SMART INDUSTRIAL INNOVATION AS ENABLER TO DRIVE NEW VALUE CHAINS FOR TEXTILES AND AEROSPACE

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1. INTRODUCTION TO THE AEROSPACE SECTOR IN EUROPE

Hardly any other industry has been as severely affected by the COVID-19 pandemic as the aerospace industry. The unprecedented crisis has led to a sharp downturn of the world economy, and especially the aeronautics sector is affected, because global and regional air travel restrictions lead to an almost stop of passenger air transportation.
Besides the COVID-19 crisis, the recent climate change discussion created enormous pressure on all air traffic participants. It became clear, that aircraft must become more climate-friendly and therefore more fuel-efficient and lighter. However, the current situation offers the opportunity to explore new smart industrial innovations and to accelerate the development towards sustainable green technologies.
Before analyzing the market opportunities in the aftermath of the COVID-19 crisis, we first have a look at the previous situation.

1.1. SITUATION BEFORE COVID-19

Within previous years, the number of passenger transport by air has grown rapidly. 2019 marked another rise of 3.8 % compared to 2018 [1]. In 2019, air passenger transport in the European Union (EU-28) amounted to over 1.1 billion passengers. More than 7.700.000 flights have been counted in Europe summarizing domestic and international flights for passenger and cargo [2]. The decrease of travel fares due to low-cost carriers, the growth of the middle class especially in Asia as well as the growth in airport infrastructure spending, have fueled this upward trend [3].

At a global level, the increase in orders and deliveries of aircraft has led to an expansion in production and productivity and resulted in a 10% growth in sales [4]. In 2019, the civil aeronautics sector showed a strong economic performance, resulting in increased deliveries export orders and backlog. While Boeing’s deliveries took a severe hit in 2019 due to the two 737 MAX crashes and the subsequent delivery halt and grounding of the fleet, Airbus was able to outpace its previous record by eight percent. Airbus delivered 863 commercial aircraft to 99 customers. Within 5 years, Airbus was able to increase its production backlog by 17%, reaching a total number of 7.482 aircraft [5].

1.2. SITUATION DUE TO COVID-19

Due to the COVID-19-epidemic and the associated global and regional air travel restrictions, a decline of 59% in world total passengers transport can be witnessed in the year 2020 [6]. Within Europe, the domestic and international passenger & cargo flights were reduced by 51,88 % (in high times even by around 90%), corresponding to a reduction of approximately 4. Mio flights compared to 2019 [2].

While some European airlines went bankrupt, others are restructuring their fleet by reducing aircraft or by replacing old aircraft by new and more fuel-efficient ones. Airlines ground a high percentage of their fleet and still suffer dramatic losses of revenue. As a consequence, many airlines either cancel or postpone orders, with an immediate effect on the entire civil aviation industry value chain. Experts preview a drop of aircraft deliveries within the next years. Until September 2020, Airbus has delivered a total of 341 aircraft, which is a reduction of around 40% compared to the same period in 2019 and still has the comfort of a huge backlog (7,441 aircraft) [7]. Particularly suppliers with a high dependency on aircraft manufacturers are struggling under these circumstances. Government policies and support, as well as national funding programs, might support suppliers in short term, but the risk not to survive this crisis due to a weak financial situation, or by losing critical workforce of highly skilled employees, is real. This may cause severe problems for the whole supply chain, offering on the other hand opportunities for companies entering new in the sector. Present forecasts predict a full recovery of the sector (in best case) by end of 2023.

2. THE EUROPEAN CIVIL AERONAUTICS SECTOR

During the last decade, the rush for increasing production rates has been in the focus of aircraft manufacturers and the whole supply chain within the aeronautics sector. It became apparent that the civil aeronautics sector should invest more in areas like full deployment of digitalization or smart automation technology. As aircraft manufacturers and suppliers have temporarily reduced production rates to adapt to the lower market demand, this situation now offers the possibility to take a breath in the race for production, to rethink their business model and to use their personnel for other activities [8]. The current situation should represent an opportunity for the sector to invest in the future, by pushing innovation and by using advanced and smart technologies.

In respect of the EU dual-use regulation (DU) in the GALACTICA project, only innovation and new ideas for civil use are supported and accepted. That’s why our focus lies on the European civil aerospace sector.

2.1. DEFINITION

Civil aeronautics has been defined by the Aerospace and Defence Industries Association of Europe (2020) as “*the civil aeronautics sector includes* ***all certified flying objects, manned and unmanned, along the life-cycle****, i.e. the complete range of categories of commercial aircraft, business jets, regional jets, general aviation, […], as well as a broad range of transport aircraft and rotor-wings, training and simulation services, Maintenance Repair & Overhaul (MRO) and air traffic management ground systems* [9].

2.2. BRIEF OVERVIEW

405.000 jobs
(2019)

178 billion in revenue
(2019)

109 billion in export
(2019)

The civil aeronautics industry can be characterized as one of the EU’s key high-tech sectors on the global market [10]. In 2019, more than 405.000 highly qualified employees have been working across Europe in the sector, making the civil aeronautics sector one of the world-leading industries in providing employment, innovation and economic growth [10]. In 2019 the growth trend of recent years within the sector has continued. The annual revenue in 2019 generated by European companies within the civil aeronautics industry has increased by approximately 40% in comparison to 2010 - generating EUR 178 billion in revenue [11].

The exports of the civil aeronautics industry provide an important net trade balance to the European economy. In 2019 the export share of the whole European aeronautics sector increased to 83%, generating around EUR 109 billion [10].

Europe is home to some of the largest companies within the industry. Particularly, it is home to one of the two leading aircraft manufacturers worldwide – AIRBUS. In 2019, the company generated more than EUR 70,5 billion in total revenue out of all European production sites with a global order book value of EUR 471 billion [12].

Europe is also home of some of the biggest companies within the supply chain including ROLLS-ROYCE PLC, SAFRAN AIRCRAFT ENGINES, Thales and LEONARDO S.P.A., DASSAULT AVIATION, LIEBHERR etc. with the main concentration in France, Germany, Italy, UK, Spain, Poland and Sweden. This makes Europe world leader in the production of civil aircraft, including helicopters, aircraft engines, parts and components. Besides the big companies, the civil aeronautics sector consists of a great variety of small and medium-sized enterprises (SMEs), which are spread across Europe and contribute to a huge spectrum of technologies, integrated capabilities, and innovative potential.

2.3. MARKET STRUCTURE

The aerospace sector has a specific supply structure. Scientifically, the ideal tier structure can be described within the form of a pyramid of supplier relationships (Tiers). The supplier interrelationships start with the manufacturer (Original equipment manufacturer (OEM), which is supplied by a system manufacturer (Tier 1), whereas the components of a system are ordered from component manufacturers (Tier 2) and their suppliers (Tier 3, etc.) [13].

