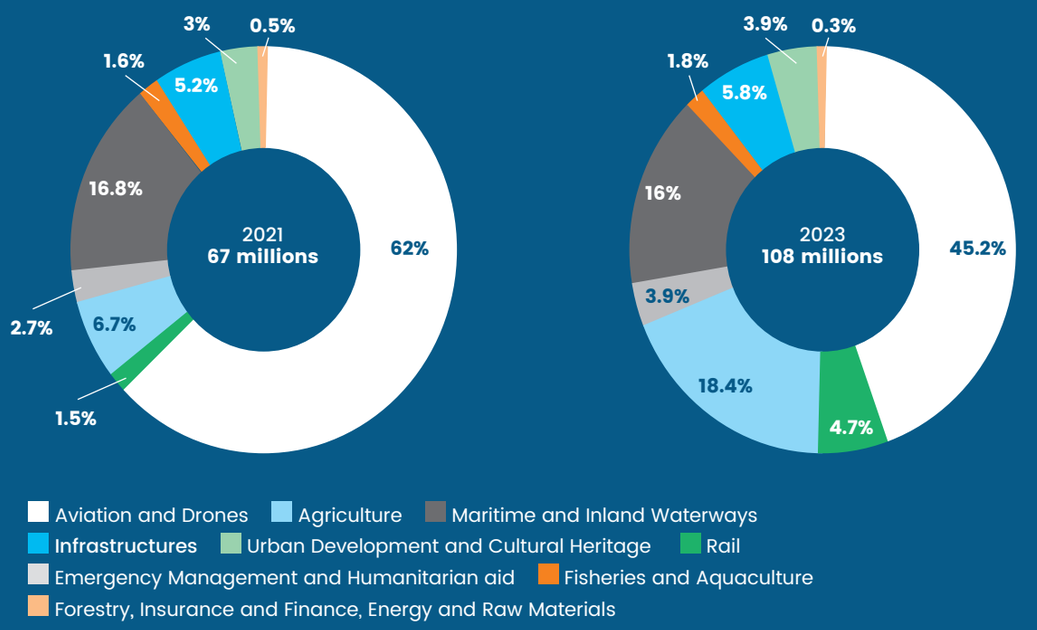
Cumulative revenue 2021-2031 by segment
Source: GNSS Market Report, Issue 1, copyright © European GNSS Agency, 2022



Global installed base of GNSS devices by segment
Source: GNSS Market Report, Issue 1, copyright © European GNSS Agency, 2022



Installed base of 'Other' by segment
Source: GNSS Market Report, Issue 1, copyright © European GNSS Agency, 2022



2.5.2
EGNSS: Galileo and EGNOS

At the end of the last century, the **European Union** established that this technology was of fundamental importance and decided, in 2000, to develop its own global satellite navigation system - Galileo. The Galileo infrastructure is owned and controlled by the EU, which has mandated the **European Space Agency** (**ESA**) to manage the technical and technological aspects of the satellites, their launch into orbit and the system upgrades.

As of April 2022, Galileo is the only GNSS to be under civilian control at worldwide level

The EU project is based on the construction of two complementary infrastructures: the **Galileo global navigation satellite system** and the **EGNOS** (European Geostationary Navigation Overlay Service) **augmentation system**, which aims to improve the services offered by GPS and Galileo across the European continent.

Thanks to the EGNOS and Galileo programmes, EU countries have been able to develop from scratch the scientific basis that today enables Europe to be technologically, geopolitically and economically independent in the field of satellite navigation.

EUSPA - What is Galileo?

EUSPA - What is EGNOS?

Galileo and EGNOS represent an opportunity for the entire European economy. The **European Space Programme Agency** (**EUSPA**) expects the global installed base of GNSS receivers to grow steadily to around 10.6 billion devices by 2031. Most of the receivers are installed in consumer products, from smartphones and wearables to a wide variety of IoT products. The second largest segment by number of users is the road segment, where GNSS technology is one of the key components of a large number of applications and services.

The growth trend of **GNSS receivers** to 2031 is also confirmed in other more specialised industries where satellite navigation serves as an enabling technology, namely:Air navigation;

- Drones and aviation-related applications;
- Agriculture and land management (forestry, etc.);
- Maritime and inland waterways navigation;
- Rail;
- Infrastructure;
- Urban development and cultural heritage management;
- Management of emergencies.

The satellite navigation sector comprises three distinct but complementary assets: the Ground Segment, the Space Segment and the User Segment.

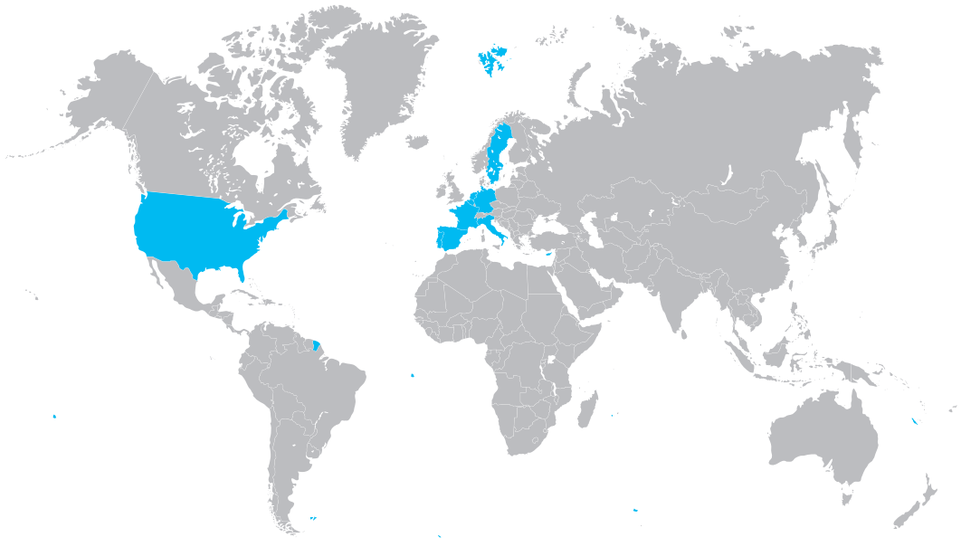
2.5.3
Ground Segment - Ground Bases and Control Centres

The **Ground Segment** includes the control centres and the network of ground stations that monitor the constellations and the signals transmitted by the satellites.

Thales Alenia Space Italia (**TASI**) has played a key role in the development of the satellite navigation sector in Europe.
For the EGNOS system, TASI was responsible for the development and installation of the **remote monitoring stations** (**RIMS**), which are fundamental in guaranteeing the system's **augmentation services**. In view of the Italian company's experience in the development of augmentation systems, TASI was selected by the South Korean Space Agency to develop the Korea Augmentation Satellite System (KASS), the Korean national system similar to EGNOS.

Thales Alenia Space Italia led the design and implementation of Galileo's **Precision Timing Facility** (**PTF**) at ESA's Fucino centre near Rome.
The PTF is equipped with atomic clocks (active hydrogen maser and cesium clocks), which set the reference time for the Galileo system, and includes the **Galileo Reference Chain** (**GRC**), which controls the accuracy of the Galileo signal in the ground segment.
Italian research organisations, particularly those based in Turin, were actively involved in the development of this control system, with a fundamental contribution coming from the **National Institute of Metrology** (**INRIM**), in collaboration with the **Politecnico di Torino**, supported by **ALTEC** and the **Fondazione LINKS** research institute. The PTF is the heart of the Galileo system as it enables the entire constellation to ensure an extremely high-performance signal at global level.

Ground Stations of the Galileo satellite navigation system
Source: ESA



Italy hosts one of the two control centres of the Galileo constellation, the Galileo Control Centre (GCC)

The centre is operated by **Telespazio** from the **Fucino Space Centre** (see Chapter 2.4). The Italian GCC works in synchrony and redundancy with its twin centre in Oberpfaffenhofen, Germany. The two GCCs monitor the health of all satellites and signals via a network of Galileo Sensor Stations evenly distributed across the entire globe and communicate with satellites via the network of Up-Link Stations.

Telespazio has managed the integration and validation activities for the entire Galileo system and is also responsible for the constellation's simulator.
Through its shareholding in **SpaceOpal**, a company 50% owned by the German Space Agency DLR Gesellschaft für Raumfahrtanwendungen (GfR) mbH, Telespazio acts as prime contractor for the Galileo constellation. SpaceOpal manages Galileo's 30 orbiting satellites and monitors their health status from various ground stations scattered across the planet and from its three main control centres in Oberpfaffenhofen in Germany, Fucino in Italy, and Torrejón de Ardoz in Spain. The company operates a real-time service for all Galileo signal users, called NAVCAST, which ensures that the **Galileo Open Service Signal-in Space** (**SIS**) has a healthy status for each satellite.

2.5.4
Space Segment – Satellites and components

The **space segment** includes the satellites that orbit the Earth. In this segment, Italy has contributed to the construction of several satellites of the Galileo constellation.
In particular, TASI is part of the group of the European space companies that ESA selected to develop the system. In the early development stages of Galileo, TASI led the integration and test activities for the 4 satellites of the **IOV** (**In Orbit Validation**) phase, the so-called GIOVE satellites, as well as the development of the GIOVE-B satellite payload. TASI designed and assembled the **antennas** and **signal generation units** for the 22 satellites of the FOC (**Full Operational Capability**) phase.

In parallel with the completion of the constellation of the first version of the system, the European Commission mandated ESA to begin preliminary studies for the design of the second version of Galileo (Galileo 2nd Generation - G2G).
In recent years, ESA has launched several calls for tenders to study cutting-edge technological solutions for all components of the system.
TASI has secured a contract worth 772 million euro from ESA, to build six of the twelve satellites of Galileo 2nd generation and to develop and implement the new ground segment. In particular, TASI will develop the new **Advanced Orbit Determination and Time Synchronisation** (**ODTS**) algorithms test platform, which is set to significantly improve Galileo's performance in terms of positioning and timing.
The launch of the second-generation of Galileo satellites is scheduled for the end of 2024.

Leonardo has developed the IRES-N2 (Infrared Earth Sensor) required to control the attitude of the satellites, as well as the **Passive Hydrogen Maser** (**PHM**) **atomic clocks**.
The accumulated error of one second every three million years makes Leonardo's atomic clocks the most accurate ever made for the satellite navigation sector. Their contribution is essential to ensure the accuracy of the navigation signal sent back to Earth from satellites orbiting at almost 23,000 km above its surface. Each Galileo satellite mounts two of these clocks to increase the accuracy and resilience of the system.
Leonardo is developing a more compact version of the atomic clock for installation on the Galileo 2nd generation satellites.
The **Mini Passive Hydrogen Maser** is being developed under an ESA contract funded by ASI, and represents the state of the art in atomic clocks. The Mini PHM is smaller, lighter and more energy-efficient than the PHM whilst maintaining the same performance. In particular, the Frequency Drift is in the order of 1x10-14 after one week and less than 1x10-15 after 30 days.

2.5.5 User segment - Signals and Receivers

The **user segment** encompasses all applications that make use of **Positioning**, **Navigation and Timing** (**PNT**) data. These data are obtained from GNSS receivers, which analyse and process the signals received from satellites to calculate the user's position and the exact time, thus enabling services based not only on position but also on precise time information.

The user segment is therefore very diverse. Over the last decade, the use of user position information - and sometimes also time information - has found applications in many areas. As can be deduced from the Market Report 2022 published by EUSPA, the domains that make up the user segment of satellite navigation systems cover different areas of application in both the mass market and more professional markets. Each domain has specific requirements, both technical and financial, and the receivers available on the market therefore differ in terms of the services offered, their performance and, of course, their cost. While the cost of a GNSS receiver is around a dollar for mass market applications, such as those used in smartphones, the cost can run into the tens of hundreds of dollars for scientific applications or applications that require very high precision.

Satellite navigation is an enabling technology in many areas where position information is essential, such as:

- logistics and transport, both road and rail
- air and maritime traffic control
- smart mobility
- self-driving vehicles: road vehicles, aircraft, drones, ships, construction machinery, material extraction machinery, agricultural machinery, etc.
- tourism and the entire leisure sector
- monitoring of infrastructure such as bridges and dams
- land monitoring (e.g. landslides, flooding, aqueducts)
- management of rescue teams in emergency situations

In other fields, the analysis of GNSS signals is used to study other phenomena. In fact GNSS has applications in the meteorology area and in more scientific fields, e.g. the study of the upper ionosphere.

In addition to position information, applications that use time information are also becoming increasingly important. GNSS receivers are used to synchronise various types of networks, from electricity to telephony and data networks, and to manage financial transactions.

Considering the range of possible applications, the market for satellite navigation applications is clearly not only linked to the availability of the technical solutions but to the existence of laws and regulations. The availability of signals from a system owned by the European Union (Galileo) has certainly facilitated the development of the European GNSS market.

Another one of Galileo's important contributions to the world of satellite navigation is the **Search and Rescue service** (**SAR**). With this service, which is already operational across Europe, Galileo is the first GNSS system to contribute to the global search and rescue service **COSPAR-SARSAT**. For years, this service operated via satellites placed in low earth orbit (LEO), which came with some disadvantages: lack of continuity of the monitoring service, slow response to a distress alert and the inability to warn people in distress that their SOS had been received. The need to overcome these limitations led to the launch of a new service called **MEOLUT**, to which all GNSS systems will contribute. Galileo was the first GNSS to bring into operation its SAR service, which enables continuous, instantaneous and global monitoring of SOS signals and their localisation, therefore speeding up the start of rescue operations and, above all, sending a "**Return Link**" to confirm to the people in distress that their distress signal has been received.

EUSPA - Search and Rescue (SAR)

2.5.6 Italy's role

Italy has had a leading role in the development of the EGNOS and Galileo systems from the very start, both through the involvement of major aerospace companies (Thales Alenia Space Italia, Leonardo, Telespazio) and through its membership of ESA, to which Italy is the third net contributor. In fact, the EU has signed a **delegation agreement** with ESA, mandating the latter to manage the design, launch, implementation and technical validation phase of the European Union's satellite navigation programme. The Italian Space Agency (ASI) has played a leading role in promoting the system and in coordinating scientific research at national level in order to build the required capabilities.

Italy has also contributed significantly to the definition and development of the Galileo OSNMA service.
Qascom, an SME specialising in GNSS applications and space cybersecurity solutions, and **Fondazione LINKS**, a private research organisation, have supported Airbus Defence & Space in the study and simulation of cryptographic techniques to be used to define the structure of the OSNMA signal.

Qascom is an innovative SME that develops engineering services in the GNSS sector.
The company specialises in developing solutions in the areas of authentication, cryptography and the simulation and mitigation of natural and intentional interference that affects GNSS signals. One example is the Satellite Security Testbed (SVTB), a simulator developed with Software Defined Radio (SDR) technology for testing resilience against interference and attacks on the radio frequency of the communication channel used to control satellites. The SVTB can simulate both the uplink stations, enabling the definition of the structure of the transmitted signal and the chosen modulation, and the attacker's position. The testbed also allows the simulation of jamming attacks on the radio frequency signal and smart jamming on data.
Qascom has considerable experience in the development of spoofing and jamming detection and mitigation solutions at receiver level, using different solutions such as integrating the GNSS receiver with inertial sensors, Receiver Autonomous Integrity Monitoring (RAIM) solutions, trusted clocks, signal of opportunities (e.g. use of scatterometry), etc.

Qascom

2.5.7
The Near Future

With a view to encouraging GNSS receiver manufacturers to adopt Galileo - the latest global system to be declared operational in 2016 with the opening of the "Initial Services" phase - the EU is focusing on what are called "**Galileo Differentiators**", i.e. innovative services that are enabled by specific features of the Galileo signals:

- the authentication of the message transmitted by the Galileo satellites using cryptographic techniques - **OSNMA** (**Open Service Navigation Message Authentication**);
- the enabling of highly accurate positioning - **HAS** (**High Accuracy Service**);
- the **Search and Rescue** service (**SAR**).

These innovative services are at different stages of development: for OSNMA, a public testing phase conducive to making the service available began in November 2021, HAS is still in a prototype phase and **SAR** was declared operational in 2020 and since then, geographical coverage has been gradually extended.

With reference to OSNMA, within the scope of the H2020 programme, EUSPA has financed a number of projects to validate the use of this signal in various fields. The forefather of these projects was GIANO, led by **Thales Alenia Space Italia**, which ended in early 2021 with the development of a new version of the TASI timing receiver enabled to receive the OSNMA signal. The PATROL project, led by **Qascom**, focuses on the development of a tachograph designed for the automotive/road segment. It uses the OSNMA signal to provide position authentication. **Fondazione LINKS** is leading the **ROOT** project, which studies the benefits of using OSNMA for the synchronisation of 5G telecommunications networks.

The whole of the Italian aerospace ecosystem, both institutional bodies and private organisations, is actively engaged in the research and development of applications that are able to exploit Galileo's **PRS** (**Public Regulated Service**) signal.
The PRS is a high-performance signal that is resilient to natural and intentional interference such as **jamming**, **spoofing** and **meaconing**.
The PRS will only be accessible to institutional users and is designed for regulated uses such as emergency management and public safety services. Italy's PRS-related activities focus on the development of high-performance receivers and involve the industry's major companies, Telespazio, Leonardo and Thales Alenia Space Italy. ASI acts as the contracting authority for the **Galileo and GPS dual constellation receiver** project, in collaboration with the **Galileo National PRS Authority**, which is managed by the Prime Minister's Office through the Office of the Military Advisor, in compliance with the Programme Agreement signed with the Prime Minister's Office and the Ministry of Universities and Research.

Another area that has grown in importance since the US and EU announced their intention to return to the Moon is the study of possible positioning and navigation solutions to be used on its surface. The Lunar **GNSS Receiver Experiment** (**LuGRE**) involves **Qascom** and is the result of an agreement between ASI and NASA within the scope of the ARTEMIS multi-agency programme for the colonisation of the Moon.

LuGRE will develop a GPS/Galileo receiver capable of using satellite navigation signals sent to Earth for **navigation and positioning activities on the Moon's surface**. The receiver will be positioned in the Mare Crisium region of the Moon in 2023, on a lunar vehicle launched in 2022 as part of the CLPS 19-D mission.
Qascom is one of the first companies to propose a satellite receiver capable of operating on the lunar surface by exploiting signals received from GNSS satellites orbiting the Earth, in an extremely complex environment and with extreme reference parameters. The great advantage of this solution is that it exploits an existing space infrastructure that is already fully operational without the need to build a new one specifically for the Moon, thus achieving cost savings.

Qascom and ASI to land Italy and Galileo to the Moon for the first time

Service / Product	Description	Application area	Company
Remote monitoring stations (RIMS)	Design, positioning and management of RIMS for augmentation services (Satellite Based Augmentation Systems - SBAS)	**GNSS augmentation services at local level**	**Thales Alenia Space Italia**
Set-up of Timing Facilities	Design, testing and implementation of hardware (atomic clocks) and software to set up timing facilities for satellite navigation systems	**Hardware and Software dedicated to Time Facilities**	**Thales Alenia Space Italia, INRIM, Politecnico di Torino, ALTEC**
Teleport facilities	Teleport services for managing satellite constellations	**Management of GNSS constellations**	**Telespazio, SpaceOpal**
In Orbit Validation (IOV) Full Operational Capability (FOC)	Services for integration and testing of satellite components and payloads dedicated to satellite navigation	**Satellite integration and testing for GNSS applications**	**Thales Alenia Space Italia**

Service / Product	Description	Application area	Company
Design of GNSS satellites	Design, integration and construction of satellites for GNSS constellations	**Construction of satellites with satellite navigation payloads**	**Thales Alenia Space Italia**
Atomic clocks	Design and construction of atomic clocks using Passive Hydrogen Maser (PHM) technology	**Components for timing applications**	**Leonardo, INRIM**
GNSS Software Defined Radio (SDR) receivers	Design and construction of highly-reconfigurable and adaptable GNSS s oftware-defined receivers	**Prototyping of GNSS-based solutions**	**Qascom, Fondazione LINKS**
Simulators of GNSS signals and signal interference	Design and development of software systems to simulate GNSS satellite signals and signal interference	**Prototyping of GNSS-based solutions**	**Qascom**

2.6 Earth Observation

Earth Observation (EO) encompasses all applications that use orbiting satellites to collect data about our planet. This type of observation has become an indispensable tool in many sectors for analysing the Earth's physical, chemical and biological systems. The sector was initially born to meet military and security needs and then evolved to expand into other areas.

According to the Geospatial Industry Outlook and Readiness Index - GeoBuiz Report cited by the European Space Agency, the value of the Earth Observation industry as a whole reached 58 billion dollars in 2019.
The Industry Survey 2021 of the **European Association of Remote Sensing Companies** (**EARSC**) highlights that the European industry is characterised by small and medium-sized enterprises: 70% with less than 10 employees and 93% with less than fifty.
Italy ranks fifth in Europe by number of EO service companies, and fourth by number of employees.

European Association of Remote Sensing Companies – EARSC

According to the EUSPA EO and GNSS Market Report of the **European Space Programme Agency** (**EUSPA**), revenues from the sale and marketing of advanced Earth Observation data and services, i.e. the downstream sector, are set to increase from 2.8 billion euro in 2021 to 5.5 billion euro in 2031.
The global data-related market is expected to grow steadily, at a CAGR of 3.5 per cent, with revenues forecast to reach approximately 800 million euro in 2031.
The market for advanced Earth Observation services is expected to see even higher growth, with an expected CAGR of 6.8 per cent and a projected turnover of about 4.7 billion euro by 2031.

EUSPA – EU Agency for the Space Programme

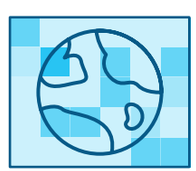
It is important to note that the global market is still driven by the upstream segment, i.e. the part related to the construction, launch, operation and maintenance of EO satellites and constellations. This segment accounts for about 70% of total revenues. The role of governmental, military or emergency management applications is still predominant and accounts for between 50% and 60% of revenues.

2.6.1 Earth observation payloads

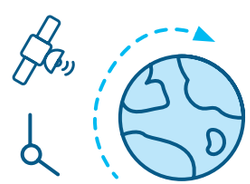
The satellites used in this sector are positioned on different orbits and carry **remote sensing payloads** mainly from two macro-categories: **optical and thermal sensors** operating in the visible to infrared wavelengths of the electromagnetic spectrum, and **radar sensors** monitoring the lower part of the electromagnetic spectrum.
The three key parameters for these sensors are **spatial resolution** expressed in pixels, **temporal resolution**, which measures the frequency at which a satellite can return to fly over a defined geographical area again, and the **swath**, i.e. the width of the area that the sensors can examine.

Imaging technologies have advanced considerably over the years.
The first meteorological satellites were equipped with **passive optical imaging systems** that provided better spatial resolution but were unable to capture images in the conditions of cloud cover. The development of **radar and hyperspectral systems** makes it possible to capture and analyse images from beyond the band of light visible to the naked eye, including therefore in overcast conditions.
The spatial resolution of sensors is one of the areas where technology is advancing more rapidly. Satellites with payloads that allow high resolution (between 1 and 10 metres per pixel) and very high resolution (less than 1 metre per pixel) are becoming increasingly common, even in the commercial sector.

