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Strategies for the sky: A comparative analysis of the use of knowledge sources in Italian aerospace SMEs and large enterprises

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1. Introduction

In today's world, technological progress is advancing at an unprecedented pace, and this phenomenon in turn helps to foster even more rapid innovations. In other words, technological progress triggers a virtuous cycle in which each discovery paves the way for further advances, fostering a dynamic environment of continuous improvement and discovery.

This progressive cycle is particularly evident in the aerospace sector, which is at the forefront of technological evolution. Indeed, it is a high-technology industry, subject to rapid technological advancement because of its ever-increasing applications. As a result, aerospace companies are constantly pressured to innovate and adapt to technological progress in order to remain competitive and not be excluded from the market. Thus, the aerospace sector represents a suitable ground for investigating the dynamics that shape companies' Research and Development (R&D) decisions and the motivations that drive them.

This study seeks to draw attention to some of these dynamics with the aim of highlighting the main differences that differentiate large companies in the sector from Small and Medium Enterprises (SMEs), especially with regard to the use of external knowledge sources and the right balance between exploratory and exploitative activities. In fact, the unique characteristics of the industry cause companies to frequently resort to the use of collaborations both with other companies in the industry and with relevant universities and research institutions. These collaborations, along with other open innovation frameworks, shape the aerospace sector, making it a very interesting area to study companies' use of external knowledge sources. For this reason, this thesis seeks to understand the differences in the use of external sources of knowledge by SMEs and large companies in the sector, attempting to reveal the main objectives pursued by companies when engaging in external collaborations. In addition, the characteristics of high technological content and rapid advancement of innovation imply constant attention to the latest technological developments, or else the risk of rapid obsolescence of one's production. In this regard, this thesis also questions the possibility of reconciling exploration and exploitation activities in companies with a more limited resource endowment. In fact, the simultaneous pursuit of exploration and exploitation activities implies a great amount of effort and a great expenditure of resources for companies. However, an engagement on both fronts makes it possible to stay abreast of technological development in the industry while at the same time exploiting the firm’s present competencies and technologies and ensuring a commercial return. Thus, we examine whether SMEs with limited resource endowments prefer an organizational ambidexterity-oriented strategy or a one-sided strategy focused either on exploration or exploitation.

To answer these questions, this thesis uses information gathered through a series of interviews with representatives of six companies, three SMEs and three large firms in the Italian aerospace landscape. The content of these interviews was analyzed using a Grounded Theory approach, which allowed the development of a sufficiently complete picture of the R&D strategies adopted in the Italian aerospace industry, which can be used as a lens through which to interpret the strategic choices of companies, large and small. Thus, the results obtained from this thesis shed light on the strategies adopted by companies to navigate the virtuous circle of technological progress, offering a roadmap for navigating the complex and dynamic aerospace landscape.

In detail, the following thesis opens with a detailed literature review that discusses firms 'use of internal and non-internal knowledge sources and their difficulties in balancing exploitation and exploration activities. Based on these contributions, two research questions are then developed. This is followed by an updated analysis of the aerospace industry and a section dedicated to the methodology that was followed throughout the study. Finally, the thesis closes with the presentation and discussion of the results and an attempt to answer the initial research questions by interpreting the new information that emerged from the analysis.

2. Literature Review

2.1 The nature of innovation

Present-day literature is unanimous in identifying the role of innovation as a key factor in the process of economic growth. Technological progress enables the introduction of new processes, products, and services, increasing productivity and market competitiveness on a large scale. This dynamism enables a process that continuously reshapes industries, helping to promote progress and creating a cycle of prosperity.

2.1.1 Innovation as a driving force of economic development

The relationship between economic growth and technological progress has been intuitively articulated at least since the time of Adam Smith. In his famous work "The Wealth of Nations" (1776), Smith argued for the possibility that productivity gains could emerge from specialization achieved through the division of labor or through technological improvements. For this reason, as early as 1776, Smith stressed the importance of technological progress for economic growth. Over the years, innovation and its importance to the economy have been addressed by numerous researchers. Among the economists who made innovation their preferred area of practice, one of the most influential was Joseph Schumpeter. His reputation as the *prophet of innovation* can be traced back to his several attempts to explain the workings of the economy largely in terms of innovation (McCraw, 2007). In his work, Schumpeter tried to explain the cyclical pattern of the economy based on the major technological innovations of the time (1939). He suggested that the first long cycle of economic development had been based on the spread of the steam engine and textile innovation that occurred in the latter part of the 18th century; the second cycle had been made possible by the spread of the railways and technological changes in mechanical engineering and the steel industry; and finally, the third cycle had been enabled by the diffusion of electricity, the internal combustion engine, and the chemical industry. Schumpeter's focus on technological progress is evident in two other important works, namely "The theory of economic development" (1911) and "Capitalism, Socialism and Democracy" (1942). The author builds his ideas around the concept of *creative destruction*, which he identifies as the engine of economic growth in the capitalist world. This concept, in fact, describes how economic performance is driven by the process of innovation that simultaneously allows for the creation of new economic opportunities and the destruction of obsolete ones (1942). In other words, innovation is the driving force that leads to the continuous creation of new enterprises and industries while causing the disappearance of others. This incessant innovation that characterizes capitalist systems means that products, services, and processes are always at risk of becoming obsolete and disappearing from the market. It therefore follows that, to guarantee the survival of firms and enterprises, they must be able to adapt their processes, products and services to new technologies and innovations in order to remain competitive on the market. And it is here that Schumpeter's theory allows us to emphasize the importance for companies to invest in the area of R&D, as this type of investment is crucial for keeping the company abreast of the latest technological innovations and thus to remain in the market (Freeman, 2004). This is extraordinarily evident today. Companies, especially those employed in high-tech sectors where technological progress is very fast, must rely heavily on R&D to ensure that their products and services do not become obsolete. This area has thus, in just a few decades, gone from being placed on the periphery of corporate agendas to becoming the center of growth strategies. Nowadays, companies are facing a *Schumpeterian renaissance*, with innovation being identified as the driving force behind effective competition and economic development (Freeman, 2003). Thus, the topic of innovation is particularly interesting and pertinent today, which is why it was selected as the focus of the following research.

2.1.2 The evolution of technological process: paradigms and trajectories

To better understand how companies interface with and adapt to technological innovation processes, it is important to understand how these take place. There are numerous scholars who have described technological progress as an evolutionary process, in that at any given time there is a wide variety of efforts aimed toward the advancement of technology, which are to some extent competing with each other (Dosi and Nelson, 2014). With his concept of *creative destruction*, Schumpeter (1942) had already described an evolutionary process dictated by the destruction of obsolete technologies and enterprises and the emergence of new and innovative ones. There later followed many other contributions from scholars who also framed technological development similarly. Among these, one of the most interesting theories is that proposed by Giovanni Dosi (1982), who developed a framework for the analysis of innovation processes based on the concepts of technological paradigm and technological trajectory. Dosi (1982) builds his thinking on the basis of a parallelism with the concept of scientific paradigm introduced by Kuhn (1962) and defined as the conceptual and methodological framework that guides a scientific community at a given historical moment[1]. It makes it possible to identify what problems are relevant to the scientific community and proposes resolution schemes for those problems. According to Kuhn (1962), science progresses to a stage of *normal science* as long as scientists operate within the established paradigm, attempting to solve problems through the established conceptual and methodological framework. However, within a certain paradigm, anomalies can emerge and multiply. When a new paradigm emerges which can explain the anomalies encountered, a scientific revolution may occur, causing the old paradigm to be replaced by the new one. The dynamic with which the author describes scientific progress makes it evident that this is not so much a linear and cumulative process, but rather one marked by revolutions and paradigm shifts. According to Dosi (1982), the nature and procedure of technology work similarly to those of science. Therefore, he identifies technological paradigms that function similarly to those of science (Dosi and Nelson, 2014). They, too, allow to identify operational constraints on prevailing practices and problem-solving heuristics that are considered most promising. These are cognitive frames shared by engineers in a given field that influence what they think they can do for the advancement of a technology (Constant, 1980 cited in Dosi and Nelson, 2014). The technological progress that occurs within a paradigm is referred to as a technological trajectory (Dosi, 1982). The latter can thus be defined as a pattern of normal problem-solving activity[2] on the ground of a technological paradigm (Dosi, 1982). In analogy with Kuhn's normal science, technological trajectory also defines a series of incremental innovations based on previous progress (Dosi, 1982). The innovation process thus has a characteristic of cumulativeness, due to the fact that new innovations build on previous ones. However, the technological process in Dosi's model (as well as the scientific process in Kuhn's) proceeds by alternating stages of continuity and discontinuity. Continuous change is, as mentioned, related to progress along a technological trajectory defined by a technological paradigm. Discontinuities, on the other hand, are caused by the emergence of a new paradigm in response to limitations that cannot be resolved by incremental progress[3].

[1] A scientific paradigm is a set of beliefs, values, techniques and methods that are shared by a community of scientists working in a particular field of study. This includes accepted theories, laws, hypotheses, models, experiments and tools that shape the foundation for research and comprehension in that field.

[2] The activity of problem-solving defines progress within a certain technological paradigm

[3] A paradigm shift can also be a consequence of the interplay of economic factors, institutional variables, political or social changes.

2.2 Firms' adaptation to technological innovation

Assuming that economic growth has an evolutionary trend driven by the relentless proceeding of technological innovations, it can be concluded that it is crucial for enterprises to effectively adapt to new technological paradigms that emerge and fit into the innovative trajectory. It is therefore critical to the survival of the firm that it be able to reconfigure and integrate its internal and external sources in such a way as to adapt to changes in the industry in which it operates.

2.2.1 The importance of dynamic capabilities

The ability of the enterprise to adapt to changes in the environment has been linked in the relevant literature to the so-called dynamic capabilities. (Teece, Pisano, Shuen, 1997). The introduction of the concept of dynamic capabilities has allowed further articulation of the resource-based view of the firm, the conceptual framework that seeks to explain how firms can achieve competitive advantage based on their resources (Eisenhardt and Martin, 2000). Indeed, when a firm's resources have the characters of value, rarity, inimitability, and non-substitutability, the so-called VRIN attributes, then the firm will be able to gain a competitive advantage over other firms in the industry (Barney, 1991; Nelson, 1993). Dynamic capabilities make it possible to explain how such competitive advantage is maintained in very dynamic markets, where rapid change necessitates the manipulation of knowledge resources (Teece, Pisano and Shuen, 1997; Grant, 1996). In fact, in these kinds of markets, dynamic capabilities allow one to "*integrate, build, and reconfigure internal and external competencies to address rapidly changing environments*" (Teece, Pisano and Shuen, 1997 p. 516).

In detail, dynamic capabilities enable the firm to adapt effectively to the rapidly changing environment through three main components:

- perception capability, through which the firm conducts market analysis and identifies new trends in technology;
- acquisition capability, namely, the ability of the enterprise to acquire external resources and develop internal ones (through the introduction of new technologies, training of personnel, creation of partnerships);
- transformation capability, that is, the adaptation and reconfiguration of its internal resources (e.g., through product and process innovation, organizational restructuring, etc.).

So, the dynamic capabilities of the enterprise are crucial for it to recognize the presence of new technological trajectories and thus adapt effectively to them.

2.2.2 Responding to new trajectories through Knowledge Management

To understand how firms react to the emergence of new technological trajectories, it is useful to refer to the concept of Knowledge Management (KM). This discipline, while still young and developing, has been identified by many scholars as an area of fundamental importance for organizational innovation (Tsai, 2016; Gloet and Samson, 2016). Numerous definitions of KM are reported in the literature, although none of them is widely agreed upon. The following are some of them.

"KM is the process of continually managing knowledge of all kinds to meet existing and emerging needs, to identify and exploit existing and acquired knowledge assets and to develop new opportunities." (Quintas et al., 1997, p.387)

"KM deals with the management of knowledge related activities such as creating, organizing, sharing and using knowledge in order to create value for an organization." (Yew and Aspinwall, 2004, p.44)

"KM is a discipline that promises to maximize innovation and competitive advantage to organizations that practice knowledge capture, documentation, retrieval and reuse, creation, transfer and sharing of its knowledge assets in a measurable way, integrated in its operational and business processes." (Dayan and Evans, 2006, p.69)

Therefore, KM is a broad concept composed of various activities that affect not only research itself but also business practices. The goal pursued through KM is to improve the organization's knowledge assets in order to achieve better knowledge practices, better organizational behaviors, better decisions, and better organizational performance (King, 2009). Knowledge assets include knowledge in the form of written documents, such as manuals and patents, or stored in electronic repositories[4], knowledge held by workers themselves on how to do their

[4] For instance, the so-called best-practice databases.

jobs, knowledge held by teams working together, and knowledge that is embedded in the company's products, processes, and relationships (King, 2009). In fact, all activities carried out within KM are related to knowledge assets and range from identifying, creating, sharing, transforming, preserving, renewing, disseminating, and applying knowledge (King, 2009).
In the relevant literature, the importance of information technology for information management is emphasized, as this often necessitates the use of systems and technologies to easily store and retrieve information. However, KM does not equate only to technology management nor to information management. Although information technologies are indeed important, they should not be understood as a cornerstone of KM (McAdam and McCreedy, 1999; Sarvary, 1999). In fact, another important element is the human dimension. Knowledge is primarily found in people and is developed through a learning process. Effective KM therefore implies that knowledge moves from being a human asset to becoming a corporate asset (Begoña Loria, 2008). Indeed, the KM process implies that it is the tacit knowledge of various experts that has to accumulate in companies, structured and codified over time, becomes embedded in software, hardware and accepted procedures (Leonard, 1998). Physical systems must serve to store the knowledge of individuals who have moved on to other functions, other jobs, other organizations (Leonard, 1998). Also consistent with this view is the idea that the goal pursued through KM is organizational learning (King, 2009). Levitt and March (1988, p.319) described organizational learning as the process of "*encoding story inferences into routines that guide behavior*". In other words, organizational learning indicates the process of incorporating what has been learned into the fabric of the organization. Therefore, KM strategies help the organization to incorporate knowledge into business processes so as to improve its performance (King, 2009).

2.2.3 A model of knowledge management

Efficient and effective KM provides benefits to an organization, such as improved organizational processes, innovation, individual and collective learning (Arif, Nunes and Kanwal, 2021). The improvement of these processes leads to intermediate outcomes, such as better decisions, organizational behaviors, products, services, and relationships (King, 2009). As a result of all these processes, better organizational performance is achieved. There are numerous KM models developed to describe this concatenation of events[5], but there is no single, agreed-upon framework that garners consensus among all scholars. However, a very valuable model for theoretical description is the one developed by King (2009), which attempts to summarize the most important contributions to KM theorization.

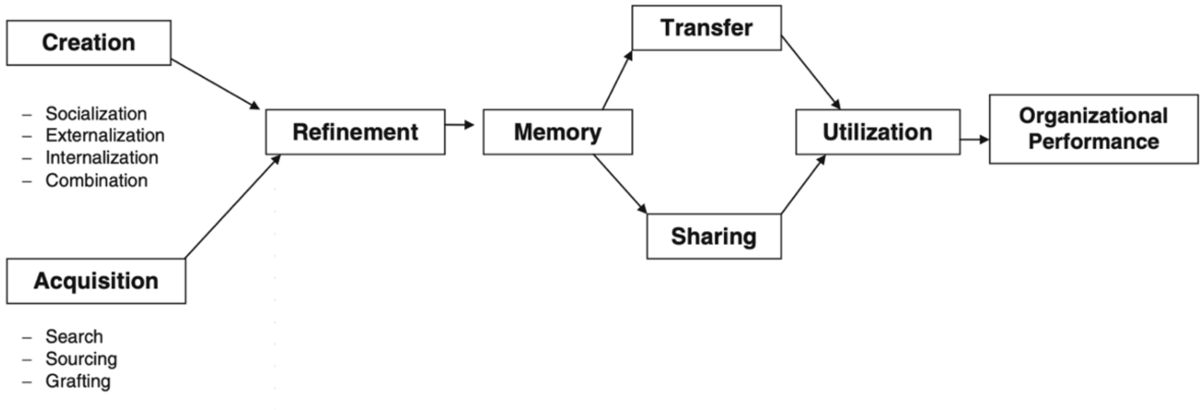

Table 1. A model of knowledge management
Source: King, R.W. (2009) Knowledge Management and Organizational Learning (p.7)

One of the prime merits of this model is the emphasis on the initiation of the KM cycle, which can come either from the creation or the acquisition of knowledge by the organization (King, 2009) (see Table 1).

