Grant Agreement No.: 760941

Project acronym: RESISTANT

Project title: Large riblet surface with super hardness, mechanical and temperature resistance by nano functionalization

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Thematic Priority: PILOTS-03-2017 Pilot lines for manufacturing of nanotextured surfaces with mechanically enhanced properties

Starting date of project: 1st of January, 2018

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D9.1 – Business model to support the partners aiming at the commercial exploitation of the project results

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Dissemination Level		
PU	Public	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

Table of Contents

List of abbreviations / Nomenclature

Abbreviation	Definition
ACI Europe	Airports Council International Europe
APAC	Asia Pacific Countries
ASK	Available Seat Kilometers
ATM	Air Traffic Management
BCM	Billion Cubic Meter
BM	Business Model
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
DOA	Description Of Actions
DPCI	Derwent Patent Citation Index
DWPI	Derwent Word Patent Index
EASA	European Union Aviation Safety Agency
EPCM	Engineering, Procurement and Construction Management
EU	Europe
FAA	Federal Aviation Administration
IAG	International Airlines Group
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IP	Intellectual Property
LCCs	Low Cost Airline Growth
MRO	Maintenance, Repair and Overhaul
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OPEX	Operating Expense
R&D	Research & Development
RPK	Revenue Passenger kilometres
SME	Small and Medium Enterprises
SWOT	Strengths. Weaknesses, Opportunities, Threats
TRL	Technology Readiness Level
VOC	Volatile Organic Compounds

Glossary

Technical definitions

Turbojet
In turbojet engines, the air passes from the front of the engine and enters the combustion chamber. The fuel inlet and igniter is located in this section. The turbine is then driven by the exhaust air, which finally exhausts at a high speed from the rear of the engine. This produces the reaction that pushes the aircraft forward. Turbojet is the simplest form of all aircraft turbine engines.

Turboprop
Turboprop are mainly useful for lower speed applications. In this type of engine, the energy exhaust is used to drive the propeller, after reducing the air speed through a gearbox. Turboprop engines provide a greater fuel efficiency and performance, at slower airspeeds. Thus, it is mainly used for small transport aircraft. However, the propellers are less efficient as the aircraft speed increases. The same type of engine used to power the rotor in a helicopter (instead of a propeller) is called a turbo shaft engine.

Turbofan
In turbofan engine, a part of the air is exhausted without passing it through the core, which produces additional thrust. These engines are also called 'bypass jets' and are more efficient than turboprops. Turbofans are the modern version of an aircraft turbine engine and are found on high-speed transport and fighter aircrafts.

Reciprocating compressors
A piece of equipment that increases the pressure of a process gas by positive displacement, employing linear movement of the driveshaft.

Centrifugal compressors
Any machine for raising the pressure of a gas by drawing in low pressure gas and discharging significantly higher pressure gas by means of mechanical rotating vanes or impellers.

Market definitions

Acceptor Market
The analysis of the Acceptor Market focuses on understanding if there would be a demand for a specific product or service and which would be the set of potential customers for it.

Reference Market
The analysis of the Reference Market focuses on evaluating the competitive scenario investigating the main players in the market.

Business Models Definitions

Business Model
A plan for the successful operation of a business, identifying sources of revenue, the intended customer base, products, and details of financing.

Business Model Canvas

A Business Model Canvas relies in nine building blocks that explain the logic behind how a company creates value, captures value and how value is shared along the value chain:

1. **Costumer segments**, which the organization creates value for.
2. **Value proposition**, which includes services and products, that satisfy a customer segment needs and solve its problem.
3. **Channels**, which are used by the organization to deliver, communicate and sell value propositions.
4. **Customer relationships,** which the organization creates and maintain with each customer segment.
5. **Revenue streams,** which are the result of successfully “selling” the value proposition to the customer segments.
6. **Key resources**, which are necessary to offer and deliver the value proposition.
7. **Key activities**, which need to be performed in order to deliver the value proposition.
8. **Key partnerships**, which refers to the network of suppliers and other partners that make it possible for the organization to deliver the value proposition.
9. **Cost structure**, which comprehend all the costs associated with the business model operation.

1 Introduction

The present document represents deliverable "**D9.1: Business Model to support the partners aiming at the commercial exploitation of the project results**", developed under the responsibility of PROD, supported by RINA-C, in the framework of Task 9.3 "Market analysis and provisional business model" led by RINA-C.

The document is mainly divided into two main sections: the first one is related to the Market Analysis (RINA-C responsibility) aimed at investigating both the Acceptor and the Reference markets; the second one is related to the Business Modeling activities (PROD responsibility), aimed at evaluating the potential commercialization routes for the project results to penetrate the investigated markets.

Thus, the document is mainly divided into two main chapters:

- Chapter 2 is related to the **Market Analysis** aimed at providing an overview of the reference sectors, namely **nanocoatings, aircraft turbine engines and avionics MRO and industrial compressors**, investigating their market size, main trends and barriers as well as competing scenario.
- Chapter 3 is related to the **Business Modeling** activities, aimed at evaluating the potential commercialization routes for project partners based on the business models identified, with respect to the main project results, namely **nanoriblets** applied at the **two demonstrators**, **aircraft turbine engine and centrifugal compressors**.

Finally, conclusions are provided.

2 ReSiSTant project and main results

The main objective of ReSiSTant project is **to develop, upscale and industrially demonstrate up to TRL 7 reliable manufacturing processes to obtain nanostructured riblet surfaces** to be applied in Aircraft Turbofan Engines and industrial Compressors to reduce drag and the related fuel consumption and emissions. Indeed, ReSiSTant consortium aims at the realization of simple, safe, low cost in terms of CAPEX and OPEX, replicable deposition and manufacturing process able to realize large scaled areas with highly ReSiSTant nano- and microstructured surfaces to be applied on newly built and existing turbomachinery blades in order to increase their performances and reduce their wear. ReSiSTant innovation (nanocoatings and their manufacturing process) will be demonstrated in two different industrial lines, embedded into the product portfolio of three globally acting enterprises from the consortium (GEDE, MAN-ES and LHT).

Indeed, MAN Energy Solutions is a world market leader in the field of industrial compressors. GEDE Aviation (GEDE) is one of the leading companies worldwide developing and researching high efficient jet turbines. Last one is Lufthansa Technik AG (LHT), a world leading aircraft MRO (Maintenance, Repair and Overhaul) company which covers the aftermarket and retrofit market.

Hereafter a short description of the two demonstrators is provided according to their current status[1]

- **Demonstrator 1a: Test rig at Graz University of Technology**

Demonstrator 1 consists in the application of nanoriblet in an aircraft turbofan engine with the aim of determine the benefit of riblets applied to turbine frame and/or airfoil surfaces in terms of performance efficiency, fuel consumption reduction, noise level reduction.

In Figure 2.1 the current state of the test rig (lower half) and the modified version (upper half) of the test rig used in ReSiSTant are shown. Coloured parts are being designed, manufactured and assembled in the project.

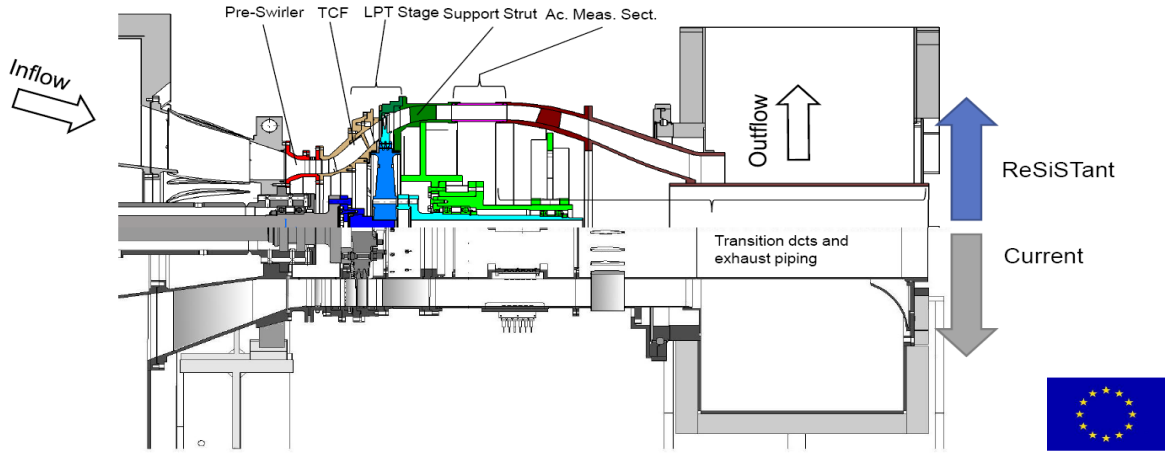


Figure 2.1: DEM1 test rig design (currently and modified)

This modified design of the test rig, with particular attention to the turbine centre frame and the low pressure turbine rotor, is representative of a state of the art for what concerns the low pressure turbine engine module.

[1] Source: D6.1: “Demonstration KPI Panel”

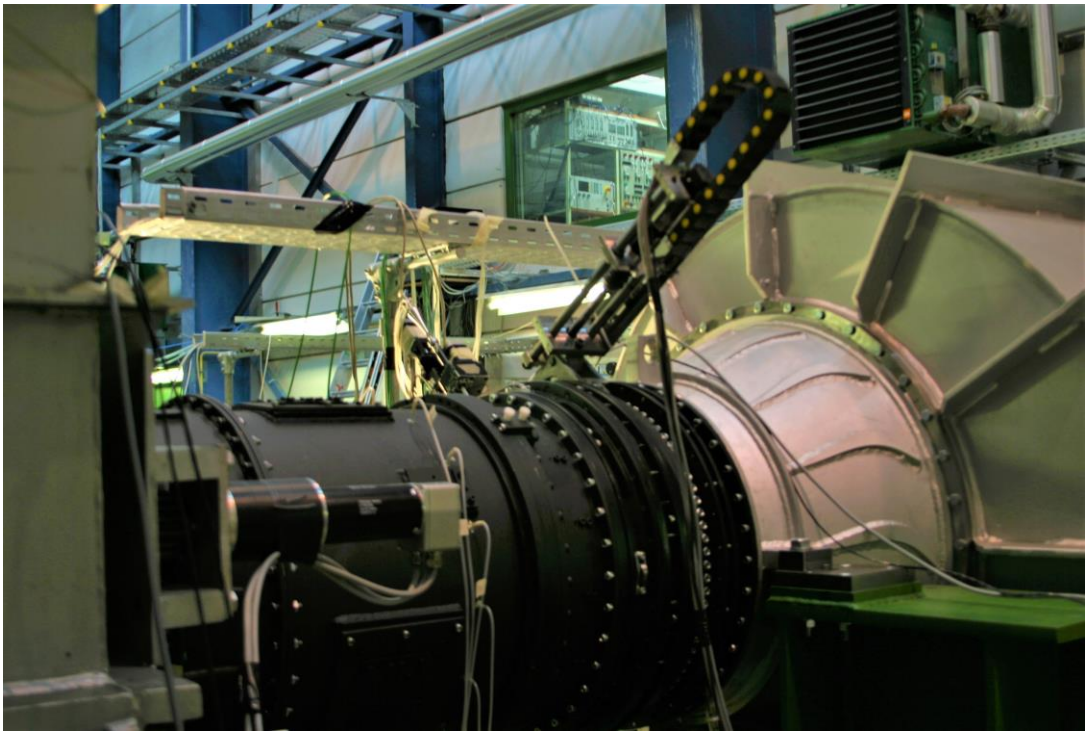


Figure 2.2: DEM1 installed on this tests bench

- **Demonstrator 1b: Test rig at Lufthansa Technik**

Demonstrator 1b consists of a used CFM 56 engine from an Airbus A340. As it is a retired engine, there are not airworthiness limitations. It is employed to test nanoriblet coated turbine blades in validation experiments and CFD simulations.

Figure 2.3 Test rig at LHT

On the following images, instrumentation used on the test rig is described:

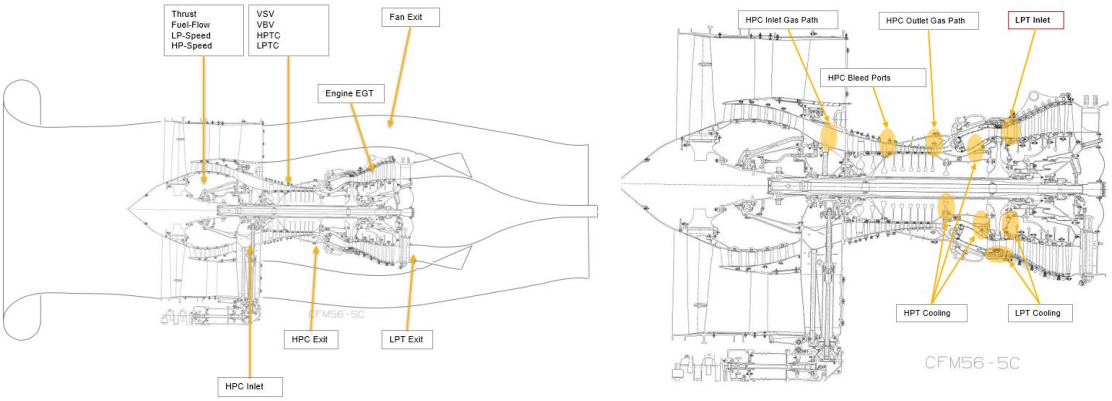


Figure 2.4 Instrumentation for validation experiments

- **Demonstrator 2: Test rig at RWTH Aachen University**

Demonstrator 2 consists in the application of nanoriblet in an industrial compressor with the aim of reducing the aerodynamics shear stress losses increasing the efficiency, the corrosion protection and the potential lifetime.

Figure 2. shows the modified test rig design of Demonstrator 2, upgraded for a wider range of operating conditions. This allows a higher flexibility in terms of the investigation of radial compressor stages. The main characteristic of the test rig is the closed loop setup enabling testing conditions at increased inlet pressure.

