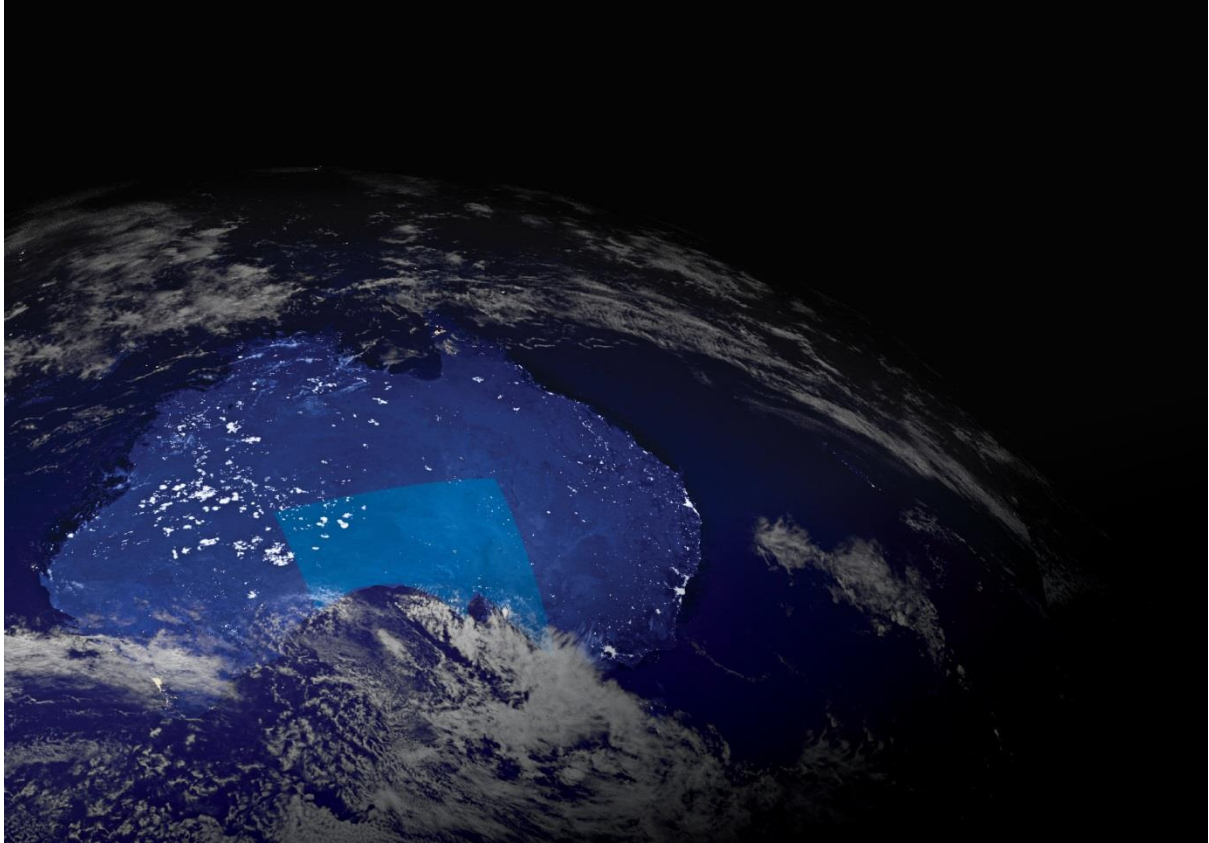


AEROSPACE CLUSTERS

World's Best Practice and Future Perspectives

An Opportunity for South Australia



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*“Quod Invenias Explorans Spatium
Progressus Est Humanitatis”*

- Human Progress is in Space Exploration

Hon Jay Weatherill
- Premier of South Australia

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Executive Summary

The following report provides an in-depth analysis of the phenomenon of clusters in the aerospace sector, with particular attention to those that have greater emphasis on the space segment.

Aerospace clusters differ consistently from other high-tech clusters, particularly with respect to the geographical dimension of their economic impact and the related knowledge spillovers. As a result of the sector's unique features – namely the global dimension of the value chain, the average size of the investment, the length of the development process of a new product/service, the strategic importance of the aerospace industry for the national economy, and the very nature of the products and services delivered – aerospace clusters exhibit higher levels of internationalisation. The common practice of collaboration among clusters in international aerospace programs creates wide and deep networks for commercial relations and knowledge transfer that cross the traditional regional dimension, acquiring stronger international connotations.

The analysis carried out on an heterogeneous sample of clusters - in terms of location, geomorphological features, governance, date of establishment, government support, extension of the value chain – clearly points out the presence of common elements that are vital in determining the success of the world's best practice. The clusters considered are: the Aerospace Valley of Toulouse, the BavAIRia Aerospace Cluster, the Luft- und Raumfahrt Baden-Württemberg cluster, the Bangalore Aerospace Cluster, the Lombardia Aerospace Cluster, the Harwell Science and Innovation Campus, and the US aerospace clusters of Colorado and New Mexico. The results of the comparison of the best practice analysed highlight the elements that are paramount in determining the competitiveness and innovativeness of an aerospace cluster, for each one of the four dimensions of the *Porter's Diamond Model*: the Factor Conditions; the Context for Strategy and Rivalry; the Related and Supporting Industries; and the Demand Conditions.

As for the *Factor Conditions*, there is clear evidence that **universities and research institutions** provide significant impetus to aerospace clusters, thanks to their ability to provide both support to **R&D activities** and **highly skilled human capital**, essential in high value added industries and in particular in aerospace. In addition, adequate **infrastructure** is essential to guarantee that concentration (of people, firms, institutions, etc.) produces beneficial effects and does not create congestion, which would eventually hamper the cluster's activity.

The comparison of the clusters' *Contexts for Strategy and Rivalry* underlines the pivotal role played by **Institutions For Collaboration** (IFCs) in promoting interaction between the cluster's members and between the cluster as a whole and external partners. In this respect, IFCs foster the attraction of **Foreign Direct Investment**, which brings international companies (and thus expertise) to the cluster. A key element for the development of a network of industrial players is the presence in the area of one or more **anchor firms**, usually multinational companies, prime, tier 1 and 2 contractors, able to attract a wide array of specialised suppliers at different levels of the value chain. Finally, the context for strategy and rivalry is believed to benefit from the participation in **international programs**, and evidence indicates that an **adequate level of public involvement** (mainly through fiscal incentives that encourage innovation) leverages the cluster's potential for innovation and competitiveness on the international landscape.

With respect to the *Related and Supporting Industries*, the common features exhibited by the clusters analysed are: high levels of **interconnection** both with other aerospace clusters and with clusters in other sectors, a high degree of **internationalisation** (from the multidimensional perspective of

commercial linkages, cooperation in R&D, attraction and retention of talent), and **specialisation** in highly innovative segments of the value chain as a source of competitive advantage. Evidence shows that the **support from the research** sector is of the utmost importance.

The analysis of the *Demand Conditions* illustrates how, given the strong international connotations of aerospace clusters in general, each one of them is expected to benefit from the forecasted long-term **growth in the global demand for aerospace-related products and services**, as well as from the constantly **increasing level of integration between aerospace and other sectors** (such as security, telecommunications, environmental monitoring, agriculture, healthcare, etc.). Those clusters that exhibit stronger internationalisation are likely to draw higher benefits from these trends. On the other hand, they all face the **increased competition from the emerging players** from the Asia-Pacific region: since a large share of the future demand is expected to originate from this area, the proximity of such competitors would foster the match between demand and supply, relegating the clusters taken as world's best practice to a marginal role in the future. For this reason it is essential for the clusters to be supported by a significant **domestic demand**, originating from both the civil and the defence sectors.

The results of the analysis constitute a valuable tool to evaluate the presence of favourable conditions in South Australia for the potential implementation of an aerospace cluster in the state. Evidence shows that the region offers congenial geomorphological features for research and testing activities, as well as proximity to the Asia-Pacific region, which, as anticipated, is generating increasing volumes of demand for aerospace and space-related products and services. In this context, the state exhibits proper expertise in the three spheres of the *triple helix model* (industry, academia, government). Major contractors are already established in the area, and enhance the inception of innovative small and medium enterprises. Universities and research organisations carry out cutting-edge research in space-related fields and provide highly skilled human capital. The South Australian Government has established within Defence SA a new office for *SA Space industry and R&D Collaboration*, with the aim of supporting the growth of the space economy, encourage international collaboration between industry, researchers and educational institutions operating within the space sector in South Australia, and promote international cooperation. The new Defence SA office has developed the *Space Innovation and Growth Strategy South Australia: Action Plan 2016-2020*, which sees the active involvement of the main stakeholders in the sector. The main milestones of this strategy are:

- Mapping of the state's space ecosystem through the *South Australian Space Capability Directory 2016*.
- Establishment of the *Space Hub*, which includes the South Australian Space Forum, a series of periodical events focused on the space industry with the goal of bringing together researchers, entrepreneurs, academics, private consultancies and public employers.
- Engagement in international cooperation through a wide array of institutional activities, such as the international Astronautical Conference 2017 which will be held in Adelaide from the 25th to the 29th of September.

The evidence above suggests that South Australia is home to a vibrant ecosystem for innovation and entrepreneurship, with the optimal conditions for the implementation of an aerospace cluster.

Introduction

This report provides an insight into the dynamics and the distinctive features of aerospace clusters in the global economy. Aerospace clusters constitute an exceptional example in the universe of the industrial cluster phenomena in terms of potential for innovation and socioeconomic development. At the same time they exhibit some unique features which heavily distinguish them from any other high value-added industrial cluster, in terms of the dynamics that govern the interactions among players and of the dimension of knowledge spillovers, which transcend the local boundaries to posit themselves on an international perspective.

Chapter 1 identifies the unique characteristics of aerospace clusters from a theoretical viewpoint: here the vast academic literature concerning the topic is synthesised to frame the concept of Aerospace Cluster within a more defined scheme that is able to depict its unique features, when compared to other industrial clusters, in terms of socioeconomic impact, potential for innovation and dynamics of knowledge spillovers. This template constitutes the theoretical basis of the analysis carried out in the following chapters.

Chapter 2 constitutes the heart of the report: it offers a detailed portrait of some of the world's most relevant aerospace clusters by analysing the composition and extension of their value chain, the environment in which they operate and the impact they have generated throughout the years, in an effort to understand the primary sources of competitiveness that have brought them to become the main drivers of innovation and socioeconomic development. Each cluster is briefly introduced by a general overview about the history of the national aerospace sector and the related policies. The core of the analysis is represented by the application of the Porter's Diamond model to break down the inner features of each cluster in the four dimensions of *Factor Conditions*, *Context for Strategy and Rivalry*, *Related and Supporting Industries*, and *Demand Conditions*. The final section of this chapter studies some examples of newly-implemented aerospace clusters in Costa Rica and Brittany using the same methodological approach.

Chapter 3 reconciles the empirical evidence with the theoretical framework introduced in chapter 1 and draws further conclusions about the distinctive traits that connote this unique cluster phenomenon, in an effort to pinpoint a general framework that comprises common features that are critical to the successful implementation and growth of the aerospace clusters analysed, as well as in the definition of the clusters' competitiveness and innovativeness. Lastly, the chapter examines the opportunity to implement an Aerospace Cluster in the State of South Australia by investigating the existence of the favourable conditions identified in the report, and by extracting valuable lessons from the best practice illustrated.

Methodology

The following report is the natural progression of the work undertaken by Gabriele Lania “*An International Comparison of Space history, policy and Industrial Capability*”, and it is built around a complex methodological backbone which defines some rigorous criteria at every stage of the analysis. Lania’s work has been essential in providing a methodological and quali-quantitative basis to the paragraphs that introduce the national environment in which the clusters operate.

The general theoretical framework is derived from Michael Porter, who first defined industrial clusters in his work *The Competitive Advantage of Nations* (1990) and developed his Diamond model to evaluate the competitiveness of the local industry. The Diamond Model is introduced in chapter 1 and widely used in chapters 2 and 3 to offer in-depth analysis of the single elements that shape the competitiveness and the innovativeness of the clusters identified as best practice. This methodological choice is grounded in the fact that the Diamond Model constitutes a central element in the Microeconomics of Competitiveness course held by Professor Michael Porter at the Harvard Business School: this framework has been extensively utilised in the analyses carried out by Harvard graduate students on aerospace clusters such as the ones in Toulouse, Querétaro and Hamburg¹.

The clusters chosen as subjects of analysis have been selected following a threefold criterion for identification. Firstly, partially following the methodology developed by Gregory M. Spencer², the clusters identified had to satisfy minimum dimensional criteria in terms of employment (at least 1,000 workers), to which we added a lower threshold of no less than 50 cluster members (from the three spheres of the *triple helix model*). Secondly, the clusters included in chapter 2 are those mentioned in Section V of the OECD report *The Space Economy at a Glance 2014*, and thirdly, priority has been given to those clusters that put stronger emphasis on the space segment and in which the latter constitutes a relevant source of knowledge and innovation. These stringent criteria have been loosened as for the clusters classified as “emerging” in section 2.7, in order to provide the reader with a more thorough portrait of the recent trends in the aerospace industry. The selection has been carried out by keeping some balance between the nations that can exhibit a plurality of aerospace clusters given their higher cluster-level industrial organisation, and the geographical distribution of the single clusters, which implies different environmental conditions and access to different markets, in an effort to conduct the analysis over the most diversified sample possible.

In addition, Spencer’s methodological framework has been utilised to identify, for each cluster and when possible, the so-called *Anchor Firms*, namely those major contractors that, because of their dimension and their activity, are able to attract a wide and diversified network of smaller suppliers at different stages of the value chain: the companies identified as *Anchor* employ no less than 500 units.

While the author has endeavoured to guarantee the comparability among the clusters taken into consideration, this effort has been stymied by the lack of homogeneity in terms of available data pertaining to the examples analysed. This heterogeneity is due to a wide range of reasons: in some cases (for instance, Bangalore) information asymmetry and the lack of reliable sources made it

¹ Jyot Bawa, Iker Cillero Etxebeste, Michael Konialian, Jonathan Naharro Martin, Hugo Ruiz-Taboada, *Aerospace Cluster in the Toulouse Region*, 2013

Jose Lyra, Juan Manuel Garcia-Sanchez, Liliana Olarte, Pedro Rangel, Rodrigo Quintana, *Aerospace Cluster in Queretaro, Mexico*, 2015

Roman Belotserkovskiy, Eva Gerlemann, Santiago Jariton, Campbell Lewis, Kirsten Porter, *Hamburg Aviation Cluster*, 2009

² Gregory M. Spencer, *The Economic Impact of Anchor Firms and Industrial Clusters*, 2013

impossible to find figures concerning the total employment and/or the total turnover, while in other cases such data was simply unavailable for security reasons. Although it was impossible for the author to address such issues, it is worth highlighting that these are somehow symptomatic of those economic sectors where high growth rates make data unreliable within short timeframes, and the entrenched interconnections with the defence sector result in information being classified.

1. Aerospace Clusters: Theoretical Framework

The conceptual definition of *Business Cluster* has constituted a momentous turning point for a number of fields such as strategic management, entrepreneurship theory, industrial organization economics, urban studies and so on. This groundbreaking concept, as theorised by Michael Porter in *The Competitive Advantage of Nations* (1990), draws its origins from Alfred Marshall's Industrial District Model³. Marshall's industrial district stems from the tendency of a number of firms competing in similar industries to locate themselves in the same area. The model predicts that this co-location choice brings about direct benefits in terms of productivity and innovation through the following three sources:

- *Knowledge spillovers*: the concentration of firms operating within the same industry in a city allows for easier inter-firm knowledge transfer, thus facilitating innovation and growth.⁴
- *Labour pooling*: concentration increases the presence of a skilled, homogeneous workforce, which brings about knowledge transfer and improvement of industry skills. The availability of a large number of skilled workers triggers a virtuous cycle by attracting, in turn, new firms in the area
- *Cost advantages*: concentration allows for the sharing of suppliers, resources and innovation

A more refined picture of the regional economy dynamics comes from François Perroux's *Growth Pole Theory* (1955): this framework slightly widens the scope of analysis by describing the regional poles built around 'industrialising industries', namely those that are able to attract both upstream and downstream manufacturers. This theory conceives regional agglomerations as not depending on supporting institutions such as universities or governmental departments, therefore it does not take into account the multidimensional nature of regional economies. In addition, poles are mere input-output systems in which externalities are irrelevant.

In his work concerning the competitive advantages of nations, Michael Porter scaled up Marshall's industrial district theory and Perroux's growth pole theory to develop the concept of *Cluster*. Following his definition, a cluster is "*a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities*"⁵. Clustering is therefore a nonlinear process whose whole is greater than the sum of its parts, and which generates innovation and socioeconomic development within a defined territory by bringing together a wide range of different players (in terms of nature, interests and roles):

The geographic scope of a cluster relates to the distance over which informational, transactional, incentive, and other efficiencies occur.

More than single industries, clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services as well as providers of specialized infrastructure. Clusters also often extend downstream to channels or customers and laterally to manufacturers of complementary products or companies related by skills, technologies, or common inputs. Many

³ Alfred Marshall, *Principles of Economics*, 1890

⁴ "Marshall-Arrow-Romer (MAR) externality". Edward L. Glaeser; Hedi D. Kallal; Jose A. Scheinkman; Andrei Shleifer, *Growth in Cities*, 1992

⁵ Michael Porter, *The Competitive Advantage of Nations*, 1990

*clusters include governmental and other institutions (e.g. universities, think tanks, vocational training providers, standards-setting agencies, trade associations) that provide specialized training, education, information, research, and technical support. Many clusters include trade associations and other collective bodies involving cluster members. Finally, foreign firms can be and are part of clusters, but only if they make permanent investments in a significant local presence.*⁶

The definition provided by Porter conveys the idea of a cluster as an evolution of the concept of industrial district, in that the firms involved operate within the same supply chain rather than within the same industry. For this reason, the overall degree of competition in a cluster is lower and cooperation is higher, when compared to industrial districts. Indeed, the most relevant characteristic of clusters is the accentuated cooperation occurring between its components. The two founding elements of the concept of an industrial district, namely competition and physical proximity, leave room for other features: vertical relations gain more relevance as the focus shifts over the logical interconnections occurring among the different components of the cluster, and nullify the role of proximity in favour of long networks of global collaboration. Two *caveats*⁷ are to be made about these last statements: i) clusters do not exclude competition, they are rather the *locus* where competition and cooperation coexist, either because they occur on different dimensions or because '*cooperation at some levels is part of winning the competition at other levels*'; and ii) while territorial boundaries are undoubtedly less defined, the local dimension is not downgraded. The same forces that, through *comparative advantage*, have led to the delocalization of activities where the latter can be performed at lower costs, have pushed together the segments of the value chain where companies are able to generate *competitive advantage* through an ongoing process of innovation that involves the chain as a whole. Porter defines outsourcing as a second-best solution, as it lacks the connection to economic activities occurring in the broader social environment of a territory. As a wide academic literature shows, those communities with higher concentration - and thus a higher number of social networks - are able to generate significantly more innovation, which is in turn the source of competitive advantage. The cluster is an evolution of the industrial district in the sense that it generates local socioeconomic development through a more complex mechanism that overcomes mere competition to encompass other innovation channels that exploit intra-firm complementarities and pressure from other players.

Indeed, clusters differ from industrial districts as for the spectrum of players involved. The prominent role of complementarity allows for the active participation of a wider range of stakeholders, which can be grouped under two macro-categories:

- **Primary players:** those who are vital for the implementation of a cluster initiative
 - Companies
 - Governments
 - Financial Institutions
 - Research Centres
- **Institutions for Collaboration (IFCs):** those who promote interest towards the cluster initiative and set up and maintain communication channels among the stakeholders in order to guarantee an adequate level of collaboration
 - Chambers of Commerce
 - Industry Associations

⁶ Michael Porter, *Location, Competition and Economic Development: Local Clusters in a Global Economy*, 2000

⁷ Ibid.

- Professional Associations
- Trade Unions
- Technology Transfer Organizations
- Quality Centres
- Think-Tanks

Not only did Porter provide a definition of cluster, but he also developed an analytical framework to describe and evaluate the overall business environment of a cluster, and to portray the interactions occurring among its factors during the process of competition and innovation. The *Porter's Diamond Model* consists of four **interrelated components** and two **exogenous parameters**, which determine the intensity of the interactions among the cluster's components and are not controlled by the latter.

▪ **Interrelated Components:**

- **Factor Conditions:** these are the elements that are deeply entrenched in the socioeconomic, political and geographic context in which the cluster operates. Elements such as human capital, infrastructures, knowledge, sources of financing and expertise play a key role in shaping the competitiveness and innovativeness of a cluster. The paramount role of these components lies in the fact that some of them (such as the morphology or the location) are specific to the single cluster and thus hardly replicable, while others (for instance the stock of human capital, the bulk of knowledge and the expertise) are the result of a long-standing development process undertaken by the territory from a social, economic and political perspective, therefore they require long-term strategic commitment to be replicated.
- **Demand Conditions:** specific customers which constitute a substantial bulk of demand in specialized segments. A lively, elastic demand is able to generate significant pressure on firms to pursue constant innovation, thus stimulating them in the achievement and preservation of competitive advantage. The different nature (public/private), origin (domestic/foreign) and consistency of the demand require tailored adaptation strategies, as the ability to attract and satisfy large shares of demand is the ultimate measure of a cluster's competitiveness and innovativeness.
- **Related and Supporting Industries:** the presence of a network of interconnected industries along the whole value chain is the key for innovation. These industries provide cost-effective specialised inputs and participate in the innovation process. The level of interconnection with related and supporting industries determines the cluster's ability to generate innovation at the system level and results ultimately in widespread socioeconomic development when interconnections among different industries bring about cross-fertilisation and knowledge spillovers.
- **Context for Strategy and Rivalry:** success is determined by the way in which companies are set up, managed and targeted. Strategic rival interaction is one of the key determinants of pressure to innovate. From a different perspective, strategic collaboration among companies can as well leverage the potential for innovation of the local system when firms are able to share unique resources and expertise to achieve a common goal. This is the micro-foundation of the cluster effect: the final outcome is bigger than the sum of its components. At the aggregate level, the cluster must be equipped with proper structures and managed with proper policies that can create the optimal conditions for the firms' rivalry and cooperation. In order to do so, it is ultimately essential to consider the sophistication of the companies' approach to competition.

- **Exogenous Parameters**

- **Chance:** occurrences that are uncontrollable by the firms, and create discontinuities in which some actors gain competitiveness and other lose positions.
- **Government:** its action through economic intervention, legislation and/or regulation can shape each one of the single components. The intervention can occur at local, regional, national or international level.

The following scheme illustrates the graphic formulation of the Porter's Diamond and the interactions occurring between its components and its exogenous parameters.

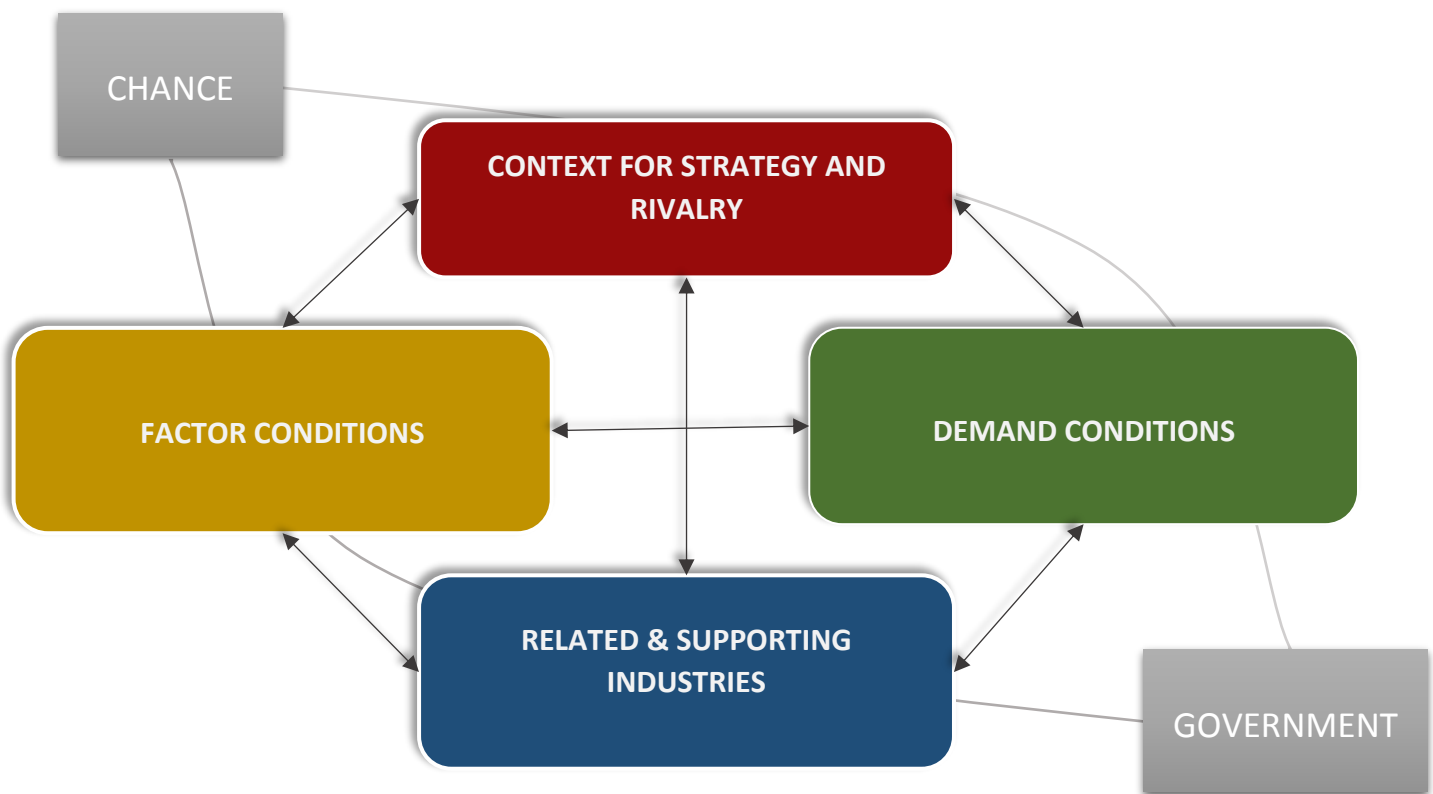


Figure 1: Porter's Diamond. Source: author

The model has been revised, suggesting that the effects of multinational activity should be included as a third exogenous parameter⁸. Porter's original model has been therefore extended to the generalised *double diamond model*⁹, which formally includes multinational activity.

So far we have classified clusters as a strategic aggregation that generates socioeconomic development through innovation deriving from the complementarity, proximity and collaboration of a number of (public, private and institutional) players. Innovation is a pivotal component, therefore it requires proper channels through which knowledge can flow and trigger learning processes.

⁸ John H. Dunning, *The competitive advantage of countries and the activities of transnational corporations*, 1992

⁹ Chang H. Moon, Alan M. Rugman, Alain Verbeke, *A generalized double diamond approach to the global competitiveness of Korea and Singapore*, 1998

To understand the processes through which knowledge is transmitted, shared and developed in order to generate innovation we can refer to the *Triple Helix Model* that was first introduced by Henry Etzkowitz and Loet Leyesdorff in 1995¹⁰.

The model describes the patterns of interaction between the three main categories of players within an economy, namely Academia, Industry and Government. The action of these three macro-categories are carried out in a nonlinear, interactive way, and their areas of intervention often overlap, giving rise to hybrid phenomena and trilateral networks. As a result, knowledge spreads across the whole system through cross-fertilization in its various forms: university-based spin-off firms, joint development programs between companies and government laboratories or research centres, and so on. It is worth highlighting that the very interactive nature of the model assigns equal relevance to each one of the macro-categories, therefore innovation can result from the initiative of one or more components. The nonlinear nature of the triple helix excludes the presence of a “leader” (at least in its traditional sense): leading and supporting functions live within a dynamic environment characterised by fluid relationships, and they can therefore be transferred and shared.

A detailed framework of the triple helix model (as revised by Luis Farinha and João J. Ferreira¹¹) is illustrated in figure 2.

¹⁰ Henry Etzkowitz, Loet Leyesdorff, *The Triple Helix. University-Industry-Government Relations: A Laboratory for Knowledge-Based Economic Development*, 1995

¹¹ Luis Farinha and João J. Ferreira, *Triangulation of the Triple Helix: a Conceptual Framework*, 2013

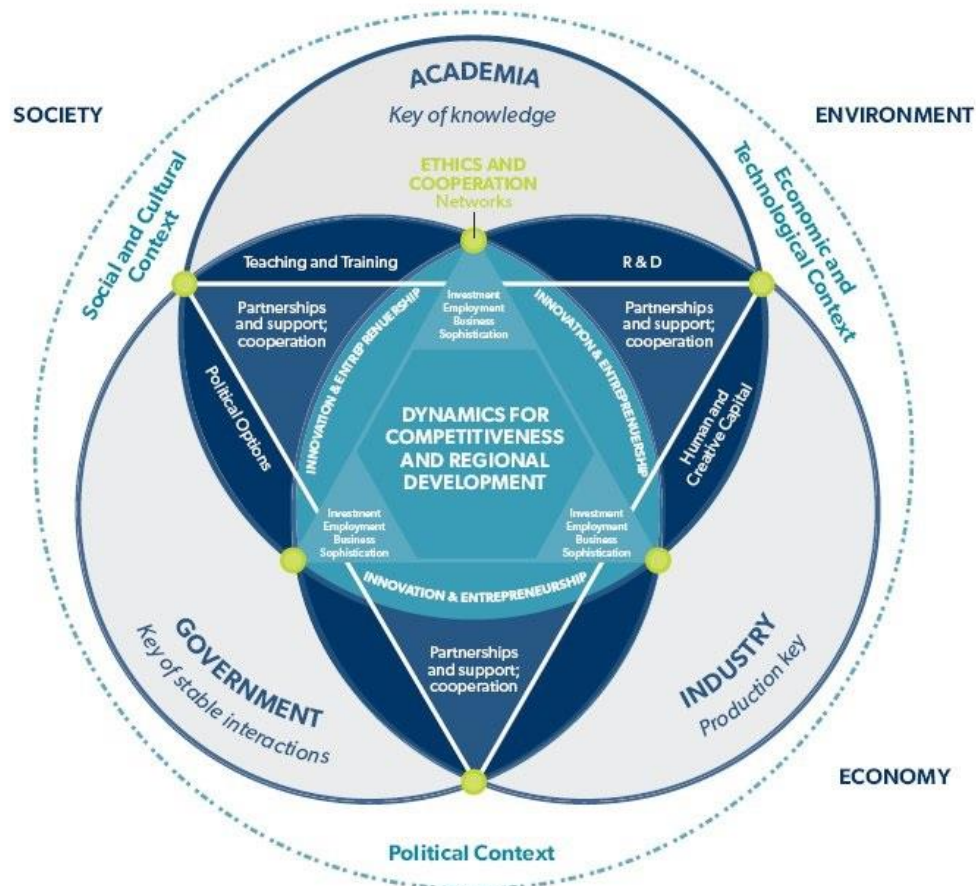


Figure 2: the Triple Helix Model. Source: Farinha and Ferreira, 2013

In conclusion, a cluster can be summarised as a plural entity which embeds a global perspective in a local economic activity, carried out through a variety of interactions among a wide range of participants, which establish both vertical (supplier-manufacturer-dealer-customer) and horizontal links, fostered by geographical proximity and by the presence of a common infrastructure that allows knowledge to be shared. Competition through specialization results into a cooperative effort towards innovation that ultimately provides competitive advantage to the local system, thus generating widespread socioeconomic development.

1.1 A Unique Form of High-Tech Cluster

The development of a cluster theory has led to the definition of different categorisation criteria. According to the nature of their competitive advantage, the doctrine has identified the following clusters:

- *High-tech clusters*: strong presence of high technology, both in the production process and in the output. Significant reliance on the knowledge economy: primary role of universities and research centres.
- *Historic know-how-based clusters*: industry-specific/traditional activities whose presence in the area stretches over a long period of time (years or even centuries), and for which the members have developed a unique *know-how*.

- *Factor endowment clusters*: comparative advantage dependent upon a specific (often geographic) feature of the cluster.
- *Low-cost manufacturing clusters*: the main source of competitive advantage is the low cost of labour force. This phenomenon is typical of industries such as automotive, electronics or textiles, which have burgeoned in developing countries and have established commercial channels with developed countries.
- *Knowledge services clusters*: driven by the availability of a skilled workforce at lower cost, these clusters are a recent phenomenon, and typically provide a range of increasingly standardised knowledge services (software development, engineering support, analytical services, etc.).¹²

Our attention will focus over the first class of clusters, namely those with a high intensity of technology and knowledge.

As highlighted by Calvosa^{13 14}, high-tech clusters are characterised by the pivotal role played by what Asheim & Coenen call 'Analytical Knowledge'¹⁵ - namely the "*knowledge to understand and explain features of the universe*"¹⁶ - in the innovation process, which strongly relies on the scientific results of academic research. In the sectors where analytical knowledge prevails, innovation stems from the creation of new knowledge, often as a result of the collaboration between firms (mainly their R&D departments) and research organisations (universities, research institutes, laboratories, etc.). This implies that the outcome of the process is primarily radical innovation. Knowledge and innovation are codified through patents and scientific publications¹⁷.

High-tech clusters require an ongoing process of technological knowledge upgrade in order to sustain innovation, and thus competitiveness, therefore it is fundamental for them to be part of a network that crosses the boundaries of the local economic system, as the local pool of knowledge is undoubtedly insufficient. They need an international knowledge exchange to access the latest scientific findings.

Perhaps the sector in which regional agglomeration fits more than any other the epitome of a high-tech cluster is the biotechnology industry. Its *corpus* of knowledge consists of an immense bulk of patents, licencing and scientific papers, thanks to the fact that Academia (mainly universities) incubates Industry, thus initiating the innovation process. Consequently, despite the relevance of infrastructures, the most important resource is human - rather than physical - capital.

On the contrary, the cluster phenomena within the aerospace industry show a number of inner features that create some significant divergences with the pinpointed framework. Indeed, when compared to other sectors such as biotechnology, aerospace clusters appear to be quite unique, to the point that it could be argued whether they actually abide by the Porter's cluster paradigm or not.

¹² Stephan Manning, *New Silicon Valleys or a new species? Commoditization of knowledge work and the rise of knowledge services clusters*, 2013

¹³ Paolo Calvosa, *Le strategie regionali per l'innovazione dei cluster ad alta tecnologia in una prospettiva evolucionista*, 2010

¹⁴ Paolo Calvosa, *Regional Innovation Policies for High-Technology Firms: The Importance of the Cluster Life Cycle*, 2013

¹⁵ Bjørn T. Asheim, Lars Coenen, *Knowledge bases and regional innovation systems: Comparing Nordic Clusters*, 2005

¹⁶ Bjørn T. Asheim, Lars Coenen, Jerker Moodysson, Jan Vang, *Regional Innovation System Policy: a Knowledge-based Approach*, 2005

¹⁷ Bjørn T. Asheim, Meric S. Gertler, *The geography of innovation: Regional innovation systems*, 2005

Before developing an insight into the latter aspect, it might be useful to provide the reader with a more synoptic perspective.

Aerospace is defined as ‘*The branch of technology and industry concerned with both aviation and space flight*’. More specifically, it is a multidisciplinary field that encompasses science, engineering and business in an effort to fly in (aeronautics) and beyond (astronautics) the Earth’s atmosphere with the ultimate goal of gaining a thorough understanding of Earth and outer space.

The aerospace industry ranks among the largest high-technology employers in the developed world: historically, aeronautics have represented the main source of revenues, and the civil aviation manufacturing sector in particular has long been the largest employer within the whole aerospace industry. However, over the last decade space-related activities have been increasingly playing a significant role in aerospace. From 1998 to 2014, the space sector experienced a 10.71% CAGR (*compound annual growth rate*).¹⁸ In 2014 launch and ground services, satellite manufacturing, satellite television and communications, government exploration, military spending and other interests resulted in global space economy reaching an historical peak of US\$330 billion worldwide, a 9% increase compared to 2013. The largest share of the annual revenues (76%) originated from commercial activities (+9.7% compared to 2013), while the remainder in revenues derived from government expenditure (which experienced a 7.3% growth with reference to the previous year)¹⁹.

These trends are only the latest evidence of an ascendant trajectory undertaken by the space sector in the last decade, which was driven by an unprecedented expansion in the range of civil/commercial applications of space innovation. As a sector with high R&D intensity, space has generated a vast array of technologies that have resulted in momentous improvements to our everyday lives. So far, space-driven innovations have provided benefits to travel, entertainment, environmental management, energy, resources, finance, transportation, logistics, communication, homeland security, rescue systems, defence, surveillance and border control, agriculture, weather forecasting and emergency response, science, biotechnology and healthcare, and the number of future opportunities is expected to rise thanks to the advent of new applications (space energy, space tourism), sectors (private space launches) and services (nanosatellites, broad commercial use of space). In particular, nanosatellites are likely to be the driving force of the commercial exploitation of space: a report from *SpaceWorks Enterprises* has stated that, despite the backlog due to limited launch opportunities in 2015 and the major launch failures of the vectors Antares, Falcon 9 and Super Strypi that occurred between 2014 and 2015, ‘*the commercial sector will increase its proportional representation over the next three years, to the extent that it will soon account for the majority of spacecraft launched in the 1 – 50 kg class*’, to the point that it ‘*will contribute over 70% of future nano/microsatellites*’²⁰.

The countless opportunities offered by space innovation have led many countries to organise their national space industries in the form of clusters, as this form of industrial organisation allows for enhanced efficiency in terms of production and innovation through the exploitation of the economies of proximity, knowledge spillovers and interaction among the players.