Knowledge creation refers to the development of new knowledge or the replacement of existing knowledge with new content (Nonaka, 1994). These processes can take place inside the boundaries of the firm or in collaboration with partners. In his model, King (2009) refers to the knowledge creation model developed by Nonaka and Takeuchi (1995) (see Table 2). The so called SECI model[6] is based on four main stages:

1. Socialization (a transfer of tacit knowledge to tacit knowledge). It is the stage in which tacit knowledge is transmitted informally, through the sharing of experiences and direct observation of practitioners already equipped with technical skills.

[5] Among the numerous KM process cycle models that seek to be summarized in King's model: 3-step model of Davenport and Prusak ("Generate, Codify/Coordinate, Transfer") and the 7-step model of Ward and Aurum ("Create, Acquire, Identify, Adapt, Organize, Adapt").

[6] The SECI model is a model of knowledge creation within organizations which occurs through a process of converting tacit and explicit knowledge through the four processes considered above (Nonaka and Takeuchi, 1995).

2. Articulation or externalization (a transfer of tacit knowledge to explicit knowledge). This is the stage when knowledge transmitted in tacit form is made explicit through transposition into a formal code and through articulated language. This makes knowledge more easily understood and shared with others.
3. Combination (a transfer of explicit knowledge to explicit knowledge). The different sources of explicit knowledge are combined to create new ideas and concepts. In doing so, explicit knowledge is integrated by creating new forms of explicit knowledge.
4. Internationalization (a transfer of explicit knowledge to implicit knowledge). This is the stage in which individuals absorb explicit knowledge, thus incorporating it into their implicit knowledge base. From the latter, it is then possible to derive new learning that can repower that circuit[7].

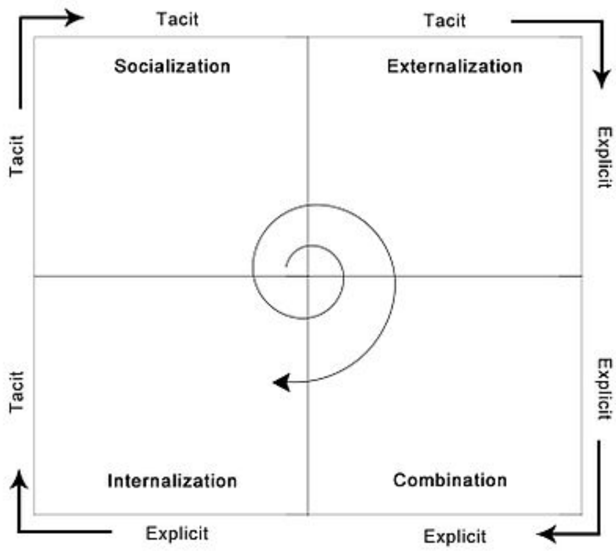

Table 2. The SECI model of knowledge creation
Source: Nonaka, I. & Takeuchi, H. (1995) The knowledge creation company

The model describes a dynamic and continuous process that highlights the significance of the flow and conversion of knowledge within an organization. It consists of a knowledge spiral, in which each rotation through the four SECI phases leads to more complex and greater knowledge. The model thus highlights the importance of effective knowledge management within companies in order to promote and stimulate the creation of new knowledge and thus enhance the company's ability to innovate.

[7] Illustrative of these four modes respectively are apprenticeships, literature survey reports, "lessons learned" repositories and individual or group learning through discussions (King, 2009).

However, the model developed by King (2009) emphasizes how the KM cycle can be triggered not only by the creation of knowledge within the company's boundaries, but also through the acquisition of knowledge from outside the company. In this regard, the author identifies some processes for gathering knowledge from outside the company, which include:

1. Searching, the process of searching for available knowledge. This might include activities such as scanning industry reports, monitoring market trends, investigating competitor activities, conducting literature reviews.
2. Sourcing, the process of identifying and selecting the resource to be used and to rely on.
3. Grafting, that being the addition of an individual who possesses the desired knowledge or expertise that is not currently available within the organization. This might involve hiring a new employee, a consultant or advisor or even forming partnerships with other organizations.

Once the enterprise has created or acquired new knowledge, it must become part of the organizational memory. Before this happens, the new knowledge goes through a phase of so-called refinement, in which it is filtered, selected, and optimized. This is the phase in which new knowledge, both implicit and explicit, is codified and organized and then evaluated according to the criteria of the corporate memory. In order for new knowledge to have the widest possible impact in the organization, it must be transferred or shared. King (2006a) describes transfer and sharing as two ends of a continuum. Knowledge transfer is the communication of knowledge from a sender to a known recipient (King, 2006a). Sharing is less targeted dissemination, such as through an archive, to people who are often not known to the contributor (King, 2006b).

2.3 Internal and external sources of knowledge

The model of knowledge management elaborated by King and explained above shows that knowledge acquisition by a firm can derive from sources internal or external to the firm itself. Thus, the adaption to new technological trajectories can be consequence to the in-house development of new knowledge or to its acquisition from the outside of the firm.

2.3.1 The complementarity of internal and external R&D

Until the 1980s, a linear view of the innovation process had led to the emergence of the belief that the development of innovations followed a research-to-market trajectory (Svetina and Prodan, 2008). Therefore, a firm's innovative capacity was seen as the direct product of its R&D activity and investments. However, this framework failed to explain the heightened phenomenon of innovation among SMEs that clustered all over the world, especially in Europe. It became evident that in this context innovation was rather the product of interactive learning processes (Pavitt, 1998). It was acknowledged that the learning process does not occur in a vacuum, but rather in relation to a social context (Johnson, 1992; Lundvall, 1992). The idea of a linearity of the innovation process thus gave way to the framework of the learning economy[8], in which innovation was represented as a technical and social process based on the interaction between firms and the environment (Asheim and Isaksen, 1997; Lundvall, 1992). When improving production processes or developing a new product or service, firms engage and cooperate with their suppliers, customers, knowledge institutions[9] and even with their own competitors (Svetina and Prodan, 2008).

The need to draw on external sources is also a consequence of the increasing complexity of knowledge itself. The development of products and processes requires to rely on increasingly complex technologies and to draw on different scientific disciplines (Johnson, Loren and Lundvall, 2002). In addition to that, rapid technological processes also cause shorter product life cycles and faster product renewal (Rigby and Zook, 2002). All these elements contribute to a substantial increase in the cost of in-house R&D investment. Tapping into external

[8] The concept of the learning economy was first introduced by Lundvall and Johnson in the early 1990s. The two authors created an economic model in which business success and, in general, economic development are largely determined by the ability to improve one's collective and individual learning capabilities (Lundvall and Johnson, 1994).

[9] e.g., universities and laboratories.

technology sourcing can alleviate some of these challenges, but this option still requires major efforts, including large coordination capabilities and greater flexibility (Rigby and Zook, 2002). When conducting external R&D, the capital needed is smaller, and the risks are substantially reduced, and in case of failure or organizational crisis, limited damage is inflicted on the firm. However, the tacit nature of innovation and the risks associated with loss of technological competitiveness are perceived as obstacles to external R&D activities and are therefore an incentive that pushes firms toward a higher level of in-house R&D activities (Narula, 2001). Thus, the challenge for a company's management is to find the best balance between internal and external R&D activities so as to take advantage of both.

These considerations are in line with the idea that internal and external sources of knowledge are complementary in their contribution to a firm's innovation performance (Cassiman and Veugelers, 2006). Today even large organizations active in innovation cannot rely solely on internal sourcing; they also need knowledge from outside to develop their innovations (Rigby and Zook 2002). However, internal R&D still plays a central role, as firms with a stock of knowledge based on internal R&D are better able to recognize, evaluate and absorb external sources. The idea that external know-how can be better assimilated and utilized through the firm's prior internal knowledge is identified by Cohen and Levinthal (1990) with the notion of *absorptive capacity*[10]. This concept is in line with Rosenberg's (1990) view that a basic internal research capability is often essential for monitoring and evaluating research conducted elsewhere. In addition, access to external know-how can increase the productivity of internal R&D activities, at least when the organization shows a willingness to accommodate external ideas (Veugelers, 1997).

2.3.2 A classification of internal and external sources of knowledge

It is therefore possible to distinguish in the first instance between internal and external sources that companies can draw on to adapt their processes, products, and services to new technological trajectories. As for external sources, it is possible to distinguish them on the basis

[10] Absorptive capacity is defined Cohen and Levinthal (1990) as "*the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends*".

of a geographic factor[11] between local, national, and international ones (Belussi, McDonald, and Borrás 2002) (see Table 3).

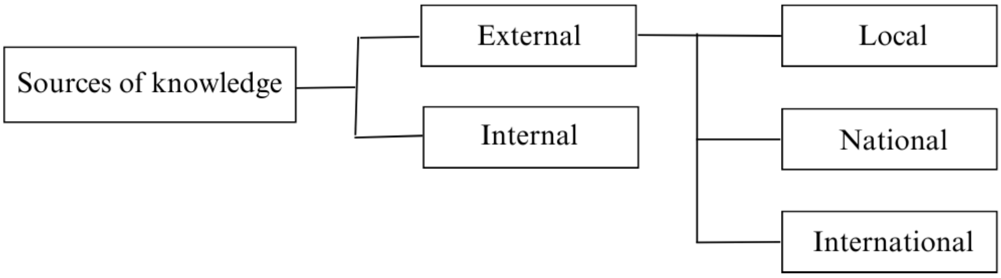

Table 3. Classification of sources of firm knowledge
Source: Belussi, McDonald, and Borrás (2002, cited in Svetina and Prodan, 2008)

In-house, companies build knowledge mainly through internal R&D activities and learning from continuous process improvements (Svetina and Prodan, 2008). Employee skills are also an important source of new knowledge, in fact firms often organize internal education and training programs with the aim of building and further improving the internal knowledge base of the firm (Svetina and Prodan, 2008). Although this is an option that requires larger investments, having a strong internal knowledge base within the company can be very beneficial. First, it can enable the development of the expertise required to manage and acquire external knowledge. There are also cases where failure to invest in internal R&D has negatively affected the long-term stability of the firm. For example, Malerba (1985, cited in Pisano, 1990) cites the case of electronics companies which in the early 1960s decided to license new integrated circuit technologies rather than develop the necessary in-house R&D capabilities, resulting in difficulties in competing in the marketplace in later years.

The alternative to in-house R&D is to acquire it externally by collaborating with customers, suppliers, and other companies, or by forming partnerships with public, semi-public and private institutions.

- Collaborations between companies

Most firms maintain relationships with both business partners and their competitors. A study by Keeble et al. (1998) of firms located in the Cambridge region revealed that 76 percent of them maintained close ties with other firms. A great deal of information exchange often takes

[11] The geographical criterion allows to distinguish external sources of knowledge based on where they are located geographically, breaking them down into three categories, namely local, national and international resources.

place between supply chain actors, which can range from technical knowledge to information on market trends. For example, suppliers of equipment and materials can provide important information on the organization of production, logistics and other functions. But other, more formalized forms of inter-firm cooperation also exist, ranging from joint ventures, subcontracting, and research collaborations to sharing equipment and customer information (Svetina and Prodan, 2008).

- Partnerships between firms and institutions

These include various bodies, including universities, research institutes, incubators and other knowledge institutions providing scientific research inputs to innovative firms (Keeble and Wilkinson 2000). These are support organizations that can channel information and knowledge and translate codified academic knowledge into practical and accessible know-how (Gambarotto and Solari, 2004).

Both collaborations with other companies and partnerships with knowledge institutes can be differentiated based on their geographical location. According to Belussi, McDonald, and Borrás (2002) these external actors can be located:

- locally, in the immediate vicinity;
- nationally, somewhere in the country;
- internationally, elsewhere outside national borders.

For a long time, the focus of research on business collaboration and partnerships with institutions was limited to considering the local level, thanks to the strand of studies on research in territorial clusters. The territorial proximity that characterizes these interactions is defined as bringing a number of advantages, including the possibility of frequent face-to-face interactions and knowledge spillovers (Capello and Faggian, 2005). Additionally, local interactions have often been described in the literature as the most appropriate environment for knowledge exchange because of cultural, social and organizational proximity (Lundvall, 1992). Some authors have even suggested that knowledge exchange within local clusters could replace internal R&D (Capello and Faggian, 2005). However, such claims have led to a heated debate in the literature, with some authors suggesting that interactions with distant partners are at least as important as those with local actors (Malmberg and Maskell, 2006). Malmberg and Maskell (2006) were among the academics who demonstrated that interactive learning should be understood as a combination of near and far interactions. This view is also supported by the rapidly evolving and increasingly complex nature of technology itself. This implies that, if companies want to keep up with industry innovation, they must tap into the most advanced knowledge available, and this necessarily involves looking beyond the local level. Therefore, if firms want to keep up with innovations, the use of local knowledge sources is no longer sufficient. In fact, relying only on local interactions can instead lead to a lock-in effect (Keeble and Wilkinson, 2000). Thus, this stream of literature suggests that, to maintain a steady flow of new knowledge, firms must cultivate ties within and outside the cluster (Svetina and Prodan, 2008).

2.3.3 The option of external sources of knowledge

Having established that successful innovative firms make a complementary use of internal R&D and external sources of knowledge - and that these are found locally, nationally and internationally so that the firm can maintain a comprehensive view of technological innovation in the industry and adapt to it accordingly – let us move on to considering in what situations a firm decides to resort to the use external sources of knowledge.

As mentioned earlier, the use of external sources of knowledge can be advantageous in certain circumstances, as it allows benefits, including a more agile response to radical technological change and exploration of new domains. These are also defined by Gambardella and Turrisi (1998, cited in Narula, 2001) as *reversible investments*. In fact, the capital required from the firm is lower than that necessary for in-house activities; therefore, in case of failure or organizational crisis, the damage to the firm is more limited (Narula, 2001).

Narula (2001) developed a model that attempts to explain what factors lead a company to opt for external knowledge sources. This model consists of two frameworks, one static and one dynamic. The static framework evaluates the choice between internal and external sources based on the company's distribution of competencies and their strategic importance. In contrast, the dynamic framework accounts for changes in the static framework based on the stage of development of the technology.

Narula (2001) uses the term *non-internal activities* to identify both:

- *external activities*, which include arms-length relationships such as licensing, R&D contracts, outsourcing and other customer–supplier relationships.
- *quasi-external activities*, such as strategic alliances which are often undertaken between competitors.

In general, external activities are a much more widespread phenomenon than quasi-external activities. Alliances are a complex organizational form and require considerable resources to maintain collaborative activity, compared to simpler arrangements such as outsourcing

(Narula, 2001). Companies collaborate with competitors only with the utmost caution and only on specific, carefully designed projects (Narula, 2001).

The static framework

The model is based on the contribution of Granstrand, Patel and Pavitt (1997) who proposed a model of four types of core and complementary competencies (see Table 4).