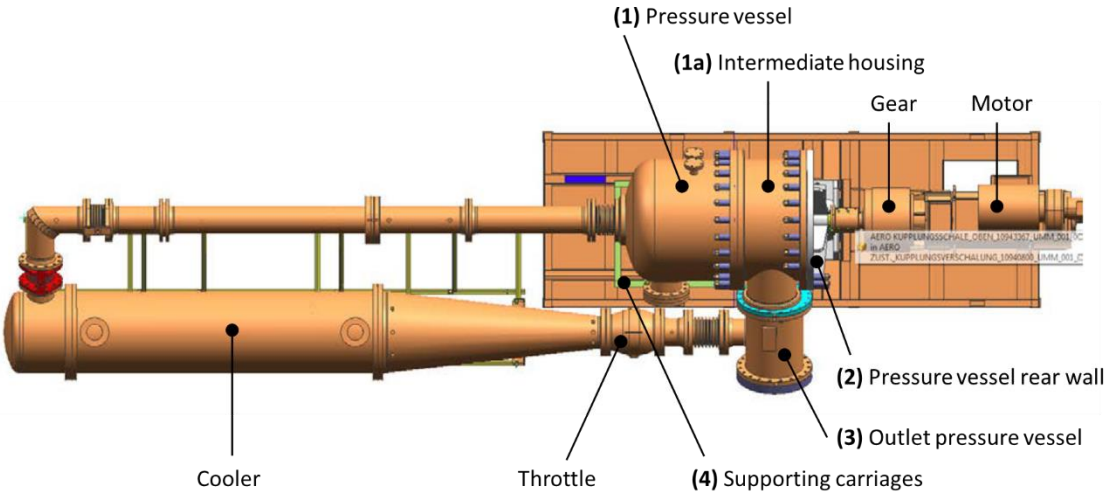


Figure 2.5: DEM2 test rig with modified design

Indeed, the main goal of the riblet application in centrifugal compressor stages is the reduction of losses leading to an increased performance. Hence, less energy is needed for the same pressurization of the working fluid. In a different way of evaluation, a higher outlet pressure can be achieved at the same rate of drive power.

Figure 2.6: Test rig of Demonstrator 2 at IKDG, RWTH Aachen

3 Market Analysis

The market analysis aims at providing an overview of the main sectors of applications of the nanoriblets investigated for the project purposes, namely the aircraft turbine engines and avionics MRO and the industrial compressors sectors. Moreover, an overview of the nanocoating market is initially provided, highlighting the main trends and barriers and taking into account the most promising applications and the related advantages (economic, social and environmental) that make them more appealing for potential customers. Then, the analysis moves on providing an in depth overview of the main application markets, providing the market size and growth rate, the forecasted demand for the next 5-10 years as well as the main sector key players, resulting in potential customers for the nanoriblets producers. As also depicted within the DoA the attention will focus not only on the EU region but will also provide a general overview of extra EU countries.

3.1 Nanocoating market: trends and barriers

Nanocoating is the result of an application where nano-structures build a consistent network of molecules on a surface. Thus, nanocoatings are substrates coated with nanomaterials by a film of thickness in the nano-range (10^{-9} m). Among the main advantages they give, these coatings provide weather resistance to protect coated surfaces from getting degraded. It is a growing line to expand the usage in the Europe region, and some of its applications are already in use whereas many more are still under development. Indeed, nanocoatings have become an integral part of various end-use industries, ranging from manufacturing to medical & healthcare. End-user industries have started to realise the advantages of using nanocoatings over conventional paints and coatings. This combined with increased R&D activities have led to the growth of the nanocoating market. As depicted in Figure 3.1, it is forecasted that the **North American nanocoatings market will be the widest**, with a volume of 2,11 million tons in 2026 (equivalent to a value of 10,97 billion USD), **followed by European and Asiatic ones**, expecting to reach in 2026 approximately the same values around 1.300 tonnes. The EU market is expected to grow at a CAGR of 23% (kilotons) and 24,5% (USD million) between 2016 and 2026.

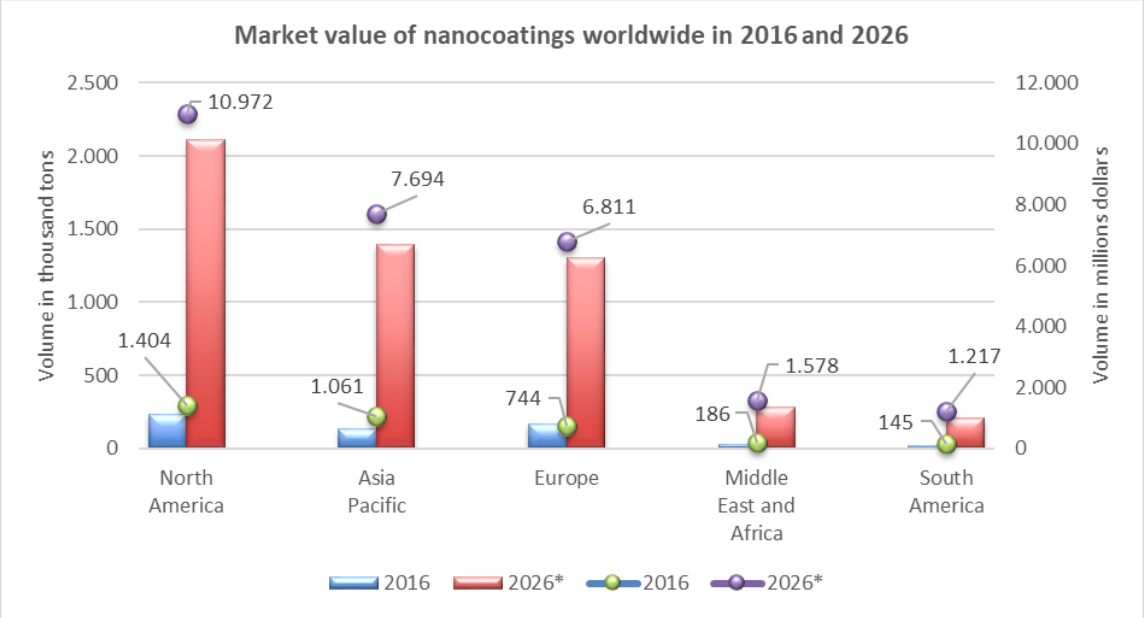


Figure 3.1: Market value of nanocoatings worldwide in 2016, with a forecasted figure for 2026 *estimated forecast (Sources: Statista and RINA Elaboration)

The European Government has stringent regulations associated with the coatings industry due to the harmful VOC content, but nanocoatings are known to be a promising alternative to the conventional coatings because of its low VOCs that will result in increased demand in EU during the forecast period (2016-2026).
The major countries in the European region that are driving the market for nanocoatings are Germany, the U.K., France, Spain, Italy, Norway, the Netherlands and Belgium (NKWOOD Research, 2017). **More than thousand companies in the nanotechnology sector in Germany** and approximately many more research institutes in the same field are continuously researching to develop better products and services, which are mostly funded by the federal government of Germany. Thus, resultant to these conditions, the German nanocoatings market is the largest shareholder in the EU market.
This is also confirmed by the patent mapping analysis that has been performed in order to better understand this market. The analysis has been done out exploiting Derwent Innovation (website: www.derwentinnovation.com) database. Derwent Innovation is unrivalled as a search and analytics platform for IP and business-critical decision making. It is powered by best-in-class technology including artificial intelligence, together with unparalleled expertise in patent data and IP workflows built in. It is underpinned by global, standardized patent data including bibliographic data, full text documents, drawings, Derwent Word Patent Index (DWPI) and Derwent Patent Citation Index (DPCI). The tool offers patent and literature collections.
In this context, the patent scenario analysis is provided with the aim to identify patents temporal trend submission, patent publications countries as well as trend of the main applicants. The patent surveillance study selected patents from 2000 up to day, using a simple query referring to nanocoating in general. The query selected a total of 653 patents in the period under analysis (corresponding to 337 DWPI families). As it can be noticed from the following figures in the period under consideration (2000-2019) there was a positive temporal trend until 2014 (with an exception for 2006); from that year there was a negative temporal trend until 2017 achieving then a steady trend. Probably the research activities achieved a steady trend also depending on the application field of nanocoatings.
Concerning the patents geographical panorama, there has been great interest towards patent applications from countries as China, US and Europe. Main players emerging from the analysis are primarily linked to the plasma functional coating sector or the sector of nanomaterials in the areas of nanopowders, thin film coatings and devices. They are Europlasma and Ngimat, who submitted 21 and 17 patents respectively. In the following the main results of the patent scenario analysis are reported.

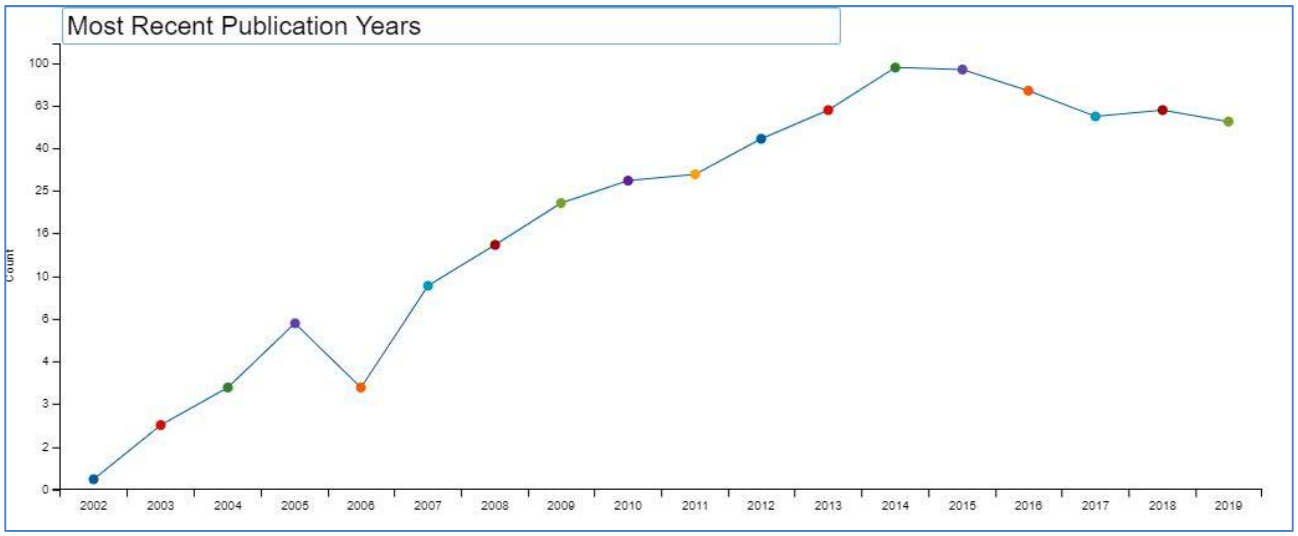


Figure 3.2: Patent temporal trend (2009-2018) – Nanocoating

Figure 3.3: Patent Publication Countries

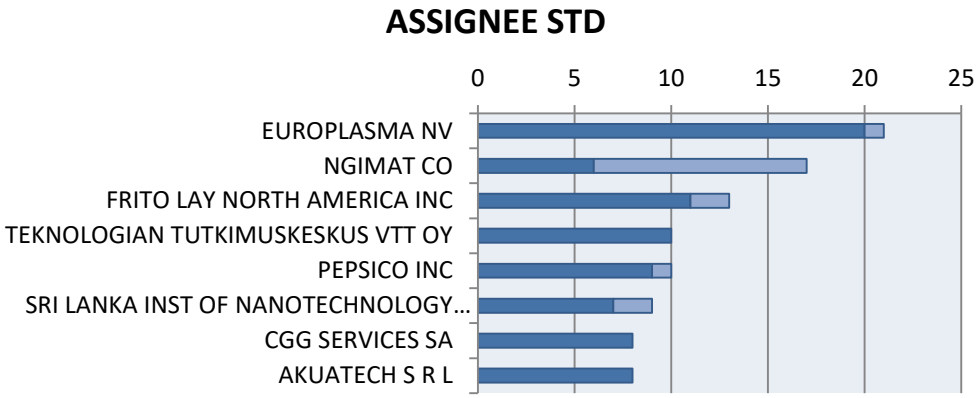


Figure 3.4: Top 8 main applicants

Looking more in details to EU patents' status, as already mentioned, it is again confirmed that Germany is the leading country in the R&D activities on nanocoatings/nanotechnologies.

Figure 3.5: Overview of countries patents publications with respect to nanocoatings and nanotechnologies (8175 patents (3974 INPADOC families))

Trends and barriers for the nanocoatings market are provided within Figure 3.6, where the SWOT analysis put in evidence where the advantages and disadvantages of the nanoriblets may be conceived (respectively Strengths and Weaknesses) as well as the main trends and barriers from the market perspective (respectively the Opportunities and Threats).