On the other hand, aerospace clusters turn out to be quite unique – and somehow heterodox – when compared to other high-technology fields such as biotechnology, automotive and ITC. Some of these peculiarities are so profound that may result in consistent discrepancies with the very notion of a

¹⁸ Gabriele Lania, *An International Comparison of Space History, Policy and Industrial Capability*, 2016

¹⁹ The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

²⁰ SpaceWorks Enterprises, *2016 Nano/Microsatellite Market Forecast*, 2016

cluster, to the point that they pose some challenges related to the cluster analysis in terms of quantitative measurement of key parameters, such as economic performance or innovation.

Table 7. Knowledge spillovers and flows in aerospace and biotechnology

Variable	Aerospace	Biotechnology
The main sources of knowledge spillovers	Large designers and final assemblers	Universities, venture capital firms and government labs
The main spillover beneficiaries	Tier 2 and 3 firms	Entrepreneurial SBFs
Nature of knowledge externalities	Codified knowledge on supply chain management: designs, tech specs, TQC, JIT, manufacturing blueprints	Codified (publication and patent) and personal knowledge on biotech products and processes, on financing and management
Most frequent geographical dimension of knowledge externalities	International (companies in different countries)	Local, regional and national (companies and institutions in the area)
Number of personnel involved in typical spillover	Thousands	Dozens
Duration of spillover processes	Years	Years
Level of organization of knowledge flows	Highly structured by major firms, and linked to markets	Spontaneous, and less structured with technology markets emerging
Hierarchy of flows	High	Low
Amount of knowledge flowing	Massive, due to complex products (thousands of documents per product)	Scattered (a few articles/ patents per flow)

Figure 3: comparison between aerospace and biotech clusters in terms of knowledge spillovers²¹

Aerospace clusters are a regional economic entity, whose international orientation does not constrain the extension of the economic activity to a narrow local dimension. Its specific features, such as the global scale of the benefits deriving from the innovation process, or the capital-intensive production processes and thus the high barriers to entry, require the scope of action to go beyond the local boundaries to involve a wide range of players on a global scale. While the value chain is global, the regional agglomeration stands within the core of the aerospace's competitive advantage - the ongoing innovation process - which in turn needs to be nurtured through an iterative exchange of information with analogous entities operating in different geographical contexts. Competition is based on and produces innovation, but the latter cannot be triggered without international cooperation. Cooperation does not limit itself to the exchange of information and expertise, but it can take the form of providing unique assets (knowledge, technologies, infrastructure) in exchange for participation to given development programs, space missions, *et cetera*. This exchange is not classifiable as a monetary transaction, but rather as a barter, and it can involve a wide range of different players in nature, such as firms, universities, space agencies, associations, research organisations, or even national governments. For instance, the European Space Agency (ESA) has concluded significant barter agreements concerning the maintenance and upgrade of the International Space Station²².

²¹ Jorge Niosi, Majlinda Zhegu, *Aerospace Clusters: Local or Global Knowledge Spillovers?*, 2005

²² Robert Veldhuyzen, Elena Grifoni, *No Exchange of Funds – The ESA Barter Agreements for the International Space Station*, 1999

Aerospace clusters are undoubtedly a momentous source of innovation. Nonetheless, the production of knowledge is not quantifiable with precision due to one fundamental reason which is both technical and political. On the basis of its historical connections with the defence and military sector, the aerospace industry tends to protect its processes and products through secrecy rather than through patents. Similarly, companies, research organisations and universities seldom publish scientific papers or license technologies. The (international) supply chain is the only channel for knowledge spillovers, which arise through mechanisms such as inter-firm partnerships or Original Equipment Manufacturer (OEM) training schemes that allow knowledge to be transmitted among organisations and to cross regional boundaries. On the other hand, the globalisation of supply chains has brought about high regional specialisation in the manufacturing of value-added products, thus generating a self-enforcing mechanism in which specialisation strengthens the international dimension of knowledge spillovers. As a result, it may be the case that production and innovation are carried out separately in two distinct geographical areas, or even clusters.

Aerospace clusters are generally based on strong international connections, both in terms of physical exchange and of knowledge transfer. The increasing recourse to outsourcing has worn away the local components of the input-output table, thus making it difficult to quantify and evaluate the local impact of industrial activity in the sector. The aerospace industry underwent a deep globalisation process whereby many entities have transferred productive segments of the value chain from the US and Europe to developing countries, to the extent that outsourcing has become the main channel for knowledge flows²³. It mostly involves non-core activities (due to the aforementioned competitive advantage and secrecy reasons), as well as manufacturing and R&D of subsystems in order to share risks and costs, and it strongly relies on components standardisation. The general pursuit of cost reduction and efficiency maximisation has brought to the application of supply chain methodologies such as just-in-time- manufacturing, as well as an overall increase in international competition between prime players and in entry opportunities for developing countries. By partaking the global value chains as subcontractors of standardised components, these countries have slowly started to develop more sophisticated aerospace industries thanks to the knowledge spillovers resulting from their participation.

Notwithstanding the paramount relevance of human capital, contrary to other typologies of high-tech clusters, aerospace exhibits a stronger dependence on physical capital: assets such as plants, launching sites and carriers have a lifespan of decades. Furthermore, infrastructures require significant capital expenditures. For these reasons, 'aerospace clusters are long term phenomena'²⁴ and the implementation of a new regional initiative should be carried out bearing in mind the fierce competition that new entrants would be likely to face.

On a higher level of analysis, aerospace clusters challenge two fundamental frameworks introduced in this work, namely the *triple helix model* and the *Porter's Diamond*:

- From a *triple helix* perspective, the direction of the industry-academia interaction is reversed (when compared to other high-technology clusters). For instance, in biotechnology clusters it is usually the university that incubates industry. What happens in the aerospace sector is probably the opposite: clusters require universities and research centres to provide a specific set of knowledge and human capital to satisfy their demand, often in exchange for specialised

²³ Jorge Niosi, Majlinda Zhegu, *Multinational Corporations Value Chains and Knowledge Spillovers in the Global Aircraft Industry*, 2010

²⁴ Jorge Niosi, Majlinda Zhegu, *Aerospace Clusters: Local or Global Knowledge Spillovers?*, 2005

technologies and expertise. The industry attracts and pushes for the development of a highly skilled and very specific human capital²⁵.

- As for the *Porter's Diamond*, aerospace clusters reshape the role given to the government. Due to the strategic importance of the aerospace sector and the broad socioeconomic development that it brings about, they show a high level of government direct involvement and interaction with the cluster's members, to the point that the latter can participate in (or even direct) the design of industrial policies and programs. For these reasons, the author argues whether the government can be considered a fully exogenous parameter or not, thus increasing the complexity of the analysis of this specific family of clusters

Along the same line of thought of the second point, Niosi and Zhegu claim that aerospace clusters do not easily fit the paradigm provided by Porter: once *Perroux* clusters, they have progressively taken the appearance of *Marshallian* industrial districts as the value chain became international. Furthermore, they do not show the dynamic factors predicted by Porter: there is an evident lack of inter-firm competition within the cluster (although it is tangible on a global scale) and the impact on local demand is negligible. Indeed, the aerospace industry is inherently export-oriented.

The absence of significant inter-firm competition derives from a very common feature among aerospace clusters around the world, namely their structural composition. Despite the propulsive role that can be played by government (e.g. space agencies) in the creation of an aerospace cluster, they normally are the result of the private initiative of a restricted number of major anchor firms (often only one), usually a Prime company or a large OEM (Tier 1 and 2 companies), which consequently attracts a network of diversified suppliers in the form of small and medium enterprises (SMEs). Anchor firms stimulate the concentration of a constellation of minor companies through the creation of economies of specialisation that attract a pool of homogeneous, highly-skilled workers. In addition, the presence of one or more large Multinational Corporations (MNCs) leverages the degree of internationalisation of the whole cluster through Foreign Direct Investment (FDI), international trade and information exchange channels.

1.2 Dynamics of knowledge flows and innovation

The aforementioned factors determine a very typical feature of the cluster phenomenon, namely the knowledge spillover, to take on extremely distinguishing traits from a geographical viewpoint.

The very nature of the sector, the role of MNCs, the global extension of value chains, the recourse to outsourcing and the high level of components standardisation, the relevance of physical infrastructure, the wide use of offset agreements (foreign subcontracts, technology transfer, co-production, FDI, training, licensing), strategic alliances and the key role of collaboration among players on a local, national and international level and all its implications in terms of cross-fertilisation, the mobility of human capital and the bulk of codified and uncoded knowledge in it, the export-oriented market, the pivotal role of innovation as major source of competitive advantage, the R&D intensity, all these elements constitute channels for knowledge diffusion - and ultimately innovation - and have led to the undisputed prevalence of international knowledge spillovers over local ones, as suggested

²⁵ Jorge Niosi, Majlinda Zhegu, *Aerospace Clusters: Local or Global Knowledge Spillovers?*, 2005

by Niosi and Zhegu for aerospace clusters²⁶ (2005) and in particular for the aeronautics subsector²⁷ (2010).

Evidence shows how knowledge spillovers occur mainly between Prime companies, Tier 1 and Tier 2 manufacturers, and that these are then exploited on a local scale through the involvement of Tier 3 and 4 SMEs. The diagram in figure 4 refers to the Montréal aerospace cluster, and it illustrates both its composition and the dynamics of its knowledge flows. For the sake of clarity, the arrows not pointing to any specific member are intended to represent a transmission of knowledge to a third player which does not belong to the cluster. In addition, it is possible to see the local knowledge interchange occurring between the upper and lower tiers, and among Industry and Academia. As a matter of fact, the players outside the triangle include the University of Montréal, the National Research Council of Canada (NRC), the Canadian Institute for Advanced Research (CIAR), and the École de Technologie Supérieure – Université du Québec.

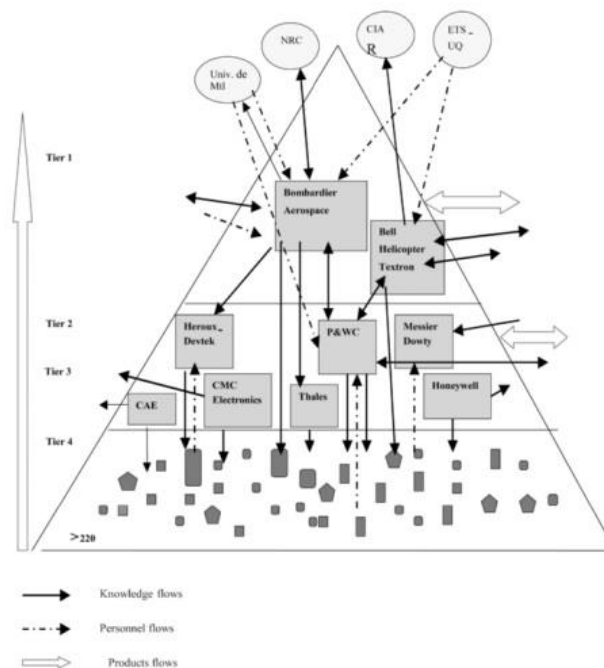


Figure 4: structure and dynamics of knowledge, personnel and products in the Aero Montréal aerospace cluster. Source: Niosi and Zhegu, 2005

²⁶ Jorge Niosi, Majlinda Zhegu, *Aerospace Clusters: Local or Global Knowledge Spillovers?*, 2005

²⁷ Jorge Niosi, Majlinda Zhegu, *Multinational Corporations, Value Chains and Knowledge Spillovers in the Global Aircraft Industry*, 2010

2. World's Best Practice

This chapter offers an insight into the most relevant examples of organisation of the local aerospace sector in the form of clusters. As anticipated in the methodology, the analysis is carried out coherently with the general framework provided by Professor Michael Porter in his *diamond model*, first theorised in *The Competitive Advantage of Nations*.

The model breaks down the elements that foster or hinder the competitive advantage of each cluster by analysing them from a multidimensional perspective that takes into consideration the cluster's inner features of its *Four Interrelated Components* (for further reference see chapter 1), namely the Factor Conditions, the Context for Strategy and Rivalry, the Related and Supporting Industries, and the Demand Conditions.

The analysis carried out in this chapter will provide a detailed description of the specific characteristics shaping the cluster's performance on a case-by-case basis. The purpose is to highlight, for each cluster, the unique features of its four dimensions that determine its competitiveness, while pinpointing from a holistic perspective the elements that are common to each one of the best practice analysed in this report. This dual viewpoint starts from the inner specificities of each cluster in order to contextualise them in a more general framework aimed at identifying the factors that are fundamental in determining the success, the performances, the competitiveness and the innovation potential of an aerospace cluster in the international landscape.

Starting from the analysis carried out for each of the selected clusters, it is possible to draw some general conclusions concerning the common elements that play a decisive role in the four dimensions of the model. These are synthesised as follows:

- I. Factor Conditions
 - Geomorphological characteristics and location
 - Universities and Research Centres
 - Infrastructures
 - Skilled Human capital (and ability to develop and retain talent)
 - Financial capital (access to credit, Venture Capital)
 - Favourable ecosystem for innovation and entrepreneurship
 - Availability of financing
 - Proximity and concentration (without congestion)
 - Know-how and expertise
 - Low cost of labour
- II. Context for Strategy and Rivalry
 - Active Role of Institutions For Collaboration
 - Adequate level of Public Intervention
 - National and system-level strategy
 - Incentives to start-ups and R&D
 - Presence and diversification of anchor firms
 - Network of specialised SMEs
 - Foreign Direct Investment
 - Extension of the value chain
 - Involvement in international programs

III. Related & Supporting industries

- Interconnections with clusters in other sectors
- Interconnections with other aerospace clusters
- Membership in broader networks
- Large pool of suppliers
- Specialisation
- Support from research sector
- Internationalisation
- Smart outsourcing strategies

IV. Demand Conditions

- High demand for innovation
- Increasing world demand and ability to attract it
- Threat from emerging players
- Domestic civil demand
- Relevant demand from defence sector
- Large export

2.1 France

The 20th century *Space Race* between the United State and the Soviet Union somehow overshadowed France's unrelenting achievements in the space sector from the 1960s on. Nonetheless, the country has long been among the world leaders in this field and its contribution was fundamental in advancing independent European space development and in overpowering the US-USSR duopoly. As a matter of fact, in 1965 France has been the sixth country with an artificial satellite (*Asterix*) in orbit (after USSR, US, UK, Canada, and Italy), and the third to do so using its own rockets. Furthermore, France provided a vital impulse in the creation of the *European Space Research Organisation* (ESRO) and the *European Launcher Development Organisation* (ELDO), which merged into the *European Space Agency* (ESA) in 1975.

In 2015 the budget of the French national space agency, the *Centre National d'Etudes Spatiales* (National Centre for Space Studies, CNES) amounted to €2.126 billion (US\$2.371 billion), with a 1.3% decrease compared to the previous year. This reduction was mainly due to a decrease in Governmental expenditures (€1.232 billion, -3.6% compared to 2014), while the share of expenditures devoted to the financing of ESA projects underwent a sharp increase (€894 million, +10.2% compared to 2014), although including debt reduction contribution as well²⁸. Not taking into account the European Space Agency, France exhibits the fifth highest budget devoted to space worldwide²⁹. The national involvement in European space activity is particularly evident in the development program of the *Ariane* launcher led by the ESA: as at December 2014, the CNES committed to providing 52% of the total funding of the *Ariane 6* development program. Furthermore, the Kourou spaceport located in French Guiana is a vital infrastructure for the European space activity, thanks to its proximity to the equator.

From a broader perspective, the space sector constitutes an important niche of the French aerospace industry: it accounts for 14% of its revenues and 8% of full-time employment³⁰. The sector shows higher revenues and employment shares when compared to other primary countries in the international arena. The aerospace industry in France is one of the leading sources of socioeconomic development in the country, and it has been characterised by an outstanding resilience to exogenous shocks during the years of financial crisis. 2015 has been defined as a record year by the *Groupe des Industries Françaises Aéronautiques et Spatiales* (French Aerospace Industries Association, GIFAS), with a €58.3 billion turnover (\$64.7 billion, +8.5% compared to 2014), mainly within the civil sector (77%). It is worth highlighting the strong orientation to exports, which amounted to €39.4 billion (\$43.7 billion): France is the world's leading exporter of aerospace products and services, and its main trading partners are Germany, the United States and China³¹. The overall appreciation of the US dollar in the last five years has contributed to the export growth. Aerospace employed 185,000 people (+2.7% on a yearly basis) and 3000 net jobs created. The sector covers the vast majority of the supply chain, thus benefitting from the contribution to value creation given by a wide range of related and supporting industries: the latter contribute to the total turnover with €20.3 billion (\$22.5 billion)³². It is worth mentioning that the country's morphology and geographical position have fostered the development of the national aerospace sector: the abundance of vast plains and the capillary network

²⁸ The Space Foundation, *The Space Report 2016 – The Authoritative Guide to Global Space Activity*, 2015

²⁹ Ibid.

³⁰ OECD (2014), *The Space Economy at a Glance 2014*, OECD Publishing.

³¹ Ibid.

³² GIFAS, *Review of 2015: a record year for the French Aeronautical, Space, Defence and Security Industry*, 2016 press release

of canals allow for a relatively easy transportation of components and subassemblies. In addition, the country's position between the Atlantic Ocean and the Mediterranean Sea is strategic with reference to the access to markets such as Middle East and United States.

Space Revenues	Government Expenditures in Space	% Government Expenditures/Total Revenues	Global Government Expenditures
€8.162 billion	€2.126 billion	26.04%	24%

Table 1: French Public Expenditures in Space. Author's elaboration based on data from The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

As the table shows, the ratio between public expenditures and total turnover in the French space industry mirrors the global average.

The example of France is extraordinarily relevant for the purpose of this work, as its aerospace sector strongly relies on a clustered industrial organisation. France hosts three major regional aerospace clusters: the *Aerospace Valley* based in Toulouse, the *ASTech* Cluster in Paris and the Provence-based *Pégase* cluster³³. In addition, an intense promotion and prospection activity started in 2005 and carried out by the local development agency *Investir en Finistère* together with GIFAS has led to the recent implementation of the *IEF Aero* aerospace and defence cluster in the French region of Brittany. The *Aerospace Valley* will be the subject of our analysis, while the development of IEF AERO will be analysed in the section dedicated to emerging clusters.

Among the key factors that have shaped the development of the French Aerospace industry, two in particular are worth mentioning:

- I. **The all-encompassing role of GIFAS:** throughout the years, the *Groupement des Industries Françaises Aéronautiques et Spatiales* has been able to involve the entirety of the sector's stakeholders and to exert a strong coordination role among them. As a result the whole system is characterised by high levels of cooperation among the economic players, particularly with respect to the R&D activities. The system exhibits a deep information exchange and is able to develop concerted strategies for future development.
- II. **Collaboration between prime contractors and suppliers:** as a result of the industry's long-standing establishment, its components have built strong multi-level inter-firm relationships. This aspect has led to stable demand over time, joint development and inter-tier workforce mobility. The overall effect is an enhanced innovation potential within the system.

Notwithstanding the undisputed overall solidity, in recent times the sector suffered from the contraction of military expenditures, along with an increase in international competition due to the entry of international rivals from developing countries, which can rely on a lower cost of labour. A number of institutional features weaken the overall competitiveness. The government owns consistent shares of private companies (as at 2015, the French state held the 10.95% of Airbus Group³⁴), and it frequently resorts to subsidies and public procurement procedures concerning high technology industries, with significant distortionary effects over competition that ultimately burden innovation. French companies are subject to heavy taxation schemes: the Corporate Income Tax (CIT) amounts to 33.3%, and an additional 3.3% of the taxable income is paid in the form of social contribution tax. A 3% contribution is due to dividend distributions, and companies with a turnover

³³ OECD (2014), *The Space Economy at a Glance 2014*, OECD Publishing.

³⁴ Airbus Group Registration Document 2015

exceeding €250 million benefit from an additional 10.7% temporary CIT surcharge (until December 2016).

On the other hand, France has established a combination of subsidies and tax incentives to foster private research and development and the establishment of new innovative enterprises. The scheme includes a R&D tax credit as a 30% of the eligible R&D expenditures up to €100 million (5% for expenditures exceeding this threshold), as well as a favourable fiscal regime for revenues derived from property rights (15% CIT) and full exemption from corporate tax for accredited innovative start-ups. The current system incentivises R&D partnerships as contracting-out to public sector is double-counted, thus doubling the tax credit. In addition, salaries paid to research personnel (final-year doctoral and post-doctoral) on their first permanent contract are quadruple-counted for two years³⁵ as for the tax credit, in an effort to increase the tertiary employment. This particular policy belongs to a more general supporting attitude towards R&D in France: according to the 2012 World Bank Indicators, France scored 13th in the world's highest R&D expenditures as a percentage of GDP (2.23%)³⁶.

2.1.1 The Aerospace Valley

The *Aerospace Valley* is the most important European aerospace cluster, particularly in terms of employment: including the related SMEs and around 8500 researchers, the total workforce amounts to some 132,500 people (124,000 industrial employees). These numbers constitute around one third of the total French aerospace workforce, and the scientists carrying out R&D activities in this area represent 45% of French national R&D potential in the aerospace sector³⁷. At present, the activities of the cluster encompass the regions of *Languedoc-Roussillon-Midi-Pyrénées* and *Aquitaine-Limousin-Poitou-Charentes* in the southwest of France.

Although being formally established as an association on the 13th of July 2005 after governmental approval, the history of the local aerospace industry dates back to the early 1900s, when the aircraft manufacturer *Latécoère* was founded in 1917 in the city of Toulouse, which would have later become the centre of the cluster. The city had been elected for its distance from the German front and for its already existing industrial apparatus. Since then, and through the crucial intervention of the French Government, the local industry has undergone continuous development. Main milestones include the transfer from Paris to Toulouse of two of the finest engineering *Grandes Écoles* – namely the *Institut supérieur de l'aéronautique et de l'espace* (ISAE-SUPAERO, 1961) and the *École Nationale de l'Aviation Civile* (ENAC, 1968) – and the foundation of the Toulouse-headquartered *Airbus Industrie* consortium in 1971, which constituted the main anchor firm, attracting a wide number of SMEs along its supply chain.

Nowadays the whole cluster consists of 853 members³⁸ organised into seven different bodies, or *Collèges*, according to their nature: SMEs, industry leaders, training organizations, research centres, economic development organizations, public and regional bodies, trade organizations and related partners. As shown in the picture below, the cluster extends to the entirety of the value chain and covers a wide range of applications: structures, materials and processes, energy and electro-mechanical systems, air transport safety and security, navigation telecommunications and observation, critical systems engineering, electronic systems integration, and execution platforms,

³⁵ Invest in France Agency, SayOuiToFrance-Innovation, *France's Research Tax Credit*, 2013

³⁶ http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?year_high_desc=true

³⁷ <http://www.aerospace-valley.com/en>

³⁸ The full directory is available at the following link: http://www.aerospace-valley.com/Annuaire_Directory/index.html#p=1

man-machine Interface, maintenance repair & overhaul (MRO), and highly complex systems design and integration. The most relevant segment is represented by Prime operators and System Integrators. A huge galaxy of 504 SMEs orbits around an elite of Original Equipment Manufacturers (OEMs), such as Dassault-Aviation, Stelia Aerospace, Thales Alenia Space, SAFRAN, Turbomeca, and the world's leading aircraft manufacturer Airbus (together with its Defence and Space unit).

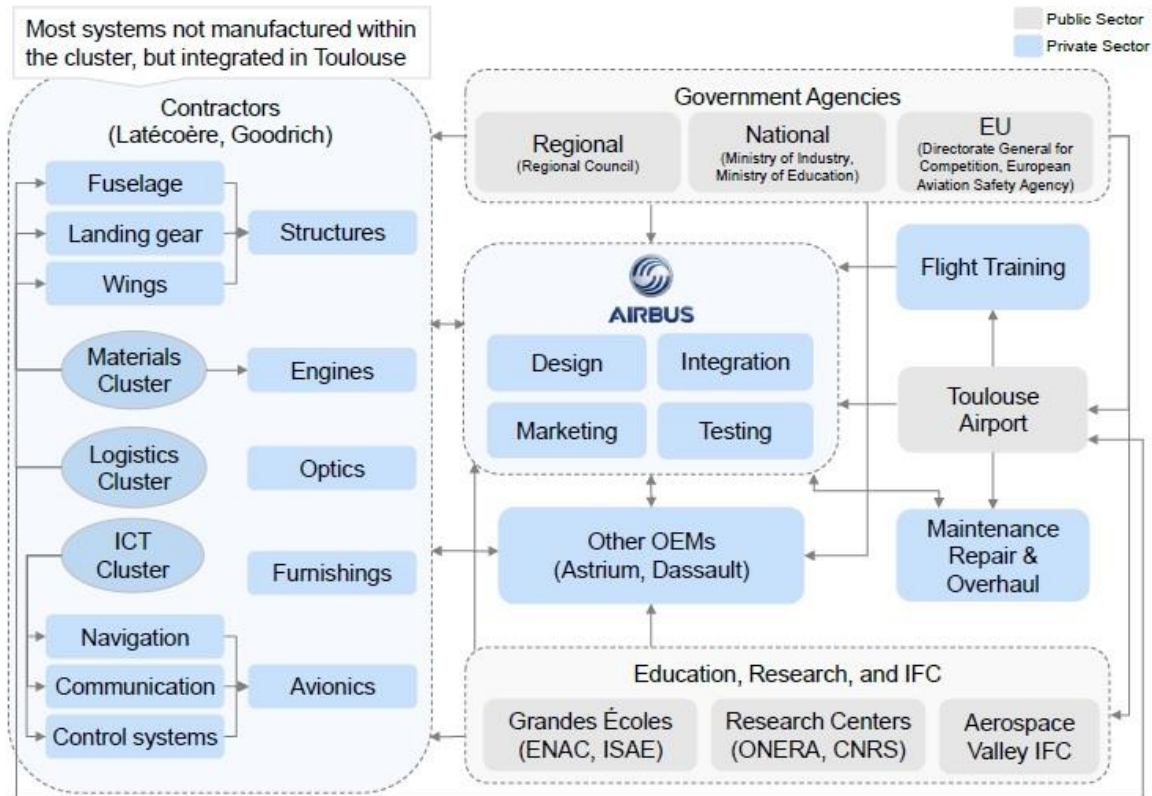


Figure 5: Aerospace Valley cluster map. Source: Bawa, Etxebeste, Konialian, Martin, Ruiz-Taboada³⁹

Notwithstanding the massive industrial apparatus, the role of non-corporate players is paramount: besides the already mentioned ENAC and ISAE-SUPAERO, the Centre National de la Recherche Scientifique (National Centre of Scientific Research, CNRS) and the Office National d'Études et de Recherches Aéropatiales (National Office for the Aerospace Study and Research, ONERA) are among the main research centres responsible for the technological advancement of the cluster. The Aerospace Valley Association, established by decree of the French Government, carries out a vital coordination role of the general activity of the cluster, acting as the primary Institution For Collaboration (IFC).

The latter aspect is particularly remarkable: thanks to the crucial role played by non-corporate players, the Aerospace Valley exemplifies of the triple helix paradigm. In the worlds of the European Aerospace Cluster Partnership (EACP), *Aerospace Valley is a "triple helix cluster" [...] rather than a primarily business oriented "supply chain SME cluster"*.⁴⁰

³⁹ Jyot Bawa, Iker Cillero Etxebeste, Michael Konialian, Jonathan Naharro Martin, Hugo Ruiz-Taboada, *Aerospace Cluster in the Toulouse Region*, 2013

⁴⁰ <http://www.eacp-aero.eu/index.php?id=26>

As evidence of the relevance of the triple helix model for the overall performance, the Aerospace Valley stands out among the world leaders in terms of R&D: in the year 2015 the cluster has been assigned some 450 projects for a total value of €1.1 billion⁴¹.

All these factors have contributed over time to leverage the efficiency and the performance of the cluster: in the timeframe from April 2015 to March 2016 aerospace products have constituted 73.8% of total exports of the region Languedoc-Roussillon-Midi-Pyrénées, and 9.22% of national export⁴².

Coherently with the general aerospace cluster framework that envisions the international dimension of the cluster activity, at present the Aerospace Valley is formally liaising with other major aerospace clusters.

Cluster analysis

The figure illustrates the Aerospace Valley cluster analysis within the Porter's Diamond framework. Starting from the original work carried out by Bawa, Etxebeste, Konialian, Martin and Ruiz-Taboada in 2013, this scheme intends to provide the reader with an updated picture of the current situation of the Toulouse cluster in order to understand the latest evolutionary trends undertaken by the different dimensions of the cluster

⁴¹ <http://www.aerospace-valley.com/en>

⁴² http://lekiosque.finances.gouv.fr/regionales/cadre_regionales.asp?TF=Cles&lreg=12

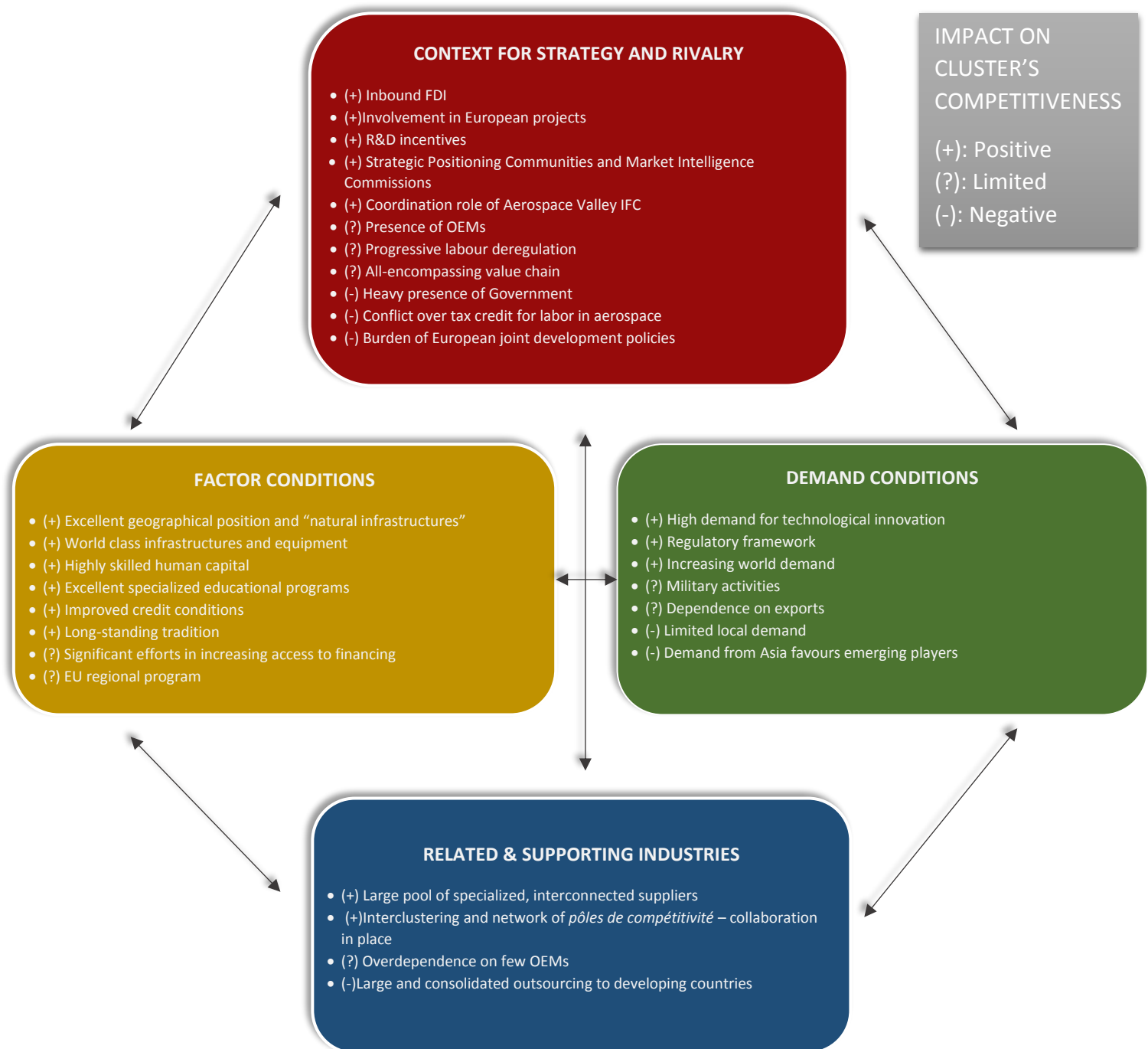


Figure 6: Porter's Diamond Analysis of the Aerospace Valley. Source: author.

Factor Conditions

In the Bawa et al. 2013 Toulouse aerospace cluster analysis, the factor conditions were assessed as "very good". In a timespan of three years every single aspect of the overall scenario has shown at least some degree of improvement. At present, the factor conditions may be defined as highly favourable, if not optimal.

As already pointed out in the previous analysis, the geomorphology of the region allows for easy transportation of assembled/semi-assembled systems. The vast plains have fostered the geographic diffusion of the cluster, as well as constituting an optimal landscape for establishing transport facilities

such as airports, roads and railways. In addition, the Garonne River and the related network of canals constitute a critical asset for this purpose. The geographic position is strategic with respect to the main international trade routes, and the Pyrenees constitute a valuable training field for the development of aero/astronautics flying skills. The infrastructural endowments of the region provide vital contributions to the economic activity of the cluster. The Toulouse airport, for instance, represents the main testing facility and the primary hub for the logistics related to aircrafts and spacecrafts: the Airbus A300-600ST (Super Transporter) or *Beluga*, mainly assembled and maintained in Toulouse, frequently operates there. Generally speaking, the Toulouse airport is highly integrated with Airbus, and hosts its Flight Test Centre. The numerous physical interconnections sprouted thanks to the region's geomorphology and its natural and artificial infrastructures have led to a wide territorial extension of the cluster, which has progressively encompassed every segment of the aerospace value chain. An important contribution to this latter aspect derives from the long-standing tradition of the aerospace industry in the area: which has also led to the development of an inestimable *know how* over time. The industry benefits from a copious highly skilled workforce, which mainly comes from the already mentioned *Grandes Écoles* and a wide number (around 600) of training courses offered by the cluster. In general, the specialised educational system of the area represents a global best practice. In addition, the cluster's workforce is enriched by international mobility, which has been enhanced through cooperation agreements with other clusters: for instance, the Hamburg Qualification Initiative is an exchange in the field of training established between the aviation clusters of Hamburg and the French Aerospace Valley.

The issue concerning SMEs financing was already outlined in the 2013 report. On that occasion the authors reported an increasing effort by the IFC and the Regional Council to set up agreements with financial institutions (investment funds, regional banks, consultancies). Today the scope of action has widened towards increasing the volume of FDI following a general trend in the French aerospace industry that sees an average of 19 new foreign investment decisions per week⁴³. As evidence thereof, on the 17th of February 2016 a new agency, *Invest in Toulouse*, was launched with the purpose of attracting investments in Space, Digital and Life Sciences. Following the turmoil that affected the markets in the aftermath of the financial crisis, nowadays the recovered stability has led to easier access to credit at better conditions. Finally, in the long run the cluster is expected to benefit from the broader ERDF-ESF Programme for Midi-Pyrénées and Garonne 2014-2020, which *aims to boost economic growth and contribute to achieving the Europe 2020 targets for smart, sustainable and inclusive growth. It will help the region enhance innovation and value-added research activities, encourage energy transition and offer adapted training programmes. More than 42% of the overall budget is allocated to research, innovation and competitiveness of SMEs and more than 13% to lifelong training actions. Moreover, specific actions are foreseen within the Youth Employment Initiative framework – orienting young NEET (Not (engaged) in Education, Employment or Training) over the labour market by appropriate training paths and channelling these operations over one of the global objectives of the OP: encouraging the participation of the local population in moving over inclusive growth via specifically designed training and employment support.*

Context for strategy and rivalry

The main strength highlighted by the 2013 analysis, namely the development trajectory driven by inbound FDI, keeps pushing the growth of the cluster. As a result there is widespread optimism about the attainability of the goal set by the association at the time of the foundation (2005): creating 40,000 new jobs by 2025. 13,000 were created in the years 2005-2009 and another 10,000 in the years 2012-2015. The cluster has established a unitary mechanism to develop a coordinated, system-wide

⁴³ Business France, *French Excellence in Aerospace*, 2015

strategy: the members are grouped into 9 *Strategic Positioning Communities* (SPCs) based on the companies' areas of expertise (such as Aeronautics, Space, Embedded Systems, etc.). A second structure bridges the SPCs with the markets in order to proactively shape the strategy according to the latest commercial opportunities and targets: 3 *Market Intelligence Commissions* (MICs) have been established with this purpose. SPCs and MICs work together to *create a global intelligence envelope*.

The primary role of Aerospace Valley in the international arena is mirrored by the high degree of involvement within EC-ESF projects⁴⁴. This element encourages the inception of innovative firms, provides sound regulatory standards to aerospace products and services, and enhances the competition and cooperation among the single firms constituting the cluster and between the latter and non-member companies. The positive and negative consequences of the presence of few large OEMs have remained unchanged in these three years: such massive anchor firms still constitute a double-edged weapon, with their ability to attract a large number of small supplier SMEs and at the same time subdue rivalry through their imbalanced contractual power. The recent labour reform should increase the competitiveness of the system as a whole by speeding up the dynamics of employment and increasing labour market flexibility, but the Aerospace Cluster shows one particular deeply-rooted feature that may constitute a major source of competitive disadvantage from an international perspective: the all-encompassing value chain, while fostering intra-cluster cooperation, hampers the cluster specialisation (in contrast with a general trend occurring worldwide), particularly in those high-end segments where the Aerospace Valley may seek competitive advantage. Despite the liberalisation process, the governmental shares in key companies are still relevant (e.g. the State holds a 10.95% share of Airbus), and massive government procurement still represents a distorting factor for competition. Furthermore, while the high standards imposed by the European regulatory framework stimulate innovation, the inclusion in a wider community strategy at the European level burdens the development of the single companies and of the cluster as a whole: one example is the European scale of the Airbus manufacturing chain. Finally, despite the fiscal incentives to R&D and the tax credit law passed in late 2012 to cut the cost of employment, as of 2014 the Aerospace Valley and the national aerospace industry as a whole called for wider tax credit schemes in order to foster competitiveness.