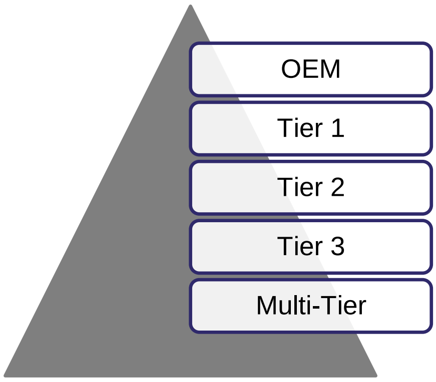


Figure 1: Schematic representation of the aerospace supply chain
Source Supply Chain Excellence Initiative 2016

Here a short description of the different supplier levels

- **OEM:** Companies with approval to manufacture a particular type of aircraft. The four largest OEMs in civil Aeronautics worldwide in terms of revenue and number of aircraft deliveries in the fiscal year of 2019 are Airbus Group (Europe), Boeing Commercial Airplanes (USA), Bombardier Aerospace (Canada) and Embraer (Brazil) [14]

- **Tier 1**: System manufacturers are responsible for the development and manufacturing of technically complex systems like engines, cabin systems, landing gears, aerostructures, fuel management etc. They are required to adhere to aviation regulations.

- **Tier 2:** Component manufacturers build component groups ready for installation by system manufacturers or OEMs. These components can be e.g., mechanical parts, wheels & brakes, avionics & hydraulics, seats. They are responsible for the manufacturing process, but not necessarily for component development. Depending on the contract with the OEM or Tier 1 company, they are required to adhere to aviation regulations, or to produce according to instructions of their customers, but need to be certified to aviation standards.

- **Tier 3:** Parts manufacturers produce parts or components according to the specifications of the component manufacturer (“extended workbench”). These manufacturers have little or no aviation regulations responsibilities, but they are usually certified to aviation standards.

- **Multi-Tier:** Multi-tier manufacturers supply materials, norm parts or equipment to all levels of the supply chain. This also includes personnel services [13]

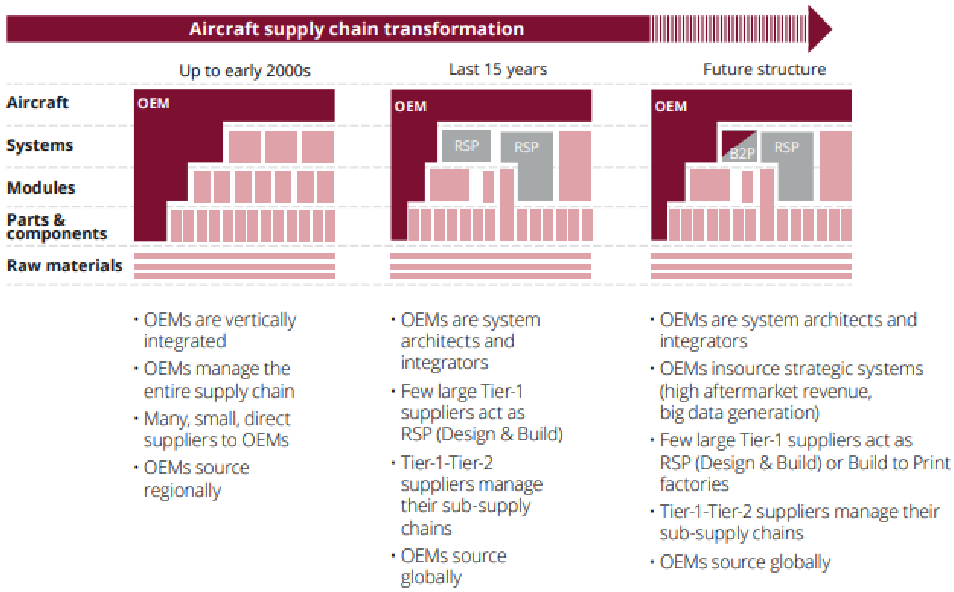


Figure 2: The aircraft supply chain transforms again into a middle ground of OEMs as system integrators and OEMs as vertically integrated [15]

Therefore, the affiliation to the value chain and industry segments can vary. Within the supply chain, the ideal-typical form of a pyramid is more characterized by many overlaps and intersections between the different relationships. Belonging to a tier level can differ between the industry segments in which a company is active. A direct supplier to an OEM for a certain product can also be categorized as Tier 2 or 3 in other product segments. With the interlinking of delivery also comes a responsibility, which is assumed at each individual level of the value chain. Especially legal and certification requirements can be a challenge for suppliers of lower tiers (see chapter 2.5). Most SMEs within the supply chain are mostly anchored into the lower tier structure, a high dependency on other tier-suppliers can be identified. In the current situation, balancing supply-side over-capacity with reduced order books faces most suppliers with new risks, challenges but also opportunities. The crisis leads to re-evaluating existing product portfolio and breadth of operational as well as manufacturing capabilities [16].

2.4. FUTURE DEVELOPMENTS

Aviation is one of the fastest-growing sources of greenhouse gas emissions [17]. In 2019, more than 915 million tons of carbon dioxide (CO2) worldwide were produced by flights. The global aviation industry, therefore, produces around 2% of all human-induced CO2 emissions [18]. Due to the increasing global demand for mobility, the demand for more sustainable aviation is growing. While airlines reduce their fleet to optimize costs and try to optimize economical and efficiency aspects, the demand for green technologies in civil aviation increases. The civil aviation industry is strongly aware of the need to decarbonize. Before COVID-19, the International Civil Aviation Organization (ICAO) forecasted that by 2050 international aviation emissions could have tripled compared to 2015 if the industry is not taking countermeasures [17].

Even though the COVID-crisis has reduced the enormous growth of this industry, the recovery to pre-COVID-19 levels is expected by 2023. Therefore, investments in cleaner aircraft and fossil fuel alternatives and sustainable solutions to reduce emissions drastically can contribute to long-term resilience and new revealed markets for the civil aeronautics industry [19]. To achieve climate neutrality, the European Green Deal sets out the objective to reduce transport emissions by 90% by 2050 (compared to 1990-levels). The aviation sector will contribute to this reduction. That's why in the last years the main focus in R&D was directed towards the reduction of emissions. The European aviation ecosystem recently announced a joint commitment to work with policymakers to achieve **net-zero CO2 emissions by 2050**. [20]. One possibility to contribute to this objective is to decrease weight. Here a window of opportunity opens for textile industry through the development of light and load-bearing material.

Regarding innovation, the COVID-19 crisis revealed the necessity to develop **new hygienic solution and concepts,** especially for the cabin sector. On one hand, these concepts are needed urgently to enable save flying right now, on the other hand, this aspect will be in general focus for the future, as other deceases or pandemics will occur. Here arises an opportunity for innovation and products coming from the textile sector.

Another area in aeronautics with potential for innovation and intersectoral ideas is the field of **unmanned air vehicles (UAV**). The kind of activities comprises a manifold of commercial application for small drones (octocopters and fixed-wing) in the short and medium range up to larger UAV able to transport people and cargo over short and medium distances. As this area is still in a development phase and regulation is just underway, new business models still have to be created. This area is considered to have a huge growth potential in the near and middle future.

2.5. AUTHORITIES AND ORGANIZATIONS

The International Civil Aviation Organization (ICAO) as sub-organization of the United Nations is the responsible organization for civil aviation. The core task is the standardization and regulation of civil aviation, with the aim of a safe and efficient air transport.