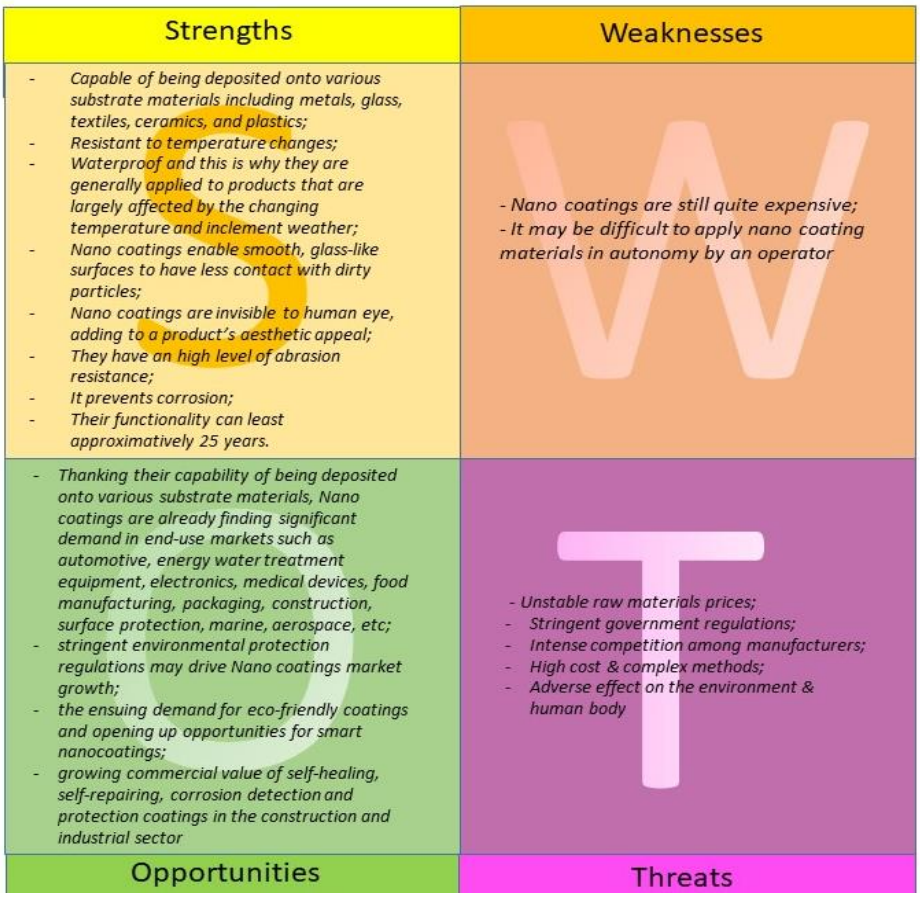


Figure 3.6: SWOT Analysis of Nano coating materials
Source: RINA-C Elaboration

As can be understood by the SWOT analysis, the following **Strength Points** for the nanocoatings market can be identified:

- Nanocoatings are temperate resistant, which is why they are generally applied to products that are largely affected by the changing temperature and inclement weather. Such products include vehicles, aircrafts, ceramic tiles, and glass windows.
- Nanocoatings are waterproof.
- Nanocoatings are invisible to the human eye adding to the product an aesthetic appeal. Because it offers a clear, colorless protection that is virtually invisible to the naked eye, nanocoatings does not compromise an item's natural gloss and transparency.
- The technology's ability to resist UV light damage and abrasion allows for a maximum product life span. These features also make nanocoatings ideal for trucks, boats, buses, and essentially all types of vehicles as they can protect painted surfaces.
- Corrosion in one of the biggest enemies of metal. With nanotechnology coatings, metal durability is enhanced, hence why industries, like automotive and aerospace, rely heavily on this technology. In the aircraft manufacturing market, for example, the parts and materials are largely made of magnesium alloys. But because they easily corrode due to its high chemical reactivity, nanotech coatings are applied. This technology is how even being

thought as an effective replacement for certain metals used in the development of aircraft airframes;

- One of the most sough-after benefits of nano coating is its durable longevity. Because the benefits of nano coatings include resistance to sea water, salty air, light scratches, UV damage and particles, you can expect a nano-coated item to last for years;
- As mentioned, nano coated products do not easily accumulate dirt. But on rare occasions that foreign elements like dust, water marks, bird fouling, or algae do adhere to the surface, a quick rinse using a soft, damp sponge and clean water should already do the trick. This capability makes regular and frequent maintenance a thing of the past, enabling consumers to save time, effort and money (Coating world).

Instead, concerning **Opportunities**, nanocoatings are capable of being deposited onto various substrate materials including metals, glass, textiles, ceramics, and plastics nanocoatings are already finding significant demand in end-use markets such as automotive, energy water treatment equipment, electronics, medical devices, food manufacturing, packaging, construction, surface protection, marine, aerospace, etc.
Few of the major factors driving growth in the market include stringent environmental protection regulations, the ensuing demand for eco-friendly coatings and opening up opportunities for smart nanocoatings; growing commercial value of self-healing, self-repairing, corrosion detection and protection coatings in the construction and industrial sector.

For what concerns **Weaknesses,** is important to underline that nanocoating materials are still quite expensive and it may be difficult, for an operator, for example of the automotive industry, to apply in autonomy the coatings on the surface he is working on, due to the need of the nanocoating application to have particular air condition in the local of manufacturing and the surface to be coated has to be in perfect condition for the application on the best way.

Instead, with increasing adoption of Nano coatings, newer challenges (**Threats**) have been introduced in the market. Factors like unstable raw materials prices, stringent government regulations, intense competition among manufacturers, high cost and complex methods are hindering the market growth. The last few years have witnessed rising concerns regarding the adverse effects of nanocoatings on the environment & human body. Nanoparticles, being small in size, pose a high risk of getting absorbed into the living organisms, reaching their bloodstream and organs, and interfering with the normal functioning of the body. Nanoparticles, if not handled properly during the manufacturing of nanocoatings, can act as air pollutants with the potential of causing severe respiratory diseases. There are many speculations regarding the safe use of nanocoatings in the food and packaging industry. For instance, Food and Drug Administration (FDA) in the U.S tested the nanomaterials for pharmacotoxicity (NKWOOD Research, 2017).

Concerning the competitive landscape of the nanocoating market, the main players have been identified both from desk analysis. At global level, the main companies are the following:

- Eikos Inc.;
- Nanofilm Ltd. (Pen Inc.);
- PPG Industries Inc.;
- AkzoNobel N.V.;
- Aquashield Technologies;
- BASF;
- Inframat Corporation;
- Surfix BV-Advanced Nanocoatings;
- Admat Innovations;
- Integran Technologies;

- Nano-Care AG;
- Nanophase Technologies Corporation;
- Bio-Gate (Syntosbeteiligungs Gmbh);
- Nanovere Technologies LLC;
- CG2 Nanocoatings Inc.;
- Nilima Nanotechnologies;
- P2i Ltd.;
- Tesla Nanocoatings.

Among the above mentioned, a short description of the main European companies and main products are provided in table below.

Table 3.1: Main European Companies operating in European nanocoatings market

AQUA SHIELD	AquaShield maintains a worldwide research and development network through partnerships with leading nanotechnology laboratories. AquaShield Products ranging from Fabric, Textile and Leather Treatment, Concrete and Stone Treatment, Complete Car Coatings, Permanent Wood Treatment, Antimicrobial Treatment, Glass Treatment to Metal Care. The company, in 2018, has reached a revenue of about 22.4 Million Dollars. Website: https://aquashield.net/
BASF The Chemical Company	BASF portfolio is organized into six segments: Chemicals, Materials, Industrial Solutions, Surface Technologies, Nutrition & Care and Agricultural Solutions. BASF generated sales of around €63 billion in 2018. BASF uses nanotechnology to develop new products and improve existing ones. Website: https://www.basf.com/
inframat®	Inframat Corporation is a high technology company founded in 1996 to develop nanostructured materials to improve performance and extend the life of coated components. Key lines of business include Sponsored Research and Advanced Material Sales. Inframat sells a wide variety of advanced materials, including nano-based materials, solid oxide fuel cell (SOFC) materials, grinding media for laboratory and industrial use, and a proprietary line of thermal spray and welding feedstocks and equipment. The company has reached, in 2018, a revenue of about 28,1 Million Dollars. Website: http://www.inframat.com/

	Surfix BV is a nanocoating service provider, who operates in the in 'Lab- on- a- chip' and Point- of- Care Diagnostics sector. They believe that micro- and nanotechnology are an integral part of sustainable solutions for major global challenges in healthcare, food and energy. Accurate and precise control of surface properties is a prerequisite for our customers to exploit the full potential of their world-changing devices. This is enabled by Surfix's proprietary surface modification technologies, which not only yield excellent surface properties but also enable patterning with superior spatial control. Company has estimated to have reached, in 2018, a revenue of about 32,3 Million Dollars. Website: https://www.surfix.nl/
	Nano-Care Deutschland AG is an internationally leading specialist in the production of ready-to-use high-tech coatings and their precursors. create invisible high-performance coatings based on their expertise in nanotechnology, bionics and process engineering. By combining innovative new materials with well-established foundation technologies, they create intelligent hybrid systems (INTELLIGENT HYBRIDS®) that set new benchmarks in multiple market sectors. Website: https://nano-care.com/
	P2i is a technology solutions provider with over ten years of experience developing liquid repellent nano coatings. With a focus on the consumer electronics industry, the company works directly with OEMs to make devices water resistant, improving their reliability and enabling them to survive liquid exposure in everyday accidents. In 2018, Company have reached a revenue level of about 23 Million Dollars. Website: https://www.p2i.com/

Source: Company Websites and Owler.com

3.2 Overview of European aviation sector: aircraft turbine engine and aircraft MRO

Aeronautics is the leading sector in aerospace and defence, concentrating a full spectrum of technologies and integrated capabilities. This sector includes all certified flying objects, manned and unmanned, along the life-cycle, including Maintenance Repairs and Operations (MRO) and Air Traffic Management (ATM) ground systems. The activities of the **air sector are highly concentrated, both geographically (in particular EU countries) and in terms of the few large enterprises involved**, while SMEs operate in all countries in niche markets and MRO.
According to (ASD, 2018), **aeronautics is one of the EU's key high-tech sectors on the global market**:

- Having a total turnover of around EUR 160 billion (in 2016), with 72% in the civil field and 28% in the military field.
- Providing more than 500.000 jobs (543.000 in 2016). Employment in the aerospace sector is particularly significant in the United Kingdom, France, Germany, Italy, Spain, Poland and Sweden.
- Being a world leader in the production of civil aircraft, including helicopters, aircraft engines, parts and components.
- Playing a leading role in exports, amounting to € 106 billion with 72% in the civil field and 28% in the military field.

Moreover, **a sizeable share of value added is spent on Research and Development (R&D) expenditure**. In this framework, Research & Development (R&D) refers to innovative activities undertaken by corporations or governments in developing or improving new services or products. It includes the Research and Technology activities (R&T) which concern the design, feasibility studies, and maturation processes for technologies. In aeronautics, cycles are significantly long and requires capital intensive effort. For example, an aircraft's journey from its conception to its commercialization typically takes fifteen to twenty years. The level of R&D spending in the European civil aeronautics amount to nearly €10 billion: as regards R&D, increased private financing by companies and customers has been observed, amounting to 2/3 of the total R&D investment. Governments support the R&D of civil aeronautical programmes to 1/3 of the total investment[2].
Nevertheless, the high investment in R&D is not reflecting the research in nanotechnologies and nanocoatings, even if the potential applications of nanotechnology in the transport sector are enormous. Indeed, the match between the advantages derived from using nanotechnology (e.g. new, improved or tailored properties) and the market needs in the transport sector such as (more) sustainable, safer and economic transport modes has triggered huge public and private investments in the field. Nevertheless, the patent mapping analysis performed showed no relevant activities in this field. Indeed, the patent surveillance study selected patents from 2009 up to day, using the query "nanocoat* AND (aviation OR aircraft)". The query selected a total of 21 patents in the period under analysis (corresponding to 8 DWPI families). As it can be noticed from the following graphs in the period under consideration (2009-2019) there was a positive temporal trend until 2015. From that year there was a negative temporal trend. In particular, there has been great interest towards patent applications from countries as US and Europe. Main players emerging from the analysis were primarily linked to the aerospace sector or the sector of helicopter production. They are Bell Helicopter Textron and Goodrich Corporation, who submitted 8 and 7 patents respectively. In the following, the main results of the patent scenario analysis are reported.

[2] This split reflects two kinds of R&D programmes: some are co-financed by industry and public funding while other programs are fully financed by industry

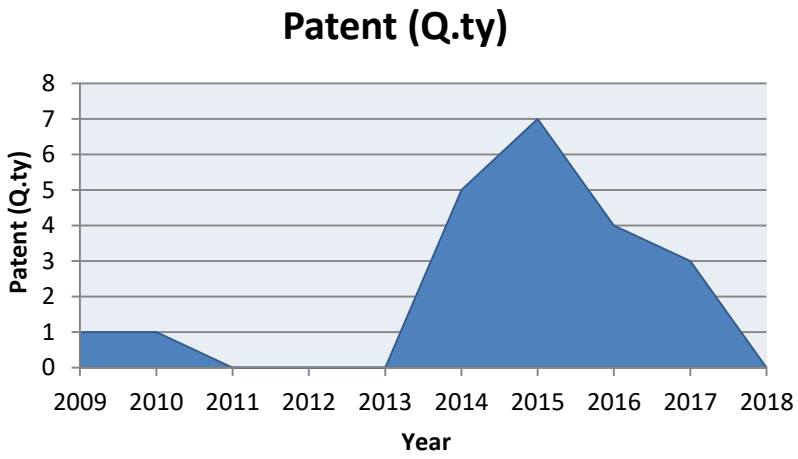


Figure 3.7: Patent temporal trend (2009-2018)

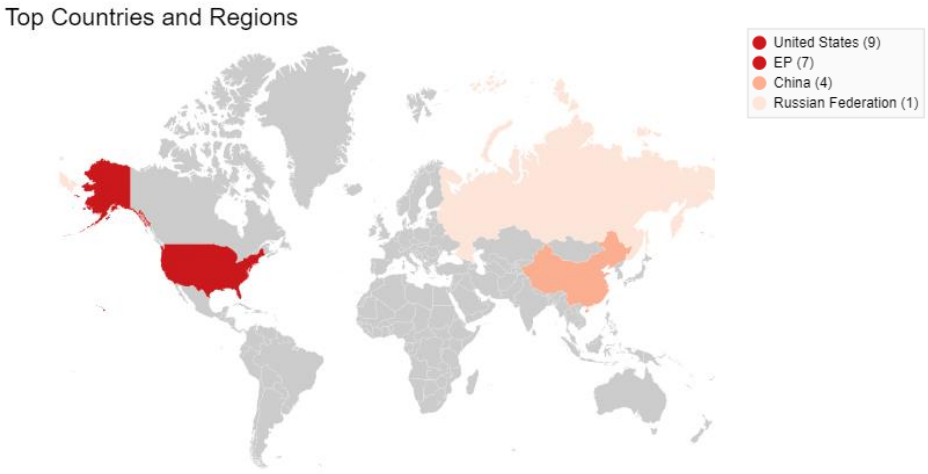


Figure 3.8: Patent Publication Countries

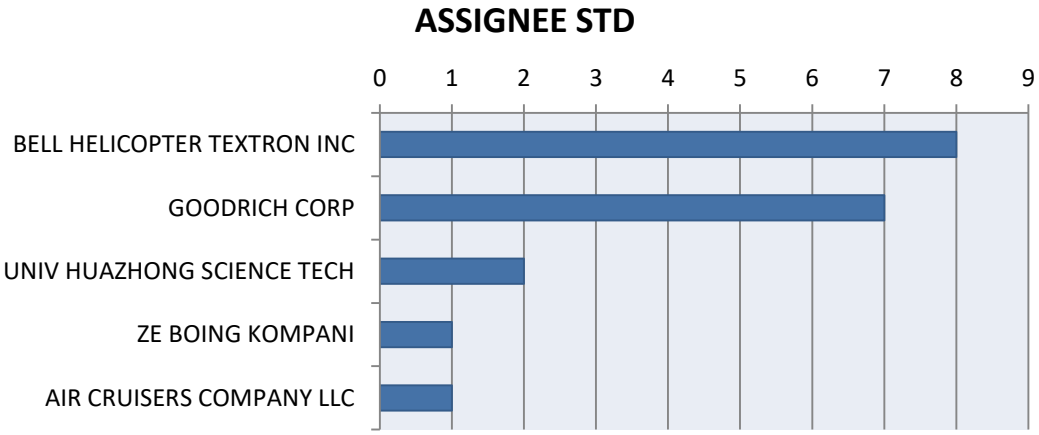


Figure 3.9: Top 8 main applicants

This may also evidence that nanotechnology has not been significantly incorporated into the aviation sector. Failing to meet the full set of industrial requirements (e.g. production volumes, automation and / or quality assurance) is preventing further deployment into mass-markets whereas stringent

performance requirements (e.g. stiffness, strength, wear-resistance) at reasonable cost may have limited its use. Stringent certification requirements derived from transporting human beings but also long development times and costs (especially relevant in the aeronautics sector) do not ease the situation.