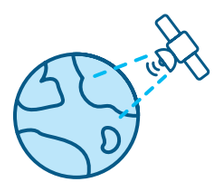
Key parameters for capturing a satellite image



Spatial resolution
Resolution in pixels of the scanned image

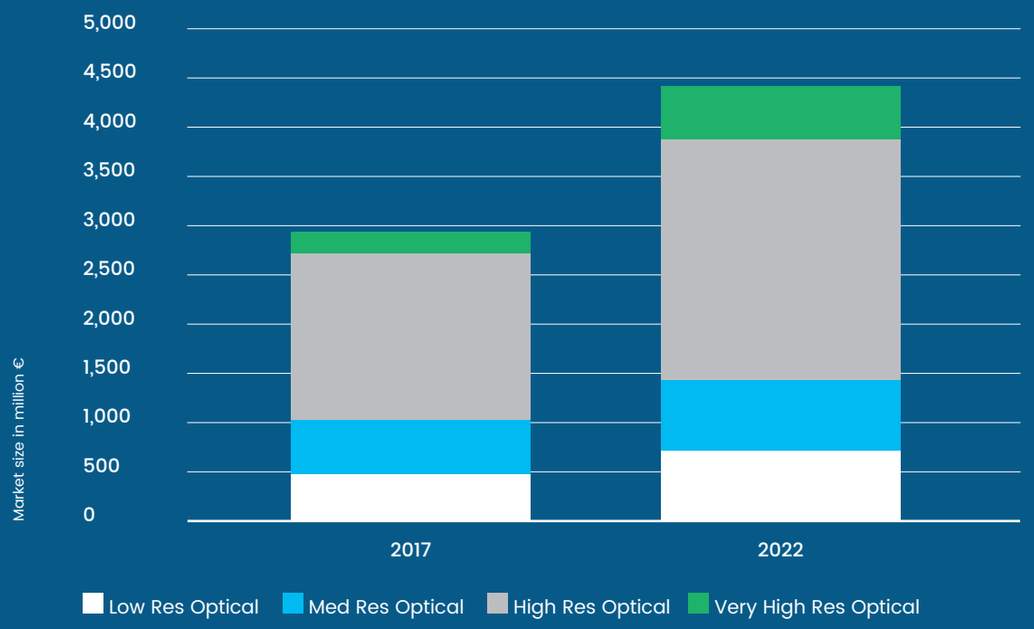


Temporal resolution
Frequency at which a satellite collect data of the same location

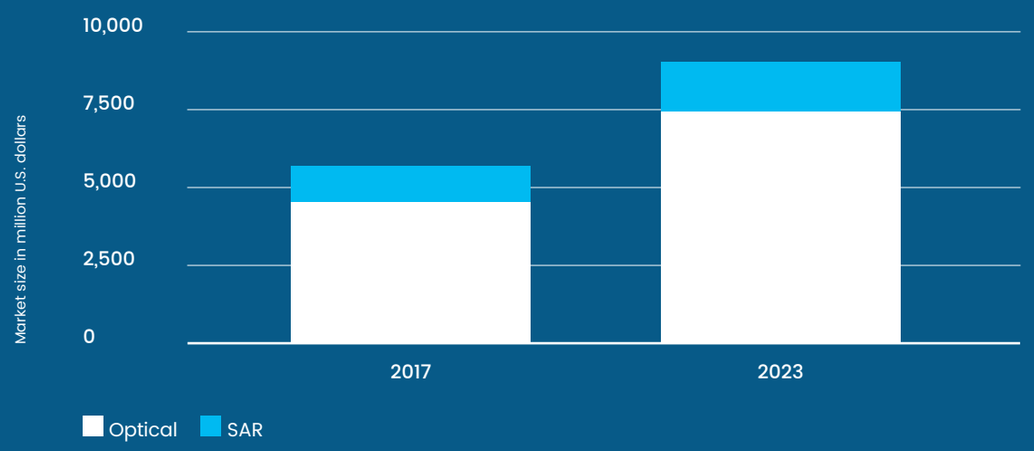


The Swath
Width of the area visible to the sensor

EO Optical market by resolution 2017-2022
Source: "Copernicus Market Report 2019 by PwC"



Size of the global EO satellite data and service markets in 2017 and 2023, by technology
Source: Statista



From the perspective of technologies used for Earth Observation, optical sensors have always played a leading role. This applies also in the field of EO data utilisation, where the majority of the industry will continue to exploit data generated by optical sensor-based systems.

Earth observation is now considered an enabling technology for many other technologies and industries (see Chapter 3):

- Monitoring of coastlines and oceans, their level and characteristics;
- Monitoring air quality and composition, in particular, the monitoring of pollutant gases and greenhouse gases;
- Meteorology and weather forecasting services;
- Monitoring of water resources;
- Monitoring the Earth's crust and its movements;
- Land monitoring and land use from the standpoint of agriculture/forestry, pollution mitigation and soil consumption;
- Services related to emergency management.

The market is experiencing a period of rapid development due to the emergence of constellations of **nanosatellites** (see Chapter 2.3) with payloads dedicated to EO. Thanks to this innovation, **wholly private enterprises** are now appearing on the market for the first time.

2.6.2 The European Earth Observation System, Copernicus

Italy has a leading role in this specific sector, as it is involved in the implementation and management of the European Union's Earth Observation system - the Copernicus constellation.

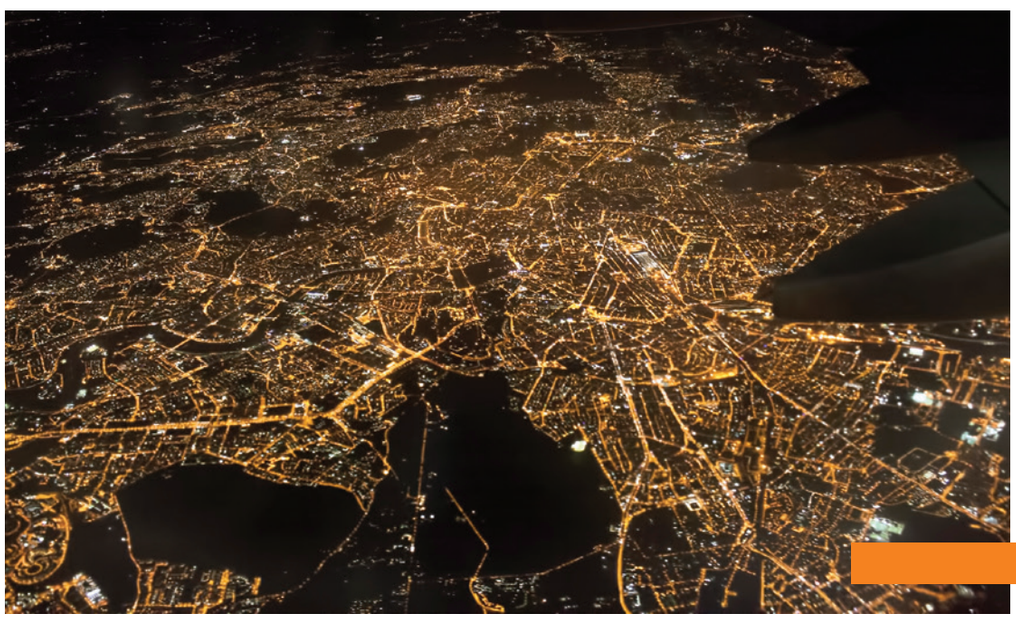
Copernicus is a constellation made up of pairs of satellites, each with a specific feature, and is managed by the European Space Agency.
Italy is the second largest contributor to this constellation.
The first three pairs of satellites, called **Sentinels**, were launched between 2014 and 2018. The Sentinel-1 satellites are equipped with an **interferometric radar**. The Sentinel-2 satellites have an optical-type payload designed to provide **multispectral data**. The last pair, Sentinel-3, was specifically designed to monitor the planet's crust and oceans, including vegetation monitoring.

The Sentinel 1A and 1B pair was built by **Thales Alenia Space Italia**, which engineered and assembled the satellites. Thales Alenia also designed one of the most innovative components, the **C-band synthetic aperture radar**. Thales Alenia Space Italia, in collaboration with **Leonardo**, is also developing the second generation of Sentinel 1, the twin Sentinel 1C and 1D satellites. The use of the C-band synthetic aperture radar represents one of the strengths of the Italian aerospace system.

Copernicus

The **Italian Institute of Geophysics and Technology** (**INGV**) is one of the main users of this technology, which enables land monitoring in all weather conditions. The data collected can be used to create **digital elevation models** (**DEMs**) and **ground deformation maps**. INGV is specialised in the implementation of advanced **multi-temporal interferometry** techniques, which enable the reconstruction of the temporal evolution of all the displacements affecting a given geographical area, even following natural events such as earthquakes or extreme weather events.

Aerial view of Rome by night



Within the Copernicus project, in 2020 Thales Alenia Space Italia secured contracts for the **ROSE-L mission** and the **CIMR** (**Copernicus Imaging Microwave Radiometer**) **mission**, the latter in collaboration with **OHB Italia**. **Leonardo** will instead build the hyperspectral observation instrument for the **CHIME** (**Copernicus Hyperspectral Imaging**) **mission**. The optical payload made in Italy will be able to analyse the unique spectral signature of a variety of substances, allowing the analysis of key parameters such as air pollution, water transparency or the health of certain types of vegetation. **Sitael**, a leader in the field of small satellites, electric propulsion and satellite electronics, will manufacture the Instrument Power Unit (IPU) of the hyperspectral instrument.

2.6.3 Cosmo-SkyMed and PRISMA: Italian excellence

Italy is one of the few countries in the world to have a constellation of Earth observation satellites: Cosmo-SkyMed.
Cosmo-SkyMed (**COnstellation of small Satellites for Mediterranean basin Observation**) is an Italian-controlled dual-use (civil and military) satellite constellation developed and operated by the Italian Space Agency and the Italian Ministry of Defence.

The main feature of the four satellites that make up the first generation is the presence of a high-definition X-band, multi-resolution, multi-polarisation Synthetic Aperture Radar (SAR), capable of producing 1,800 images per day per satellite.

The Cosmo-SkyMed constellation is positioned in low Earth orbit (LEO). The first generation was launched between 2007 and 2010. The first satellite of the second generation (CSG) was launched in 2019 and a second satellite was launched in 2022. The CSG will have of a total of four satellites capable of providing data with higher resolution compared to the first series.
Thales Alenia Space Italia has been tasked with the construction of the four CSG satellites. The marketing of the data generated by the Cosmo-SkyMed constellation is managed by **e-GEOS**, a joint venture between Telespazio (80%) and ASI (20%). E-Geos collects and processes satellite data at the **Matera Space Centre**. The company is building a global network of Commercial Ground Stations so as to be able to acquire constellation data more rapidly.

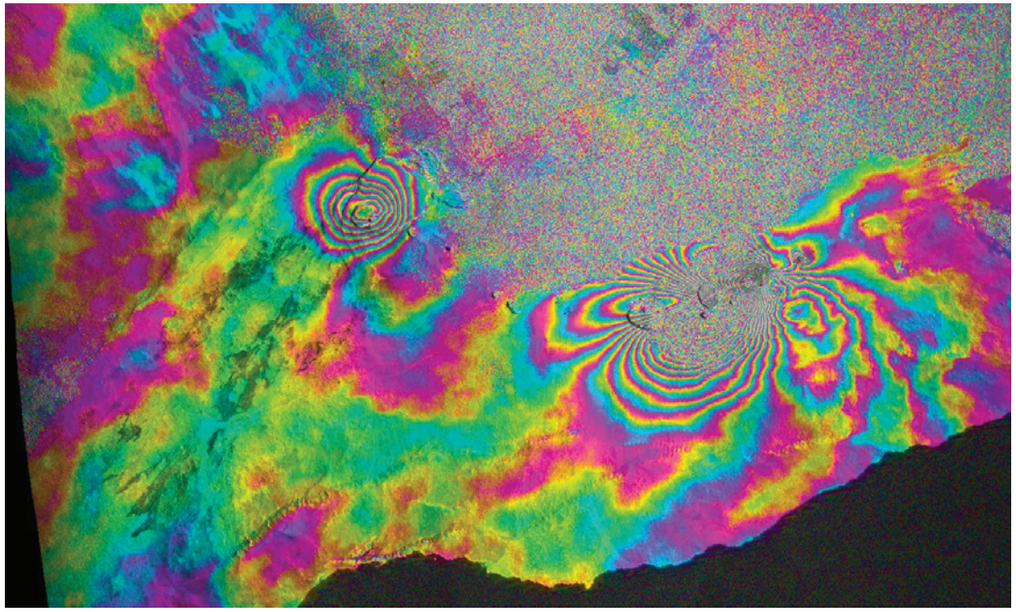
Geo-information services offered to the market include:

- high definition land monitoring (terrain and landslide analysis, thematic mapping for city management, precision agriculture, cultural heritage),
- rush mapping to support natural disaster management,
- implementation of technology platforms dedicated to defence and intelligence services (braINT),
- monitoring of oil leaks in Near Real Time,
- platforms (SEonSE) for maritime surveillance and ship localisation services,
- Inherent Defect Insurance (IDI).

In 2019, ASI launched the **PRISMA** (**PRecursore IperSpettrale della Missione Applicativa**) satellite into LEO orbit on a VEGA launcher.
The new satellite completes Italy's Earth Observation capabilities with high-definition electro-optical instruments that can integrate SAR data generated by the Cosmo-SkyMed system. The payload is able to identify the **spectral signature** and thus, the **chemical and physical composition of the Earth's surface**.
PRISMA mounts a hyperspectral sensor capable of acquiring multispectral images in 240 total bands: VNIR - Visible and Near-InfraRed (#66, 400 1010 nm) and SWIR - Short-Wave InfraRed (#174, 920 2505 nm). The satellite also uses a panchromatic camera with a medium spatial resolution of 5 metres. The PRISMA system is able to analyse an area of 200,000 square kilometres per day. In an initial phase, **all data generated by PRISMA will be available free of charge and in quasi-open data mode**. The satellite was built by OHB Italia and Leonardo. Data management is via the ASI Space Geodesy Centre in Matera.

ASI, ESA and large companies take a leading role in the Earth Observation segment of the Italian aerospace industry, with strong focus on upstream activities. This approach is favoured by the dual civilian-military use of the Cosmo-SkyMed constellation. However, the processing and use of data generated by EO satellites have become enabling technologies for many downstream industrial sectors, from construction to infrastructure maintenance, logistics and land protection.

Interferogram made with a constellation of COSMO-SkyMed radar satellites of the Italian Space Agency (ASI) above Kilauea, Hawaii, which shows the Earth's deformation after an eruption on March 5, 2011
Source: NASA



2.6.4 Artificial Intelligence and Earth Observation

The large amount of data collected from satellites and EO constellations is giving great impetus to the development of data processing applications based on **machine learning and artificial intelligence** (**AI**).
Latitudo 40 has developed a platform that automates the processing of the images produced using artificial intelligence and machine learning algorithms. The start-up's acquisition engine receives and analyses data from multiple sources: institutional, such as Copernicus or private, such as Planet and Capella Space.
Deep learning and computer vision algorithms make it possible to identify the features requested by the customer in the images being processed. The system has a modular structure based on the use of AI Bricks, each specialising in the analysis of a specific detail.
The system can currently classify:

- objects such as buildings, swimming pools and different types of vegetation;
- land use (agricultural use, forest areas, developed plots, etc.);
- CO2 emissions;
- heat bubbles in urban areas;
- areas of coastal erosion.

The Latitudo 40 solution enables the monitoring of specific areas to identify changes over a given period of time. This "**change detection**" is used in agriculture and for urban planning.

Latitudo 40

Planetek (see Chapter 3.3) is active in the field of Earth observation data management and integration.
The company specialises in land monitoring software and geoinformation services, supplied to customers via cloud.
The Rheticus platform accesses open EO maps and satellite data, including those obtained from Copernicus, to monitor infrastructure, land and agricultural areas.
The Preciso solution, on the other hand, is designed to provide thematic maps and geospatial indicators that are useful in urban planning or to monitor vulnerable areas of the Earth's surface, such as those susceptible to landslides or coastal erosion.
Planetek has developed a hardware platform to increase the capability of satellites to process EO data. The On-board Payload Data Processing (OPDP) capabilities and the framework for developing such capabilities, called the **Space Payload Data Processing system (spacePDP)**, were developed in collaboration with SITAEL and GEO-K. In fact, for many satellites, the ability to send and receive data to/from ground stations is a structural limitation. Thanks to this innovative approach, the satellite is able to process more data on-board, thus reducing the amount of information that needs to be sent to the ground.

Planetek Italia

2.6.5 The Near Future

The Earth Observation sector is experiencing a major acceleration due to the increasing availability of data from different sources. Two trends stand out clearly:

- The lower cost of access to low Earth orbit (see Chapter 2.1) coupled with the possibility of building small, high-performance satellites (see Chapter 2.3) is making it increasingly easier for new players to enter this market.
- The abundance of big data has triggered the need to develop data management solutions, including those with real time capabilities. An interesting role can be played by quantum computing, which is able to dramatically speed up the post-processing of satellite and SAR radar images thanks to its high-performance computing capabilities (see Chapters 3.2 and 3.3). Among the companies active in this sector, **PLANETEK** is working on the implementation of High-Performance Computing (HPC) platforms and the use of quantum technologies for data processing.

The Italian ecosystem is being strengthened by launches of the second generation of the Cosmo Sky-Med constellation. The satellites of this new generation increase the flexibility of use even in the strategic military sphere where knowledge of the territory is a factor of primary importance. The launches will end in 2025, with the launch of the fourth new-generation satellite in orbit. The complete constellation will make it possible to offer very high resolution imagery for both institutional and private users.

In December 2021, the Italian government, in collaboration with the Italian Space Agency and the European Space Agency, announced that part of the Italian National Recovery and Resilience Plan funds allocated to the space segment will be invested in the creation of a constellation of small satellites dedicated to Earth observation. The investment will amount to around 900 million euro. From the outset, the new Italian-controlled constellation has been designed to complement the European constellation Copernicus. In May 2022, Samantha Cristoforetti, the Italian astronaut of the European Space Agency announced live from the International Space Station (ISS) that the new Italian EO constellation would be called IRIDE - a name chosen by Italian students through a national competition.

Service / Product	Description	Application area	Company
C-band synthetic aperture radar	Radar designed to obtain high-definition images of the Earth's surface even in conditions of thick cloud and heavy rainfall	**Payloads for EO satellites**	**Thales Alenia Space Italia, Leonardo,**
EO payloads with higher computing capacity	Payloads dedicated to EO satellites, able to guarantee higher-performance computing and to reduce data flows to/from ground stations	**Payloads for EO satellites**	**PLanetek**
Hyperspectral optical payloads	Payload to identify the spectral signature and thus, the chemical and physical composition of the Earth's surface	**Payloads for EO satellites**	**Leonardo, OHB Italia**
EO satellite data	Provision of Earth observation data from the Cosmo-SkyMed constellation and the PRISMA satellite: • high definition land monitoring (terrain and landslide analysis, precision agriculture, etc.); • rush mapping to support natural disaster management; • platforms dedicated to defence and intelligence services (braINT); • monitoring of oil leaks in Near Real Time; • platforms (SEonSE) for maritime surveillance and ship localisation services; • Inherent Defect Insurance (IDI).	**Geoinformation services**	**e-GEOS, Centro ASI di Matera**

Service / Product	Description	Application area	Company
Ground deformation monitoring models	Digital elevation models and ground deformation maps for multi-temporal analysis	**Land monitoring**	**Istituto Nazionale di Geofisica e Vulcanologia**
Change detection software solutions	EO data analysis software to detect changes over time in specific areas, such as agricultural areas and, in particular, vulnerable areas such as the coastline	**EO data analysis**	**Latitudo 40**
Geoinformation software and services	Software platform for the analysis of EO satellite data using dedicated algorithms and Artificial Intelligence	**EO data analysis**	**Planetek, Latitudo 40**

03/

Target Industries and Sectors

3.1 Agri-food

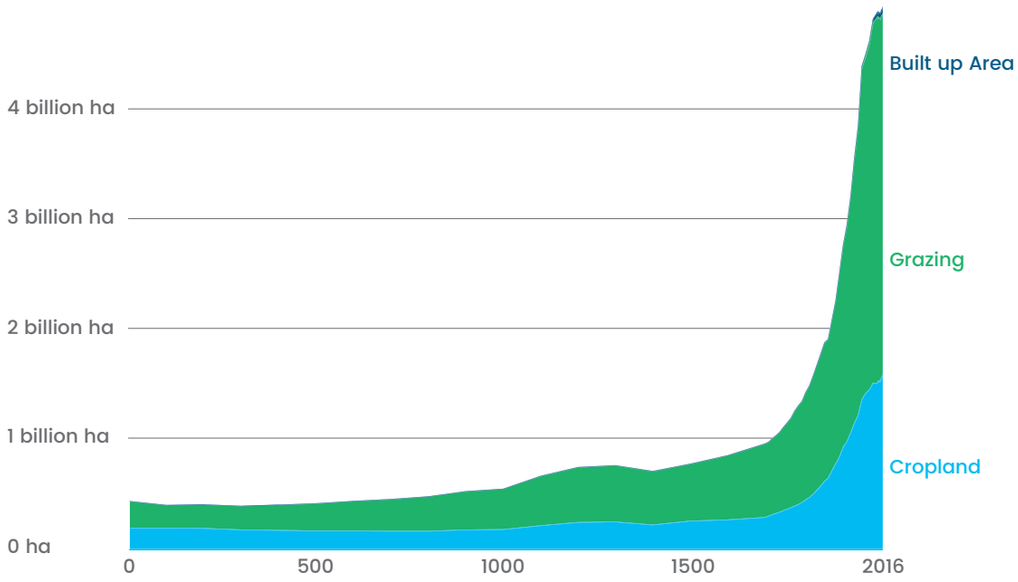
The agri-food sector is facing the dual challenge of an ever-growing global population and the limited availability of new land for crop and livestock production. The scarcity of water and other resources used in production, as well as the high environmental impact and low efficiency of traditional production methods are forcing the farming sector to take a technological leap - and this is where aerospace can play a strategic role.

OECD-FAO Agricultural Outlook 2021–2030

According to an OECD-FAO Report published in 2021, the global demand for agri-food products will continue to grow annually by more than 1% between 2021 and 2030.

This continuous rise in demand clashes with the increasing scarcity of new land for agricultural activities, which adds to other problems such as pollution and the desertification and urbanisation of existing agricultural land.
The **Intergovernmental Panel on Climate Change (IPCC)** estimates that in 2019, 500 million people were already living in areas affected by desertification. It is therefore essential to increase agricultural productivity to be able to sustainably feed a global population that is projected to hit the 8.5 billion mark by 2030.

Habitable land used for agri-food production (crops + livestock), in billions of hectares
Source: OurWorldInData - History Database of the Global Environment (HYDE) / CC BY



In addition to occupying around half of the planet's habitable land, in 2019 the agricultural sector was responsible for roughly 21% of all greenhouse gas emissions from human activities (the whole of food system was responsible for 25-30% of greenhouse gas emissions) and for 95% of particles of ammonia in the atmosphere. It also used 70% of global water resources.
The indiscriminate use of insecticides also threatens the survival of insects that play an important biological role, such as pollinators (bees and butterflies) and predators of phytophagous insects (ladybirds): it is estimated that almost half of the planet's insect species are in rapid decline.
Intensive agriculture is a contributing factor and, at the same time, a victim of environmental pollution, which reduces the yield of many crops due to lack of water, desertification and rising temperatures.

The introduction of new technology in the agricultural sector is crucial to ensure the sustainability of the entire industry.
Solutions enabled by aerospace innovation already play a major role: according to the Space Economy Observatory of the Politecnico di Milano university, more than 50% of start-ups have the agricultural sector as their target market.
For the processing chain, the introduction of new technology and innovations will make it possible, on the one hand, to improve aspects linked to food safety and, on the other, to significantly prolong the shelf-life of food.

There are five main areas where aerospace technology can be applied to AgriFood:
- Satellite monitoring for precision agriculture
- Satellite positioning for autonomous farm vehicles
- Developing crops that are more resistant to disease and adverse weather conditions
- Efficiency-enhancing technologies and soilless culture
- Improving food safety and security

3.1.1 Satellite monitoring systems for precision agriculture

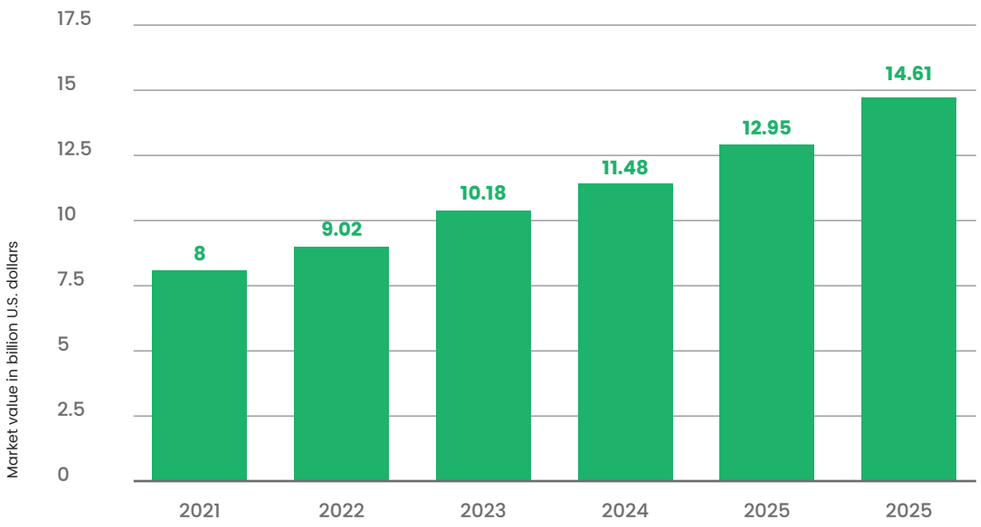
Earth observations plays a major role in generating analytical data to support the agricultural activities concerned with monitoring stress factors in crops.
In fact, the ever-increasing availability of high-performance satellites make it possible to implement remote sensing, i.e. the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (see Chapter 2.6 Earth Observation).