Related and supporting industries

During the last years the cluster managed to consolidate its strengths concerning related and supporting industries, along with a significant improvement in terms of those features that in the 2013 analysis had been identified as having an overall limited impact on the cluster's competitiveness.

The network of specialised suppliers has further spread its ramifications, and it now consists of more than 500 SMEs partaking in the vast majority of the value chain. Their relevance within the innovation environment is leveraged by the large number of R&D projects they are involved in. The role of the IFC was crucial in advancing the R&D, as well as building and strengthening the interconnections among the cluster members, and between the latter and the supporting industries. The once nascent collaboration with related clusters has developed consistently thanks to the leadership position that Aerospace Valley has within the Clusters Working Group in the *Network of European Regions Using Space Technologies*. The Aerospace Valley is following a diversification strategy on a global scale whose key step is the liaison with European clusters in related domains. At the same time the cluster has scaled up its *inter-clustering* action both with the other EU aerospace clusters that are members of the EACP network and with other prime players in the international arena. The Aerospace Valley has currently 6 formal cooperation agreements in place with other international aerospace clusters:

⁴⁴ <http://www.aerospace-valley.com/en/page/european-projects>

Hamburg Aviation (Hamburg, Germany), Aéro Montreal (Montreal, Canada), Farnborough Aerospace Consortium (Farnborough, United Kingdom), CECOMPI (Sao José dos Campos, Brazil), Skywin (Wallonia, Belgium) and OSSA (Turkey). The steering committee is striving to achieve bilateral agreements with a total number of 10 clusters in the fields of aeronautics, space and embedded systems in the future. This strategy is fostered through the European Aerospace Cluster Program (EACP). Other agreements include: Hegan (Memorandum of Understanding, Bilbao, Spain), AVSI (MoU, Austin, Texas), Subsea Valley (MoU, Asker, Norway), Tianjin Free Trade Zone (Tianjin, China). Besides its fundamental coordinating function, the role of the IFC has been pivotal in enhancing the inter/intra-sectorial development of the cluster. To sum up, the potential interconnections identified in the previous analysis have been nurtured consistently in recent times, and their impact can thus be classified as positive. The cluster is now part of the broader French network of the so-called *pôles de compétitivité*.



Figure 7: location of the French "pôles de compétitivité". Source www.competitivite.gouv.fr

The issues that the organisation has failed to address are the already mentioned overdependence of the related and supporting industries on a restricted elite of OEMs, and the increasing process of outsourcing undertaken by the whole cluster, and in particular by its main aeronautics companies.

As already discussed, OEMs have mixed impacts on the cluster. From an industry perspective they have been fundamental in the process of spontaneous development of the network of related and supporting industries, but on the other hand they have always represented a rigid - "dogmatic" to some extent – and homogeneous demand for a wide spectrum of firms. This constitutes a burdening factor, as it stifles the firms' ability to adapt to, and proactively interact with, the continuously evolving

international environment, and it prevents small firms in particular from properly competing on a global scale.

Outsourcing to those countries with competitive advantage in terms of labour costs is a general trend of the whole aerospace industry. The process is not detrimental per se but it needs to be accompanied by the identification of other sources of competitive advantage at higher segments of the chain. Since innovation in aerospace is a long process, the short-run impacts of outsourcing are considered to be negative: outsourcing constitutes the starting point for the industrial development in other countries, as it inherently involves a certain degree of information transfer. Competition over assembly and manufacturing might therefore be a transitory phenomenon bound to evolve into fierce competition in other markets. In recent years many companies of Aerospace Valley have undertaken this path, increasing their share of outsourcing towards low-wage countries. For instance, in 2015 Airbus has announced an outsourcing contract with India for €1.8 billion (US\$2 billion)⁴⁵, and the company has formally stated that they are *committed to outsourcing larger work packages to suitable long-term partners and trusted Tier One suppliers*⁴⁶.

By contrast, the cluster has little scope of action in addressing these occurrences as they are both hardly reversible in the short run and driven by market forces and inner features of the aerospace industry.

Demand conditions

As a world leader in research, development and innovation the cluster is at the forefront of technological innovation, therefore it is well prepared to meet the global need for technological advances. This attitude is enhanced by the stringent regulatory framework built by the European Union, which stimulates firms through strict requirements in terms of security, efficiency and environmental impact. There is clear evidence of a constant increase in the world demand for aircrafts, space equipment, infrastructures and space-related services, along with an overall ageing of the national fleets. While the cluster is well positioned to play a leading role in the satisfaction of the global demand, the growing need for maintenance, repair and overhaul due to the ageing of the national fleets might be further exploited by increasing the MRO activities within the cluster, which are so far dominated by design, assembly and integration. Military activity still represents a driver for innovation but, as evidenced by Bawa et al. the custom of 'cost plus' contracting is detrimental to the achievement of cost effectiveness. Furthermore, the new *Military Programming Law*, which covers a timespan of five years (2014-2019) implies the reduction of military equipment (mainly planes and helicopters) without any replacement plans, as well as reducing the budget devoted to maintenance of aerospace equipment. In 2015 the budget of the Defence mission amounted to €31.4 billion (US\$34.8 billion), while the funds devoted to Civilian and Military Dual Research totalled to less than €300 million (US\$332.5)⁴⁷.

The Large share of production exported by the Toulouse cluster is obviously an indicator of competitiveness, but from a demand perspective it implies that, as already happened in recent times, the cluster system is largely exposed to fluctuations in demand due to exogenous parameters, namely the exchange rate between the euro and other currencies. In addition, the local demand for the cluster products constitutes an insignificant share of the total. Finally, the downside of the growing world

⁴⁵ <http://indianexpress.com/article/india/india-others/aircraft-manufacturer-airbus-supports-pm-modis-make-in-india-initiative/>

⁴⁶ <http://www.airbus.com/company/market/>

⁴⁷ Source: Ministry of Defence, Defence Key Figures, 2015 edition, <http://www.defense.gouv.fr/content/download/400382/6028076/file/Chiffrescle%CC%81s2015GB.PDF>

demand is that it is still mainly attracted by Asia: the development of the aerospace industry in China, India, and other Asian tigers is likely to absorb a consistent portion of the new demand, favouring those emerging players which are geographically and politically closer to these markets, at the expense of traditional clusters such as the Aerospace Valley.

2.2 Germany

The aerospace history of Germany dates back to the beginning of the 20th century. The country was among the world leaders in the development and manufacturing of civil and military aircrafts, and the planes crafted by Wilhelm Emil Messerschmitt in 1923 represented a global excellence. The innovation in the field of aerospace activities received significant impulse in the aftermath of World War I, when the constraints imposed by the Allied Powers over Germany aimed at limiting the latter's offensive capability shifted the focus of its military industry from artillery to the development of rocket technology. In less than 20 years the country pioneered the sector and produced cutting-edge innovation. Despite turning out to be insufficient to guarantee Germany the victory over the Allies, the national rocket technology and expertise was so advanced that German engineers were forced to transfer their knowledge by compulsorily working for the winners. This event has had paramount implications for the future development of American and French space capabilities.

Germany, however, insisted in growing its aerospace sector and, after redefining its new role in the international political landscape, it endeavoured to fill the technological gap with the world's superpowers. The second half of the 20th century saw Germany recovering its primary position among the leading countries: in 1969 AZUL, the first German satellite, was successfully launched, and the nation joined the USSR, the USA, France, Great Britain, Italy, Canada, Japan and Australia in the circle of countries with their own satellites orbiting the Earth. This event constituted the starting point of a long-term partnership with NASA (e.g. the Spacelab program ran from 1973 to 2000) and of a series of multilateral partnerships within the European framework that eventually led to the foundation of the ESA. As evidence thereof, Germany contributed significantly to the development of the *International Space Station* (ISS) and it is the first contributor to the European Space Agency (in 2014 its contributions constituted the 24.6% of the agency's total annual budget, namely €765.72 million over a total of €3,117.2 million⁴⁸). As the data in the following table suggest, the share of government expenditures over the total turnover generated by the space sector in Germany is significantly higher than the world average (35% vs. 24%).

Space Revenues	Government Expenditures in Space	% Government Expenditures/Total Revenues	Global Government Expenditures
€3,883 billion	€1,383 billion	35.61%	24%

Table 2: German Public Expenditures in Space. Author's elaboration based on data from The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014 and German Aerospace Industries Association (BDLI), *KEY FIGURES OF THE GERMAN AEROSPACE INDUSTRY*, 2015

Today, Germany puts constant and significant effort into the aerospace sector and particularly into space activity. The *Deutsches Zentrum für Luft- und Raumfahrt* (German Aerospace Center, DLR), namely the national aerospace agency, was founded in 1997 as the result of a merger among different institutions - the *Aerodynamische Versuchsanstalt* (Aerodynamic Laboratory, AVA), the *Deutsche Versuchsanstalt für Luftfahrt* (German Laboratory for Aviation, DVL), the *Deutsche Forschungsanstalt für Luftfahrt* (German Research Institute for Aviation, DFL) and the *Gesellschaft für Weltraumforschung* (Society for Space Research, GfW) - with the *Deutsche Agentur für Raumfahrtangelegenheiten* (German Agency for Space Flight Affairs, DARA). The national policies have led to the establishment of several partnerships both inside Europe (with the coordination of the ESA) and outside, with a number of both old and new players (such as China, Kazakhstan, Mexico).

⁴⁸ The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

The national industry is widely characterised by its cluster organisation, with a focus over the upstream activities: Germany hosts some of the most important aerospace clusters in the European Aerospace Cluster Partnership (EACP) and in the international landscape. Our attention will focus on two players in particular: the *BavAIRia* aerospace cluster and the LR BW (*Luft- und Raumfahrt Baden-Württemberg*) cluster in Baden-Württemberg, but it is important to mention the Hamburg Aviation aerospace cluster as well, as it hosts one major Airbus production site and has ongoing cooperation agreements (e.g. the Hamburg Qualification Initiative) with the Aerospace Valley of Toulouse. The Hamburg cluster initiative has been thoroughly analysed in a 2009 report by Roman Belotserkovskiy, Eva Gerlemann, Santiago Jariton, Campbell Lewis and Kirsten Porter⁴⁹.

2.2.1 The *BavAIRia* Aerospace Cluster

The German region of Bavaria has been one of the main international aerospace hubs for over a century, representing a primary pole of research and innovation. Its constitution as a cluster dates back to the year 1961 when the Minister of Defence Franz Josef Strauß allowed the German entrepreneur and pioneer of aeronautics Ludwig Bölkow to establish the *Industrieanlagen-Betriebsgesellschaft*, a center for industrial research in aerospace, in proximity to his production plants in Munich⁵⁰. Government investment has contributed shaping the cluster according to the *triple helix* paradigm. As of 2006 the cluster is steered by the association *BavAIRia Eingetragener Verein* (whose establishment was commissioned by the Bavarian State Ministry of Economic Affairs and Media, Energy and Technology), which serves as IFC and represents the ensemble of members and stakeholders of the industrial and research landscape. The mission of *BavAIRia* is *to identify the Bavarian core competencies in aerospace and space applications and to strengthen the key links with each other in order to increase the global competitiveness of these industries*⁵¹. The mission is carried out through technology transfer, marketing, supply chain management, training, consulting and internationalisation. The funding scheme of the cluster is heavily dependent on the regional government which contributes through public funding to almost 60% of the total budget, while the remaining 40% is mainly sourced from membership fees, consulting & project funding, EU sources (40%)⁵². The cluster directly and indirectly employs around 36,000 engineers, technicians and commercial aviation industry specialists, with an annual turnover of €7 billion. By taking into account the induced workforce employed in Bavarian airports and the ground staff of the airlines operating in the area, the total amount of the aerospace workforce increases to 61.000 units⁵³.

The cluster consists of some 550 companies (90% of them are SMEs) and a total of 18 research institutions among universities and research centres. The key success factor of *BavAIRia* is its extension along the whole aerospace value chain: the cluster exhibits a high degree of expertise diversification thanks to the compresence of 3 OEMs, 4 Tier 1 suppliers, a significant network of well-positioned suppliers, engineering service providers, 18 world-class science and training institutions and cutting-edge infrastructure such as the Galileo Control Centre and the Munich airport. Finally, *BavAIRia* carries out an extraordinary networking function among its industrial and academic partners: by leveraging

⁴⁹ Roman Belotserkovskiy, Eva Gerlemann, Santiago Jariton, Campbell Lewis and Kirsten Porter, *Hamburg Aviation Cluster*, 2009. Link:

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.568.5477&rep=rep1&type=pdf>

⁵⁰ Helmuth Trischler, *The "Triple Helix" of Space - German Space Activities in a European Perspective*, 2002

⁵¹ Source: Invest in Bavaria. <http://www.invest-in-bavaria.com/en/range-of-sectors/aerospace-satellite-navigation.html>

⁵² <http://www.eacp-aero.eu/index.php?id=33>

⁵³ Ibid.

the region's leadership in the IT sector, the IFC has built strong linkages among its members and stakeholders, thus enhancing the cluster's potential for innovation by upgrading the operational perspective to an international and inter-sectorial dimension. The cluster benefits from its proximity to the German Aerospace Center (DLR) in Oberpfaffenhofen, thus representing a vital hub for the national aerospace activity. At present, the DLR operates 8 scientific institutes and facilities⁵⁴ involved in space-related R&D. The other main research institutes include TU München, Universität der Bundeswehr, various Fraunhofer Institutes⁵⁵, the Max Planck Institutes, Hochschule München, the Ludwig Bölkow Campus Aerospace & Security and the European Southern Observatory (ESO).

Acknowledging the pivotal role played by the cluster in the socioeconomic development of the region, the National and State Governments have implemented the *Bavarian Cluster Policy*, a sound industrial policy in order to leverage the beneficial effects by building bridges with other industries. In addition, it is important to mention the regional agency *Invest in Bavaria*, and its key activity of cluster promotion and business support to national and international investors.

The Aerospace Cluster was restructured in 2011, adding a specific Space Applications division to the Space Division. The purpose of the institutional reorganisation was to foster the development of the local space industry by thoroughly exploiting the increasing opportunities offered by space technologies in a wide range of fields, such as tourism and leisure, agriculture and forestry, transport, traffic and logistics, environment and health. Its key industry players are EADS Defence & Security, Eurocopter, MTU aero engines, Premium Aerotec, Diehl, Liebherr, IABG, EADS Astrium, MT Aerospace, Kayser-Threde and Grob Aircraft

The features detailed above have driven the cluster's extraordinary development: BavAIRia has had a critical role in the recognition of Bavaria as the leading European region in the aerospace sector, and among the top five locations worldwide in terms of aerospace innovation. Its leadership stands in the following sectors: engine manufacturing, design, electric propulsion, components, avionics, simulation and training, satellites and earth monitoring. The feverish research activity has identified the fields of electric engines and aircrafts, small and micro satellites, and Global Monitoring for Environment and Security (GMES) as the main trajectories for future development and innovation.

The cluster is part of the European Aerospace Cluster Partnership (EACP), it has currently established international cooperation agreements with other aerospace clusters, and is seeking collaboration with other regions where large OEMs have established their presence. BavAIRia is currently endeavouring to increase and strengthen the involvement of SMEs in the global supply chain.

⁵⁴ [http://www.invest-in-](http://www.invest-in-bavaria.com/fileadmin/media/documents/publications/Sectors/IIB_Flyer_Aerospace_EN_www.pdf)

[bavaria.com/fileadmin/media/documents/publications/Sectors/IIB_Flyer_Aerospace_EN_www.pdf](http://www.invest-in-bavaria.com/fileadmin/media/documents/publications/Sectors/IIB_Flyer_Aerospace_EN_www.pdf)

⁵⁵ Among others we can mention the Fraunhofer Institute for Silicate Research, the Institute for Building Physics, the Institute for Embedded Systems and Communication Technologies, the Institute for Microsystems and Solid State Technologies, and the Research Institution for Casting, Composite and Processing Technology.

Cluster analysis

The diagram provides a schematic insight into the inner features of the BavAIRia aerospace cluster, according to the usual breakdown envisioned by the *Porter's Diamond* framework. The analysis of the factor conditions, the context for strategy and rivalry, the related and supporting industries, and the demand conditions describes an overall situation which can be indisputably defined as optimal. The following paragraphs intend to clarify the reasons why the BavAIRia cluster can be taken as one of the main world's best practice.

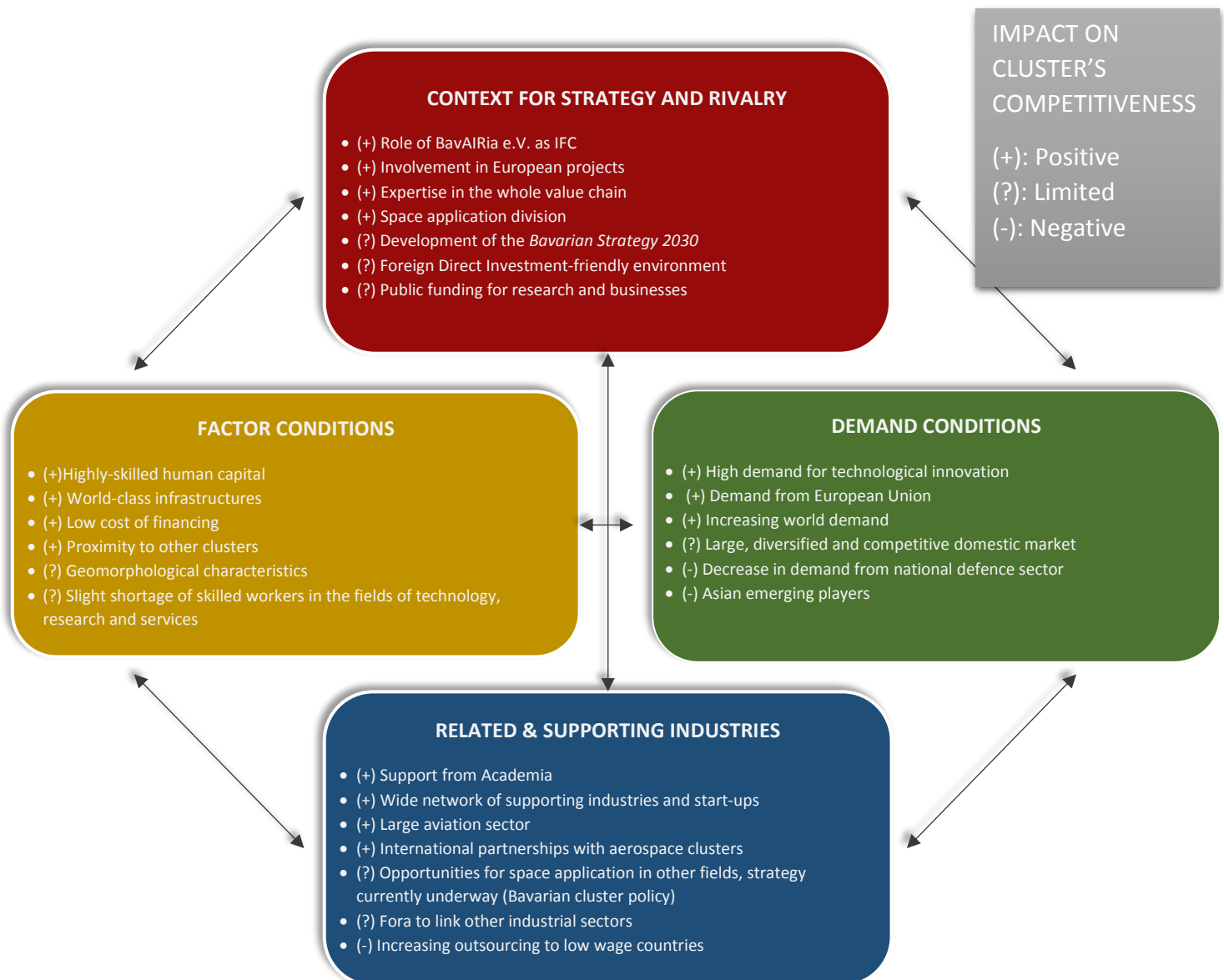


Figure 8: Porter's Diamond Analysis of the BavAIRia Aerospace Cluster. Source: author.

Factor Conditions

The factor conditions of Bavaria can be defined as excellent: the cluster has a large, highly skilled human capital, which is constantly replenished by the 18 universities and research centres in the region. For instance, the city of Munich provides more than 200 specialised tertiary graduates in aerospace disciplines from Bundeswehr University, the Munich University of Applied Sciences and Technische Universität München annually. This achievement is fostered by the presence of world-class infrastructures in the area. The Munich airport is capable of hosting and operating wide-body aircrafts

such as the Airbus A300-600 Beluga Super Transporter, which is essential to the transfer of large components and subassemblies. This feature makes up for the relative lack (when compared to other clusters) of waterways that allow for transportation by barge, and allows the local industry to further exploit its proximity to other aerospace clusters such as the Aerospace Valley or the Luft- und Raumfahrt Baden-Württemberg cluster. In addition, the region of Bavaria hosts the Galileo Control Centre, the German Space Operations Centre, the Galileo Test Area, the Earth Observation Centre, and one of the ESA Business Incubator Centres. On the other hand, in recent times the aerospace sector exhibited a chronic shortage of experienced specialised workers in the fields of high technology, research and services, despite the growing share in the international recruitment of young professionals. It is important to highlight that, thanks to the general stability of the German economy, firms operating in Bavaria can access financing at the lowest interest rates in Europe.

Context for strategy and rivalry

The development of the Bavarian aerospace context for strategy and rivalry has been widely fostered by BavAIRia e.V., which was established as IFC in 2006. Since then, the association has endeavoured to promote collaboration among the companies, and between the industry, universities, research institutes and the government, with outstanding results to date: the links established allow for the joint development of the cluster strategy. The association has been constantly engaged in connecting the cluster's stakeholders, as well as representing and promoting the latter around the world to strengthen its international image and competitiveness. The networks built by the e.V. are aimed at enhancing the innovation process of the cluster as a whole, and include the final users as well: in this regard we can mention the GNSS User Fora organised by BavAIRia since 2004. The cluster's excellence is mirrored by the high degree of involvement in the most important European space projects, namely Copernicus and Galileo: the high degree of involvement encourages the inception of innovative firms, provides sound regulatory standards to aerospace products and services, and enhances the competition and cooperation among the single firms constituting the cluster and between the latter and non-member companies. In addition, the cluster is the first ambassador of ESA's Integrated Applications Promotion (IAP). The context for rivalry benefits from the cluster's unique feature of having expertise in every segment of the supply chain: the 550+ members of the cluster include many Prime, Integrator and Tier 1 firms (e.g. Airbus, EADS Defence & Security, Liebherr, Astrium, Cassidian, MTU Aero Engines, Diehl Aerospace) as well as a wide network of SMEs and small innovative suppliers. The presence of a relatively large number of anchor firms has attracted a number of different suppliers, thus creating an optimal environment for intra-cluster competition. The Bavarian Ministry of Economic Affairs and the agency Invest in Bavaria have developed the Bavarian Strategy 2030⁵⁶, a long-term plan for the development of the industry, which also includes a focus on the space sector. The national and federal Governments play an active role in this strategy through the public funding of aerospace R&D.

Related and supporting industries

The significant extension of the supply chain embraces a wide variety of supporting industries and innovative start-ups, and the innovation potential of the system is scaled up by the strong interconnections with academia (universities, technical schools and research centres). Furthermore, the aviation sector has a prominent role in the region and it fuels the whole aerospace industry, and the cluster has established international cooperation agreements with the following clusters: Abu Dhabi, Bangalore, Quebec, Russia and Shanghai. The BavAIRia e.V. acknowledges the high concentration of firms belonging to sectors that offer appealing opportunities through the application

⁵⁶ http://www.invest-in-bavaria.com/fileadmin/media/documents/publications/Sectors/Aeronautics-Strategy_Luftfahrtstrategie_2015_EN_www.pdf

of space technologies, therefore it is carrying out a system-wide strategy which includes creating solid relationships between aerospace and other sectors.

Demand conditions

As already evidenced for the Aerospace Valley, the local aerospace sector faces tailwinds resulting from the increasing world demand, and the huge potential for innovation deeply rooted in BavAIRia appears to be appropriate to satisfy the increasing demand for technological innovations. The aforementioned involvement in the European aerospace activity ensures a stable demand from the Community. From a regional and national perspective, Bavaria is part of a large, diversified and competitive market, although it must be pointed out that this does not entirely translate into domestic demand. On the other hand, a significant contribution comes from the aviation industry, in particular from the related logistics sector. In contrast, the growth in terms of domestic demand is hampered by the decline in military expenditures: according to OECD data, since 2012 these have constantly decreased from 1.31% to 1.17% of the GDP, as a result of the austerity policies carried out by the national Ministry of Defence. Finally, similarly to other clusters, the BavAIRia foreign demand might be significantly absorbed by the new players in the international competitive arena.

2.2.2 The Luft- und Raumfahrt Baden-Württemberg (LR-BW) cluster

The region of Baden-Württemberg constitutes, along with Bavaria, the core of the German space industry: its tradition dates back to the beginning of the 20th century (when it became the home of the *Zeppelin*), its development went hand in hand with the national aerospace sector and in recent years it has experienced a significant growth thanks to the historical abundance of highly qualified human capital (although the trend has diverged in recent times). The critical driver for the development of the space sector in the region is indeed the presence of high-quality academic institutions (universities and research centres), whose main representative is the University of Stuttgart: the school has the largest Aerospace Faculty in Europe and state-of-the-art infrastructures, and it trains roughly 80% of the country's aerospace engineers⁵⁷.

By hosting 25% of the region's aerospace companies and 80% of the related academic institutions, the City of Stuttgart constitutes the centre of the *Luft- und Raumfahrt Baden-Württemberg Cluster*, which was officially founded in 2005 after a five-year promotion and prospection activity carried out by a specialised body of the Ministry of Economy established in compliance with the will of the aerospace companies operating in the area. The initial impetus coming from the private sector has been channelled by the government into the creation of the *Forum Aerospace Baden-Württemberg e. V.*, an association which serves as the cluster's IFC. By constituting the pivotal role of the triple helix, the association aims at advancing the local aerospace industry in the international competitive arena. The e.V draws its financing mainly through member fees and external services such as advocacy, marketing, contract management and market analysis, thus the cluster is self-sustainable and independent from the Government's financial support. The Forum's activities are classified into 8 areas of operations: working group of Defence and Security, working group Supply Chain, Fairs, Council of Aerospace Baden-Württemberg, Participation in national bodies, Participation in the Federation of German Aerospace Regional Forum, Participation in the European Aerospace Cluster Partnership, and Participation in NEREUS-Network of European Regions Active in Space. In addition, the IFC has shown great commitment in the promotion of STEM (Science, Technology, Engineering, Mathematics) capabilities in the area: one major example is the project initiated in 2010 named "From

⁵⁷ Source: Enviacon International, *German Aerospace Industry*, 2013

Baden-Württemberg into Space", which is addressed to young students and aims at nurturing and retaining local young talent.

The Forum advances multi-level cooperation: the Baden-Württemberg cluster exhibits strong local interconnections with clusters from other sectors (e.g. automotive) established in the area, and it endeavours to develop collaboration at the international level with other aerospace clusters. The high degree of local intra-cluster cooperation represents the unique feature that distinguishes LR-BW from other aerospace clusters in the world, as it allows for enhanced innovation and knowledge spillovers from a broader perspective. Furthermore, the cluster actively partakes in some European cooperation projects such as the *Future Aerospace Network* and the Interreg project TRANSETAERO.

Following a double orientation both towards the local territory and the international value chain, the cluster's activities encompass the following fields: satellites, avionics, sensors, actuators, mechanical components, and navigation systems. At present, the cluster consists of 80 members (taking into account the members from industry and academia) divided as follows: 43 SMEs, 26 large enterprises, 8 academic institutions (universities and research institutions), and 3 organisations⁵⁸. Among the companies we find some world-class anchor firms, such as Diehl Aerospace, Airbus, Thales Alenia and Astrium, which have attracted a number of specialised suppliers and are expected to continue in this direction in the future. The industry players that constitute the cluster employ some 15,000 people, and the cluster exhibits an annual turnover that exceeds €4.5 billion.

Since the early years of its formal establishment as an association, the cluster has devoted significant attention towards space – in particular in satellite communications – by putting relevant effort in the development of an industrial niche which could proactively generate significant innovations in these fields. In order to achieve this objective, in 2008, 11 SMEs, 2 corporations, 4 academic institutions and 8 organisations have come together, on the initiative of Tesat-Spacecom GmbH, Backnang Town and the Stuttgart Region Economic Development Corporation, to establish the *DESK – German Centre for Satellite Communications*. This association can be considered as a "sub-cluster" within the broader framework of LR-BW with the purpose of pioneering a specific niche of the space industry in order to transform the area into a global pole of excellence in this field.

Cluster analysis

Coherently with the general framework utilised so far, the scheme in the picture below provides an in-depth illustration of the cluster's characteristics, classified into the four thematic areas referring to the factor conditions, the network of related and supporting industries, the general context for strategy and rivalry, and the demand conditions that the cluster has to face.

⁵⁸ Source: <http://www.clusterportal-bw.de/en/cluster-data/cluster-database/clusterdb/Clusterinitiative/show/clusterinitiative/forum-luft-und-raumfahrt-baden-wuerttemberg-ev/>

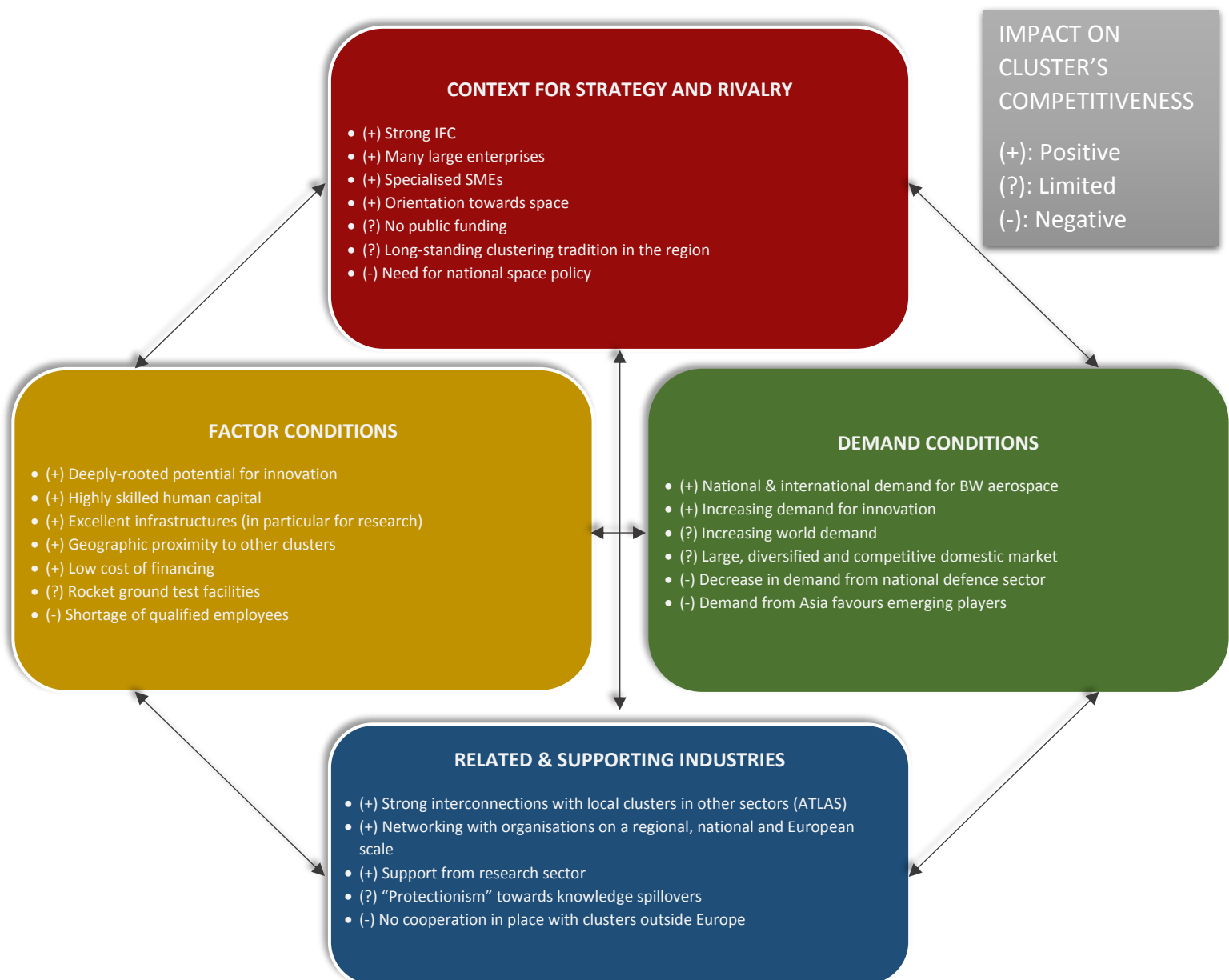


Figure 9: Porter's Diamond Analysis of the Luft- und Raumfahrt Baden-Württemberg Aerospace cluster. Source: author.

Factor Conditions

The factor conditions of the Luft- und Raumfahrt Baden-Württemberg (LR-BW) cluster show some particularly favourable features with respect to the development of the local aerospace industry. Firstly, the region is characterised by an outstanding inclination towards innovation that dates back to the 19th century, when Baden-Württemberg became the birthplace of the automotive sector: here Carl Benz patented the first motorised vehicle in 1886. The system has since placed significant effort in pursuing innovation, and as of today the region is the top European investor in terms of R&D as a percentage of GDP (4.8%), as well as representing the top German region for inventiveness, with 138 deposited patents per 100,000 residents⁵⁹. A 2014 aggregated measure of innovativeness that combines indicators such as R&D investment, patents and high-skilled labour force has classified

⁵⁹ Source: Baden-Württemberg Study Guide. <http://www.bw-studyguide.de/en/research/inventive-genius.html>

Baden-Württemberg as the most innovative EU region, way ahead of world-class champions such as Bavaria and Île de France⁶⁰. This environment is fostered by a state-of-the-art aerospace infrastructure (both in terms of operative and research facilities) with a limited number of comparable cases worldwide: the town of Lampoldhausen, for instance, hosts one of the few non-US-based rocket ground test facilities (the others are located in Woomera-South Australia, Mahendragiri-India, Zagorsk-Russia, and Refshaleøen-Denmark, while the two based in the UK are no longer active). The cluster benefits from its proximity to other important aerospace poles such as Bavaria, Toulouse and Lombardy, and from the easy and inexpensive access to capital that characterises the whole German economy.

Although the region – and the city of Stuttgart in particular – is home of some schools of excellence in the field of aerospace engineering, the leading association has highlighted that the cluster's development is heavily constrained by the shortage of highly skilled workers. In order to tackle this issue LR-BW has founded the *German Aerospace Academy* (ASA) as well as promoting the study of STEM among primary education institutions.

Context for strategy and rivalry

The Luft- und Raumfahrt Baden-Württemberg cluster is steered by a strong, proactive and efficient IFC – *the Forum Aerospace Baden-Württemberg e. V.* – which serves as a fundamental stakeholders network and promotion tool of the cluster through a broad spectrum of activities. The e.V. is not dependent on public contribution and draws its own funds from membership fees and from the provision of services such as marketing and consultancy. Its broad scope of action posits the forum at the crossroads between academia, government and industry. The significant relative presence of industrial players operating at the high levels of the value chain (EADS, Liebherr Aerospace, Airbus, Thales just to name a few) compared to the absolute dimensions of the cluster (33% of the total members): this dense concentration of OEMs results in enhanced rivalry among Prime, Integrators and Tier 1 & 2 companies, which is beneficial from a double perspective of innovation and industry development. As a matter of fact, large corporations invest high volumes of their turnover in R&D, and attract a number of small and medium enterprises. The remarkable presence of OEMs has indeed generated a wide network of specialised suppliers in high-tech segments of the aerospace value chain. From a systemic perspective, the cluster has pursued a strong innovation-oriented strategy, constituting the main competitive advantage against those aerospace industries which leverage on a lower cost of labour. Coherently with the path traced, the LR-BW cluster is betting on the space sector, as it constitutes a major driver of innovation and knowledge: in this respect, the already mentioned DESK initiative intends to develop the satellite technology within the region.

It is important to highlight that the aerospace cluster initiative keeps to the Baden-Württemberg long-standing cluster tradition. Its success has thus been fostered by the presence of well-established business models, managerial *know-how*, infrastructure, networks and so on. The cluster is substantially independent from National Government funding. While this allows for full ownership of the system's strategy, quicker decision-making and greater risk propensity, it deprives the cluster of an important source of financing. In 2016 the urge for a joint national aerospace strategy that can coordinate the regional clusters has brought the political leaders of Baden-Württemberg, Bavaria and Bremen to call for financial support from the Central Government.