Looking into the future, nanotechnology may keep penetrating into the transport sector provided that it delivers clear advantages as compared to competing solutions that still offer room for significant improvements. Despite the long lifetimes of transport vehicles (from 10 years to more than 30 years) results in a slow market penetration rate, it also results in potentially huge advantages (e.g. 99.9% of the energy consumption during an aircraft lifetime is consumed during use) that could justify investments in new materials, processes or tools.

Of special note is nanocoating use in the aerospace sector against the backdrop of healthy outlook for commercial aviation and robust aircraft production and deliveries. In this sector, as depicted in figure below, nanocoatings may:

- help turbine blades and landing gear withstand high temperatures and friction wear;
- enhance performance of aero engine parts by increasing corrosion resistance and crack healing;
- reduce weight of airframe structure while simultaneously imparting high strength and toughness;
- enable development of highly responsive aircraft electro communication systems; and lowers aviation carbon footprint, aircraft MRO costs and enhances engineering effectiveness and safety.

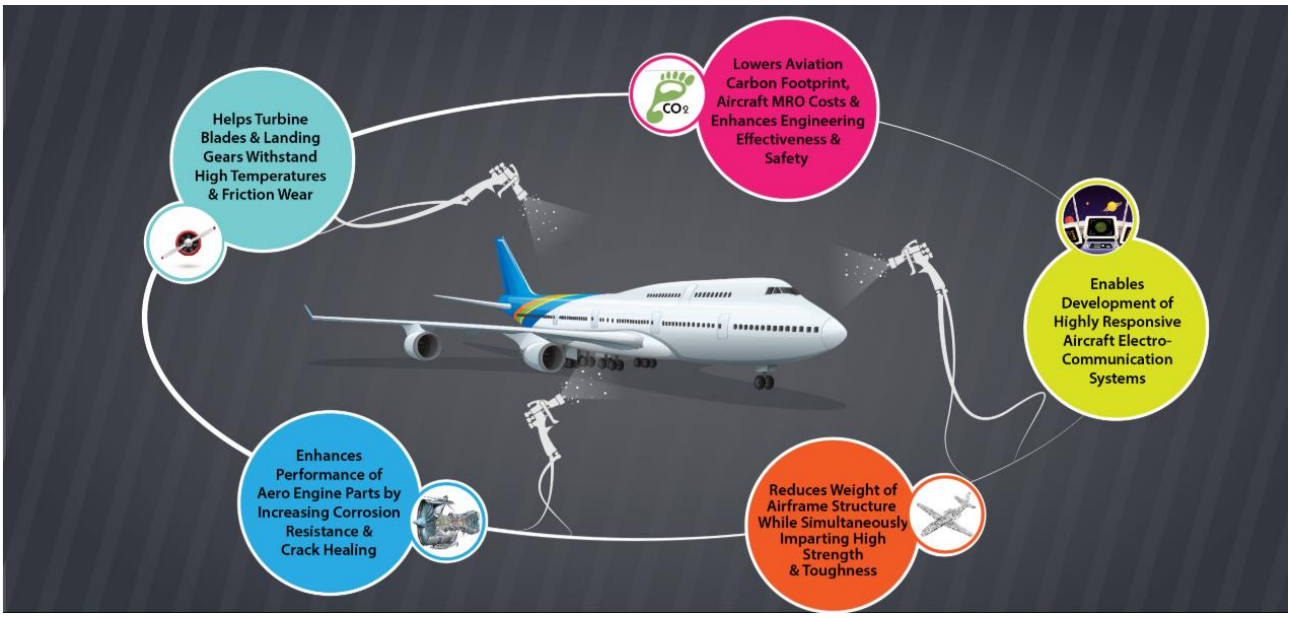


Figure 3.10: Five benefits of using nanocoatings in aerospace materials (Global Industry Analysts, 2019)

Given this, the following paragraphs provide an overview of both the aircrafts turbine engine and MRO markets at EU level in order to detail the status of these industries, main drivers and trends' forecast for the next years to be useful then for Business Modeling activities.

3.2.1 European aircraft industry and aircraft turbine engine market

European flights increased by 1,3% in April 2019 compared with April 2018 and next forecast foreseen a further increase of 1% in flights. (European Civil Aviation Conference Area, 2018).

Figure below provides the main contributors to flight growth in April 2019. Seven states added more than 50 flights per day to the European local traffic (excluding overflights) growth in April 2019 (vs. April 2018). At the other end of the scale, pilot strikes at SAS Scandinavian Airlines resulted in significantly fewer flights in Sweden, a decrease in domestic air passengers also played its part, with an apparent shift to rail, Norway (-103 flights/day) and moderately fewer flights in Denmark (-36 flights/day).

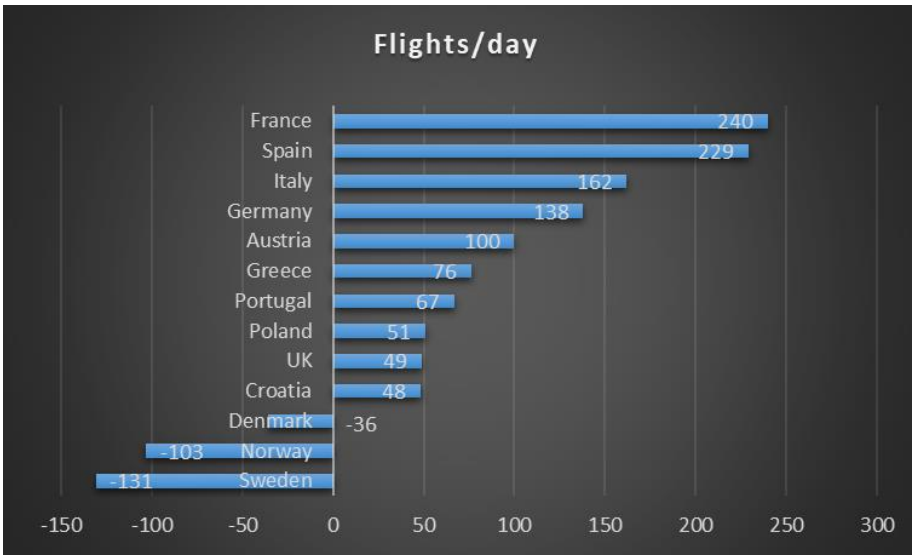


Figure 3.11: Main changes to traffic on the European network in April 2019 (Source: EUROCONTROL 2019)

One feature of the European airline industry today is that more than half the profits of the European airline industry are being generated by the three large airline groups (IAG, Air France-KLM and the Lufthansa Group) and Ryanair (the big four) – though the latter is now facing new cost challenges. But IAG, Air France-KLM and the Lufthansa Group are not reliant for the bulk of their profits on intra-European markets. This is also confirmed by figure below providing the top aircraft operators in April 2019. The aircraft operators which added the most flights to the network on a daily basis were Ryanair (+123 flights), Air France (+118 flights), Vueling (+45 flights), LOT (+42 flights) and Wizz Air (+35 flights).

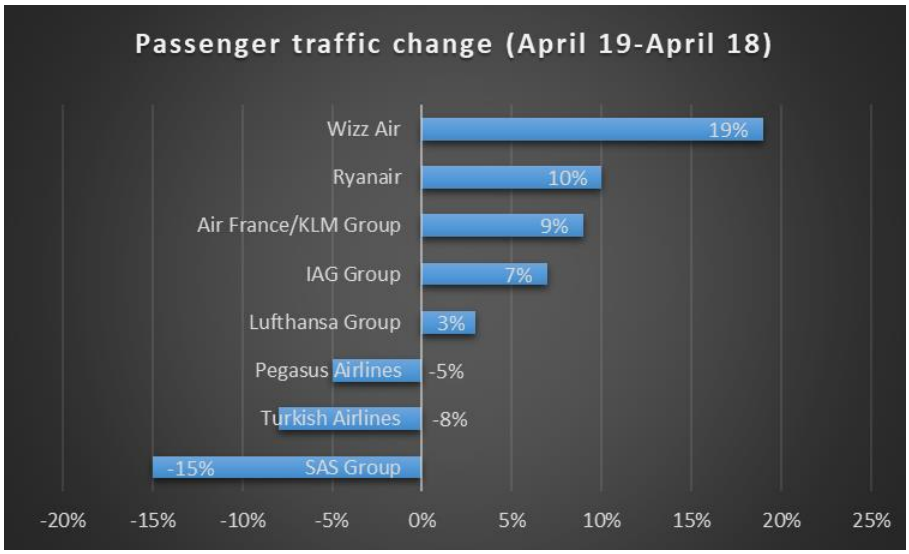


Figure 3.12: Passenger traffic change (Source: EUROCONTROL STATFOR, May 2019).

In addition, IATA (International Air Transport Association, 2019) reported several indicators confirming the growing trend of this market segment as follow:

- European scheduled passenger traffic (RPK) increased by 4,9% in March 2019 (vs. March 2018)
- The Capacity (ASK) was up by 5,4% growing by 7,1%;
- The total passenger load factor was 83,7% (vs. 84,1% in March 2018).

ACI Europe[3] reported overall passenger counts at European airports to grow by 3,8% in March 2019 (vs. March 2018) whereas overall aircraft movements increased by 2%. During the first quarter of 2019 (vs. same quarter in 2018), overall passenger counts at European airports increased by 4,4% with overall aircraft movements up 3,1% on beginning of 2018 (European Civil Aviation Conference Area, 2018).

In the framework of this growing sector dominated by four main leaders, **the market for aircraft engines is anticipated to register a CAGR of 5,89%, during the next 5 years (2019-2025)**. The aircraft engines market value is expected to reach 81,8 billion USD with North America as the largest market and Asia Pacific as the fastest growing one (MordorIntelligence, 2019). Indeed, there are many drivers justifying the growth of the aircraft engines market:

- To cater to the growing air traffic, several airlines are revamping their fleet by procuring new aircraft, which is generating demand for new engines.
- New aircraft programs, like Boeing 777X and COMAC C919 are powered by newer generation engines like GE9X and Leap-1C. Such developments in newer generation aircraft are supporting the growth and development of lightweight, advanced propulsion systems.
- Failure of aircraft engine during operation and delay in deliveries are some of the factors hampering the growth of the market.
- Growing concern over aviation emission may act as an opportunity for fuel-efficient and lightweight engines.

As already mentioned, the **aero engine demand is directly dependent on the aircraft demand that is spawning record growth in the global fleet.** According to (Oliver Wyman, 2018), for the beginning of 2029, forecast projects a total fleet of 39.175 aircrafts, up more than 11.600 from the 2019 total of 27.492. Between 2019 and the beginning of 2024, the in-service fleet will grow annually at 3,9% — a pace that will slow to 3,3 percent for the next five years (see figure below).

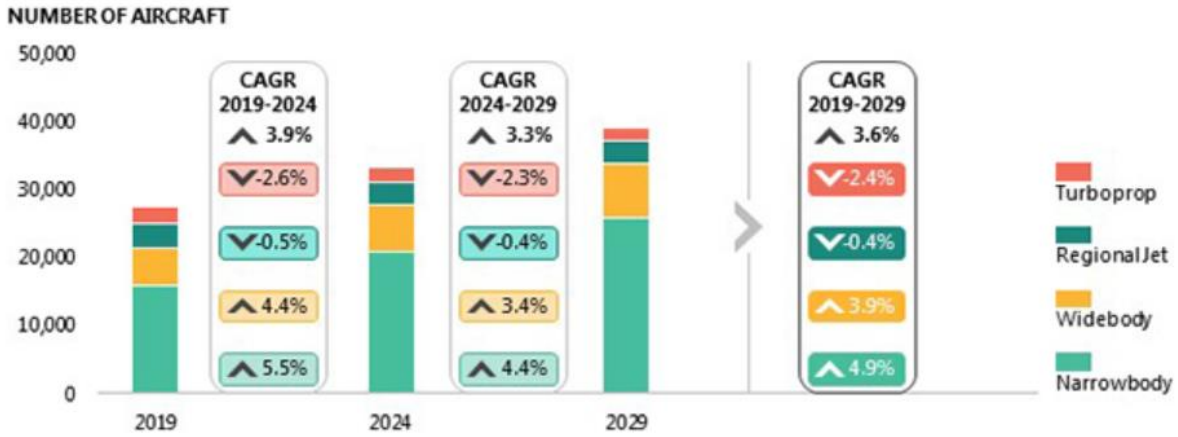


Figure 3.13: Global Fleet Forecast by Aircraft Class (2019-2029) (Sources: Oliver Wyman)

Given this, the aero engine demand may be derived as it comprised two segments: engines installed on airplanes at the time of delivery, and spares. The former is the result of multiplying the number of airplanes sold by the number of engines mounted on the airplanes, and the latter is the result of multiplying the number of engines mounted on airplanes at the time of delivery by a spare ratio of

[3] Airports Council International Europe

10%. The engine is the most expensive equipment to purchase among components of an airplane, and engine prices account for about 20% of the amount of airplanes sold. According to (Japan Aircraft Development Corporation, 2019) **the total number of engines sold over the 2019 to 2038 period will be 87.685 of which 80.764 will be jet engines for both passenger jets and freighter jets, and 6.921 will be turboprop engines for passenger turboprop airplanes**. Their total sales value will amount to 1,36 trillion U.S. dollars (2018 market prices). Of that amount, jet engines will account for 1,35 trillion U.S. dollars, and turboprop engines will make up the remaining 15 billion U.S. dollars.