The European Aviation Safety Agency (**EASA**) is the aviation authority of the European Union. The EASA was established in 2002 by decision of the European Parliament and the Council in order to achieve a uniform level of safety and environmental protection throughout the EU in the civil aviation sector. The agency's tasks are to provide the European Commission with its expertise in the areas of flight safety and international aviation. EASA is individually responsible for the implementation of specifications of the ICAO into European Law in the form of law drafts and the development of their own guidelines. [3]

AIRCRAFT CERTIFICATION REQUIREMENTS

Certification requirements for civil aircraft are derived from ICAO Airworthiness of Aircraft and the ICAO Airworthiness Manual, Part V State of Design and State of Manufacture. In the EU, these are contained in EC Regulation 748/2012 Annex I - Part 21. These Part 21 regulations also include procedures for the **approval of design organization (Sub-part J or EASA Part 21/J):** Organizations must have demonstrated their qualification in developing aeronautical products, parts and appliances, define changes or repair procedures**. Production organizations (Sub-part G or EASA Part 21/G)** must officially approve a quality system in production. These processes are known respectively as Design Organization Approval (DOA) and Production Organization Approval (POA). Such approvals are a necessary pre-requisite for obtaining product certification.

Production according to 21 / G may only be carried out based on approved production data provided by a Part 21 / J design organization. Aeronautical products should therefore not be designed or modified by approved 21G organizations on their own – they always need necessary technical data of a Part 21J design organization. In addition, a production organization may not perform any maintenance on its own components. This requires an additional approval as a maintenance organization in accordance with **EASA Part 145**. [21] [22]

2.6. RESEARCH, DEVELOPMENT AND INNOVATION ABILITY

10% of industrial turnover
2019

Investment of 8 billion € In R&D activities
(2019)

RESEARCH & DEVELOPMENT IN CIVIL AERONAUTICS IN EUROPE

The time span from the first research and development activities to the decommissioning of an aircraft type is in general several decades. Technological innovations can therefore in general only be introduced with relatively long lead times. Companies invest primarily in the further development of already established products and in highly application-oriented research projects.

Investment in research, development, and innovation (RDI) is vital for the development and competitiveness of the civil aeronautics industry in Europe. RDI expenditures represent 10% of industry turnover, one-third of which being financed by the public sector [10]. In 2019, an estimated amount of EUR 8 billion was invested in civil aeronautics R&D activities by private and public stakeholders [9]. According to the European Commission, every Euro invested in aeronautics R&D creates an equivalent additional value in the economy annually thereafter [10]. New technologies and innovations must comply with a large number of safety regulations and comply with existing patents. Therefore, RDI activities within the civil aeronautics sector can be characterized as highly complex and competitive. However, this competitiveness is also the key driver for new, innovative, and sustainable solutions.

The number of patent applications of EU companies also testifies the EU's dynamism in the sector and its developing role in the world's aerospace industry. Based on the International patent classification system, between 2002 and 2016, the growth in patent applications in the field of 'Aircraft; aviation; cosmonautics' addressed to the European Patent Organization (EPO) grew by 162 %, compared with just 46 % in manufacturing on average. When examining the country origin of approximately 428 patent applications in the EU-27 in 2016, two Member States accounted for over 70 % of total patent applications: Germany recorded the highest share with 36 %, ahead of France (35 %) and Spain (9 %) [23]

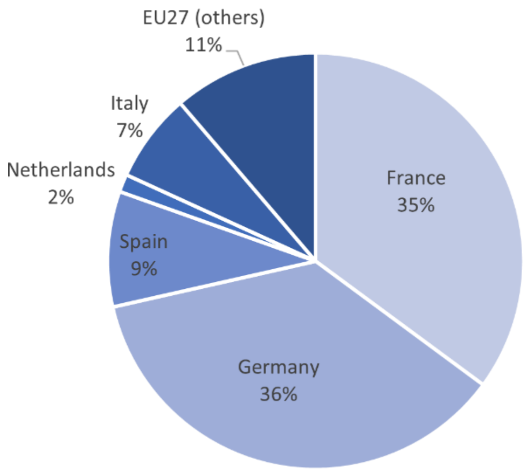


Figure 3 Graph 9: Breakdown of patent applications made to the EPO in aerospace equipment by country origin, EU-27, 2016 [23]

Within the last years, there has been a significant increase in the pace of development and application of new technologies and concepts of operation within the civil aeronautics sector. Public funding, research cooperation and joint projects are still of great importance as research institutions act as a bridge between research and industrial application and work closely with companies in the civil aeronautics industry.

3. THE EUROPEAN SPACE SECTOR

3.1. BRIEF OVERVIEW

With the beginning of the private spaceflight industry and further development of satellites, the traditional space boundaries and business models have changed radically [24]. Especially within the last decade, the European space sector has transformed. This transformation has been fulfilled through major technology advancements, new entrepreneurial awareness and new policy developments. Particularly the sector of “NewSpace” thrives technology and business model innovations providing and broadening new products and services. Within decades, the traditional space sector has shifted from a highly institutional sector towards a key innovation driver worldwide.

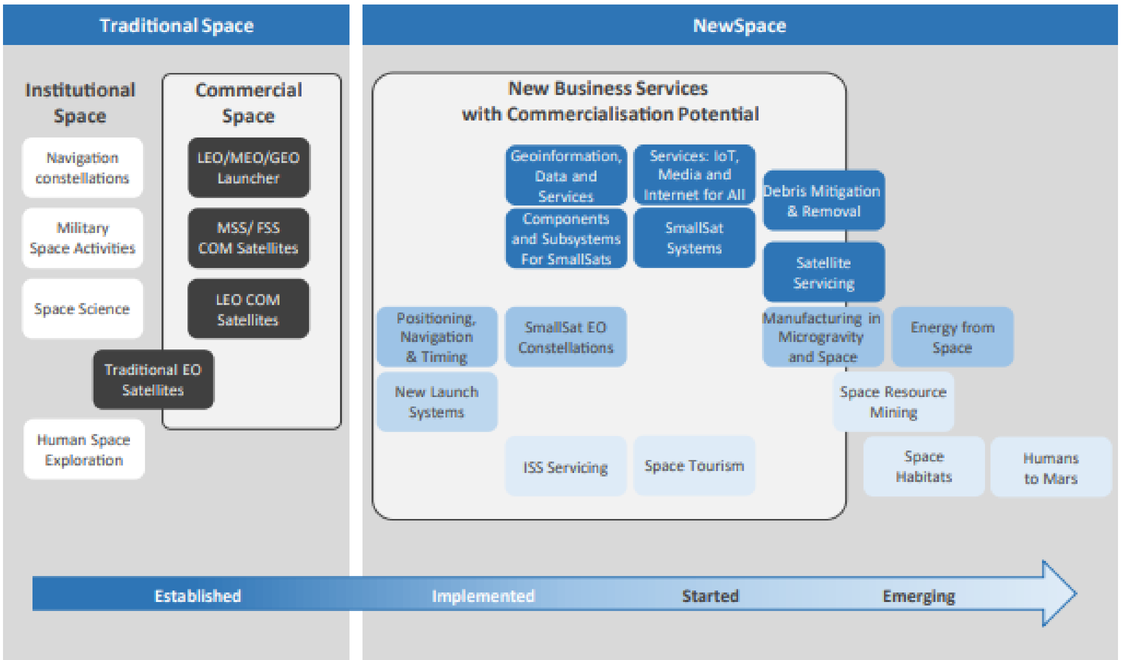


Figure 4: Spectrum of space business services according to their level of maturity [24]

In order to adapt technological changes and innovative developments, companies within the space sector are forced to generate revenues outside the traditional institutional space sector. Therefore, many companies have a broadly based business model or seek other (private) financial support [24].