⁶⁰ Source: State Statistics Office Baden-Württemberg (2014), cited in Baden-Württemberg International, Agency for International Economic and Scientific Cooperation, *Baden-Württemberg – Germany's attractive location for investment*, 2015

Related and supporting industries

The Luft- und Raumfahrt Baden-Württemberg cluster benefits from a unique business environment: the aforementioned long-standing cluster tradition in Baden-Württemberg encourages communication channels with clusters operating in other sectors. The inter-cluster cooperation is a way to improve and diversify knowledge flows among industries and to proactively create new opportunities for the application of space-based innovation. The Future Aerospace Network has been set up to connect aerospace with traditional industries and exploit possible synergies. Whilst great effort has been placed by the IFC to achieve this, further credit must be given to the Ministry of Economy and Finances of Baden-Württemberg, which has mapped the Regional Cluster Atlas of Baden-Württemberg in 2012, in an effort to scale up inter-cluster cooperation at the regional level. Furthermore, the Forum has established a multi-level network, which has bridged the cluster with organisations at the regional (AFBW - Alliance for fiber-based materials, Mechatronics Competence Network Baden-Württemberg, Microsystems Technology Baden-Württemberg e. V., Baden-Württemberg International), national (Federal Association of the German aerospace industry e. V., BavAIRia e. V., Berlin-Brandenburg Aerospace Alliance e. V.) and European level (EACP - European Aerospace Cluster Partnership, NEREUS - Network of European Regions active in Space). Furthermore, the LR-BW cluster has benefitted from the outstanding support of the (public and private) research sector: among the research institutions we can mention the University of Stuttgart, the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, the Steinbeis Foundation, the Institute of Textile and Technology Denkendorf. In addition, the German Aerospace Centre (DLR) has established a research centre in Stuttgart, which employs more than 700 researchers operating in the fields of high-performance fiber-ceramic, polymeric and hybrid composites, vehicle concepts, laser systems, energy technologies and propulsion systems. The presence of a DLR facility points out how the space sector is regarded as strategic for the national economy.

The regional potential for innovation has been a key driver in the local socioeconomic development as it represents a paramount source of competitive advantage in the international arena. This evidence has led the cluster members to adopt what could be considered a “protectionist” strategy for innovation: indeed, the scope of action of the international partnerships does not go beyond the EU boundaries. This strategy, while guaranteeing the exclusive over internally developed innovation in the past, is becoming more and more unfeasible and inappropriate to the international dimension of knowledge spillovers and of the aerospace value chain. The need to divert this trend has been acknowledged and there is evident will to advance international collaboration in research and development, but so far no major detailed measures have been fully undertaken in this direction.

Demand conditions

Thanks to its competitive advantage in the field of innovation and high value added operations, the Luft- und Raumfahrt Baden-Württemberg cluster is undoubtedly going to benefit from the increasing demand for cutting-edge technologies which has been driving the aerospace sector in recent times, provided that – as stated earlier – the cluster undertakes a broader and deeper strategy of international collaboration with global key partners. For this reason, the the Ministry of Economic Affairs of Baden-Württemberg and the BW Fairs association have jointly established the Agency for International Economic and Scientific Cooperation *Baden-Württemberg International*. A higher degree of openness towards international collaboration might provide the key to better exploit the opportunities offered by the increase in global demand.

Despite the aforementioned national military strategy which decreased the budget allocated to national defence, as claimed by Baden-Württemberg International the regional aerospace sector benefits from a significant domestic and international demand, and experiences global diffusion

thanks to a general orientation towards exports of the region: according to the European Commission, the 2014 BW's export volume amounted to € 181 billion (16.1% of German exports) This commercial attitude towards international markets will be crucial in tackling the "cannibalisation" of the global demand by the emerging players from Asia.

2.3 India

When the world's superpowers started to develop their national aerospace industries, India was a British colony and it remained as such until 1947, when it proclaimed its independence from the Crown. In the following decades, covering the space gap with more developed countries became one of the priorities of the Indian government: the year 1961 represented the first milestone towards this direction, with the establishment of a national space program and the foundation of the committee that would later become the Indian Space Research Organisation (ISRO) in 1969. Three years later the ISRO became part of a broader aerospace strategy that was entirely steered by the national *Department of Space* (DoS). Starting from that moment, the Indian aerospace industry underwent an incessant growth through continuous evolution, and the country is now among the key global players in the sector, as well as a primary commercial partner for the world's leading countries. Throughout the years, India went from being the primary outsourcing destination of the low-end segments of the value chain due to its incomparable advantage in terms of labour cost, to becoming a world-class pole of innovation through the inner growth of knowledge and capabilities. At the time of its foundation, the national space agency had no infrastructures or capabilities whatsoever, nonetheless it successfully designed, manufactured and launched its first satellite *Aryabhata* in 1975, 14 years after the establishment of the national space program. Notwithstanding its inherently dynamic nature, the rapid development process that involved the Indian aerospace industry revolved around three steady pillars:

- I. **Active role of the Indian Government:** historically, momentous support to the Indian aerospace sector was provided by the Indian government. The already mentioned ISRO is the only space agency to internally develop, design and assemble its own vectors through large public procurement procedures which brought about the establishment of countless SMEs in the sector. Furthermore, in 1992 the space agency established its own commercial branch, Antrix Corporation, with the purpose of selling space-derived innovations (technologies and services) in international markets. In addition, in 1959 the Council of Scientific and Industrial Research of India established the National Aerospace Laboratories (NAL), the only public R&D institution in both the aeronautical and astronautical field. The Laboratories are equipped with state-of-the-art facilities and, as of 1993, the institution has its own commercial division. The Government has a strong presence in the manufacturing segment as well, with the defence state-owned company Hindustan Aeronautics Limited (HAL) which is now a major player in the global aerospace manufacturing. Furthermore, public intervention has always aimed to steer the economic activity towards the development of the space sector in particular.
- II. **Large use of Offset Agreements:** following a common practice in the aerospace industry, India has made wide use of Offset Agreements with the purpose of strengthening linkages between buyers and suppliers. This custom has resulted in deep commercial networks (both at a national and international level) which brought about large accumulation of knowledge and expertise, and eventually led to the development of the sector.
- III. **Competitive advantage in labour cost:** India has traditionally been known for its ability to provide low-cost labour force, being this its primary source of competitive advantage. In the process of economic growth the country has been able to extend this feature even to skilled labour: wage rates are about 60% lower than developed countries and the industry is structured as labour-intensive⁶¹. This feature contributes to preserving the competitive

⁶¹ A.T. Kearney Inc., *India Aerospace: Poised for Takeoff*, 2009

advantage, as well as leveraging the marginal contributions to productivity deriving from innovation of physical capital.

In recent times the Indian Aerospace Industry has undergone dramatic development, exhibiting 9% Compound Annual Growth Rates in the years 2013-2014⁶² as a result of increased military expenditure and increased global demand, thus exceeding the analysts' forecasts which predicted a 4/5% growth rate in the years following the 2008 economic crisis. India has been successful in doing so by serving a large share of the global demand for aircrafts and related services, as well as through the domestic development of a space program which was specifically tailored to exploit the opportunities offered by civil and commercial application of space-related innovations in the field of satellite navigation, telecommunications, health, and so on. Today, the paramount role of India in the global space sector is pointed out by the fact that it is one of the few countries outside the US to host a rocket ground test facility, in Mahendragiri

The Indian industry is pushed by both the booming demand for space-related services and a highly supportive policy environment: recent trends involve a leading position in the field of Low Earth Orbit (LEO) satellites, while the country is expected to face stronger competition as for reusable vectors (rockets)⁶³. The industry mainly consists of Tier 3 companies, which flourished as a result of the outsourcing process undertaken by the world's leading aerospace companies, and it exhibits some interesting features in terms of software-hardware integration thanks to the unique *know-how* of the country. In addition, the national sector has attracted in the last decade global leaders such as Airbus, EADS and Boeing.

The ISRO has always played a paramount role in the national space industry, acting as a public anchor firm for the hundreds of SMEs in the supply chain. For this reason, the Department of Space has traditionally benefitted from significant public funds: according to ISRO data, the estimated 2015 space budget amounted to \$1,229.78 million, a 2.1% increase compared to 2015.

While the Indian aerospace industry is spread across the whole country, its core is constituted by the region of Karnataka and by its capital Bangalore. Known as the *Indian Silicon Valley* due to its burgeoning high-technology sector, Bangalore has long been representing the vital centre of the Indian space sector, to the point that, since the inception of the Indian space program, it has



Figure 10: The centres of Indian Space Programme. Source: Sunil Mani, "The Flight from Defence to Civilian Space: Evolution of the Bangalore Aerospace Cluster", 2009

⁶² Source: invest Karnataka, <http://www.investkarnataka.co.in/focus-sector-aerospace>

⁶³ Narayan Prasad, *Industry participation in India's space programme: Current trends & perspectives for the future*, 2016

been hosting the headquarters and the facilities of the main institutions (ISRO), companies (HAL) and research centres. As shown in figure 10, Bangalore is the Indian city with the highest presence of institutions related to the Indian space programme: as a consequence of the public procurement procedures undertaken by these government, an increasing number of companies concentrated throughout the years in the area, thus becoming the main aerospace cluster of India. As evidence of the importance of the area in the international competitive arena, since 2012 the city has been home of the Bengaluru Space Expo, the world-class International Exhibition and Conference on Space Technologies, Equipment and Products. As evidence thereof, a report by the Centre of Development Studies has shown how Bangalore includes almost the entirety of the Indian aerospace Sectoral System of Innovation⁶⁴.

The next chapter will provide a deeper picture of the aerospace cluster located in the city of Bangalore and in the region of Karnataka.

2.3.1 The Bangalore Aerospace Cluster

Bangalore is the epicentre of the Indian aerospace economy, with an outstanding focus on the space sector. Keeping to the tradition of the industry, the city is home of one of the world's main aerospace clusters: its origin does not date back to a specific moment as there is no formal constitution of the cluster in the form of association, but its development went hand in hand with the implementation of the aforementioned national space program. Initially conceived as a manufacturing industrial district, during the last 50 years the cluster has evolved from one of the main outsourcing destinations for low-end aerospace activities (thus fostering the establishment of *Tier 3* companies) to a world-class innovation pole capable of attracting global corporate leaders such as Airbus and Boeing. Nowadays the cluster is responsible for the absolute majority of the national aerospace economy: its export share accounts for 65% of the total. The fundamental driver of this evolutionary process was the growth of R&D institutions, both public and private, in the area, which have been progressively awarded an increasing number of international contracts, thus attracting a growing bulk of knowledge which integrated the capabilities developed internally through the academic development of the area. The twofold competitive advantage in terms of both labour cost and innovation has created a virtuous circle which has brought the cluster among the world leaders in the aerospace industry, and in particular in the space sector which constitutes the predominant activity of the local system.

The outstanding economic development generated by the cluster has led the industry to go beyond the city borders and to create economic spillovers over the whole territory, thus creating a regional space economy with strong linkages with related and supporting industries. As at 2013, the aerospace sector in Karnataka accounted for 28% of the regional GDP⁶⁵. The state exhibited a GDP per capita growth rate of 16.04% in the same year⁶⁶. The state's percentage of people living below the poverty line was 20.91%, versus a national value of 21.92%⁶⁷. The urban unemployment was 27% and the rural was 5%, versus a national average of respectively 34% and 16%⁶⁸. Clearly the aerospace sector can be held accountable for the socioeconomic development of the region, and credit must be mainly given to the fact that manufacturing strongly relies on labour, thus increasing the households' disposable income. Further contribution derives from the strong interconnections with related and supporting

⁶⁴ Sunil Mani, *The flight from defence to civilian space: Evolution of the Bangalore Aerospace Cluster*, 2010

⁶⁵ Source: Government of Karnataka

⁶⁶ <http://statisticstimes.com/economy/gdp-capita-growth-of-indian-states.php>

⁶⁷ Source: Government of India. 2013

⁶⁸ Source: *Economic Survey 2012-13*, Government of India. 2012–2013

industries in the region, firstly the IT sector. The paramount role played by the aerospace sector - primarily in the city of Bangalore and secondly in the whole Karnataka - has led the state Government to develop a specific aerospace policy for the decade 2013-2023, with a strong focus on a cluster approach. The strategy includes incentives to FDI in R&D, tax incentives and Special Economic Zones to foster trade.

Since 2001 the Bangalore aerospace cluster has experienced a significant growth in the nature and number of its players, with an increase in foreign demand and in the number of foreign companies. Nonetheless, the core is still constituted by the four public (and publicly-owned) players HAL, NAL, ISRO (along with its commercial branch Antrix) and the Indian Institute of Science. Furthermore, the academic and governmental spheres of the triple helix saw an increasing participation of foreign players. Following a framework proposed by Prof. S. Mani⁶⁹, we can classify the cluster's main players according to their nature. Among the R&D institutions we can find the National Aerospace Laboratory (NAL), the Indian Space Research Organisations (ISRO) and its commercial branch Antrix. The domestic manufacturing firms are comprised of, among others, the Hindustan Aeronautics Limited (HAL), the Taneja Aerospace and Aviation Limited, and Dynamatic Aerospace, while the foreign companies include EADS/Airbus (with its Airbus Engineering Centre India, AEI), Bell and Boeing. The deeply-rooted IT skills in the region have fertilised the aerospace cluster, resulting into enhanced integration between these two sectors: among the software firms partaking the cluster we can mention Infosys, WIPRO and QuEST. In addition, the regional industry has undergone a significant diversification phase, in which a number of companies, mainly operating in the automotive sector, have entered the aerospace value chain as manufacturers and suppliers of components for global OEM and Tier 1 companies. Firms such as Tata Motors were able to leverage their expertise in providing high-quality parts at a low price, while at the same time guaranteeing high quality standards in materials and engineering. Finally, the cluster is well internationalised, with a number of commercial agreements in place with global OEMs.

Cluster analysis

Coherently with the framework utilised so far, the following section provides an in-depth analysis of the cluster's features following the breakdown template provided by the Porter's Diamond model. The specific case for the Bangalore Aerospace Cluster is shown in figure 11.

⁶⁹ Sunil Mani, *The Flight from Defence to Civilian Space: Evolution of the Bangalore Aerospace Cluster*, 2010

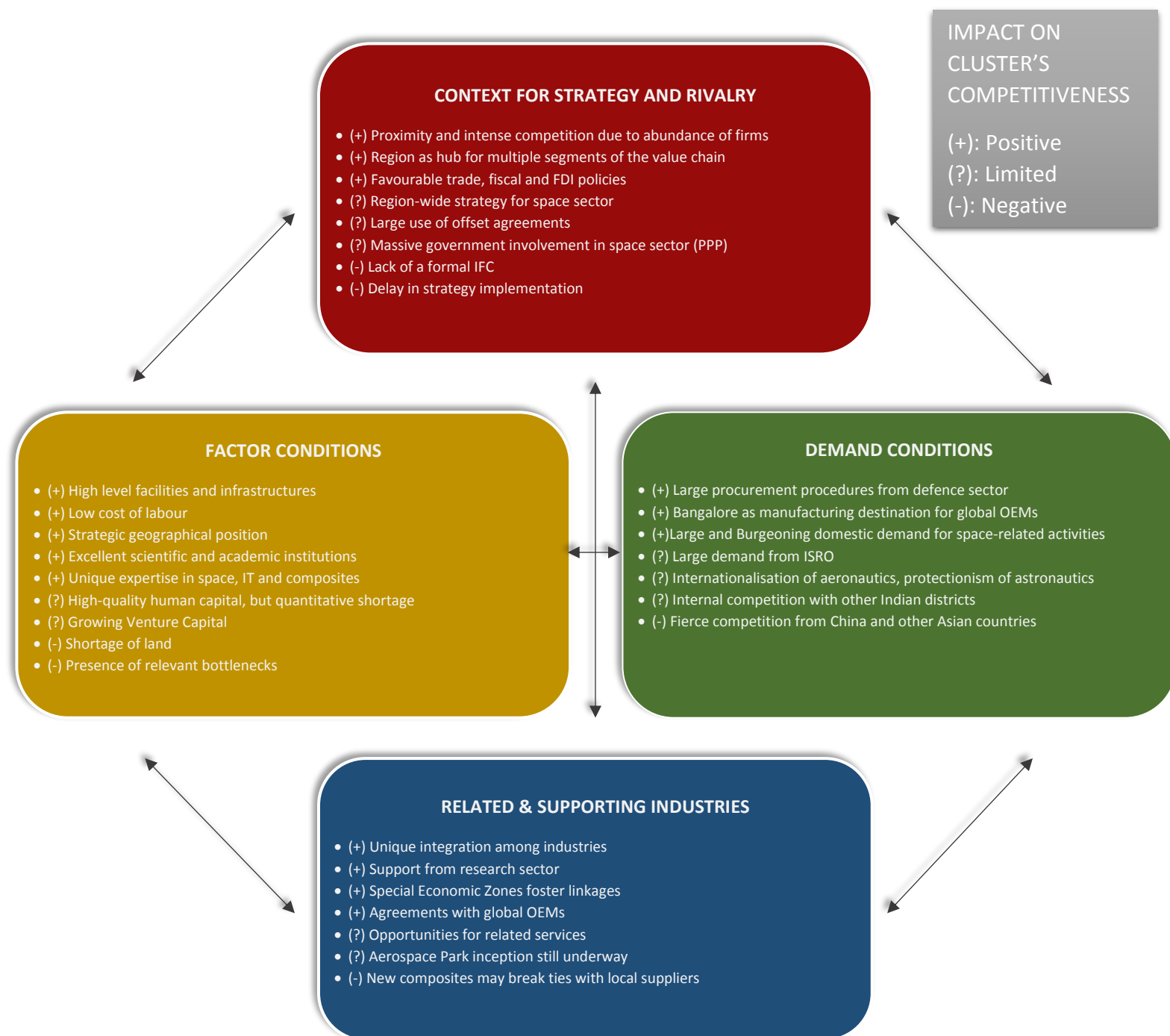


Figure 11: Porter's Diamond Analysis of the Bangalore Aerospace Cluster. Source: author.

Factor Conditions

The key competitive advantage of the Bangalore aerospace cluster, and the main driver of its development, is constituted by the large availability of low-cost labour force. This copious pool of human capital is capable of delivering high quality products and services at conditions unattainable by the traditional players. The productivity of India's huge workforce is leveraged by world-class high-end infrastructures and facilities, such as the Bangalore Airport, the HAL Airport and the Mahendragiri rocket ground test facility, besides a number of research facilities (e.g. the *Nilakantan National Trisomic Aerodynamic Facility* – NTAF – or the Composite Structures Laboratory) owned by the

National Aerospace Laboratories (NAL). In addition, the cluster is located at the crossroads of the old and new international aerospace markets (between Europe and the Asia-Pacific region), constituting a priority partner for powers such as India, Russia, EU and Japan. Thanks to the knowledge spillovers deriving from decades of outsourcing, the region of Karnataka and the city of Bangalore in particular have developed cutting-edge expertise in the space sector, as well as in the fields of Information Technology and Composite Materials. The area exhibits a growing and unequalled ability to attract venture capital, thanks to favourable public policies towards this direction. On the other hand, the aforementioned human capital appears to be quantitatively insufficient to satisfy the booming international demand for manufacturing services: notwithstanding the presence in the area of academic institutions of excellence such as the Indian Institute of Science and the Indian Institute of Management, the cluster is still to address its relative shortage of highly skilled labour force, and companies usually have to resort to internal training programmes⁷⁰. Furthermore, the companies operating in the cluster have to deal with a chronic shortage of land due to the physical congestion of the area: such congestion negatively affects the infrastructural efficiency and creates some worrying bottlenecks in the logistics of the supply chain that heavily burden the economic activity. For this reason, the government strategy aims at a broader distribution of the aerospace industry over the Karnataka region, reducing the concentration over the Bangalore district. To address the issue of land shortage, the government of India abolished the old *Land Acquisition Act*, introducing the *Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act* in 2013.

Context for strategy and rivalry

The cluster shows an outstanding degree of rivalry due to the high number and concentration of firms at every stage of the value chain: according to a PwC report⁷¹, the cluster comprises more than 50 large companies surrounded by an ecosystem of some 2000 SMEs. Their proximity and their large numbers enhance competition within the cluster, enhancing its potential for innovation. From a broader perspective, the area constitutes a hub for a wide range of sectors, such as raw materials, automotive, IT, services, and biotechnologies. More aerospace-related hubs involve manufacturing, MRO, design and engineering, and R&D. The government has established a favourable environment for strategy and rivalry through a mix of fiscal, FDI and trade policies. For instance, the latter include the inception of aerospace Special Economic Zones to foster intra-region trade in Belgaum, Bangalore, Devanahalli, Chitradurga, and other. Newly-established companies of every size benefit from tax exemptions on electricity tax and other benefits such as reimbursement of CTS and interest-free loans on VAT. Furthermore, the government allows 100% FDI on manufacturing and R&D in the civil aerospace sector, while the threshold is lowered to 26% in the case of military activity in order to safeguard national security from international inference. FDI is coordinated by the agency *Karnataka Udyog Mitra* (KUM) which acts as the sole broker for investments. All these policies are part of a broader region-wide development strategy⁷² which was adopted in 2013 by the Department of Industries and Commerce and it is currently underway. Some vital aspects of this plan are experiencing heavy delays: for instance, the creation of a *Bangalore Aerospace Park* has been widely promoted in the past five years, but as of today the project is far from being completed.

Throughout the years the local space industry has made large use of offset agreements with the purpose of establishing long-term commercial relationships among firms both inside and outside the region. While this approach has proven effective in its purpose, it has indeed brought about

⁷⁰ Source: <http://readnow.isentia.com/Temp/102143/639800389.pdf>

⁷¹ Pricewaterhouse Coopers, *Karnataka- Aerospace Hub of India*, 2010

⁷² Department of Industries and Commerce, *Karnataka Aerospace Policy 2012-2023*. For further information, please refer to http://gubbilabs.in/demo/investkarnataka/sites/default/files/Aerospace%20Policy_Final.pdf

protectionism and heavy distortions in the competition between firms. Furthermore, competition has been constrained by the aforementioned wide public involvement in the aerospace sector through the massive use of Public-Private Partnerships in the provision of infrastructural endowments, although this tool has favoured the blossom of numerous aerospace-related SMEs. The public involvement has been conceived as a substitute of IFCs, thus depriving the cluster of a vital tool for its development.

Related and supporting industries

The Bangalore Aerospace Cluster is unique in its kind, as it exhibits an outstanding degree of integration with the other industrial hubs of the area in particular with the IT industry: space-derived innovations are used in a wide set of applications (entertainment, environmental control, etc.) and the space sector itself benefits from the cross-fertilisation with sectors, above all IT. As a side effect, leading players in other sectors (e.g. automotive) have undergone a deep process of diversification which has led them to operate within the supply chain as manufacturers of subcomponents. Fostered by proximity and concentration, the degree of integration is so high and deeply-rooted in the local economy that, besides the lack of data, it is nearly impossible to quantify for instance the indirect and induced effects of the aerospace sector over employment. Further impulse derives from the massive support provided by the research sector, once mainly comprised of public entities (ISRO, NAL) and now increasingly driven by large(foreign) private companies (such as Airbus). The aforementioned Special Economic Zones strengthen linkages between aerospace and its related and supporting industries, but the full inception of the Bangalore Aerospace Park might constitute an additional facilitating factor for them. There are some relevant international partnerships with world-class OEMs already in place, with key players such as Boeing, EADS, Lockheed, Rolls-Royce and Honeywell, but the protectionism towards national space sector has prevented any relevant inter-cluster partnership in the international aerospace sector. The cluster has always exhibited strong interconnections with the local suppliers of raw materials, but the recent advent of new composite materials – a field in which Bangalore is striving to acquire a leadership position – may break these ties, consequently having negative effects over supporting industries.

Demand conditions

The local aerospace industry - and the space sector in particular – benefit from large Public Procurement Procedures: as already discussed, historically they originated from ISRO in its effort to build regional and national infrastructures, and the defence compartment has increasingly played a leading role in terms of procurement. This involvement has recently led India to have its own satellite-based navigation system, thus achieving independence from foreign infrastructures. This components adds to a large and booming domestic demand for space-related products and services. The reason India exhibits such a high domestic demand is mainly cultural: traditionally, Indian companies have always considered personal relationships an essential aspect of business, thus giving higher priority to this aspect over convenience. The size of the ISRO programmes directs domestic demand particularly towards the space sector. On the other hand, from an international perspective Bangalore continues to represent an elite destination for OEMs, with all the associated opportunities in terms of agreements and partnerships with international players. Traditionally the country, and thus the Bangalore and Karnataka cluster, has been seeking internationalisation in aeronautics, while carrying out highly protectionist policies as for astronautics in order to develop and retain innovation and knowledge in this sector⁷³: the FDI policy is aimed at achieving a higher degree of openness towards

⁷³ Sunil Mani, *The Flight from Defence to Civilian Space: Evolution of the Bangalore Aerospace Cluster*, 2010

the international space sector (by reducing public intervention in favour of private initiative), which will scale up the potential for innovation of the region.

The increasing world demand is likely to be partly absorbed by the Bangalore cluster but, in doing so, the latter has to overcome the twofold fierce competition stemming from internal and external rivals. At the national level, other districts in India are developing (aero)space capabilities at dramatic growth rates: among others we can mention the cities of Chennai, Delhi, Hyderabad and Nagpur. Perhaps the strongest source of competition both in aeronautics and astronautics is external and it is represented by the rising power of China and other Asian developing countries that can exhibit even lower cost of manpower and are at an advanced stage of their evolution process, being already a well-established destination for outsourcing in the international competitive arena.

2.4 Italy

Historically, Italy played a primary role in the history of the aerospace sector, with a long-standing tradition that dates back to the aftermath of the WWII. As a matter of fact, the rapid development of the Russian aerospace industry and the launch of the first artificial satellite *Sputnik 1* on the 4th of October 1957 had raised concern among the Allies about the military power of the Soviet Union. This led the western countries to cover the gap with Russia, thus giving to aerospace and space activity in particular new strategic, military and political connotations⁷⁴. Within this climate of fierce competition Italy has drawn momentous benefits in terms of development of its own national aerospace industry, being a critical outpost in the old continent for the US. As a consequence of the close cooperation with NASA, Italy was the third country, and the first in Europe, to design, manufacture and launch its own satellite *San Marco 1* on the 15th of December 1964. The new perspectives offered by the launch have led to the implementation of the *SIRIO* project in 1968, which brought about the successful launch of a TLC satellite in 1977. The vital importance of the aerospace sector for the country's socioeconomic growth was widely acknowledged by the successive national governments in the 1970s: the first national space plan (*Piano Spaziale Nazionale 1979-1983*, PSN) was approved in 1979 and led eventually to the foundation of the Italian Space Agency (*Agenzia Spaziale Italiana*, ASI) on the 30th of May, 1988.

Italy has been playing a paramount role in the European race to space: the country has been at the frontline of the foundation of the European Space Agency (officially established in Bruxelles on 15 April 1975), and as of today it is the third largest contributor with some €350 million (nearly US\$390 million, 13% of the total⁷⁵). The uninterrupted involvement of the country's aerospace industry in the European framework started in the '70s/'80s with the participation to the ESA/NASA *SpaceLab* programme, and as of today Italy provides vital contribution to the Galileo and Copernicus programmes along with the probes *Cassini*, *Planck* and *Gaia*, as well as key participation to the *Rosetta* mission by providing the probe's solar panels, the orbiter's scientific tools VIRTIS, GIADA, WAC and the *Philae* lander's SD2, besides skilled workforce to the project team. In recent times ASI and the Italian Ministry of Defence have commissioned to Thales Alenia Space the realisation of the Earth Observation System COSMO-SkyMed. In addition, the expertise built through the Vega programme has constituted a fundamental starting point for the development of the European launcher *Ariane 6*. As of today, Italy has – through ASI – international collaboration agreements in place with NASA, Roscosmos, the Chinese Space Agency (CNSA), the Japanese Space Agency (JAXA), the Canadian Space Agency (CSA) and the Israel Space Agency (ISA).

According to the Italian Trade Agency, in 2014 Italy's aerospace sector ranked 7th in the world and 4th in Europe (Italian Trade Agency, 2014), with some 60,000 employees⁷⁶. It generates revenues for €13 billion with a strong orientation towards exports (€7 billion in 2014). The Italian space sector employs 6,000 people⁷⁷ and constitutes more than 10% of total aerospace revenues, with 34.91% deriving from Government expenditures. The public demand is responsible for 68% of its revenue, compared to a European average of 54%⁷⁸.

⁷⁴ Michelangelo De Maria, Lucia Orlando, Filippo Pigliacelli, *Italy in Space*, 2003

⁷⁵ The Space Foundation, *The Space Report 2016 – The Authoritative Guide to Global Space Activity*, 2015

⁷⁶ T-Mag, Source: <http://www.t-mag.it/2014/06/18/lindustria-aerospaziale-in-italia/>

⁷⁷ The Space Foundation, *The Space Report 2016 – The Authoritative Guide to Global Space Activity*, 2015

⁷⁸ Annalisa Cristini, Giancarlo Graziola, *Misure e Rilevanza degli Spillovers delle Industrie ad Alta Tecnologia, con Particolare Attenzione all'Industria Spaziale: il Caso Italiano*, 2013, cited in: Gabriele Lania, *An International Comparison of Space History, Policy and Industrial Capability*, 2016

Space Revenues	Government Expenditures in Space	% Government Expenditures/Total Revenues	Global Government Expenditures
€1.6 billion	€ 0.558 billion	34.91%	24%

Table 3: Italian Public Expenditures in Space. Author's elaboration based on data from *The Space Foundation, The Space Report 2015 – The Authoritative Guide to Global Space Activity, 2014*

The development of the Italian space industry stemmed from the necessity to reorganise the productive capability inherited from WWII, but the actual shift from a scientific to an industrial approach occurred in the '70s thanks to the political action in coordinating the three triple helix forces. In addition, ASI served as a channel for the Italian companies to enter the international aerospace market. Nowadays the industry is among the world's excellences: it is characterised by a strong R&D intensity (nearly 15% of total turnover) and it is mainly organised in clusters. In fact, the national aerospace sector consists of 6 regional clusters in Piedmont, Lombardy, Tuscany, Lazio-Abruzzo, Campania, and Apulia, together with a "supercluster" at the national level, namely the *Cluster Tecnologico Nazionale Aerospazio (CTNA)*⁷⁹. Key members of the aerospace industrial fabric are world leading companies such as Thales Alenia, Leonardo-Finmeccanica, Piaggio Aerospace, ELV S.p.A., Agusta Westland, Avio, Selex ES and Telespazio: with a deep level of integration with the wide network of SMEs that is typical of the Italian economy.

Within this landscape the *Lombardia Aerospace Cluster* of Varese constitutes the national excellence in terms of productivity, and in 2015 it was awarded with the Bronze Label by the European Secretariat for Cluster Analysis (ESCA), making it one of the best industrial clusters in the European Union. In light of its outstanding features, the cluster is included in our analysis.

2.4.1 The Lombardia Aerospace Cluster

The Lombardia Aerospace Cluster is located in one of the four leading European regions (the others are Catalogne, Rhone Alpes and Baden-Württemberg) in terms of innovation and production: it generates 21.7% of Italian GDP⁸⁰. Formally established in 2014 as a recognised association constituted by the *Comitato Promotore del Distretto Aerospaziale Lombardo* (Lombardy Aerospace District Organising Committee) - which was founded in 2009 by 8 firms and by the *Unione Industriali della Provincia di Varese* (Varese Province Industry Association) - the *Lombardia Aerospace Cluster* is the latest stage of a dynamic 100-year-old industrial tradition in the aerospace sector.

The financing structure is extremely simple and it mirrors the private nature of the initiative: at present the available funds come from membership fees, but the cluster intends to diversify its sources by attracting donations, public funding at the regional, national and community level, venture capital and project funding. Currently it has 81 active members (74 industrial players, 6 among universities and research centres, and one professional organisation) as part of a broader network embracing nearly 180 SMEs, 25 Large Companies and some 40 public research institutes. According to 2016 data, the cluster employs 15,800 people and generates a total turnover of € 4.6 billion. Among the aforementioned large share of SMEs, roughly half of them employ less than 50 workers⁸¹. In the national landscape, the Lombardia Aerospace Cluster stands out for its pronounced international

⁷⁹ The Space Foundation, *The Space Report 2016 – The Authoritative Guide to Global Space Activity, 2015*

⁸⁰ *Annuario Statistico Regionale, 2015*

⁸¹ Source: Lombardia Aerospace Cluster census, http://www.aerospacelombardia.it/aerospace/cms2.nsf/fe_home_new?Readform

edge: among the Italian aerospace districts, LAC is the best performing in terms of foreign trade, with exports for € 1.9 billion (34% of the national aerospace export)⁸².

Throughout the years, and well before its official constitution as an association, the cluster has developed expertise in the following fields of the aerospace sector⁸³:

- I. **Trainer aircrafts, helicopters and vertical flight, satellites and scientific payloads:** the companies active in this subsector represent only the 6.5% of the total members of the cluster, on the other hand they employ 38.9% of the total workforce.
- II. **Avionics and system integration, systems and equipment, structures, tools and systems for production, testing and maintenance, special materials:** these companies constitute the largest share of members (38.5%) and 31.1% of the total workforce.
- III. **Mechanical components and subsystems:** the companies operating in this field are 28.4% of the total, employing 17.6% of regional aerospace labour force.
- IV. **Generic materials:** this subsector constitutes a minority share, both in terms of companies (1.8%) and employment (0.8%)
- V. **Services:** companies operating in space-related services are the 24.8% of the cluster's members, with 11.6% of total workforce.

The main industrial players operate in the first subsector. Among them we can mention Leonardo-Finmeccanica (through the former Agusta Westland and Alenia Aermacchi), Thales, Selex Galileo, Compagnia Generale per lo Spazio, Gemelli, and Spaziosystem. Large companies are responsible for the 66% of the cluster's aerospace employment. The cluster encompasses every layer of the production chain, from Prime contractors to Tier 4 SMEs.

With respect to Academia, the industries partaking in the Lombardia Aerospace Cluster are the *Politecnico di Milano*, the Pavia University, the *LIUC-Universita' Cattaneo* and the *Universita' degli Studi Milano-Bicocca*. In addition, the cluster benefits from the participation of research institutes such as National Institute of Astrophysics (INAF), the National Research Council (CNR-*Istituto Nazionale delle Ricerche*), the Joint Research Centre of the European Commission, as well as a number of other private institutes. In addition, the cluster has internally established the *Nucleo Tecnico Scientifico* (Technological Scientific Group, NTS) constituted by R&D experts from both universities and the private sector with the purpose of developing knowledge from a cluster-wide perspective. The Group is in charge of a national strategic plan for science (*Piano Tecnologico Scientifico*, PTS) and provides vital support to the technical committee of the CTNA. When compared to other clusters analysed so far, there is clear evidence of a somewhat marginal role of government; for instance, at the time of its constitution, public contributions from *Regione Lombardia* to the cluster's association amounted to €50,000.

The Lombardia Aerospace Cluster constitutes a driving force in the Italian and European landscape: it is part of the aforementioned NEREUS network and EACP, and is currently establishing informal contacts with other clusters both at the national and international level, in particular those operating in Germany (Baden-Württemberg, Hamburg). Such linkages are expected to grow as the cluster's innovativeness and presence in the international competitive arena gain momentum. The cluster can exhibit some outstanding participations in projects of global relevance: for instance, among the most important achievements we can mention the construction (carried out by Selex-ES and *Politecnico di Milano*) of the SD2 drill mounted on the *Philae* lander of the *Rosetta* mission. In addition, the

⁸² Source: Istituto Nazionale di Statistica (ISTAT), 2015

⁸³ [http://www.aerospacelombardia.it/aerospace/cms2.nsf/8586D9DF7CA96F58C1257FCE00312571/\\$FILE/Presenziazione%20Cluster_2016_v4.pdf](http://www.aerospacelombardia.it/aerospace/cms2.nsf/8586D9DF7CA96F58C1257FCE00312571/$FILE/Presenziazione%20Cluster_2016_v4.pdf)

Lombardia Aerospace Cluster plays an active role in international research projects such as DEDALO, VIRGILIO, OPTIMAL, CRYOPLANE, PLANK–ESA, and SMART FUEL ADSP FRIENDCOPTER.

Cluster analysis

This section illustrates the features of the four dimensions constituting the Porter's Diamond of the Lombardia Aerospace Cluster. The factors conditions, the context for strategy and rivalry, the related and supporting industries and the demand conditions will be analytically broken down, identifying the single elements of the four dimensions according to the intensity and direction of their impact over the general cluster's performance and potential for growth and innovation.