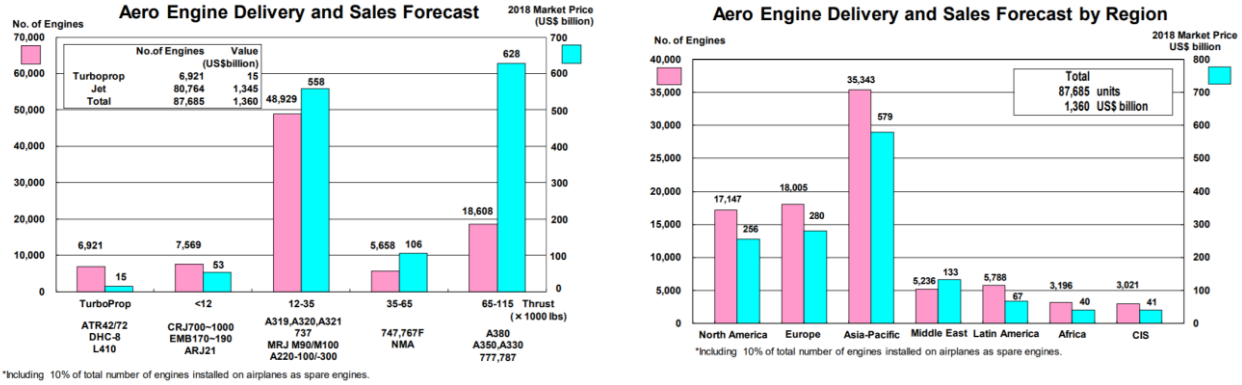


Figure 3.14: Aero engine delivery and sales forecast per type (on the left) and by region (on the right)

By region, the Asia-Pacific region, which has the highest demand for airplanes, is the biggest market. The number of engines sold in the region will be 35.343, with a 40% share of engines sold, and the sales value will be 579 billion dollars, with a 41% share of sales. This will be followed by 18.005 units (21% share) and 279 billion U.S. dollars (20% share) in Europe, and 17.147 units (20% share) and 256 billion U.S. dollars (18% share) in North America. In the Middle East, the number of sales will be around 30% of the level in the U.S. and Western Europe, at 5.236 units; however, since there is strong demand for wide body jets, the sales value will be 133 billion U.S. dollars, which is around 50% of the level of the U.S. and Europe.

3.2.2 European aviation MRO

The global air transport MRO market, valued around 82 billion USD in 2018 and expected to reach 110 billion USD by 2025, will be driven by the growth and changing composition of the global fleet. In particular, the MRO landscape is changing across multiple facets, as hereafter (Source: Frost and Sullivan):

- OEMs are looking to increase their share of revenue from the aftermarket;
- There is a shift in the Global Fleet Base, as Asia-Pacific is set to host the largest fleet base going forward, overtaking North America and moving far ahead of Europe;
- The MRO needs of new generation aircraft are different due to the usage of new-age materials
- Low Cost Airline Growth (LCCs) are highly cost-sensitive, forcing MROs to run efficiently to come up with competitive pricing
- Global Expansion of established MROs such as Lufthansa Technik, AAR, SR Technics and AFI-KLM that are setting up bases in APAC to tap the market.

In this context, it is imperative for businesses to develop strategies to align with or counter the impact of these changes to survive in this highly competitive space and overcome the different barriers (provided in table below).

Table 3.2: MRO sector, technical and non-technical barriers

Barriers related to:	Type of barriers:
Heavy maintenance	• Inspections take up majority of downtime: due to the sheer size and complexities of an aircraft, a lot of time and money is spent only on assessment • Inability to forecast maintenance growing fleets are leading to increasing unplanned jobs, disrupting routine maintenance • Cost competitiveness the rapid growth of LCCs has increased the demand for cost-efficient maintenance
Line maintenance	• Expansion and addition of terminals expanding airports require services to support larger areas while maintaining efficiency • Inefficiencies in resource allocation dynamic changes in flight schedules require quick deployment of manpower and equipment • Increasing need for shorter turnaround time (tat) more than ever, need to reduce lead time for resource deployment
Logistics	• Unavailability of real-time monitoring no visibility into incoming jobs from heavy maintenance, cabin services, or line maintenance • Difficulties in parts handling and storage very strenuous and time-consuming to manually move heavy parts in and out of the shop floor • Increasing aircraft complexities new-generation aircrafts are leading to longer downtimes due to increased difficulties faced by technicians
Fleet management	• Unstructured repair management lack of a centralized repository to perform smart sourcing for repairs • Lack of unified solution use of multiple separate programs in parallel by various departments, causing confusion and resulting in delays and losses • Delays and losses in delivery of spares lack of visibility into the delivery status and location of spares and components

Given this, **among the different segments of the aircraft MRO market** (e.g. airframe engine, component, line, etc.) **the aircraft engine MRO market is expected to reach 37,4 billion by 2025 with a CAGR of above 5% during the next 5 years (2019-2024).** This is due to several factors generating further demand for engine maintenance and thus a potential market for the nano-riblets. For example the ageing fleet of the aircraft both in the military and commercial aviation industry is one of the major driving factor for the growth of this market. The growth of emission regulations for the airspace by various regulatory bodies like FAA, EASA, IATA and ICAO among others are fostering the engine maintenance for older aircraft (since their emissions are higher compared to the newer generation aircraft). Moreover, the rapid fleet expansion plans of the airlines and military forces are anticipated to further boost the growth of engine MRO market during the forecast period. **New engines, while much more fuel-efficient, are operating at ever higher temperatures and pressures, resulting in more expensive MRO visits to restore and replace increasingly expensive materials. Thus,** the size of MRO market is dependent from different factors, such as aircraft new deliveries due to fleet growth, aircraft replacement/retirement and average aircraft age).

In terms of fleet growth, China is one of the principal growth engines behind the rising size of the fleet. Between 2019 and 2029, China is forecast to receive 3.981 more deliveries than retirements, an increase in fleet size of 114%. Asia Pacific is expected to see a 50% net increase in aircraft over the same decade. While North America will accept the most aircraft deliveries in absolute terms over the next 10 years, the region's fleet will grow only 15 percent, as most deliveries will replace jets being retired.

Figure 3.15: Fleet growth by region 2019-2029 (Oliver Wyman, 2018)

Given this, the delivery and retirement patterns will result in a change in overall global distribution of aircraft that favors Asia (see figure below on the left). The mature regions of North America and Western Europe are forecast to experience relatively modest growth over the next 10 years, growing at just 1,4% and 2,5% annually. Asia represents the highest levels of growth, with the regions of China, India, the Middle East and Asia Pacific growing at annual rates of 7,9%, 9,9%, 4,7%, and 4,2% over the next 10 years. After a short-term rebound in fleet size, Eastern Europe is forecast to return to lower growth levels of just over 2% per year, while Africa is expected to continue to struggle to modernize and grow the infrastructure needed to increase the regional fleet.

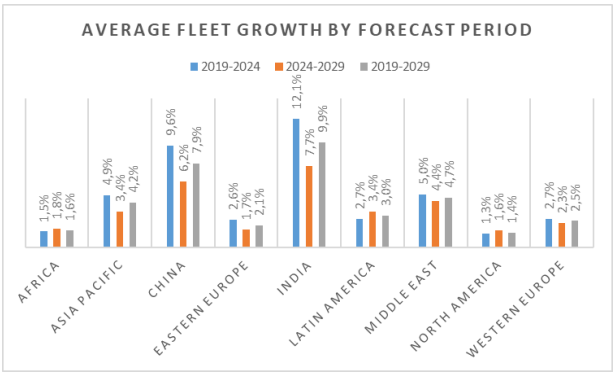


Figure 3.16: Fleet growth by region 2019-2029 (Source Oliver Wyman)

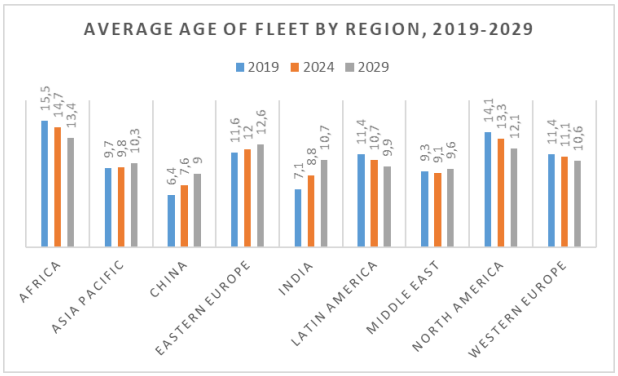


Figure 3.17: fleets development in Europe (Source: Worldwide Market Forecast 2019-2038 JADS)

As fleets grow, the average aircraft age will vary among regions. North America, Western Europe, Latin America, and Africa will see the age decrease as older fleets are replaced with new deliveries. In contrast, the fleets in China, India, Eastern Europe and Asia Pacific will age as aircraft stay in service to meet increased demand, leading to greater emphasis and importance for aircraft maintenance programs.

In this framework, the average age of passenger aircraft is forecast to decrease slightly from 10,4 years to 9,8 over the next 10 years, as thousands of newly delivered aircraft hit the market and older aircraft are removed from the fleet. However, the average age of cargo aircraft is forecast to increase from 22,2 years to 24,2 by 2029. Cargo aircraft are remaining in service longer than ever, driven by the success of passenger-to-freight conversions that keep older passenger aircraft flying.

	2019	2024	2029
PASSENGER	10.4	9.9	9.8
CARGO	22.2	23.3	24.2
OVERALL	11.3	10.9	10.7

Figure 3.18: Gobal fleet average age by aircraft usage, 2019-2029 (Oliver Wyman, 2018)

New-generation aircraft, equipped with more fuel-efficient engines and sophisticated technology, will begin to represent a larger share of in-service aircraft.
Most of these aircraft will be larger narrowbodies, as airlines move toward aircraft with improved operational flexibility. The goal is to accommodate more passengers with airplanes that are cheaper to operate than the larger, less flexible widebody aircraft that tend to dominate long-haul flights. This transition also reflects a greater willingness by passengers to accept smaller cabins on long-haul flights than what was the norm just 10 years ago. This move to replace older-generation aircraft will slow MRO spend in the first half of the next 10 years, as the number of expensive late-life maintenance events declines with the retirement of aging aircraft and as the intervals between scheduled maintenance lengthen for the newest jets.
In this framework, when looking at the European level, according to Figure 3.19 the new deliveries considering both the aircrafts growth and older aircrafts replacement (accounting for over than half of new deliveries) could constrain the MRO sector. Nevertheless, the MRO market is expected to grow from 19 billion USD to 27 billion at a CAGR of 3,3%, that is very healthy for a largely mature sector. The engine segment is expected to be a driver of overall MRO growth until 2025 as per the global trend.
Western Europe is foreseen to be the world's third largest engine MRO market, growing at an average CAGR of 2,3% annually up to 2028 and expecting to generate 58 billion USD in engine MRO demand. Among the world's smallest MRO regions, Eastern Europe will nevertheless see solid growth in its engine aftermarket over the next decade (1,7%) (MRO Network, 2019).

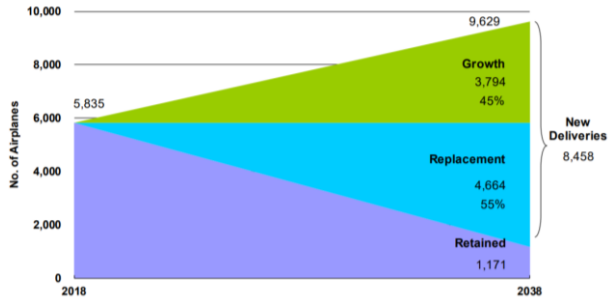


Figure 3.19: fleets development in Europe (Japan Aircraft Development Corporation, 2019)

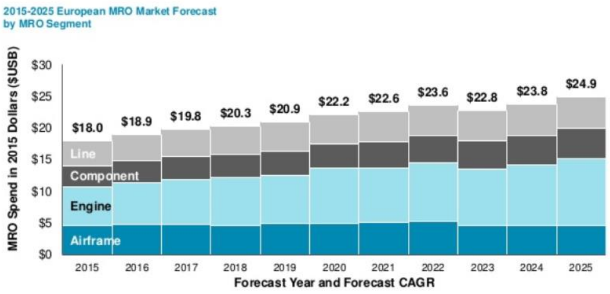


Figure 3.20: European MRO Market Forecast (2015-2025)

3.2.3 Leading aircraft engine manufacturers and MRO service providers

The global businesses for aircraft engines and maintenance component repair and overhaul services (including parts sales) are highly competitive. Both U.S. and non-U.S. markets are important to the growth and success of the business. Product development cycles are long and product quality and efficiency are critical to success. Research and development expenditures are important in this business, as are focused intellectual property strategies and protection of key aircraft engine design, manufacture, repair and product upgrade technologies. Aircraft engine orders and systems tend to follow civil air travel and demand and military procurement cycles.
In this context, when evaluating the potential customers for the producers of the nanoriblets developed within the project the main players in the engine manufacturing and MRO have been evaluated and described highlighting their key features in terms of market size, services provided, number of employees, etc.