In October 2016 the EU set a strategic pathway to strengthen its competitiveness within the global space sector. A new European space strategy was developed aiming to

- maximize the benefits of space for society and the EU economy, by promoting the use of Galileo services in mobile phones, cars and for timing and synchronization of European critical infrastructure, as well as by improving access to space data for start-ups

- ensure a globally competitive and innovative European space sector, by making it easier for companies and start-ups to access space data via dedicated industry-led platforms so that they can develop services and applications; by promoting more private investment for start-ups, in particular in the context of the Investment Plan for Europe and the Pan-European Venture Capital Fund-of-Funds
- reinforce Europe's autonomy by accessing space in a safe and secure environment, by supporting the development of cost-effective, reliable and competitive European launchers
- Strengthen Europe’s role as a global actor and promoting international cooperation. [25]

EUROPEAN INSTITUTIONAL PROGRAMS

The **European Space Agency (ESA)** is Europe’s gateway to space. With more than 22 members, it shares financial and scientific resources in order to conduct its diverse activities for scientific and commercial missions. The mandatory activities (space science programs and the general budget) are funded by a financial contribution from all the Agency’s Member States, calculated in accordance with each country’s gross national product [26]. In addition, ESA conducts a number of optional programs. Each Member State decides in which optional program they wish to participate and the amount they wish to contribute. In 2020, the agency generated a budget of around € 6.68 billion. Figure 5 gives a short overview of the contribution, activities and funding source [27]. As shown in Figure 5, the main contributors to the annual budget for 2020 were France, Germany, Italy and the UK. The complete purpose of the ESA can be found in the Annex.

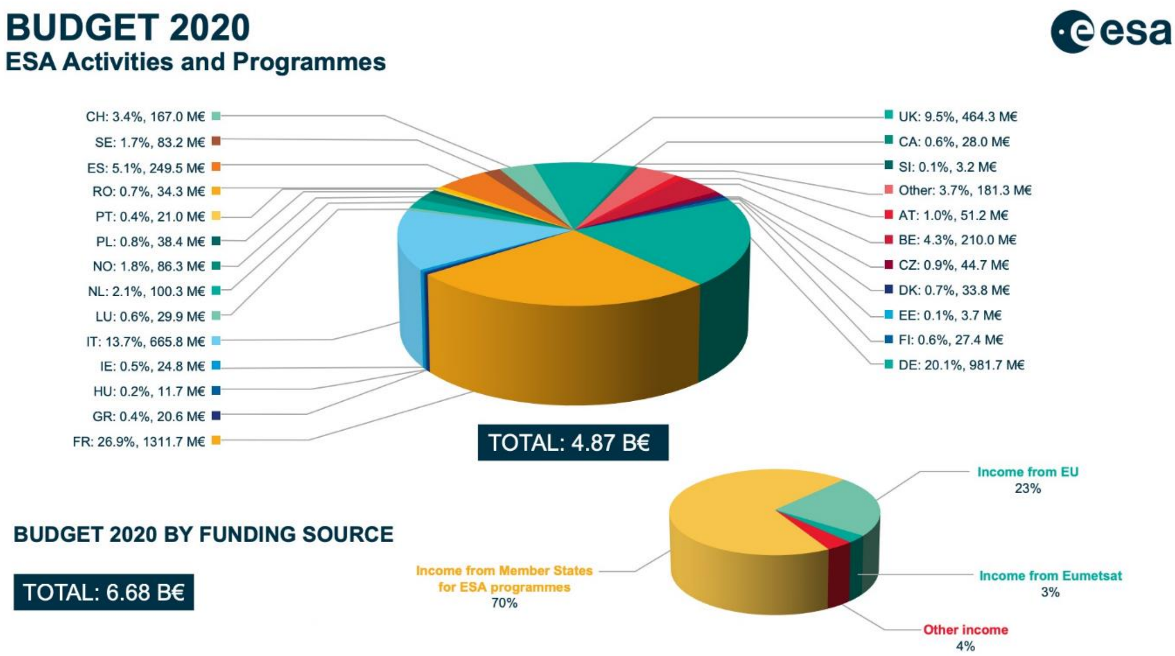


Figure 5: ESA Budget by country for 2020 [26]

3.2. RESEARCH, DEVELOPMENT AND INNOVATION ABILITY

Space research has its main objective and challenge to foster a cost-effective competitive and innovative space industry (including SMEs) and research community to develop and exploit space infrastructure to meet future union policy and societal needs.

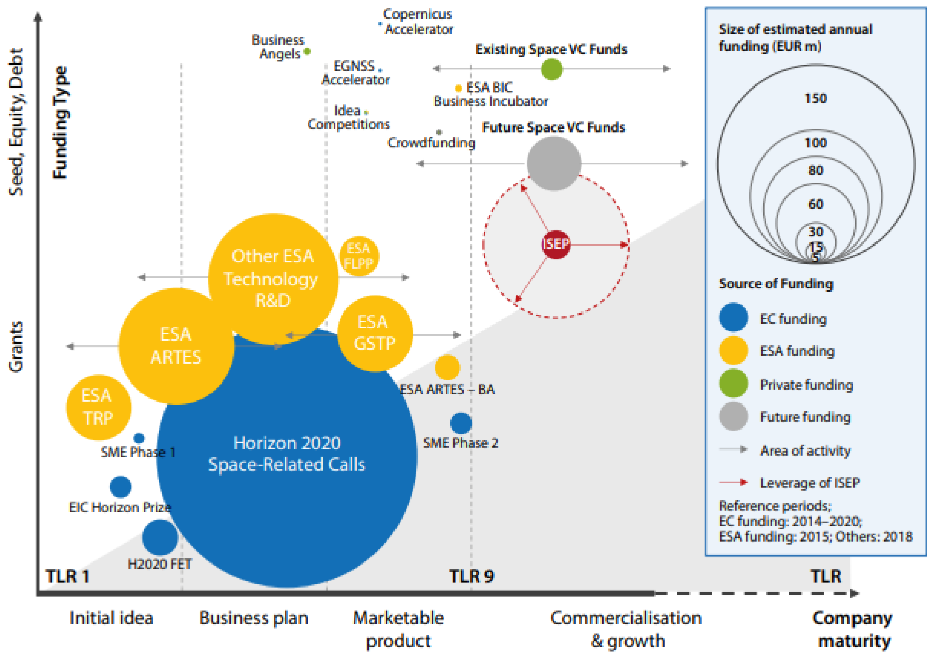


Figure 6: Overview of space-focused financial instruments in Europe and estimated annual funding volume [24]

Figure 7 shows an overview of all available funding instruments and the availability for SMEs in the European space sector sorted according to the technology readiness level (TRL). Several R&D funding programs exist to support the early development of a company itself—most notably the SME Instrument of the EU's Horizon 2020 [24] [28]. However, there is a gap in space-focused funding for the commercialization and growth phases. While Europe has reasonably good access to public funding dedicated to space, private funding sources are lagging far behind. Besides that, the space sector keeps huge barriers for SMEs. It is a very selective and competitive sector with a highly complex funding landscape which often lacks the financial solution to develop and deploy new technologies.