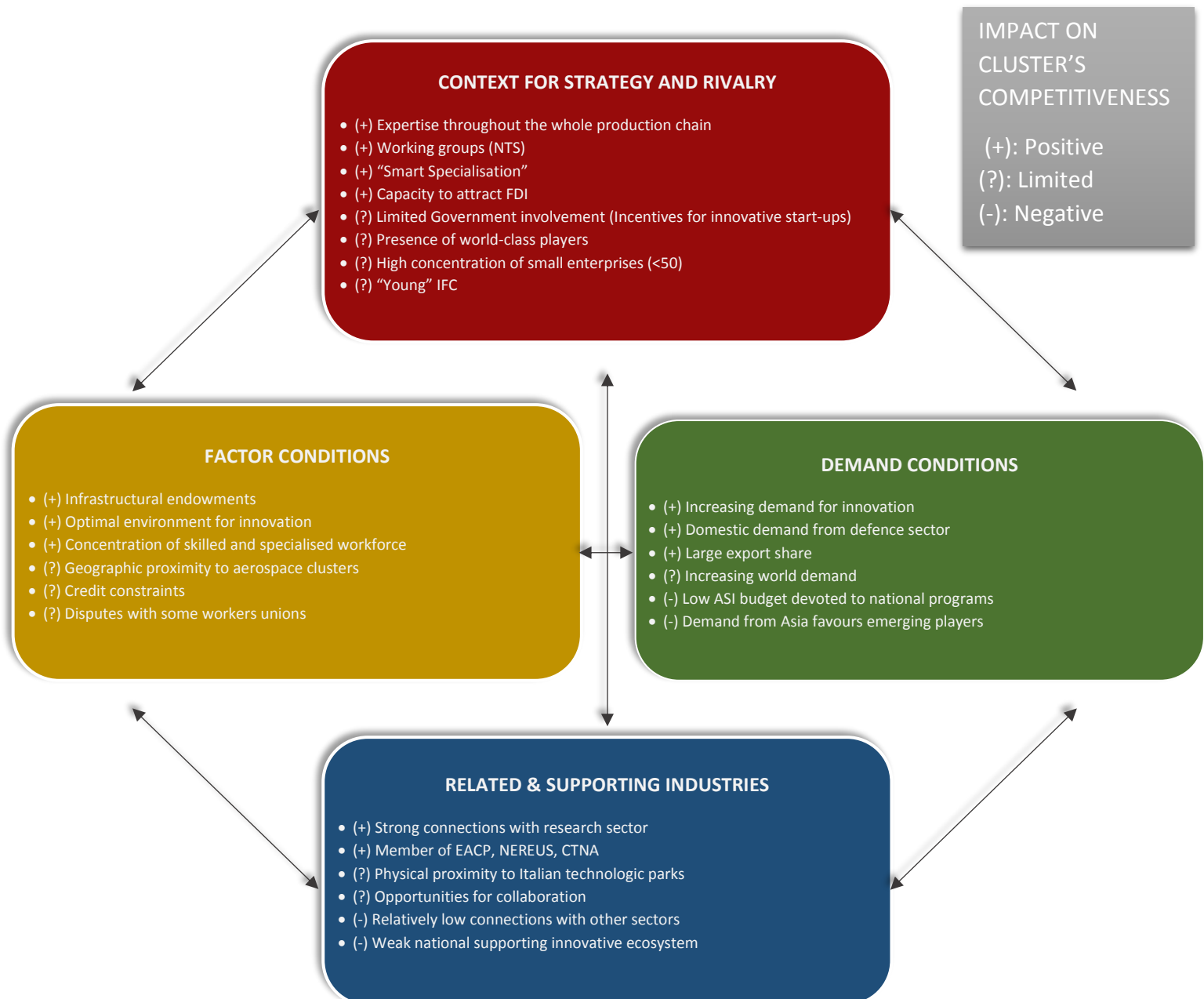


Figure 12: Porter's Diamond Analysis of the Lombardia Aerospace Cluster. Source: author.

Factor Conditions

Lombardy is the leading Italian region with respect to infrastructures: efficient and high-capacity roads, railways, airports (among others, the intercontinental Malpensa Airport, the first in Italy for cargo services) and waterways allow for easy, cheap and on-time transport, with huge benefits for *just-in-time* production processes. In addition, as anticipated the region ranks first in terms of innovation. The local workforce is highly educated (30% of new recruits are graduated in engineering and scientific subjects⁸⁴, more than 50% of the employees achieved a tertiary degree, and the vast majority is aged between 25 and 40) and increasingly nurtured by world-class universities based in Lombardy and in particular in the city of Milan: in the academic year 2015/2016 the *Politecnico di Milano* ranked 24th worldwide in Engineering and Technology, while the *Bocconi University* of Milan ranked 22nd worldwide in Management⁸⁵. In addition, a common practice among the cluster's industrial members is to set up specific in-company training programs to internally develop specific skills. Formal cooperation agreements will leverage the performances of the cluster, which is located close to other world-class aerospace clusters such as Aerospace Valley, BavAIRia and LR-BW.

Among the factor conditions a potential burden may derive from the difficulty Italian companies face in accessing sources of financing: the negative economic conjuncture has brought about stronger credit constraints and financing at less favourable conditions. On the other hand, the Italian economy has recently entered a recovery phase, and the above-average return on investment in the aerospace sector may loosen such constraints. A more significant source of concern is represented by the inner features of the Italian labour market and, in particular, by the strong influence of workers' unions: in June 2014 the failure to transfer funds related to the COSMO-SkyLab program has led to harsh contrasts between institutions and the Thales Alenia workers, which eventually resulted in a strike.

Context for strategy and rivalry

During its centennial activity in the aerospace sector the regional industrial system has gathered huge expertise in a wide number of segments of the value chain. As of today, despite a symptomatic degree of outsourcing which affected every long-standing aerospace industry in the developed countries, the *Lombardia Aerospace Cluster* has been able to preserve this feature, with some aircrafts (Agusta Westland) and satellites (Thales) entirely built within the district. On the other hand the cluster is developing a strategy of *Smart Specialisation* aimed at scaling up the system's competitiveness through the following actions ("4C Formula"): *Choices* (limited set of priorities), *Competitive Advantage*, *Critical Mass*, *Collaborative Leadership*. Strategy and rivalry are shaped around 5 Working Groups: Technical and Scientific Group (NTS), Marketing & Internationalisation Group (GLMI), Supply Chain Group (GLSC), Formation Group (GLF), Credit and Financing Group (GLCF).

The region shows a high capacity to attract Foreign Direct Investment: according to the agency *Invest in Lombardy*, in 2015 the Province of Milan attracted 30% of the total national FDI⁸⁶. Compared to other aerospace clusters analysed in this report, the *Lombardia Aerospace Cluster* exhibits a lower level of government involvement: public entities do not participate in the IFC and the main fostering action carried out by the national and local governments mainly consists of financial incentives to R&D and, above all, to the establishment of innovative start-ups (incubators are common practice in Lombardy). Furthermore, as for the case of the Toulouse aerospace cluster, the presence of world-class prime/integrator companies has been fundamental in attracting a wide array of supplying SMEs, but the limited number of the former hampers competition and rivalry at multiple levels of the value

⁸⁴ Cluster Tecnologico Nazionale Aerospazio, *Strategic Development Plan 2013-2017*, 2012

⁸⁵ Source: QS university rankings 2015/2016

⁸⁶ Source: <http://www.infodata.ilsole24ore.com/2015/10/12/capitali-esteri-in-italia-il-30-degli-investimenti-e-destinato-a-milano-e-provincia/>

chain. In addition, SMEs constitute 88% of the cluster's industrial players and about 50% of them employ less than 50 people: such companies invest less in R&D activities, thus limiting the potential for innovation of the cluster. In addition, the cluster's IFC is relatively young and thus its governance mechanisms are still to achieve full maturity.

Related and supporting industries

The Lombardia Aerospace Cluster exhibits a high level of interconnection with universities and research centres: active academic members of the cluster include the Politecnico di Milano, the National Institute of Astrophysics (INAF), the National Research Council, the Department of Physics of the University of Milan, the Joint Research Centre of the European Commission, along with a number of private research centres. The cluster has activated a Scientific Technical Group and Focus Groups to coordinate R&D activities. Since 2009 Lombardia Aerospace Cluster has launched R&D projects for a total value of about €30 million⁸⁷. Furthermore, the cluster is part of relevant partnerships in the aerospace industry - such as the NEREUS network, the Italian Cluster Tecnologico Nazionale Aerospazio (CTNA) and the European Aerospace Cluster Partnership – abiding by the international trends in the aerospace sector which bring about the creation of inter-cluster channels for knowledge transfer. Keeping to its tradition of national innovator, Lombardy is home to the two technological parks *Kilometro Rosso* and *Parco Tecnologico Padano*, and their physical proximity to the *Lombardia Aerospace Cluster* may offer interesting opportunities for cross-fertilisation and for the establishment of other, innovative connections with related industries. The cluster is currently developing informal contacts with other aerospace clusters outside of Italy, in particular with those located in Bavaria and Baden-Württemberg whose features have been widely discussed in the previous sections. Further momentum will derive from the establishment of more formal, institutionalised channels. On the other hand, compared to other clusters, *Lombardia Aerospace* suffers from a weaker network of interconnections with local supporting and related industries: the strong orientation to exports, while representing an overall positive feature, implies that internally developed innovation seldom results in nurturing related domestic industries. In addition, the overall national environment is not as supportive to innovation as in the case of France and Germany: The *European Innovation Scoreboard 2016* has classified Germany as the European *Innovation Leader* with a national score 21% higher than the European average, while France is defined as a *Strong Innovator* with an *Innovation Performance Index* 9% higher than the European average. Italy is instead a *Moderate Innovator* according to the *Scoreboard*, and its *Innovation Performance Index* is 17% lower than the European average⁸⁸.

Demand conditions

The increasing demand for innovation constitutes an outstanding opportunity for the Lombardia Aerospace Cluster: the cluster puts strong emphasis on the space sector, thus having a higher potential for innovation as evidenced by the high expenditure for R&D. In addition, the cluster benefits from a domestic demand which mainly consists of military expenditures: according to [globalsecurity.org](http://www.globalsecurity.org), the overall 2014 budget devoted to defence amounted to \$27.4 billion, with a 5.18% CAGR in the years 2010-2014⁸⁹. As anticipated, the cluster is significantly export-oriented: as of 2014 the cluster exported goods for €55.1 million to Singapore, €38.5 million to Algeria, €34.2 million to USA and €29.6 million to the UK. The constantly increasing world demand will reinforce this orientation, although with the usual *caveat*: the burgeoning Asian markets are growing thanks to the advent of new players from developing countries, and these are expected to acquire the lion's share of the global demand. Notwithstanding an adequate public expenditure in the aerospace sector, it is important to point out

⁸⁷ Cluster Tecnologico Nazionale Aerospazio, *Strategic Development Plan 2013-2017*, 2012

⁸⁸ Source: *European Innovation Scoreboard 2016*

⁸⁹ <http://www.globalsecurity.org/military/world/europe/it-budget.htm>

that the 2013 budget devoted to national space programs amounted to a mere 30% of the total (the remaining 70% consists of ESA contributions), with a majority share (€123 million, 50.2% of the budget) devoted to national programmes allocated for earth observation, and only €2 million invested in launcher programmes⁹⁰.

⁹⁰ The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

2.5 United Kingdom

The history of British aerospace can be traced back to the end of the XVIII century, when the “father of the aeroplane” Sir George Cayley first theorised in 1799 the concept of the modern aircraft as we know it, namely a flying machine with fixed wings and separate systems for lift-off and landing, control and propulsion based on the physics of flight. The path paved in the field of heavier-than-air aircrafts did not remain unfollowed, and the industrial revolution opened new scenarios: William Samuel Henson and John Stringfellow patented the first steam-propelled flying machine in 1842, and in 1866 the first aeronautical society, the Aeronautical Society of Great Britain, was founded. The institution, which was renamed Royal Aeronautical Society (RAeS) and became increasingly international throughout the years, is now a professional organisation devoted to defining and promoting high quality standards in the aerospace sector, disseminating specialised information and supervising the formulation of public and industrial policies concerning aerospace.

In the first half of the 20th century the growth of the British aerospace sector was primarily driven by aeronautics, through the massive public procurement operated by the British Air Ministry and the military division in order to provide the Royal Air Force with cutting-edge equipment. The greatest accomplishment is undoubtedly the development of the Supermarine Spitfire, the fighter aircraft used by the Allied countries which turned out to be crucial for the outcome of WWII. The victory allowed the UK to access the disruptive German rocket technology, thus making the country one of the pioneers in the space sector. The feverish research activity in the field resulted in the country being the third in the world (and the first in Europe) to indigenously design, manufacture and launch its own satellite, the Ariel 1, in 1962, following the footsteps of the US and USSR.

Due to some major hardships encountered in the inception of a domestic launch capability between the ‘50s and ‘60s, the UK adopted a more pragmatic approach to aerospace, shifting the focus of the national strategy on the downstream segment of the industry, putting aside the upstream segment which was regarded as politically eye-catching but economically unprofitable. Unlike other world powers, Britain implemented a number of aerospace policies aimed at supporting the growth of a space-related industry from a commercial perspective, thus “delegating” upstream activities such as the development of launch systems to international organisations, for instance the European Launch Development Organisation (ELDO). This bold and pragmatic strategy paid off within a short timeframe: although making the UK aerospace activities less spectacular and appealing, it allowed for the early development of unparalleled expertise in a wide array of fields such as aircrafts, propulsion systems (with companies such as Rolls-Royce and Reaction Engines, which is currently developing the cutting-edge SABRE rocket engine), communications, scientific applications and satellites. Activities in upstream fields such as satellite and spacecraft manufacturing have been carried out indirectly through ESA participation, and as of 2015 the UK was the 4th main contributor with £226.6 million. This contribution resulted in major UK involvement in the ESA telecommunication projects *NeoSat*, *AnySat* and *Inmarsat Communications Evolutions*⁹¹.

The UK public aerospace policy historically consisted of wise and targeted interventions aimed at providing crucial infrastructures and equipment, such as science platforms and payloads, which could stimulate and leverage the development of private companies and specific competences of excellence: the market-oriented space policy aims at funding upstream R&D in order to nurture downstream businesses⁹². This strategy has brought about the establishment of one of the largest

⁹¹ Royal Aeronautical Society, *UK Space Policy: A Hidden Success Story*, 2014

⁹² Ibid.

aerospace industries in Europe, but with a marginal focus on space segment due to its lower profitability. This paradigm has been continuously implemented until recent times: as a matter of fact, with a 2014 public budget of £291.5 million⁹³ and an aggregate **direct** turnover of some £4.8 billion⁹⁴, the UK space economy exhibits the highest public expenditure/total turnover ratio among the countries analysed so far, and it is worth highlighting that the funds devoted to the national space agency constituted a minority share (£75.3 million). An overview of this aspect is illustrated in the table below. By taking into account the indirect and induced economic effects, the British space economy exhibits a 7% compound annual growth rate and it is worth £11.6 billion, and the national government expects to increase this figure up to £ 40 billion by 2030 (as stated in the National Space Plan). The UK space economy constitutes the 38.7% of the whole British aerospace sector, which employs 110,600 people in total and whose turnover amounts to £29.2 billion. UK aerospace exhibits a heavy reliance on international markets: the total exports amount to £ 26.3 billion and account for the 91% of final demand⁹⁵.

Space Revenues	Government Expenditures in Space	% Government Expenditures/Total Revenues	Global Government Expenditures
£4.8 billion	£0.2915 billion	6.1%	24%

UK Public Expenditures in Space. Author's elaboration based on data from The Space Foundation, "The Space Report 2015 – The Authoritative Guide to Global Space Activity", 2014, and London Economics, "The Case for Space 2015 – The Impact of Space on the UK Economy", 2015. Note: only direct revenues taken into account.

Research and Development activities in the civil space sector are thus carried out through low levels of public investment, mostly under the aegis of the European Space Agency. In this regard, as of 2012 the British Government increased its **5-year** contributions to ESA for £1.2 billion, in exchange for enhanced involvement in European projects. This 25% increase in public spending has attracted foreign direct investment from major international companies such as Lockheed Martin Space Systems, Aerojet Rocketdyne and Thales Alenia Space. As a result the ESA established a new satellite technology centre in Harwell (Oxfordshire) which has immediately led to increased specialisation in this upstream segment. The development of the latter subsector has given a new vital impulse to British Aerospace and to the space segment in particular. On the other hand, the encouraging perspectives surrounding the British aerospace industry are currently facing the threat of the *Brexit* consequences, with the institutional and economic uncertainty undermining the future development of the sector. While the preservation of the ESA membership is not a matter of doubt, the tariffs on international trade make imports more expensive and exports less appealing. Furthermore, while on the one hand the depreciation of the Great Britain Pound is likely to mitigate the second effect on British exports, on the other it would reinforce the first. In addition, in the words of the ADS chief executive Paul Everitt, *"...it would become harder to win inward investment, competing with other nations would become more and more difficult. The combination of our flexible labour market and access to Europe makes us attractive to international investors"*⁹⁶.

⁹³ The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

⁹⁴ Source: London Economics, *The Case for Space 2015 – The Impact of Space on the UK Economy*, 2015 (Cited in: Gabriele Lania, *An International Comparison of Space History, Policy and Industrial Capability*, 2016)

⁹⁵ ADS Group Ltd., *UK Aerospace Outlook 2015*, 2015

⁹⁶ <http://www.telegraph.co.uk/finance/newsbysector/industry/defence/11666311/Brexit-would-harm-UKs-56bn-aerospace-and-defence-industry.html>

Britain is by far one of the major aerospace players in Europe and in the world: as evidence thereof it is worth mentioning the Farnborough International Airshow, a world-class aerospace exhibition that gathers all the main international investors and policymakers in the global aerospace sector. Given its long-standing tradition and its popularity worldwide, the event represents one of the key moments of the international aerospace agenda. Notwithstanding its relevance in the international landscape and the intentions of the Government stated in the National Space Plan, the British aerospace industry does not quite follow a cluster structure, with one major exception: the town of Harwell (Oxfordshire) is indeed home of one of the most advanced European aerospace clusters, the Harwell Campus. The cluster is home to some of the world's major aerospace companies and it exhibits a high degree of involvement in the ESA projects, thus focusing primarily over the space segment. For this reason, the Harwell Campus will be the subject of our analysis in the following paragraphs.

2.5.1 The “UK Space Gateway” of the Harwell Science & Innovation Campus

Developed through targeted public investment in the research sector, Harwell has long been representing one of the main innovation poles of the United Kingdom, being at the forefront in fields such as medicine, atomic energy and information technology since the first half of the 20th century. In particular, the beginning of its history as a scientific district coincides with the inception of the local aerospace industry in 1937, when the Royal Air Force Station Harwell was built in the area to host several RAF bomber squadrons during WWII. Since then, Harwell became home to a number of cutting-edge facilities in a wide array of fields: the Medical Research Council opened its laboratory in 1945 and a Radiobiology Unit in 1947, while in 1946 the Ministry of Supply had taken over the site and established the Atomic Energy Research Establishment. The prosperous scientific ecosystem led to momentous achievements such as the first nuclear reactor (commissioned in 1947) and the world's first transistorised computer (1953).

However it was the establishment of the Rutherford High Energy Laboratory in 1957 that laid the foundations for the future inception of an aerospace sector in the area, with a primary focus on the space segment. After merging with the Atlas Computer Laboratory and the Appleton Laboratory, the centre – renamed Rutherford Appleton Laboratory since then – built a number of world-class facilities that are available to companies to test their space systems. These scientific facilities include:

- The Diamond Light Source: a particle accelerator (similar to the CERN Large Hadron Collider) which is used to study innovative aerospace engineering solutions.
- The Central Laser Facility (CLF): a world-class laser laboratory able to recreate the environmental conditions in the core of stars.
- The ISIS pulsed neutron and muon source: a research centre which pioneers the field of innovative materials.
- RAL Space, a company owned by the Science and Technology Department, involved in some 200 international space programs such as the Galileo European Satellite Navigation System, the Venus Express orbiter, the TopSat Earth Observation system, the Rosetta mission, the Herschel Space Observatory and the Planck space telescope.
- The Satellite Applications Catapult Centre⁹⁷: an innovation centre with the purpose of driving economic growth through the commercialisation of research and satellite applications.

⁹⁷ The Satellite Application Catapult is a government program that “brings together people and organisations to encourage economic growth” (source: Debra Werner, SPACENEWS, *Catapulting Britain's Space Industry*, 2016. http://www.harwellcampus.com/uploads/manager/file/Space%20News-2016-01-18_extract4.pdf). The centre “provides support to businesses to develop and commercialise space technologies and satellite applications for the downstream sector” (source: Invest in Oxfordshire, *Oxfordshire Sector Profile – Space Technologies*, 2016. <http://www.oxfordshirelep.com/sites/default/files/Space%20Technologies.pdf>)

- The European Centre for Space Applications & Telecommunications: an ESA department which carries out innovative R&D activity in the field of satellite communications.

The laboratory is operated by the Science & Technology Facility Council, and it constitutes “a thriving and collaborative environment for research”, where cross-fertilisation is everyday practice. Some 1,200 workers support the research activity of more than 10,000 scientists and engineers in the fields of particle physics, space, materials, ICT, biology, medicine, energy, security and environment.

The presence of these facilities fostered the formal establishment of a space cluster, which occurred in 2013 as part of the Harwell Campus, in which the *Space and Satellite Applications* is one of the 5 core fields together with Life Sciences and Healthcare, Big Data and Supercomputing, Energy and Environment, and Advanced Engineering and Materials. The company RAL Space is the major anchor of the space cluster: it employs some 200 people and provides state-of-the-art facilities and infrastructures to member start-ups and companies, fostering the bottom-up innovation process.

Established in 2013 through a limited partnership between Harwell Oxford Developments Ltd. (a joint venture between the private companies Prorsus and Development Securities) and the two public organisations STFC (Science and Technology Funding Council) and the UK Atomic Energy Authority, the Harwell Science & Innovation Campus is comprised of some 200 start-ups and large companies that employ more than 5000 people. In particular, the UK Space Gateway consists of some 60 space companies based in the Harwell-Oxford Area: it is worth noticing that nearly 1/3 of them operate in the upstream segment. Besides RAL Space (which employs 200 people alone) we can mention some global contractors such as Boeing, BAE Systems, Elecnor Deimos, Rolls-Royce, Thales, Ball Aerospace & Technologies Corp. and Leonardo-Finmeccanica. These major contractors have triggered the establishment of a number of specialised high-tech SMEs and start-ups, operating both in the upstream and downstream segments. Among others we can mention GeoCento (Earth Imagery), InteraSight (Remote Sensing), Magellium Ltd (Satellite Imagery), Oxford NanoSystems Ltd (Nanotechnologies), Guyana (Artificial Intelligence), Oxford Space Systems (Satellite Components), and VTOL Technologies Ltd (Vertical Take-Off and Landing Remote Aircrafts)⁹⁸. The impact of these private players is leveraged by the institutional players participating in the cluster at different levels, offering a wide range of services such as consultancy, legal and commercial support, and the provision of fundamental infrastructure for research. The main Institutional players involved are the Enterprise Europe Network, the ESA Business Incubation Centre, the Intellectual Property Office, Invest in Oxfordshire (Oxfordshire Local Enterprise Partner), UK Trade and Investment, and the aforementioned Space Applications Catapult. The true core of the cluster’s potential for innovation is constituted by the outstanding R&D capabilities embedded in the players from Academia: the two main Universities, namely the University of Oxford (ranked 3rd for computer science and 10th worldwide for Engineering and Physics according to QS World University Rankings 2015) and the Oxford Brookes University, exhibit a significant presence in the area with a number of research groups in the fields of planetary science, microelectronics, energy, robotics and sensors, along with several laboratories which constitute altogether the unique cutting-edge research infrastructure of the campus, worth around £2 billion and allows for unique opportunities of collaboration between academia and the innovative companies located in the area.

The Harwell cluster constitutes a unique example both in the national and international landscape, in the sense that, contrarily to the overall UK space strategy, it exhibits a more balanced attention towards upstream applications, as well as a stronger industrial focus on the upper-end segments of the value chain: in recent times the system has devoted great effort to developing the satellite industry

⁹⁸ Source: Harwell Space Launchpad Showcase 2013

in the area, and specifically the nanosatellites subsector, which offers endless and extremely profitable opportunities in a wide array of fields. In addition, the high degree of integration with the research sector further leverages the potential for innovation of the cluster as a whole, with outstanding positive externalities for the area in terms of innovation, FDI attraction and socioeconomic development. The Harwell campus has been so successful that it is playing a fundamental role in achieving the government's long-term goal of increasing the total value of the British space sector to £40 billion by 2030. As stated in the National Space Plan, the government is committed to do so by replicating the so-called "Harwell Effect" by implementing other aerospace clusters in the United Kingdom.

Cluster analysis

This paragraph provides the reader with a competitiveness analysis of the Harwell space cluster according to the Porter's Diamond framework utilised so far to identify the best practice emerging from other clusters analysed. The single elements that characterise the factor conditions, the context for strategy and rivalry, the related and supporting industries, and the demand conditions are evaluated according to their impact – which can be positive, limited/uncertain, or negative – over their dimension of reference.

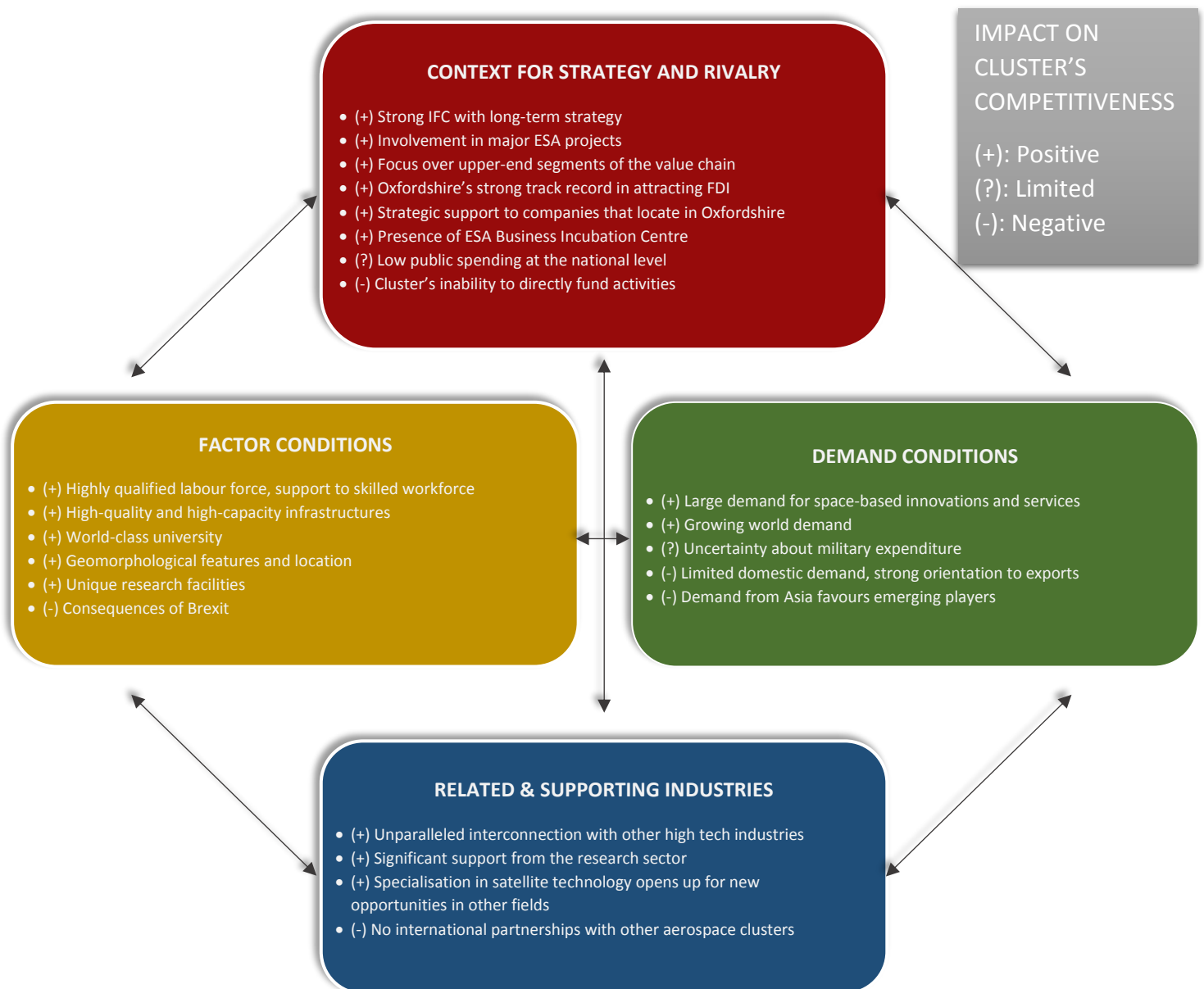


Figure 13: Porter's Diamond Analysis of the Harwell Cluster. Source: author

Factor Conditions

The environment in which the cluster operates exhibits a number of excellent characteristics in its factor conditions, which have had a fundamental role in shaping the cluster's potential for innovation. The latter benefits from the availability of a large pool of highly skilled employees: according to Invest in Oxfordshire 46% of the resident working age population (namely some 192.000 units) have at least a university degree or an equivalent diploma, a figure which is 11% higher than the national average⁹⁹. This pool of workers is constantly enriched by the universities of Oxford and Oxford Brookes, which represent two of the world's excellences in the fields of engineering and physics. In addition, a STEM program carried out by the Space Studio Branbury and supported by the UK Space Agency, the European Space Agency and the National Space Academy promotes the study of scientific disciplines

⁹⁹ Invest in Oxfordshire, *Oxfordshire Sector Profile – Space Technologies*, 2016. Source: <http://www.oxfordshirelep.com/sites/default/files/Space%20Technologies.pdf>

among high school students, encouraging them to undertake a career path in these fields. The UK Space Agency is also primarily involved in helping companies find the qualified manpower they need through a dedicated office established in 2014. Acknowledging the pivotal role of human capital in the British space sector, in the same year the UK government started to provide financial support to attract and retain PhD students in the space sector¹⁰⁰, thus successfully addressing the lack of skilled workers nationwide. Besides the aforementioned world-class research facilities that are made available to local companies for the testing of their products, the cluster's commercial and R&D activities benefit from high-capacity and high-quality connection infrastructures: Oxfordshire has excellent connectivity by road (A3, M4, M40) and rail (direct connection with London in 56 minutes), the Heathrow Airport is within close proximity and the whole county is equipped with superfast broadband. The morphology of the region fostered the development of the local space industry thanks to the large availability of land, which allows for concentration without creating bottlenecks. The cluster is also proximate to Fairbrough, where one of the most relevant international aerospace events is held every two years (the already mentioned Fairbrough Air Show), and Oxford University is part of the so-called Golden Triangle (Oxford-Cambridge-London, with the Imperial College and the University College), a world-class knowledge hub with an aggregated R&D income of £1.4 billion per year. The only condition that constitutes a major source of concern is the economic and political fallout of the so-called Brexit, namely the exit of the UK from the European Union: the climate of uncertainty which followed the referendum outcome is currently hampering investment decisions, and the depreciation of the pound increased the cost of importing raw materials and subassemblies.

Context for strategy and rivalry

The context for strategy and rivalry the key feature of the Harwell cluster is constituted by the Institution For Collaboration that steers the cluster, namely the Harwell Science & Innovation Campus: the IFC is the result of a public-private partnership and it adopts an holistic approach which embraces a wide array of high value added sectors, not only the space segment. This wise approach leverages tools that are typical of the private sector to generate public value, and is the key to the cluster's success. As a result of the increasing relevance of the district and of the growing public investments in space, Harwell has become a primary partner of several major ESA projects, such as the Rosetta mission and the new orbiting telescope Herschel, thus encouraging the inception of many specialised companies with relevant connections to the international community, besides providing sound regulatory standards to aerospace products and services, and enhancing the competition and cooperation among the member firms. Contrary to many long-standing aerospace clusters, Harwell is increasingly focusing on the upper segments of the value chain, and this strategy is fostered by the traditional attraction potential of the region towards Foreign Direct Investment: the presence of some major international contractors such as Thales Alenia Space and Lockheed Martin¹⁰¹ that act as anchor firms has attracted a number of highly innovative companies of various dimensions, whose establishment is facilitated by institutional support provided by bodies such as Invest in Oxfordshire, or the ESA Business Incubation Centre.

Notwithstanding this highly favourable portrait of Harwell's context for strategy and rivalry and the key role of private initiative in scaling up the local potential for innovation, the cluster's competitiveness would surely benefit by a stronger commitment of the British government in the national space activity: as already pointed out, the largest share of the national space budget consists

¹⁰⁰ Debra Werner, SPACENEWS, Catapulting Britain's Space Industry, 2016. Source: http://www.harwellcampus.com/uploads/manager/file/Space%20News-2016-01-18_extract4.pdf

¹⁰¹ Invest in Oxfordshire, *Oxfordshire Sector Profile – Space Technologies*, 2016. Source: <http://www.oxfordshirelep.com/sites/default/files/Space%20Technologies.pdf>

of contributions to ESA (~75%¹⁰²). In addition, as already pointed out by the Royal Aeronautical Society in a 2014 report, the Harwell cluster's catalyst role for the national industry is burdened by the inability to directly fund its own activities¹⁰³.

Related and supporting industries

Compared to every other cluster analysed in this report, the Harwell cluster exhibits a major distinctive feature in its related and supporting industries, which enhances its competitiveness and its innovativeness. The cluster is in fact embedded in a broader organisation, the Harwell Campus, which serves as an all-encompassing institution that embraces a wide array of high value-added sectors, thus providing unique linkages among the different industries. Thanks to these connections the cluster is able to benefit from enhanced cross-fertilisation from other fields while in turn providing them new solutions and applications for internally-developed space innovation. This element makes Harwell a major hub of innovation in the world, with an unparalleled level of inter-sectorial knowledge spillovers. Space industry innovation is also nurtured at multiple levels by the outstanding support deriving from the research sector, which works in close collaboration with major contractors as well as SMEs and innovative start-ups, providing them with key infrastructures for testing and research that leverage the development of new products and services. Further opportunities for enhanced collaboration with related industries originate from the recent focus on the satellite subsegment, driven by both the private R&D and the public investment (both at the national and international level, with the Satellite Applications Catapult and the ESA European Centre for Space Applications & Telecommunications). On the other hand the cluster exhibits a lower degree of openness towards international partnerships, with no formalised involvement in international programs such as the aforementioned European Aerospace Cluster Partnership (EACP) and the NEREUS network.

Demand conditions

As widely discussed in the previous chapters, the Harwell space cluster faces similar demand opportunities and challenges as other aerospace clusters operating in developed countries: global markets call for space-based innovations and services and the world aerospace demand faces constant increases every year, on the other hand the rapidly growing players from emerging countries are likely to attract vast portions of these demands due to the fact that they are proximate to the core of this trend (Asia) and are able to satisfy these requests within shorter timeframes and at lower costs. In addition, UK military expenditures exhibit a steady focus on defence with an unclear strategy when it comes to space, thus further limiting the already inconsistent domestic demand: as a matter of fact, 91% of British aerospace demand is from exports¹⁰⁴.

¹⁰² The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

¹⁰³ Royal Aeronautical Society, *UK Space Policy: A Hidden Success Story*, 2014

¹⁰⁴ ADS Group Ltd., *UK Aerospace Outlook 2015*, 2015

2.6 United States

The United States of America represent the undisputed founding fathers of modern aerospace and, above all, their momentous effort in the conquest of space provided a tremendous push to the global space sector in the second half of the 20th century. Through a very complex equilibrium of political alliances and rivalries the US have been able to constantly raise the bar in terms of knowledge and technology standards. Together with the USSR, America constituted the driving force of the race to space, mainly thanks to the political weight that was given to this challenge within the framework of the Cold War.

Since the very beginning of the 20th century the US have been the global leaders in the aviation sector as they were home of the world-class companies Boeing, Grumman, Lockheed and Northrop. Furthermore, the establishment of the first governmental body dedicated to aviation dates back to 1915, when the federal agency NACA (National Advisory Committee for Aeronautics) was established. Things took a decisive turn at the end of WWII, when the victory over Germany gave the Allies the opportunity to access the advanced German rocket technology, thus paving the way to the future development of the American space capability. The leadership in Aviation and the first mover advantage in Space brought about the birth of the modern aerospace sector.

The escalation of tension and rivalry with the USSR and the new military application of aerospace innovation led the government to design the strategic development of the national aerospace sector. As a consequence, the 1958 National Aeronautics and Space Act dissolved the NACA and transferred its assets and personnel to the newly established *National Aeronautics and Space Administration* (NASA). After suffering scorching defeats from the USSR, which had been the first to put an artificial satellite (the Sputnik 1) in orbit and to accomplish the first manned spaceflight, the US eventually retaliated with Project Apollo, which resulted in the first man setting foot on the Moon's surface in 1969. As a result of the distension of the USA-USSR political relationships, the following years saw a paradigm shift from competition to cooperation among the two superpowers, which led to the joint development of the International Space Station (ISS).

The US have always been at the forefront of aerospace innovation, with momentous achievements such as the first global navigation satellite system (GNSS) *Transit*, and the *Space Shuttle*, which introduced the concept of *reusability* in the field of space exploration. Such innovative attitude has always been backed by the implementation of a huge national space program, and as of 2014, with US\$42.956 billion the US ranked first worldwide in terms of Government budget devoted to space. This amount constituted the 13% the global space activity for the same year¹⁰⁵. With US\$17.646 billion, NASA absorbed the 41% of the national space budget, and the amount of funds available remained substantially stable in 2015 and 2016¹⁰⁶. The main customer of the US space industry is the national defence sector, followed by civilian space programs implemented by the US Government. The private involvement is on the rise, along with the share of revenues deriving from commercial customers. In particular, in recent times the national private space sector has gained an increasingly larger market share in the field of launch and space transport services, as well as pioneering the sector of civilian space flight: among the companies at the forefront we can mention Benson Space Company, Bigelow Aerospace, Interorbital Systems, Masten Space Systems, Orbital Science Corporation, Space Adventures, SpaceX and Virgin Galactic. Furthermore, the US Government has been carrying out an

¹⁰⁵ The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

¹⁰⁶ Source: NASA Budget Estimates – Fiscal Year 2015. The 2016 data is notational.

https://www.nasa.gov/sites/default/files/files/FY15_Summary_Brief.pdf

intense supporting action with reference to the national industry: the 2010 National Space Policy aims at enhancing the national commercial space capabilities by fostering both international cooperation and the establishment of commercial space companies in a competitive environment that is beneficial to innovation.

The US aerospace sector is one of the main driving forces of the national economy: as a whole it accounts for US\$144 billion in US exports, attracting FDI for US\$22.7 billion in 2013 (with a 7.7% CAGR since 2008). The international appeal of US aerospace derives from the size of the market, its skilled workforce, its infrastructure and the highly favourable policies put in place both at the state and national level. Direct employment in the sector amounts to some 500,000 units, and aerospace provides around 700,000 jobs in related and supporting industries¹⁰⁷. Aggregated civilian and defence aerospace activities accounted for some US\$220 billion in 2013¹⁰⁸.

Narrowing the focus over the space segment, as illustrated in the table below this generates a total turnover of US\$87.2 billion, with a relevant share (almost 50%) deriving from government expenditures.