The processing of satellite images and data using Artificial Intelligence and Machine Learning technology makes it possible to feed systems with accurate weather forecasts and real-time alerts, and to monitor the effects of climate change and manage the associated risks (such as fires and floods).

These data also feed the tools used in **precision agriculture**, i.e. decision support systems that enable real-time monitoring of croplands and crop yield forecasting, optimising the use of resources and the environmental impact.
Satellite data can also be cross-checked with information obtained from ground-based sensors and/or sensors mounted on remotely-piloted or autonomous drones to produce highly detailed maps.
These processes make it possible to determine the actual water requirements of crops and plan the sustainable use of water for irrigation. It is estimated that the water saving effect of these solutions can be as much as 40-60 percent. It is also possible to simulate the quantity and type of pesticides the crops need, assess soil fertility and identify the most suitable crops based on the data collected.

There is still plenty of room for growth for this innovative sector: Statista estimates that its market value will increase from 8 billion dollars in 2021 to 14.61 billion dollars in 2026.
According to the Smart AgriFood Observatory of the Politecnico di Milano university, in Italy the percentage share of agricultural land managed according to the agriculture 4.0 method increased from 3-4% in 2020 to 6% in 2021. With regard to agriculture 4.0, which also includes precision agriculture, the Italian market is growing steadily, totalling 1.3 billion euro in 2020 and around 1.6 billion euro in 2021.

Forecasted market value of precision farming worldwide from 2019 to 2026
Source: Statista

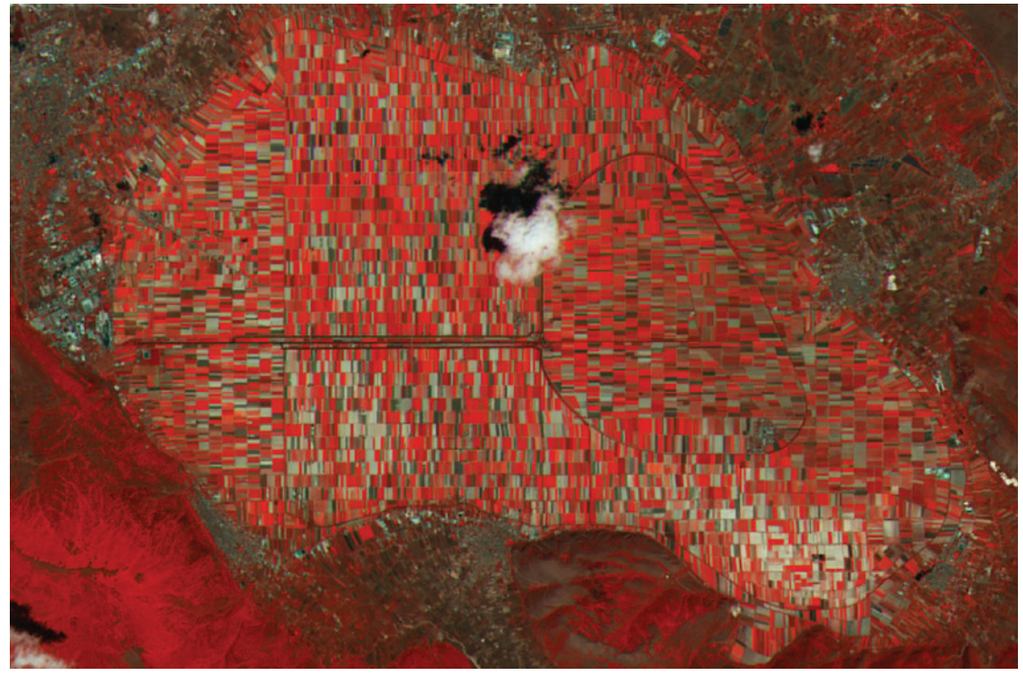


The European Earth Observation satellite system, **Copernicus** (see Chapter 2.6 Earth Observation) is the primary source of high-resolution images for the territory of the European Union.

Copernicus

Among the services offered by Copernicus, the **Land Monitoring Service** provides information on land cover and use and land cover changes over time and is widely used in the fields of agriculture and food safety.
The data provided by Copernicus can be used to assess land use intensity, crop conditions and projected yields.

Image taken by the Copernicus Sentinel satellite's multispectral camera, highlighting the differences in vegetation cover and chlorophyll content. This is used to provide key information on plant health (the brighter reds indicate more photosynthetically active vegetation)
Credit: ESA – CC BY-SA IGO 3.0



An Italian supplier of precision agriculture systems is **Elaisian**, which makes weather stations that collect data from sensors deployed in the monitored fields and successively cross-checks these with information extrapolated from the analysis of the satellite imagery from the Copernicus constellation.
A customised report is prepared for each analysed field to assess plant health, water stress and nutrient stress, thus enabling operators to intervene on a predictive basis. The Elaisian solution is already used to monitor olive groves, vineyards and orchards.

Elaisian

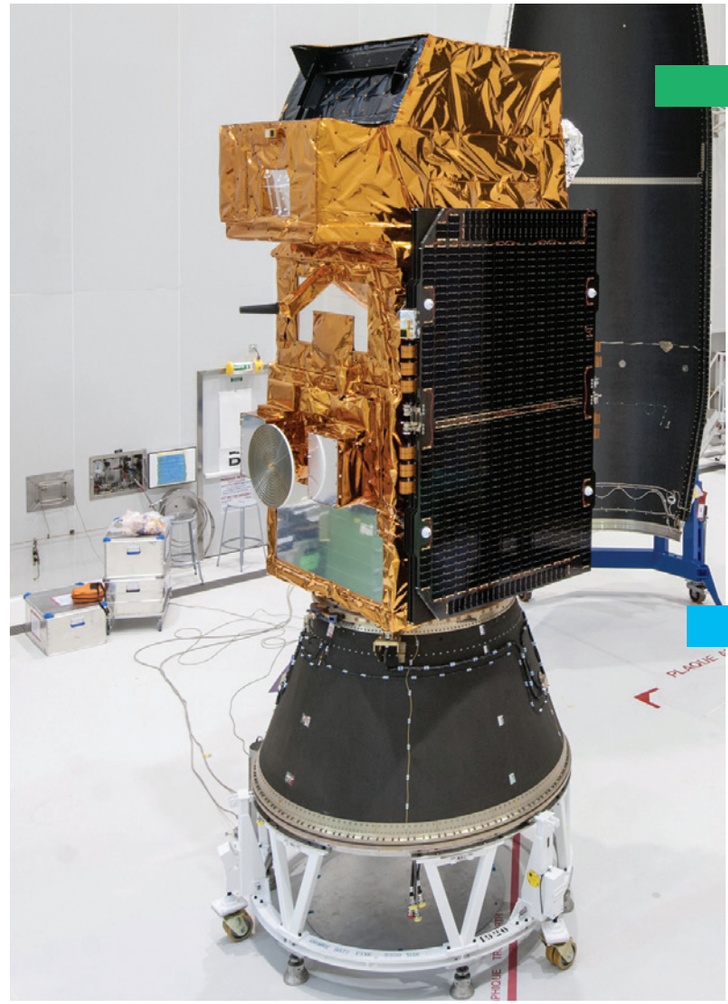
Another example of "Made in Italy" innovation is the Roman **SME OMICA**, which supplies smart crop management systems designed to increase productivity.
Collecting data from various measurement systems (sensors and up-to-date satellite images) on a single platform enables **Variable Rate Application**, i.e. the variable distribution of fertilisers, chemicals and seeds in croplands.

OMICA

The company **Agricolus** offers cloud applications for farmers and agronomists, to monitor the production process and support data-driven decisions.
Through the Copernicus Open Access Hub portal, Agricolus has access to Sentinel-2 satellite data and processes these to provide vegetation indices to end users. The integration of satellite imagery is done through the **DIAS** (Copernicus Data and Information Access Service) service of the ONDA consortium, backed by the European Commission and ESA. Satellite imagery is then cropped to field boundaries with the support of L3Harris Geospatial technologies. The Sentinel-2 bands are processed by Agricolus to calculate multiple indices of vigour, water stress and chlorophyll.
The company is also experimenting with the use of imagery from the Airbus Spot 6 and Pléiades satellite systems to obtain higher-resolution images: from 10 metres with Sentinel-2 to 1.5 metres with Airbus Spot and down to 50 centimetres with Pléiades.

Agricolus

Copernicus - Data and Information Access Services



Sentinel-2A Earth Observation satellite
Credit: ESA,
M. Pedoussaut, 2015 –
CC BY-SA IGO 3.0

Earth observation data can also benefit marine-based industries, particularly in the aquaculture sector.
The company **G-nous** has created **Fishalitycs**, a platform that uses AI to process data provided by the Copernicus Marine Environment Monitoring Service (CMEMS) and integrates these with data collected by IoT devices to implement precision aquaculture.

Fishalytics - Precision Aquaculture

This solution enables aquafarmers to optimise feed distribution, monitor sea conditions and key water indicators, such as nutrient content and temperatures, and plan activities to mitigate potential risks, reducing the environmental impact and optimising productivity.

In Italy there are also several initiatives dedicated to the analysis of big data provided by satellite systems

Among these, **E-Geos**, a joint venture between Telespazio (80%) and ASI (20%), has set up the land monitoring platform **Agri-Geo**, which analyses big data provided by the Copernicus and CosmoSkyMed constellations for use in agricultural and forestry management.
The system provides farmers with information on the health of each crop, i.e. their vigour relative to the crop's current growth stage: low vigour values may be due to a number of factors, e.g. the presence of pathogens, excess or deficiency of nutrients or water.
The platform's analysis capability also makes it possible to build a time series for each parcel of land in order to optimise the future use of resources.

The open source, free-to-use **Agrosat** platform, developed by CNR in collaboration with Istituto per la BioEconomia, combines digital technology, IoT and Big Data with products born out of scientific research to create a direct link between research, businesses and farmers.
Agrosat provides direct access to data obtained from the NASA and ESA/EUMETSAT platforms and uses these to estimate crop health with a view to maximising yields and optimising the use of water, pesticides and fertilisers.

AgroSat

3.1.2 Satellite positioning for autonomous farm vehicles

Geo-positioning technologies optimise the operations of agricultural vehicles using data provided by the **Galileo** satellite constellations and local Real time Kinematic (RTK) positioning systems, with accuracy down to a few centimetres.
Thanks to these technologies, the new automated sowing and weeding systems make it possible to minimize vehicle movement and know the exact position of each seed/plant, thus reducing the use of resources like fuel, fertilisers, herbicides and pesticides.

The **EarthAutomations** start-up is finalising the development of **Dood**, a rover equipped with a three-point hitch and PTO, capable of working both automatically and via wireless remote control. The culmination of several years of research and development, DooD incorporates satellite navigation to work the fields and is particularly suited for work in orchards and vineyards. EarthAutomations is one of the 10 start-ups selected for the "Bravo Innovation Hub Agrifood", an acceleration programme promoted by the Italian Ministry of Economic Development within the scope of national operational programme (PON) dedicated to Enterprises and Competition.

EarthAutomations

Developed from the idea of a rice farmer in Vercelli, the **MOONDINO** robot is able to carry out the mechanical weeding of rice paddies from the initial stages of rice cultivation.
Immediately after dry seeding, the robot is able to determine, with the help of high-precision satellites, where the rice has been sown, row after row, and consequently carry out its hoeing and tillage operations between the still hidden rows, thus controlling the weeds before they develop.
The start-up that developed MOONDINO - **Eco process & solutions** - is based in Lugano and has among its partners for the development of autonomous driving systems the company **ARVAtec**, founded by a group of researchers of the Department of Agricultural Engineering of the Università degli Studi di Milano.

MOONDINO

3.1.3 Technologies enabling the development of improved crops

Among the technologies linked to space exploration, of primary importance are those employed and developed to enable solutions that ensure the survival of humans during current and future long-term space mission, i.e. to feed astronauts. These technologies are known as "Space Farming".
The inhospitable conditions in space, coupled with the high cost of taking supplies into orbit, have pushed research towards the development of **bio-regenerative life-support systems**, which are indispensable for recycling scarce and valuable resources in a confined environment like a spacecraft or space station.
These efforts have led to the development of **speed-breeding technology**, already used by NASA to accelerate crop growth in space, which uses advanced LED technology to simulate intensive and prolonged day-long regimes of 22 hours so as to accelerate photosynthesis to achieve more rapid growth of crops.

Speed-breeding technology enables six harvests of wheat per year

This method can also be used to accelerate the breeding cycle of some staple crops, providing an alternative solution for improving non-GM crops. Speed-breeding enables six harvests of wheat per year (as opposed to two in traditional commercial crops), as well as the rapid and natural selection, through cross-breeding techniques, of plant varieties with optimal genetic traits for improved yield, drought resistance and adaptability in highly variable climatic conditions.

Based on this technology, the **Agroservice Group** has created a new isothermal complex consisting of 3 growth chambers, capable of speeding up the process of selecting and genetically improving plant varieties. The aim of the project is to identify new plant varieties with improved yield and quality and, at the same time, reduce operating costs.

Agroservice

3.1.4 Efficiency-enhancing technologies and soilless culture

Also on the topic of Space Farming, i.e. meeting the need for food in space, the project launched in 2020, led by ENEA, focusses on the development of a technological garden to grow micro-vegetables in orbit.
Funded by ASI, the module developed by **ENEA** as part of the Hortspace project consists of a 1 m^3 closed-loop, multi-level hydroponic cultivation system featuring LED lighting, water recycling and no use of pesticides or agrochemicals.
The project has enabled the development of an "ideotype", i.e. a type of plant with the ideal characteristics to adapt to the environment it is grown in.

HortSpace

#video
Un orto spaziale per la Terra

In addition to improving productivity for traditional field crops, the prospect of cultivating plants in transportable "soilless" modules opens up the potential to grow fresh produce anywhere: the possible applications include growing crops in extreme environments such as deserts, Arctic and Antarctic bases or harsh environments like military bases and contaminated or polluted areas, and growing fresh fruit and vegetables in inner city areas where they will be purchased and consumed.

The Italian start-up **BioPic** has developed a Space Farming system to grow vegetables using lamps designed specifically for this purpose.
This approach makes any corner within a structure suitable for growing plants. The solution relies on space-derived, energy-efficient LEDs to replace sunlight and uses certified organic seeds planted in special biodegradable medium, natural fertiliser organic activators to prevent disease and nanotechnology that releases nutrients in a controlled manner through soluble microspheres.
The company has also developed a new type of greenhouse for desert cultivation that reduces energy and water consumption by up to 90%.

BioPic

The Italian start-up **Serranova** employs luminescent powders derived from rare earths to accelerate plant growth. When applied to glass and shelves, the powders absorb any source of light and convert it to a spectrum between 400 and 700 nm to activate photosynthesis in a cost-effective and clean way. The key element of Serranova's system is the patented photoluminescence technology, which significantly reduces water and energy consumption: activating the LED lamps for one minute allows the rare earths to generate photoluminescence for a further 9 minutes. This increases speed of growth by 300%, while reducing energy and water consumption by 70% and 95% respectively. Thanks to this saving in resources, NASA has asked the start-up to evaluate the use of its greenhouses in space.

Serranova

3.1.5
Technology for improving food safety and security

Food safety standards and tools can be implemented today thanks to the challenges posed by space travel: in fact is was precisely the need to protect the health of astronauts that led to the development of the Hazard Analysis and Critical Control Points (HACCP) system in the 60s - a system that analyses and controls biological, chemical, and physical hazards across the entire food chain.
Food safety is still a topical issue today but with the added complexity of the prolonged duration of space missions, which on the one hand extends the procurement times associated with supplies and, on the other, poses additional concerns for the physical and mental health of astronauts.

With these limitations, the nutritional aspect of space missions was dealt with in an essential manner, being concerned only with providing astronauts with the indispensable nutritional values in the form of pills or dehydrated food, without considering taste and enjoyment.
To adequately support the physical and mental well-being of astronauts, since 2007 the Italian company **Sudalimenti**, owner of the Tiberino brand, has been preparing meals for astronauts based on traditional Italian recipes, the aim being to evoke the flavours of their homeland and make them feel a bond with planet Earth. The meals are packaged in sterilised and sealed thermal packaging following heat treatment that reduces the water content to 10-15%. This extends the life of the meals without using preservatives or colouring agents and ensures that the food is completely safe to eat. Born out of the company's experience making products for space missions, the OUTFOOD range of Tiberino 1888 is a line of ready-to-eat meals for lovers of the outdoors and all those activities that require simple, hearty food that is quick and easy to prepare.

Sudalimenta

The human diet in space has long been the subject of study given that the extreme environmental conditions make it particularly challenging to prepare and eat meals, which must nevertheless provide all the necessary nutrients to enable astronauts to work at their best. In zero gravity conditions, the production of bone cells is significantly reduced and the perception of taste (both sweet and salty) is amplified to a point that the production and preservation methods used for some types of foods need to be modified. The research and studies conducted to overcome these problems have identified techniques and treatments to preserve food without compromising its nutritional value.

The Italian start-up **EAT Freedom**, founded in 2021, applies the knowledge gained from research in space to produce ready-to-eat and dehydrated meals for lovers of sport and adventure seekers, using superior quality and highly nutritious ingredients. Some of these meals will be added to astronauts' diet and consumed at the International Space Station.

EAT Freedom

3.1.6
The Near Future

Food and the cultivation of food are central to man's presence in space and the exploration of space. The **Artemis** project, which aims to land humans on the moon by 2025 and represents the next step towards the long-term goal of establishing a self-sufficient presence on the Moon, needs to find effective solutions to ensure the availability of food for astronauts. Today there are many projects aimed at identifying new tools and technologies to make space outposts more self-sufficient and providing capability to meet complex nutrition needs across longer periods of human presence.
The solutions identified to respond to the extreme conditions in space and during the Artemis mission can also meet the growing demand for agricultural products on Earth and ensure that this demand is efficiently and cost-effectively satisfied even in adverse growing environments such as big cities or remote areas like the Antarctica or deserts, and populated areas prone to desertification. Not only that, these same solutions can be a response to the extreme droughts that are becoming ever more frequent in the European continent, where there is a growing need to make more rational use of water resources and reduce pollution from agricultural activities.
In the field of agriculture, scientific studies by various experts (including the Italian researcher Valentina Sumini, winner of the **Nasa Big Idea Challenge**) indicate that integrated systems of hydroponic, aeroponic and aquaponic greenhouses are of fundamental importance in ensuring the in-situ production of all the food resources needed to support human space missions, and in terms of maximising the use of resources (on Earth also).

Nasa Big Idea Challenge

With several linked projects, the research and experiments carried out by **ENEA** have been particularly fruitful. Its innovations combine technological solutions for use in confined spaces with standardised processes and automated systems, while meeting quality and safety requirements at the same time. These solutions have to ensure the absence of any pollutants that could potentially harm astronauts, both in the production of fresh food and in the resource recycling processes. To name a few of these projects:

- The REBUS project to develop bio-regenerative life support systems based on the integration of organisms like plants, fungi, bacteria and cyanobacteria, in such a way as to maximise the use of available resources and, at the same time, minimise the use of external resources by recycling the organic matter produced (food, plant and physiological waste).
- The SOLE project to develop a cultivation chamber for use in space, with LED lighting able to enhance the nutraceutical properties of the micro-vegetables grown. Using a demonstrator for the soilless cultivation of plants using artificial solid-state lighting (LED), the project will investigate the best light combinations in terms of duration, intensity and spectral quality, optimised for the different phases of plant growth. The demonstrator will be equipped with non-destructive analysis systems to monitor the growth and health status of the plants in real time, even remotely, automating the data collection and analysis process and making it possible to carefully evaluate the resources needed to produce certain quantities of fresh food, thus reducing operating times.
- The IDROZAFF project, a demonstrator for the cultivation of plants that are used to produce natural or recombinant molecules of pharmaceutical interest, is working on the cultivation of pharma-grade saffron (i.e. of pharmacological quality and purity) to be used in a formulation to treat age-related macular degeneration.

Among the other important projects, in 2019 the Department of Agriculture of the Università degli Studi di Napoli Federico II set up the first laboratory in Europe dedicated to the characterisation of plants for regenerative life support systems. The laboratory stems from a collaboration with the ESA within the scope of the **MELiSSA** (Micro-Ecological Life Support System Alternative) programme.
The MELiSSA research programme focusses on closed-loop life support systems, with an ecosystem-based approach. The aim of the programme is to carry out research into the development of circular economy-based food production systems and technologies and the findings are then utilised by the **Melissa Foundation**.
The ideas developed by the MELiSSA programme have several practical applications on Earth: among the main ones is the cultivation and introduction of Spirulina (a protein-rich algae) into the diets of people in equatorial African countries to supplement the local diet, which traditionally lacks certain essential nutrients.
Another application concerns the reduction of water consumption at industrial food processing plants, thanks to new space-derived recycling techniques that use a system of membranes and photo-bioreactors purify waste water for re-use.

Melissa Foundation

Experiments have been conducted on the ISS to make meat using 3D printing

Besides growing traditional crops in space, experiments have also been conducted on the ISS to make meat using a 3D printer capable of processing biological material.
This has also made it possible to examine the effect of microgravity on the proliferation and differentiation of cells in the production of cell-cultured meat. Cell proliferation and differentiation serve as the basis for all muscle tissue formation. Therefore, understanding what impact weightlessness has on these two processes is essential to be able to standardise the production of cultured meat in space.

Other projects focussed on the biological 3D printing of foods studied innovative pasta shapes, such as the futuristic pasta spheres with the accompanying seasoning, sauce, pesto and cream inside to avoid spillages on space suits or sensitive orbital equipment in absence of gravity. In addition to use in space, 3D food printing solutions can also help solve the problem of world hunger in different ways: for example, by avoiding food waste and improving the efficiency of food production, or integrating proteins from widely available sources, such as insects, in a form more acceptable to the Western world.

Food in space is also the theme of the **Deep Space Food Challenge** launched by NASA and, in parallel, by the Canadian Space Agency in cooperation with the Methuselah Foundation, which rewards the best scoring international projects.
Teams are invited to create novel food production technologies and systems that require minimal inputs and maximize the output of safe, nutritious, and palatable food for long-duration space missions, with the potential to improve production processes and benefit people on Earth.

Deep Space Food Challenge

Among the many ideas submitted, from methods for turning microalgae into crispy snacks to a space-based bread maker, one of the prize winners was the Italian initiative **Chloe NanoClima**, presented by the company **JPWorks**. The submission proposes an innovative method for growing nanoplants and microgreens in single, autonomous and contamination-proof ecosystems, thus optimising resources and production times to provide the safest, quickest-growing and most nutritious plant-based superfoods.
This idea also could have numerous applications on Earth, from human nutrition in deprived areas to sports nutrition, as well as to feed military personnel.

JPWorks

Service / Product	Description	Application area	Company
Agro-meteorological station	Weather stations with sensors deployed in the monitored fields, cross-checked with information extrapolated from the analysis of the satellite images	**Satellite monitoring systems for precision agriculture**	**Elaisan**
Omica Farm	Prescription maps and geo-referenced alerts via satellite imagery to support strategies to improve productivity and reduce the usage of resources	**Satellite monitoring systems for precision agriculture**	**OMICA**
Fishalitycs	Platform that uses satellite and marine technology to process data in order to implement precision aquaculture	**Satellite monitoring systems for precision aquaculture**	**G-nous**
Agricolus Observa	Satellite data processing to provide vegetation indices	**Satellite monitoring systems for precision agriculture**	**Agricolus**
Dood	Autonomous rover for orchards and vineyards	**Satellite positioning for autonomous farm vehicles**	**EarthAutomations**
MOONDINO	Autonomous robot for mechanical weeding	**Satellite positioning for autonomous farm vehicles**	**Eco process & solutions**

Service / Product	Description	Application area	Company
ISEA	Creating new crops through the accelerated genetic improvement of plant varieties	**Technologies for more efficient use of resources in agriculture and/or soilless culture**	**Agroservice**
Indoor Gourmet vegetable garden	Special lamps and innovative processes to reduce agricultural waste	**Technologies for more efficient use of resources in agriculture and/or soilless culture**	**BioPic**
SerraMID	Use of luminescent powders derived from rare earths to accelerate plant growth.	**Technologies for more efficient use of resources in agriculture and/or soilless culture**	**Serranova**
Tiberino 1888 OUTFOOD	Ready-to-eat meals for lovers of the outdoors that require simple, hearty food that is quick and easy to prepare.	**Technology for improving food safety and security**	**Sudalimenta**
EAT Freedom	Production of superior quality and highly nutritious long-life ready meals for lovers of sport and adventure seekers.	**Technology for improving food safety and security**	**EAT Freedom**

3.2 Energy, Environment and Infrastructure

The use of space technology to monitor the Earth's service, the atmosphere and the impact of human activity is revolutionising the way we plan and manage buildings, infrastructure, natural areas and areas of historical and artistic interest. Satellite technologies have the advantage of being able to cover huge expanses of land in a very short time, with increasing accuracy and cost savings over time thanks to the improvements in sensor capabilities and the lower cost of satellite launches.