A detailed overview of all market segments in the space sector can be found in the Annex.

4. BEST PRACTICES IN OTHER INDUSTRIES

4.1. TEXTILES USED IN AEROSPACE

BEST PRACTICES AND EXAMPLES

Textiles have been an important material since the beginning of aerospace. Lightweight materials like silk or canvas were some of the initial materials used in the first aircraft and gave the pioneers the possibility to make their dream of flying reality. Nowadays high-performance textiles are used in aircraft and spacecraft because of their efficiency and flexibility while reducing costs. Highly developed special textiles have become an essential component of the manufacturing process and have a high potential for future development. [29] [30]

GENERAL REQUIREMENT PROPERTIES FOR TEXTILES IN AEROSPACE:

- Safety
- Lightweight
- Resistance to water, fuels, fire, high temperatures
- Provide advanced insulation
- Easy maintenance
- Durability
- Enhance of comfort and design
- Hygiene and Infection Control
- Recyclable

Technically the main challenges are **safety** (mainly flame retardancy) and **weight reduction**. It is estimated that for every 1 kg of weight saved in an aircraft, yearly 80€/ per aircraft seat is saved in fuel costs, whilst a 100 kg lighter load can increase the range by 100km. The same challenges occur in the space sector where extra weight in a spacecraft increases fuel consumption and costs significantly. New technologies and today common textile materials have been developed in the space sector because reliability, safety and comfort have high priority. [29] [30] [31]

APPLICATION OF TEXTILES IN AEROSPACE

- Wings, Body parts.
- Curtains.
- Wall covers.
- Seat covers.
- Furnishing fabrics
- Fiber-reinforced composites
- Technical fabrics
- Nylon tyre cord
- Seat belt Webbing
- Air bags
- Floor carpet/covering
- Rotor blades
- Circuit boards
- Webbing for aircraft
- Aircraft upholstery
- Fly-Bag
- Parachutes
- Space shuttle
- Space suits and clothes
- Tyres

RAW MATERIALS AND ESSENTIAL PROPERTIES

Common raw materials in aerospace are Carbon fibers, Kevlar fiber, E- Glass fiber and numerous other textile fibers e.g.: Poly fiber, Boron fiber, Acrylic, Nylon, Polyeurathene, Vinyl ester, Alumina-boria-silica fibers etc. [32] [29]

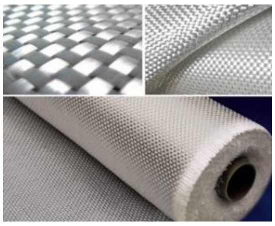


Figure 7 E-glass [29]

The essential properties of textile composites in aerospace applications are:

- High specific modulus.
- High specific strength.
- Resistant to chemicals and organic solvents.
- Good fatigue.
- Non-sensitive to harmful radiations.
- Thermal insulated and thermal resistant.
- Impact and stress resistant.
- Better dimensional stability and conformability.
- Low flammability.
- Recyclable.

AIRCRAFT INTERIOR DESIGNING

Figure 8 Cabin interior [32]

The modern interior of an aircraft uses many different textile developments. The industry develops e.g. higher quality and more robust cables which, unlike rubber or plastics, are coated with resistant specific textiles. The target is to provide higher levels of durability and resilience. Many parts primarily made of rubber or flexible plastic in the past are replaced by textile mixtures that have demonstrated durability in many applications. Since cabin design exists, fabrics have been involved. Here hard-wearing, comfortable and safe fabrics are required for covering seats. They must demonstrate properties for everyday use: easy to clean, be fire-resistant and free of pollutants that could evaporate and pollute the air. Modern materials such as microfibers, nanotechnology, new plastics, artificial leather, fillings made of sustainable materials such as hemp for the upholstery and linings have revolutionized the use of textiles in interiors. [29] [33] Specific maintainability properties required for aerospace interior textiles:

- Washable.
- Abrasion resistance.
- Tear resistance.
- Moisture resistance.
- UV stabilization.
- Material standardization.
- Hygiene and Infection Control.

FUTURE DEVELOPMENTS

New developments of textiles in the aerospace sector are vital for the future development of high-performance air- and spacecraft. Low weight, high strength, cost efficiency, ease of working with the materials, and safety are all parameters that can only be achieved using new materials. **Intelligent or "smart" textiles** with additional functions are particularly interesting. Work is currently being carried out on **self-luminous textiles** with incorporated metal threads that can emit light when stimulated by electricity (e.g. for cabin interior ceiling). Innovations, such as incorporating **bionics** into the development of new textile solutions, will open completely new solutions for engineers and scientists. Thinkable e.g. is a versatile spider silk, which is considerably more resilient and at the same time elastic in comparison to steel threads of the same thickness. The main aim is always to lower the weight and raise efficiency. A key topic is the implementation of **sustainable textiles** and the opportunity to **recycle materials**. E.g., future targets foresee to have a 100% recyclable aircraft. What remains to implement new textiles, is the challenge of developing **efficient production processes**. [33] [31] [29]

4.2. ADVANCED MANUFACTURING IN AEROSPACE

BEST PRACTICES AND EXAMPLES

Aerospace has always been at the forefront and a leading industry in the use of advanced manufacturing technologies. Because of the unique challenges and high **product complexity** that exist for designing air- and spacecraft under extreme environmental conditions, materials must be strong, lightweight, and resistant to temperature and corrosion. Further the **process complexity** with demand on fine, tight-tolerance features that require micro- and nano-machining methods, including laser machining and welding. Aerospace often comes up first with innovative advanced manufacturing approaches, which later are implemented in other industries. [34] [35]

ADDITIVE MANUFACTURING (AM) AND 3D DESIGN

The term AM encompasses many technologies including subsets like **3D Printing, Rapid Prototyping**, **Direct Digital Manufacturing**, **layered manufacturing** and **additive fabrication** with a number of benefits that help the aerospace industry to improve its production process and efficiency with advanced materials and unique geometries. The scope of AM ranges from preproduction visualization models, lattice structures, to a creation of single replacement parts. This reduces the number of possible failure points and simplifies assembly. AM is also moving toward building large parts up to two meters in size. [36] [34]

Need: As in 3D metal printing porosity issues, fissures, cracks, and poor fusion between the metal layers in the finished product can occur, there is a need for **developing reliable standards**. This is possible by generating materials with big data to have a good understanding of all components. [37]
New **3D design solutions** like **Virtual Reality**, **Mixed Reality and Augmented Reality** not only help to realize precision manufacturing but also strengthen the respect of safety regulations. In general, there is still a serious **skill shortage** in the industry. [38]

ROBOTICS AND PRECISION MANUFACTURING

Numerous improvements in the manufacturing machinery have already reached the aerospace manufacturing plants: Special **software** advances for **machine control** and **simulation**, **assembly processes**, and **inspection;** Robots for lifting and handling. **Robotics** and **automation** in the factories of the future will lead to less labour-intensive processes. Robot tasks include **inspection**, **drilling** and **fastening**, **welding**, **sealing** and **dispensing**. Large, fixed **auto-riveting** robots and **laser machining** are used to connect aircraft sections. In general, Robotics take over more and more hazardous work, such as welding, **coating** or **painting**, and help to produce more cost-effective. [34] [37]