Space Revenues	Government Expenditures in Space	% Government Expenditures/Total Revenues	Global Government Expenditures
US\$87.2 billion ¹⁰⁹	US\$42.956 billion ¹¹⁰	49.26%	24%

UK Public Expenditures in Space. Author's elaboration based on data from The Space Foundation, "The Space Report 2015 – The Authoritative Guide to Global Space Activity", 2014

The US aerospace sector is the main driver of innovation in the national economy: according to a 2014 report from the National Science Foundation, in 2012 the sector exhibited a 10.1% R&D intensity (namely the ratio between total R&D expenditures and total sales), second only to the pharmaceutical sector (12.7%) but with a wider range of possible applications. This value is significantly higher than the average R&D intensity of the American economy (3.3%)¹¹¹.

The United States aerospace industry, and the space sector in particular, are structured following a cluster framework: for instance the most important is the Seattle Aerospace Cluster, which is renowned for being the first and largest aerospace cluster worldwide. The industry is spread throughout the whole national territory, and there are some 15 states hosting aerospace clusters with a more pronounced presence of space-related activities¹¹²: among others it is worth mentioning California, Texas, Florida, New Mexico, Alabama and Colorado. It is important to point out how the focus on space is typical of those clusters located at closer proximity to the equator.

2.6.1 The Colorado Aerospace Cluster

The Colorado aerospace industry has been playing a primary strategic role in the US economic and political framework since the '50s: in the aftermath of WWII the state was chosen as industrial pole thanks to its location which was sheltered from the potential threat of enemy countries. Military activity was in fact fundamental to the development specific capabilities that fostered the

¹⁰⁷ U.S. Department of Commerce, International Trade Administration, *AEROSPACE SPOTLIGHT – The Aerospace Industry in the United States*, 2016

¹⁰⁸ OECD, *The Space Economy at a Glance 2014*, 2014

¹⁰⁹ Source: <http://www.worldatlas.com/articles/all-about-the-space-industry.html>

¹¹⁰ The Space Foundation, *The Space Report 2015 – The Authoritative Guide to Global Space Activity*, 2014

¹¹¹ Source: National Science Foundation, 2014. Link: <https://www.nsf.gov/statistics/2015/nsf15303/nsf15303.pdf>

¹¹² OECD, *The Space Economy at a Glance 2014*, 2014

development of the aerospace industry in the area: Colorado was the central node of the complex radio communication network that connected US troops located in Asia and Europe with the central command. The Army air bases of Lowey and Peterson developed a unique know-how in photographic intelligence, thus paving the way for the future fields of Communication, Earth Observation and Monitoring. In the following decades both public and private investments pushed the aerospace industry by providing production plants, facilities and infrastructures. The deeply rooted presence of the Air Force served as a catalyst for the growth of a local industrial system and for the development of universities and research centres operating in the field of aerospace. Optimal climatic conditions and a supportive socio-political environment contributed to the development of the local aerospace sector, which naturally underwent a clustering process.

At present, the Colorado Aerospace Cluster is "*A Mile Closer to Space*"¹¹³. It is the national champion in terms of private aerospace employment over total employment: the 170 aerospace companies (78% of which are located in the Metro Denver and Northern Colorado areas) and their 400 suppliers provide direct employment for 25,120 private sector workers and 27,740 military personnel. The cluster exhibits strong interconnections with related and supporting industries, providing jobs for another 109,350 units and thus bringing the total direct and indirect employment to 162,210 people. What is more, the cluster's employment appears to be extremely stable and resilient to economic conjuncture, following countercyclical dynamics when compared to the American aerospace sector as a whole: in the five-year period 2010-2015 employment underwent a 0.9% increase, against a 3.3% decrease in the sector at the national level. The 2014/2015 increase in employment amounts to 0.4%, in contrast to a 1.2% decrease nationwide. The relevance of aerospace for Colorado is mirrored by a simple comparison between the state's employment in the sector and the national data: 0.9% of the regional workforce is employed in the cluster, while the national concentration index amounts to a mere 0.2%. The cluster's sales amount to some US\$16.530 billion¹¹⁴, while the Colorado industry's space exports in 2013 totalled \$300 million and demand mainly originating from New Zealand, Canada and Saudi Arabia¹¹⁵. The local aerospace ecosystem operates in the fields of R&D, design, manufacture and maintenance of guided missiles, aircrafts (including Unmanned Aerial Vehicles), spacecrafts and space vehicles, satellites and communications equipment, navigation and detection instruments, launch systems, mission support and other aviation and space-related services.

The Colorado Aerospace Cluster stands out as an extremely sophisticated organism which encompasses a highly educated labour force, world-class companies and excellent research institutions, all united through a deep network of synergies between the different players.

- **Industrial players** include the following major contractors: Ball Aerospace & Technologies Corp., Boeing, Harris Corporation (operating in the segments of Critical Networks, Space and Intelligence Systems, and Visual Information Solutions), Lockheed Martin, Northrop Grumman, Raytheon Company, Sierra Nevada Corporation (with its Space Systems Group and Intelligence, Surveillance and Reconnaissance Group), and the Lockheed Martin Atlas and Boeing Delta joint venture United Launch Alliance, whose Human Launch Services division works in close cooperation with NASA.
- **Governmental players** primarily consist of the US Air Force and the Department of Defence, which holds the lion's share of the interests and activities in the cluster. The area is home of the following major military installations: the Air Force Bases of Buckley, Peterson, Cheyenne and Schriever.

¹¹³ <http://www.spacecolorado.org/why-colorado/mile-closer-infographic/>

¹¹⁴ Source: *Launch! Taking Colorado's Space Economy to the Next Level*

¹¹⁵ Source: Advance Colorado

- **Academic players** include the U.S. Air Force Academy (2nd nationwide for undergraduate aerospace engineering programs). The state is home of 13 four-year and 15 two-year public institutions, some 30 private and religious institutions and around 10 occupational and technical schools, for a total of around 70 institutions offering aerospace-related programs.

The excellent performance of the Colorado Aerospace Cluster is enhanced by the coordination and promotion activity carried out by two Institutions for Collaboration (IFCs). The Colorado Space Coalition (CSC) brings together the major aerospace industry stakeholders (companies, military leaders, academic organisations and economic development groups) with the aim of ensuring continuous expansion of the local aerospace industry through promotion, provision of advocacy services to its members and through the establishment of a network able to foster collaboration among the cluster's stakeholders. CSC is an industrial affiliate of the Metro Denver Economic Development Corporation, an institutional entity which brings together a number of economic development groups in the area with the purpose of fostering territorial socioeconomic growth. In doing so, the Metro Denver Economic Development Corporation encompasses players of a different nature, including economic development organisations and the councils of counties and cities in the Metro Denver and Northern Colorado Region. The Corporation is in turn affiliated to the Denver Metro Chamber of Commerce.

The most remarkable aspect about the Colorado Aerospace Cluster is probably the fact that its outstanding economic performance and potential for innovation is significantly driven by the large share of the space sector within the broader activity of the aerospace industry as a whole. In addition to the aforementioned employment concentration index, it is worth highlighting that in 2011 the sole local space sector accounted for the 3.8% of the Colorado's private sector gross domestic product¹¹⁶.

Cluster analysis

This section breaks down the Colorado Aerospace Cluster according to the usual classification into factor conditions, context for strategy and rivalry, related and supporting industries, and demand conditions.

¹¹⁶ Source: *Launch! Taking Colorado's Space Economy to the Next Level*

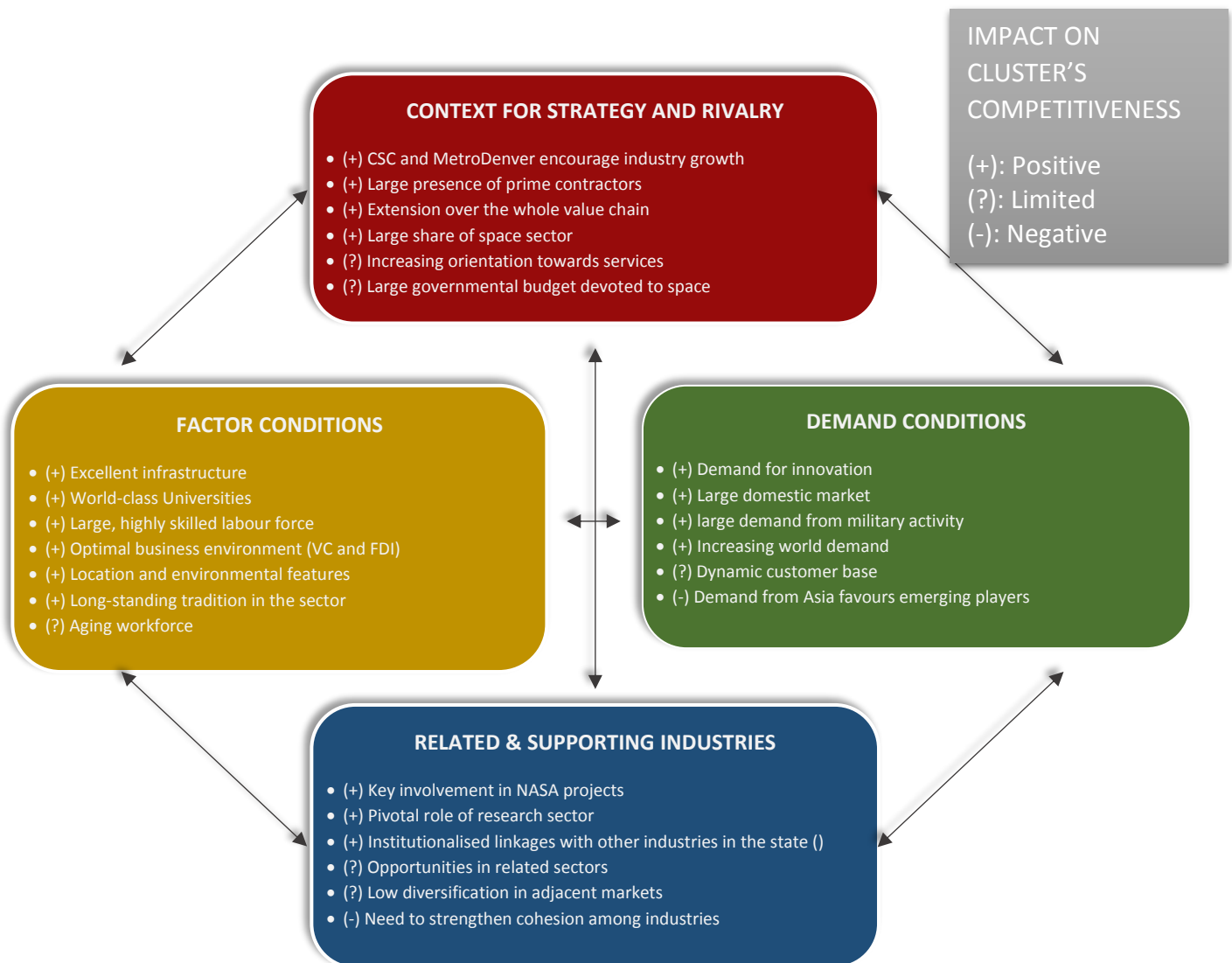


Figure 14: Porter's Diamond of the Colorado Aerospace Cluster. Source: Author.

Factor Conditions

The factor conditions of the Colorado Aerospace Cluster can be qualified as excellent: the state owns an excellent infrastructure consisting of four Air Force bases (Buckley, Peterson, Cheyenne and Schriever) the world-class Denver International Airport, the commands of the Air Force (AFSPC), the US Army (SMDC/ARSTRAT), the US Department of Defense (US Northern Command USNORTHCOM) and the NORAD, the Advanced Mobile Propulsion Test (a rocket ground test facility) in Durango, along with 7 state-of-the-art federal research laboratories. The latter are the National Oceanic and Atmospheric Administration, the University Corporation for Atmospheric Research, the National Centre for Atmospheric Research, the Cooperative Institute for Research in the Atmosphere, the national Solar Observatory, the National Institute of Standards and Technology, and the Cooperative Institute for Research in Environmental Sciences.

With reference to the Academia players, Colorado hosts the following world-class universities: the University of Colorado Boulder (CU-Boulder) and its Laboratory for Atmospheric and Space Physics (LASP), the Universities of Colorado Colorado Springs (UCCS), the United States Air Force Academy, the Colorado School of Mines and its Centre for Space Resources, the Colorado State University (CSU)

and the Metropolitan State University of Denver. The research activity carried out by these universities is coordinated by the Universities Space Research Association. These in addition have provided the cluster with a large bulk of highly skilled labour force, mainly specialised in aerospace and mechanical engineering, software development, and business operations. With reference to this aspect, the industry is facing some hardships in terms of workforce turnover, with the latter undergoing a relevant ageing process. The government and the private sector are addressing this issue through programs aimed at promoting STEM among high school students, but positive effects of this intervention are going to show in the long run. Colorado offers a fertile business environment, with a low cost of doing business (the corporate income tax rate is 4.63%, making the state among the best in terms of tax climate according to the Small Business & Entrepreneurship Council). From an entrepreneurial point of view, Colorado offers great opportunities, with Venture Capital funding for some \$18 million per 100,000 people¹¹⁷, with start-ups increasingly accessing this source of financing. The geographic features and the location of Colorado have been responsible for the establishment of the aerospace industry in the 20th century - thus allowing the area to develop a unique know-how thanks to its long-standing tradition in the sector – and they still play a relevant role in the industry: the state's proximity to the burgeoning Asian markets makes the Cluster a privileged commercial partner, the Rocky Mountains constitute a great training facility for pilots and the clear skies foster space activities.

Context for strategy and rivalry

The aforementioned Colorado Space Corporation and Metro Denver play a fundamental role for the cluster's development by carrying out activities aimed at fostering collaboration within the cluster and by supporting the establishment of companies in the area with tailored advocacy and marketing services. In addition, their mission is to develop a fiscal and regulatory framework that supports the socioeconomic growth of the area. Furthermore the two IFCs have encouraged the trajectory undertaken by the cluster towards the internal development of the space sector, which now constitutes a larger share of the cluster's aerospace activity when compared to other examples, thus leveraging the industry's potential for innovation by fostering the birth of innovative firms in this subsector.

As anticipated in the introductory paragraph, the Industrial players include some of the world's most important OEM companies. As usual, their presence serves as catalyst for a wide ecosystem of smaller suppliers along the production chain, but in this specific case the high concentration of a large number of contractors provides another source of innovation, namely the increased competition and cooperation among large companies. The long-standing tradition of the Colorado aerospace industry has brought about the attraction of a wide spectrum of firms, thus covering the whole length of the value chain. Notwithstanding a symptomatic depletion due to the latest outsourcing trends, the multifaceted and versatile know-how developed by the system through the operation in multiple segments constitutes an all-encompassing source of innovation and differentiation, which ultimately result into competitive advantage when compared to other emerging clusters. Nonetheless, in recent times the Cluster is slightly moving towards the specialisation in the sector of aerospace-related services (for instance, IT and engineering).

The outstanding volume of the space-devoted government budget may be of some concern: this element constitutes a double-edged sword, as the main source of growth and innovation may become the first cause of a cluster-wide crisis should the federal funding shrink.

¹¹⁷ Source: Nerdwallet 2015, cited in spacecolorado.org

Related and supporting industries

As mentioned in the factor conditions analysis about the infrastructures devoted to research, the research sector provides significant support to the Colorado Aerospace Cluster. The presence of institutions such as the aforementioned NOAA, UCAR, NSO, National Science Foundation, along with the universities cited above, implies ongoing and cutting-edge research in the fields of atmospheric and climatic sciences, monitoring, earth and space observation, thus providing an outstanding propellant to the development of innovation. Furthermore, the cluster is significantly involved in all the major NASA projects, such as the development of the spacecrafts *Dream Chaser*®, *New Horizon*, *Orion* and *Osiris-Rex* (which involve respectively Sierra Nevada Corporation, Ball Aerospace and Lockheed Martin), besides the Joint Polar Satellite System jointly developed by Ball Aerospace and Sierra Nevada Corporation. Other NASA projects include the Jupiter spacecraft, the Jet Propulsion Laboratory, the Solar Probe Plus mission, the Tracking and Data Relay Satellite-M¹¹⁸. The active role of Metro Denver an IFC constitutes a vital connection with related industries such as bioscience and communication, and related ones like financial services and energy. This structure in addition allows the exploitation of the endless opportunities arising in the fields of ICT, advanced materials, renewable sources, health and biotechnologies. On the other hand, in order to do so it is necessary to further strengthen the linkages and the cohesion among industries, by intensifying the cluster dynamics and possibly by implementing a cluster-wide organisation for the other industries: this need has arisen following a joint strategic analysis carried out by the Colorado Office for Economic Development and International Trade together with the Brookings Institution and the Rockefeller Foundation¹¹⁹.

Demand conditions

Being a major hub of innovation, as well as one of the world leaders in the aerospace sector, the Colorado industry is capable of meeting the booming demand for innovation that is mirrored by the constant increase in the range of possible applications of aerospace-related products and services in the fields of TLC, healthcare, environmental monitoring and so on. Two elements in particular have been playing a fundamental role in developing the potential for innovation of the cluster, by providing a colossal impulse to the R&D activity: firstly, the large domestic demand (for space-related products and services but most of all for aeronautics) has always represented a great source of revenues for the prime contractors operating in the field; secondly, the huge public demand driven by military activity constituted a momentous stimulus for the innovation process, in particular through the procurement of extremely specific and innovative projects. Both these elements provide vital impulse to the state's R&D intensity (whose investment in it, again, amounts to 10.1% of revenue) by dedicated financing for cutting-edge investments, human capital and infrastructure.

In line with the other major clusters analysed so far, the Colorado Aerospace Cluster receives large and direct benefits from the constant increase in global aerospace demand, with a particular focus on space-oriented and space-derived activities (to which the cluster is particularly oriented). Again, on the other hand the cluster has to face fierce competition from emerging aerospace clusters that are blooming in developing countries, due to the lower cost of labour force and, simultaneously, to the increasingly global dimension of the value chain, which has been driven by the growing outsourcing in the lower-ends of the production chain. Such players are meeting an increasingly large share of the world demand due to geographical proximity to the emerging markets of origin. This aspect makes it even more difficult to embrace an increasing global demand which is already not easily accessible. Further uncertainty within the demand conditions is represented by the evolution of the customer base, which shifted from being concentrated among a restricted number of governments with

¹¹⁸ Metro Denver Economic Development Corporation, *AEROSPACE: Colorado Industry Cluster Profile*, 2016

¹¹⁹ Source: *Launch! Taking Colorado's Space Economy to the Next Level*

homogeneous requests, to a more widespread demand that expresses more specific needs (mostly due to the burgeoning presence of the private space sector). The focus on the manufacture of space infrastructure has been replaced by a wider array of space-related services.

2.6.2 The New Mexico Aerospace Cluster

In the words of George Whitesides, CEO and president of Virgin Galactic, “New Mexico is the birthplace of America’s spaceflight”. In fact, as his predecessor Will Whitehorn remembered, the first footage of the Earth as seen from space was taken by a V-2 rocket that was launched from New Mexico. In the early ‘40s the state’s outstanding environmental conditions (namely the abundance of uninhabited land, clear skies, optimal climate and excellent visibility) determined the establishment of the Air Force bases of Holloman and Kirtland, thus favouring the defence-led inception of a cutting-edge branch of the national aerospace industry. The military activity has brought about the interdiction of the airspace over the area to commercial flights, thus allowing for better testing activities. The need for a qualified and specialised workforce resulted in the growth of an aerospace-related academic community in the area: as a consequence, the constantly increasing availability of highly qualified human capital triggered the development of the aerospace sector outside the boundaries of military applications.

The defence sector imparted vital momentum to the local aerospace industry, but it was able to do so thanks to some key facilitating conditions. The optimal environmental conditions and the key role played by academia (with its state-of-the-art human and physical capital), combined with the wide support of the public sector and the boldness of private entrepreneurs brought about the development of what is now a broad and growing aerospace cluster in southern New Mexico. The latter employs over 8,000 workers for a total aerospace-related payroll of US\$300 million per year¹²⁰. Nowadays the cluster comprises more or less the whole territory of New Mexico, with a particular concentration of activities in the city of Albuquerque and in the counties of Doña Ana, Luna, Otero, and Sierra. The cluster is particularly active in the space segment and its branches of space launch (spacecrafts, rockets, satellites), testing, Unmanned Aerial Systems (UAS), and ground stations, and in recent times it has developed a system-wide commitment towards pioneering the new sector of commercial spaceflight.

In order to foster the growth of this segment the State Government has financed the construction of Spaceport America, the first spaceport entirely devoted to commercial spaceflight. The project has had to deal with several hardships that hampered its realisation, for instance the heavy delays that the commercial spaceflight sector has experienced in previous years, but as of today the infrastructure is ready and SpaceX is now a tenant of the facility, in addition to the main one Virgin Galactic. The project has created 1,400 jobs with figures expected to increase as the facility moves into operation (according to the Chief Executive Officer of *Spaceport America* Christine Anderson).

From a triple helix perspective the cluster displays a wide, diversified and well-integrated array of players from the three sectors of academia, industry and public sector. The latter sees the involvement, among others, of the New Mexico’s State Government, the New Mexico Partnership (an Economic Development Agency) and of the United States Air Force.

As for the academia we can mention, among others, the Eastern New Mexico University–Roswell, the New Mexico State University (with an excellent graduate program in Aerospace Engineering), the Embry Riddle Aeronautical University, The New Mexico Tech and the University of New Mexico, along

¹²⁰ Source: Mesilla Valley Economic Development Alliance. <http://www.new-mexico-space-industry.com/>

with the following research facilities: the Air Force Research laboratory, the Sandia National Laboratories (Government-owned and contractor-operated facility), the NASA White Sands Test Facility and the Los Alamos National Laboratory (whose technologies have been used in the Mars Science Laboratory mission's Curiosity Rover, deployed on Mars in 2012).

The industry sphere sees the participation of some world-class companies, such as Raytheon Ktech, Honeywell Aerospace, L-3 Communications Vertex Aerospace, General Dynamics, Northrop Grumman, Eclipse Aerospace, Lockheed Martin and Titan Aerospace (acquired by Google in 2014), along with the two cutting-edge companies Virgin Galactic and SpaceX, pioneering respectively the fields of Commercial Spaceflight and Reusable Launchers. Furthermore it is worth mentioning the pivotal role played by Boeing in the local industrial landscape: the company is the major driver of the aerospace ecosystem, developing groundbreaking products and services together with a network of nearly 80 businesses operating in New Mexico (particularly in Albuquerque and Las Cruces). Boeing's activity in the area employs 245 people and creates economic value for US\$140.5 million, generating direct and indirect employment for some 4,000 units. The company's strong Corporate Social Responsibility policy has provided contributions to local charities for US\$327,000¹²¹.

Cluster analysis

The diagram below provides the usual decomposition of the cluster's features according to the Diamond model designed by Michael Porter. The application of the model to the specific case of New Mexico indicates that the local aerospace cluster exhibits excellent factor conditions in particular.

¹²¹ Boeing 2015 annual data.

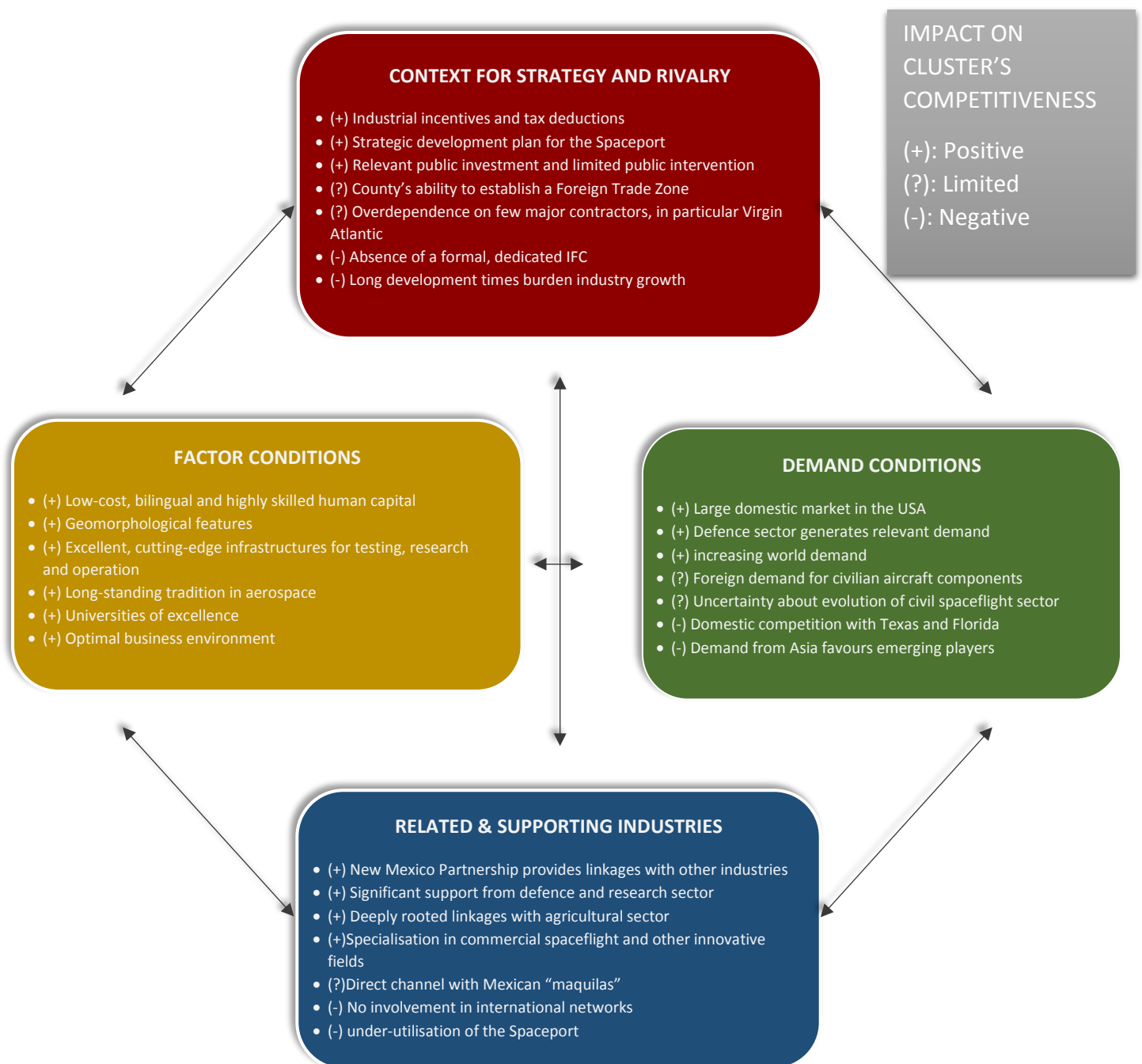


Figure 15: Porter's Diamond Analysis of the New Mexico Aerospace Cluster. Source: author.

Factor Conditions

One of the key elements of success for the New Mexico aerospace cluster is the highly skilled labour force, whose depth is enhanced by the growth of aerospace manufacturers. Human capital exhibits the distinctive feature of being bilingual, thus allowing for enhanced knowledge exchange and commercial opportunities in the booming Latin America markets. The workforce is also available at a relatively low cost, as wages are significantly lower than other aerospace clusters. As anticipated in the introductory paragraph, new Mexico's aerospace industry flourished thanks to its unique geomorphological features, and as of today this element still plays a fundamental role for the sectorial growth: the altitude (roughly 1500m above the sea level), the flat territory, the optimal visibility and

climate conditions (some 340 sunny days per year) allow for the testing of a wide array of components and subcomponents year round.

Those activities would not be possible if it weren't for the excellent infrastructure in the area. The cluster is equipped with more than 20 federal state and private research facilities, among which one can mention the Los Alamos National laboratory, the Sandia National Laboratories, and the Air Force Research Laboratory, and it also hosts the Las Cruces International Airport, the first and most experienced FAA-approved UAS test centre. Besides the aforementioned Air Force bases, the cluster is also home to state-of-the-art test facilities, such as the new Mexico State University Physical Science Laboratory, the White Sands Missile Range, the NASA's Johnson Space Centre – White Sand Test Facility (WSTF) and the SpaceX High-Altitude Test Facilities. Probably the most outstanding infrastructure is *Spaceport America*, the world's first commercial spaceport, which will inaugurate the era of commercial spaceflight in the near future. The facility is owned by the state's government (which, starting from 2007, devoted US\$225 million to the project) and leased to Virgin Galactic for 20 years: the company will use the infrastructure to inaugurate the era of space tourism. Other users of the platform include Boeing, Celestis and Lockheed Martin. The fact that New Mexico is pioneering such sector is coherent with the state's long-standing tradition of innovator in the aerospace sector, but significant contribution derives from the academia. The area is home of academic institutions of excellence, such as the Central New Mexico Community College (CNM), the Eastern New Mexico Community College (ENMU-Roswell), the Embry Riddle Aeronautical University (ERAU), the New Mexico State university (the only one in New Mexico and Western Texas to offer an Aerospace Engineering Graduate Program), the New Mexico Tech (NMT) and the University of New Mexico. These institutions provide specialised labour force and technical equipment for cutting-edge R&D activities.

The system depicted above operates within an extremely favourable business environment, which includes world-class operators and their related FDI in the area. The city of Las Cruces, for instance, has been widely recognised as one of the best small metro areas for business and careers by Forbes and by the Milken Institute.

Context for strategy and rivalry

The New Mexico state's Government fosters the inception of high-tech aerospace companies by providing industrial incentives, together with an articulated system of tax benefits: for instance, receipts of aircraft manufacturers deriving from selling aircrafts or aircraft parts, selling related services, launching, operating or recovering a spacecraft, and providing research, development testing and evaluation services are tax-deductible. The top corporate tax rate on income is reduced to 6.6% in 2016 and to 6.2 in 2017. Furthermore the Job Training Incentive Program (JTIP) is a workforce development incentive programme that reimburses part of the employees' wages for up to 6 months for newly-created positions in qualified or expanding businesses. The program also covers workers' training if it is carried out in a NM public educational institution¹²². This evidence is part of a broader model of public involvement, in which the government fosters the sector growth through incentives and massive public investments (the planned budget for the Spaceport alone amounted to US\$225 million) but abstains itself from direct intervention and influence over the economic activity of the cluster: we can therefore state that the latter exhibits an optimal level of governmental involvement.

The pivotal role played by *Spaceport America* in the growth of the space industry has led to the establishment of a tailored strategic development plan for the facility, in order to foster the growth of specialised companies around the infrastructure. This plan stretches through a 5-year period and

¹²² Source: <http://nmpartnership.com/wp/wp-content/uploads/2014/11/commercial-spaceflight.pdf>

identifies the key sectors where to intervene (e.g. commercial spaceflights, UAS) through targeted marketing actions, while enhancing the development of a specialised human capital through educational campaigns that encourage students to pursue STEM-related careers.

Some economic and commercial benefits may derive from the inception of a Foreign Trade Zone, which would allow companies to receive duty-free imports mainly from the Mexican *maquilas*¹²³ located in Ciudad Juarez at extremely convenient prices. The strategy and rivalry dynamics of the cluster are heavily influenced by the role and presence of a restricted number of major contractors: this aspect, while fostering the inception of a specialised supply chain and the development of specialised segments of the space sector, on the other hand reduces competition at every stage of the value chain, thus decreasing the cluster's potential for innovation. Although the number of major contractors is increasing (with companies such as SpaceX and Google establishing their presence in the cluster), it is also important to mention that Virgin Galactic, one of the major companies in the area and the only anchor tenant of the *Spaceport* until 2016, is running late on its development plan of the facility. Given the overdependence of the supply chain in the commercial spaceflight segment on Virgin Galactic, any delay burdens the overall development of the sector. The presence of a dedicated Institution for Collaboration might address this issue.

Related and supporting industries

The New Mexico Aerospace Cluster is part of a wider network, the New Mexico Partnership, which supports the economic development of the state through the growth of a number of key sectors: advanced manufacturing, aerospace & defence, digital media & IT, emerging technology, energy & natural resources, and value-added agriculture. The bridging activity carried out by this economic development agency allows for numerous inter-industry linkages which allow for new and innovative opportunities for the application of space innovation to other sectors. The growth of the space sector in the area is also fostered by the significant support deriving from the defence sector, which has traditionally had a strong presence in the area since the 1940s. The aerospace sector works in close cooperation with the agricultural sector, as the climate conditions of the area call for innovative techniques for cultivation: an example of this long-standing cooperation is represented by the Jornada Experimental Range, a research facility established in 1912 by the United States Department of Agriculture's Agricultural Research Service, which is today a cutting-edge site for the experimental application of UAS to agriculture.

The cluster's proximity to Mexico allows for easy connection with over 300 supporting maquilas, namely Mexican manufacturing companies that nurture the low-end segments of the value chain by providing raw materials, electronic components and so on: this outsourcing strategy allows the cluster to focus its manpower on the upper-end segments of the value chain. It will be interesting to study how the ecosystem of related and supporting industries will evolve following the evolutionary trend of the cluster towards specialisation in fields such as commercial spaceflight and UAS, whose long-term future perspectives leave a number of questions unanswered. It is also important to point out that the ecosystem of related and supporting industries suffers from the fact that the cluster does not participate to any international networks (as in the case, for instance, of the Toulouse cluster and BavAIRia, which are both members of the European Aerospace Cluster partnership). Furthermore, while the *Spaceport* constitutes a significant supporting infrastructure, the absence of a commercial

¹²³ "Maquila" is the Mexican name for the manufacturing firms that produce a wide variety of products, from electronics to automotive parts. Maquilas are involved in the so-called *Maquiladoras*, namely manufacturing operations in a free trade zone, where factories import material and equipment on a duty-free and tariff-free basis for assembly, processing and manufacturing, and then export the assembled, processed and/or manufactured products back to the country of origin.

spaceflight sector and its related and supporting industries causes the facility to operate at a loss, as its capacity is under-utilised.

Demand conditions

As in the case of Colorado Aerospace Cluster, the New Mexico cluster operates in an environment characterised by a large domestic market: aerospace and the space segment have large demand in the US, which widely benefits from public investment: large demand originates from the defence sector and the Air Force in particular, whose operations in the area have been a driver of growth of the sector since the 1940s. In addition, the US are the ideal place where to develop a commercial spaceflight sector: the latter is likely to be exclusively targeted to extremely wealthy people (according to estimates from Virgin Galactic, each flight would cost more than \$200,000 per person), and the US ranks first in terms of number of billionaires according to Forbes¹²⁴. The 540 US billionaires would likely constitute the main bulk of the demand for commercial spaceflight. The cluster also benefits from booming global demand for aerospace products and services, and for space-related innovation in general, thanks to the constantly increasing range of possible applications to other sectors. There is evidence of a large foreign demand (mainly from Mexico, Canada, Israel, China and Germany) for civilian aircraft components, but the long-term impact on an industry which is rapidly specialising in the space segment is still to be evaluated.

Notwithstanding the encouraging perspectives offered by the commercial spaceflight sector, the latter is still at the embryonic stage of its long development process, thus there is still wide uncertainty about the future of this segment. In addition, in this field the area has to face fierce domestic competition from Texas and Florida, regarded as more viable alternatives by companies operating in commercial space such as XCOR Aerospace and RocketCrafters Inc., which have recently decided to locate there some of its activities (for instance, the XCOR headquarters of its Commercial Space Research and Development Centre are in Midland, Texas). Furthermore, as for every other cluster in developed countries, New Mexico has to deal with the possibility that the vast share of the increasing world demand coming from Asia will be absorbed by emerging players in the area, thus relegating the cluster to play a marginal role in the future development of the global aerospace sector.

2.7 Emerging Clusters

The positive externalities resulting from the development of the national and local space industry, along with the future growth perspectives driven by the dramatic increase in terms of opportunities offered by the space sector, have recently led many countries outside the traditional circle to embark in the journey towards the 'new space economy' in an effort to follow the path traced by the world's traditional super powers. The globalisation of the aerospace value chain has represented a significant opportunity for developed countries to participate in the international space economy, and for developing countries to access state-of-the-art technologies by leveraging their own competitive advantage in terms of low-cost labour.

As a result, an increasing number of new players are entering the global aerospace arena, or strengthening their position within it. Their entry strategy often revolves around organising the local aerospace industry from a cluster perspective. In addition, the huge potential for job creation and access to technology calls for the development of tailored industrial policies to trigger and foster the

¹²⁴ <http://www.forbes.com/sites/katiesola/2016/03/08/the-25-countries-with-the-most-billionaires/6/#959ab9a461bd>

growth of a robust ecosystem. For these reasons, while aerospace clusters have traditionally sprouted thanks to the ‘gravitational attraction’ of the so-called *anchor firms*, the most recent cluster initiatives show in some cases a higher level of governmental involvement, whose driving force constitutes a key facilitating factor for the process, and allows to speed up the development process in order to reduce the gap between the new entrants and the traditional players. Notwithstanding the vital propelling role of government, evidence shows (such as the case of Costa Rica) how even the most recent cluster initiatives require an existing industrial structure to grow and develop.

This chapter illustrates some of the world’s most interesting recent phenomena with the aim of highlighting their distinctive features, their drivers and their success factors, in order to provide further up-to-date guidance for the potential implementation of an aerospace cluster in other contexts.

2.7.1 Costa Rica

As at 2011, the World Bank Group classified Costa Rica as the Latin-American country with the highest potential for innovation. As evidence thereof, 26% of national export consisted of high technology products, such as integrated circuits and computer components. Within this vital innovation ecosystem, the Government drafted the *Plan Nacional de Desarrollo 2010-2014* (National Development Plan, PND), a strategic framework which identified aerospace sector as one of the sectors that will drive the country’s development in the immediate future: space sciences in particular have been included among the strategic goals for innovation and competitiveness.