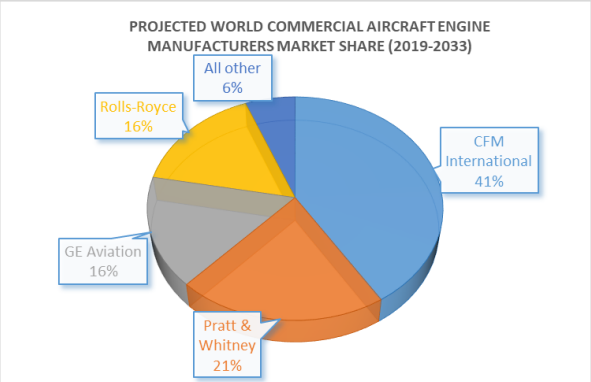


Figure 3.21: Market share of main players Engine Manufacturing (Forecast international Platinum System)

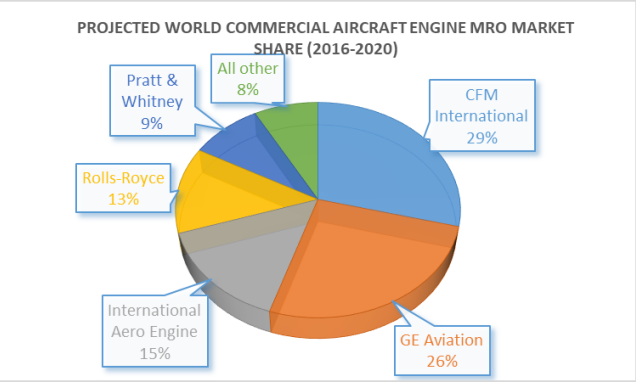


Figure 3.22: Market share of main players Engine MRO market (Statista 2019)

As depicted by figure above, the engine market is dominated by **General Electric, Rolls-Royce plc and Pratt & Whitney**, in order of market share. General Electric and **Safran** of France have a joint venture, **CFM International**. Pratt & Whitney also have a joint venture, **International Aero Engines** with Japanese Aero Engine Corporation and **MTU Aero Engines** of Germany, specializing in engines for the Airbus A320 family. Pratt & Whitney and General Electric have a joint venture, **Engine Alliance** selling a range of engines for aircraft such as the Airbus A380.
Instead, the prominent players in the aircraft engine MRO market are **Pratt & Whitney, Lufthansa Technik**, **Rolls-Royce plc, United Technologies Corporation, GE Aviation, and Safran**. Among other relevant players in the engine MRO segment there are also International Aero Engine, MTU maintenance, SR Technics, AIRBUS MRO alliance, AFI-KLM.
The major engine MRO providers are entering into long term partnerships or forming joint ventures to grow their engine MRO customers. For instance, Lufthansa Technik formed joint ventures with various engine manufacturers like Rolls-Royce plc, GE Aviation, and MTU AERO ENGINES AG for providing engine MRO operations for customers in the European Union. Also, the use of advanced technology for providing maintenance services will help these companies attract new customers by reducing their maintenance costs. However, the long term contracts of theairlines operators (military, commercial and general aviation) with these MRO providers will act as a barrier for the new players to enter the market.
Figures below provide the factsheets of the main players in both sectors, aircraft engine manufacturers and MRO services providers.

GE Aviation

Company Profile: GE Aviation designs and produces commercial and military aircraft engines, integrated digital components, electric power and mechanical aircraft systems. The company also provides aftermarket services to support the products.

Head Office Country	Ohio, United States
Web	https://www.geaviation.com/
Revenue 2018	$30,57 bln
Revenue: %var 2018/2017	13,15%
Engine deliveries (volume)	3.943
Engine deliveries: %var 2018/2017	27,65%
MRO Services (% of revenues)	62%
Number of Employees 2018	48.000
Employee: %var 2018/2017	-19,29%
Engines in service around the world	33.000
Investment in R&D	$1,5 bln

Sources: Annual Report and Statista

Rolls Royce Civil Aerospace

Company Profile: RR Civil Aerospace is a major manufacturer of aero engines for the large commercial aircraft, regional jet and business aviation markets. The business uses engineering expertise, in-depth knowledge and capabilities to provide through-life support solutions for its customers. Over the last six decades RR has become the world's leading engine supplier in business aviation, powering some of the largest, fastest and longest-range business jets available.

Head Office Country	UK, London
Web	https://www.rolls-royce.com/
Revenue 2018	€8,6 bln (42% original equipment, 58% services)
Revenue: %var 2018/2017	11,82%
Engine deliveries (units)	686
Engine deliveries: %var 2018/2017	0,44%
MRO Services (% of revenues)	15%
Number of Employees 2018	25.615
Employee: %var 2018/2017	4,13%
Engines in service around the world	13.000
Investment in R&D	Self-funded R&D cash spend up 8%; income statement charge down 14%. Gross R&D expenditure grew to €1,6m. After funding from customers and other third parties, core self-funded cash R&D spend rose 8% to £1.106m, primarily driven by: investment in new engine technologies in Civil Aerospace, specifically the UltraFan and on new business aviation engine family.

Source: Annual Report

Pratt & Whitney

Company Profile: PRATT & WHITNEY is a United Technologies Company, world leader in the design, manufacture, and service of aircraft engines and auxiliary power units.

Head Office Country	Connecticut, United States
Web	https://www.pw.utc.com/
Revenue 2018	€17,6 bln
Revenue: %var 2018/2017	17,58%
Engine deliveries (units)	779
Engine deliveries: %var 2018/2017	45,07%
MRO Services (% of revenues)	n.a.
Number of Employees 2018	41.600
Employee: %var 2018/2017	6,67%
Engines in service around the world	63.000
Investment in R&D	With annual investments of over €454mln in engineering and development, P&W rank among the top Canadian R&D investors enabling the design and manufacture of ecological, economical, and quieter engines. 1.500 specialized positions and more than 1 billion euros has been invested in R&D from 2014 to 2019 to develop the next generation of high-performance aircraft engines.

Sources: Annual Report

Safran

Company Profile: Safran is an international high-technology group, operating in the aviation (propulsion, equipment and interiors), defense and space markets. Safran supplies engines and equipment to all main producers of civil and military airplanes and helicopters providing a wide range of engines and systems in proven technological skills and expertise, and the use of innovative materials. In addition, Safran is a leading supplier of navigation and other avionics systems, which enhance flight management and safety.	
Head Office Country	Paris, France
Web	https://www.safran-group.com/
Revenue 2018	€21 bln (50% propulsion)
Revenue: %var 2018/2017	31,64%
Engine deliveries (units)	2.162
Engine deliveries: %var 2018/2017	13,61%
MRO Services (% of revenues)	n.a.
Number of Employees 2018	92.639
Employee: %var 2018/2017	58,84%
Engines in service around the world	32.500
Investment in R&D	€1,2 bln (€754 mln dedicated to propulsion)
Sources: Annual Reports and company website	

Lufthansa Technik Group

Company Profile: Established in October 1994 as a subsidiary of Deutsche Lufthansa AG, Lufthansa Technik AG is the parent company of the engineering business segment of Deutsche Lufthansa AG and the global Lufthansa Technik Group, and comprises a total of 57 companies. Lufthansa Technik is the foundation of Deutsche Lufthansa's top-tier engineering image and numbers more than 800 other airlines and commercial aircraft operators among its customers. The heart of the company is its overhaul, development, and logistics center in Hamburg, birthplace of engineering operations for the newly reestablished post-war Lufthansa in 1955. Today, more than 8,000 people work here with Lufthansa Technik AG alone. The focus is on the maintenance of commercially operated aircraft, the servicing of engines, equipment, and components, the completion and overhaul of government aircraft and large executive and private aircraft, and the field of research and development.

Head Office Country	Hamburg, Germany
Web	https://www.lufthansa-technik.com/
Revenue 2018	€5,9 bln
Revenue: %var 2018/2017	9,52%
Engine deliveries (units)	-
Engine deliveries: %var 2018/2017	-
MRO Services	+6% growth
Number of Employees 2018	22.537
Employee: %var 2018/2017	6,34%
Engines in service around the world	-
Investment in R&D	n.a.

Sources: Annual Reports and company website

3.3 Overview of European gas sector: industrial gas transport compressors

The global demand for natural gas is expected to increase by 1,6% per year for the next five years (2019-2024), with consumption reaching almost 4.000 billion cubic meters (BCM) by 2022, up from 3.630 BCM in 2016. Factors such as the increased use of natural gas across industries such as the chemical, fertilizers, petrochemicals coupled with the increasing trend of replacement of coal with gas for power generation across the developing and developed nations has supplemented the demand for natural gas across the globe. Furthermore, increased consumption of natural gas has supplemented the demand for midstream infrastructure such as LNG liquefaction and regasification terminals, underground gas storage, and associated pipeline across the globe (Preston Reine, 2016).
In this context, the usage of high capacity gas compressors is expected to witness a significant growth with the increase of associated natural gas based infrastructure, in a bid to maintain pressure loss and to ensure sufficient transportation of natural gas.
Indeed, the demand for gas compressors is quite high in the energy power sector as well as in the chemical and process industry. Both industry branches – gas transport and process industry – are well established and have a long tradition as well as extensive experience in developing efficient and safe processes. In particular, the European gas pipeline and storage system is one of the pillars of the European energy and power supply. Gas compressors build the backbone of this important system. Indeed, compressors are used in all aspects of natural gas development. In the production segment, compressors are used at the wellhead to compress gas for fluids removal and pressure equalization with gathering equipment systems. However, the primary use of compressors is in the natural gas processing, transmission and storage (particularly underground storage) segments of the industry.

Figure 3.23: The world market for industrial pumps and gas compressors in oil and gas applications (Preston Reine, 2016)

For this reason, **the gas transport sector has been selected as the main segment to be investigated for the purpose of this report, with the aim of evaluating the market size and**

opportunities for mass production and application of nano-riblets into the gas compressors for gas transport. Paragraphs hereafter aim then to provide a general overview of gas transport sector and gas compressors applications. After that, an overview of the main players in the sectors as potential customers for the nano riblets producers, is provided as well.

3.3.1 European gas sector

The dynamics of the demand for gas in the EU have been changing in recent years. The decline in demand for natural gas that has been observed over the past decade can be attributed to a number of factors: i) decreased industrial activity as a result of the economic crisis; ii) the price of natural gas compared to coal and renewables in the power sector; iii) the increased share of renewable energy and electricity storage as a result of government policy, cost reduction and technological development. This has created uncertainty about the future demand for natural gas in the EU. Nevertheless, **most projections for the next decade foresee a robust demand for gas and potential increases in pipeline and LNG imports in Europe, due to decreasing domestic gas production.** In the 2030 demand projections, the term 'gas' is unambiguous, referring almost entirely to natural gas, i.e. CH4. During this time frame, natural gas switching can represent an option for the decarbonisation of the power sector of member states that are heavily dependent on coal. In Germany, for example, as a result of the planned nuclear and coal phase-outs, it is expected that natural gas will increase its share in the electricity sector by 2030 (Agora Energiewende, 2018, p. 29). Numerous other European countries have also announced their plans to phase coal out over the next decade. As a result, significant coal generation capacity in Europe needs to be replaced by other sources of energy (Mihnea Cătuţi, 2019). Given this trend also the infrastructure of gas transport shall be adapted.

Indeed, **sustained investment in domestic gas transmission and distribution networks is essential for continuing to expand access to gas in new cities and across different economic sectors. Europe and North America have developed extensive gas transmission and distribution grids over many decades, enabling access to gas in nearly all cities. In non-OECD markets, the development of gas pipelines will be critical for enabling growth as local gas infrastructure is often lacking.** In India, for example, it is projected that domestic transmission capacity will need to increase by over 60% (from 16k km to over 26k km) by 2020 to make gas available to additional cities where gas distribution is planned (GAIL). Gas storage infrastructure is another key component of supply security. In Europe and North America, substantial underground storage capacity is available, equivalent to between 15-25% of total annual gas consumption (Cedigaz). This plays a key role in managing seasonal variability in gas demand, in particular helping to stabilize prices in the winter when demand spikes. Over 90% of global gas storage capacity is concentrated in Europe and North America, making managing gas demand variability a particular challenge in other regions. In China, gas demand is becoming more seasonally variable as consumption grows in the buildings sector and a lack of storage infrastructure is in turn straining pipeline and LNG import capacities at peak periods.

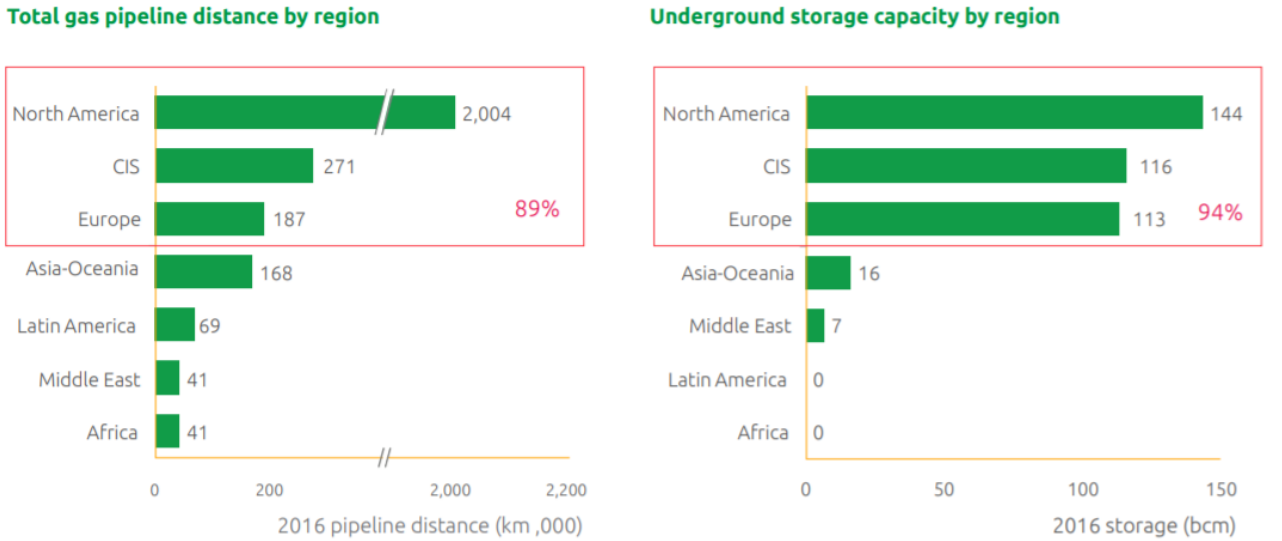


Figure 3.24: Gas pipeline and storage infrastructure (SNAM, 2018)

This trend of securing gas supply by expanding gas pipeline and storage infrastructure would thus constitute a positive trend for the gas compressors for gas transport pipelines (DG Energy, 2018).