INDUSTRY 4.0 - IOT APPLICATIONS

The radical transformation of the manufacturing processes in the aerospace sector through Internet of Things (IoT) is already ongoing. The Trend of using **Big Data, Artificial Intelligence,** and of **digital practices**: **cooperation, mobility**, **open innovation,** will modify not only production infrastructures but also the development of products and services and even the customer relationship. Beyond the before mentioned new tools, the "**Smart Factory"** is a key element of the Industry 4.0 trend. The aerospace sector strives for lower production cost and a significant increase in manufacturing efficiency through the analysis of production data. The aerospace industry and its supply chain, relying on a large network of suppliers will highly benefit from this increase in flexibility and digital integration. [39]

5. OUTCOME OF THE SECTORAL SURVEYS

Within the GALACTICA Project, we launched a survey within its clusters' members to identify the main needs of each sector in order to better design the project activities, the support mechanisms that will be launched in early 2021 and to identify interested actors and their competences. In this chapter, we describe the hot-topics, key issues and needs that have been detected. This serves as base to identify opportunities or challenges in collaboration. Shown are the answers with the highest agreement in percentage. The complete results/statistics of the survey are available upon request.

5.1. GENERAL STATISTICS: PARTICIPANTS OF THE SURVEY

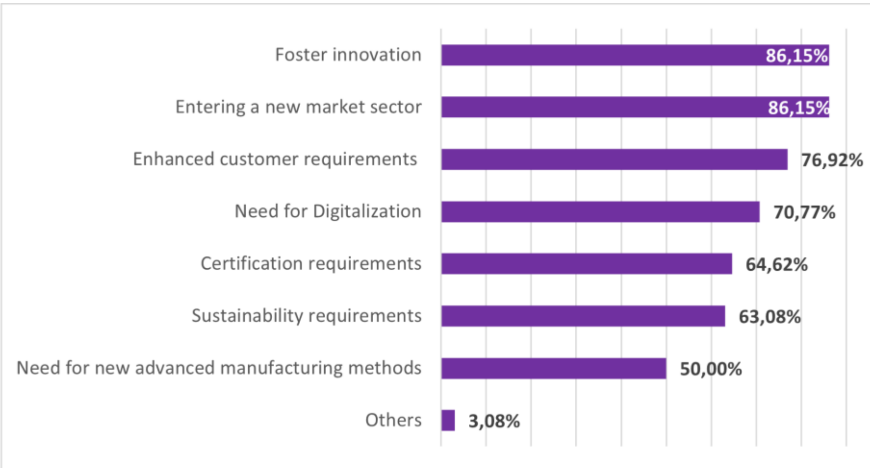
- Total responses 150, Incomplete responses 84, Full responses 66
- 86% SMEs, % Start-Ups, 88% have experience in funded R&D project collaboration

With the majority of participants being SMEs (under the terms of the EU definition) and with experience in funded R&D project collaboration, the answers of the survey build a reliable and useful base for the upcoming activities. The already existing experience in either international, national or cross-sectoral collaboration will be helpful for the successful realization of the GALACTICA activities.

5.2. IMPORTANT QUESTIONS: HOT-TOPICS, KEY ISSUES, NEEDS

- What are your current major pain points?
    (1) Loss of business due to Covid-19 >70%
    (2) Dependence on only one industry sector >60%
    (3) International competition >50%

- Which challenges/ambitions does your company/organisation face in the near future?



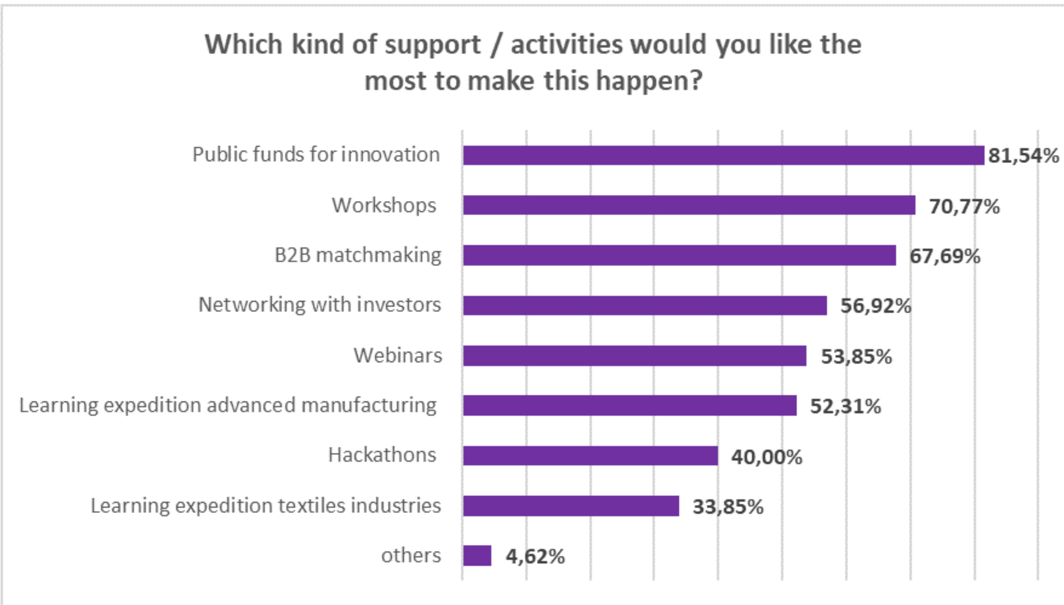
- Does your company/organisation consider to tackle those challenges through following opportunities?
  (1) R & D activities >90%
  (2) Cross-sectoral collaboration >85%
  (3) International networking/collaboration >85%
  (4) Cooperation with startup companies >45%

- Would you consider expanding your business with innovation of other industries?
  (1) Advanced manufacturing >75%
  (2) Digital services >70%
  (3) Textile industry >45%

- What would you consider your main challenges expanding your business with innovation of other industries?
  (1) Lack of contact >60%
  (2) Lack of cash >55%
  (3) Unknown market/industry >45%

SURVEY REGARDING INTEREST IN GALACTICA ACTIVITIES:

- 60% confirmed general interest in participating in cross-sectoral virtual or personal activities (training courses, workshops, on-site visits...)
- The diagram below shows which activities will probably be more attentive. More promotion for the activities with less importance will be necessary.