For the energy, environment and infrastructure sectors, each with their different specificities, the availability of information on a large scale and at regular intervals, to support current and medium, long and very long term decision-making choices of managers and public bodies, is of strategic importance, especially in a context like the current one where energy efficiency and the need to ensure environmentally sustainable socio-economic development are crucial.
Monitoring the Earth's surface is also essential to ensure that environmental assets are being properly managed. For example, the way land is used has a strong impact of the amount of carbon that soil can store.

Soil is the largest carbon sink after the oceans

Land infrastructure and urban development have led to land sealing, creating impervious surfaces. In this context, satellite technology can be used to support investigations and analyses that aim to mitigate these changes and improve urban planning processes.
The European Earth observation programme **Copernicus** (see Chapter 2.6) is one of the main sources of high-resolution imagery for the European Union. Among the products focussed on urban sprawl there is Copernicus Urban Atlas, consisting of harmonised land cover maps of hundreds of EU and EFTA cities and the surrounding areas, and **Copernicus Imperviousness**, a product analysing the spatial distribution of artificially sealed areas, derived from a semi-automated classification based on the Normalized Difference Vegetation Index - NDVI.
Both these services produce **change maps**, i.e. maps that are useful in understanding urban growth and transformation across different time periods.

Urban Atlas

Imperviousness

Space-based Earth observation technologies employ both hyperspectral optical sensors, called passive sensors because they exploit the electromagnetic energy emitted and reflected by the Earth's surface, and active sensors such as radars. The use of these sensors makes it possible to obtain images and data that contain a wealth of information on the physical, chemical and biological properties of an object, phenomenon or territory.

In the context of energy, infrastructure and the environment, the information obtained through satellite technology is of strategic importance to support:

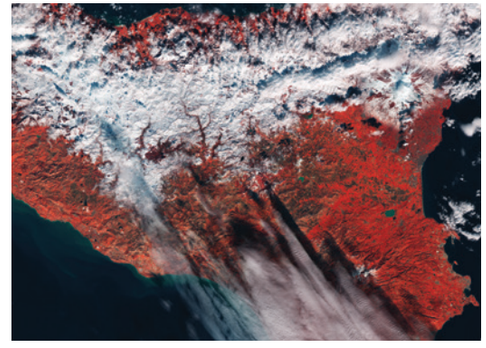
- the **selection of a site** where structures are to be built, carrying out geotechnical, geophysical and altimetric surveys;
- the **management of existing structures**, assessing their efficiency over time, controlling spontaneous vegetation encroachment and monitoring the damage and degradation to which the assets are subject;
- the **management of operational risks**, particularly those arising from natural events such as floods, fires and earth mass movements.

3.2.1 Land monitoring

The use and analysis of satellite imagery provides timely information necessary to support the planning and management of natural resources. For example, for hydroelectric power stations, satellite data can be used to accurately determine water conditions and snow accumulation during the winter season. Integrating this information with future rainfall forecasts makes it possible to accurately plan the use of the available resources and, if required, to take timely action to secure and supplement the electricity supply requirements.

In 2019, the Italian mission **PRISMA** (Precursore IperSpettrale della Missione Applicativa - see Chapter 2.6) completed the launch in orbit of a hyperspectral instrument able to work in numerous bands arranged from the visible to the near infrared (VNIR, Visible and Near InfraRed) and up to the infrared shortwave (SWIR, Short Wave InfraRed).

Example of optical data for land and vegetation monitoring. False-colour image of Sicily from the Sentinel-2A satellite, whose main optical system records 13 spectral bands, processed including the infrared channel
Credit: ESA – CC BY-SA IGO 3.0



Unlike passive optical satellite sensors, which record solar radiation reflected by our planet in a limited number of spectral bands (a maximum of about ten), PRISMA is able to acquire 240 bands. This makes it possible to **conduct a chemical-physical analysis** of the observed areas from Space so as to obtain valuable information on the availability of natural resources and support the prevention of natural hazards (such as hydrogeological) and anthropic hazards (including soil pollution), as well as to monitor cultural heritage, agricultural activities and the exploitation of mineral resources. The system can also be used to obtain additional data and information on environmental aspects, in particular with regard to:

- water resources, measuring the turbidity of water in every single point of a reservoir, identifying the clearest waters and algae colonies;
- the degree of water absorption by forests, which may provide a precursor sign of wildfire risk;
- the presence of gas flaring associated with oil extraction, determining the fire extent and recognising the chemical substances generated by combustion thanks to their spectral fingerprint.

By reducing the need for human inspections in critical areas, the acquisition of data from satellite imagery also ensures the physical safety of operators, who would otherwise be exposed to the risks of hostile environments, even during simple data collection processes. Furthermore, significant cost reductions are possible by making the **inspection of networks and infrastructure** more efficient, reducing the need for costly and time-consuming inspections.

The company **Areti** of the **ACEA** group has launched an experiment with the start-up **Gmatics** which, by applying artificial intelligence to satellite images, makes it possible to monitor the growth of vegetation at production sites and along the supply network. The processing is able to signal at an early stage the places where uncontrolled vegetation growth is most likely to cause service interruptions. Satellite images are acquired monthly, thus providing a much higher frequency of monitoring and model update than physical on-site inspections. Through this solution, it is estimated that maintenance costs are reduced by approximately 60%.

Areti

Gmatics

Gaiag is an Emilian start-up that applies satellite remote sensing to the energy, smart city and environmental safety sectors, through the production of Satellite Application Facilities (SAF) aimed at integrating satellite data into Decision Support Systems (DSS) or Decision Making Systems (DMS), based on complex calculation models.
Gaiag makes satellite-acquired information available through web applications, allowing users to directly access the final information and receive automatic advice and notifications. The applications developed by Gaiag can be used to monitor any area of interest, globally, be it an agricultural field, a photovoltaic plant or an area at environmental risk.
To carry out monitoring, satellite data are integrated with information obtained from drones or ground sensors, making it possible to keep track of parameters such as radiation levels, air and water quality, the state of vegetation, weather conditions at a given time, weather forecasts, land use and land cover change (also with reference to deforestation and desertification changes) and the presence of ice and snow.

Gaiag

The impacts of the current **climate changes** on our planet become evident over the medium to long term, both at the time of their manifestation in the ecosystems concerned and in the subsequent phase of recovery and return to pre-impact conditions. Understanding these dynamics requires large-scale observation of the numerous factors involved. Again through the use of remote sensing images and data, artificial satellites gather information that is essential for understanding **environmental issues**, making it possible to measure phenomena such as atmospheric pollution and the increase or decrease in CO2 in/emitted into the atmosphere, and to determine the health of vegetation, observe and quantify deforestation processes, assess water quality, etc. There are numerous Italian start-ups and SMEs that are able to provide a wide range of data processing services to help tackle environmental problems.

One of these is a SME founded in 2001 in Matera - **DIGIMAT** - which by leveraging expertise in the fields of prototyping, developing and engineering software for data management (both optical and radar) and post-processing (geocoding, data mosaicking), has developed hardware and software components designed for various activities in the field of Earth observation and environmental monitoring.
The company has created geospatial information systems for **monitoring environmental and heritage assets** to customer specifications.
One example is the MPAC (Monitoraggio Parco Archeologico del Colosseo) platform developed for the Italian Ministry of Culture to manage the Colosseum area in Rome. This geospatial information can be used to monitor buildings, historical structures and all local real estate assets in general.
A further example is the Space to Tree -S23 project through which the company has developed a flexible platform integrating 5G and Earth observation data for the biomechanical monitoring of vegetation in specific areas, such as urban or archaeological parks or parks in areas of particular interest, to facilitate and manage the maintenance of historical and archaeological parks more efficiently. In fact, these

types of parks require careful and customised planning of maintenance programmes due to their unique characteristics.
DIGIMAT has developed and manages some of the algorithms used by the Italian satellite Earth observation system Cosmo Sky-Med (see Chapter 2.6), which are applied by several Consortia such as the Earth and natural hazards observation consortium *Tecnologie per le osservazioni della Terra e i Rischi Naturali* (**TeRN**) and the technological innovation consortium *Consorzio per l'ambiente e l'innovazione tecnologica* (**Createc**).

Digimat

Downstream services include operators that focus their activities on the analysis of remote sensing data for the observation of environmental changes.
Meteorological Environmental Earth Observation (**MEEO**), founded in Ferrara in 2004, started out as a supplier of products and services for monitoring climate and air pollution and later expanded the application area of its products to the mapping of the earth's surface. In the area of **atmospheric monitoring**, thanks also to the recent availability of data from the ESA Sentinel-5P mission designed for this purpose, MEEO manages the collection of Sentinel-5P data on dedicated data storage and cloud computing web platforms.
In the area of environmental monitoring of the effects of climate change, MEEO offers the capability to manage large quantities of climate data (concerning atmosphere, land masses and oceans) based on the analysis of multi-spectral, multi-sensor and multi-temporal satellite data.
In this field, the company has taken part in two projects:

- ESA EO4SD - Climate Resilience Cluster project, which aims to provide a quick assessment of climate anomalies, calculating risk indicators and their historical evolution over time.
- The Life+ RainBO project, which aims to develop systems able to accurately predict severe rainfall events and their impact on the area concerned. The system has been tested in the urban area of Bologna.

MEEO

ColomboSky is an Italian start-up active in remote sensing and has developed the AquaX service for monitoring water quality on a global scale.
Starting from satellite data, this product offers environmental monitoring and prediction services to optimise the management and productivity of fish farms, reducing the risk of losses due to biological threats.
The integration of the same satellite data with oceanographic models makes it possible to measure and predict a range of parameters such as temperature, salinity, currents, wave motion and biological phenomena such as algal and jellyfish blooms, on a large spatial scale and continuously over time.

Colombosky

AquaX

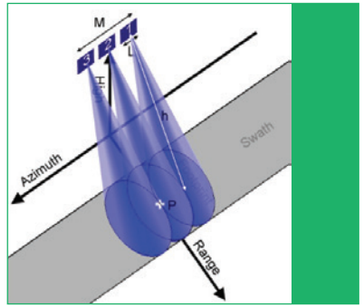
In the context of urban sprawl, the company **Planetek** has developed Rheticus Urban Dynamics.
The company manages, analyses and shares geospatial data in various fields, including environmental monitoring, smart cities, transport, security, construction and energy. Rheticus Urban Dynamics is a cloud-based tool of use in **spatial planning** as it provides land use information, impervious surfaces assessments and urban heat islands detection services.
A project dedicated to urban heat is ESA's Urban Heat Island (UHI) and Urban Thermography Project, which aims to integrate satellite data with temperature, relative humidity and wind speed data obtained from ground stations in order to support actions to prevent the impact of UHIs during heat waves, through appropriate alert and risk mitigation systems.

Planetek

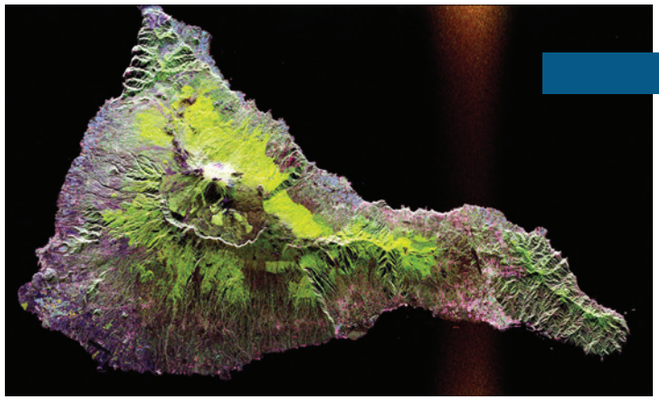
3.2.2 Infrastructure and building monitoring

Infrastructure monitoring across vast areas is usually extremely costly and time consuming and, often, beset by implementation difficulties.
Satellite technologies can be used to overcome these limitations.
In addition to the use of satellite imagery, radars and other sensors used as payloads on satellites can provide extremely precise data and measurements to enable very accurate monitoring of the areas over which infrastructures are distributed, thus making it possible to plan inspections, prioritise in-situ investigations and consequently plan maintenance work based on the availability of frequent and accurate information that can be integrated with other sources.

This is the case with **interferometric RADAR systems**, satellite instruments using Synthetic Aperture Radar (SAR) technology, through which radar images of the area under investigation can be obtained with high resolution in both the range and the azimuth directions, as shown in the figure below.



Ground-based SAR Interferometry
Credit: Wikimedia - Dantor



Radar image of the Teide volcano on the island of Tenerife in the Canary Islands
Courtesy NASA/JPL-Caltech"

These systems enable the creation of time series of ground displacements in order to better understand the evolution of the deformation phenomena affecting infrastructures. Starting from the latter, the accuracy of the technique can be improved by processing the RADAR electromagnetic signal, making it a methodology applicable in near-real time.

#video
Sistemi di osservazione dallo spazio per lo studio delle deformazioni della superficie terrestre

In the **planning** phase, through spatial analysis, satellite technology can be used to identify the optimal route along which to lay infrastructures that develop linearly, or through the creation of thematic maps relating to the geomorphological features of the area concerned, for the preliminary planning of the works.
In the **management** phase, applications are available to monitor the stability of the ground before, during and after the works, including the monitoring and analysis of the impact that the infrastructure concerned has on the surrounding environment.
3D and 4D Multidimensional SAR technologies can be used to create 3D reconstructions of the scene observed with a high degree of detail (suitable for urban areas), accurately monitoring any deformations of the ground targets over time.
The availability of high resolution spatial data provided by the **Cosmo-Skymed** satellite sensors (see Chapter 2.6) makes it possible to estimate millimetre deformations in individual ground structures, such as those caused by thermal expansion (5D Imaging).

Examples of companies that use these data are **NeMeA Sistemi** of Sanremo, which works on **the interpretation of RADAR/SAR data** obtained from the COSMO-SkyMed satellites, under the Italian Space Agency's SME Open Call.
For public administrations, this means being able to know about and monitor their territory, using a study of the short, medium and long term changes in the coastline to assess the impact of marine structures and the effectiveness of the defence measures, and to draw up development and management plans, including the monitoring of unauthorised buildings.

NeMeA Sistemi

TRE ALTAMIRA is a company specialising in ground monitoring using satellite radar data. The company operates in diverse sectors and offers a set of products for the satellite measurement of surface deformations, mainly for applications in Oil & Gas, mining, hydrogeological risk and civil engineering sectors, and for use by public entities such as the Civil Protection, regional governments and basin authorities.
In the field of transport infrastructure, TRE ALTAMIRA offers historical analysis of InSAR data to identify unstable areas and reconstruct the motion "pattern" to be taken in account when planning linear infrastructures. The company also offers a service for monitoring the stability of infrastructures (roads, bridges, built-up areas) in the post-construction phase. Founded on the initiative of professors at the Politecnico di Milano university, TRE ALTAMIRA has opened a branch in Canada, which handles trade relations with the North American market.

TRE ALTAMIRA

In the field of detailed monitoring, companies like **NHAZCA (Natural HAZards Control and Assessment)**, a spin-off of the Università Sapienza di Roma, specialises in consultancy and services aimed at the assessment and mitigation of natural risks and risks associated with major infrastructures.
Detailed monitoring applies a combination of both satellite and ground-based SAR technology to detect even millimetric movements in structures and terrain, providing support in the construction and management of large infrastructure and projects for the exploitation of natural resources.

NHAZCA
Natural HAZards Control and Assessment

Survey Lab, founded in 2008 as a spin-off of the Università Sapienza di Roma, is currently working on the development of geomatic monitoring systems that use remote sensing technology for applications in the civil and environmental engineering sectors, with a focus on methods for monitoring the impacts of natural hazards on land and built-up environments.

The key service offered by the company is I.MODI, an operational prevention and investigation tool aimed at monitoring buildings and infrastructures over the medium to long term. The service aims to use Earth observation data to monitor the structural stability of buildings to help implement mitigation actions and prevent potential failures.

Survey Lab

Satellite technology can also provide useful insights for the in-depth study of the **urban heat island** phenomenon.
One example is the EU-funded **Life METRO Adapt** project, limited to the city of Milan, which saw the involvement of associations like Legambiente and Ambiente italiana, CAP Holding and ALDA but also **e-GEOS**, the exclusive global distributor of first- and second-generation COSMO-SkyMed RADAR data.

The Life METRO Adapt project, which ended in 2021, analysed data from the Terra (MODIS) and Landsat 8 missions to identify 5 classes of thermal ground anomalies, thanks to which it was possible to create maps that clearly and unambiguously indicate the areas worst affected by summer heat waves.
The satellite data was then integrated with population data in order to identify the groups of the population most vulnerable to heat waves, such as the elderly and children.

Life METRO Adapt project of the Milan Metropolitan City

e-Geos

Satellite technology allows in-depth study of the "Urban Heat Island" phenomenon

3.2.3 Emergency management

In addition to ordinary planning and management activities, **emergency management** also plays a particularly important role, especially when faced with natural disasters of ever-increasing frequency and intensity, to which our country is particularly susceptible.
The **Copernicus Emergency Management Service (EMS)** provides early warning information in anticipation of extreme events such as floods, fires or other potentially damaging natural events.
The system is also able to produce up-to-date maps with information relating to an event that has already occurred, which can be used to manage response services and monitor the evolution of the event itself.
The Copernicus EMS is accessible to all entities covered by the European Civil Protection mechanism, as well as to other regional, national and international civil protection organisations, the European Commission and EU Agencies.

Copernicus Emergency Management Service (CEMS)

In the field of emergency management, **ITHACA** collects in-situ data and data from aircraft/drones, IoT sensors, geospatial databases and satellite sources and processes and organises these in a structured manner to create high value-added maps. The service is designed to make the data more user-friendly and thus speed up the associated response actions. The company uses the Copernicus module dedicated to Rapid Mapping to produce thematic maps and vector data. Ithaca supports end customers in various application areas such as agriculture, forest management and forestry, environmental monitoring and mobility information.

ITHACA - Earth Observation in support of humanitarian emergencies

GEO-K, a spin-off of the Università di Roma di Tor Vergata, was established in 2006 to develop projects mainly linked to satellite remote sensing technology and artificial intelligence.
GEO-K has developed a set of tools for managing large amounts of radar and optical data obtained from Earth observation satellites to create thematic maps for use in land monitoring and critical infrastructure monitoring. GEO-K applies artificial intelligence algorithms and proprietary image processing techniques to provide maps that can be used to monitor forests and non-specific crops or for emergency management. The company has the capability to manage data from radar sources to monitor the ground situation even in highly cloudy conditions during adverse weather events, such as floods.

URBan ANthropogenic heat FLUX from Earth observation Satellites (URBANFLUX-ES) is a EU-funded H2020 project that investigates city warming, through the combined use of satellite imagery and conventional meteorological measurements, by separating the urban energy balance from the anthropogenic heat flux.
The project aims to:

- feed anthropogenic heat data to various applications, including climate models, to assess the effect of anthropogenic heat on the Earth system;
- build energy models to characterise the flow path of heat between buildings and the atmosphere/soil/water;
- support decisions linked to sustainable urban planning and the mapping of emissions associated with energy consumption.

GEO-K

Progressive Systems works on creating solutions that simplify the exploitation of Earth observation data for private and public actors.
The company has developed an artificial intelligence system to analyse large amounts of data and create customised alerts according to the specific requirements of each client.

Progressive Systems works with Senegal's Centre de Suivi Ecologique (CSE) to monitor fires and burnt areas that are a calamity for the African country's agricultural economy and land. The company has also collaborated on an ESA project to create real-time flood monitoring maps, developing expertise in an area that is becoming strategic in Europe, where extreme natural events are becoming increasingly common due to global warming.

Progressive

3.2.4 Energy infrastructure planning

The collection and processing of data from space sources is also playing an important role in the **planning of next-generation energy infrastructure**.
In fact, these data can be used to obtain extremely accurate information on the earth's surface and on the behaviour of natural elements that can be exploited to generate renewable energy.

This approach motivated **Universo Energia** to develop Solìsia, a software platform for measuring the efficiency of solar farms. Solìsia combines solar irradiation data, geo-localised weather data and the production data of each solar farm linked to the platform. Most of the Earth observation data used by the software is obtained from the European Copernicus constellation.

Universo Energia

i-EM adopts a multidisciplinary approach to ensuring the efficient management of power generation plants, especially from renewable sources, and grid and storage facilities.
i-EM's advanced analytics platform combines Earth observation data, weather forecasts and bigdata collected from ground-based sensors and analyses these with artificial intelligence and machine learning techniques. The simultaneous use of these technologies enables i-EM to provide its customers with customised services for the management of their energy production and transport assets.
The company monitors around 800 renewable energy plants in 20 countries.

i-EM

In 2021, ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile) won the tender for the INSURE project *(INnovation in SUstainable offshoRe dEcommissioning)*, funded by ESA under the ARTES 4.0 programme, designed to encourage the extensive use of space-derived technologies in new areas.
The project is being carried out by an Italian consortium consisting of ENEA, Eni, METAPROJECTS, IRSPS, NEXT Ingegneria dei Sistemi, SRS Servizi di Ricerche e Sviluppo, and TIM.
INSURE will use data from sensors installed on aerial and submarine drones, GNSS and Earth observation satellites to manage the **dismantling** of **hydrocarbon extraction platforms (oil and natural gas) and the decommissioning of marine wind farms** at the end of their life cycle. The project will use data from the Copernicus constellation and GNSS sensors to monitor the conditions of marine platforms.
Based on the data collected, it will be possible to understand whether some of these energy production facilities can be converted to hydrogen production from renewable sources or for other uses, such as tourism.

ENEA Progetto INSURE

#video
Progetto INSURE INnovation in SUstainable offshoRe dEcommissioning

3.2.5
Monitoring systems that use signals from Global Navigation Satellite Systems (GNSS)

Innovative systems capable of cost-effectively generating 2.5D information and maps (otherwise known as 3D level-of-detail) can be realised through the use of signals from globally available Global Navigation Satellite Systems - (GNSS) (see Chapter 2.5).
The use of **GNSS sensors** makes it possible to monitor position changes with great accuracy.
This type of application can be used in the field of land and infrastructure management to monitor, for example, ground deformation, landslide displacements or movements in buildings, bridges and constructions of various types.
There are various types of GNSS sensors.
For applications requiring very precise monitoring, high-precision professional sensors and receivers (see Chapter 2.5) would be the preferred choice as they are able to monitor changes of a few centimetres (or in some cases a few millimetres). In other cases, lower precision sensors can be used to monitor land and infrastructure at low cost. 3D maps of the territory can also be created using data obtained through advanced GNSS signal processing techniques, integrated with other data from Earth observation systems. With these techniques, digital twins of the observed area or infrastructure can be created to calibrate control and maintenance activities even more precisely.

Geomatics Research & Development (GReD), founded in 2012 as a spin-off of the Politecnico di Milano university, supplies solutions based on geodesy and geomatics to monitor the environment and structures/infrastructures, through the analysis and interpretation of the gravity field and GNSS data.
In order to detect deformation of infrastructure and ground movements, GReD has launched an end-to-end monitoring service based on affordable GNSS instruments. The monitoring service, called GeoGuard, can be applied to high-voltage power lines, dams, bridges and landslides.

This field also includes real-time and near-real-time monitoring, often carried out by systems that integrate ground-based data with satellite data. An example is the **Quakebots SAT** system developed by **Wise Robotics**, which combines the algorithmic vibrational component of measurements on buildings and infrastructures with a positional component linked to the use of GNSS, thus making it possible to detect even the smallest displacements.

GeoGuard - Earth Monitoring Services

Quakebots SAT

Miniaturised low-cost GNSS sensors enable continuous monitoring of wide areas

The use of low-cost and energy-efficient miniaturised GNSS sensors is at the heart of DEDALOS-SAT, a **Spaceexe** product designed for high-precision continuous monitoring of infrastructure and buildings.
DEDALOS is designed to monitor all those areas that are subject to ground deformation due to landslides or subsidence or to the nature of the soil itself, in order to quickly identify movements that could damage an infrastructure.
The system employs advanced IOT sensors with GNSS receivers capable of receiving and processing signals from multiple GNSS constellations, thus ensuring very high coverage and quality of the service even in built-up areas where the reception of signals from a single constellation may be weak due to the orographic configuration of the land or the presence of very tall buildings. In particular, the company is working to incorporate into its products advanced signals from the Galileo satellite system which, when fully operational in late 2022/early 2023, will allow access to authentication services.