This declaration of intent was preliminary to further in-depth assessments aimed at promoting and mapping the national aerospace ecosystem. In 2013 the Costa Rica Foreign Trade Ministry (*Ministerio de Comercio Exterior*, COMEX), on behalf of the Government of Costa Rica, has commissioned the *Duke University Center on Globalization, Governance & Competitiveness* (Duke CGGC) to draft a report aimed at providing an overarching insight into the country’s role within the global competitive arena¹²⁵.

The report highlights the key features of the national aerospace industry in terms of composition, companies’ ownership, core activities, identification of local Original Equipment Manufacturers (OEM), possible sources of competitive advantage, facilitating factors (infrastructure and human capital), and potential trajectories for upgrade.

As of 2011, according to PROCOMER the number of Costa Rican firms operating in the aerospace sector amounted to 110, with over 4,000 employees. The Duke’s report applied stricter criteria: by counting only those firms operating in aerospace manufacturing and support services, the authors identified 29 firms (with some 2,000-3,000 employees). Furthermore, the majority of them were US-owned, 12 of them had been established since 2000 and, only two of them (Mechania Engineering and Ad Astra Rocket) were Costa Rican. The most mature companies in the sector operated in MRO (Maintenance, Repair & Overhaul) services, while recent entrants ‘focused on higher value services’ (software, design and engineering) which require a labour force with tertiary education. Due to the country’s inability to compete against countries with low cost of labour, Tier 3 and 4 manufacturers consequently shifted towards a high-quality/low-volume production framework. This choice brings the significant advantage of highly sophisticated products, but on the other hand it made the national industry unattractive to large-scale suppliers. In order to breakeven and to seek financial sustainability

¹²⁵ Penny Bamber, Gary Gereffi, *Costa Rica in the Aerospace Global Value Chain – Opportunities for Entry & Upgrading*, 2013

in the long run, these manufacturers diversified their sales markets by widening their production to other sectors (i.e. automotive, consumer electronics, medical devices), but this strategy has hampered the firms' capacity to internally develop specific sectorial *know how*.

Furthermore, the authors identified five critical issues as potentially detrimental to the development of a national aerospace industry:

- I. 'A relatively small labour force combined with competition with other established export-oriented economic sectors[...]': there is an evident excess of demand for skilled workers within the engineering and IT sector, while Multinational Corporations (MNC) tend to retain talent by setting up internal training programs.
- II. Entry of local firms is hampered by the shortage of financing sources and technological expertise.
- III. National infrastructure is outdated and is burdening the MRO business.
- IV. Domestic demand is insufficient to sustain national production. The neutrality of Costa Rica is considered as an additional source of disadvantage, as the absence of a national army means no defence spending.
- V. No commitment from lead firms to establish operations in Costa Rica.

As for the last critical issue, the report has identified the Costa Rican company *Ad Astra Rocket* as the potential 'anchor firm': the company has been providing sophisticated services to the aeronautic industry since 2005, and as of 2011 it constitutes the most important aerospace firm in the country. At the time it was carrying out the development of a plasma engine, as well as establishing liaisons with local suppliers and universities. The company is now carrying out the joint development of a new Variable Specific Impulse Magnetoplasma Rocket (VASIMR) in cooperation with their American branch. The implementation of a support network of SMEs was considered vital for the evolution of *Ad Astra Rocket* from a local OEM firm to a pivotal node of the future national aerospace industry.

On the other hand, the report glimpsed as many opportunities as the main strengths of the country's economy. Besides the well-established presence of MRO firms and the focus over high-quality components manufacturing, the leading role of Costa Rica in the field of renewable energies and the emergence of a florid software sector due to the boom in IT skills have brought these two sectors to stand out as the main driving forces for the development of the national aerospace industry.

Finally, the report stressed the necessity of an 'innovative industry growth strategy' in order to establish and maintain a presence within the global space sector.

This statement has been further pinpointed in a working document¹²⁶ drafted by the Consejo Nacional de Investigación y Desarrollo Aeroespacial (National Council for the Aeroespacial Research and Development, CONIDA), which provided the Government with a number of recommendations in order to develop an all-encompassing strategy structured around five pillars: academic, commercial, technic and technologic, legal, institutional and financial.

- I. *Academic*: in order to fill the gap between demand and supply of skilled workforce, the government was suggested to invest in national universities and create a number of specialised programs within the aerospace field. While developing national STEM (Science, Technology, Engineering and Mathematics) skills, another objective was to attract foreign talent by improving the international relations network.

¹²⁶ CONIDA, *Documento de Trabajo: Consideraciones para la Elaboración de una Política Pública que Impulse el Sector Aeroespacial en Costa Rica*, 2014

- II. *Commercial*: these guidelines involved attracting FDI and development of the national industry through the achievement of international certifications, and through the elaboration of a technological and commercial strategy.
- III. *Technic and Technologic*: this pillar stressed the relevance of Research & Development in the fields of aerospace materials, equipment and vectors, energy efficiency and renewable sources
- IV. *Legal*: the document recommended the subscription of those international agreements and treaties related to space, in order to stand out as a relevant interlocutor to the international community.
- V. *Institutional and Financial*: the involvement of all the relevant participants from a wide variety of sectors is considered vital for the development of the national space industry. Therefore it is of the utmost importance to build interconnections between the traditional elements of the triple helix model (Academia, Government and Industry), as well as civil society and financial system.

The guidelines have been carefully followed, thus leading to significant progress towards the upgrade of the national space sector. As a result of a targeted national strategy aimed at increasing the available skilled workforce and promoting its own country-specific sources of competitiveness (namely the optimal geographical position, the political stability and the business environment), in recent times Costa Rica has been experiencing a significant increase in Foreign Direct Investment (FDI) towards high technology sectors, including aerospace. On the other hand, this capital flow has had relevant influence on the morphology of the Costa Rican national aerospace industry, by consolidating the presence of MRO operators and by favouring the inception of a wide network of SMEs. Nonetheless, as of 2013 the lack of a local anchor firm was still evident and, despite the recent growth of *Ad Astra Rocket*, the process is yet to be completed nowadays.

2.7.1.1 The Costa Rica Aerospace Cluster

The *Costa Rica Aerospace Cluster* (CRAC) was officially launched on the 8th of March 2016, as a result of a process that formally dates back to 2014. In January of that year, Costa Rica hosted in San Jose the *Aerospace Meeting Central America*, an international business convention to 'bring together industry professionals' and organise 'customised meetings between OEMs and suppliers'¹²⁷. This event was fundamental in articulating the aerospace companies' common interest to cooperate for the growth of Costa Rican aerospace industry, whose exports in the year 2015 accounted for a total of US \$1,557 million according to the *Promotora de Comercio Exterior* (PROCOMER), the agency devoted to the promotion of the country's export.

*"We see business opportunities for this sector, in 2015 we exported more than \$1.5 billion in sectors associated with the aerospace industry, such as electronics, plastic, metal, etc. **But to be competitive the industry must join, unite talent, share good practices and promote the country**"*

~Pedro Beirute Prada, PROCOMER General Manager

Acknowledging this mutual interest within the sector, in 2015 PROCOMER began the identification activities to define the members of the cluster on the basis of the 2011 joint initiative *Mapeo*

¹²⁷ *Learning Expedition for the Aerospace Industry in Central and Latin America*, <http://www.bciaerospace.com/central-latin-america/elementsindex/download/leaflet-aerospace-costa-rica.pdf>

Aeroespacial with the *Instituto Centroamericano de Administración de Empresas* (INCAE) and the *Asociación Centroamericana de Aeronáutica y del Espacio* (ACAE), an assessment of the Costa Rican companies constituting the national aerospace sector. The cluster initiative has been conceived as an answer to the lack of ‘meaningful [inter-firm] linkages’¹²⁸ in the national industry.

The cluster, implemented by PROCOMER with the support of the *Instituto Tecnológico de Costa Rica* (ITCR) consists of 25 companies operating in various fields, and employing some. These companies are mainly Tier 3 and 4 firms, along with a number of service operators. These firms can be sorted into three categories according to their area of operations:

- **Entirely (mostly) Aerospace-Focused:** companies such as Ad Astra Rocket, Avionyx, Coopesa.
- **General Machine Shops:** e.g. Artemisa Precisión, Diez Olrich, Olympic Precision, Techshop International.
- **Components Manufacturers:** e.g. Irazu Electronics, L3 Communications.

It is important to highlight how the vast majority of the firms operating in the Aerospace manufacturing Global Value Chain and which are part of the cluster are US-based. Costa Rican companies - for instance Ad Astra Rocket, Artemisa Precisión, Coopesa, Techshop International, Tico Electronics - constitute a residual component.

In addition, the cluster involves other non-corporate strategic partners: academies, institutions and organisations. As for academies, the primary stakeholders involved are the *Instituto Nacional de Aprendizaje* (National Institute of Apprenticeship, INA), the *Instituto Tecnológico de Costa Rica* (Costa Rican Institute of Technology, ITCR) and the *Universidad de Costa Rica* (University of Costa Rica, UCR). The institutions involved are the *Cámara de Industrias de Costa Rica* (Chamber of Industries of Costa Rica, CICR), the *Dirección General de Aviación Civil* (General Directorate of Civil Aviation, DGAC), the already mentioned Promotora de Comercio Exterior (Promoter of External Trade, PROCOMER). Among the organisations we find the *Asociación Centroamericana de Aeronáutica y del Espacio* (Center-American Association of Aeronautics and Space, ACAE), the *Coalición de Iniciativas de Desarrollo* (Coalition of Development Initiatives, CINDE), and the *Instituto de Normas Técnicas de Costa Rica* (Institute of Technical Norms of Costa Rica, INTECO).

¹²⁸ Luiz Alagaráz, Andrey Barrantes, Evelyn Cooban, José Ernesto Pacas, Michael Pothius, *Condiciones y Oportunidades para el Desarrollo de la Industria Aeroespacial en Costa Rica*, INCAE, ACAE, PROCOMER, 2011

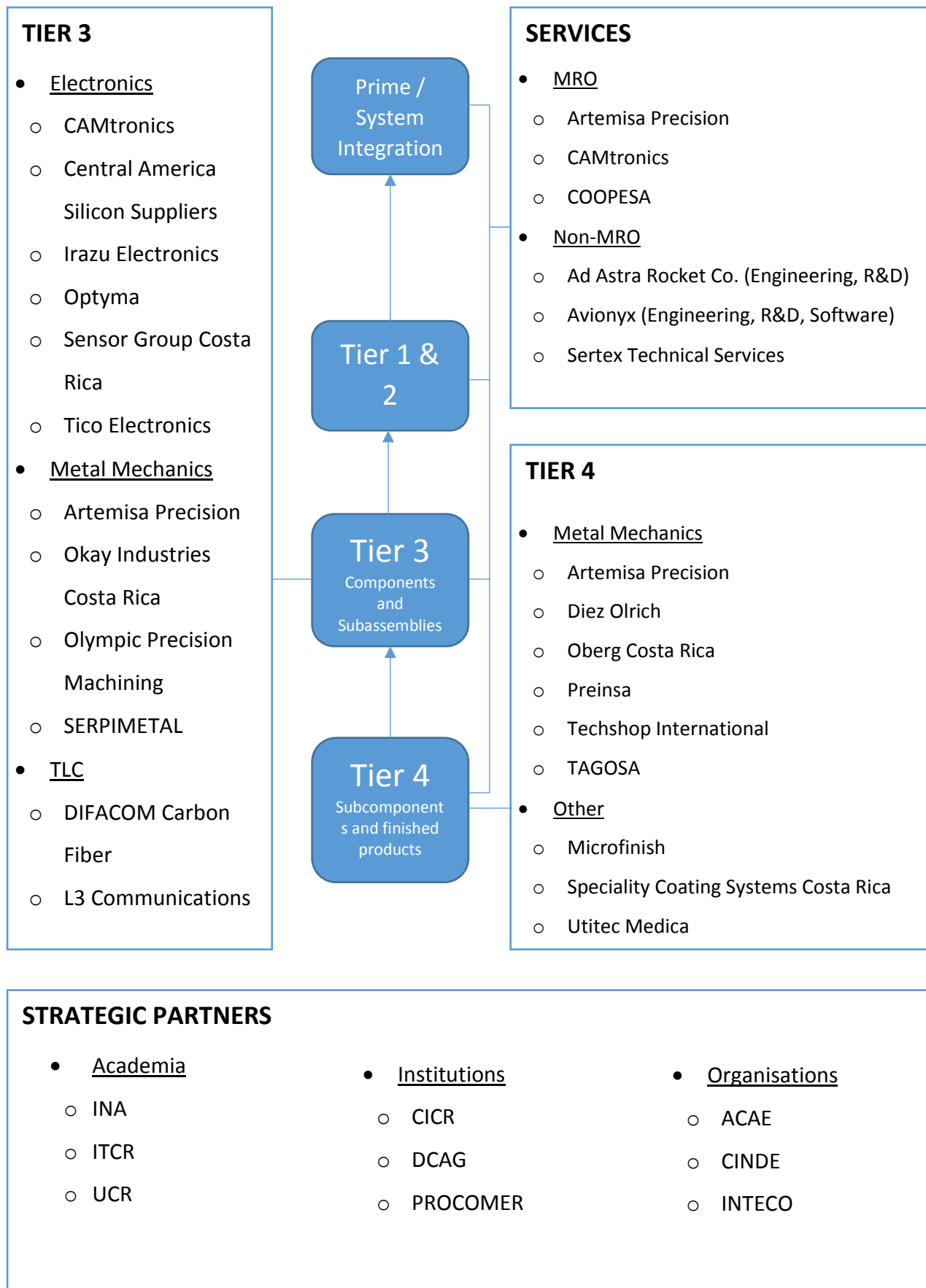


Figure 16: structure of the Costa Rica Aerospace Cluster. Source: author (using data from CINDE)

Cluster Analysis

A Porter's Diamond cluster analysis has been carried out in order to provide the reader with a detailed understanding of the Costa Rican distinctive features and conditions under which the aerospace cluster has been implemented. The figure below briefly summarises the features of the Factor Conditions, the Context for Strategy and Rivalry, the Demand Conditions, and the Related and Supporting Industries.

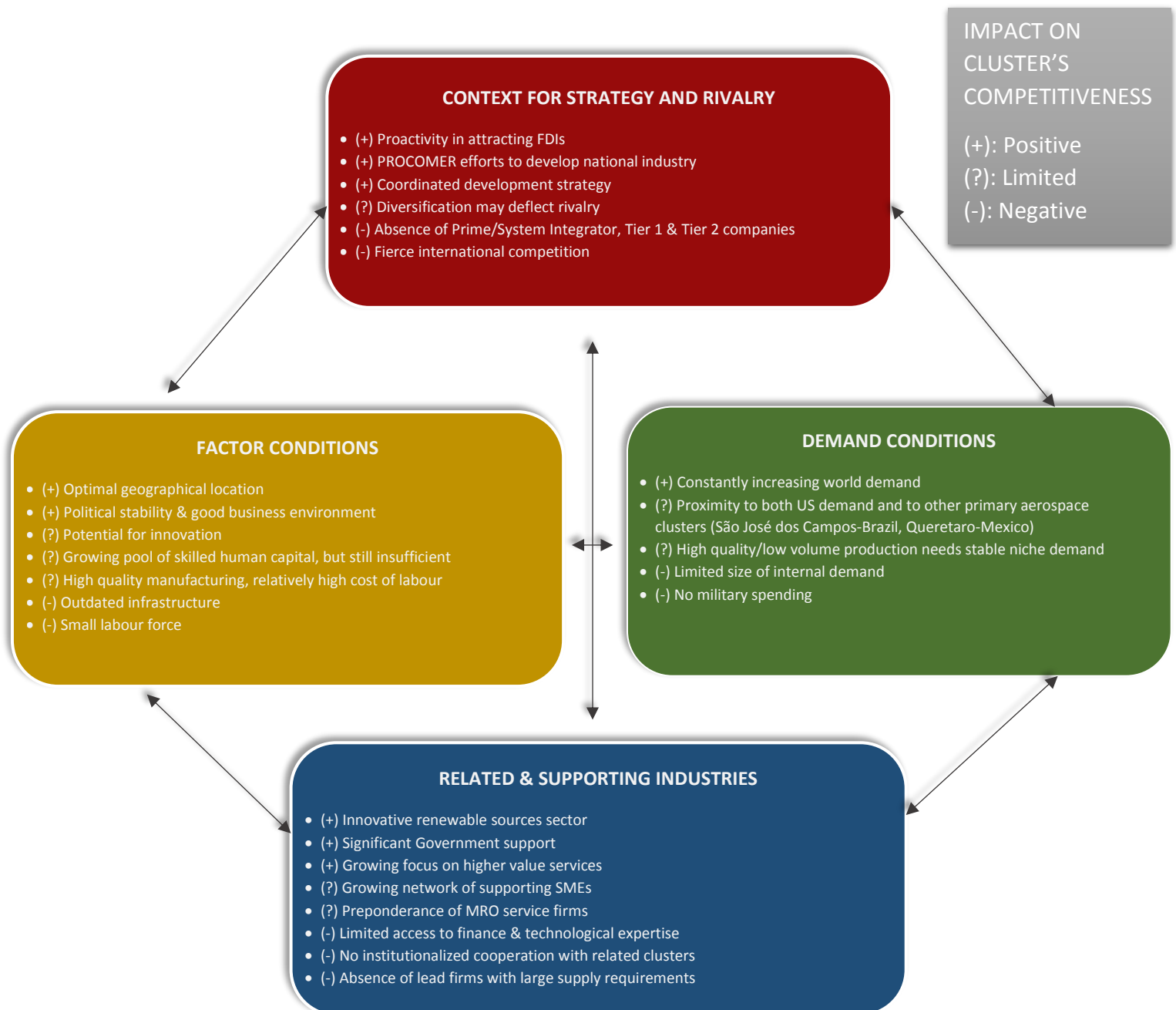


Figure 17: Porter's Diamond Analysis of the Costa Rica Aerospace Cluster. Source: author

Factor Conditions

Costa Rica benefits from an excellent position for space launches. The relatively small distance (around 1.000km) from the equator allows for heavier payloads to be launched (earth rotation impacts

additional velocity to the rockets) and it is easier to position satellites on the desired orbit. In addition, the wide presence of sea prevents any launch failures from causing significant collateral damage. Furthermore, the tropical climate allows rocket launches to be performed all year round in facilities located at similar distances and with similar climate conditions (e.g. the Centre Spatial Guyanais in French Guiana). The country is well renowned for its flourishing economic environment, its political stability and the high quality of life, to the point that it was given the nickname of the *Switzerland of Latin America*.

Among Latin countries, Costa Rica displays the highest potential for innovation: a relevant share (26%) of national export consists of high-technology products, and there is a burgeoning pool of highly skilled human capital in the fields of engineering and information technology. Nonetheless, the stock of human resources appears to be inadequate to the requirements necessary to fully exploit the country's potential and the opportunities offered by the space sector. In particular, the small size of the local workforce in absolute terms generates an excess of demand which reduces the dynamism of the labour market, thus hamstringing one of the main channels for knowledge spillover.

In terms of labour cost, Costa Rica exhibits a competitive disadvantage when compared to other players in the aerospace international arena. For this reason, the national manufacturing sector has been focusing on high quality products, at the expense of production volumes.

An element of concern is represented by the current state of the national infrastructure related to aerospace: the national aerospace economy mainly relies on MRO operations, but these firms need a significant update in terms of physical capital. This necessity is emphasised by a reduction in the number of Latin America clients due to mergers and the economic crisis.

Context for Strategy and Rivalry

Since 2007 the CINDE has been working proactively to attract Foreign Direct Investment in the national aerospace sector. At the same time (since 2006) PROCOMER has been carrying out a constant effort towards the development of Costa Rican aerospace sector through a number of initiatives (such as the mapping of local firms, or the establishment of CORAAL, namely a union of 6 firms to design and manufacture the platform AURORA for the Ad Astra plasma engine) which have had relevant impact in terms of system coordination. In addition PROCOMER takes credit for being the pivotal node of the cluster project, which has received fundamental contributions from other institutional players such as UNOOSA (United Nations Office for Outer Space Affairs), the Ministry of Foreign Trade and CINDE. The cluster is part of a broader coordinated national development strategy, which also included the foundation of the National Council on Aerospace Research and Development (CONIDA) by the Ministry of Science and Technology. As a result, the national industry has been provided with a network of inter-firm linkages that foster growth in the sector. A regulatory framework for strategic competition has thus been put in place, nonetheless some inner features of Costa Rican strategic environment represent a significant burden on the national space industry. Fierce international competition aside, the fact that manufacturers operate also in other sectors might deflect competition away from space-related activities, and there is an unsatisfied need for the presence of a large OEM company (Prime/System Integrator, Tier 1 or Tier 2). Both these factors hamper the innovation process as they prevent firms and workers from developing specific capabilities within a defined sector, thus reducing the potential for knowledge spillovers that are typically consistent in an aerospace cluster.

Related & Supporting Industries

Costa Rica is the undisputed world leader in the field of clean energy: in 2015 99% of the country's energy production came from renewable sources. Costa Rica is expected to become a world leader in the development of new propulsion systems, thanks to the transfer of its expertise in the fields of solar technology and biofuels to the aerospace sector (in particular astronautics), where renewable sources allow for new and encouraging opportunities in engine development.

The Government, in cooperation with other institutions, has provided relevant support in mapping and connecting related and supporting industries: it is possible to cite as an example the mapping of the aerospace industry carried out by PROCOMER, INCAE and ACAE, but it is worth mentioning the impulse to R&D deriving from government efforts (e.g. CONIDA). PROCOMER in particular has been fundamental in implementing and promoting the cluster initiative within and beyond the national borders, also by attending commercial events related to aerospace. In 2014 the city of San Jose hosted the AeroSpace Meetings Central America, in order to develop connections between MNCs and local firms. In addition, a number of initiatives (such as the PROPYME: '*Programa de Apoyo a la Pequeña y Mediana Empresa*', support program for the small and medium enterprises) have been set up in order to provide local related and supporting firms with the certifications needed to join the international aerospace market.

Costa Rican aerospace companies are increasingly focusing on higher value services, thus constituting a niche in the international competitive arena. This happened alongside with the recent blossoming of a network of aerospace-related and supporting SMES, which is yet to reach a mature stage. The preponderance of MRO service companies is not an issue *per se*, but the absence of large firms with high volumes of supply requirements constitutes an obstacle to the development of local supporting industries. Another burden, although presumably less oppressive, is represented by credit access: Costa Rica exhibits an efficient financial sector, but the latter has experienced some hardships in meeting the consistent capital requirements of aerospace industry, to such an extent that around two thirds of the main industries are foreign-owned. While foreign ownership facilitates the cluster's internationalisation, on the other hand foreign firms tend to retain their highest value segments in their country of origin, thus limiting innovation in the long run.

Demand Conditions

Despite the growing opportunities offered by the world markets, Costa Rican domestic demand is insufficient for absorbing a significant portion of the national production. But what is even more relevant is the fact that Costa Rica is a neutral country: the national constitution prohibits from having its own standing army. Since military spending has always constituted a relevant source of financing as well as being a key driver of innovation, Costa Rica shows a certain disadvantage when compared to other nations. Comparatively higher cost of labour has forced the industry to rely on high-quality production. This choice creates an imbalance between supply and demand, shifting contractual power towards the latter.

Furthermore, the country's position constitutes a double-edged sword: while on the one hand the proximity to the US and to other clusters (such as Queretaro in Mexico and São José dos Campos in Brazil) offers promising market and cooperation opportunities, on the other it poses some additional challenges in terms of international competition, as it puts the Costa Rican cluster in an environment characterised by strong and increasing competition from emerging players (in Latin America and Asia) that pursue an extremely aggressive commercial strategy on the international arena.

2.7.2 The IEF AERO Aerospace Cluster in Brittany

The IEF AERO aerospace cluster was founded in the year 2007 on the initiative of *Investir en Finistère - l'agence de développement économique finistérienne* (IEF), a regional development agency located in the Finistère department of Bretagne (Brittany) together with the vital involvement of the *Groupe des Industriels Français de l'Aéronautique Spatial Défense* (Group of French Aeronautics, Space and Defence Companies, GIFAS). The cluster was established after a two-year feverish *promotion and prospection* activity, which highlighted the beneficial effects of a system-wide coordination of the aerospace companies operating in the west-Brittany area. Such strategy was aimed at enhancing the stakeholders' visibility and facilitating long term partnerships, which were regarded as vital to the development of the Aeronautics-Space-Defence industry in West Brittany.

The cluster was established with the purpose of achieving the following objectives¹²⁹:

- Promote dynamics in ASD (Aeronautics/Space/ Defence Electronics) of the west Brittany region
- Represent member companies to major clients of the sector
- Bring together all ASD stakeholders of west Brittany to develop the ecosystem
- Help new ASD activities setup in the region.

These objectives are pursued through 7 missions¹³⁰:

- I. work in partnership with the GIFAS
- II. promote cluster expertise to all major clients of the sector
- III. foster the collaboration of joint answers to requests for quotation (RFQs) -IEF AERO is not meant to provide answers to RFQs
- IV. organize business events
- V. take part in ASD related conferences, symposia, congresses, tradeshow, etc.
- VI. organize workshops on ASD for the members
- VII. analyse and encourage potential joint development activities

Nowadays the cluster is comprised of 32 industrial members encompassing the whole supply chain. The composition of the latter is shown in figure 18. This aspect is particularly remarkable if we consider the relatively small size of IEF AERO when compared to other examples. In this regard, the presence of three Prime/Integrator companies was fundamental in attracting operators at lower segments of the value chain. The system is characterised by a strong support from the cluster's members (in particular from the two major defence companies DCNS and Thales), and by the coordination role of the agency *Investir en Finistère* and GIFAS. The firms directly employ more than 5000 people in the area, their total capital endowments exceed €860 million (>US\$954 million) and the aerospace revenue generated by the local system in the last year amounted to more than €7 billion (>US\$7.8 billion), accounting for roughly the 12% of the total French annual aerospace turnover. The numbers related to total employment are a reductive representation of reality due to the fact that, for some companies, the data is unavailable. As for the capital endowments and revenue, there is a heavy upward bias due to the unavailability of regional data on capital and turnover referring to Dassault Systems: the total endowments and the total aerospace turnover are thus to be regarded as heavily inflated and unreliable. A detailed map of the cluster members is provided in the annexes.

¹²⁹ <http://www.ief-aero.fr/Objectives-and-mission-216-0-0-0.html>

¹³⁰ Ibid.

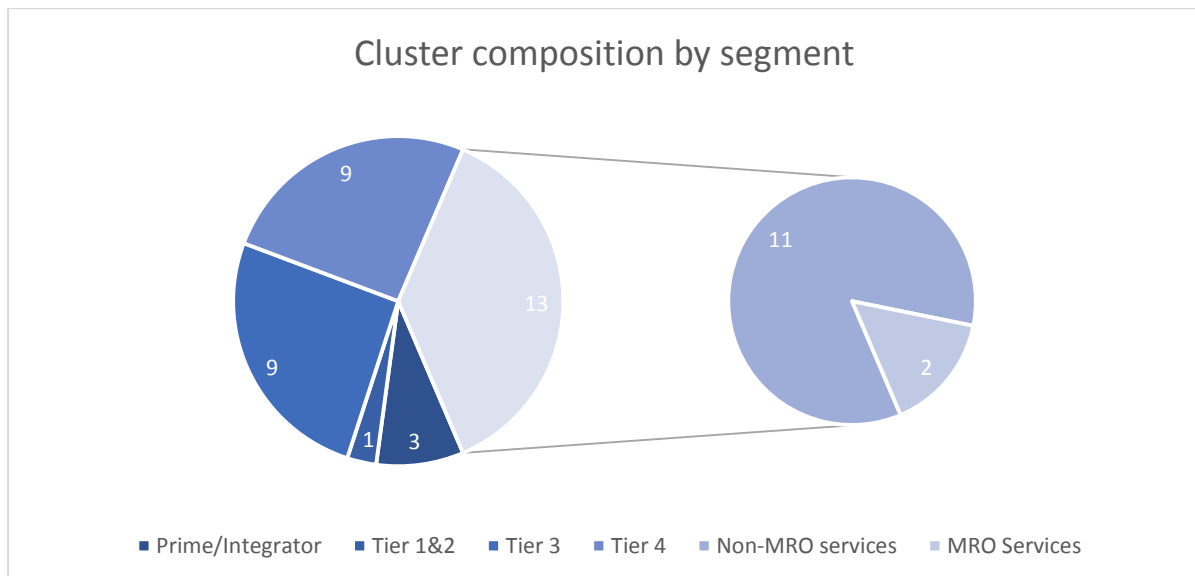


Figure 18: Cluster composition by segment. Author's elaboration based on data available on <http://www.ief-aero.fr/Industry-231-0-0-0.html>

The IEF AERO cluster exhibits the typical characteristics predicted by the triple helix model: besides the Industry, we can observe a substantial presence and involvement of Government and Academia.

With respect to Academia, the cluster members are: the *Centre Européen de Réalité Virtuelle* (European Centre for Virtual Reality, CERV), the *École Nationale Supérieure de Techniques Avancées* (National institute of Advanced Techniques, ENSTA Bretagne), the *Institut Supérieur de l'électronique et du Numérique* (Institute of electronics and digits, ISEN), the *Brest Département de génie mécanique* of the *Institut Universitaire de Technologie* (University Institute of Technology, IUT), the Lab-STICC research laboratory (a joint venture between TELECOM Bretagne and the University of Brest), the *Lycée des Métiers Aéronautique, Mécatronique, Sanitaire & Social*, TELECOM Bretagne (and its research centre), and the *Université de Bretagne Occidentale* (University of West Brittany, UBO). In addition *BRETAGNE VALORISATION*, a Technology Transfer Office dedicated to innovation, promotes the transfer of knowledge and technology from the 9 academic institutions in Bretagne to industry. Brittany is the 2nd region in France for digital R&D¹³¹.

Institutional multi-level support is granted by *Bretagne Développement Innovation* (regional agency for development and innovation, BDI), the municipality of Brest, the Chambers of Commerce and Industry of Brest, Morlaix and Quimper, the Department Council of Finistère, the Regional Council of Brittany, the *Délégation Interministérielle à l'Aménagement du Territoire et à l'Attractivité Régionale* (Interministerial Delegation for the Territorial Management and Regional Attractiveness, DATAR), the *Directions Régionales des Entreprises, de la Concurrence, de la Consommation, du Travail et de l'Emploi* (Regional Directorates for Enterprises, Competition Policy, Consumer Affairs, Labour and Employment, DIRECCTE), and *Space-Aero*, besides the aforementioned *Investir en Finistère* and GIFAS.

Since its foundation, IEF AERO has increasingly become a landmark for the establishment and development of high technology industries in Brittany, and nowadays it encompasses regional excellence in the field of virtual reality, electronics, software development, high precision machining, and composite materials. As a result, the cluster has developed a broad network of relationships with other sectors. This evolution has been channelled through the liaison with TELECOM Bretagne, which

¹³¹ Invest in Bretagne, 2016 brochure. Source: http://www.invest-in-bretagne.org/wp-content/uploads/2016/06/Bretagne_creative_competitive_2014_ENGLISH.pdf

has been endeavouring to preserve its leading edge position in the field of turbocodes. In order to do so, TELECOM developed industrial partnerships which eventually resulted into the establishment of PRACOM, a joint cluster of industrial companies & research entities. The company is also one of the main members of NEWCOM, the European research Network of Excellence in Wireless Communications. Thanks to the strategic involvement of TELECOM within IEF AERO, the cluster benefits from a direct channel with a wide spectrum of related and supporting industries.

Despite the limited dimension of IEF AERO when compared to other major aerospace clusters, the presence of major players such as TELECOM, Thales and DCNS, as well as the support received from GIFAS have been identified as paramount¹³² to the successful establishment of the cluster and to the strengthening of its strategic positioning in the competitive arena.

Cluster analysis

The following diagram depicts the IEF AERO cluster analysis within the Porter's Diamond framework. This picture intends to provide a detailed insight into the inner features of the cluster, as identified under the standard four perspectives of the diamond analysis framework.

¹³² Céline Barredy, Isabelle Dostaler, Nathalie Gardes and Corinne Gourmel-Rouger, *Aerospace Clusters and Competitiveness Poles: A France-Quebec Comparison*, 2015

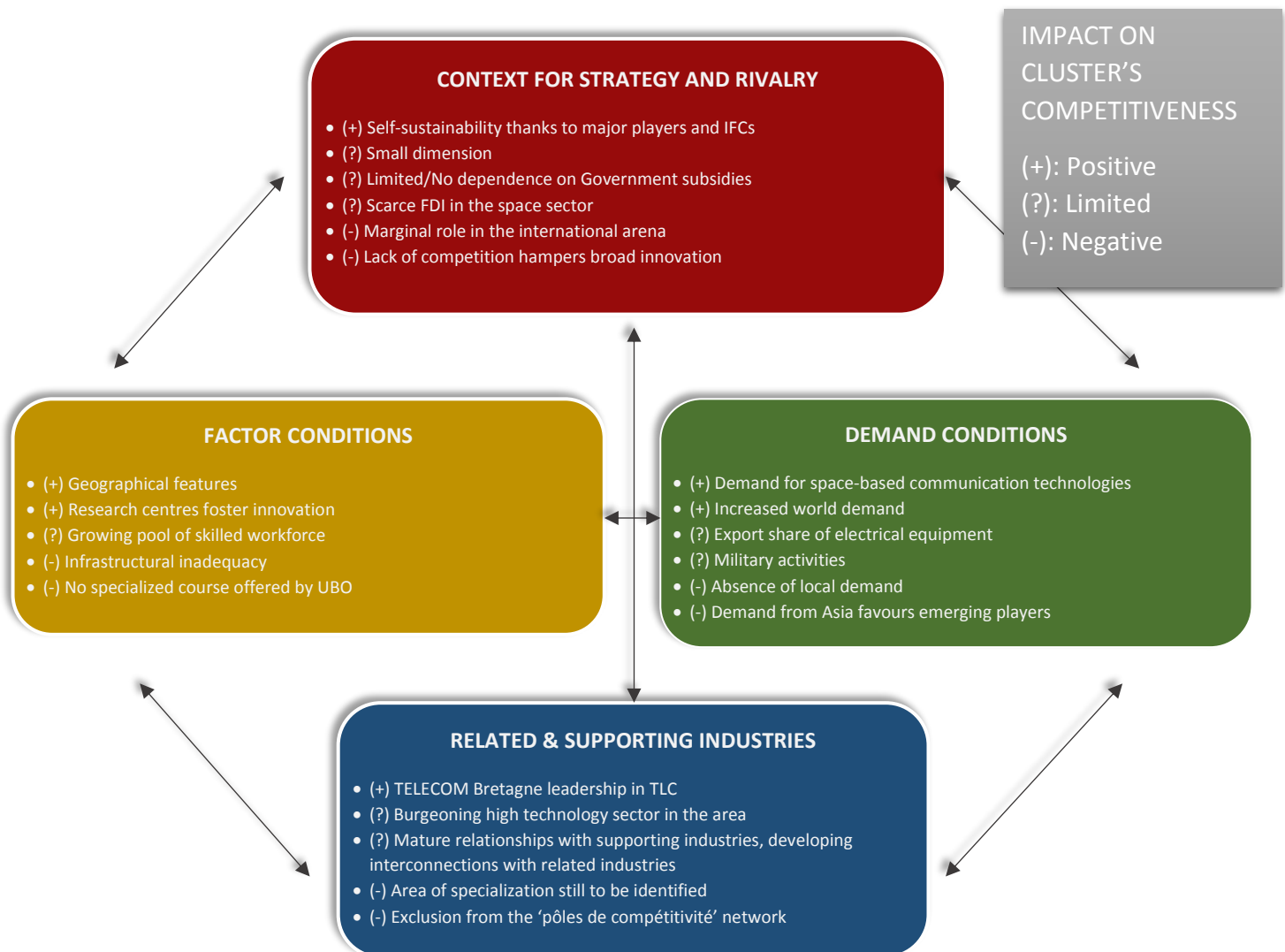


Figure 19: Porter's Diamond Analysis of the IEF AERO aerospace cluster. Source: author

Factor Conditions

In its favour, the IEF AERO cluster has some relevant geographical features: it is mainly concentrated in a single, narrow district (Finistère) with a number of direct accesses to the sea, thus making it easier to transport large components and subassemblies via barge: the territorial cohesion and the attitude towards cooperation constitute an added value to the local factor conditions. Furthermore, the cluster benefits from its proximity to other primary aerospace clusters, such as Harwell (UK) and the Toulouse Aerospace Valley. The cluster includes some 10 research centres (both academic and private) with disrupting technologies and world-class expertise: the vast majority of the cluster's potential for innovation lies in their hands. In addition, the presence of such institutions has made a significant contribution in the increase of the pool of skilled workers with tertiary education: for instance, as of 2016 46% of graduates from TELECOM Bretagne worked in Brittany¹³³ (they constituted 11% in 2013¹³⁴). The data referring to the year 2016 also shows a 19% salary increase in the last 5 years, and 80% of the graduates were employed within 3 months from graduation. On the other hand, two major

¹³³ *Le premier emploi des ingénieurs de Télécom Bretagne - Telecom Bretagne engineers : entering the job market, 2016 survey*

¹³⁴ *Telecom Bretagne engineers : entering the job market, 2013 survey*

sources of concern must be mentioned: the University of Western Brittany (UBO) offers no specific PhD courses in space science, and the regional infrastructure (airports, launching sites, communications) shows a certain degree of backwardness which fails to be justified by the small dimensions of the cluster.