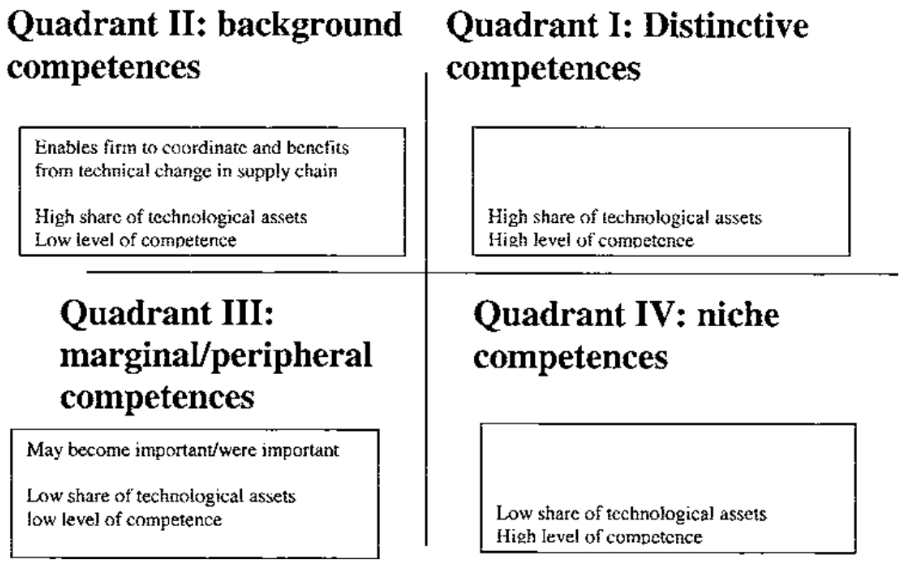

Table 4. The distribution of competences
Source: Based on Granstand, Patel and Pavitt (1997 cited in Narula, 2001)

These are classified as following:

1. Distinctive competences represent the core of the firm, which command a high share of technical resources of the company;
2. Niche competences regard technologies possessed by the firm but small in terms of resources they command. They are complementary to the distinctive competencies;
3. Marginal or peripheral competences are those sectors that used to be important in the past or are expected to become in the future, but where right now not many resources are invested;
4. Background competences represent resources that utilize a small amount of the firm's technological assets but are much important but are needed by the firm to coordinate and utilize crucial competences.

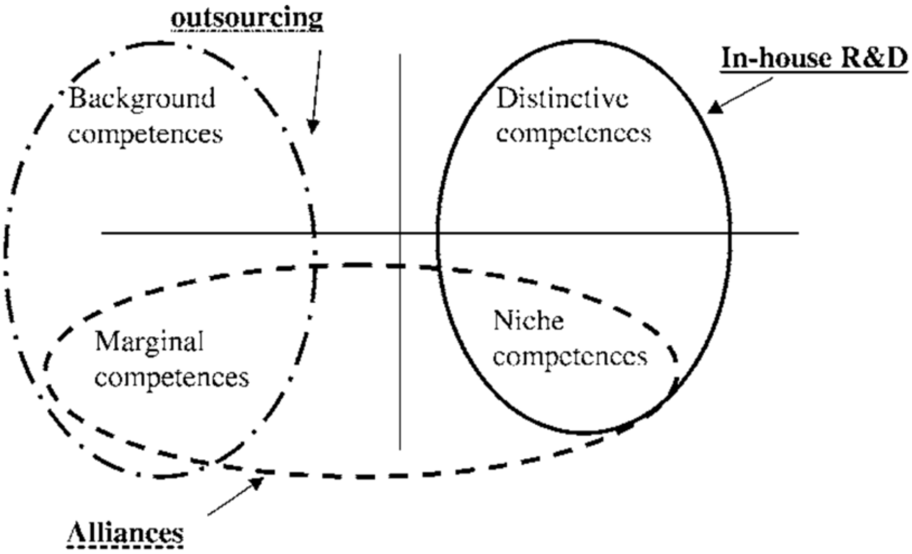

Table 5. The static view: relationship between competences and internal/non-internal R&D
Source: Narula (2001)

According to the model, firms will, *ceteris paribus*, opt for in-house R&D for innovation concerning distinctive competences. As for marginal or peripheral competences and niche competences, which are strategically less important for the firm, can be undertaken through alliances, even though their degree of externalization will ultimately depend on the specific strategic importance. Finally, background competences are the preferred areas for outsourcing (Narula, 2001) (see Table 5).

The dynamic framework

However, Narula (2001) also develops a dynamic framework, which accounts for changes in the firm's choice between internal procurement and non-internal resources depending on the stage of development of the technology under consideration. To describe such stages of development, the author refers to the idea of technological paradigms and trajectories developed by Dosi (1982), distinguishing the development of a technology in three phases: pre-paradigmatic, paradigmatic, and post-paradigmatic.

- Pre-paradigmatic technology

At this early stage, the technology and its underlying products are still under development and standards have yet to be established. In such a situation, the high competition and tacit nature of the technology would lead the firm to prefer to keep its niche and distinctive competencies in-house. This would allow the firm to have control over the development process and the resulting intellectual property, while ensuring strategic alignment. In-house R&D could also be combined with strategic alliances in order to access the additional resources needed and sustain these competencies.

- Paradigmatic technology

At this stage, technology has achieved a certain level of acceptance, thus establishing a dominant paradigm. Companies can therefore outsource more technologies and undertake more niche areas of competence through alliances. However, at this stage strategic alliance can be challenged by the rapid evolution of technology and limited patent protection.

- Post-paradigmatic technology

In the latter phase, technological change starts to slow down, uncertainty is reduced, and property rights become clearly defined. It is no longer the technology itself that determines a company's competitive advantage, but rather factors such as marketing and economies of scale. These elements contribute to companies' preferred choice of technology outsourcing. The need for strategic alliances is also reduced, as technological change is much slower.

Both the static and dynamic models proposed by Narula (2001) do not attempt to identify clear rules in firms' innovation choices, nor do they claim to be exhaustive in explaining the phenomenon. Rather, these models should serve as guidelines for understanding how firms might behave when it comes to decisions on R&D activities. Firms are idiosyncratic and path-dependent, and thus numerous strategic and economic issues not considered here could be driving R&D decisions.

2.4 The issue of organizational ambidexterity

The KM model developed by King (2009)[12] considered in the previous paragraphs highlights the importance of the creation and acquisition of new knowledge in order to keep the company abreast of technological evolution. However, the model also emphasizes the relevance of the subsequent stages of KM, that is, those stages in which technological knowledge is given implementation and execution with the goal of achieving productivity and efficiency in the company's production processes.

The company's requirement to focus its resources on both the creation or acquisition of new knowledge and the exploitation and refinement of existing capabilities has been addressed by the literature on organizational ambidexterity. This strand of literature is based on a number of studies on organizational adaptation that suggest the need for firms to adapt and align their structures in the face of environmental and technological change (Schumpeter, 1934; Thompson, 1967). March (1991) first suggested that the challenge of corporate adaptation fundamentally lies in the need to leverage existing assets and capabilities while simultaneously innovating to stay abreast of market changes. As the author puts it, "*the fundamental problem facing an organization is to engage in sufficient exploration to ensure its present viability and, at the same time, devote sufficient energy to the exploration to ensure its future viability*" (March, 1991, p.105). The idea of organizational ambidexterity was introduced to describe a firm's ability to explore new opportunities whilst simultaneously exploiting existing capabilities. Exploitation refers to efficiency, control, certainty, and variance reduction. Exploration, on the other hand, refers to search, discovery, autonomy, and innovation (March, 1991).

The concept of organizational ambidexterity has also received much attention because of the debate over its impact on corporate performance. Some scholars have insisted that the enterprise must choose between exploitation and exploration, excluding the possibility of pursuing them simultaneously. For example, Porter (1996) suggested that the firm must decide between a strategy based on differentiation or low costs otherwise if it pursued both it would be *stuck in the middle*, resulting in a negative impact on its performance. Other authors, however, have affirmed the possibility that the simultaneous pursuit of exploration and exploitation can lead to an improved firm performance. These include March (1991) and

[12] As already mentioned in earlier paragraphs, King's work attempts to summarize the most important contributions in the KM literature and can therefore be considered one of the most comprehensive works on the subject.

Tushman and O'Reilly (1996), who argued that firms that focus only on exploitation achieve results that are predictable but not necessarily sustainable. In fact, they would improve their short-term performance, but may not be able to adapt to future environmental changes, resulting in an obsolescence process (March and Levinthal, 1993; Gianzina-Kassotaki, 2017). In a specular way, companies that focus solely on exploration succeed in continuously generating ideas and innovations but fail in transforming them into profitable products and services. Hence, companies should be able to simultaneously pursue exploration and exploitation to ensure their competitiveness in both the short and long term (Gibson and Birkinshaw, 2004; Junni et al, 2013).

2.4.1 Strategies to achieve organizational ambidexterity

Early authors who addressed the issue of organizational ambidexterity framed it in structural terms. For example, Duncan (1976) first suggested how exploration and exploitation activities involve conflicting pressures on the firm's resources. The best way to manage these trade-offs between conflicting demands is to create a dual structure, in which some business units focus on alignment and others on adaptation (Duncan, 1976). This idea of organizational ambidexterity persists to this day and is referred to as structural ambidexterity.

However, alongside the latter, the idea has also developed that organizational ambidexterity does not necessarily require separate structures for different activities. On the contrary, it can also emerge if exploration and exploitation activities are pursued by employees within the same unit. According to this view, individuals are left free to choose between exploitation-oriented and exploration-oriented activities in their daily work (Gibson and Birkinshaw, 2004). This type of organizational ambidexterity has been referred to as contextual ambidexterity.

The distinction between structural and contextual ambidexterity can thus be summarized as a spatial distinction, indicating whether organizational ambiguity is pursued in separate units within the firm or jointly within the same unit.

Although the distinction between structural and contextual ambidexterity is the most recurrent in the literature, researchers have also identified other strategies that can be adopted by firms to achieve organizational ambidexterity. Kang and Snell (2009, cited in Kassotaki, 2022) attempted to synthesize the different modalities of organizational ambidexterity within a typology consisting of four main types (see Table 6). This typology is constructed based on two dimensions, namely:

- Temporal dimension (*time*), which captures the extent to which ambidexterity is pursued by the firm simultaneously or sequentially over time.
- Spatial dimension (*space*) captures instead whether ambidexterity takes place within independent or interdependent organizational units, namely whether it is structural or contextual ambidexterity (Kang and Snell, 2009 in Kassotaki, 2022).

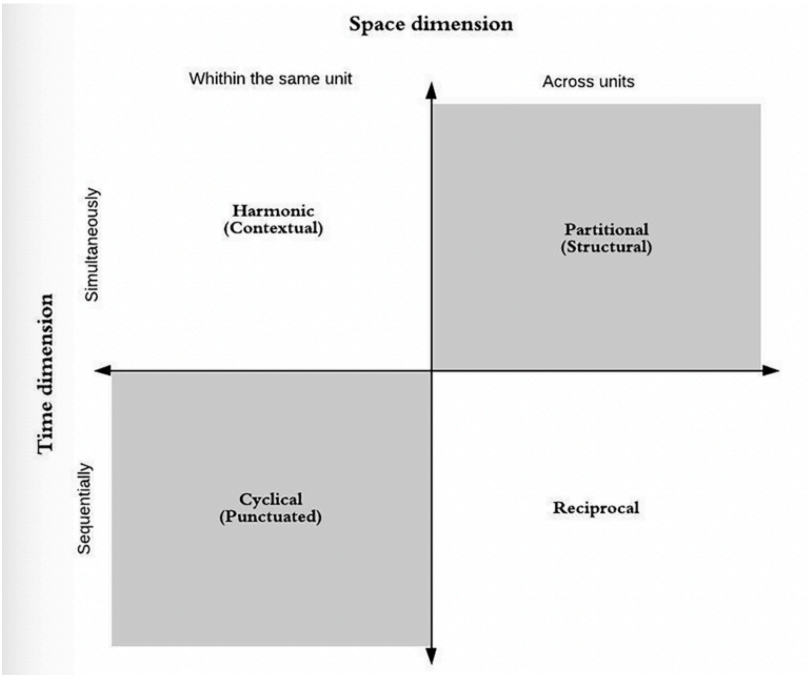

Table 6. A typology of organizational ambidexterity
Source: Kang and Snell (2009, cited in Kassotaki, 2022)

- Contextual or harmonic ambidexterity

As previously mentioned, it involves the simultaneous pursuit of exploration and exploitation within the same business unit (Kang and Snell, 2009). This type of ambidexterity requires individuals within an organization to autonomously decide how to balance their time between conflicting demands (Gibson and Birkinshaw, 2004). This flexibility is rare and hard to imitate, thus can make a potential source of competitive advantage. It is important that leaders must show complex, ambidextrous behaviors in order to foster a culture of both exploration and exploitation (Andriopoulos and Lewis, 2009). Establishing this type of ambidexterity can be very costly, but can be often found in corporate venture units, which are able to simultaneously developing new capabilities and leveraging existing ones (Gibson and Birkinshaw, 2004).

- Structural or partitional ambidexterity

It involves a dual structure in organization, in which structurally independent units are responsible for exploration and exploitation (Kang and Snell, 2009). Each unit is characterized by its unique organizational structure, with its own management, culture, and systems. They operate independently but are subject to the coordination of a senior management team and brought together by a shared vision (Tushman and O'Reilly, 1996). This type of ambidexterity is prevalent in financial services firms but also in firms that create strategic alliances or inter-firm networks (Kassotaki, 2022).

- Cyclical ambidexterity or punctuated equilibrium

It is produced by the alternation between long periods of exploitation and shorter periods of exploration within the same business unit. These bursts of exploration require a change in structure and routines, thus cyclical ambidexterity hinges on effective switching of rules, conflict management, and flexibility (Cantarello et al., 2012). It can be fund most frequently in in technologically oriented and R&D-focused firms, such as those in the biotechnology or software industries.

- Reciprocal ambidexterity

It involves the sequential application of exploitation and exploration among different units of an organization (Gianzina-Kassotaki, 2017). The exploration results of one unit B feed into the exploitation activities of another unit A, while the results of unit A flow back as inputs for unit B (Simsek et al., 2009). This type of ambidexterity requires continuous information exchange and joint decision making. It is mostly encountered in organizations engaged in strategic alliances.

2.4.2 Factors impacting on organizational ambidexterity

The link between ambidexterity and business performance has been investigated by many scholars. Most studies conducted in this area have looked at various aspects of firm performance, including sales growth, profitability, return on investment, and market share, identifying a positive relationship between these factors and organizational ambidexterity (Kassotaki, 2022). These studies confirm a positive association between simultaneous exploitation and exploration effort and firm innovation, better financial performance, and higher survival rates (O'Relley and Tushman, 2013).

However, some studies have also identified a number of conditions, both internal and external to the firm, in which organizational ambidexterity yields the greatest effects on performance (Junni et al., 2013; O'Relley and Tushman, 2013).

As for the environmental factors influencing the impact of organizational ambidexterity, a number of studies have demonstrated that the firm’s ability to pursue simultaneously exploration and exploitation is made more valuable by conditions of environmental dynamism. This is present, for example, in high-tech and knowledge-intensive service firms, as opposed to less dynamic sectors such as manufacturing industries (Junni et al., 2013). In these dynamic industries, firms must continuously seek new opportunities while leveraging existing resources to ensure survival against fierce competition. Indeed, dynamic environments are usually more uncertain environments in which to operate because gaining competitive advantage can be very uncertain due to the rapidly changing nature of the industry and the higher level of competition (O'Relley and Tushman, 2013).