Spaceexe

3.2.6
The Near Future

The role of data

Italy can count on one of the most complete and competitive ecosystems in the world when it comes to monitoring the Earth's surface, the environment and infrastructure.
As is the case of other space technologies, the role of public decision-makers and long-term funding is crucial. From the standpoint of space infrastructure, the path has already been mapped out.
From 2025, the Italian ecosystem will have access to even more complete and detailed data on the Earth's surface thanks to the completion of the launch of the second generation Cosmo Sky-Med constellation (see Chapter 2.6).
The offering in the field of Earth observation will then be completed by the new constellation of small satellites positioned in Low Earth Orbit (LEO), which the Italian government has confirmed will be implemented in December 2021 with PNRR funding. In May 2022, Samantha Cristoforetti, an Italian astronaut of the European Space Agency, announced from the International Space Station that the new constellation will be called Iris.

Another sector of high focus for Italy is promoting the practical use of data to create high value-added services for both the private and public sectors, the so-called downstream market.
Earth observation constellations, GNSS sensors and other technologies are producing more and more data of increasingly good quality and reliability.
The Italian government is funding the Copernicus Mirror Programme, designed to accelerate the growth and competitiveness of the Italian offering and market of

geo-spatial services. One of the most important outcomes of the programme will be the creation of an **Infrastructure Enabling the Geospatial Services Market, designed to be open, scalable and interoperable. The infrastructure, partly financed with PNRR funds, will provide** spatial and non-spatial data to make it easier to implement new high value-added services.
Specifically, a system will be created to allow companies to have easier access to technologies for the advanced processing of this type of data, including Big Data Analytics and High Performance Computing techniques, and then to implement a market place for geo-spatial applications and services.

Italy will have the capability to preside over the entire value chain in this highly strategic sector

In fact, the country will have at its disposal the latest-generation of optical and radar monitoring satellites, teleports for managing the constellations and the data they generate, as well as a complete supply chain for the sale of data and the value-added services enabled by the management of these data and the entire space infrastructure.

ENEA Magazine - Mirror Copernicus per lo sviluppo e la competitività della Space Economy italiana

Energy production

The energy supply and production sector already makes extensive use of many space technologies, such as Earth and atmospheric observation, satellite navigation and the use of advanced materials developed for space exploration missions.
The synergetic use of all these technologies is set to grow in the near future, both to increase the efficiency of ground-based systems and to meet the challenges posed by the scheduled space exploration missions.

In addition to the management of energy infrastructure, one area that will play a key role is energy production. Space exploration and new programmes for the colonisation of the Moon and Mars are accelerating the development of multiple innovations in this area as well.
The Artemis programme for the return of humans to the Moon sees the involvement of ESA and ASI and represents a major breakthrough in so far as it envisages the presence of astronauts on the Moon for long-duration stays of one to three months (see chapter 2.2).

ASI – ARTEMIS Programme

Human and robotic presence on the Moon, and potentially on Mars, will require a source of energy capable of meeting the needs of astronauts and the machinery used.
Among the solutions being studied, the use of mini-nuclear reactors appears to be one of the most functional responses to the aims of the missions.
The use of small reactors would establish a reliable and durable source of energy and would be the preferred solution in place of alternatives like hydrocarbon sources or solar energy, which is only available in the case of direct radiation from the Sun.

One of the most advanced projects is **NASA**'s **Kilopower** project to develop mini-reactors for active nuclear fission, capable of continuously and reliably generating around 10 kilowatts of electricity. These mini-reactors will be easily transportable and able to satisfy the needs of an initial space settlement.

NASA - Kilopower

Since 2021, the **ENEL Group** has collaborated on a project led by the Italian Space Agency to research innovative solutions to support a human base on the Moon as part of the ARTEMIS programme.
ENEL is involved in the study of how to generate energy for the base and how to manage it in an environment characterised by extreme and highly challenging conditions. ENEL's involvement is functional to the energy company's strategy of focusing on increasingly innovative and efficient technologies, including space-derived technology, to produce and store energy. There appears to be plenty of room for the development of innovative photovoltaic technologies and for the wireless transmission of energy, designed both to reduce the need for fixed infrastructure and to power vehicles or outposts.

ENEL - The Moon: Enel's new innovation lab

Service / Product	Description	Application area	Company
Monitoring vegetation growth	Application that monitors vegetation growth at production sites and along the grid, using artificial intelligence to analyse satellite imagery in order to plan maintenance	**Energy infrastructure monitoring**	**Gmatics**
Decision upport systems	Platform for monitoring specific areas of land, integrating satellite data with information obtained from drones and ground-based sensors to provide strategic information to decision makers	**Land and infrastructure monitoring**	**Gaiag**
Geospatial information systems	Geospatial information systems for monitoring environmental resources and heritage sites, tailored to customer's needs and specifications	**Land and infrastructure monitoring**	**DIGIMAT**
Monitoring weather events and extreme weather events	Analysis of multispectral, multi-sensor and multi-temporal satellite data for environmental monitoring and land management purposes, with a focus on the impact of climate events	**Climate and air quality monitoring**	**MEEO**
Water monitoring application	Platform for monitoring water quality to increase fish farm productivity and for monitoring biological phenomena in the marine environment	**Water monitoring**	**Colombosky**
Spatial planning platform	Cloud platform for monitoring land use and land cover for spatial planning purposes	**Monitoring of land cover**	**Planetek**
Application for the interpretation of data from Cosmo Sky-Med	Application for land monitoring based on radar/sar data obtained from the Cosmo Sky-Med constellation, with a focus on changes in coastal zones	**Land and coastal monitoring**	**NeMeA**
Monitoring of mining areas	Land monitoring application using satellite imagery for the Oil&Gas, mining and civil engineering sectors	**Land monitoring**	**TRE ALTAMIRA**
High-precision monitoring of ground deformation and movements in infrastructure	Detailed monitoring of ground and structural deformation using SAR technologies, even with millimetric precision, for the management of natural resources exploitation and infrastructure maintenance	**Land and infrastructure monitoring**	**NHAZCA**

Service / Product	Description	Application area	Company
Geomatic monitoring systems	Geomatic monitoring systems for the medium-long term monitoring of buildings and infrastructure	**Land and infrastructure monitoring**	**Survey lab**
Land monitoring for emergency management and planning	Land monitoring for natural disaster preparedness and response	**Land monitoring**	**Ithaca**
Processing of Earth observation data using Artificial Intelligence	Platform for managing large amounts of radar and optical data from Earth observation satellites in order to create thematic maps for monitoring land and critical infrastructure	**Land monitoring**	**GEO-K**
Platform for the management of solar farms	Platform for measuring the efficiency of solar farms	**Energy infrastructure monitoring**	**Universo Energia**
Platform for the management of renewable energy plants	Advanced analytics platform for the management of renewable energy plants, combining Earth observation data, weather forecasts and bigdata collected from ground-based sensors	**Energy infrastructure monitoring**	**i-EM**
Processing of Earth observation data using Artificial Intelligence	Artificial intelligence-based platform that analyses large amounts of data and creates customised alerts according to the specific requirements of each client, thus simplifying the use of the data	**Land monitoring**	**Progressive Systems**
Monitoring of land and critical infrastructure using GNSS sensors	Monitoring service to detect deformation of infrastructure and ground movements, based on GNSS sensors. Main areas of application: high-voltage power lines, dams, bridges and landslides	**Land and infrastructure monitoring**	**GReD**
Real-time monitoring of land and critical infrastructure using GNSS sensors	High-precision real-time and near-real-time monitoring of critical buildings and infrastructure through a hardware platform that integrates GNSS sensors and an algorithmic vibrational component	**Monitoring of buildings and infrastructure**	**Wise Robotics**
High-precision continuous monitoring of infrastructure and building	IOT sensors with multi-constellation GNSS receivers for the continuous monitoring of buildings and infrastructure	**Monitoring of buildings and infrastructure**	**Spaceexe**

3.3 Chemicals and New Materials

The aerospace sector is continuously searching for innovative materials to meet the technical challenges that space poses in terms of strength, reliability and weight reduction. Improving the performance of materials is a key factor in ensuring the success of space missions, reducing costs and increasing safety levels.

Investments in this sector are huge and cover applications in all aerospace fields, from launchers to satellite components, from materials used to ensure safe re-entry of rockets and spacecraft into the atmosphere to those used to improve the performance of the electronic components.
The need to plan and manage the entire life cycle of a product in a sustainable way is becoming a top priority in this sector too.
Lighter materials can contribute directly to reducing the consumption of fuel and raw materials, while specifically engineered materials can help make certain processes more controllable, such as the total burn-up of a satellite during re-entry into the atmosphere at the end of its life cycle.
Among the most important required features are low specific weight, low outgassing and high resistance to heat, mechanical stress and radiation. Among the most commonly used materials besides aluminium, titanium and carbon fibres are **ceramic materials**, **composite materials** and so-called **metamaterials**.

3.3.1 Ultra-high performance materials

Ceramic materials are particularly suited for the construction of spacecraft components due to their high mechanical performance and thermal resistance.
Specifically, these materials are able to withstand very high temperatures, as in the overheating phases during re-entry into Earth's atmosphere, as well as the extreme cold in space. This type of material plays a crucial role in the construction of rockets and shuttles, including reusable rockets, as it guarantees consistent performance over time.

The collaboration between **Centro Italiano Ricerche Aerospaziali (CIRA)** and **Petroceramics** has led to the development of a new highly resistant ceramic material, **ISiComp.**
Petroceramics is a spin-off of the Università degli Studi di Milano, focussed on the development of high-performance advanced ceramic and composite materials for use in the aerospace, automotive, medical, energy storage and defence industries.
ISiComp is a reinforced ceramic composite able to withstand extreme thermal and mechanical stresses and can be manufactured rapidly and cost-effectively.
The composite was designed to be part of the Space Rider robotic space shuttle with automatic re-entry (see Chapter 2.1) and to be reused for several missions, so as to cut costs and speed up maintenance times.
The material has already passed the test phases that simulated atmospheric re-entry from space and managed to handle the impact of a high-enthalpy hypersonic flow reaching a temperature of 1200°C for about 10 minutes without any obvious signs of degradation.

Petroceramics is an investee of Brembo, one of the most innovative manufacturers of braking systems on the market and one of the world leaders in this highly innovative sector, the aim of the investment being to facilitate and enhance technology transfer between the two sectors: from aerospace to automotive, and vice versa. Shifting the focus to other sectors, the company is also developing ceramic products for the biomedical sector.
Some ceramic materials are highly biocompatible and meet the strength requirements needed for implantable prostheses. In this area, Petroceramics has patented a new silicon nitride-based material for bone endoprostheses, which is biocompatible and highly resistant to stress and thermal variations.

Petroceramics

S.A.B. Aerospace has carried out research in the field of ceramic materials designed to guarantee the structural integrity of spacecraft capable of re-entering the atmosphere.
In particular, in collaboration with the CNR's **Istituto di Scienza e Tecnologia dei Materiali Ceramici (ISTEC)**, it has developed a new-generation ceramic material for spacecraft equipped with Structural Health Monitoring Systems (SHMS). ISTEC is a research centre entirely dedicated to the research and design of ceramic materials (monolithic and composite), designed to withstand extreme stresses and perform optimally even in harsh environments such as space.

ISTEC has the know-how to manage the entire chain of development leading to the use of new ceramic materials in practical applications, spanning from researching the requirements and developing prototypes, to the test phase in the lab and under real conditions. The centre is active in basic research, applied research and collaboration with industries. In the aerospace sector, ISTEC has collaborations with many Italian and European players, including AVIO and Airbus.

S.A.B. Aerospace

Istituto di Scienza e Tecnologia dei Materiali Ceramici – ISTEC del CNR

ISTEC has turned a number of project ideas, born out of research into ceramic and bioceramic materials, into knowledge-intensive spinoffs in diverse sectors, spanning from biomedical to cosmetics and energy:

- **GreenBone** adopts a unique approach to developing bone substitutes. Specifically, GreenBone produces a highly innovative acellular compound that can be used to fill some types of bone voids during surgery;
- **Finceramica**, a spin-off founded in the 90s, is now one of the major European players in the design and development of prostheses for use in orthopaedic surgery and, in particular, in neurosurgery. The company produces high-bioavailability bone substitutes for use in regenerative surgery;

- **Recover Ingredients** adopts a circular economy approach to exploiting waste from fish farms to make high value materials for applications in the cosmesis and agriculture sectors;
- **IPECC** develops components for sectors that use piezo technology.

ISTEC: Startup & Spinoff

Another spinoff from ISTEC is **ZENIT Smart Polycrystals**, which combines ceramic materials technology with 3D printing.
ZENIT is able to precisely control the composition of a crystal in three dimensions.
This innovative approach makes it possible to design and manufacture crystals based on transparent ceramic materials, with performance and properties superior to crystals currently available for industrial applications (single crystals). ZENIT can produce crystals of highly customisable sizes and composition by adding dopant ions that give the crystals distinctive properties according to the specific needs. ZENIT crystals are used in the production of lasers, particularly high-power lasers, in the industrial and biomedical fields. The use of ZENIT polycrystals can mitigate the thermal distortion effects typical of single crystals, thus increasing the precision and/or efficiency of the laser system. ZENIT is currently validating its technology with selected customers.

ZENIT Smart Polycrystals

K3RX is a spinoff of the Consiglio Nazionale delle Ricerche (CNR) specialising in the production of Ultra High Temperature Ceramic Matrix Composites (UHTCMCs) able to withstand extreme temperatures (above 2000 degrees centigrade) with a limited erosion rate.
The company has a catalogue of UHTCMC products that includes tiles for Thermal Protection System (TPS) of spacecraft, nozzles for propulsion systems and mechanical connectors. Some of the materials used have self-repair capabilities.

K3RX

Composite materials are also becoming increasingly popular in the space sector due to their stress and thermal resistance properties.

Avio is one of the leading large industrial groups in Italy in the field of research and production of composite materials for the aerospace industry. The company uses these materials for the construction of rocket engines and tanks. Avio has patented systems for filament winding of carbon fibres for the production of tanks and also uses a new type of pre-impregnated carbon fibre composite to build engines for Vega launchers (see Chapter 2.1).

AVIO

Another major player in the Italian ecosystem is **Leonardo**, which uses carbon fibre to make aeronautical components, in particular at the Foggia plant where the Boeing 787 contract is being handled.
In 2021, Leonardo invested in the setup of a pilot plant for the production of high-performance carbon fibre in collaboration with **MAE**, a company specialised in engineering production lines for the production of polymeric fibres. The investment is supported by Invitalia (Agenzia nazionale per l'attrazione degli investimenti e lo sviluppo d'impresa) in view of its strategic value and potential systemic impact on many Italian industries. The plant will increase the capacity of the Italian industrial ecosystem to produce carbon fibre, decreasing dependence on foreign countries and increasing technical and scientific expertise in the sector. The new carbon fibres will be produced using innovative methodologies.
The project aims to support technology transfer to other sectors that could benefit from the low weight and strength of carbon fibres, particularly the automotive, construction, textile and energy sectors.

MAE

INVITALIA

Bercella specialises in the production of composite material components for aerospace and motorsport applications.
Its extensive experience allows the company to manage the entire process, which starts with the design and creation of new materials and ends with the testing and production phase. These highly innovative materials with very high performance in extreme environments are used in the space sector but also in the defence sector, where requirements are particularly stringent and mission-critical.
Bercella uses filament winding, autoclave or advanced compression moulding techniques in its production processes. The company has in-house CNC machining and painting capabilities for components requiring a precision tolerance of a few microns, such as reflectors used in military applications.

Bercella

Still on the topic of innovative materials used in space, **Ensinger** develops and produces high-performance plastics suitable for various applications.
In addition to high mechanical resistance, particularly to vibrations during launch into orbit, the main requirements met by these materials are low outgassing in vacuum conditions and good resistance to high levels of radiation in space.
A further strength is their weight. The polymers developed by Ensinger for the aeronautical sector have a weight of around 1.3 g/cm3, far less than the 2.7 g/cm3 of aluminium commonly used for applications requiring the same strength requirements. These materials are used to make components for installation in solar panels, insulation materials for cables and platforms used in satellites.

Ensinger

3.3.2 Metamaterials

Metamaterials are **materials that do not exist in nature**, that have specific and unusual electromagnetic characteristics and properties owing their molecular structure and chemical composition.
Their use is of particular interest in fields linked to the propagation of electromagnetic waves, such as telecommunications (see Chapter 3.3).

Wave-Up (see Ch. 3.3) specialises in the use of metamaterials for the production of high-performance, ultra-flat antennas and arrays capable of effectively handling some of the limitations of traditional technologies. In particular, Wave-up engineers and manufactures metasurface antennas. This particular type of processing method increases the ability to handle and guide electromagnetic radiation, ensuring a high level of performance. The result is high accuracy in managing the flow of radio waves and increased capability of the antenna to send and receive data, even in difficult and extreme conditions.

Wave-Up

ALMA Sistemi is researching the use of metamaterials in telecommunications and earth observation.
The company took part in the Plasma Meta-Materials - M2P project, which proposed innovative ways to build antennas for telecommunications and navigation using plasma and metamaterial-based technologies.

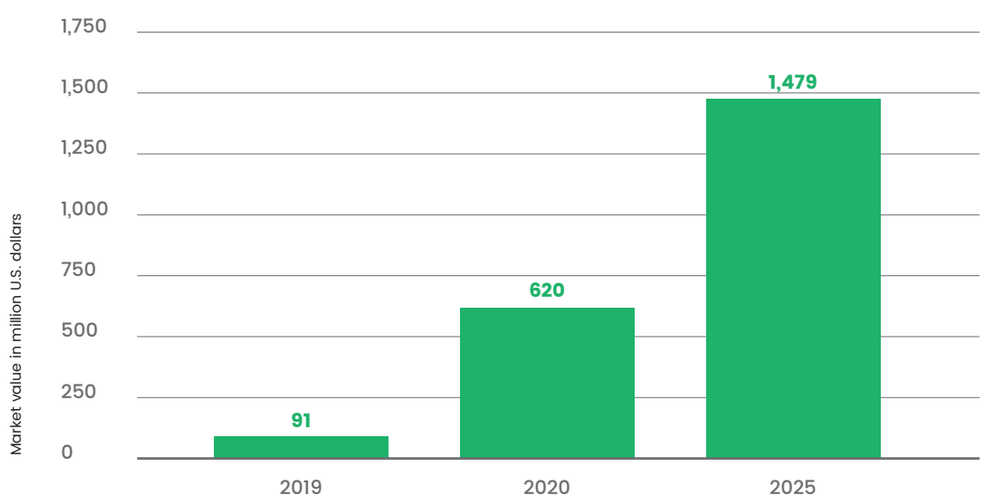
Alma Sistemi

Among the new materials used in aerospace and designed for use in various applications, it is impossible not to mention **graphene**, discovered in 2004.

This material, composed of a single layer of carbon atoms, can lend itself to countless uses, including space applications where low weight and strength are essential requirements, thanks to its excellent electrical, mechanical and thermal properties.
The global market value of graphene is expected to exceed $2 billion by 2025.

In the field of avionics and space systems, graphene is considered a high-performance material both for cooling on-board electronics and for making flexible touch screens.
Italy is well positioned on graphene research and use, and many industry and innovation players are part of **Graphene Flagship**, the European Union's graphene research initiative. One of the major companies involved is **Leonardo**, which, through long-term investments, is planning to use this material to build various types of apparatus. Graphene will enable the building of stronger structures with the same weight, or with high-performance electrical or thermal properties. The material could also be used to produce highly efficient and lightweight cooling systems for satellites and space exploration vehicles. The company is also investigating how graphene can be used to make on-board electronics, e.g. for displays, or for sensors capable of exploiting graphene's properties, as in the case of certain components of radar or optical equipment.
Despite being a material with countless interesting features, the production of graphene on an industrial scale is complicated. Once the technological limitations of production are overcome, graphene is expected to see very rapid implementation in the coming years in the field of batteries, chip production and extremely light and energy-efficient sensors.

Market value of graphene worldwide from 2019 to 2025 (in million U.S. dollars)
Source: Statista



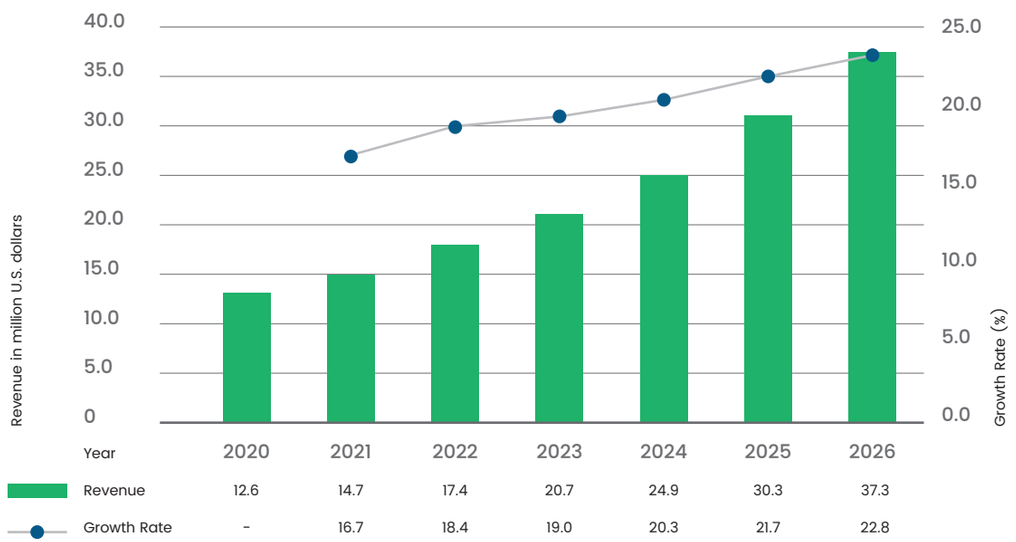
Directa Plus is one of the world's largest domestic and global producers of graphene nano-platelets.
The company is among only a few in the world capable of using physical processes only and not chemical processes to produce graphene, providing a high quality and sustainable end product. In fact, the use of chemical compounds is almost entirely absent and production waste is reduced.

Directa Plus

3.3.3 3D printing

In addition to the intrinsic properties of materials, the way in which they can be used efficiently to create high-performance components is crucial.
The aerospace industry was among the first to use **3D printing**, also known as additive manufacturing, initially for research and rapid prototyping applications and later to manufacture components. It was only in the early 2000s that this technology was fully integrated into industrial processes in the aerospace sector, thanks to its ability to create parts and components with a monolithic design, simplifying and speeding up production.

Additive Manufacturing: Revenue Forecast, Global, 2020–2026
Source: Frost & Sullivan Global Additive Manufacturing Growth Opportunities, Published: 2022-02-16



Year	2020	2021	2022	2023	2024	2025	2026
Revenue	12.6	14.7	17.4	20.7	24.9	30.3	37.3
Growth Rate	-	16.7	18.4	19.0	20.3	21.7	22.8

According to data from Frost & Sullivan, the global additive manufacturing market is growing strongly, with a projected CAGR of 20.4% from 2021 to 2026.

Roboze has developed a range of 3D printing materials and technologies.
Its proprietary Filament Fusion Fabrication (FFF) technology is believed to be among the most accurate 3D printing technologies in the world.
Roboze has also developed a number of materials and polymers, such as PEEK, Carbon PEEK, Carbon PA and ULTEMTM AM9085F, capable of ensuring above-standard levels of chemical, thermal and mechanical resistance. The polymers, super-polymers and composite materials developed by Roboze meet the industry's need for lower weight, increased efficiency and replacement of traditional materials.
In particular, these materials combined with innovative 3D printing methods make it possible to replace certain metal alloys normally used, significantly reducing the weight of the components manufactured whilst ensuring the same performance levels.

#video
Roboze's Beltless 3D-Printing Technology - Overview & Benefits

The company has also patented a 3D printing system based on a mechatronic movement with gears and without the use of belts, called Beltless System, which is able to ensure a level of accuracy down to 0.01 mm. This technology facilitates process repeatability, with an estimated accuracy up to six times higher than that achieved with conventional belt 3D printers.

Roboze

HB Technology is active in the field of space engineering projects and services.
The company is one of the leading Italian manufacturers of complex metal parts using Selective Laser Melting (SLM) 3D printing technology.
HB Technology also uses Roboze's FFF technology to print high-performance polymeric materials. In particular, the company uses Roboze's Peek (Polyether Ether Ketone) product, a colourless organic thermoplastic polymer that, due to its excellent strength, stability and fire resistance, is used in the aerospace industry as a substitute for metals and alloys to make parts that need to withstand heavy loads. HB Technology has studied this material in detail through the SCAMP (Smart Components mediante Additive Manufacturing Polimerico) project financed by the Lazio region and led by Thales Alenia Space Italia. The project tests highly innovative polymeric materials for use in the production of satellite parts and components.