KEY-TOPICS

Taking the results of our survey we derived three tendencies for the aerospace market in regard to the GALACTICA Project:

1) **Need of collaboration**
   Our survey as well as our market research showed in the aerospace sector the need of collaboration through different industries. There is a high interest in collaboration to learn from the other sectors and to extend their own business. The participants aim for:
   a. Cross-sectoral collaboration
   b. International Networking
   c. New contacts / get to know a new market/industry

2) **Financial support**
   Financial support is a main topic to develop the present and future of the industry. It should help:
   a. To foster innovation
   b. To foster R&D activities
   c. To expand the business
   d. To compensate the loss of business due to Covid-19

3) **Interest in other sectors**

The general high interest in advanced manufacturing and digitalization correlate with the current evolution in the aerospace sector. The industry is driven by more efficiency and new targets, that already and will in the future even more include Robotics, Automation, Advanced Materials, 3D Printing/Rapid Prototyping, Augmented/Virtual Reality as well as design and simulation software, PLM Tools, Digital Mock-Ups, Big Data, Internet of Things, Cyber Security etc.
The results show a lower direct interest in the textile industry which is not surprising. Textiles play an important role in aerospace (see chapter 4.1.). Not all SMEs see the link to this sector yet. But here we see the chance of GALACTICA using the “Outsider Effect” resulting in a mix of new creative ways of thinking, innovation and improving the business.

6. CONCLUSION, OPPORTUNITIES, BARRIERS, RECOMMENDATIONS

Summing up the survey results and the market studies, it became clear, that there are several potential cross-sectoral collaboration opportunities. At a first glance, the aerospace industry has an only high correlation with the advanced manufacturing sector. From up-to-date topics like the implementation of **robotics** and **precision manufacturing**, **digitalization** strategies, **additive manufacturing**, new **3D design** solutions like **Virtual Reality**, **Mixed Reality**, **Augmented Reality** and the **Industry 4.0** trend in general, the aerospace sector will highly benefit through efficient and flexible production processes. In general, there is still a serious **skill shortage** in the industry related to these topics.

At second glance, the great potential of cross-sectoral collaboration with the textile industry is apparent. Combining forces to create innovative and new products tackling the current joint challenges in **sustainability**, **circular economy** and **recyclable materials**, as well as **lightweight** materials and production, will help to achieve the net-zero CO2 emissions target by 2050. In addition, the COVID-19 crisis revealed the necessity to develop **new hygienic solutions** and **concepts,** especially for the cabin sector. **Innovative cabin surfaces and textiles** have become essential and deserve special attention for the future, as other pandemics may emerge.

Nevertheless, the aerospace industry presents some barriers for collaboration. Especially legal and certification requirements can be a challenge for suppliers of lower tiers. In general, **customer** (OEM) **requirements** within this ”closed market” of established supply-chains are demanding. A solution could be to start as a **build-to-print** (or **extended workbench**) company and use the collaboration with experienced aerospace organizations, which in addition ensure the mandatory **safety standards.**

Further future development potential lies also in the new area of unmanned air vehicles (UAV) and in the recently opened space sector.

It became obvious that GALACTICA project with all the foreseen support activities can contribute to help overcome the barriers and to create new cooperation and new value chains between companies and organizations of the three involved sectors.

ANNEX

SPACE SECTOR MARKET SEGMENT

Segment	Description	Proponents Examples
Launcher Industry	Companies that develop launch vehicles and facilities to provide access to near and outer space. These companies also provide launch services, sometimes complemented by rockets sourced from other suppliers (e.g. Soyuz being launched by Arianespace). With the advent of smallsats this domain has received a new impetus to develop micro launchers such as Electron.	• Arianespace • Blue Origin • Rocket Lab • SpaceX • The Spaceship Company • ULA • Vega
Satellite Manufacturing	Companies that develop and build satellites for satellite applications and services for commercial, civilian and military users. With the advent of the CubeSat standard, small, mini, micro and nano satellites complement classical—big—satellites.	• Airbus Defence & Space • ISIS • OHB • Planet • SSL • ThalesAleniaSpace
Satellite Services	Companies that provide satellite services by single satellites or constellations, in low Earth orbit (LEO), medium Earth orbit (MEO), geostationary orbit (GEO) or any other orbit deemed appropriate. Typical services involve satellite communication, Earth observation, satellite navigation and integrated applications.	• DigitalGlobe • OneWeb • Orbcomm • Planet • SES • Spire
Ground Equipment	Companies that develop hardware and software for mission control centres, telemetry and telecommand systems (e.g. Deep Space Networks), as well as GNSS receivers and communication terminals (e.g. VSAT).	• Hughes Network Systems • ND Satcom • Terma • ViaSat
National Security	Companies that provide services and applications in the interest of national security, including satcom, Satnav, Remote Sensing and Space Situational Awareness. This domain is more concerned by service availability than cost.	• Airbus Defence & Space • Boeing • Lockheed Martin • OHB • Satellite Imaging Corp.
Crewed and robotic Space Science and Exploration	Companies that manufacture specific crewed and robotic exploration vehicles such as probes, orbiters and landers, support the operation of these vehicles and/or perform the retrieval and processing of the data acquired during the science or exploration mission. With the renewed interest in crewed exploration beyond LEO (e.g. cis-lunar space), new players emerge, often originating from space tourism ambitions or incentive prices (Google Lunar X-Prize).	• Airbus Defence & Space • Astrobotic • Boeing • MDA • Moon Express • PT Scientists • Sierra Nevada Corp. • SpaceX
Space Tourism (incl. Habitation)	Companies that manufacture and operate space vehicles as well as habitats in space, providing access to space for everyone that can afford the ticket and is fit enough for flight. So far space tourism has focused on suborbital flight, but once this step has been successfully reached orbital flight will certainly follow. NASA is supporting the development of this domain by its ISS cargo resupply contracts and commercial crew awards.	• Airbus Defence & Space • Axiom Space • Blue Origin • Boeing • Sierra Nevada Corp. • Virgin Galactic
Energy, Mining, Processing and Assembly	Companies that aim to manufacture goods in space, building upon resources in space (e.g. solar energy), on the moon, asteroids or on Mars. While asteroid mining has attracted some interest, space-based energy harvesting is waiting for the first serious start-ups.	• Deep Space Industries • MDA • Planetary Resources • Shackleton Energy Corp.

Figure 9 Market segments with descriptions and proponents [24]

EUROPEAN SPACE AGENCY PURPOSE

The full definition of our purpose comes from Article II, Purpose, Convention of establishment of a European Space Agency, SP-1271(E), 2003, which states:

- *ESA's purpose shall be to provide for, and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems:*
- *by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;*
- *by elaborating and implementing activities and programmes in the space field;*
- *by coordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;*
- *by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.*

LIST OF REFERENCES

[1] "European Union: Eurostat Statistics Explained," 2020. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php/Air_passenger_transport_-_monthly_statistics#Development_of_air_passenger_transport_at_EU_level. [Accessed 07 December 2020].

[2] I. a. A.-B. Flightaware, "Operational Impact on Air Transport," 2020. [Online]. Available: https://data.icao.int/coVID-19/operational.htm. [Accessed 07 December 2020].

[3] Statista, "Statista," 2020. [Online]. Available: https://www.statista.com/statistics/1118397/air-passenger-transport-european-union/. [Accessed 07 December 2020].

[4] G. A. I. A. (BDLI), "Industry Figures of the German Aerospace industry," [Online]. Available: https://www.bdli.de/sites/default/files/2020-07/Branchendaten_2019_E_0.pdf. [Accessed 07 December 2020].

[5] Airbus SE , "Airbus delivers strong 2019 commercial aircraft performance," [Online]. Available: https://www.airbus.com/newsroom/press-releases/en/2020/01/airbus-delivers-strong-2019-commercial-aircraft-performance.html. [Accessed 07 December 2020].