As for the internal elements of the enterprise to be considered in assessing organizational ambidexterity, some relevant factors are market orientation and the enterprise's resource endowment (Kassotaki, 2022). Market orientation increases the firm's ability to respond to current and future customer needs (Kassotaki, 2022). Low resource endowment, on the other hand, can reduce the impact of organizational ambidexterity, as limited resources reduce the firm's ability to efficiently pursue both exploration and exploitation (O'Relley and Tushman, 2013). Indeed, Cao et al. (2009) suggest that young firms may benefit more from a one-sided orientation rather than an ambidextrous strategy, as opposed to large firms, which are able to benefit most from such a strategy.

In detail, Cao et al. (2009) point out that two different understandings of the same concept have emerged in the literature. Indeed, March (1991) had introduced the idea of organizational ambidexterity by framing exploration and exploitation as two ends of the same continuum. Thus, trade-offs between the two activities are inevitable, as in a kind of zero-sum game, and organizational ambidexterity refers to managing trade-offs to find the right balance between the two types of activities. More recently, an alternative conceptualization of organizational ambidexterity has emerged, in which exploration and exploitation are understood as independent activities orthogonal to each other (Gupta et al., 2006 in Cao et al., 2009). Firms can thus engage fully in both activities and organizational ambidexterity is understood as a firm's ability to maximize levels of exploration and exploitation simultaneously. These two alternative views of organizational ambidexterity have been called the Balanced Dimension (BD) and the Combined Dimension (CD) (Cao et al., 2009).

However, it should be remembered that pursuing both exploration and exploitation activities can carry risks, as focusing too much on exploitation allows for short-term successes but risks obsolescence. Conversely, if the company prioritizes exploration, it increases the risk of failing to take ownership of R&D results. According to Cao et al. (2009), BD maintains control over these risks because of the trade-off it requires, while CD increases such risks because it maximizes both dimensions of exploration and exploitation. In short, firms' resource availability acts as a buffer to mitigate these risks, which is why Cao et al. (2009) conclude that maximizing exploration and exploitation benefits only large firms with ample resources. In fact, the latter allow firms to respond to potentially harmful risks in a timely and effective manner. Thus, CD enhances firm performance through the generation of a pool of complementary resources that can be leveraged across both exploration and exploitation activities. Conversely, when a firm has fewer resources to deploy, it will be limited in its efforts to provide sufficient resources to maximize both exploration and exploitation and will instead benefit more from a trade-off strategy between the two dimensions. In such cases, BD reduces the performance damaging effects of over engagement in exploitation to the detriment of exploitation and vice versa. In short, CD is more advantageous for enterprises with great access to resources, while BD is more beneficial for firms with limited resources at their disposal.

3. Research Questions

To ensure survival in a high-tech, knowledge-intensive industry that advances very rapidly, the enterprise must be able to recognize the emergence of new technological trajectories in its industry and adapt accordingly. This adaptation process is defined in the literature as a reconfiguration of the firm's internal resources and an acquisition of new external resources and expertise (Teece et al., 1997). So, the emergence of new trajectories in an industry's technological innovation requires firms in that industry to acquire the new skills needed to master these new technological trends. This therefore requires the learning of new skills and the acquisition of new resources from outside the company and the simultaneous adaptation of the resources and skills already present within the company.

Since companies of different sizes have very different resource endowments, we can imagine that this adaptation process can vary substantially depending on firm size and, therefore, on the set of resources at its disposal. In detail, we can imagine that larger firms operating in high-tech, knowledge-intensive industries have more resources to devote to R&D, especially internally conducted R&D, which enables them to develop tailor-made solutions and ensure the protection of strategic knowledge developed within the firm. In contrast, smaller firms have limited resources at their disposal, and thus investment in in-house R&D is likely to be lower. Consequently, SMEs will be more inclined to seek knowledge resources outside the firm's boundaries, either through external or quasi-external sources.

Therefore, our first research question is as follows:

> *RQ1. How do SMEs and large companies in the Italian aerospace sector differ in their use of external and quasi-external knowledge sources for R&D activities? Do SMEs rely more often on external and quasi-external knowledge sources compared to large companies?*

In addition, considering the theme of organizational ambidexterity, we can advance the hypothesis that simultaneous effort in the direction of both exploitation and exploration may be more frequent in large enterprises. This is because an organizational ambidexterity strategy can be very costly, as it requires the allocation of sufficient resources to both areas of innovation and production so that both can operate effectively. SMEs tend to have more limited

resources at their disposal than large firms[13], and thus these might be thought to be insufficient to ensure the efficient simultaneous operation of the two domains. Therefore, as suggested in the literature (Cao et al., 2009), the limited resource endowment of SMEs may make the pursuit of a one-sided strategy more efficient than a strategy of organizational ambidexterity.
Accordingly, our second research question is the following:

> *RQ2. How do SMEs and large companies in the Italian aerospace sector differ in terms of the perceived cost-effectiveness of strategies? Do SMEs find it more cost-effective to pursue a strategy focused on exploration or exploitation, rather than a strategy of organizational ambidexterity?*

Answering these research questions will make it possible to analyze in detail R&D-related choices made by firms of various sizes. The goal is to produce a comparative analysis capable of bringing out the main differences between large firms and SMEs, thus seeking to understand how varying resource endowments impact research and production decisions.
The context considered to answer these research questions, that is, the industrial sector in which the companies operate, is the Italian aerospace sector. Indeed, the choice of this sector allows us to evaluate R&D decisions in an industrial context that is among the most high-tech and knowledge-intensive and in which, therefore, companies' R&D choices play a key strategic function.

[13] The resource endowment of SMEs is comparable to the situation faced by young firms, cited by Cao et al. (2009) when they suggest that young firms may benefit more from a one-sided orientation rather than an ambidextrous strategy.

4. The industry

4.1 The aerospace industry

As mentioned in the previous paragraphs, R&D activities, effective KM, and organizational ambidexterity are particularly important for companies operating in high-tech and knowledge-intensive industries. Among the many sectors that fall under this category is aerospace, particularly its space segment, which has experienced accelerated development in recent years due to the emergence of various satellite applications and the advent of the *New Space*[14]. Indeed, the aerospace industry offers extremely complex products and services, such as aircraft and satellites, that require years of research before they are fully developed and commercialized. In addition, the industry is characterized by the continuous search for new technologies and materials that can improve the efficiency and safety of products. It is therefore undoubtedly an industry that requires intensive R&D.

Adding to this is the fact that this is a knowledge-intensive industry, where the type of knowledge is highly technical. An aerospace company must therefore be able to manage, store and transfer specialized knowledge, both among its employees and with external partners. Moreover, a successful company operating in this field must undoubtedly be able to pursue the exploration of new ideas and technologies while keeping production in step with market demand, thus showing organizational ambidexterity.

Therefore, given the characteristics of this industry and the companies operating in it, this study will focus particularly on companies operating in the Italian aerospace sector in order to answer the research questions formulated at the end of the previous chapter.

4.2 The aerospace sector in Italy

Italy is the world's sixth space power and the third largest contributor to the European Space Agency (ESA). It is one of the few countries that possess the entire industrial chain of space activities within its borders, from launchers to satellite applications (Fazioli, 2020). The

[14] New Space is the term used to refer to the new generation of firms in the space sector that aim at commercializing access to and the use of space. The term also refers to the innovate and lower costs through new business models, technologies, and operational strategies. This movement is led by companies such as SpaceX, Blue Origin, and Planet, among others (Bell, 2018).

industrial maturity of the Italian aerospace sector is matched by an equally well-developed institutional set-up that is among the most effective internationally (Fazioli, 2020). Hence, the Italian aerospace sector is among the most developed in the world. However, this industrial and institutional maturity are the result of a decades-long and complex process of industrial development (Landoni, 2020).

4.2.1 The development of the Italian aerospace sector

The earliest advances in the space sector originated from technological advances in aviation (Landoni, 2020). As it has been the case in many other countries, Italy's space industry grew out of the skills developed through aeronautical missions and with the contribution of technological advances in sectors such as telecommunications and electronics (Landoni, 2020). In detail, the earliest contributions to the field date back to the first half of the 20th century, with ideas elaborated by personalities such as Gaetano Arturo Crocco, father of the gravity assist maneuver, still used today in many space missions, and Giulio Costanzi, who first proposed the idea of nuclear propulsion for rockets. Other important names contributed to the development of the field with important research, including Luigi Gussalli, Luigi Crocco and Aurelio Robotti (Savi, 2017). However, to this day, the father of Italian astronautics is considered to be Luigi Broglio. In fact, Broglio was the originator of the San Marco project, which led Italy to become the third country in the world[15] to autonomously launch its own satellite, the San Marco I, into orbit, thus gaining autonomous access to space (Scandone, 1979). Although the satellite was launched from a U.S. base with an American launcher, the team that made the mission possible was all Italian (Savi, 2017). The launch of the San Marco I took place in 1964, simultaneously with important institutional developments in the sector. In fact, during the 1960s, Italy joined the first European space organizations, ELDO (European Launcher Development Organization) and ESRO (European Space Research Organization), acquiring a central role in European space policy (Landoni, 2020).
However, the industrial development of the sector encountered some initial difficulties. These early struggles were traced by Landoni (2020) to the low profitability of Italian research. He based his work on the idea that a country's or region's ability to produce innovations in a given technology could be examined as the result of the process of acquiring technological expertise

[15] Italy became the third country to autonomously launch its own satellite after the United States and the Soviet Union.

gained over time. For this reason, he used the Revealed Technological Advantage (RTA) index, a proxy measure used to assess a region's technological specialization.
Comparison with the RTA ratios of other European countries does not suggest, for the period between the late 1960s and the late 1980s, a particular technological advantage of Italy in space patent production (Landoni, 2020). A subsequent analysis that considers the ratio of R&D investment to patents brings out the low profitability of Italian research. Italy's low propensity to produce patents was identified by Landoni as the product of a system of institutions that provided little incentive to protect innovation. The low innovative activity had been supported by the state through a delicate balance between large state-owned enterprises and widespread private entrepreneurship (Landoni, 2021). Among the large publicly held companies, it is most important to mention the Finmeccanica Group, nowadays known as Leonardo S.p.A. Founded in 1948, Finmeccanica has been among the large companies that have made a major contribution to the development of industry, especially since the 1980s (Landoni, 2021). Founded as a publicly owned company, Finmeccanica has subsequently undergone major privatization processes, although the government has always continued to hold a minority stake (Landoni, 2021).
After the uncertain start that had shaped the sector until the 1980s, the Italian aerospace industry recovered its position considerably in the following decades. In fact, with the crisis of the state-owned participation system and the consequent resignation of the state-owned manufacturing apparatus, new institutions emerged to create and support the innovative industrial activity of Italian companies, including the Italian Space Agency (ASI) (Petroni and Verbano, 2000).
This marked a shift from a rationale of direct state intervention to spread new technologies in the sector to a strategy that uses demand to direct firms toward high-tech industrial specializations of interest to the national economy. This change has led to a co-evolution of the industrial structure of the aerospace sector and the institutional system that supports it (Fazioli, 2020). Thus, in the case of the Italian aerospace sector, a profitable link between industry and institutional set-up has emerged, which has been crucial to the development of this high-tech sector.

4.2.2 Numbers and structure of Italy's aerospace sector

The aerospace sector is a strategic area for our country's economic growth in the coming years[16] (Bussi, 2021). As mentioned in the previous paragraph, Italy has on its territory the entire industrial chain of space activities (Fazioli, 2020). It is therefore a very broad and heterogeneous supply chain, including basic and advanced R&D activities, manufacturers of space hardware (e.g., launch vehicles for spacecraft, satellites, probes, orbital stations and shuttles) and non-spacecraft (civil and military aviation vehicles), suppliers of final products and services that interact with satellite networks (e.g., satellite navigation equipment), as well as companies that maintain the ancillary parts of spacecraft and non-spacecraft (OECD, 2007). Already in 2019, the total revenue generated by the sector was about 14 billion euros, corresponding to about 0.65 percent of GDP (Ernest and Young, 2019). Subsequently, the Covid19 pandemic that began at the turn of 2019-2020 caused a slowdown in the development of the sector and the emergence of critical issues relevant to its future development. However, thanks in part to the propulsive drive of national and supranational institutions, the aerospace supply chain soon returned to being a priority area for investment, effectively breaking out of the stalemate caused by the pandemic in an incredibly short time. (Ernest and Young, 2019). It is therefore estimated that the Italian aerospace industry will follow the strong growth trend that will characterize the industry globally, bringing the sector to an estimated value of 28.37 billion euros by 2027 (Statista, 2020).

The industry's rapid growth trend is also confirmed by the figure on the number of companies working in the aerospace sector, which grew from 514 to 543 between 2018 and 2020 (Istat, 2020). In line with this increase, the aggregate turnover of these also grew by about 5.1 percent (Istat, 2020). About 89 percent of these enterprises are engaged in the production, repair and maintenance of spacecraft and related devices, and satellite telecommunications. The remaining 11 percent of enterprises deal with air transport of passengers and cargo, both on Earth and in space (Ambrosetti, 2022). The total number of people employed in the aerospace supply chain amounts to about 47,300 people[17] (Fazioli, 2020).

[16] In fact, the Plan for Recovery and Resilience (PNRR), the plan developed by the Italian government to stimulate economic recovery and regrowth after the Covid19 pandemic by also using next-generation EU funds, sees the aerospace sector (and all its applications) as a huge driver for the Italian economy and beyond. For this reason, among the various resources and investments allocated to the sector, the PNRR allocates more than 1.29 billion euros for satellite and Earth observation technologies.

[17] Most recent data dates to the year 2018.

From a structural point of view, this industrial landscape is characterized by firms of all sizes that focus specifically on the industry. In fact, the leading large manufacturers are flanked by a large and vibrant community of SMEs, which collectively account for as much as 40 percent of the industry[18]. Among the leading manufacturers in the is Leonardo S.p.A.[19], a company that has always been at the center of the development of the Italian industrial supply chain. Leonardo S.p.A. is present in as many as 15 Italian regions[20] and is involved in a variety of areas, from the development of satellite and payload systems, to the management of satellite launch and in-orbit control services, to Earth observation and satellite navigation systems. In fact, these large companies are able to manage the entire product cycle, from design to construction to maintenance, although many of them outsource a significant portion of these activities (ITA, 2019). Outsourcing is often carried out by smaller companies, which tend to specialize more in certain niche areas, such as the production of components with high technological and quality standards. These SMEs are in fact highly specialized and represent micro-centers of excellence. Their enhancement on an international scale is made possible by collaboration with both large domestic companies and research centers and university clusters (ITA, 2019; MIMIT, 2020). Most of these SMEs are concentrated in the Italian regions of Lazio, Lombardy, Piedmont, Campania, and Apulia, contributing to the structuring of proper technological districts (Fazioli, 2020).