HB Tecnology

The **BEAMIT** group specialises in the design and production of materials and metal alloys for 3D printing.
The company manages all stages of production of a component: design and selection of the material to be used (polymers, metal alloys or ceramic-based), printing and quality control and conformity of the end product.
BEAMIT focusses on the use Powder Bed Fusion (PBF) printing technology that can print components in 13 metal materials. The company has printing platforms of different sizes (250x250x200mm, 400x400x360mm and 280x500x360mm) that can also operate in multi-laser mode, i.e. with four laser beams working simultaneously on the material to be printed.
BEAMIT also processes ceramic materials using NanoParticle Jetting (NPJ) technology. A key area of interest for the space sector is the possibility of printing components that can weigh up to 60% less than those made using traditional technologies, thus reducing the cost of transportation to orbit while maintaining the same performance.

BEAMIT

Caracol has developed proprietary technologies for the 3D printing of large components for the aerospace industry using high-performance materials.
In particular, the company has engineered flexible 3D printing hardware platforms that use robotic arms to rapidly print large-scale monolithic components. Caracol is able to print these large monolithic components and finish them on CNC machines using ultra-high performance ceramics and composites, according to specific requirements. Caracol can rely on proprietary algorithms and a patented extrusion system that ensures time savings compared to traditional techniques and significant waste reduction. In the printing of aircraft fuselages, Caracol's solutions enable high-precision machining to achieve a dimensional tolerance of 0.1 mm.

Caracol

There is an italian industrial chain specialized in testing of products and materials that must guarantee high performance in critical conditions

3.3.4 Material testing

The need to comply with very stringent standards and to ensure that a specific material or a specific 3D-printed product is able to guarantee a high level of performance has contributed to the emergence of **an Italian industrial chain specialising in testing**.
The aim is to increase the reliability of products and reduce the probability of malfunctions in space or during critical phases such as launch into orbit.
Companies operating in this sector use technologies and methodologies that can be applied in many industrial fields that require high performance in critical conditions, such as the energy, automotive or biomedical sectors.

Sòphia High Tech has developed expertise in the field of engineering and testing for various industries, including the defence and space sectors.
The company specialises in checks and testing and has extensive know-how in the field of **structural simulation**. Sophia High Tech has consolidated experience in the management of mission critical applications, particularly in the mechanical and electronic sectors.

Sophia High tech

Non-destructive testing of components and materials is one of main activities of **Tec Eurolab**.
The company carries out laboratory tests on materials using traditional techniques and non-destructive testing surface methods, i.e. Visual Inspection (VT), Liquid Penetrant Testing (PT) and Magnetic Particle Testing (MT).
Tec Eurolab also specialises in volumetric non-destructive testing using advanced technologies: RT Film (Film), RT Non Film (Computed Radiography - CR), RT Non Film (Computed Tomography - CT), Ultrasonic Testing (UT). Tec Eurolab can provide services for the engineering and advanced simulation of 3D components, and validate the production process.

Tec Eurolab

Labormet due specialises in the supply of quality control services.
In particular, the company has an in-house laboratory for metrological analysis and industrial X-ray computed tomography.
Tomographic techniques allow in-depth non-destructive analysis, such as dimensional checks, defect analysis and scan vs reference comparisons. Labormet due's laboratories handle the measurement and characterisation of composites and metals. The company collaborates with various aerospace and defence groups.

Labormet due

TiberLab, a spin-off of the Tor Vergata di Roma university, specialises in the implementation of simulation software.
TiberCAD is a software used in the design and advanced simulation of nanostructures in the fields of micro-nanoelectronics, nanotechnology and advanced materials. TiberCAD adopts a multi-scale approach that can be employed in the simulation of multiple models, such as particle transport or mechanical deformation of materials.

TiberLab

The need to test new materials in heterogeneous industrial fields prompted ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile) and CNR (Consiglio Nazionale di Ricerca) to establish **CERTIMAC**, a technical body with scientific expertise and state-of-the-art laboratories. The body has a laboratory equipped for the qualification of fibre-reinforced composite materials, also in the field of infrastructure.

Certimac

3.3.5 The near Future

There are many new materials that could unlock new applications and products with innovative features.
In this context, both ceramic and composite materials, with their lightweight and resilient characteristics, could be used in range of other fields such as the aeronautics, automotive or biomedical sectors. However, the standardisation and certification time frames for these new materials, especially in the case of dual-use technology (civil and military), are long and subject to very complex procedures.

Lunar materials

One area where the research of new solutions has been very active concerns the possibility of using **lunar regolith** for the construction of buildings and infrastructure. The idea is to exploit the material found on the Moon to reduce the costs of transporting and building lunar bases and structures. Additive manufacturing of lunar regolith bricks would make it possible to exploit the physical properties of the material, which has the ability to capture and store solar energy during the day and maintain structures at temperature during the hours of darkness. Regolith also appears to be effective in shielding astronauts at space bases from radiation.

The same 3D printing techniques in low gravity conditions could be exploited to establish human settlements on Mars and, in the distant future, on other planets in the solar system. They could be used to create mining facilities for minerals or other raw materials on celestial bodies that have a near-zero gravitational field, such as planetoids or asteroids.
Tests and research activities in this specific field could have spin-off effects on the development of technologies enabling the 3D printing of buildings on Earth, using alternative instead of traditional materials, possibly locally available, to keep costs and lead times down.

Research is also looking into hydrogen and oxygen production systems that exploit the ice potentially present inside regolith to produce energy and breathable air for future human settlements. **Thales Alenia Space** is working on the development of a demonstration payload for ESA lunar missions that uses molten salt electrolysis to extract oxygen from moon rock.

Hyperspectral technology for identifying materials from space

The ability to use satellites to identify ground-based materials and their chemical composition is evolving rapidly thanks to technology. **Hyperspectral** technology, also known as **spectroscopy**, has been used in laboratories for more than a century to identify chemical substances and their composition by studying the emission spectrum of an element which, under certain physical conditions, determines its "spectral signature".
Satellite hyperspectral technology combines "imaging" and spectroscopy in a single system.

Italy is playing a leading role in this area thanks to **PRISMA (PRecursor HyperSpectral Satellite Application Mission)** (see Chapter 2.6).
PRISMA is able to identify even small quantities of materials on the earth's surface, such as asbestos on the roofs of houses, and can also determine the quality of water and identify its pollutants (minerals, chemicals, plastics, etc.), and characterise the conditions of the atmosphere and the chemicals it contains.
Italian leadership in this particular sector will be consolidated by the second generation system, PRISMA2G, whose development was announced by the Italian space agency ASI in early 2022.

ASI – PRISMA 2G

Service / Product	Description	Application area	Company
High performance ceramic materials	Reinforced ceramic composite able to withstand extreme thermal and mechanical stresses, as in the case of re-entry of spacecraft into the atmosphere	**Materials able to withstand extreme stresses**	**Petroceramics**
High performance ceramic materials	Biocompatible silicon nitride-based material for bone endoprostheses	**Biocompatible material for prostheses**	**Petroceramics**
High performance ceramic materials	New-generation ceramic material for spacecraft equipped with Structural Health Monitoring Systems (SHMS)	**Materials able to withstand extreme stresses**	**S.A.B. Aerospace**
Acellular material for surgical implants	Latest generation acellular material that can be used to fill some types of bone voids during surgery	**Biocompatible material for prostheses**	**GreenBone**
Biocompatible prosthesis	High-bioavailability bone substitutes for use in regenerative surgery (orthopaedic surgery and neurosurgery)	**Biocompatible material for prostheses**	**Finceramica**
Circular economy-based approach to using waste products	Exploiting waste from fish farms to make materials for applications in the cosmesis and agriculture sectors	**Chemical compounds**	**Recover Ingredients**
Piezo components	Components using high-performance piezo technology	**Composite materials**	**IPECC**

Service / Product	Description	Application area	Company
Polycrystals for lasers	Production of crystals based on transparent ceramic materials with performance and properties superior to crystals currently available for industrial applications, for high-power precision lasers	**Transparent ceramic materials**	**ZENIT Smart Polycrystals**
Ultra-High Temperature Ceramic Matrix Composites	Production of Ultra High Temperature Ceramic Matrix Composites (UHTCMCs) able to withstand extreme temperatures (above 2000 degrees centigrade) with a limited erosion rate, for use in extreme applications (e.g. thermal protection systems for re-entry of spacecraft into the atmosphere)	**Materials able to withstand extreme stresses**	**X3RX**
High-performance composite materials	Pre-impregnated carbon fibre composite for building engines for launchers	**Composite materials**	**Avio**
Carbon fibre	High-performance carbon fibre at a lower cost	**High-performance carbon fibre**	**MAE, Leonardo**
High-performance composite materials	Design and production of high-performance composite materials for aerospace and motorsport applications	**Composite materials**	**Bercella**
High-performance plastics	Lightweight plastics with high resistance to mechanical stress, low outgassing in vacuum conditions and good resistance to high levels of radiation in space	**Plastics**	**Ensinger**

Service / Product	Description	Application area	Company
Metamaterials	Metamaterials for the production of high-performance, ultra-flat antennas and arrays	**Metamaterials for telecommunications**	**Wave-Up**
Metamaterials	Plasma and metamaterial-based technology for building antennas used in telecommunications and navigation	**Metamaterials for telecommunications**	**Alma Sistemi**
Graphene cooling systems for satellites	Highly efficient and lightweight cooling systems for satellites and space exploration vehicles	**Satellite components**	**Leonardo**
Production of graphene nano-platelets	Production of graphene nano-platelets via physical processes only	**Graphene production**	**Directa Plus**
High-performance 3D printing	Filament Fusion Fabrication (FFF) 3D printing technology using materials and polymers with high physical and mechanical performance	**3D printing**	**Roboze**
Ultra-high precision 3D printing	3D printing system based on a mechatronic movement with gears and without the use of belts, called Beltless System, able to ensure a level of accuracy down to 0.01 mm	**3D printing**	**Roboze**
3D printing with metal alloys	3D printing of complex metal parts using Selective Laser Melting (SLM) printing technology	**3D printing**	**HB Technology**

Service / Product	Description	Application area	Company
3D printing with metal alloys	Design and production of materials and metal alloys for 3D printing. Use of Powder Bed Fusion (PBF) printing technology	**3D printing**	**BEAMIT**
3D printing of large-scale monolithic components	3D printing of large-scale monolithic components using high-performance materials, through a proprietary hardware platform (based on the use of robotic arms)	**3D printing**	**Caracol**
Advanced material testing and simulation	Checks and tests, and structural simulation services	**Quality control and simulation**	**Sòphia High Tech**
Advanced material testing	Laboratory tests on materials using traditional techniques, non-destructive testing surface methods and volumetric non-destructive testing using advanced technologies	**Quality control**	**Tec Eurolab**
Advanced material testing	Supply of quality control services. In particular, the company has an in-house laboratory for metrological analysis and industrial X-ray computed tomography	**Quality control**	**Labormet due**
Simulation of nanostructures	Software used in the design and advanced simulation of nanostructures, applied in the fields of micro-nanoelectronics, nanotechnology and advanced materials	**Simulation of materials**	**TiberLAb**
Certification and qualification of materials	Technical body with a laboratory equipped for the qualification of fibre-reinforced composite materials, also in the field of infrastructure	**Certification Body**	**Certimac**

3.4 Telecommunications

The main contribution that new aerospace technologies make to the telecommunications sector is the possibility of bringing data transmission to any corner of the Earth, with widespread distribution, overcoming the barriers of long distances and rougher terrain.

Globally, the internet access gap between different countries has gradually widened, according to each country's level of development.
This is not only due to economic factors but also to challenges in bringing connectivity to geographical areas that have complex orography and low population density. Many technologies are currently being developed to provide broadband connectivity services even in hard-to-reach areas or have a low population density or are otherwise underserved.

3.4.1 High Altitude Platform Stations – HAPS

The aerospace industry has completed numerous studies and research projects to bring to market stratospheric platforms capable of providing mobile network connectivity and transmission in areas not covered by terrestrial networks.
High Altitude Platform Stations (HAPS) make it possible to deploy wireless broadband in areas that would otherwise be hard to reach with ordinary technologies (i.e. mountainous areas, deserts, etc.) or that are currently unserved for other reasons.

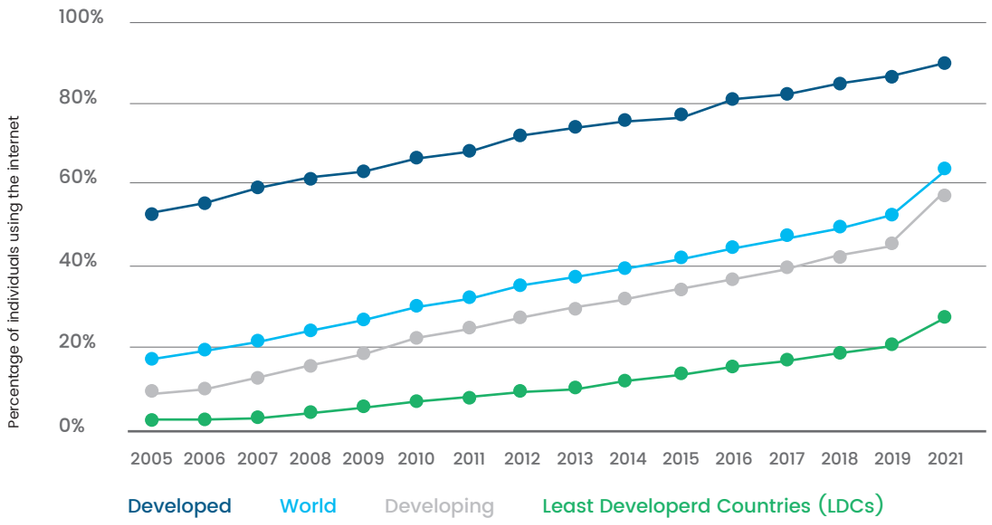
HAPS are flexible and easily deployable according to the needs of telecommunications companies. For example, they can be rapidly deployed to provide broadband and other telecommunication services in emergency situations such as natural disasters, or to handle other types of events that result in a temporary strong increase in demand.
The possibility of interconnecting HAPS (inter-HAPS links) makes this solution very flexible given that the use of ground network infrastructure is reduced.

This is the business sector of **Stratobotic** (see section 3.2), a start-up company based in Turin that is conducting feasibility studies on the use of HAPS technology in contexts where there is a requirement to extend the ground telecommunications network across the sea.

This is achieved by establishing a bridge connection between the national ground-based antennas and different types of vessels, using telecommunication payloads installed on board stratospheric balloons. The platforms are then optimised for autonomous station keeping, launch and recovery activities using artificial intelligence. Stratobotic offers HAPS prototyping services for building customised stratospheric platforms and payloads dedicated to low-cost earth observation. The company is also working on the development of low-latency data transmission equipment.

Stratobotic

Percentage of global population accessing the internet from 2005 to 2021, by market maturity
Source: Statista



3.4.2
Latest generation antennas

The need to ensure increasingly stable and high-performance connections in satellite telecommunications, even on the move, is leading to the emergence of new generations of antennas.
The growth in innovative antennas and customised telecommunication services is also driven by number of IoT connected devices on the market. The intensity of data traffic related to IoT devices is continuously increasing and it is estimated that this trend is similarly reflected in satellite connections.

When it comes to broadcasting, **Digital Video Broadcasting Satellite** (DVB-S) technology offers two types of applications. The first is Direct To Home (DTH), i.e. the classic application for domestic use where the main challenge is the build terminals (i.e. antennas) that have a low visual impact for installation on historical buildings and/or in areas of great landscape value.
The second is Direct to Vehicle (DTV).
The latter is a technological sector that has a long-term goal (target 2030) to equip cars with terminals that are capable of receiving satellite signals for the exchange of information (audio/video content) or for real-time vehicle monitoring.

In this field, **Wave-Up** proposes solutions that lie somewhere between the world of research and industrial/commercial applications.
The company designs metamaterial-based **ultra-flat antennas**, dielectric lenses, polarisers, shaped reflectors and arrays. Metamaterials are materials that are artificially engineered to give them precise electromagnetic properties that naturally occurring materials do not possess. By using metamaterials with innovative electromagnetic properties, Wave-up is able to implement highly efficient beam-forming solutions in ultra-flat antennas.

Wave-Up

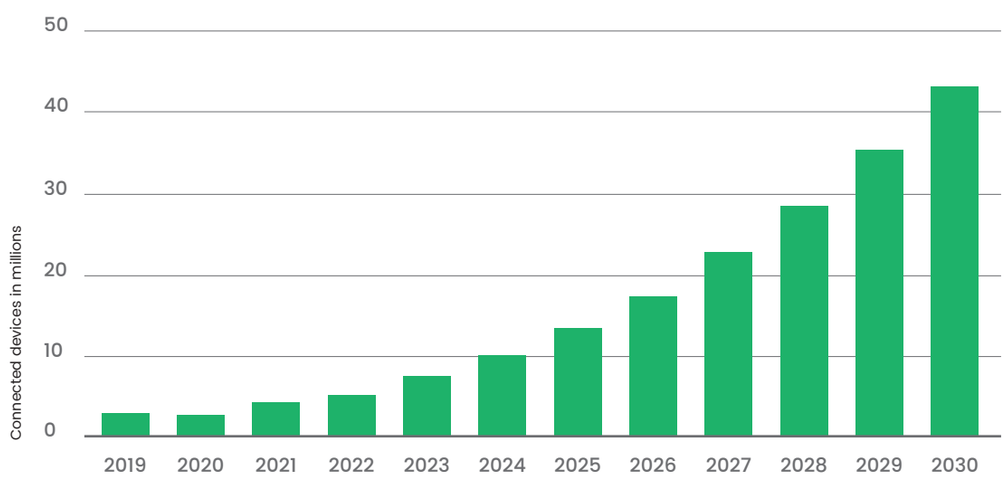
The emergence of small constellations of satellites in low orbit (see Chapter 2.3) and the growing demand for customised antennas and products for telecommunications has led **RF Microtech** to design and manufacture antennas and phased arrays for telecommunications, according to customers' requirements.
The company, established in 2007 as a spin-off of the Università di Perugia, develops solutions for companies and system integrators operating in the telecommunications, SatCom, aerospace, localisation and manufacturing industries. The company has decades of experience in the production of flat array antennas, high-power and high-efficiency radars, beam forming networks, reflect-arrays and transmit-arrays. RF also produces components such as microwave filters and dedicated sensors.

RF microtech

In this sector, **Antech Space srl,** founded in 2016, offers turn-key solutions for Ka, K, Ku, X, C, S and L band telecommunications.
The company produces fixed and mobile antennas, the electronic parts for their management and radio frequency instrumentation for signal reception and transmission. Antech specialises in the production of **Antenna Control Units (ACU)** for satellite systems in GEO/LEO/MEO orbits (see Chapter 2.3).

Antech Space

Number of Internet connected devices worldwide from 2019 to 2030, satellite-based
Source: Statista



Metamaterials have electromagnetic characteristics that do not exist in nature

3.4.3
Satcom on the move - SOTM

The main innovations in this sector concern both ground-based data receivers/transmitters and platforms in orbit around the Earth.
In the field of mobile services, **Satcom on the Move (SOTM)** refers to all applications associated with mobile satellite communications technology, with reference in particular to means of road, sea or air transport.
The basic principle behind SOTM is that a vehicle equipped with a satellite antenna is able to establish communication with a satellite and maintain this communication while the vehicle is moving. This technology area includes IoT and **M2M (machine-to-machine)** terminals that interconnect via non-geostationary broadband constellations (satellites in orbit moving relative to the user's position on Earth) for applications with global coverage of telemetry, tracking for land and/or maritime transport, alarm devices, geo-positioning and asset tracking.

A typical example of a situation where, due to particularly complex orography, there is limited access to telecommunication and broadband services is a ship on the open sea, at a long distance from ground-based communication stations.
Given that the demand for broadband connectivity and telecommunication services for industrial use is also growing in these environments, new technologies specific to these fields of application are emerging.
Specifically, when vessels are far out at sea, the ability to have accurate global maritime route tracking and carry out spatial analysis has been made possible by the advent of **Automatic Identification System (AIS)** technology, which is able to provide a wide range of information on the vessels and their position in a standardised format.
In fact, for some years now, ships over 300 tonnes are mandated to carry an automatic identification system. AIS transponders automatically transmit information at regular intervals. These signals are received by AIS transponders installed on other ships or by land-based systems. However, the signals have a horizontal range of about 40 nautical miles (74 km), which means that AIS traffic data is only available around coastal areas or in the ship-to-ship zone.
Satellite-Based Automatic Identification Systems (SAT-AIS) overcome this limitation, improving tracking and tracing by relying on aerospace technology. They use small orbiting satellites equipped with AIS transponders to receive information from the ship and relay it back to the ground station.

In collaboration with the Italian Space Agency, **MBI S.r.l.** has conducted the first experiment in Italy to launch a SAT-AIS system on-board a stratospheric balloon to test its reception capacity. The advantage of this solution is the significant reduction in cost compared to launching satellites with dedicated payloads.

MBI

Also active in the field of multi-band satellite systems for SOTM communication is **Ingegneria dei Sistemi (IDS)**, which markets big data transfer solutions that use a remotely controllable multi-band transmission system.
IDS's antennas are designed to work with all the main bands (X, Ku and Ka) in aeronautical, naval and ground applications. The company is working to implement the use of the Q-band in future products.

IDS

3.4.4
The Near Future

The number of mega-constellations for telecommunications in low earth orbit is growing rapidly. Likewise, the number of small and very small satellite constellations for specific uses is also growing (see Chapter 2.3).
Intra-satellite communications for small satellites are, and will increasingly become, a crucial factor for the management of these constellations.

In 2021, **Stellar Project**, a start-up founded in 2016 as a spin-off of the Università di Padova, launched **LaserCube** (see Ch 2.4), a low-power, high-performance miniaturised laser communication terminal specifically designed for mini-satellites, which features two different configurations, downlink and inter-satellite link, bringing innovation mainly associated with the high speed of data transmission.
LaserCube mounts an optomechanical unit featuring a dual-stage pointing system. The innovative payload developed by Stellar Project brings the inter-satellite communication performance typical of large satellites to constellations of small satellites.

Stellar Project

The strong growth of data produced by satellites required a new approach for their transmission to ground stations

Another area where technological progress has accelerated is the field of satellite observation of weather and climate and in monitoring the earth's surface and atmosphere.
Over the past 10 years, various sensors (radar, lidar, radiometers, etc.) in the 30-300 GHz band have come onto the market. These sensors can be used to expand knowledge of meteorological and climatological phenomena and improve the associated prediction models. However, as the resolution and number of sensors increases, and the number of satellites with this type of payload increases, so does the amount of data collected.
The need for a suitable transmission system to send information to ground stations can be satisfied by adopting an integrated **TeLeCommunication-Earth Observation (TLC-EO)** approach.

A study on the feasibility of a satellite payload for high-frequency transmissions for use in both Earth observation and telecommunications was the subject of the work carried out by the Advanced Research and Engineering for Space (ARES) consortium, a collaboration between scientific institutions (Università di Roma Tor Vergata) and industrial partners (Rheinmetall Italia and TEchnological Consulting Services - TECS). The study in question, which goes by the name of **PayLoad for Advanced Telecommunication, Observation and Navigation - PLATON**, is based on the use of the millimetre band to exploit the efficiency of high frequencies in terms of transmission, and will include a dual Tx/Rx system in the Ka/W band.
The TLC-EO approach is a very practical and cost-effective solution for managing communications between earth observation satellites and ground bases in a more integrated and efficient way.