[6] ICAO , [Online]. Available: https://www.icao.int/sustainability/Documents/COVID-19/ICAO_Coronavirus_Econ_Impact.pdf. [Accessed 07 December 2020].

[7] Airbus SE, "Airbus September 2020 commercial aircraft orders & deliveries," [Online]. Available: https://www.airbus.com/newsroom/press-releases/en/2020/10/airbus-september-2020-commercial-aircraft-orders--deliveries.html. [Accessed 07 December 2020].

[8] Deloitte, "Post Covid-19 Aerospace Industry - An opportunity to embrace the 4.0 Era?," [Online]. Available: https://www2.deloitte.com/fr/fr/pages/covid-insights/articles/post-covid-19-aerospace-industry.html. [Accessed 07 December 2020].

[9] Aerospace and Defence Industries Association of Europe, "2020 Facts & Figures," [Online]. Available: https://www.asd-europe.org/sites/default/files/atoms/files/ASD_FactsFigures_2020.pdf. [Accessed 07 December 2020].

[10] European Commission, "Aeronautics Industries," [Online]. Available: https://ec.europa.eu/growth/sectors/aeronautics_en. [Accessed 07 December 2020].

[11] Statista, "European aeronautic industry turnover from 2010 to 2019," [Online]. Available: https://www.statista.com/statistics/638529/european-aeronautic-industry-turnover/. [Accessed 07 December 2020].

[12] Airbus SE, "Financial results and annual resport," [Online]. Available: https://www.airbus.com/investors/financial-results-and-annual-reports.html. [Accessed 07 December 2020].

[13] S. C. E. Initiative, "Supply Chain Excellence in der deutschen Luftfahrtindustrie - Status Quo und Perspektiven für den Luftfahrtstandort Deutschland," https://www.german-aerospace.de/wp-content/uploads/2017/07/240606_Studie-SCE-in-Deutschland.pdf, 2016.

[14] Statista, "Key figures of the four largest aircraft manufacturers worldwide in FY 2019," [Online]. Available: https://www.statista.com/statistics/269920/key-figures-of-the-four-largest-aircraft-manufacturers/. [Accessed 07 December 2020].

[15] h&z Unternehmensberatung, "Competitiveness of European Aerospace Suppliers - a joint analysis of France and Germany," [Online]. Available: https://huz.de/wp-content/uploads/2019/03/20180425-hz_KeaPartners-Aerospace-supplier-study-_released-final-small8061.pdf. [Accessed 07 December 2020].

[16] Roland Berger, "HOW THE COVID-19 CRISIS IS EXPECTED TO IMPACT THE AEROSPACE INDUSTRY," [Online]. Available: https://www.rolandberger.com/de/Point-of-View/How-the-COVID-19-crisis-is-expected-to-impact-the-aerospace-industry.html. [Accessed 07 December 2020].

[17] European Commission, "Reducing emissions from aviation," [Online]. Available: https://ec.europa.eu/clima/policies/transport/aviation_en. [Accessed 07 December 2020].

[18] Air Transport Action Group (ATAG), "Facts & Figures," [Online]. Available: https://www.atag.org/facts-figures.html. [Accessed 07 December 2020].

[19] OECD, "COVID-19 and the aviation industry: Impact and policy responses," [Online]. Available: http://www.oecd.org/coronavirus/policy-responses/covid-19-and-the-aviation-industry-impact-and-policy-responses-26d521c1/. [Accessed 07 December 2020].

[20] "GTP," 2020. [Online]. Available: https://news.gtp.gr/2020/11/19/europes-aviation-bodies-commit-to-reach-net-zero-co2-emissions-by-2050/.

[21] "Aeroimpulse," 2020. [Online]. Available: https://www.aeroimpulse.de/en/insights/.

[22] M. Hinsch, Industrielles Luftfahrtmanagement - Technik und Organisation, Berlin Heidelberg: Springer-Verlag , 2010.

[23] "OECD," 2020. [Online]. Available: https://stats.oecd.org/Index.aspx?DataSetCode=PATS_IPC#.

[24] p. o. t. E. Innovation Finance Advisory in collaboration with the European Investment Advisory Hub, "The future of the European space sector - How to leverage Europe's technological leadership and boost investments for space ventures," 07 December 2020. [Online]. Available: https://www.eib.org/attachments/thematic/future_of_european_space_sector_en.pdf.

[25] E. Commission, "Space," [Online]. Available: https://ec.europa.eu/growth/sectors/space_en#:~:text=A%20Space%20Strategy%20for%20Europe&text=Reinforce%20Europe's%20autonomy%20in%20accessing,actor%20and%20promoting%20international%20cooperation.. [Accessed 07 December 2020].

[26] E. S. Agency, "ESA facts," [Online]. Available: https://www.esa.int/About_Us/Corporate_news/ESA_facts. [Accessed 07 December 2020].

[27] E. S. Agency, "ESA facts," [Online]. Available: https://www.esa.int/About_Us/Corporate_news/ESA_facts. [Accessed 07 December 2020].

[28] E. Commission, "Space," [Online]. Available: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/space#Article. [Accessed 07 December 2020].

[29] "Textilefocus," 2020. [Online]. Available: http://textilefocus.com/application-of-textiles-in-aerospace-engineering/.

[30] "textileblog," 2020. [Online]. Available: https://www.textileblog.com/textile-application-in-aerospace-industry/.

[31] "Ingenieur," 2020. [Online]. Available: https://www.ingenieur.de/technik/fachbereiche/raumfahrt/erprobung-textilien-in-schwerelosigkeit/.

[32] "Textilelearner," 2020. [Online]. Available: https://textilelearner.blogspot.com/2014/07/what-is-aerospace-textile-application.html.

[33] "ARTS," 2020. [Online]. Available: https://arts.eu/de/insights/artikel/textilien-in-der-industrie-die-bedeutung-von-modernen-textilien-in-der-luft-und-raumfahrt/.

[34] "ASME 4key," 2020. [Online]. Available: https://www.asme.org/topics-resources/content/four-key-advanced-manufacturing-technologies-used.

[35] "Cincom," 2020. [Online]. Available: https://www.cincom.com/blog/uk/configuration/aerospace-manufacturing-advanced-manufacturing.

[36] "European Commission 3D," 2020. [Online]. Available: https://ati.ec.europa.eu/reports/sectoral-watch/industry-40-aeronautics-3d-design-applications.

[37] "ASME," 2020. [Online]. Available: https://www.asme.org/topics-resources/content/advancing-additive-manufacturing-in-aerospace.

[38] "ITportal," 2020. [Online]. Available: https://www.itproportal.com/features/advanced-manufacturing-for-a-more-efficient-aerospace-industry/.

[39] "European Commission Industry 4.0," 2020. [Online]. Available: https://ati.ec.europa.eu/reports/sectoral-watch/industry-40-aeronautics-iot-applications.

[40] "Aeroreport," 2020. [Online]. Available: https://aeroreport.de/de/innovation/feuerfest-und-moeglichst-leicht-textilien-fuer-die-luftfahrt.

[41] "Slideshare," 2020. [Online]. Available: https://www.slideshare.net/akaashi20/aerospace-textiles.