4.2.3 Technological districts and the National Aerospace Technology Cluster

The geographical concentration of aerospace companies in Italy is a very prominent aspect that characterizes the industry. In fact, companies operating in the sector are concentrated in 13 main innovation districts, located in the Italian regions of Lombardy, Piedmont, Liguria, Tuscany, Lazio, Sardinia, Veneto, Emilia Romagna, Abruzzo, Umbria, Apulia, Basilicata, and Campania (MIMIT, 2020). These districts represent ecosystems of knowledge and know-how in that they bring together large companies, SMEs, startups, as well as research centers and universities, which actively collaborate with the former to advance innovation processes (Battaglia, 2022). Districts differ from each other in their areas of specialization and the

[18] 40 percent of these are small and medium-sized enterprises, and the remaining 60 percent are micro-enterprises, with fewer than 10 employees and a turnover of more than 2 billion euros.
[19] Leonardo S.p.A. is a leading manufacturer not only in Italy but at international level as well.
[20] Leonardo S.p.A. is present either directly or through its joint ventures dedicated to the aerospace sector, Thales Alenia Space (Leonardo 33% and Thales 67%) and Telespazio (Leonardo 67% and Thales 33%).

technology of the companies operating in them (MIMIT, 2020). The most prominent examples include the Lombardo Aerospace Cluster, which specializes in satellites for scientific purposes from Earth observation to space exploration. There is also a focus on robotics and electronics there, thanks to the activities of the Leonardo Cluster in Nerviano (Battaglia, 2022). In the Piedmont Aerospace District, great attention is placed on pressurized modules, probes and rovers developed by the Thales Alenia Space pole. Lazio Innova, the Lazio region's technology cluster, is home to Telespazio, a joint venture between Leonardo (67%) and Thales (33%) that deals with satellite control, and Elv, a leading launcher manufacturer. Other major clusters include the one in Campania, which is strongly committed to creating synergies among large industrial groups, and Apulia, which hosts Italy's first spaceport in Grottaglie (Battaglia, 2022). Technological districts, with their various skills and specializations, thus contribute to an extremely rich and cutting-edge industrial base. In fact, a comprehensive view of the industry at the national level can come from observing the National Aerospace Technology Cluster (CTNA), under which all regional technology districts are brought together (MIMIT, 2020). The CTNA is an association that brings together the main public and private players operating in the aerospace sector in Italy, from large to medium and small enterprises, research centers and universities, government agencies and national platforms, industrial federations, and regional aerospace industrial and technological districts (Troisi et al, 2021). The National Cluster is responsible for, among other things, setting priorities based on national policies and technological developments and ensuring that the Italian aerospace industry plays a robust and proactive role globally in both aeronautics and space research (ITA, 2019). CTNA data show that these are mostly SMEs, highly specialized and often engaged in collaborations with large global companies. Within the districts, companies often collaborate in partnerships, both with other companies and with universities and research institutes, with the goal of conducting research and developing innovative products. In fact, the aerospace industry, being a high-tech sector, requires highly advanced know-how from the players operating in it (Battaglia, 2022). In this type of industry, companies must constantly invest in innovation to remain competitive in the industry. It follows, therefore, that efforts and investments in R&D for companies operating in this sector are crucial to ensure that they stay abreast of technological advances and know how to remain competitive in a rapidly and constantly changing market. Italian aerospace districts and the companies operating in them are precisely involved in numerous R&D projects co-funded by national and international programs (ITA, 2019). Although the number of private players operating in the sector and financing these activities has been continuously growing in the past years, the main developments in the space segment continue to be mainly related to the programs of national and international space agencies. In the case of the Italian space industry, the two main flagship agencies are the European Space Agency (ESA) and the Italian Space Agency (ASI) (MIMIT, 2020).

4.2.4 Institutions of the aerospace sector

At the European level, ESA is the key institution. It was founded in 1975 and created by merging the previous organizations, namely ELDO and ESRO, acquiring a central role in European space policy. The goal pursued with the creation of the ESA was to effectively coordinate European efforts in space exploration, research and innovation and, ultimately, to avoid duplication (Landoni, 2020). In Italy, on the other hand, the main institution in the sector is the ASI, a national public body under the Ministry of University and Research, established in 1988 as a result of Italy's growing role in the sector and the increasing importance of space policies (Vurchio and Giunta, 2021). Since its early years, ASI has followed the model of some of the best international experiences, initiating an extensive exploration program and major international collaborations. At the European level, ASI actively participates in all ESA programs (Vurchio and Giunta, 2021). In addition to ESA, the United States is the international partner with which ASI has established the most privileged relationships, having expanded its collaboration with NASA through bilateral agreements over the years. With regard to ASI's duties and activities, these consist mainly of allocating public funds to selected companies and other industry players to participate in national space programs (Fazioli, 2020). ASI also plays a key role in promoting, supporting, and coordinating Italian participation in ESA programs (Vurchio and Giunta, 2021). Operations are therefore planned on the basis of financing made available to the agency, and this is precisely why the ASI plays such a central and decisive role in the Italian aerospace sector.

4.3 Latest developments in the aerospace industry

In recent years, the aerospace industry has been facing a series of structural changes that are causing it to undergo profound restructuring (Emerton, 2017). Institutional and governmental players in the field have increasingly been complemented by new private players, from innovative startups to research centers. This development has been enabled by the growing commercialization of the industry, driven primarily by the proliferation of small satellites and the use of off-the-shelf components. The growing popularity of satellites also expands the variety of satellite applications, which are increasingly revolutionizing our lifestyles. All these developments that have shaped the industry in recent years have been termed as *New Space*.

4.3.1 Changing industry players

In the early decades of space development, the main players in the industry were public agencies because of the very high cost of operations. Being at the beginning of the learning curve and the limited availability space-qualified devices forced difficult and time-consuming design and development, with rigorous testing, often accompanied by redundancies, resulting in high associated costs and long development times (Ince, 2020). In fact, research, design and launch activities at that time required substantial human and financial resources, resources that only a few governments were able to afford (Emerton, 2017). To date, with the standardization of many satellite technologies and the consequent emergence of economies of scale, this sector has become accessible to many more players, from public and private institutions to large and small universities, to new and innovative startups. (Emerton, 2017).

First, several new space powers are emerging on the global scene, starting with China, India, Japan, and other OECD countries, thus seeking greater independence in their operations in the sector globally (Emerton, 2017). Despite the emergence of these new space powers, Europe continues to maintain a world-leading position in the space sector. European industry can boast highly advanced technologies and systems and competitive products dedicated to a wide range of both public and private users[21]. In addition, independent access to space and the resulting implications enables European countries to strengthen their position in the global geostrategic landscape (Emerton, 2017).

[21] Most notably, European satellite operators and space service providers are major players in the global Earth Observation (EO) and Satellite Communications (SatCom) markets.

Parallel to the emergence of new space powers on the global scene, the number of private and corporate players operating in the sector is also significantly increasing all over the world. While previously the space segment relied primarily on institutional support, today private participation has become crucial. For instance, in 2018 the sector grew to €370 billion globally, 80 percent of which can be attributed to commercial activity and the remaining to public spending (Di Pippo, 2022). The emergence of these new private actors should not be interpreted as a process of withdrawal of public authorities from the space business (Emerton, 2017). In fact, private actors do not replace but rather add to existing public entities, thus contributing to a more composite and complex industry landscape. This means that industry incumbents face increasing competition in commercial markets, both for the production and supply of space systems and for their downstream applications, as more and more players seek to enter the aerospace value chain (Emerton, 2017). Under pressure from new entrants, the space sector increasingly resembles other high-tech commercial industries, where optimized operational strategies and cutting-edge R&D programs become critical to succeed in such a competitive environment (Rapp and Dos Santos, 2015).

4.3.2 Satellite miniaturization and its implications

An important central factor in the restructuring of the space sector is the increasing implementation of technological innovations, which have contributed greatly to recent advances in satellite miniaturization (Emerton, 2017). In fact, the proliferation of nano- and micro-satellites has been a key factor in making satellites accessible to many more players in the industry (Rapp and Dos Santos, 2015). In fact, most of the new players on the industrial scene rely on small satellites that, despite their size, are capable of providing very sophisticated services. But that of satellite miniaturization is actually a trend that began to spread as early as the early 1990s and has only become more and more widespread since then[22].

The first satellites launched in history were quite small by the standards of later years. For example, Sputnik I[23] was 83 kilograms and the American Explorer I[24] weighed only 14 kilograms. Soon, however, developments in the field turned to much larger satellites. These

[22] For example, in a time segment in which this phenomenon of micro- and nano-satellite deployment was particularly pronounced, namely the time frame between year 2009 and 2013, the number of operational small satellites grew by as much as 37.2 percent (SpaceWorks, 2014 in Rapp and Dos Santos, 2015).

[23] Sputnik I was launched in 1957

[24] American Explorer I was launched in 1958

were the years of the Cold War, and space-faring countries increased the size of their satellites to meet communication and defense requirement (Ince, 2020). The large size of these early satellites was accompanied by tedious and time-consuming development of components and subsystems that, as mentioned in the previous paragraphs, required large economic investments and very advanced technical skills, thus contributing to make large satellites the realm of few wealthy governments and large companies (Ince, 2020). However, between the 1960s and the 1980s, much smaller satellites, often created with much more limited resources and for amateur, educational and research purposes, also began to emerge. For example, among these early small satellites, one finds those used by amateur radio communities or for testing new systems or proofs of concept. However, small-satellite technology began to experience real development starting from the 1980s, thanks to a group of young engineers led by Matin Sweeting at the University of Surrey, in the United Kingdom (Ince, 2020). The Surrey group in fact acquired an innovative approach to the development of small satellites, based on the use of off-the-shelf components that made the cost of these small satellites far cheaper than that of large governmental ones. In fact, these followed the same design and development approach as the larger ones, but due to a simpler and faster design and the use of off-the-shelf components, they required less time and resources to be created. In addition to significantly reducing design and creation costs, among the main competitive advantages of small satellites is that they could be developed and deployed very quickly (Ince, 2020). In fact, because small satellites are much more standardized and modular than large satellites, manufacturing techniques have been able to adapt over time to some typically industrial production processes, such as the mass production techniques of the automotive industry and the integration of state-of-the-art automation (Emerton, 2017). As a result of these developments, not only did it become possible to produce many more satellites, but it also made it possible to do so in substantially shorter time frames.

One of the most paradigmatic examples of these changes is OneWeb's fleet of 900 satellites. In fact, the British communications company manages to produce 40 to 60 satellites per month, compressing the cost to between $400,000 and $500,000 per satellite[25] (Emerton, 2017). Overall, therefore, it is possible to claim that the proliferation of small satellites has revolutionized the space sector, making it more accessible to many new players. This applies not only to the production and launch of the satellites themselves, but also to all those activities

[25] OneWeb also carried out the largest launch campaign, managing to send new satellites every 21 days (Emerton, 2017).

that develop from the services provided by these satellites. It follows that the aforementioned changes occurring within the satellite industry have produced and will continue to produce in the coming decades enormous changes in numerous other sectors. This new phase of development of the space sector has been referred to by many as *New Space*.

4.3.3 Satellite applications

Communications and Internet connectivity

Satellites have become a key element of global communications. In fact, huge constellations of nano- and micro-satellites underpin the operation of Internet connectivity and the Internet of Things (IoT) (Ince, 2020). In particular, micro-satellites have a number of technical advantages, including small antennas and low latency, which make them particularly suitable for transmitting messages and short data packets. In addition, constellations of micro-satellites enable increasingly cheap and widespread Internet access, even in the most remote corners of the world, which prior to the advent of these constellations were either devoid of such service or were poorly served (Ince, 2020). Indeed, a number of companies active in this field have begun to proliferate in recent years, ranging from new space startups to large, well-known companies with large amounts of capital to invest[26]. Among the most well-known examples is that of Starlink, the project initiated by the company SpaceX to provide global Internet coverage through the use of micro-satellites in Low Earth Orbit (LEO) (McDowell, 2020)[27].

Earth Observation and Remote Sensing

The field of remote sensing has been revolutionized by the advent and spread of micro- and nano-satellites. Indeed, the ability to launch large numbers of satellites into orbit makes it possible to acquire images of any point on Earth. These images can then be adapted to a growing number of applications, such as precision agriculture, natural resource management, urban planning, and climate change analysis (Ince, 2020).

[26] Among them, not only do we find large companies that come from a specifically space background (e.g., SpaceX), but also companies with large amounts of capital but traditionally active in a completely different sector (e.g., Amazon). The interest shown by the latter category confirms the trend towards commercialization of the space sector and the greater diversity of investments and players operating in it.

[27] Low Earth Orbit (LEO) is an orbit located at an altitude between 160 and 2000 km. Starlink satellites are therefore not in geostationary orbit (GEO) or medium orbit (MEO), where most satellites have traditionally been located. This allows Starlink to greatly reduce communication latency and delay and enables the provision of a broadband, high-speed connection.

New remote sensing satellites can be based on different technologies, particularly three main ones, namely:

- Optical or multispectral. These are satellites that collect data in the optical bands of the electromagnetic spectrum, from ultraviolet to infrared (Li et al., 2023). One example of satellite based on such a technology is Landsat, a series of satellites launched by NASA.
- Synthetic Aperture Radar (SAR). These satellites use radars that emit signals that are reflected from the Earth's surface and then collected by the satellite itself. The time it takes for the signal to return to the satellite makes it possible to determine the distance between it and the Earth's surface, thus producing a three-dimensional image (Li et al., 2023).
- Radio frequency (RF) sensing. This technology enables satellites to detect radio signals emitted from Earth and use them for various purposes, including monitoring maritime traffic, detecting radio signals, and measuring ocean temperatures. A well-known example is the Italian COSMO-SkyMed system (Li et al., 2023).

Science and technology

The increasing use of small satellites is also being pursued by space agencies, such as NASA and ESA, universities, and research institutes for scientific and technology development purposes. These goals are being pursued primarily through the use of a particular type of small satellites, CubeSat, which weigh only a few kilograms and carry several advantages, including affordability and ease of launch (Ince, 2020). Among the various applications for scientific purposes are space exploration, particularly exploration of the Solar System using CubeSats, the study of the Earth and terrestrial phenomena such as climate change or monitoring of water resources, and finally the study of astrophysical phenomena such as cosmic rays or black holes (Ince, 2020).

Defense

The introduction of micro- and nano-satellites is also revolutionizing the defense sector. In fact, features such as their small size and ease of launch make them ideal in unforeseen emergencies where rapid deployment is needed (Ince, 2020). For example, they can be used to identify military posts, monitor troop movements, and provide communications in critical and poorly connected areas (Borowitz, 2022). An additional advantage is that these new technologies can be developed relatively quickly, so they can also be tested and exploited quickly (Ince, 2020).

Indeed, these satellites are often equipped with state-of-the-art sensors and systems and artificial intelligence-based data processing algorithms (Borowitz, 2022).

5. Methodology

5.1 Methodological decisions

The research questions investigated in this study focus on whether there is a preference on the part of aerospace SMEs for external sources of knowledge as opposed to large firms operating in the same segment. In addition, the objective of the study is to understand whether the limited resource endowment of SMEs constrains the predisposition to ensure organizational ambidexterity in a high-tech, knowledge-intensive industry such as the aerospace sector.

Hence, since these are research questions that require articulated answers to explain the reasons behind companies' choices, qualitative research was identified as the best option. In detail, qualitative research has a useful explanatory function in explaining the reasons behind firms' preferences and strategies. It makes it possible to explore in depth the factors that determine the preference for internal or external sources of knowledge, as well as the factors influencing the organizational ambidexterity of firms. In addition, aerospace firms operate in a complex and unique context, where the application of qualitative research can help to understand environmental factors impacting on firms' strategic choices.

Since this study focuses on the Italian aerospace sector, it was necessary to identify the most suitable companies operating in the field to partake in the study. Given the nature of the research questions and considering the comparative character of the study itself[28], the choice of a multiple case study was deemed to be the most suitable approach for analysis. Since the study aims to reveal differences and similarities in the strategic and organizational choices of SMEs and large firms, it would not have been possible to proceed with a single case study. Furthermore, it was decided to avoid the analysis of only two case studies, one of an SME and one of a large company, for fear that the results would have been too case-specific and limited to the two companies.

It was thus decided to proceed by considering two or three case studies per company category considered in the study[29]. This choice allowed for a broader comparison among companies

[28] The study aims at analysing differences in strategic choices and operations of SMEs and large firms operating in the aerospace industry.