Service / Product	Description	Application area	Company
Satcom on the move - SOTM / Antennas and phased arrays	Antennas and phased arrays for telecommunications, customised according to customers' requirements	**Antennas and phased arrays for telecommunications**	**RF Microtech**
Satcom on the move - SOTM	Multi-band satellite antennas for SOTM communications	**Antennas for telecommunications**	**IDS**
Satcom on the move - SOTM / Satellite telecommunications systems	Antennas, dedicated radio frequency interfaces and peripheral electronics for mobile and fixed broadband satellite telecommunications systems	**Broadband satellite communications**	**Antech Space srl**
Inter-satellite laser link for small satellites	Payload for communications between small satellites using inter-satellite laser link technology	**Satellite payloads for communications between satellites, Cybersecurity**	**StellarProject**
Satellite-Based Automatic Identification Systems - SAT-AIS	SAT-AIS payload mounted on a stratospheric platform e.g. a balloon) for ship monitoring and tracking.	**Vessel monitoring**	**MBI S.r.l.**
High Altitude Platform Stations – HAPS	Use of HAPS stratospheric platforms to create telecommunications networks	**HAPS with payload for telecommunications**	**Stratobotic**
Ultra-flat antennas	Metamaterial-based production of ultra-flat antennas	**Reconfigurable antennas**	**Wave-Up**

3.5 Mobility, Transport and Tourism

The transport and mobility sector is undergoing rapid change, spurred on by the drivers of energy transition, cooperative/connected/automated mobility, new service models and user behaviour. Transport is fundamental to the economy, and efficient and sustainable mobility, vital for the market and citizens' quality of life, is actively enabled by an extensive network of satellite services.

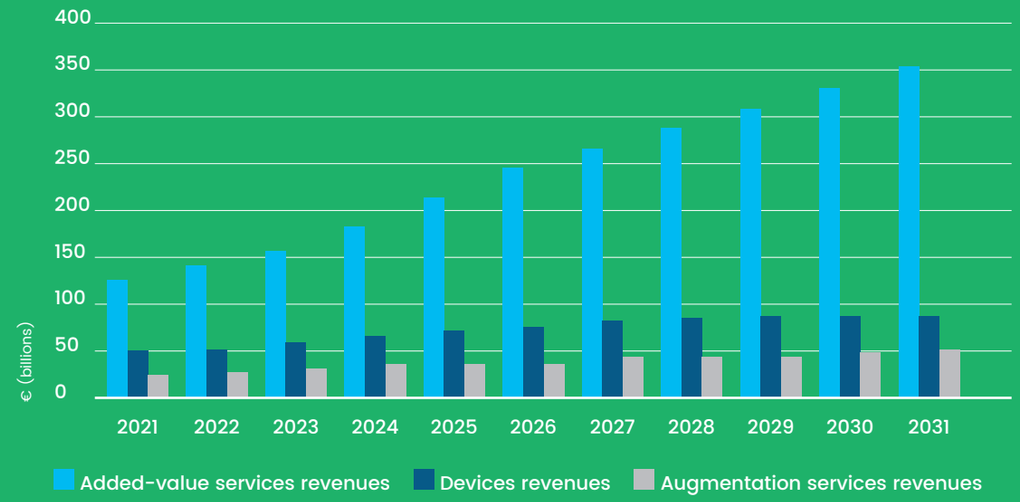
Satellite navigation services (see Chapter 2.5), satellite communications (see Chapter 2.4) and earth observation (see Chapter 2.6) contribute in different and synergetic ways to the evolution of the world of mobility, logistics and tourism.
These enabling technologies provide crucial information for the management of advanced services and products. Increasingly, data are provided in real-time or at very close time intervals.
At national level, the National Research Plan (PNR 2021-2027) devotes great attention to the transport sector, both in terms of its driving force for the national economy, and in terms of its role as a driver of development in the economic and industrial sectors, the country's traditional areas of excellence. The aim of this specific focus and concentration of efforts is to take the transport infrastructure sector back to the frontier of technological advancement and to revive the tradition of innovation that has characterised Italian industry in this sector.
Investments in the sector mainly concern the use of innovative technologies, including aerospace technologies, to achieve sustainable mobility.

3.5.1 Satellite navigation services market

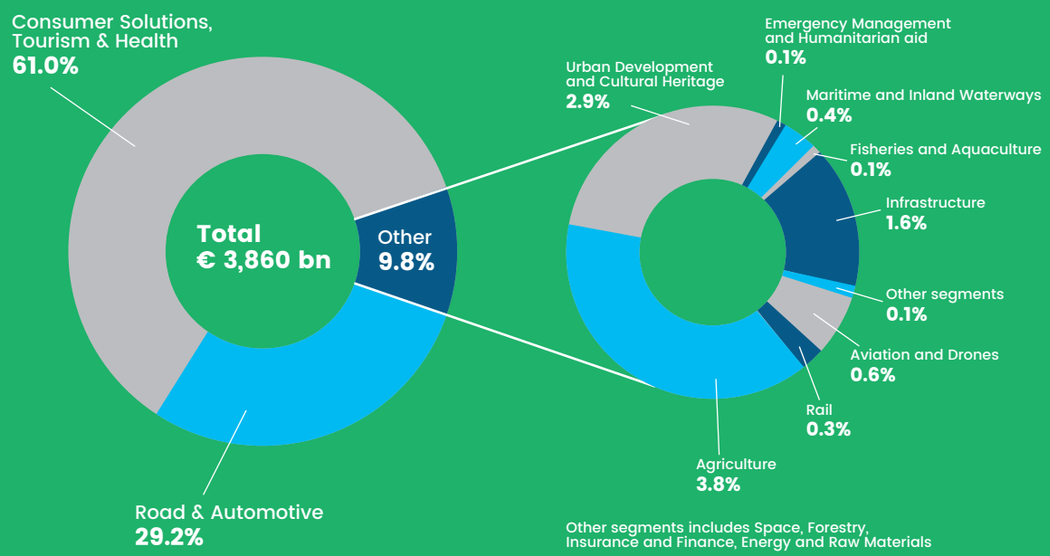
Geo-positioning, satellite navigation and assisted driving are the most exploited satellite services used to engineer innovative products in the Mobility, Transport and Tourism sector

The worldwide market of Global Navigation Satellite System (GNSS) satellite navigation and positioning technology is showing strong growth.
The "EO and GNSS Market Report - Issue 1 2022" of the European Union Agency for the Space Programme confirms this trend for both devices and services. In 2021, global revenues from the sale of GNSS devices totalled EUR 48.4 billion and growth is expected to reach EUR 87 billion in 2031.
The services sector is expected to grow even faster: in 2021, the global market reached EUR 150 billion, and the forecast for 2031 is for steady growth to EUR 405 billion. According to this projection, the Asia-Pacific region will play a leading role in this expansion phase. Global revenues of the GNSS

Revenue from GNSS devices sales and services
Source: EO and GNSS Market Report – Issue 1 2022



Cumulative revenue by segment 2021-2031
Source: EO and GNSS Market Report – Issue 1 2022



downstream market will grow from EUR 199 billion in 2021 to EUR 492 billion in 2031, at a CAGR of 9.2%. In particular, value-added services will grow by 11% per year, from EUR 126 billion in 2021 to EUR 354 billion in 2031.

EUSPA Market Report 2022

The EUSPA report highlights that up to 2031, 90% of market revenues will come from the consumer sector (61%) and the road & automotive sector (29.2%).
In detail, in the latter sector, most revenues will be generated by advanced navigation services, Advanced Driver Assistance Systems (ADAS), emergency assistance and intelligent fleet management applications.

Thanks to satellite services, start-ups providing high value-added services in the mobility sector are increasing.
Satellite navigation and accurate positioning ensured by GNSS constellations like Galileo (see Chapter 2.5) are real enabling technologies for the development of advanced applications, services and products.
Italian start-ups in the sector of remote sensing and satellite-based mobile services were mostly established by university research groups. This sector, in which Italy is playing an important role, is an example of how public and private capital can find common ground to enter one of the most promising business sectors for the coming years.

3.5.2 Mobility and transport

The mobility and transport sector makes extensive use of space technologies to provide communication services and navigation and positioning services (see Chapter 2.5).
Navigation based on Global Navigation Satellite Systems (GNSS), such as GPS and Galileo, has been available with very high accuracy and reliability since the early 2000s.
The new frontier for innovation lies in the ability to integrate this type of technology with advanced solutions that allow authentication of user position or the use of data fusion techniques to provide high value-added services without heavy investments in physical infrastructure on the ground.

SpaceEXE, established in 2013 under the ESA-BIC start-up incubation programme, has developed EAGLE, an innovative **urban traffic monitoring** device.
EAGLE integrates a high-precision GNSS receiver with position authentication capability through a proprietary technology. EAGLE can be mounted on any type of vehicle and communicate its precise and authenticated position to the city infrastructure.
This technology can be used by public administrations to create **fluid and flexible** Limited Traffic Zone **(ZTLs)** and therefore manage access to city centres in a smarter way without using standard physical barriers.

The platform makes it possible to manage traffic by implementing differential access to the city centre based on specific needs, e.g. in the case of events, road closures to cut pollution or maintain air quality, requirements of commercial businesses.

Spaceexe EAGLE

Implementation of user position authentication services as the next step towards Smart Mobility

These services enable new types of applications for use by public administrations in the field of traffic, parking and police management, as well as more efficient forms of fleet monitoring for both the public and private sectors.

In the field of assisted driving, **Aresys**, founded in 2003 as a spin-off of the Politecnico di Milano, has extensive experience in numerical signal processing applied to remote sensing systems.
Its products range from synthetic aperture radar systems, which can monitor even millimetre displacements of observed targets, to prospecting systems based on seismic reflection, mainly used in the field of hydrocarbon exploration.
The company has used its know-how in the fields of imaging, interferometry and tomography to develop an **Advanced Driver Assistance system** (ADAS) that exploits radar technology.
Among the different sensors and technologies used in ADAS systems, radar is essential in standard obstacle detection applications but is also increasingly being proposed for advanced imaging tasks, often in combination with optical and lidar sensors, using data fusion techniques that allow vehicle control units to obtain information from multiple sources for better accuracy and high resilience.

Aresys Automotive Radar

EICAS Automazione has conducted numerous research projects and experiments in the field of precise localisation of vehicles (automotive sector) and Automated Guided Vehicles - AGVs (industrial sector).
EICAS has developed a platform that uses data fusion algorithms to combine data from GNSS and GIS systems with data obtained from other vehicle-mounted sensors for use in **collision avoidance and autonomous driving applications**.

EICAS Automazione

Another sector where space-derived technology is being widely applied is the **railway** sector.
Italian companies of interest in this field include **Intecs Solutions**, a system

engineering company that designs and builds software, platforms and dedicated hardware for the aerospace, defence, telecommunications and transport sectors.
In the latter field, the company has harnessed the technical expertise acquired in the aerospace sector, particularly with regard to communications resilience and capability for sending and receiving ground data in Ka-band, to bring to the market a new class of railway communications and rail network safety products.
In particular, **E-Muser** - the Enhanced MUlti SEnsor Data Handler for Railways - is designed to provide trains with high-performance connectivity capable of automatically switching between terrestrial and satellite telecommunication networks while complying with safety regulations and railway industry standards.
The use of E-Muser facilitates the adoption of the latest European safety standards for rail traffic, enabling constant monitoring of train routes and paving the way for autonomous driving in the rail sector too. The product ensures high-performance satellite connectivity through use of the Ka-band (see Chapter 2.4). Another product designed to ensure redundant communications in the railway sector is the MULTI BEARER NODE (MBN), which can automatically switch between fibre optic connections and wireless connections in LTE or Ka-band.

Intecs Solutions

In the field of fleet tracking, **GAG Technology** has developed the **Cloud Carfleet platform** to provide automotive companies and fleet managers with a unique system, based on GNSS technology, to manage and monitor the fleet and improve vehicle tracking and maintenance management.
This solution is designed for organisations with a fleet of at least 30 vehicles. The service automatically collects, integrates and consolidates data relating to rentals, fuel, motorway companies and insurers, covering the entire corporate fleet management process: daily fleet management, ecological aspects and taxation (automatic calculation of taxes, salaries and non-deductible depreciation). In addition, GAC Car Fleet is supplied in Software as a Service mode. Access is therefore possible from any computer with an internet connection and no local installation of the software is required.

GAC Technology

Planetek (see Chapter 2.6) has developed an approach that integrates information from various sources, in particular GNSS, GIS and other types of data from sensors installed on vehicles and road infrastructure. The company specialises in the implementation of platforms for the use of geo-localised information.
In the field of infomobility, Planetek has developed a vertical platform, adaptable to customer needs, that integrates GNSS, earth observation and GIS data and data from other sources for the efficient management of public transport, reducing running costs and increasing the quality of the service for end-users with a view to encouraging greater use of public transport. The platform is designed for all providers of transport services, from freight transport to the management of other types of fleets with connected vehicles.

Planetek

Continuing on the topic of transport, **NeMea Sistemi** has used its expertise in GIS to implement solutions that combine information from space sources with high-precision maps and Geographical Information Systems (GIS).
One example is TRUCKS - Transporti Eccezionali, a platform designed to manage and automate the routing and subsequent authorisation process for the transportation of loads of an abnormal size. The system is able to provide results based on transportation type and the size of the vehicle, taking into account the morphological characteristics of the road network and its capacity to handle abnormal loads.

Nemea Sistemi

3.5.3 Indoor positioning

Indoor positioning is a special and challenging field, where several technologies are exploited simultaneously to provide users with an efficient positioning and navigation service even when GNSS satellites are not in sight.
The indoor mobility sector has been growing steadily since 2013. The target market will reach a projected turnover of approximately USD 41 billion in 2022.
The global indoor positioning market offers countless effective applications in areas ranging from mobility to tourism and logistics. These applications enable navigation to gates or information facilities, turn-by-turn navigation to entertainment venues, and customer routes through shops.

The creation of **hybrid receivers** capable of handling signals from satellite navigation systems and other sources is gaining industry-wide recognition.
ProEsys, a start-up incubated by ESA BIC Lazio in 2015 (see Chapter 1), makes hardware and software platforms for the Industrial Internet of Things sector, which exploit LoRa technology and can operate on terrestrial or satellite telecommunications networks. In particular, its products contain GNSS and Ultra-Wide Band (UWB) receivers to enable high-precision indoor localisation services.

The ProeEsys platform consists of two components that work synergistically.
The first is WEARLOC-1, which is a wearable tracker that can worn by an individual or placed on an asset/vehicle. The product integrates LORAWAN™, UWB and GNSS technologies to ensure optimal outdoor and indoor coverage. The LoRaWAN™ low power system is used for outdoor communication, with a range of up to 15 km from the gateway. The device uses UWB technology for communications and precise indoor localisation. WEARLOC-1 mounts other sensors, such as an accelerometer, and is totally waterproof.
The second device, called SMARTLOCK-3D, is the system that enable the 3D localisation of the WEARLOC-1 target trackers. The platform is based on the implementation of a network of anchors that make it possible to locate the target trackers with very high accuracy, both indoors and outdoors. Outdoors, the device can achieve accuracy down to less than 1 cm and an approximate angle of 0.07°. SMARTLOCK-3D is designed to be integrated in industrial or logistics environments that have existing infrastructure installed given that there is no interference due to its low power density of approximately -41 dBm/MHz.

ProEsys

Continuing on the topic of indoor positioning, **Gipstech**, a spin-off company of the Università della Calabria, has developed an indoor navigation system capable of guaranteeing effective positioning in situations where GPS is of no help.
GiPStech's inertial engine enables **inertial tracking**, i.e. to accurately detect the user's steps and determine the direction of movement regardless of the orientation of the device used (smartphone, sensors, etc.).
GiPStech solutions include geomagnetic localisation, which uses the compass sensor in smartphones to analyse the unique magnetic footprint of each building, created by the interaction between the earth's magnetic field and the materials used in the structure of the building. The inertial engine uses algorithms that improve the accuracy of positioning for both pedestrians and vehicles in situations where satellite signals are subject to interference or lack precision, such as in urban canyons and under tree cover.
In the case of indoor localisation, available Wi-Fi and Bluetooth signals are also integrated to deliver accuracy down to one metre. This approach allows existing signals to be exploited without the need to install dedicated beacons, thus reducing costs and deployment time. Gipstech has entered into an agreement with Here Technologies, a European leader in the field of maps and automotive localisation services.

GiPStech

3.5.4
Tourism and cultural heritage applications

Services based on information obtained from Geographic Information Systems (GIS) have been used for some time but applications have been limited over time due to the difficulty of retrieving, analysing and managing this information.
Specifically, GIS can play an important role in creating maps enriched with information, points of interest and earth observation imagery to be offered both to businesses in the tourism sector and end users.
The spatial analysis functions of GIS make it possible to create new value-added services to provide a large amount of information to users, even in real time. For example, in addition to images obtained from earth observation satellites, satellite data concerning air quality or the atmosphere can be integrated for highly accurate and customised weather forecasting.

In the field of tourism mobility, the hydro-meteorological start-up **MobyGIS S.r.l.** has developed **Mysnowmaps**, an operational service for the high-resolution monitoring of snow depth, which integrates in-situ observations with satellite data.
The service combines the latest hydrological models with artificial intelligence techniques, integrating satellite data, Big Data, AI, physical models and GIS to provide water supply analyses and forecasts.
Users can access the Mysnowmaps portal to check real-time snow conditions, predicted accumulation, slope inclination and exposure and snow depth throughout the Italian Alps. Useful information for hikers, ski mountaineers and skiers, who can consciously plan their excursions and, at the same time, contribute to the monitoring of snow conditions, sharing their excursions and observations with the entire community of enthusiasts. In 2020, the start-up won the EC EU Space for 'Blue Economy Challenge' of the Copernicus Masters.

Mysnowmaps

In this particular sector, it is important to create customised products according to the end customer's requirements, as GIS and earth observation data can be exploited at multiple levels.
Planetek has a great deal of experience both in the collection and processing of optical and radar data from earth observation satellites, and in the management of the entire workflow through the implementation of dedicated software platforms.
A prime example is the SIWGREI platform, a WebGIS Information System of the Italian Hiking Network, developed specifically for the Italian hiking association Club Alpino Italiano (CAI). Through SIWGREI, CAI members have access to a web GIS containing all the information they need to plan excursions: elevation profiles, high-resolution maps, satellite images, points of interest. The system also allows trails to be downloaded to mobile devices for use during hikes.
SIWGREI is designed as a trail management tool for CAI administrators, who use it collect information from users and personnel to add geo-location information, which is then used to manage and maintain the trails and signage.

A more all-encompassing approach is adopted in the N@VITour feasibility study, funded by the European Space Agency under the ARTES20 integrated applications promotion programme.
The programme aims to promote applications that make synergetic use of multiple space technologies, in particular, satellite navigation, earth observation and satellite communications. N@VITour integrates these three technologies to provide visitors to parks and nature reserves with very detailed and up-to-date information for the enjoyment of the natural areas, and to ensure connectivity services even in areas where there is no land-based mobile network coverage.
N@VITour uses GPS and the EGNOS augmentation service (see Chapter 2.5) to provide very accurate positioning services: Galileo support will be implemented as soon as the European constellation is fully operational. The platform is also designed to make it easier for park operators to collect information to support the management of their park assets. The Majella National Park in Abruzzo is currently the main user of this experimental platform.

Planetek

A niche sector but with high growth potential is the field of aviation meteorology for light recreational aircraft.
In this area, **SpazioFuturo** has responded to market demand by developing the European MicroMeteorology for Aircraft (EMMA) service.
The application processes high-resolution weather forecasts to deliver weather observations updated in real time with satellite data. EMMA is based on proprietary algorithms. The system can also be used in flight via the dedicated GABBIANO app, which allows the pilot to carry out weather-based flight planning and receive up-to-date information every 15 minutes. GABBIANO displays meteorological information on winds, humidity, visibility, the presence of cumulonimbus clouds and rainfall, as well as a range of other useful data for flying ultralights.
SpazioFuturo has also designed a satellite modem to provide data connectivity to devices that use GABBIANO even at altitudes out of range of terrestrial networks. Looking to the future, SpazioFuturo's approach is interesting for its target market. In fact, the growth of short-range in-flight Wi-Fi could be very rapid when the first electric vertical take-off vehicles become available.

SpazioFuturo

Electric aircraft and autonomous aircraft will boost high-precision aeronautical meteorology

3.5.5 The Near Future

Many aerospace-derived technologies are to be regarded as enabling technologies for the development of high value-added products and services in the mobility sector. In particular, many companies and start-ups base their products on satellite navigation (see Chapter 2.5) and earth observation (see Chapter 2.6) technologies.

A concrete example of an area where satellite navigation technology is set to play a major role is in railway signalling.
For years, **Rete Ferroviaria Italiana** has been experimenting with the use of navigation systems in the ERTMS system (European Rail Traffic Management System), which aims to increase the safety of rail transport and expand the capacity of rail infrastructure. So far, the system has only been used on high-speed lines and on the busiest train lines due to the high implementation cost.
In cooperation with Hitachi Rail, ASI, ESA and EUSPA, RFI has developed and tested an ERTMS Level 2 system based on satellite navigation technology.
Using these technologies, the cost of equipping the line can fall compared to a standard system, making it possible to extend the ERTMS system to low traffic lines or those with limited infrastructure, i.e. regional lines.

The opportunity to kick-start very high added-value services and applications in areas linked to mobility and transport is in part subject to the availability of space infrastructure that is able to meet the very strict safety requirements.

The Galileo satellite navigation system will enable the implementation of all those applications that are subject to extremely high safety requirements and standards, such as those in the railway sector or those linked to self-driving vehicles. In fact, the Galileo system is entirely controlled and managed by the European Union, designed for civilian use and optimised to be resilient with very high performance.

Mobility as a Service

The Italian government has decided to invest PNRR funds (see Chapter 1) in the urban mobility sector.
In the call put out in October 2021 to identify the first cities to take part in an initial large-scale trial, the Ministry for Technological Innovation and Digital Transition (MITD) and the Ministry for Infrastructure and Sustainable Mobility (MIMS) defined the concept of Mobility as a Service (MaaS) as follows: *"MaaS is a new concept of mobility that envisages the integration of multiple public and private transport services, generally belonging to various modes of transport and exercised by a diversity of operators, accessible to the end user through a single digital channel. These services are managed through "intermediation platforms" (technological tools, procedures, rules), which offer different functionalities - such as information, multimodal journey planning and booking, journey management, integrated payments across multiple modes, post-trip services - capable of meeting the specific mobility needs of customers in a customised way and enabling users to access any mobility service as and when required"*.

1 Manifestazione di interesse 'MaaS4Italy'

The first three big Italian cities to take part were announced in February 2022: Milan, Naples and Rome. The Mobility as a Service approach will make extensive use of technologies to manage and monitor the fleets of various types of vehicles owned by different operators. In July 2022, three more cities were selected to take part in the trial: Bari, Florence and Turin.
In this context, the extensive use of space-based technologies, such as satellite navigation and earth observation, will be crucial for the early-stage planning of the service and for the successive management phase after roll-out. The initiative is important as it will be conducive to the development of new expertise in the sector and is designed to involve private actors and start-ups.

Urban Air Mobility

Another upcoming generational leap in the mobility sector is represented by **Urban Air Mobility (UAM)**, which presents itself as a fertile breeding ground for innovators and investors alike.
The Urban Air Mobility approach combines the low environmental impact of electrically powered vehicles with the development of new business models for the air transport and civil aviation sector. Europe is currently leading the sector with the highest number of companies and start-ups.
Italy has also started to design and test these new electric-powered, short-range flying vehicles. The first commercial tests are expected in 2024/2025, with the first services to be rolled out in 2026 to coincide with the Milano Cortina Winter Olympics.

Walle, founded in 2020, is designing an ecosystem for the complete management of the Urban Air Mobility service and the means to implement it. The idea behind **Walle Air** is to create a service for transporting people along inter-city routes under 50 km using eVTOLs, i.e. electrically powered vehicles with vertical take-off and landing capabilities. The system is still in the design phase. The first operational flights are scheduled for 2025.

Walle

Another Italian company working in this direction is **Digisky**, a company specialising in development of payloads for drones and light aircraft for earth observation activities, which is currently designing an autonomous, zero-emission **flying taxi**.
The first experiments with passengers on board are scheduled to take place during the Paris 2024 Olympics. DigiSky is also contributing to the development of the Italian "**vertiport**" - **SkyGate**- which aims to be an accelerator of technological innovation in the field of Urban Air Mobility.

Digisky

This new sector of very short-haul air mobility using electric-powered vertical take-off vehicles also poses new challenges for operators of both airports and traditional ground transport services. In fact, new business models need to be developed and existing infrastructures need to integrated with new dedicated airports for these vehicles, even located in city centres or on top of buildings.
On this basis, **Atlantia**, a company operating in the motorway and airport infrastructure sector, has invested in the German company **Volocopter**. The first tests of Volocopter's electric vertical take-off vehicle took place between 2021 and 2022. A pilot service could be launched between 2024 and 2026, in Rome, Paris and Singapore.