Indeed, natural gas goes from the well into gathering and treatment systems and from there into pipelines. These steel pipelines are often several thousand kilometres long. Over these distances pressure losses arise that require the gas to be recompressed in compressor stations. These compressor stations are located typically at 150 to 200 km distance along pipelines and are the most important parts of the gas transmission system, of which compressors are the core parts.

3.3.2 Industrial gas compressors

The global industrial gas compressor market was estimated around 29 billion USD in 2018 and it is expected to reach over 46.37 billion USD by 2025, at a CAGR of slightly above 6% between 2019 and 2025 (Source: Zion Market Research).

Looking at the different types of compressors on the market, the centrifugal and reciprocating air compressors are expected to dominate the reference market, gas transport. In particular, **the centrifugal segment is expected to account for the largest air compressor market share registering the highest CAGR (4.23%)** over the next 5 years period (2019-2025). Centrifugal systems are energy-efficient and are capable of compressing higher mass flows as compared to other compressor types.

As mentioned above the gas industry dominated the market in 2018 and is expected to be the fastest growing segment during the forecast period due to factors such as growing demand for gas from the power sector, expanding city gas distribution infrastructure, continuous capacity additions in petrochemical units and to the growing need to expand natural gas pipeline infrastructure (MarketWatch, 2019).

Moreover, factors that will propel the growth further are the increasing population, technological advancements, growing natural gas preference and need to replace aging infrastructure. **Asia Pacific dominated the market across the globe with China and India accounting for a major share.**

Low maintenance, effective operation at lower costs, retrofitting of existing systems, and growing adoption of variable-speed systems are other factors propelling the product demand across also other key end-use industries.

On the other hand, the declining cost of and increasing investments in renewable power generation are hampering the demand for natural gas-fired power generation, in turn, negatively impacting the demand for centrifugal compressors in the power generation industry.
Thus, also with the rising energy consumption, one of the major factors driving this market are growing need for energy-efficient compressor systems. Energy-efficient compressors are witnessing high demand owing to their cost-effective operations. For example, the governments of various economies have introduced stringent norms for gaseous emissions, which has eventually increased the demand for energy-efficient equipment. Indeed, compressors are identified as a relevant emission source that has the potential to produce emissions to the atmosphere during oil and gas production, processing, transmission and storage. These emissions typically increase over time as the compressor components begin to degrade and nanocoating may help in this. Manufacturers are making strides to become more energy-efficient, amidst rising end-user demands and changing energy efficiency standards, in several nations. If the manufacturers manage to increase the efficiency of centrifugal compressors at significant levels, the centrifugal compressors can become the preferred choice in a wider range of applications, in turn, driving the market.
In this context, in economic terms, sales of air compressors are less likely to witness significant gains in some of the world's more developed markets. Nonetheless, the technology will always have thriving markets as long as there are developing countries eager to compete with the industrialized world.

3.3.3 Leading gas compressors manufacturers

European markets are mainly driven by the emergence of next generation compressed air systems with low maintenance and eco-friendly features and EU industrial leaders in this sector are currently facing the challenges of low-cost Chinese and Asian industrial competitors. EU actors in this market need for energy efficient, eco-friendly and reduced CAPEX solutions to reaffirm their role in the global market.
When evaluating the potential customers for the producers of the nanoriblets developed within the project the main players in the industrial gas compressors manufacturing have been looked at.
Top three key players operating in the gas compressor market include Siemens, Atlas Copco and GE. Other players in the market are Ingersoll-Rand, Sulzer, MAN Energy Solutions, etc.
The leading companies are taking up partnerships, mergers and acquisitions, and joint ventures in order to boost the inorganic growth of the industry. For instance, GE completed the acquisition of Alstom's power and grid business unit which significantly impacted the regional as well as the global landscape of the gas compressor market. According to the recent scenario, while GE and Siemens are witnessing a downturn in terms of fewer numbers of their flagship energy products and services, both the giants are actively involved in restructuring business strategies. Siemens is expected to supply compressor trains for a gas pipeline expansion project in Canada.
In general, these manufacturers are developing eco-friendly and low-maintenance systems to encourage end users to opt for next-generation products. Companies such as Atlas Copco and Ingersoll Rand, Inc. have been developing next-generation systems with high-performance capabilities to differentiate their products in a highly competitive market. Some of the features offered by these products include reduced noise levels and increased efficiency. The compressors' manufacturers seek to satisfy the challenges of the customer with novel and ever more complex equipment. As a result of this there has to be a real partnership between the manufacturer and the customer. The need to innovate is seen as the way to ensure a high level of compressed air efficiency and reliability.

In this context, the top three players above mentioned have been evaluated and described highlighting in dedicated factsheets their key features in terms of market size, services provided, number of employees, etc.

SIEMENS

Company Profile: This company was founded in the year 1847. Siemens has been operating its business via different reportable segments such as energy, healthcare, real estate, industry and many more. It performs core activities in energy, infrastructure, industry and healthcare fields. This company is also well specialized in industry solution along with infrastructure. Its turbo compressors play a key role in the core process of several industries like oil and gas. OEM services are also offered for the compressor fleet as well as for those compressors that are manufactured originally by its acquired companies.	
Head Office Country	Munich, Germany
Web	https://new.siemens.com
Revenue 2018	€ 12,4 bln for the Power and Gas division
Revenue: %var 2018/2017	-19,39%
Orders (volume)	13.717
Compressors deliveries: %var 2018/2017	2,91%
% of revenues related to compressors	n.a.
Number of Employees 2018	46.800
Employee: %var 2018/2017	N.A.
Investment in R&D	$700 mln (in Power and Gas)
Sources: Annual Report and Statista	

Atlas Copco

Company Profile: The Atlas Copco Group is a world-leading provider of sustainable productivity solutions. The Group offers customers innovative compressors, air treatment systems, vacuum solutions, industrial power tools and assembly systems, and power and flow solutions. Atlas Copco develops products and services focused on productivity, energy efficiency, safety and ergonomics. Principal product development and manufacturing is located in Sweden, Belgium, France, Germany, Italy, Czech Republic, United Kingdom, United States, China, India, South Korea and Japan. The company was founded in 1873, is based in Stockholm, Sweden, and has a global reach spanning more than 180 countries. In 2018, Atlas Copco had revenues of BSEK 95 (BEUR 9) and approximately 37.000 employees. The Compressor Technique business area provides compressed air solutions; industrial compressors, gas and process compressors and expanders, air and gas treatment equipment and air management systems. The business area has a global service network and innovates for sustainable productivity in the manufacturing, oil and gas, and process industries. Principal product development and manufacturing units are located in Belgium, the United States, China, India, Germany and Italy.

Head Office Country	Stockholm, Sweden
Web	https://www.atlascopcogroup.com/
Revenue 2018	43.972 bln SEK (only Compressor Technique)
Revenue: %var 2018/2017	12,97%
Compressors deliveries (volume)	3.943
Compressors deliveries: %var 2018/2017	11,79%
% of revenues related to compressors	90%
Number of Employees 2018	37.000
Employee: %var 2018/2017	10,02%
Investment in R&D	N.A.

Sources: Annual Report and Statista

GE Oil and Gas

Company Profile: This brand was established in the year 1892. Its products as well as services start from aircraft engines, power generation, medical imaging, to industrial products and equipment for oil and gas production. The compressors are being used for several applications like natural gas, petrochemicals, pipelines, refineries and GTL as well as LNG. It is one such segment that offers compressors like BCL, SRL, RB, MCL/V and VH series.

Head Office Country	London, UK
Web	https://www.ge.com/
Revenue 2018	$23.000
Revenue: %var 2018/2017	33%
Compressors segment revenues	$6 bln
Compressors segment revenues: %var 2018/2017	-4,76%
% of revenues related to compressors	19% (related to oil &gas sector)
Number of Employees 2018	65.800
Employee: %var 2018/2017	N.A.
Investment in R&D	N.A.

Sources: Annual Report and Statista

4 Business Model

The objective of this business model is to **describe**, from a qualitative point of view, the **organizational structure** that the consortium has to create in order **to commercialize the achievements of RESISTANT project.**

Nanoriblets are the main exploitable result of the RESISTANT project. They will be properly customized and designed to be supplied to costumers. All partners of the consortium will support this commercial exploitation, leaded by GEDE, MES and LHT.
Also, the consortium will commercialize the related technologies that are being developed in this project, namely: nanoriblets design algorithms, nanocoating formulations, nanocoating materials and manufacturing process technology.

There are two main strategies to be considered in order to organize the commercialization of the RESISTANT project outcomes.
The first one is the **establishment of a new company** (Newco) with the specific task of nanoriblets commercialization under an EPCM scheme. This seems to be the best idea in order to coordinate all partners' contribution to the selling process.
Another possible strategy is the **concession of a certain technology to a partner** in order to provide a turn-key solution to costumers. For example, NCT or LHT could sell nanoriblets coatings or BST could commercialize optimization algorithms. IFAM could sell tailored riblets and nanocoating composition solutions, etc.
This two approaches are complementary and intended to offer a wider product portfolio to potential customers.

4.1 Goal and Scope

Considering the market and activities of the partners and the goal of the RESISTANT project, it was planned to create two different business models: one for industrial compressors and another for aircrafts turbine engines.
However, after preliminary works defining these business models it have been found out that they are very similar, being the target market the only significant difference. Thus, in this document there will be only explained **one business model for the two products (nanoriblet applied at the aircraft engines and nanoriblet applied at the industrial compressors).**
Moreover, aircraft turbofans are a particular application of a broader concept, **gas turbines**. As nanoriblets can be applied also to these engines, their related markets have been included into the business model, too.

4.2 Methodology

The Business Model Canvas is a complete and systemic method that allows reducing the complexity of the business modelling activity, representing in effective manner all the parts and internal/external dynamics that are within a Business Model, using a visual language (visual thinking logic).

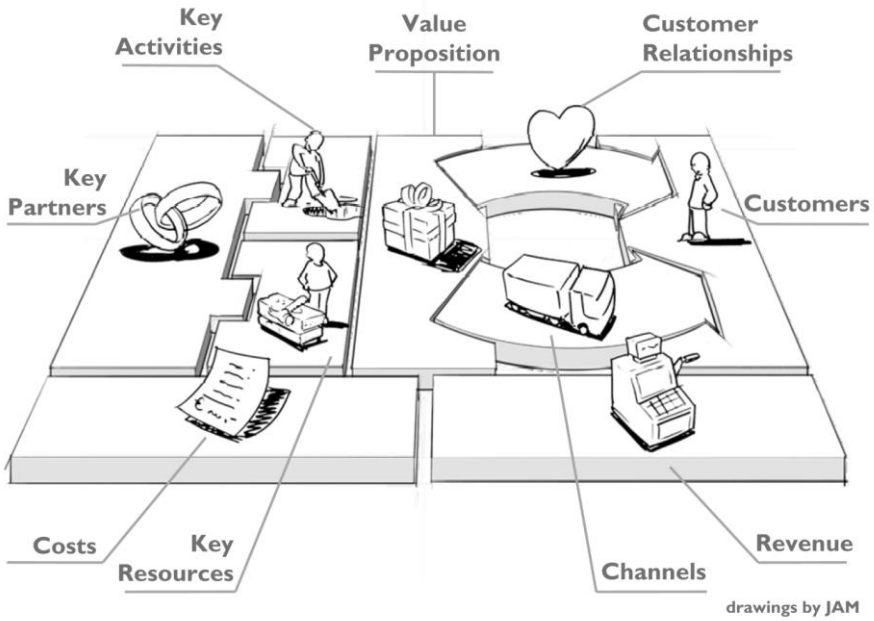
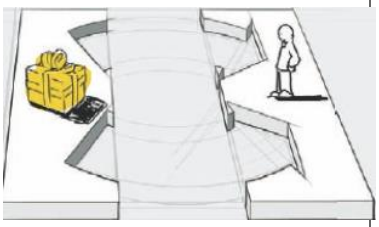
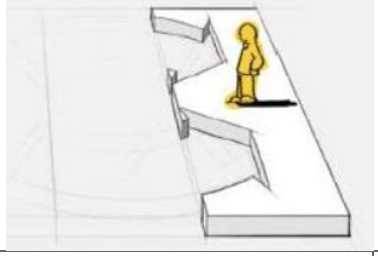
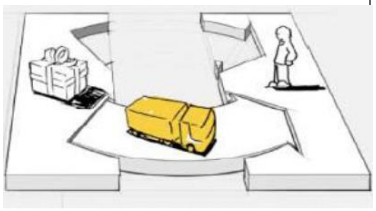
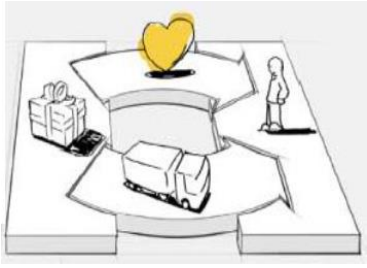
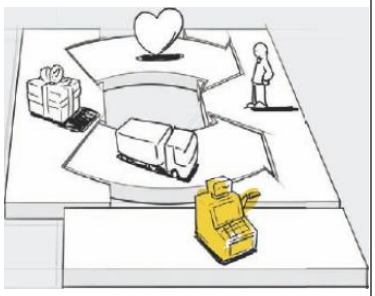
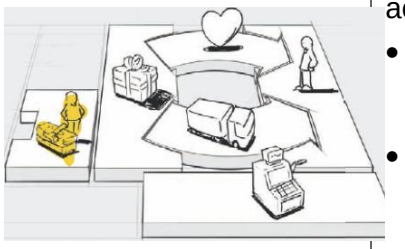


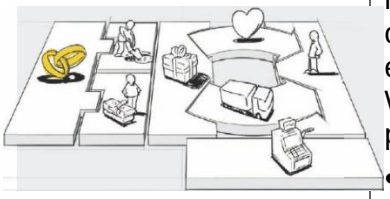
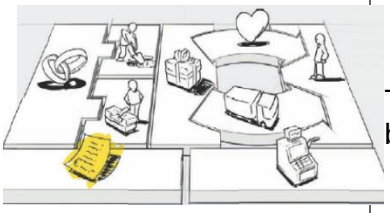
Figure 4.1: Business Model Canvas (Osterwalder, Alexander & Pigneur, Yves, 2010)

In the following Table 4.1 a brief description and meaning of the different blocks of the BM Canvas are presented, along with an explanation of their relation to the rest of the Canvas blocks.