[29] These being large companies vs. small-medium enterprises.

within the same category, so as to exclude from the analysis as many case-specific elements as possible and thus ensure greater generalization of results[30].

5.2 Sample construction

With regard to the selection of specific companies to be involved in the study, it was decided to proceed with non-probability sampling, in detail through a technique called purposive sampling[31]. This involves sampling based on specific and relevant criteria determined through an analysis of existing knowledge and theories. These criteria allow for a targeted selection of study participants so that the analysis leads to the emergence of relevant and specific information. Accordingly, the participating companies were selected based on the key criterion underlying the analysis, namely companies operating in the Italian aerospace sector. In particular, in order to guarantee consistency across the activities of the different companies and thus to render the comparison more valid, an attempt was made to identify companies whose activities fell within at least one stage of the satellite production chain, particularly micro- and nano-satellites[32]. Also considering the literature review conducted in the first chapter, an important criterion on which the sampling was based was company size, as the goal was to produce a comparison between SMEs and large companies. Therefore, an attempt was made to select companies of different sizes, from small, recently established startups to the large industry giants that have always dominated the sector.

A crucial source for finding these companies was the Catalogue "Italian Space Industry 2021-2022", produced by ASI and the Italian Trade Agency (ITA). This is the fifth edition of the catalog, which is updated on an annual basis and is produced to facilitate Italian exports in the sector. The catalog collects all company profiles of companies active in the aerospace sector with their products, services, and technologies. The 2021-2022 edition lists a total of 153 companies, including 21 large enterprises, 105 SMEs and 21 start-ups.

[30] Although case studies are not as reliable for generalization purposes as quantitative methods, this choice was deemed the most appropriate to bring out the underlying motivations behind business choices whilst ensuring greater generalization of results.

[31] Campbell et al. (2020) describes this technique as sampling in which individuals selected as research participants are consciously chosen for their suitability to further the purpose of the research.

[32] The choice of satellite production chain is due to the fact that satellite miniaturization is a central trend in New Space. One can imagine, therefore, that considering this type of product and market can be particularly representative of the dynamics of the space industry as a whole and thus also of the decisions of the companies in it.

Based on the consultation of this catalog, it was possible to identify a list of companies to approach for participation in the study. At this first stage, 32 companies were identified as possible participants since their core business fell in some way within the production chain of aerospace companies. Therefore, a group of about ten of these companies were contacted by e-mail. Among them, only two were willing to participate in the study. Next, the remaining companies were contacted, again by e-mail, and of these three more indicated their availability to partake in the research. Each time a new company was contacted, it was done by e-mail, sending a concise message of self-presentation and explaining the purpose of the research conducted. These initial e-mails were addressed to the e-mail addresses listed in the catalog, which usually corresponded to the company's press office contact, thus serving as gatekeeper. Once the company indicated its willingness to participate in the study, a brief outline of the interview was sent so that they could get an idea of the issues and topics covered and thus designate the most suitable person to conduct the interview within the company. At this point a date and time of the interview was set according to the interviewee's availability.
Once the entire recruitment phase was completed, the number of individuals who would take part in the study was six, representing six different companies of the Italian space sector. The company profiles are briefly outlined as follows.

Leonardo S.p.A.

Leonardo S.p.A. ranks among the top ten global players in the industry, with a turnover of 12.2 billion euros, 85 percent of which is achieved in international markets. Leonardo is in fact headquartered in Italy, but has a strong presence in other international markets, for example, the United Kingdom, the United States, Poland and others. It counts more than 50,000 employees in more than twenty countries around the world. It is a company specialized in the aerospace, defense and security sectors. In particular, Leonardo's activities in the space field took off from the mid-1960s, with the participation of Officine Galileo and FIAR in the first European programs promoted by ELDO and ESRO; since then, Leonardo has designed and produced a range of specialized instruments for space activities. Leonardo's main products include optical systems, star trackers, radio frequency devices, photovoltaic assemblies, power distribution and control systems, and robotic devices.

Telespazio S.p.A.

Telespazio S.p.A. is a joint venture between Leonardo (67 percent) and Thales (33 percent) and is a leading provider of satellite solutions, especially in the areas of satellite communications and geoinformation. Today it is headquartered in Rome and has more than 3,000 employees in nine countries through its various subsidiaries and joint ventures. Telespazio has more than sixty years' experience in the telecommunications and satellite television sectors, and recently began offering dedicated services to the oil & gas, utilities, maritime and telco sectors as well. Through its joint ventures, e-GEOS in Italy and GAF in Germany, Telespazio is also at the forefront in areas related to the Earth observation market. It also has a history of active participation in space programs such as Galileo, EGNOS, Copernicus and COSMO-SkyMed.

Sitael S.p.A.

Sitael is the largest private space company in Italy and is known worldwide as a leader in the small satellite industry. In fact, it is involved in a variety of activities that fall under the development of small satellite platforms, advanced propulsion systems, and on-board avionics. It provides instruments and solutions for various purposes from Earth observation to telecommunications and to science. It counts more than 250 employees and has a turnover of about 35 million. In addition, the company belongs to the Angel Group, an Italian holding company active in the rail, aerospace, and aviation markets.

Aresys S.r.l.

Aresys S.r.l. is an innovative SME, established in 2003 as a spin-off of the Polytechnic University of Milan. It focuses on providing innovative monitoring solutions for the aerospace and defense markets, as well as for the oil & gas industry. The monitoring and detection tools developed by the company are based on state-of-the-art technologies, such as microwave Radar/SAR and optical imaging, seismic surveys and vibroacoustic sensors. The company employs about 60 people and has annual turnover of about 6 million euros.

Guizzo Space S.r.l.s.

Guizzo Space S.r.l.s. is a micro-company established in 2018 with the aim of providing space-qualified micro-electronics, especially electronic boards and units, for nano- and micro-satellites. The company's product offerings find applications in the fields of optical telecommunications, scientific payloads, and robotics. The company has an average turnover of about 160,000 euros and, as a micro-enterprise, fewer than 10 employees.

Arca Dynamics S.r.l.s.

Arca Dynamics S.r.l.s. is an innovative startup focused on providing solutions for environmental sustainability and space exploitation. It also offers space traffic management and Earth observation services by harnessing its nano-satellites. Its proposed technologies include solutions for highly accurate, artificial intelligence-based collision risk analysis, tools for resource gathering, including monitoring of maritime traffic and critical infrastructure, and sustainable shipboard components. It employs fewer than 10 people and has annual sales of about 217,000 euros, thus falling into the category of micro-enterprises.

5.3 Research method

In light of the nature of the study conducted and the research questions, the technique deemed most appropriate for data collection was semi-structured interviews. This choice allowed each interview to be conducted by referring to the same list of questions contained in the topic guide. By asking similar questions to different companies, it was possible to compare their responses and bring out similarities and differences. However, the choice of semi-structured interviews also made it possible to shape the interview according to the information provided from time to time by different companies, thus allowing for a tailored case-by-case approach. In fact, this technique allows for in-depth exploration of interesting aspects that emerge during the interview that may not have been anticipated by the researcher. It also allows to delve deeper into the specific context of each company, gaining a better understanding of the reasons behind their strategic choices. To this end, the choice of semi-structured interviews is particularly appropriate precisely because open-ended questions enable the acquisition of complex qualitative data that provide in-depth understanding of firms' preferences and strategies and the motivations behind them.

As mentioned above, the main tool used for conducting all interviews was the topic guide, which allowed each interview to be structured around groups of topics of interest to the research (see Appendix A). The topic guide was constructed in advance and was initially organized around eight main sensitizing topics, which explored all relevant topics and aspects in depth. However, from the first attempts to organize the interviews, most of the companies requested that the interview did not last longer than half an hour. Therefore, due to the time limitation set by the interviewees, it was necessary from the beginning to modify the topic guide so that it would be as concise as possible. Questions and sensitizing topics were thus reduced and summarized into a shorter topic guide, whose five sensitizing topics are as follows.

Surveillance of market developments and adoption of new technologies

To investigate the systematic efforts of companies and the tools used to investigate short-, medium-, and long-term developments in the targeted market so as to identify areas where the most interesting developments are most likely to emerge. Also, it considers what factors and strategies are used to decide which new technologies to invest in.

Knowledge sourcing strategies

To identify what strategies enterprises adopt to develop and acquire knowledge; thus, to investigate whether firms generate their knowledge internally (through in-house R&D activities), if they outsource it, or if they collaborate with external parties to create it. An attempt is also made to understand the reasons behind these choices and in which cases one solution is preferable to another.

Partnerships with other firms

To analyze agreements between companies that pool their resources with the goal of pursuing common ends in research and development. The aim is to investigate how companies initiate, manage and exploit these partnerships and what advantages and disadvantages may be related to them.

Collaborations with universities and research centers

To explore how companies' collaborations with research institutions, primarily universities, arise and what advantages and disadvantages they entail. The goal is to understand how resources are shared and exchanged, and how they can affect companies' technological innovation and strategic development.

Balancing exploration and exploitation activities

To understand how firms deal with the problem of organizational ambidexterity. The goal is to try to understand what difficulties may arise in resource allocation and how firms manage themselves to pursue innovative research while maintaining stable production. It also aims to try to understand how, at the organizational level, firms sequence production and research activities.

In one particular case, namely the interview conducted with Leonardo S.p.A., it was necessary to shorten the topic guide even further, as the time allocated by the interviewee was about 15 minutes. Therefore, a different approach had to be taken in this case. Indeed, Leonardo S.p.A. was a very relevant case study for answering the research question, as it is the largest company in the aerospace industry in Italy, and it was crucial not to lose its contribution to the research due to the time limit. Therefore, preliminary research was conducted on how the company conducts R&D and based on the data already on the Internet and contained in numerous articles consulted, a number of short questions aimed at answering the research questions were modeled (see Appendix B). Although an attempt was made to keep the topic guide as comprehensive as possible, the need to reduce it and make cuts meant that some in-depth questions, particularly prompting questions, were merged, or even cut, thus losing some level of detail in respondents' answers.

5.4 Data collection

All organized interviews were conducted online and questions were asked by a single interviewer, the same for all interviews. The decision to conduct the interviews remotely was due to the need to minimize the interview time expressed by the participants and, on several occasions, also to the geographical distance of the companies' locations. However, the remote modality used to conduct interviews may have resulted in some limitations. For example, the online interaction did not allow the acquisition of much information related to the interviewee's tone of voice or physical movements. In addition, such modality can potentially hinder the creation of a bond between interviewee and interviewer. However, this was not the case, as in all instances the interviewers showed sincere availability, providing detailed answers, and rarely trying to rush to the conclusion of the interview. On the contrary, they were very curious and interested and they asked numerous questions related to the research topic and the next steps in data analysis.

All the areas touched upon by the guiding questions proved to be important in understanding the reasons for companies' choices, both in terms of R&D and production. Therefore, the content of the interviews proved sufficient to answer the research questions. This was also possible because of the broad knowledge of the topics possessed by all the interviewees. In fact, the various companies willing to participate in the research designated employees who were specialists in or responsible of the R&D department and who were able to answer the questions posed in a very comprehensive manner. These included the mission Manager at Arca Dynamics, the Chief Executive Officer (CEO) at Guizzo Space, the Head of Research Laboratories at Leonardo S.p.A., the Business Development Manager at Aresys, the Managing Director Sales and Products at Sitael. All interviews were conducted without any particular problems, and only in a couple of cases companies asked to reschedule the date and time initially set. Overall, all the interviews were conducted between May 29th and July 11th, 2023.

5.5 Data analysis

Regarding the data analysis process, the Grounded Theory method was chosen as the best option. The first step was to write all transcripts of the interviews conducted (see Appendix C). Crucial to this was the recording made while conducting the interviews themselves. The product of the transcription process was a total of six transcripts for the six interviews conducted. At this point, the coding process was initiated, and it was arranged into a first phase of open coding, a subsequent phase of axial coding, and finally a round of selective coding.
The first round of open coding was carried out by using NVivo software (version 12 R1) and resulted in a total of 132 open codes. At this point, the second stage of the coding process was also carried out with NVivo and consisted in the grouping and merging of similar codes and the creation of the corresponding axial codes. The result of this phase was a total of 40 axial codes, which were then further grouped into a second round of axial codes. This second round of axial coding resulted in 9 axial codes. In the last coding stage, the selective coding step, an attempt was made to group the axial codes according to the main research themes that appeared to be the main pillars of the research itself. This final stage of coding resulted in 3 main selective codes, namely:

- Collaboration in R&D activities
- Strategies for R&D choices
- Balancing exploration and exploitation

The entire coding process was conducted with the aim of creating a logical framework that would effectively organize the results of the analysis (see Appendix D).
Once the coding process was completed, it was decided to proceed with the creation of a result map (see Appendix E). For the latter, the use of the Nvivo software was abandoned and the Creately online program was adopted in order to create it.

Overall, the analysis process went smoothly and without major difficulties. The different coding steps were carried out without great problems, partly due to the correspondence between the answers given by different interviewees and the recurrence of certain topics, both factors that made the process of grouping similar topics easier and faster. In addition, as for the research results, all interviews were relevant in providing detailed information and comprehensive answers to the questions included in the topic guide. The Grounded Theory method played a key role in identifying and portraying the dynamics of R&D strategies prevalent in the Italian aerospace sector. The coding process, which included open, axial, and selective coding phases, facilitated a deep understanding of the data, helping to identify the central themes of the interviews. In addition, the consistency observed in the responses given by several interviewees provides a solid pillar in support of the reliability and internal validity of the results. This consistency not only indicates a convergence in the experiences and perspectives of the interviewees, but also suggests that the central themes identified are rooted in the aerospace sector, thus strengthening the internal validity of the study.
Regarding the generalizability of these results, it would be necessary to further deepen the research by including even more case studies and perhaps resorting to quantitative research techniques. However, in this context, it was decided to investigate only six case studies since the main objective was not to verify the generalizability of the results, but rather to delve deeper into the topic, to understand some of its dynamics and to better understand the phenomenon. To this end, the use of semi-structured interviews and a limited number of case studies made it possible to achieve the goal. Testing the generalizability of these results is an issue left for future research.

5.6 Ethical considerations

Although the research questions did not touch on particularly sensitive or personal topics, some ethical considerations were still necessary.
First, from the first contacts with the interviewed companies, the purpose of the research was explicitly stated, and in the first e-mail exchanges the main features of the research were also outlined, so as to provide sufficient information on the topic at hand. In addition, at this stage many companies asked a number of questions about both the topic of the research and the practical use of the information provided. Therefore, detailed answers were provided to all the questions asked.

It was explicitly stated via email that participation in the study was completely voluntary, and companies confirmed their willingness by explicitly responding to these emails.

At the beginning of each interview, permission to record the interviewee was also explicitly asked. Such permission was granted in all six cases by the interviewees verbally, before the interview itself began. In addition, the use that would be made of the audio recording was briefly explained, namely that it would be used to transcribe the content of the interview and then begin the process of coding and analysis. The interviewees verbally consented to such use.

Furthermore, although the questions were not particularly sensitive or personal, respondents' participation was still protected by ensuring their anonymity and keeping explicit only the company they worked for and their role within it.

All of this information regarding informed consent was communicated and consented to verbally during the various stages of data collection, without the use of written consent forms.