Volocopter

Back in 2018, the Italian civil aviation authority (Ente Nazionale Aviazione Civile - ENAC) signed an agreement with the Ministry for Technological Innovation and Digitisation to encourage the development of Urban Air Mobility at national level, through the promotion of an integrated legislative and control approach, consistent with the technological evolution and competences of ENAC itself.
The 2018 agreement mentions both UAM and self-driving vehicles that move Beyond the Visual Line of Sight (BVLOS) of pilots or air traffic controllers.
In 2021, ENAC published a plan to create an ecosystem for Advanced Air Mobility, namely, the "AAM National Strategic Plan (2021-2030) for the Development of Advanced Air Mobility in Italy".
The plan sets a roadmap to promote the creation and development of infrastructure, legislation and an industrial and economic ecosystem for Advanced Air Mobility. The plan proposes to make UAM an integral component of transport systems in large urban areas, perfectly integrated in efficient, inter-modal transport systems so as to reduce pollutant emissions. The activities are carried out in cooperation with the public bodies and stakeholders involved in this new approach to intercity mobility, including the European Union Aviation Safety Agency (EASA), which is responsible for coordinating this new sector at European level.

AAM National Strategic Plan (2021-2030) for the development of Advanced Air Mobility in Italy

EASA - Urban Air Mobility

#video
Getting ready for Urban Air Mobility, EASA – European Union Aviation Safety Agency

Service / Product	Description	Application area	Company
High-precision GNSS receiver	High-precision GNSS receiver with authentication capability able to accurately detect the position of a vehicle in an urban setting	**Traffic and urban mobility management**	**SpaceEXE**
ADAS with radar technology	ADAS sensors with high-precision radar technology	**Automotive sensors**	**Aresys**
ADAS	Platform that uses data fusion algorithms to manage data from GNSS and GIS systems and data from other sensors used in collision avoidance and autonomous driving applications	**Automotive sensors**	**EICAS Automazione**
Resilient communications in the rail sector	Products enabling resilient and guaranteed communications through use of terrestrial communications, LTE and satellites in Ka band, even on the move	**Railway traffic management**	**Intecs Solutions**
Cloud platform for fleet management	Cloud platform for vehicle management and monitoring using GNSS sensors	**Fleet management**	**GAC Technology**
Integrated platform for fleet management in the public transport sector	Vertical platform, adaptable to customer needs, that integrates GNSS, earth observation and GIS data and data from other sources for the efficient management of public transport.	**Fleet management in the public transport sector**	**Planetek**

Service / Product	Description	Application area	Company
Platform for managing the transportation of loads of abnormal size	Platform designed to manage and automate the routing and subsequent authorisation process for the transportation of loads of an abnormal size.	**Handling the transportation of abnormal loads**	**NeMea Sistemi**
3D positioning solutions	Hardware and software solutions for the industrial IOT sector, with accurate 3D tracking of staff and assets, indoors and outdoors	**Indoor and outdoor 3D positioning**	**ProEsys**
Platform for indoor navigation services	Platform for indoor navigation and positioning services, based on inertial engine technology	**Indoor navigation**	**Gipstech**
Snow monitoring platform	High-resolution monitoring of snow depth based on in-situ observations, satellite data and artificial intelligence	**Tourist information**	**MobyGIS**
Platform for managing hiking trails	WebGIS information system designed for hikers and park operators that manage hiking trails	**Tourist information**	**Planetek**
Cloud-based micrometeorology platform	Cloud platform with linked app to provide high-precision micrometeorology services for light recreational aircraft	**Meteorological information for aircraft**	**SpazioFuturo**
Urban Air Mobility services	Airport planning and short-range air mobility with electric-powered vertical take-off vehicles	**Very short range flights**	**Digisky, Walle, Atlantia**

3.6 Health and Biotechnology

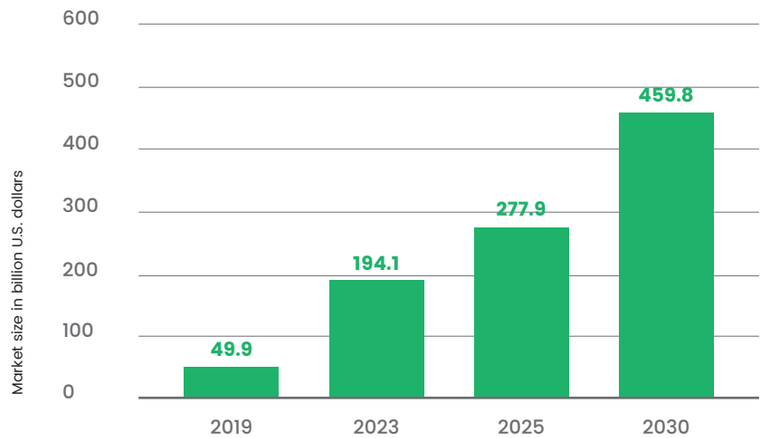
Increasing levels of anthropisation and industrialisation drive the need to keep the state of the environment under control in order to prevent potentially damaging impacts on people's health. The increasing burden on national healthcare systems requires a shift towards a mixed healthcare model, where the role of telemedicine and home care is just as important as emergency care provided by hospitals.

The environmental monitoring of entire regions, countries or continents, made possible through the use of Earth observation systems (see Chapter 2.6), provides valuable information for the management of air quality, also in real time.
A report by the European Environment Agency estimates that, in the European Union, more than 300,000 premature deaths were attributed air pollution and exposure to airborne toxic substances in 2019, the last year of measurements taken prior to the restrictions imposed during the 2020 and 2021 lockdowns.
The management of these data is therefore of paramount importance when considering solutions to improve the well-being of citizens, manage preventive healthcare policies more effectively and build new energy and transport infrastructure.

European Environment Agency - Health impacts of air pollution in Europe, 2021

The possibility of exploiting new telecommunication technologies (see Chapters 3.3 and 2.4) based on satellite constellations has paved the way for new healthcare delivery models, capable of meeting the demand for timely healthcare, with nationwide distribution and at a lower cost compared to those implemented via traditional technologies.
This and other technological advancements, coupled with the needs that came to light during the Covid-19 pandemic, have accelerated the use of telemedicine systems both in the public and private sectors, leading to strong growth in this market between 2019 and 2023, which is expected to continue at a steady pace until 2030 and beyond.
The components of this market are manifold and range from telemedicine platforms and connected medical devices to cybersecurity services for the secure management of personal data related to patients' health. The global market value could be as much as USD 200 billion by 2023 and exceed USD 450 billion in 2030.
Space-derived technologies have consistently contributed to the development of new medical technologies thanks to the possibility of investigating new areas with high innovation potential and making long-term investments to ensure the success of missions in space, as is the case with long-term stay of astronauts at the International Space Station (ISS).
Space research programmes in the health and biotechnology fields have made it possible to carry out experiments and tests that exploit microgravity conditions that can only be achieved on artificial satellites and space stations in Earth orbit.
Even the ISS is used as an orbiting laboratory to conduct research programmes and activities that could also be used in healthcare applications and to advance medicine on Earth through technology transfer.
Microgravity conditions are opening up new avenues of research in life sciences, potentially enabling new opportunities in the near future for the industrial production of certain types of molecules and compounds in orbit, which are easier and cheaper to produce in absence of gravity. Italy and the European Union have been very active in this field since the early 2000s when specific laboratories became available on the International Space Station.

Projected global telemedicine market between 2019 and 2030
Source: Statista



3.6.1 Earth observation and air monitoring

The European Space Agency (ESA) and the Italian Space Agency (ASI) use data from Earth observation constellations to improve public health by monitoring air and water quality and pollutants on Earth. In this sector, Italy plays a leading role thanks to significant investments in Earth observation constellations (see Chapter 2.6) such as Cosmo Sky-Med, and in the ground infrastructure used to collect, manage and market the data generated. Earth observation plays a key role in helping the public authorities identify critical areas and monitor environmental phenomena that may pose a health risk, whether of natural origin, such as volcanic eruptions, or manmade such as industrial emissions or acts of arson. Many of the applications developed in this field are aimed at providing data and information on the composition of the atmosphere to measure air quality.

ESA's **Sentinel-5 Precursor** satellite, also called **Sentinel-5P**, is the first Copernicus mission entirely dedicated to monitoring the atmosphere.

The specific payload TROPOspheric Monitoring Instrument (TROPOMI) is able to map numerous gases that have a major impact on health and the climate. Sentinel-5P measures a very broad spectrum of radiation between ultraviolet and short-wave infrared, providing highly accurate images and measurements of pollutants such as nitrogen dioxide, ozone, formaldehyde, sulphur dioxide, methane, carbon monoxide and aerosols, as well as alert levels for high levels of UV radiation. The monitoring service provides analyses and forecasts of the main atmospheric components at various heights above sea level, and for the successive 96 hours.

Using Copernicus data, **TerrAria** offers advanced services and products in the field of energy-environmental consulting and software development. With funding from the European Centre for Medium-Range Weather Forecasts (ECMWF), TerrAria has developed an air quality forecasting platform called **UTAQ (Urban Tool for Air Quality)**, which uses CAMS data. This mathematical tool was developed as a web application to provide high-resolution maps for forecasting air quality in urban areas, in a range of ten to fifty metres. This high level of accuracy opens up new possibilities for urban planners and all stakeholders involved in land management, as it enables both the planning of long-term actions and the timely management of emergencies caused by extreme climatic events or pollution peaks significantly above the thresholds. The service has been successfully tested in the urban area of Milan. TerrAria has also developed an application to build an inventory of emissions in the atmosphere. Nine Italian regions currently use the application and contribute to the development of the INEMAR database (INventario EMissioni ARia).

TerrAria

AMAT - Studi sulla riduzione dei livelli di inquinamento atmosferico a Milano durante il lockdown

Data from TerrAria's UTAQ platform form the basis of the ESA-funded research project **EPIdemiological and logistic COvid19 model (EPICO-19)**. Developed in collaboration with **Studiomapp**, EPICO-19 combines the use of Copernicus CAMS data, Very High Resolution (VHR) satellite imagery (accuracy down to 11cm), environmental and meteorological data and Coronavirus spread data to build analytical models for pandemic management. EPICO-19 leverages Studiomapp's platform, which uses deep learning and artificial intelligence algorithms able to classify more than 150 different classes of objects and infrastructures. The platform is able to quickly and efficiently analyse optical satellite images to provide decision makers with useful information to understand how people move around in a given area, such as counting the number of cars parked in that area, thus helping them to plan emergency response services.
The service was tested in 2021 in Emilia-Romagna, where it provided simulations and forecasts on cases and hospitalisation.

ESA - EPICO19 Project

Studiomapp

The **Earth cognitive System for CoViD-19 (ECO4CO)**, funded by ESA, exploits Earth observation data to tackle the Covid-19 pandemic, and potentially other similar pandemics in the future.
ECO4CO is led by **Telespazio** and involves a consortium of Italian companies, start-ups and universities: **e-Geos, ITHACA, Cherrydata**, and **Sapienza Università di Roma**.
The project combines artificial intelligence algorithms, data from Earth observation constellations and positioning data with non-satellite information extrapolated from the analysis of websites and social media networks. The combination of these heterogeneous data sources generates reliable and up-to-date information on areas where crowding is expected, such as parks, stadiums, markets and public places in general.
The platform provides information on evolution of the epidemic and a predictive analysis service to identify medical equipment needs to support the choices of local decision-makers. The service can therefore be useful for monitoring areas where the highest level of crowding is expected and potentially isolating possible outbreaks.

ESA - ECO4CO Project

#video
ECO4CO

Earth observation data are also used to analyse the **correlation between extreme temperatures and mortality**, or to understand how the presence and use of green areas can protect human health. The Department of Epidemiology of the Lazio region is involved in a number of research projects that use satellite data to identify the areas more exposed to heat waves (see Chapter 3.3). In detail, a study was conducted on the city of Rome, where satellite data made it possible to identify the main heat islands on the basis of air temperature data and demographic trends in the city.

DEP Lazio - Heat islands study

Satellite technologies can support critical services in the event of a collapse of traditional infrastructure

3.6.2 Telemedicine

In the field of telemedicine, the ability to ensure stable and secure services is of fundamental importance. Leveraging technologies and the experience gained in the telecommunications sector, including in the military field, Telespazio has developed **Hermes (Healthcare Emergency support system for the distributed Response and Monitoring of Epidemics in the Society)**. The project is designed to support healthcare systems in the monitoring and management of health emergencies and epidemics in particular. HERMES was implemented in collaboration with e-Geos (see Chapter 2.5), a company specialising in the management of big Earth observation data. The project exploits a ground-based satellite telecommunications infrastructure, maintained by Telespazio, and the potential of e-Geos' big Earth observation data processing capability to process data obtained from laboratories and healthcare facilities, both fixed and mobile, and from IoT sensors. The system was designed for the COVID-19 pandemic but is enabled to be adapted to manage health and environmental emergencies of different types, such as earthquakes or other catastrophes, should traditional telecommunication networks fail and the use of satellite technology become essential to deliver an effective and efficient service.

Telespazio - HERMES Project

One of the future advancements in the field of epidemiology concerns the integration of satellite and personal data to obtain information about an individual's exposure to a specific pollutant or type of harmful substance. **Kell**, active in the field of telemedicine and earth observation, is involved in ESA's **Safe AT WORK (SATWORK)** project. The project involved setting up a mobile laboratory equipped with satellite telecommunication technologies (see Chapter 2.4) and precise positioning based on satellite navigation (see Chapter 2.5) so as to implement rapid Covid-19 screening campaigns as economic activities resumed and social distances rules eased in areas affected by the digital gap and lack of infrastructure.

ESA - SATWORK Project

Kell has been involved in telemedicine and healthcare innovation since it was established in 1997. Over the years, the company has consolidated extensive experience in the field of e-health in collaboration with public bodies and private companies. Kell has developed integrated systems to support medical and telemedicine practices that integrate hardware and software capable of exploiting various types of technologies, including satellite telecommunications, to provide highly-efficient and widely-available services.

Kell

IngeniArs, a spin-off of the Università di Pisa, specialises in the design of electronic and ICT systems in the fields of aerospace, telemedicine, cybersecurity and artificial intelligence.
IngeniArs' telemedicine solutions use aerospace-derived technologies to ensure optimal performance consistent with the highest standards of personal data security and timely intervention. One example is the ESA-funded **SatNav E@syCare** project, which uses medical-grade sensors and satellite navigation systems (see Chapter 2.5) to monitor the physiological condition of patients even outside their homes or hospital facilities.
The platform allows healthcare staff and the patients themselves to monitor specific parameters and to track, if necessary, their movements (a useful feature for contact tracing in the event of an epidemic).

IngeniArs

ESA - SatNav E@syCare Project

E-Novia, a company active in setting up new businesses in the e-mobility sector, has coordinated the ESA-funded project CO.DE-19, which is part of the measures implemented to mitigate the impacts of COVID-19. The project focussed on the development of a system for the autonomous contactless delivery of medical supplies within hospital facilities using a ground-based robotic drone. The drone can cover indoor and outdoor routes using an Artificial Intelligence system and the European satellite navigation system Galileo (see Chapter 2.5), which provides high-performance navigation services even in environments with poor visibility of orbiting satellites.

ESA - CO.DE-19 Project

E-Novia

Transporting medical supplies via drones or autonomous vehicles poses special challenges: the optimal preservation of the transported items needs to be monitored and ensured.
ABZero has engineered a smart capsule for the drone transportation of perishable or biological materials, such as samples, blood bags or organs.
The capsule can be attached to drones of different types and customised according to transport needs. The transported materials are constantly monitored thanks to integrated sensors, which rely on a data transmission module and an internal battery, thus making the module totally independent from the drone transporting it.
ABZero's solution uses a Galileo satellite navigation module (see Chapter 2.5) for high-precision positioning. The smart capsule is designed to enable the fast and monitored delivery of perishable material in those environments where speed is a fundamental requirement, such as in city environments where ground vehicles may be slowed down or in the event of emergencies of various types where traditional infrastructures are either absent or out of service.

ABZero

3.6.3
Space medicine and biology

Space medicine emerged following the first human spaceflight in the 1950s.
The aim of this branch of medicine is to ensure the well-being and optimum state of health of astronauts, on which the success of missions and their own survival depends.
Space medicine has broadened its scope as astronauts' stays in orbit have increased in length. Today, medical science applied to space is an extremely multidisciplinary field as it combines medical, biological and engineering competencies associated with the physics of materials and fluids, and even psychological skills.
Data collected during missions, particularly long-term missions aboard the International Space Station, are invaluable in understanding how the human body reacts to the extreme environment of microgravity and cosmic and ionising radiation.
Studying the findings of these observations is also crucial for the design of increasingly high-performance space station modules and shuttles, particularly from the perspective of future space exploration missions (see Chapter 2.2) and the creation of permanent bases on the Moon and Mars.
In Europe, the main actor is the European Space Agency, which set up the European Astronaut Centre (EAC) to support astronauts and study the activities and consequences associated with their stay in orbit.

ESA - European Astronaut Centre – EAC

The Italian ecosystem has developed a number of highly specialised skills for astronaut management.
In particular, the **Aerospace Logistics Technology Engineering Company** (ALTEC) collaborates with ESA's EAC to provide astronaut training activities and to support the Columbus Control Centre in Germany, which coordinates research activities on the Columbus module of the ISS. ALTEC's activities include bio and space medicine studies to investigate how the human physiology reacts and adapts to weightlessness and the higher radiation conditions of environments like the International Space Station.

ALTEC

The study of biological compounds and living tissue under microgravity conditions makes it possible to collect data and carry out experiments for the development of new drugs and therapies.
Kayser Italia has developed a line of engineered micro-bioreactors for biochemical, biological and biotechnological experiments in microgravity. Kayser's experiment containers are equipped with interfaces compatible with the systems used on the ISS (and with those of capsules of other space agencies, including the Chinese Shenzhou capsule) and use experiment monitoring technologies. The design of these components ensures optimal mechanical performance and a Level of Containment (LoC) for Level 1 and 2 chemical and biological materials. The containers have different volumes according to needs, can be customised by customers and can accommodate Kayser-designed or third-party hardware.
The company entered into an agreement with ESA in 2019 to commercially exploit the KUBIK controlled-temperature incubator on board the European Columbus laboratory, which led to the commercial offering of Bioreactor Express. KUBIK has a total volume of nine litres and is designed to carry out experiments of various types. The collaboration between ESA and Kayser makes the use of this facility more accessible to industries and SMEs interested in advanced microgravity testing.

Kayser has developed a number of experiments on the ISS aimed at collecting data to improve the health of both astronauts and patients on Earth. One example is the NutrISS experiment conducted in 2021 with ASI funding. The experiment monitored the muscle metabolism of two astronauts under microgravity conditions with the aim of developing an innovative nutritional protocol to limit the loss of lean mass on long-duration missions in space. In the future, this protocol could be applied to patients on Earth who are immobilised or have very limited mobility.

Bioreactor Express

Kayser Italia - esperimento NutrISS

The United States has so far played a leading role in technology transfer from space research to medical and biotechnological fields.
In Europe, and more specifically in Italy, this type of activity was intensified when the International Space Station became operational, in particular, when the **Columbus Orbital Laboratory (COF)** was put into operation. The laboratory module was built by Thales Alenia Space in Turin, together with other components of the ISS (see Chapter 2.2), and is at the cutting edge of European research in **microgravity** conditions. The COF has specially engineered instrumentation to carry out activities associated with research into the **physics of fluids**, and in the **medical and biotechnological** fields.

Columbus Orbital Facility – COF

Italy can exploit 19% of the COF's total capacity, which it uses to conduct experiments in collaboration with universities, research centres and enterprises. The focus of many of these experiments is the study of molecules, cells, and organic compounds in microgravity conditions.
The special gravitational conditions in orbit make it possible to study how proteins, protein crystals, and other types of molecules form and grow, with an accuracy and level of detail not achievable under conditions on the Earth's surface. Another area being explored is how the human body adapts to weightlessness and the impact that cosmic radiation has on human cells, DNA and their ageing and development. These studies are crucial to collect the data needed to plan long-term deep-space missions, in particular for all missions exploring the possibility of long-term human settlements on the Moon and Mars (see Chapter 2.2).

ASI - Complete list of Italian microgravity experiments

3.6.4 The Near Future

The possibility of carrying out experiments in **microgravity** on board the International Space Station has triggered numerous high-impact studies in the fields of medicine, biology and materials science.
In the near future, the possibility of having access to facilities for the production of molecules and/or medical and biomedical products under microgravity conditions will be a competitive advantage for companies in the sector.
The absence of gravity on the ISS or on structures in low Earth orbit enables the production of certain types of molecules and biological compounds of the latest generation.
For example, the pico-particles and nano-particles used for the delivery of certain drugs for neurodegenerative diseases (such as Alzheimer's) or oncological diseases could be produced in high-throughput mode, with very high efficiency and purity compared to Earth-based standards.
In addition, microgravity could facilitate the 3D printing of organs using living cells, making it possible to build very complex structures that would be difficult to create on earth due to the force of gravity.
An interesting role is played by ESA's robotic shuttle **Space Rider** (see Chapter 2.1), engineered and manufactured mainly in Italy. The shuttle will enable experiments, and potentially small automated productions, to be carried into orbit and to bring the results back to earth. The Space Rider will be able to carry out missions of different durations according to customers' needs. The first launch of the Space Rider is scheduled for 2023.

ESA Space Rider

The importance of activities in microgravity is also confirmed by the experiments launched into orbit with the first private space mission to the ISS, operated by the US-based Axiom Space (see Chapter 2.2) in April 2022.
The mission took into orbit three experiments of the Israeli commercial service provider SpacePharma, which investigate:

- the potential benefits of microgravity for producing cultured meat, both for production back on Earth and use during human deep space missions;
- the use of amorphous calcium carbonate to mitigate the effects of weightlessness on the muscular-tendinous system of astronauts;
- the study of DNA stress in microgravity conditions.

SpacePharma collaborated with Avio in 2019 to launch its first prototype of an automated mini-laboratory, carried out with a Vega launcher (see Ch. 2.1) thanks to an agreement between the Israeli Space Agency and the Italian Space Agency.

SpacePharma launched to the ISS aboard all-private Axiom-1 Mission

SpacePharma mini-lab launched in Italy-Israel collaboration

Service / Product	Description	Application area	Company
High precision air quality forecasting service	Mathematical tool developed as a web application to provide high-resolution air quality forecasts on an urban scale (10-50 metres)	**Air quality monitoring**	**TerrAria**
Algorithms for the analysis of EO images and data	Deep learning algorithms for more efficient analysis of optical satellite imagery and for gathering spatial and environmental information	**Air quality monitoring**	**Studiomapp**
Platform for the predictive monitoring of pandemics	Automated platform that combines satellite data (EO imagery, navigation data), social media and news, traffic and medical data for predictive analysis purposes	**Predictive analysis**	**e-Geos**, **Telespazio**, **ITHACA**, **Cherrydata**
Mobile laboratory	Mobile laboratory equipped with SATCOM and NAVSAT to conduct rapid Covid-19 screening campaigns in areas affected by the digital gap and lack of infrastructure	**EO and satellite navigation applied to telemedicine**	**KELL**
Remote patient monitoring platform	Platform for monitoring the physiological condition of patients even outside their homes or hospital facilities	**e-Health**	**IngeniArs**

Service / Product	Description	Application area	Company
Platform for managing healthcare services in emergency situations	Platform to support healthcare systems in the monitoring and management of pandemics and other health emergencies. The platform combines EO data and data obtained from IoT sensors and high-precision positioning systems based on satellite navigation	**e-Health, Emergency management**	**Telespazio, e-Geos**
Autonomous and contactless delivery via drones	Contactless delivery of medical supplies and medicines within hospital facilities using autonomous ground drones that exploit Galileo satellite navigation for outdoor use and artificial intelligence algorithms for indoor use	**Logistics, delivery of hospital supplies**	**E-Novia**
Capsules for the drone transportation of perishable materials	Capsule equipped with sensors for the drone transportation of perishable materials (blood, organs, samples). The capsule uses the Galileo system for high-precision positioning.	**Drone transport of perishable materials**	**ABZero**
Experiment containers equipped with micro-bioreactors	Engineered micro-bioreactors for microgravity experiments in diverse sectors, i.e. biochemical, biological and biotechnological sectors, with experiment containers suitable for use in existing space stations and spacecraft (ISS, Shenzhou, etc.)	**Experiments in microgravity conditions**	**Kayser Italia**

About Intesa Sanpaolo Innovation Center
Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.
Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research.

About Fondazione LINKS
Fondazione LINKS is an operating entity of Fondazione Compagnia di San Paolo and Politecnico di Torino. LINKS was established with the goal of combining the best practices and expertise built over the past 20 years at national and international level in the fields of applied research, innovation, and technology transfer.
LINKS aims at contributing to an ecosystem-driven vision of progress based on the acknowledgement of the deep interdependence between society, nature, and technology. This approach makes it possible to address today's challenges by exploiting the resources of the ecosystem within a frame of sustainability, fairness, development of local territories, and the greater good.

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