Context for strategy and rivalry

As highlighted by Barredy et al.¹³⁵ the coordination activity carried out by *Investir en Finistère* and GIFAS and the presence of prime contractors such as Thales and DCNS have created optimal conditions for the self-sustainability of the cluster by attracting small and medium suppliers from various segments of the supply chain, albeit in limited numbers. Besides representing an optimal condition for the development of a joint strategy at the cluster level, this aspect constitutes the undisputed major achievement of the cluster, although it has one relevant drawback: the small number of participants and their distribution over the whole supply chain is detrimental to local rivalry and international competition. In addition, the region of Brittany is an appealing destination for foreign direct investment, but aerospace activities attract an almost irrelevant share of them. In 2014 FDI in the aerospace sector employed a total of 3 people in 1 plant¹³⁶. This evidence contrasts heavily with an overall positive trend that sees Finistère as the second district in Brittany as for FDIs, with a share of the 24% over the total inbound investments which are mainly concentrated in SMEs.

What is worth noting is that IEF AERO has not become the target of any major national industrial policies, as opposed to the development plan carried out by the French government for the Aerospace Valley. Whilst this aspect has enhanced the cluster's independence, on the other hand a national support might leverage its unique assets. The cluster is not featured among *the Pôles de Compétitivité* (see figure 6).

Related and supporting industries

The presence of the *Grand École TELECOM Bretagne* has become the catalyst for the development of a significant number of related industries in the TLC sector, thanks to the school's leadership in this field. As an induced effect, the area has seen the growth of a burgeoning high added value technologies industry thanks to the usual positive externalities stemming from the growth of Aeronautics-Space-Defence (ASD) activities involving the development of specific infrastructure, human resources and knowledge. At the same time the cluster is enhancing its interconnections with related industries, with the purpose of increasing the supply chain diversification and therefore the intra-cluster competition, as well as establishing and strengthening relationships with other aerospace clusters both inside and outside Europe. This evolution is of the utmost importance, as the lack of significant intra-cluster competition among supporting industries hampers the cluster's potential for innovation and prevents it from competing adequately on the international landscape. The cluster is still on its way towards identifying an area of specialisation, but the most interesting opportunities seem to arise from the sectors of composites and polymers, as well as the already mentioned TLC sector.

Demand conditions

As for the demand conditions, IEF AERO faces the same opportunities and challenges as the Aerospace Valley, but their intensity is obviously amplified by the cluster's dimensions and its more recent establishment, as they somehow hinder it in having access to a broader and consolidated demand.

¹³⁵ Céline Barredy, Isabelle Dostaler, Nathalie Gardes and Corinne Gourmel-Rouger, *Aerospace Clusters and Competitiveness Poles: A France-Quebec Comparison*, 2015

¹³⁶ Invest in Bretagne, *Les investissements internationaux en Bretagne*, 2014

The cluster's world-class expertise in TLC allows for some extremely interesting opportunities deriving from the growth in the demand for space-based communication services, besides the already analysed economic opportunities offered by the overall growth in the world demand for space-based products and services in general. In addition, the district of Finistère is widely export-oriented, with a high share of foreign demand for high-technology electrical equipment (10%, source: Invest en Bretagne). The significant and constantly increasing bulk of defence-related expertise could make a significant contribution to the economic performance of the cluster, but it needs increased effort and investment from the Government in the further development of the national defence industry. The cluster aims to strengthen its position in the national market and its international orientation as the region's internal demand is insufficient.

3. Conclusions – Implementing an Aerospace Cluster in South Australia

The analysis carried out so far allows us to draw some conclusions about the key features that determine the competitiveness and innovativeness of aerospace clusters. By combining the empirical evidence illustrated in the previous section with the theoretical specifications of the Porter's Diamond model we are now able to outline a unifying framework that serves as a general theory of aerospace clusters.

From a schematic comparison of the Porter's Diamonds pertaining to each one of the clusters analysed in chapter 2, it becomes apparent which elements of the four dimensions play a crucial role in determining the success of an aerospace cluster under the twofold perspective of competitiveness and innovativeness. This comparison, broken down into the usual four dimensions of the model, is synthesised in Figure 20 and constitutes the basis for a more analytical approach adopted in this chapter.

Factor Conditions

The comparison of the clusters' Factor Conditions gives some interesting outcomes. *Firstly*, it appears that **infrastructural endowments** are critical to the success of an aerospace cluster: facilities such as roads, railways, airports, ports, TLC infrastructure and so on allow for the exchange of knowledge and resources, and their high capacity is essential in preventing the formation of bottlenecks where congestion can hamper economic activity. The ability to transfer components, subassemblies and finished products of large dimensions with ease - as well as to provide related services within short timeframes - is particularly valuable in the aerospace sector, where efficiency is essential and is mainly guaranteed through *just-in-time* production processes. As high tech clusters heavily rely on knowledge and information, an adequate TLC infrastructure is needed to ensure rapid information flows. *Secondly*, since the aerospace industry is mostly based on disruptive technology, **highly skilled human capital** becomes of the utmost importance as it constitutes the original source of innovation. Furthermore, not only is the quality of human capital important, but also its size (which must be adequate to the dimension of the cluster) and, most importantly, its availability. Proximity and concentration (without congestion), which constitute a central element of the general cluster theory, in the specific case of aerospace clusters become relevant ancillary factors in that they foster knowledge transmission among individuals, firms and players, triggering knowledge spillovers and cross-fertilisation that ultimately result in enhanced potential for innovation and unique sources of competitiveness. Last but not least, every single cluster taken into account sees the key involvement of **universities of excellence and world-class research institutions**. Their role goes way beyond the simple presence in the area, as they actively partake in the innovation process and provide a qualified labour force through dedicated programs. The empirical evidence thus contradicts one of the theoretical conclusions drawn by Niosi and Zhegu¹³⁷: the latter suggested that *"in aerospace the role of universities and laboratories is secondary. They may appear late or not appear at all within the regional system. Aerospace corporations may attract these institutions [...] or change them"*. While there is wide agreement concerning the second statement (the analysed clusters were not established as a result of an incubation process of firms within academia) our evidence suggests that the active involvement of academia is probably the main driver of the clusters' innovativeness and competitiveness, and it is also a common determinant of success in every case analysed.

¹³⁷ Jorge Niosi, Majlinda Zhegu, *Aerospace Clusters: Local or Global Knowledge Spillovers?*, 2005

Context for strategy and rivalry

As for the common characteristics of the Context for Strategy and Rivalry the most outstanding feature that is worth highlighting is the crucial role covered by the presence of at least one **Institution For Collaboration** (IFC) which is able to provide the cluster with a common strategy that embraces its ecosystem as a whole, coordinating the actions and the interactions of the players belonging to the three spheres (Industry, Government, Academia), as well as managing the strategic interaction of the cluster (intended as a unitary entity) on the international landscape. The IFC fosters the establishment of given companies and provides an institutional framework that addresses rivalry towards the most productive direction. The inception of a wide and deep network of companies also follows some “natural” dynamics that derive from the presence in the cluster of one or more **anchor firms**. The single major contractor is capable of attracting specific firms that can meet its input requirements at the different stages of the value chain. The larger the number of anchor firms (and also the wider their array of activities), the wider the variety of supplying companies in the cluster. An **adequate level of government involvement** is also a key driver of competitiveness: while a marginal role of the public sector deprives the industry of a relevant funding source for long-term investment, a heavy public intervention constitutes a burden to the cluster’s operational flexibility, especially when such involvement exerts excessive influence in the hands of the public sector. Governmental involvement is beneficial when it does not weigh down the decisional structure and the strategic interactions of the cluster, when it takes the form of indirect intervention through easy access of public infrastructures, systemic industrial policies, industrial incentives for entrepreneurship and tax benefits for R&D activities. In addition, our evidence shows that another element beneficial to the Context for Strategy and Rivalry is the ability to attract relevant amounts of **Foreign Direct Investment** (FDI). This is a major driver for the inception of companies, bringing to the local district some very specific technologies and expertise, especially in the case of FDI deriving from large multinational companies. Finally, the participation of a cluster in **international programs** (for instance the ESA missions) triggers the strategic interaction among specific research institutions, companies in the upper-end segments of the value chain and their suppliers, also favouring the inception of spinoffs, joint ventures and partnerships within the cluster.

Before moving forward, one particular element must undergo further discussion: the evidence illustrated in this report suggests that there is no such thing as an optimal extension of the value chain. The analysed clusters exhibit varying degrees of value chain extension without significant differences in terms of competitiveness and innovativeness. One reason for this discrepancy may be found in another classic concept of Porter’s theory of competitive advantage, namely the dichotomy cost leadership/product differentiation. By comparing the cases of Bangalore and BavAIRia our analysis has shown that the clusters’ economic activity embraces the entirety of the value chain, even if the two clusters exhibit some significant differences in their factors. As already stated in the previous chapter, the Bangalore Aerospace Cluster is the evolution of a once manufacturing district that has internally developed activities in the higher segments of the chain thanks to the low cost of the labour factor. BavAIRia could not rely on such inexpensive factor but, on the other hand, its long-standing tradition in the aerospace sector allowed the local industry to develop unique expertise and *know-how* at every level, resulting in the delivery of a high-quality, heavily differentiated product-service mix. From a theoretical viewpoint Bangalore implemented a *cost leadership* strategy, while BavAIRia leveraged on *differentiation*. Such different strategies led to the common result that the two clusters were able to retain and develop industrial segments throughout the whole chain. The extension of the value chain is not a source of competitive advantage in absolute terms: those clusters which do not exhibit neither a low cost of labour nor a long-standing tradition (and thus expertise) in the sector cannot compete at every level of the chain, thus they have focused over the upper segments of it, seeking competitive

advantage in product/service innovation by leveraging on their highly skilled human capital and their cutting-edge R&D activities.

Related and supporting industries

The comparison of the features pertaining to the dimension of the Related and Supporting Industries suggests that, coherently with the theory, the establishment of **interconnections** is paramount for the cluster's activity and impact. Interconnections with other aerospace clusters generate channels for knowledge spillovers, information exchange and opportunities for collaboration, thus increasing the cluster's potential for innovation. From a similar perspective, integrating in the supply chain clusters operating in other industries constitutes an exceptional way of extending the positive externalities generated by the aerospace cluster beyond the sectorial boundaries. **Inter-sectorial cluster linkages** leverage the potential for local socioeconomic development by dramatically increasing the already significant indirect and induced impact generated by aerospace clusters over local economies. Building interconnections in the form of partnerships with clusters operating in other countries falls under the wider sphere of **internationalisation**: this multifaceted feature embraces a wide array of meanings, ranging from access to international markets to the presence of international agreements for collaboration with other aerospace clusters in specific projects (such as in the case of Harwell with the ESA project Rosetta) and the ability to establish new ones, as well as the implementation of and participation to common platforms for cooperation and knowledge exchange, or even the ability to attract and retain foreign talent. Throughout its history the aerospace sector has widely benefitted from internationalisation (e.g. the International Space Station) as the products and services delivered are international by their very nature. The size of the initial investment, the nature of the products and services offered, the benefits of cooperation and knowledge exchange, and the increasing need for outsourcing make aerospace clusters an inherently international phenomenon.

Specialisation in given segments of the aerospace value chain triggers the development of a network of specific related and supporting industries, thus allowing for enhanced opportunities for collaboration that lead to the joint development of extremely innovative products and services, possibly in a wide variety of sectors, where space-derived innovation is pivotal. As explained earlier, specialisation is typical and particularly evident in those space clusters of more recent inception (e.g. Lombardia, Colorado, Costa Rica): empirical evidence shows in fact that those clusters that cannot rely on cost leadership (due to low cost of labour) or diversification (due to an internal expertise still far from reaching a sufficient degree of maturity) tend to specialise in high-end segments of the value chain and seek for competitive advantage through the development of extremely specific and innovative products and services. The analysis carried out for the single clusters was characterised by the *leitmotif* of the fundamental **support from the research sector**, which usually exhibits high levels of interconnection with aerospace clusters due to the exceptional opportunities of cross-fertilisation and the mutual exchange of highly skilled human capital. An actively involved research sector that supports the cluster - by providing knowledge, human capital and facilities to develop groundbreaking innovation - is the main driver of innovativeness and competitive advantage in the dimension of Related and Supporting Industries.

Demand conditions

Moving to the Demand Conditions, each one of the clusters considered operates in an extremely dynamic environment where there is clear evidence of a large and increasing **global demand**, both for innovation and aerospace products (in particular for aircrafts and space-related technologies): it is therefore of the utmost importance to have in place all the conditions necessary to attract the highest share possible of this demand. All the clusters analysed exhibit, in addition to an outstanding potential for innovation, a **high degree of orientation towards international markets**, as witnessed by the fact

that a large share of their turnover is generated by exports. On the other hand all these clusters face the threat constituted by the **emerging players** in the aerospace sector: these are mainly located in the Asia-Pacific region, an area which will originate about one third of the forecasted global demand by 2030. Such emerging players are clearly going to attract the lion's share of this increase in demand mainly thanks to geographical proximity to its sources. In order to preserve the local dimension of the positive externalities generated by aerospace clusters it is important to safeguard and nurture the **domestic demand** for aerospace products, services and innovation. With reference to this aspect a great contribution derives from the **defence sector**: its strong presence among the demand conditions often constitutes a stable and reliable source of revenue, inputs for innovation through benchmarking, internationalisation, cross-fertilisation and knowledge spillovers, and the high level of confidentiality that characterises the cluster-defence relationships often protects innovation from imitation and appropriation by competitors.

		FRANCE	GERMANY		INDIA	ITALY	UK	USA	
		Aerospace Valley	BavAIRia	LR-BW	Bangalore	Lombardia	Harwell	Colorado	New Mexico
FACTOR CONDITIONS	Geomorphological characteristics & location			NA		NA			
	Universities and Research Centres								
	Infrastructures								
	Skilled Human capital								
	Ecosystem for innovation and entrepreneurship	NA	NA		NA		NA		
	Availability of financing						NA		
	Proximity and Concentration							NA	NA
	Know-how and expertise					NA			
	Cost of labour		NA	NA			NA	NA	
CONTEXT FOR STRATEGY & RIVALRY	Active role of IFCs								
	Adequate Level of Public Intervention								
	National and System-level strategy	NA						NA	NA
	Incentives		NA	NA					
	Presence and diversification of anchor firms		NA		NA				
	Network of specialised suppliers	NA						NA	NA
	Foreign Direct Investment			NA				NA	NA
	Extension of the value chain			NA					NA
	Involvement in International Programs			NA	NA				
RELATED & SUPPORTING INDUSTRIES	Interconnections with clusters in other sectors								
	Interconnections with other aerospace clusters			NA	NA				
	Membership in Broader networks								NA
	Large pool of suppliers			NA	NA	NA	NA	NA	NA
	Specialisation	NA	NA	NA	NA				
	Support from Research Sector	NA							
	Internationalisation				NA	NA	NA	NA	
	Smart Outsourcing Strategies	NA		NA	NA	NA	NA	NA	
DEMAND CONDITIONS	High Demand for Innovation				NA				
	Increasing World Demand and ability to attract it								
	Threat of emerging players								
	Domestic civil demand					NA			
	Relevant demand from Defence Sector	NA							
	Large Export	NA						NA	

Figure 20: matrix comparison of the clusters' diamonds. Source: author

LEGEND



Positive Conditions



Limited Conditions



Negative Conditions

NA

Not Available/Not Relevant

Opportunities for South Australia

Nowadays the aerospace industry faces continuous growth, and the space segment is undoubtedly the main driving force of this phenomenon. Through its enhanced integration of the three spheres of the triple helix model, space constitutes a paramount source of technological advancement, innovation, socioeconomic development and, ultimately, human progress.

This report provides strong evidence about how industrial clusters turn out to be particularly effective in enhancing the potential for innovation of the local industry, by building an all-encompassing network of players from the different spheres that is able to leverage the cluster's performance at every level. After having thoroughly identified the key success factors that determine the clusters' competitiveness and innovativeness, one major question arises: given the extraordinary positive impact generated by an aerospace cluster, what are the opportunities and the future perspectives for South Australia in this field?

In recent times, South Australia has experienced sustained socioeconomic growth, arising as a key player in the international competitive landscape: the state is progressively becoming a hub of innovation, and the local space sector is leading the way in the development of a space economy for the nation as a whole. Nowadays, the spectrum of possible civil applications of space-related innovations is larger than ever, with fields such as agriculture, energy, environmental control, telecommunications and national security widely benefitting from the opportunities offered by the groundbreaking technologies that the thriving aerospace sector develops every day.

South Australia is poised to take advantage of this trend, exhibiting significant capabilities across a wide range of segments. Furthermore, the state offers a complex and vibrant ecosystem that encompasses innovative companies, universities and research institutions. The state is home to around 60 players from the three spheres of Academia, Government and Industry, with space-related expertise and the potential to apply such expertise to the space sector.

Private companies in the area include major contractors (Tier 1 and 2) such as Airbus Defence & Space, BAE Systems, Boeing, Lockheed Martin, Raytheon and Northrop Grumman Australia, and other world-class aerospace multinational companies have shown interest in establishing their presence in the state in the near future. The presence of these operators has gradually attracted small and medium-sized companies that now partake in the supply chain by providing products and services in a wide array of subsegments. In this respect, South Australia is also home to companies that underwent striking development in the last decade: the professional service provider Nova Systems, established in 2000 and headquartered in South Australia, has now become a well renowned company in the international landscape, with more than 400 employees and offices all over the world. It is also worth mentioning the relevant presence in the area of the Space Industry Association of Australia, which has long been carrying out remarkable advocacy activity. The association promotes the national space sector by fostering knowledge share among its members and assisting them in carrying out their business, as well as voicing their interests at the institutional level. This activity would most likely turn out to be essential in the potential organization of the local aerospace industry according to a cluster approach¹³⁸.

¹³⁸<http://www.defencesa.com/upload/Space%20Capability%20Directory%20FINAL.%20V.2%20as%20at%2029%20August.pdf>

The vibrant industrial ecosystem is not the only asset of South Australia. The state offers an excellent academic environment, hosting three local universities (University of Adelaide, University of South Australia and Flinders University) and three international universities (University College London, Carnegie Mellon University and Torrens University Australia). In addition, the Southern Hemisphere Space Studies Program is held annually in Adelaide as a result of the partnership between the University of South Australia and the International Space University. South Australian academia is further enriched by the presence of world-class research institutions such as the Defence Science and Technology Group (DSTG): this government agency carries out cutting-edge research and development activity in the field of innovation and technology for national security. The agency bridges the demand expressed by the Australian Defence Force and the supply offered by the state's research organisations and private companies.

Space research activity in South Australia is mainly carried out by local universities, which are equipped with state-of-the-art research infrastructures, (for instance, the University of Adelaide's wind tunnel). In this respect, local university would provide the highly skilled human capital needed in the space sector: according to Asia Pacific Aerospace Consultants Pty Ltd¹³⁹, around two thirds of the workforce employed in the space industry holds a tertiary qualification (bachelor degree or higher).

It is also worth mentioning the increasing involvement of Government departments, such as Investment Attraction SA, DEWNR (Department of Environment, Water and Natural Resources) and the Department of Defence. In particular, a feverish activity of stakeholder engagement and industry advocacy is currently being carried out by Defence SA, the South Australian government agency operating in a number of defence-related fields, with a dedicated office for **SA Space Industry and R&D Collaboration**: the office aims to increase awareness about the strategic importance of the space industry, developing a plan to build a 'national hub of space industry, research and development' in the state, and strengthening international cooperation in high-tech industry and R&D in South Australia. The agency is actively involved in the promotion of the local space economy through the establishment of "space industry and R&D collaboration" with both interstate and international stakeholders. For this reason, Defence SA has developed the "*Space Innovation and Growth Strategy South Australia: Action Plan 2016-2020*", a multi-year innovation and growth strategy specifically aimed at invigorating South Australia's innovation ecosystem: to achieve this goal the agency is establishing a Space Council to voice the interests of its stakeholders from the three spheres, implementing a *Space Hub* to promote the space economy and spur collaboration among research organisations, universities, government departments, private consultancies and private companies in order to leverage the state's potential for innovation, and mapping the South Australia's capabilities and expertise in the space sector. Figure 21 shows the mission and vision of the *SA Space Industry and R&D Collaboration office* and illustrates the synopsis of the *Space Innovation and Growth Strategy South Australia: Action Plan 2016-2020*.

¹³⁹ Asia Pacific Aerospace Consultants Pty Ltd, *A Selective Review of Australian Space Capabilities: Growth Opportunities in Global Supply Chains and Space-Enabled Services*, 2015

*"QUOD INVENIAS EXPLORANS
SPATIUM PROGRESSUS EST
HUMANITATIS"*

"HUMAN PROGRESS IS IN SPACE EXPLORATION"

MISSION AND VISION

The Office of SA Space Industry and R&D

Collaborations aims to support space industry growth, and encourage international collaboration between industry, researchers and educational institutions operating within the space sector in SA.

Specifically:

- ▶ Increase awareness of the strategic importance of space applications to Australia and South Australia including their relevance to a range of industries (i.e. national security, advanced manufacturing, telecommunications, agribusiness, environment, position navigation and timing, ICT etc.)
- ▶ Develop a plan to build a 'National Hub of Space Industry, Research and Development' in South Australia where high tech industry, universities and research organisations are actively involved in a vibrant innovation ecosystem.
 - ▶ Strengthen international cooperation in high tech industry and R&D in South Australia to enhance high-quality knowledge and stimulate the commercialisation of research results.

SPACE INNOVATION AND GROWTH STRATEGY

– Action Plan 2016 – 2020

The key direction, mission and actions of the new office are articulated within the [South Australia Space Innovation and Growth Strategy - Action Plan 2016 to 2020](#).

The strategy's vision is to create a "space enabled economy" where the space sector in South Australia advances to become an important area of growth, giving rise to job creation with an increased market share in areas not traditionally linked to space.

Three pillars support the strategy:

- ▶ Growing South Australia's economy through space activity
- ▶ Invigorating South Australia's space innovation ecosystem
- ▶ Engaging international cooperation with lead countries

Growing the economy through space activity	Invigorating South Australia's space innovation ecosystem	Engaging international cooperation with lead countries
<i>Space industry - an opportunity to stimulate South Australia's economy</i>	<i>Consolidate and stimulate the capabilities and expertise, and strengthen the commercialisation of research results in the space industry</i>	<i>Develop a network of strategic partnerships in the space sector</i>
Space Hub Promoting the space economy through increasing awareness of the innovative possibilities within the space sector. Encouraging investment and collaboration within the industry.	Space Capability Directory Map capabilities and expertise in South Australia. Space Hub To promote STEM activity in the South Australian education system.	Missions and Overseas Delegations To promote State Missions led by Ministers or the Premier to countries that have notable space activity with the aim of facilitating international partnerships, agreements and joint activities.
SA Space Council To represent research organisations universities, private enterprise and government to provide a forum to discuss innovative ideas and new approaches.	Space Hub To spur collaboration among the South Australian researchers and entrepreneurs in the areas of applied research and commercialisation of research results.	International Astronautical Congress - Adelaide 2017 To promote and facilitate the involvement of South Australian stakeholders on the global stage.

Figure 21: Space Innovation and Growth Strategy South Australia – Action Plan 2016-2020

In recent times Defence SA has been proactively engaging with the local stakeholders: the South Australian Space Capability Directory 2016¹⁴⁰ represents an exceptional map of the South Australian ecosystem from the multidimensional perspective of the triple helix model, and might constitute a primary driver for the future inception of an industrial cluster in the area. Finally, testimony to the increasing importance of South Australia in the international landscape is the fact that the state will host the International Astronautical Congress (IAC) in 2017. This event is expected to provide further impulse to the already high interest for cooperation from North American and European Companies, which are increasingly looking at South Australia as an optimal destination for their foreign direct investment.

With respect to the theoretical framework utilised so far, it is worth mentioning that South Australia exhibits many of the elements of the Porter's Diamond model that our analysis identified as crucial for the success of a cluster initiative in the aerospace sector. South Australia is the only state in Australia that has developed its own space strategy for the development of the local space sector. The *Space Innovation and Growth Strategy South Australia: Action Plan 2016-2020* identifies the key direction, mission and actions needed to create a 'space-enabled economy' in South Australia, articulated around the following three pillars:

- I. **Growing South Australia's economy through space activity:** the space industry constitutes an excellent stimulus to the economy of South Australia, and is crucial for a number of sectors such as communications, environmental monitoring, mapping and monitoring, and gives strategic contribution to other priority sectors, namely national security, agriculture, mining and tourism. In order to fulfil this purpose the strategy includes a) promoting the space economy by increasing awareness of the endless possibilities within the space sector and encouraging investment and collaboration; and b) constituting a 'SA Space Council' to represent all organisations (private companies, universities, research organisations and government) and coordinate their action.
- II. **Invigorating South Australia's space innovation ecosystem:** this pillar intends to foster interconnections among industry, university and research sector to trigger endogenous growth in the state. This purpose is achieved by mapping the capability of South Australia (through the Space Capability Directory), promoting and encouraging space-related STEM activities within the local education system, and by fostering knowledge transfer among researchers and entrepreneurs in applied research and commercialisation of research outcomes.
- III. **Engaging international cooperation with lead countries:** this pillar aims at enhancing the South Australia's competitiveness in the international landscape through the market-oriented development of technologies that can encourage foreign investment, as well as attracting entrepreneurs, talent and researchers. Internationalisation will be achieved by both promoting South Australia around the world through Ministerial missions and by bringing the world to South Australia, as in the case of the International Astronautical Congress which will be held in Adelaide on September 2017.

A vital part of this newly established strategy is the implementation of the *Space Hub'*, whose key moment is represented by the South Australian Space Forum, a series of periodical events aimed at facilitating collaboration among researchers, entrepreneurs, academics, teachers, private consultancies and public employers in South Australia's space sector, with the aim of encouraging

¹⁴⁰<http://www.defencesa.com/upload/Space%20Capability%20Directory%20FINAL.%20V.2%20as%20at%2029%20August.pdf>

growth and innovation within the space economy in the state. This Space Forum has been initiated by the SA Space Industry and R&D Collaborations team and is a key action of the implementation of a *Space Hub* within the *Space Innovation and Growth Strategy South Australia – Action Plan 2016-2020*. The first Forum was held in Adelaide on the 27th of May 2016. The second *Forum* will be on the 10th of November 2016. Two other events have been scheduled for 2017, approximately in May and September.

The desired outcomes of the Space Forum are to:

- Encourage the exchange of information and latest industry developments, and identify potential opportunities and areas of growth.
- Promote the commercial application of research results and new technology.
- Assist research organisations to identify industry needs for specific innovations or new technologies.
- Identify future areas of demand by the space industry for specific, highly skilled human capital, and work with educational bodies to ensure that needs can be met, in particular within specific STEM pathways for primary and secondary schools.
- Provide a platform for South Australian stakeholders to promote latest developments and potential opportunities in the space sector to interstate and international investors.

The strategy developed by Defence SA is absolutely consistent with the theoretical outcomes of our analysis: it puts particular emphasis on key concepts such as the role of academia, the need for highly skilled human capital, the focus over innovation, the importance of coordination among the different players within the industry at every level, and the development of the international dimension of the space industry.

As suggested by the Space Capability Directory developed by Defence SA to ‘*invigorate South Australia’s space innovation ecosystem*’, the state already hosts some international major contractors that would likely constitute the anchor firms of the cluster, as well as some relevant players in the sphere of academia that would provide support and enhance the potential for innovation through higher levels of integration. In addition, should then cluster be implemented, such contractors would benefit from improved linkages with the lower-tier companies already operating in the area, which form a differentiated ecosystem of suppliers.

South Australia benefits from favourable geomorphological characteristics: flat landscapes and a relative proximity to the equator provide good conditions for aerospace-related testing activities, and a major boost to these from the potential reopening of the Woomera Test Range to civil activities (nowadays is used exclusively for military purposes). In addition, the scattered population over a vast territory constitutes an interesting bulk of internal demand for space-related systems that provide telecommunication services, environmental monitoring, emergency response and support to agriculture.

The SCD has highlighted the presence of a number of associations and government agencies which provide industrial advisory (SIAA), attract investment (Investment Attraction SA) and carry out an outstanding coordination role (Defence SA): these players would provide great contribution to the establishment of an actively involved IFC that manages a formally constituted cluster with a unitary strategy. As evidenced, the presence of such institution is vital for the competitiveness of a cluster in the global arena. Finally, from a thorough analysis of the SCD it is straightforward to identify a spectrum of space-related subsegments in which South Australia has developed unique expertise, and thus may constitute interesting areas of specialisation for the cluster: such fields include ICT,

telecommunication, sensors, intelligence surveillance and reconnaissance, nanosatellites, and environmental control.

Above all, the greatest source of competitive advantage for an aerospace cluster in South Australia, when compared to the clusters analysed in this report, is constituted by the state's geographical position and commercial relations. Thanks to its proximity to the Asia-Pacific region, South Australia is able to attract relevant shares of the constantly increasing demand for aerospace-related products and services expressed by Asian countries, and the traditionally good commercial relationships with countries such as China and India offers interesting opportunities of engagement with the emerging players in the area.

Annexes

Annex 1: IEF AERO Cluster map

COMPANY	EMPLOYEES	CAPITAL	AEROSPACE REVENUES	TIER	OTHER
ACTRIS	10	€ 40,500.00	€ 238,000.00	nonMRO services	electronic engineering
ACTUAPLAST	75		€ 8,400,000.00	4	plastic components
AFU	20	€ 270,000.00	€ 2,000,000.00	3	Precision Engineering Mechanical
AODE ELECTRONICS	15	€ 100,000.00		4, (non)MRO services	
BREIZH	15	€ 200,000.00		4	Precision Engineering Mechanical
BRETAGNE CHROME				Services	
CEPA SAS				3,4	Electronics
CEQUAD	40	€ 176,000.00	€ 7,000,000.00	3	Electronics
CRT MORLAIX	8		€ 430,000.00	nonMRO services	Engineering
DAILYQUALITY	1	€ 5,000.00		nonMRO services	Constultancy
DASSAULT SYSTÈMES	32	€ 117,866,151.00	€ 1,783,000,000.00	nonMRO services	software
DCNS	3000	€ 560,000,000.00	€ 2,800,000,000.00	Prime/MRO services	Integrator/MRO
ELLIDISS TECHNOLOGIES	3	€ 7,600.00	€ 200,000.00	nonMRO services	software
ELLIPTIKA	2	€ 20,000.00		nonMRO services	Research
EUROP3D	6	€ 55,000.00	€ 1,010,000.00	3	conception/machining
FLORIAN MADEC COMPOSITES	5	€ 8,000.00	€ 600,000.00	4	composites
HOP1-TRAINING	43	€ 1,035,488.00	€ 5,600,000.00	nonMRO services	aeronautics formation centre
INEO	50	€ 809,504.00	€ 90,000,000.00	3, nonMRO services	TLC
INSTITUT MAUPERTUIS	10		€ 400,000.00	nonMRO services	R&D, Training, technological advice
INTERFACE CONCEPT	36	€ 283,256.00		3	Electronics
KANTEMIR		€ 261,000.00		3	Precision Engineering Mechanical
KERPONT INDUSTRIE	33		€ 3,500,000.00	2	
LE GUELLEC TUBES	35	€ 565,500.00	€ 4,500,000.00	4	Mechanics
MICROSTEEL	65	€ 1,332,606.00	€ 10,824,793.00	4	
NOVATECH TECHNOLOGIES	215	€ 1,500,000.00	€ 31,000,000.00	Prime	Integrator
OCAM	20			4	Wiring
PROTECNO	55	€ 216,000.00	€ 1,800,000.00	3	Electronics
SMM TECHNOLOGIES				4	Composites
STACEM	154	€ 345,000.00	€ 13,500,000.00	4	polymers
THALES	1000	€ 184,445,120.00	€ 2,500,000,000.00	Prime	
THALES MICROELECTRONICS	450			3	Electronics
VIRTUALYS	10	€ 15,000.00	€ 513,000.00	nonMRO services	Data mining
TOTAL	5408	€ 869,556,725.00	€ 7,264,515,793.00		

Figure 21: IEFAERO cluster map. Author's elaboration based on data available on <http://www.ief-aero.fr/Industry-231-0-0-0.html>

List of Abbreviations

ACAE	Asociación Centroamericana de Aeronáutica y del Espacio
AECI	Airbus Engineering Centre India
AFSPC	Air Force Space Command
ASA	German Aerospace Academy
ASD	Aeronautics, Space and Defense
ASI	Agenzia Spaziale Italiana
AVA	Aerodynamische Versuchsanstalt
BDI	Bretagne Développement Innovation
BDLI	German Aerospace Industries Association
BW	Baden-Württemberg
CAGR	Compound Annual Growth Rate
CECOMPI	Centro para a Competitividade e Inovação do Cone Leste Paulista
CERN	European Organization for Nuclear Research
CERV	Centre Européen de Réalité Virtuelle
CGGC	Center on Globalization, Governance & Competitiveness
CIAR	Canadian Institute for Advanced Research
CICR	Cámara de Industrias de Costa Rica
CINDE	Coalición de Iniciativas de Desarrollo
CIT	Corporate Income Tax
CLF	Central Laser Facility
CNES	Centre National d'Etudes Spatiales
CNM	Central New Mexico Community College
CNR	Istituto Nazionale delle Ricerche
CNRS	Centre National de la Recherche Scientifique
CNSA	Chinese Space Agency
COMEX	Ministerio de Comercio Exterior
CONIDA	Consejo Nacional de Investigación y Desarrollo Aeroespacial
CRAC	Costa Rica Aerospace Cluster

CSA	Canadian Space Agency
CSC	Colorado Space Coalition
CSU	Colorado State University
CTNA	Cluster Tecnologico Nazionale Aerospazio
DARA	Deutsche Agentur für Raumfahrtangelegenheiten
DATAR	Délégation Interministérielle à l'Aménagement du Territoire et à l'Attractivité Régionale
DEWNR	Department of Environment, Water and Natural Resources
DFL	Deutsche Forschungsanstalt für Luftfahrt
DGAC	Dirección General de Aviación Civil
DIRECCTE	Directions Régionales des Entreprises, de la Concurrence, de la Consommation, du Travail et de l'Emploi
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DoS	Department of Space
DSTG	Defence, Science and Technology Group
DVL	Deutsche Versuchsanstalt für Luftfahrt
e.V.	Eingetragener Verein - German registered association
EACP	European Aerospace Cluster Partnership
EC	European Commission
ELDO	European Launcher Development Organisation
ENAC	<i>École Nationale de l'Aviation Civile</i>
ENMU	Eastern New Mexico Community College
ENSTA	École Nationale Supérieure de Techniques Avancées
ERAU	Embry Riddle Aeronautical University
ERDF	European Regional Development Fund
ESA	European Space Agency
ESF	European Social Fund
ESO	European Southern Observatory
ESRO	European Space Research Organisation
EU	<i>European Union</i>
FDI	Foreign Direct Investment

GDP	Gross Domestic Product
GEO	Geostationary Earth Orbit
GfW	<i>Gesellschaft für Weltraumforschung</i>
GIFAS	Groupement des Industries Françaises Aéronautiques et Spatiales
GLCF	Credit and Financing Group
GLF	Formation Group
GLMI	Marketing & Internationalisation Group
GLSC	Supply Chain Group
GNSS	Global navigation Satellite System
GVC	Global Value Chain
HAL	Hindustan Aeronautics Limited
IAC	International Astronautical Congress
IAP	Integrated Applications Promotion
ICT	Information and Communications Technology
IEF	Investir En Finistère
IFC	Institution For Collaboration
INA	National Institute of Astrophysics
INA	Instituto Nacional de Aprendizaje
INAF	National Institute of Astrophysics
INCAE	Instituto Centroamericano de Administración de Empresas
INTECO	Instituto de Normas Técnicas de Costa Rica
ISA	Israel Space Agency
ISAE-SUPAERO	Institut supérieur de l'aéronautique et de l'espace
ISEN	Institut Supérieur de l'électronique et du Numérique
ISRO	Indian Space Research Organisation
ISS	International Space Station
ITCR	Instituto Tecnológico de Costa Rica
IUT	Institut Universitaire de Technologie
JAXA	Japanese Space Agency
KUM	Karnataka Udyog Mitra

LAC	Lombardia Aerospace Cluster
LEO	Low Earth Orbit
LR BW	Luft- und Raumfahrt Baden-Württemberg
MIC	<i>Market Intelligence Commission</i>
MNC	Multi-National Corporation
MoU	Memorandum of Understanding
MRO	Maintenance, Repair and Overhaul
NACA	National Advisory Committee for Aeronautics
NAL	National Aerospace Laboratories
NASA	National Aeronautics and Space Administration
NEEF	<i>Not (engaged) in Education, Employment or Training</i>
NEREUS	Network of European Regions Using Space Technologies
NMT	New Mexico Tech
NRC	National Research Council of Canada
NTAF	Nilakantan National Trisonic Aerodynamic Facility
NTS	Nucleo Tecnico Scientifico
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
ONERA	Office National d'Études et de Recherches Aérospatiales
OSSA	OSTIM Defence and Aviation Cluster
PND	Plan Nacional de Desarrollo
PROCOMER	Promotora de Comercio Exterior de Costa Rica
PROPME	Programa de Apoyo a la Pequeña y Mediana
PTS	Piano Tecnologico Scientifico
PTS	Piano Tecnologico Scientifico
R&D	Research and Development
RAeS	Royal Aeronautical Society
RFQ	Request For Quotation
SA-SCD/SCD	(South Australian) Space Capability Directory
SIAA	Space Industry Association of Australia

SMDC / ARSTRAT	U.S. Army Space and Missile Defense Command / Army Forces Strategic Command
SME	Small-Medium Enterprise
SpA	Societa' per Azioni
SPC	Strategic Positioning Community
STEM	Science, Technology, Engineering, Mathematics
TLC	Telecommunication
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle
UBO	Université de Bretagne Occidentale
UCCS	Universities of Colorado Colorado Springs
UCR	Universidad de Costa Rica
UK	United Kingdom
USA	United States of America
USNORTHCOM	U.S. Northern Command
USSR	Union of Soviet Socialist Republics
VASIMR	Variable Specific Impulse Magnetoplasma Rocket
VAT	Value Added Tax
VC	Venture Capital
WSTF	White Sand Test Facility

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