6. Results

The results of the study provided a sufficiently complete and detailed picture of R&D decisions made by the companies surveyed. Among the most important findings is the central importance attached to R&D by these companies, regardless of their size. In fact, all the companies surveyed emphasized the centrality of R&D to their own operation and success. This result is in line with expectations: much of the existing literature consulted initially highlighted the central role of R&D for all companies operating in advanced, high-technology sectors. It was therefore expected that this consideration would also apply to the case of aerospace companies. Confirmation of the importance of R&D activities for the companies surveyed, and probably for all companies operating in the industry, made it possible to conduct and organize the remaining questions on the use of internal and external sources of knowledge and the relationship between exploratory and exploitative activities. The results are organized according to three main summary concepts (namely, the three selective codes obtained from the last stage of the coding process), which correspond to the following three paragraphs and are presented below.

6.1 Collaboration in R&D activities

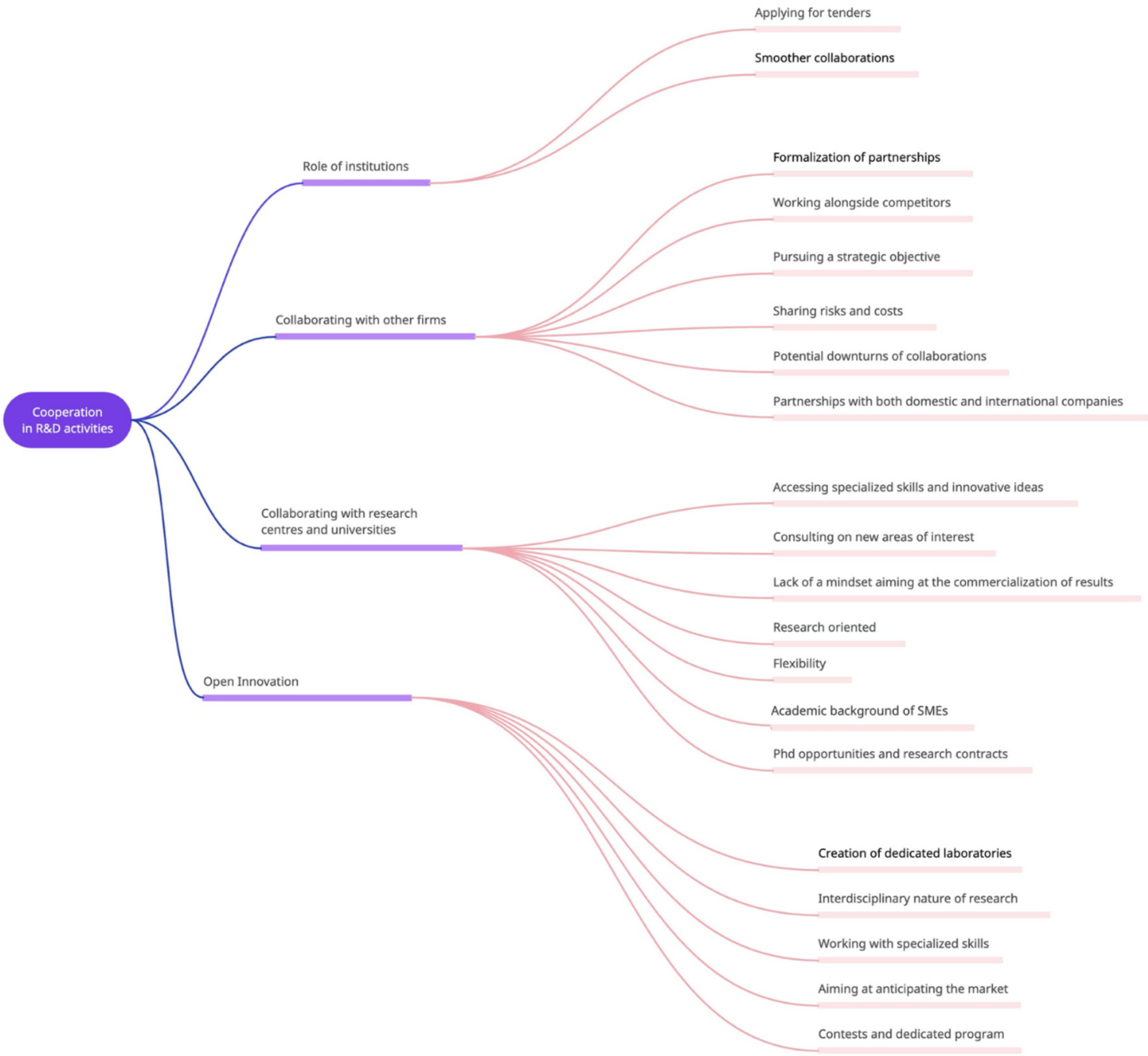

Table 7. Cooperation in R&D activities – Results map
Source: original

In addition to the importance attached to R&D, another key finding is the complementarity of internal and non-internal[33] knowledge sources used by firms to develop new technologies, products and services. All the companies interviewed confirmed that they use both types of knowledge sources to fuel their R&D activities. On the one hand, they cannot rely solely on their own internal resources as they have to adapt to the extremely rapid technological developments in the industry and the need for extremely specific skills that cannot always be

[33] Non-internal knowledge sources identify both the external and quasi-external activities mentioned in the previous chapters.

brought in-house. On the other hand, relying solely on external sources is not an option either, as in-house expertise is critical to ensuring a company's competitive advantage.

As mentioned earlier, private investments in R&D, are extremely expensive investments, involving a high level of uncertainty as they fall in the long-term funding category (Rosenberg, 1990). In fact, private companies undertake internal R&D only on competences and technologies on which there is a sufficient level of certainty, that is, which guarantee a sufficiently high rate of return on investment. Obviously, not all technologies exploited by the company can guarantee such certainty; for all those technologies that require investment that is too uncertain and does not guarantee the company a sufficient commercial return, they opt to exploit external sources of knowledge.

Another reason behind the choice of firms to conduct R&D in-house is that this allows firms to maintain a competitive edge by promoting their unique innovations and safeguarding proprietary technologies. In fact, in line with what Rosenberg (1990) explained, in-house R&D by private firms is hampered not only by the high level of uncertainty, but also by the fundamental problem of the appropriability of the knowledge produced. Since this knowledge is an on the shelf type of product, thus potentially usable by all companies, even those that had not participated in its creation, it could give rise to free riding situations (Rosenberg, 2020). For this reason, the interviews conducted revealed the great importance placed by companies on Intellectual Property Rights (IPRs), the only way for companies to appropriate the knowledge produced, limiting the problem of free riding by third-party companies.

Additionally, the interviews to some extent confirmed the importance of internal knowledge and experience also in better evaluating the various external knowledge, understanding, and selecting those that can really benefit the company. In the relevant literature, this capability given by internal experience has been referred to as *absorptive capacity* (Cohen and Levinthal, 1990). This competence was defined by the interviewees as critical, to ensure that externally acquired knowledge also contributes to keeping the company's competencies aligned with strategic objectives. In fact, according to Rosenberg (1990), acquiring external sources of knowledge: "*often requires considerable research capacity to understand, interpret, and evaluate the knowledge made available, whether basic or applied. The cost of maintaining this capacity is high because it probably requires a cadre of internal scientists capable of doing these things*".

All these elements point in the same direction: internal and external sources of knowledge are complementary for companies in the Italian aerospace industry. In line with this idea, interviewees described the possibility of collaborating with both other companies in the industry and with research centers and universities not only as an added value, but almost as a necessity. For example, a couple of interviewees suggested that aerospace companies must collaborate and keep themselves somewhat open and receptive to the outside world, otherwise research and production will quickly become obsolete. To further explore the topic of collaborations with non-internal actors, it was decided to distinguish between collaborations with other companies and collaborations with universities and research institutions.

6.1.1 Collaborations with other firms

Regarding collaborations with other companies, it was stressed in almost all interviews that remaining open to the external environment is imperative to ensure the survival of companies in this technological and dynamic sector. However, collaborations with other companies in the industry remains a very delicate matter. Indeed, it emerged several times that these are accepted only when they are in some way beneficial to the parties involved. For example, they are accepted if they enable firms to achieve a strategic goal, such as demonstrating their technologies in orbit or achieving the numbers needed to compete for national tenders. In addition, this type of collaboration is valued by companies because it allows them to greatly reduce risks and costs by distributing them among the parties.

Therefore, collaborations between companies should benefit the parties and not penalize them. In this regard, it has been repeatedly pointed out that R&D collaborations are very tricky and how they can lead to the emergence of numerous concerns. For example, one company stated that inter-firm collaborations specifically focused on R&D processes are to be avoided because of their overly strategic role. Although this certainly represents a voice out of the chorus, the delicacy of these contractual arrangements was also emphasized in the other cases. Other interviewees said they were willing to engage in such collaborations as long as they are clearly defined within a strict contractual framework. The reluctance to collaborate on aerospace R&D is a characteristic of the aerospace industry not only in Italy, but globally. This sector involves the development of highly strategic and sensitive technologies and, as a result, companies are often cautious about entering into collaborations that involve sharing technologies and knowledge that could compromise their competitive advantage.

In addition, it has repeatedly emerged that R&D-related inter-firm collaborations are actually more frequent when they involve application research rather than technology research. In other words, companies are more likely to collaborate with each other when they aim to produce a product for commercialization rather than simply introducing a new technology[34]. This result is interesting: it seems that companies are more likely to collaborate as they approach the market. It appears that when collaboration aims at producing a product that can be commercialized relatively quickly, uncertainty is reduced, and collaboration is more easily undertaken. In line with these considerations, it has been repeatedly stated that among the main advantages of business-to-business collaboration is the business mentality, which facilitates the commercialization of products[35].

However, the interviews also revealed several disadvantages associated with these collaborations. Among the challenges highlighted is the increased complexity of coordination among the participating companies or entities, which consequently increases the risk of project failure. In addition, there is the problem of fragmented ownership of the resulting product or service. This is said to lead to ambiguities in rights and responsibilities, potentially hindering the full exploitation of the innovation or even leading to disputes over its commercial use. There is also the possibility of partners backing out of their commitments, contributing fewer resources than expected or showing a lack of genuine interest. Unequal participation can also pose problems if one party disproportionately bears the workload or risks.

All these concerns clearly highlight the problem of incomplete contracts and thus the importance of clearly defining the contractual terms governing these collaborations. In line with Hart's (1988) Theory of Incomplete Contracts, drafting complete contracts[36] turns out to be too costly if not impossible because of human bounded rationality, that is, the cognitive limitation of defining all possible courses of action and their contingencies. When confronted with a course of action not provided for in the contract, the parties may behave differently than expected and give rise to disputes. Opportunism may also intervene, leading them to pursue their own interest at the expense of what is stipulated in the contract and perhaps even at the expense of others. In other words, drafting incomplete contracts leads to increased transaction costs.

Interviews revealed how companies strive to write contracts as complete as possible but, given the excessive costs associated with such process, there is always the risk of oversight. It was mostly smaller firms that expressed such concerns, probably because, given their size, they

[34] Mere technological research is much more common when it involves collaboration between companies and universities or within university and research environments.

[35] A characteristic that emerged in many interviews thanks to the comparison of inter-firm collaborations and collaborations between companies and universities and research centers. The latter, in fact, do not possess a corporate mentality aimed at product commercialization, and this often proves to be an obstacle.

[36] By complete contracts we mean contracts that provide for every single possible course of action and the respective actions to be taken.

may be more vulnerable in this regard. Large firms, on the other hand, showed limited concern about the issue of incomplete contracts, probably because of the greater bargaining power they enjoy in dispute situations. Two SMEs respondents pointed out that risks may emerge when they are not fully informed about all the legal nuances of an agreement, that is, in cases of information asymmetries[37]. These respondents also stressed that their experiences over the years have been instructive and have shaped their understanding of what a contract should include. They have become more adept at anticipating potential pitfalls and outlining contract terms more effectively; nevertheless, the problem of incomplete contracts remains present, especially for smaller firms.

As it became clear that all aerospace companies, regardless of their size, highly value collaborations with other companies, partnership preferences were also investigated. Given the small size and characteristics of the Italian aerospace industry, companies operating in it often find themselves working with companies that could be described as competitors. Although almost all of the companies surveyed confirmed a willingness to partner with their competitors, two respondents made a fundamental clarification on this point. Indeed, these interviewees pointed out that in the Italian space sector it is still very difficult to define who competitors are. In fact, the sector is still evolving and is far from being a conventional market economy with clearly defined competition. On the contrary, competition, and thus who competitors are, can change significantly based on the rules of engagement and the presence of dominant incumbents. In other words, depending on the rules of engagement and specific circumstances, firm roles may change. As it was explained by one interviewee: "*The same company in different contexts can be our partner, and when I say partner, it can be an equal partner, a sub-supplier or our prime. Or in another context, for example in a European tender where an international stringer is advantaged, that same company that in national context was our partner, becomes our competitor. So, it's an extremely flexible, extremely varied pattern*".

This interchangeability of roles underscores the dynamic nature of the industry. Another interviewee further explained this by pointing out how collaborating firms often leverage different expertise, allowing them to provide complementary inputs into a project. Even in situations where these firms offer similar products or services, or have the potential to do it, they strategically allocate their skills and contributions in such a way to ensure that the collaboration remains beneficial and does not jeopardize their individual interests.

[37] Information asymmetry occurs when one party to an economic transaction possesses more knowledge or better information than the other party. This imbalance often leads to suboptimal decisions, as the party with less information ultimately makes choices it would not have made if it had complete information.

In line with the abovementioned considerations, inter-firm partnerships can thus manifest in various forms and can evolve over time, for instance becoming more formalized or leading to the emergence of joint ventures. All interviewees made a clear-cut distinction between three main forms of partnerships, namely:

- Equal partnership, in which firms have an equal role and share in the collaboration;
- Prime relationship, in which one firm takes on a leading and managerial role in the project whilst other companies play a supportive part;
- Subcontractor relationship, whereby one firm is the primary contractor and the others provide specific components or services.

As already mentioned, firms' roles can change greatly according to circumstances. However, one interviewee also pointed out that successful collaborations are frequently maintained and they may also evolve and become more formalized[38]. The quote "*When the team wins you don't change*" encapsulates the idea that successful collaborations tend to repeat themselves. This approach underscores the value of trust and proven synergy in relationships between companies in the industry. In fact, the emergence of mutual trust between companies can actually reduce transaction costs associated with established collaborations. The importance of trust in collaborations is not industry-specific; rather, trust appears to be central to reducing transaction costs in potentially all industries. In fact, a study conducted by Filippetti and D'Ippolito (2016) confirms how in various industries successful inter-firm collaborations lead to the emergence of widespread trust between firms; this, in turn, stimulates subsequent relations among trusted enterprises, sometimes resulting in long-term collaborations.

Regarding the geographic distribution of collaborations both among enterprises and with universities and research centers, three respondents reported an equal split, with a 50/50 ratio between Italian and non-Italian collaborations. The other three, however, indicated a preference for Italian collaborations, while no firms reported a predominance of non-Italian collaborations. This bias toward collaborations with domestic actors can be attributed to the greater ease of establishing and maintaining contacts within the national territory. Moreover, the possibility of turning frequently to actor within national boundaries is also due to the fact that the national aerospace technological landscape is particularly advanced, which allows Italian companies to acquire specific knowledge and expertise without necessarily looking beyond borders. In fact, Italy boasts a variety of specialized centers and poles of excellence and that is given by the

[38] The most emblematic case is the emergence of joint ventures, that being an arrangement between two or more companies to work together on a particular project (Cambridge Dictionary, 2020).

well-established status of the sector at the national level and the advanced state of research within our country.

6.1.2 Collaborations with universities and research centers

Italian aerospace companies highly value collaborations, not only with other companies, but especially with research institutes and universities. This sentiment was echoed across all interviews. In fact, all respondents stressed the immense value of collaboration with academic institutions, regardless of company size. Thus, contrary to what was predicted based on the literature review, even larger companies with more resources at their disposal continue to place great value on collaborations, especially those with research centers and universities. These preferences can be traced back to a number of reasons.