Table 4.1: Business Model Canvas building blocks

	BM Canvas block	Description
#1 Value proposition		Description of the characteristics of the products/services offered, underlining the problems solved and the benefits expected that can be related to different aspects such as: • new needs satisfaction; • performances; • customized solution; • reliability; • novel design; • risks and costs reduction; • competitive price; • accessibility; • usability.
#2 Customer Segments		Identification of the clients segments based on their needs/benefits guaranteed. The Customer Segments represents the core of the BM. A company serves one or several customer segments (mass market, niche market, segmented, diversified, multi-sided).
#3 Channels		How a company communicates with and reaches its Customer Segments to deliver a Value Proposition. Channels are the company's interface with the customer, thus they play a relevant role in the customer experience. Channels can be physical (e.g. shops) or virtual (e.g. e-commerce/ selling platforms/ own website), direct (own shop) or indirect (franchising, wholesaler, distributors).
#4 Customer Relationships		Identification of the type of relationship the partnership has to establish and maintain with each specific customer segment. Different assistance means are recognized as effective customer relationships as: • Personal assistance based on human interaction; • Self-service: the customer should receive all the info needed in order to help himself; • Automated services: it mixes a more sophisticated form of customer self-service with automated processes offering customized services based on the customer profile and need; • Communities: increasingly, companies are utilizing user communities to become more involved with customers/prospects and to facilitate connections between community members; • Co-creation: more companies are going beyond the traditional customer-vendor relationship to co-create value with customers.

#5 Revenue Streams		Identification of the revenues model and product/service pricing model. It represents the cash flow that a company generates from each Customer Segment. Revenue streams result from value propositions successfully offered to customers (depend on the type of contract). Revenues can be derived from different sources: physical (e.g. direct selling, fee proportional to the use), virtual (use of app for selling), grants and crowd funding. There are different ways to generate revenues, such as: • Asset sale. The most widely understood Revenue Stream derives from selling ownership rights of a physical product; • Usage fee. This is generated by the use of a particular service. The more a service is used, the more the customer pays; • Subscription fees. This is generated by selling continuous access to a service; • Lending/Renting/Leasing. This is created by temporarily granting someone the exclusive right to use a particular asset for a fixed period in return for a fee; • Licensing. This is generated by giving customers permission to use protected intellectual property in exchange for licensing fees. Licensing allows rights holders to generate revenues from their property without having to manufacture a product or commercialize a service; • Brokerage fees. This derives from intermediation services performed on behalf of two or more parties; • Advertising. This results from fees for advertising a particular product, service, or brand.
#6 Key resources		Identification of Key Resources required for operating successfully. Key resources are the assets required to offer and deliver the Value Proposition to Customers. Key resources can be owned or leased by the company or acquired from key partners. Key resources can be classified as: • Physical assets such as manufacturing facilities, buildings, vehicles, machines, systems, point-of-sales systems and distribution networks; • Intellectual resources such as brands, proprietary knowledge, patents and copyrights, partnerships, and customer databases; • Human resources; • Financial resources and/or financial guarantees, such as cash, lines of credit, or a stock option pool for hiring key employees.
#7 Key Activities		Identification of the most important actions a company must undertake to operate successfully. They are required to create and offer a Value Proposition, reach markets, maintain Customer Relationships and earn revenues. Key activities can be related to:

		• Production: designing, making, and delivering a product in substantial quantities and/or of superior quality. • Problem solving: coming up with new solutions to individual customer problems; • Platform/network: networks, match making platforms, software, and even brands can function as a platform.
#8 Key Partnership		Identification of the Key Partnership describing the network of suppliers and partners that make the business model work. Companies create alliances to optimize their business models, reduce risk, or acquire resources. Some activities are outsourced and some resources are acquired outside the enterprise. We can distinguish between four different types of partnerships: • Strategic alliances between non-competitors; • Strategic partnerships between competitors; • Joint ventures to develop new businesses; • Buyer-supplier relationships to assure reliable supplies.
#9 Costs structure		The Cost Structure describes all costs incurred to operate a business model. It can be useful to distinguish between two broad classes of business model Cost Structures: • Cost-driven focus on minimizing costs wherever possible. This approach aims at creating and maintaining the leanest possible Cost Structure, using low price Value Propositions, maximum automation and extensive outsourcing; • Value-driven focus on premium Value Propositions and a high degree of personalized service. The categories of cost that interact with a business model may be: • Fixed costs: costs that remain the same despite the volume of goods or services produced such as salaries, rents and physical manufacturing facilities; • Variable costs: costs that vary proportionally with the volume of goods or services produced; • Economies of scale: cost advantages that a business enjoys as its output expands; • Economies of scope: cost advantages that a business enjoys due to a larger scope of operations.

4.3 RESISTANT Business Models

4.3.1 Business Model canvas description

Figure below provides the overview of the project BM according to the above described methodology of Alexander Osterwalder (Osterwalder, Alexander & Pigneur, Yves, 2010) while the following paragraphs provides further details.

Business Model Canvas	Designed for: RESISTANT project	Designed by: IDONIAL	Date: 5th December, 2019	Version: 1.0

Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
ENGINEERING CONSULTING SERVICES PARTNERS OF THE PROJECT WITH A CONCESSION	PRODUCTION OF NANOCOATED RIBLETS MANUFACTURING LINES MRO SERVICES CUSTOMIZATION OF THE TECHNOLOGY **Key Resources** ESTABLISHMENT OF A NEW COMPANY DEMONSTRATION LINES GENERATED TECHNOLOGIES IPR	NANOCOATED RIBLETS ASSOCIATED TECHNOLOGY	PERSONAL RELATION STRONG TIES **Channels** DIRECT SALES THROUGH OWN COMMERCIAL NETWORK WORLWIDE WEBSITE TRADE FAIRS AND CONGRESSES	GAS TURBINE MANUFACTURERS INDUSTRIAL COMPRESSORS MANUFACTURERS MRO COMPANIES

Cost Structure	**Revenue Streams**
MAIN COSTS: PRODUCTION OF MANUFACTURING LINES (SALARIES AND RAW MATERIALS) OFFICES, ASSEMBLY WORKSHOPS COMMERCIAL NETWORK (SALARIES) AND MARKETING ACTIVITIES	EPCM SERVICES OF NANOCOATED RIBLETS MANUFACTURING LINES TECHNOLOGY LICENSES LEASING OF MANUFACTURING LINES

Figure 4.2: RESISTANT Business Model Canvas

4.3.1.1 Value proposition

Our value proposition to our customers will be nanocoated riblets for gas turbines and industrial compressors. As we will demonstrate them, these technology will help to enhance the performance and reduce the weight of their products thanks to the reduction of the frictional resistance. Our main product will be **nanocoated riblets manufacturing lines in an EPCM scheme.**

We will also provide our customers with **necessary technologies** to manufacture the riblets: optimization algorithms, materials, etc.

4.3.1.2 Customer segments

As it has been previously explained, our main market targets will be:

- **Gas turbines manufacturers**: They will be interested in including these technologies in their engines.
- **Industrial compressors manufacturers.**
- Gas turbines and industrial compressors **MRO companies.**

4.3.1.3 Channels

As we will sell high value products to a reduced market, we will use a **direct sale approach**. We will have our **own salesforce**, with a **worldwide distribution**. We will make use of a **website** to provide information and support to our customers. We will assist to specific **trade fairs and technic congresses** in order to market our products.

4.3.1.4 Customer relations

We will focus on a **personal relation** with our customers, since we will have a reduced market. Our potential customers are high technology companies that will demand a customized attention. We will aim at creating **strong ties** with our customers.

4.3.1.5 Revenue streams

Our main financial revenues will be provided by the sale of nanocoated riblets **manufacturing lines** under **EPCM contracts**.

Also we will make profits of **licensing the integrating technologies** of RESISTANT project (algorithms, materials, formulations, etc.).

Leasing of the manufacturing lines will be considered too.

4.3.1.6 Key resources

Considering our 2 approach strategy, we will need to create a **new company** to organize the commercialization of our main product. It will need physical offices to support the commercial force and the technicians.

Demonstrations lines are key results of the project and also a key component in our business model and **generated technologies IPRs** are a valuable and needed asset.

4.3.1.7 Key activities

Our main activity will be the **construction of nanocoated riblets manufacturing lines**. It will be very important the ability to **customize our technology** according to specific demands from our customers.

Providing a reliable **MRO service** to our customers will be an important activity, too.

4.3.1.8 Key partnership

Granting a **concession to a partner** to commercialize RESISTANT project outcomes is an alternative approach.

Engineering services will be needed in order to scale up the technology and elaborate feasibility studies.

4.3.1.9 Cost structure

As fixed costs we have to consider the **salaries** of the HHRR (commercial network, technicians), **assembly workshops and offices**.
Variable cost are integrated by those of **raw materials** and **marketing expenditures**.
Salaries and raw materials are expected to be the majority of our costs.
Production of manufacturing lines will require the biggest part of our costs.

5 Conclusions

This document represents D9.1 “Business model to support the partners aiming at the commercial exploitation of the project results”, developed under the responsibility of PROD/IDON, supported by RINA-C, and in the framework of Task 9.3 “Market analysis and provisional business model” led by RINA-C.
The document aimed at providing a qualitative overview of the potential commercialization routes to be implemented by project consortium to penetrate the related markets, also investigated in terms of size, trends and barriers as well as potential competitors.
In particular, an overview of **nanocoating market** has been initially provided to give some insights on the context of the nanoriblets development. The market has been described by mean of patent analysis, SWOT analysis as well as reference market assessment (competitive landscape).
Then, the overview of the two nanoriblets’ application sectors have been provided, namely the (new and existing) aircraft engines and gas transport compressors sectors.
European aircraft sector represents a promising market driven by several trend of growth (flights increase to cater increase of population travelling, newer generation aircrafts to lower emissions, fleet revamping, etc.), thus reflecting a promising sector for the application of nanoriblets at both new and existing (requiring maintenance) aircraft engines.
Indeed, the **market for aircraft engines** is anticipated to register a CAGR of 5.89%, during the next 5 years (2019-2025). Its value is expected to reach 81.8 billion USD with North America as the largest market and Asia Pacific as the fastest growing one. The demand of aero engines will be directly dependent on the aircraft demand that is spawning record growth in the global fleet. The total number of engines sold over the 2019 to 2038 period is expected to be 87.685 of which more than 90% will be jet engines for both passenger jets and freighter jets. By region, the Asia-Pacific region, which has the highest demand for airplanes, is the biggest market with a 40% share of engines sold.
Concerning the global air transport MRO market, valued around 82 billion USD in 2018 and expected to reach 110 billion USD by 2025, this will be driven by the growth and changing composition of the global fleet. Among the different segments of the aircraft MRO market (e.g. airframe engine, component, line, etc.) the **aircraft engine MRO market** is expected to reach 37,4 billion USD by 2025 with a CAGR of above 5% during the next 5 years (2019-2024). This is due to several factors investigated within the report (e.g. ageing fleet, growth of emission regulations fostering the engine maintenance for older aircraft, rapid fleet expansion plans) generating further demand for engine maintenance and thus a potential market for the nanoriblets.
At European level, despite the new aircrafts deliveries potentially constraining the MRO sector, it is expected a growing trend from 19 billion USD to 27 billion USD at a CAGR of 3,3%, that is very healthy for a largely mature sector. The engine segment is expected to be a driver of overall MRO growth till 2025 as per the global trend.
Concerning the gas sector, **the gas transport sector has been selected as the main segment to be investigated** with the aim of evaluating the market size and opportunities for mass production and application of nano-riblets into the gas compressors. In this market segment, sustained investment in domestic gas transmission and distribution networks will be essential for continuing to expand access to gas in new cities and across different economic sectors. Europe and North America have developed extensive gas transmission and distribution grids over many decades, enabling access to gas in nearly all cities. In non-OECD markets, the development of gas pipelines will be critical for enabling growth as local gas infrastructure is often lacking.
This trend of securing gas supply by expanding gas pipeline and storage infrastructure would thus constitute a positive trend for the gas compressors for gas transport pipelines.
In this framework, the global industrial gas compressor market was estimated around 29 billion USD in 2018 and it is expected to reach over 46 billion USD by 2025, at a CAGR of slightly above 6%. The centrifugal compressors’ segment, dominating the gas transport sector, is expecting to **account**

for the largest gas compressor market share registering the highest CAGR (4,23%) over the next 5 years period (2019-2025).
With respect to acceptor market, namely referring to the **potential customers for the nanoriblets producers**, main players in both sectors have been investigated. Concerning aviation sector, the **main players in the engine manufacturing and MRO services** have been evaluated, while for the gas transport segment the **main reciprocating compressors producers** have been identified. Each player has been described with a dedicated factsheet highlighting their key features in terms of market size, services provided, number of employees, etc.
Concerning Business Modeling activities, two main strategies have been identified for the commercialization of the RESISTANT project outcomes, namely the nanoriblets and the related technologies behind (nanoriblets design algorithms, nanocoating formulations, nanocoating materials and manufacturing process technology). The first strategy is the **establishment of a new company** (Newco) with the specific task of nanoriblets commercialization under an EPC scheme. This seems to be the best idea in order to coordinate all partners' contribution to the selling process. Another possible strategy investigated is the **concession of a certain technology to a partner** in order to provide a turn-key solution to costumers. For example, NCT or LHT could sell nanoriblets coatings or BST could commercialize optimization algorithms. IFAM could sell tailored riblets and nanocoating composition solutions, etc. These strategies have been detailed by mean of the **Osterwalder Business Model Canvas approach without a distinction related to the sector of application of the nano riblet**, being the target market the only significant difference.

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