Firstly, collaborations with universities and research centers are pursued by companies because from them they can access advanced and highly specialized knowledge that would require too many resources to develop and maintain in-house. So, by collaborating with universities, companies can tap into this reservoir of expertise, ensuring that they remain at the forefront of technological advances. In addition, a trend was noticed whereby companies specializing in a specific domain often form partnerships with universities and institutes renowned for their expertise in that area. This was evident in almost all interviews, as respondents cited their companies' affiliations with research institutions as a cornerstone of their credibility and success. This underscores the importance that practitioners place on these academic collaborations.

In addition to providing long-term advice in companies' core business sectors, these partnerships are particularly useful in providing knowledge related to new sectors that companies decide to enter and that fall outside their traditional activities. One interviewee offered an example: "*A few years ago we became interested in the world of quantum communications because somehow it will be the future. Or at least it will be the technology that can support our business of secure, satellite or even hybrid communications in the future. Clearly all this meant first understanding who in Italy is doing these things. So, we started approaching the University of Padua and the University of Florence. We did some projects together. Sometimes then things stopped because there was no possibility to go for financing to do something together. In other cases, we went on with universities and research centers and with other companies as well, to collaborate on national research and development* *projects from both the military and the civilian sector*". This example thus underscores the importance of the specialized knowledge provided by research centers and universities in the company's process of approaching into a new field. This activity could be identified as specialized consulting in areas where the company lacks the necessary expertise, highlighting the role of universities and research centers as key players in the innovation ecosystem.

Universities and research centers have such cutting-edge and specialized knowledge at their disposal because they often deal with niche research areas that companies may find difficult to replicate internally. A major reason for this is the nature of academic institutions. Unlike companies, universities are primarily driven by the pursuit of knowledge, which allows them to engage in research without the commercial constraints and limitations that companies usually face. This freedom allows them to explore, innovate and specialize in areas that may not be immediately commercially viable but technologically significant. In contrast, for firms, venturing into highly innovative areas carries substantial risks[39]. In fact, one respondent explicitly stated that his company (which is among the large companies surveyed) does not necessarily position itself at the forefront of technology. The logic behind this is that for a company to be on the cutting edge, it cannot have expertise in all emerging technologies. Thus, instead of diving into every new technological development, it strategically relies on entities that specialize in these advances, namely research centers and universities.

Openness to these types of partnerships is considered so strategic that in recent years there is a new trend toward their internalization by larger and more resourceful companies. In fact, two of the companies interviewed, which rank among the leading large companies active in the sector, are trying to take advantage of these open innovation systems by creating special in-house structures with which they seek to place a constant focus on research. In a sense, the creation of these structures aims to integrate the goal of mere commercialization with that of continuous research. According to one respondent's words: "*These structures are a network of labs that were established three years ago out of the need to ensure a continuous focus on research. In fact, the emergence of the labs makes it possible to conduct long-term research on a continuous basis. In fact, this need emerged from the fact that previously the research and development process was marked by constant without the pressure on goal delivery. And*

[39] Among the respondents, the view emerged repeatedly that the technologies in which companies invest should not have a too low TRL. In fact, too low a TRL often corresponds to difficulties in commercializing products and services because the technology is not at the right stage of development to be industrially viable. The interviews revealed that companies may be driven to focus on technologies with low TRLs only when this is counterbalanced by sufficient institutional interest. Indeed, in such cases, entities such as the ASI or ESA can provide the necessary momentum for the advancement of still underdeveloped technologies and their subsequent commercialization.

instead, these labs have therefore enabled a shift in focus from delivery to a continuous focus on research". The introduction of these open innovation structures can also be framed as an attempt by the company to achieve greater organizational ambidexterity, that is, a better balance in the allocation of resources between exploration and exploitation activities. In these terms, it is an attempt to allocate more resources to innovative research, so as to ensure a constant focus on it and to make sure that it is carried out independently and across the board and not just as an activity subordinate to production and goal delivery.

These new systems for open innovation, however, do not replace more traditional ways of exchange between business and academia, which remain present among companies of all sizes. These tools include, for example, simple networking activities and the possibility of entering PhDs or even research contracts in collaborations with companies.

Among the advantages of collaborations with universities and research centers, only one respondent emphasized the flexibility offered by these institutions. It was mentioned that engaging with academic entities involves less formality, facilitating interactions and fostering a relationship focused on substance rather than form. This point of view also emerged to some extent in another interview, but in both cases, these were SMEs. Thus, it can be assumed that in the case of SMEs with an academic background, the flexibility aspect demonstrated by these actors is considered an important advantage. Rather, in another interview from a medium-sized company, the greater flexibility shown by universities and research centers was framed as a disadvantage of the partnership. Indeed, it was said that this often led to difficulties in managing and adhering to previously defined programs.

The difficulty of managing collaborations with universities and research centers has proven to be a fairly recurring theme, especially among medium- and large-sized companies, and in all cases has been traced to the research-oriented mentality inherent in these academic entities. This characteristic, which often prioritizes knowledge advancement over commercial viability, can be a challenge. Researchers said that their attention can sometimes veer toward applications that, while academically interesting, may not be industrially practical or economically feasible. In addition, one respondent added that a project based on collaboration between a company and a university may hit a snag when their goals diverge. For example, when the desire to publish the research clashes with the company's need for protection: *"The desire to publish, the desire to share because it's part of the scientific method, the fact that any discovery is verifiable by anyone else, but this is perfectly antithetical to the company's need for protection."*

These difficulties are not new themes in the literatures; on the contrary, they have been widely encountered. For example, in Crescenti et al. (2017) the lack of institutional proximity[40] between universities and industry is defined as a barrier to potential collaborators meeting each other. This study focuses on the Italian industrial landscape and confirms how the institutional proximity present within inter-firm or inter-university collaboration networks is lacking in the case of collaborations between corporate and academic inventors. This lack represents an obstacle the creation of networks between universities and companies. However, the study also shows how, having overcome this initial obstacle, these types of collaborations more frequently lead to patents of more general applicability. So, organizational and social proximity[41] reduces transaction costs through (respectively) contracts and social relationships (Crescenti et al., 2016). Crescenti et al. (2016) also suggest how the cognitive distance[42] separating university and industry partners can sometimes hinder communication between the two and limit the ability to absorb information from the other side. This concept helps explain many of the difficulties reported by interviewees in managing these collaborations.

6.1.3 Open innovation

The rapidly evolving innovation landscape in the aerospace industry has led to the recognition that collaboration, both with universities and other companies, can significantly amplify the commercial potential of a company, whether large, medium or small. This confirms that the use of external sources of knowledge does not occur only to compensate for the lack of resources within the company. In fact, the use of the partnerships discussed in the previous paragraphs concerns not only small and medium-sized companies, but also, if not especially, large companies. The use of external partnerships is therefore seen as an added value in this industry, because of the rapidity with which innovation proceeds and the complexity of the knowledge required to keep up with it.

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[40] Institutional proximity refers to the distance between the business and academic worlds (Crescenti et al., 2017).

[41] In Crescenti et al. (2015) organizational distance defines whether inventors share the same organizational context, such as the same company, university, or research center. Social distance, on the other hand, indicates whether inventors have co-invented in the past or share other co-inventors.

[42] Cognitive distance denotes the differences in skills, knowledge, and mental approaches among the people engaged in a collaboration. A certain degree of cognitive distance is beneficial for innovation, as it brings different viewpoints and skills into the collaboration. However, excessive cognitive distance can represent an obstacle to communication and the ability to interpret and assimilate each other’s knowledge (Crescenti et al., 2016).

As aforementioned, all the companies interviewed said they participate in various open innovation dynamics, both with other companies and with research institutions. Among the medium-to-large companies interviewed, an effort toward greater structuring of these dynamics also emerged. This is especially noticeable when looking at the diffusion among firms of laboratories dedicated to open innovation. In fact, three among the large and medium-sized companies surveyed described facilities that more or less fell into this category. Especially in two interviews, namely in the cases of two of the largest companies interviewed, these laboratories were described as facilities whose goal is to stay abreast or even ahead of the market. In detail, these laboratories are dedicated to the development of nascent technologies, thus with a low TRL index but with a promising future, in which there can be a long-term interest. Thus, basically, these laboratories host research activities that are traditionally considered risky for companies, because their development is still too uncertain and so are their potential commercial applications.

Given the nature of these R&D activities, it follows that their implementation requires very advanced and specialized skills that are difficult to find internally within companies, even in the case of the largest ones. One respondent added in this regard: "*We rely on these labs, which were created precisely to fill that science skills gap that we don't have and that it's not even fair that we have and that we keep in-house*". Thus, these laboratories serve as hubs of specialized expertise and enable firms to bridge the gap between what they inherently possess and what the innovation landscape demands. They not only complement existing expertise but are critical elements for fostering forward-looking research that can shape the future of the aerospace industry.

Two interviews conducted with large companies revealed an additional trend underlying the logic of open innovation, namely the spread of startup incubation and acceleration programs and other types of competitions. These tools are mainly used by large industry leaders, not only to pursue the company's strategic goals, but also to promote the growth of the entire industry ecosystem. In fact, large companies in the industry often promote competitions that are open to universities and startups that wish to participate. Several teams from different universities or startups then participate in the competition, where they are often asked to provide a solution to a problem or advance an innovative idea. The selection processes for participation in startup incubation and acceleration programs also work similarly. In cases where these small businesses are selected because they are considered promising or deserving, they are included in these programs. These types of competitions and programs are beneficial not only for startups or university teams, which thus have an important opportunity for growth, but also for large organizing companies, which can access a wide plethora of innovative ideas and inputs. Among the small businesses interviewed, one in particular had been selected to participate in a major incubation program and had stressed its importance to the development of their business.

6.1.4 The role of institutions (ASI and ESA)

Collaborations between research organizations, universities and companies often arise in the context of projects managed by institutions such as ESA and ASI. These types of competitions represent a firm-specific element that is unique to the aerospace industry. The tenders announced by ESA and ASI represent very important opportunities for aerospace companies, as they provide access to tools and resources (primarily, economic resources) that can greatly stimulate research and production processes. Additionally, ASI and ESA play such a central role in this industry as their tenders can potentially shape the competition itself within the industry. Indeed, as mentioned earlier, the roles of aerospace companies are mutable, and, for instance, competing companies may collaborate in the context of these calls, or cooperating companies may find themselves competing for the same position.

These tenders can also provide an opportunity to create partnerships. In fact, to participate in these tenders, numerical requirements specified in the notices must be met, so partnerships are often necessary. In fact, two of the companies interviewed mentioned this as one of the main ways to create inter-company partnerships. Of course, the partnerships that are created within ASI or ESA projects are fundamentally different from those that can be created outside of them. First, within these collaborations, ASI and ESA play an important coordinating role, thus helping to reduce high transaction costs. Through special procurement rules, they identify companies that can provide the best specialized expertise, assigning them specific roles and avoiding overlaps and conflicts of interest.

Additionally, companies have a great interest in being selected for these projects because they derive great value from them. Being associated with projects under the authority of these institutions not only provides companies with great recognition, but also functions as a powerful publicity tool. In fact, during almost every interview, these collaborations were cited precisely to communicate the companies' success and credibility. Furthermore, it emerged how companies' R&D skills are carefully screened by these institutions for selection to these types of projects. In this respect, the aerospace sector appears to host similar dynamics as the military sector. Indeed, Rosenberg (1989) suggested how private companies in the military sector were peculiar if compared to those in other industries in that they devoted substantial resources to funding basic research. This propensity was, according to the author, attributable to the fact that, through better internal R&D, private companies were able to improve their visibility and thus be more easily selected for government military procurement contracts. Similarly, aerospace companies seem to incentivize internal R&D processes as a function of the increased visibility that comes with it in the contexts of the competitions in which they participate. Thus, in the context of analyzing the R&D choices of companies in the sector, the presence of these institutions and their tenders is one of the main firm-specific elements to be kept in mind in order to understand the functioning of the sector.

6.2 Strategies for R&D choices

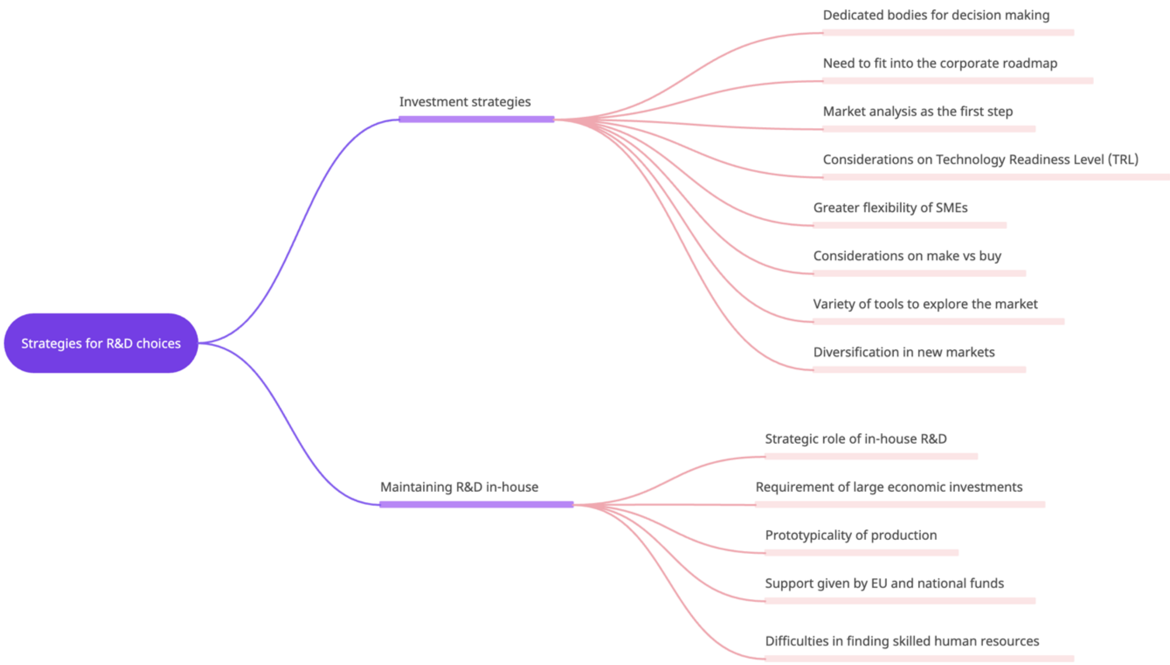


Table 8. Strategies for R&D choices – Results map
Source: original

6.2.1 Investment strategies

As mentioned in the previous paragraphs, in the aerospace sector, and particularly in its space segment, companies are forced to maintain constant attention to the evolution of technology and innovation processes, otherwise they are at risk of rapidly becoming obsolete and being excluded from the market. Maintaining attention to these developments is also instrumental in the decision-making process concerning which new technologies to adopt and invest in. When questioned about the tools used to analyze the market, the companies surveyed cited a wide variety of tools, used almost regardless of company size. Among the tools cited are:

- participation in ASI and ESA calls and projects;
- consultation of ESA harmonization cycles and reviews;
- referral to scientific literature and industry studies (journals and articles);
- participation in trade fairs, R&D working tables, symposia, and seminars;
- maintaining close contact with universities and research institutes;
- own scouting activities.

Once a new technology has been identified as being of interest to the company, a decision-making process about its possible adoption is initiated. The medium and large companies interviewed stated that they have special boards of directors in charge of making these decisions, while in the case of the SMEs interviewed this decision-making process appears to be less structured. Despite these differences, all the companies interviewed suggested similar considerations in this decision-making process. In fact, all companies, regardless of their size, seem to consider:

- technical aspects, so the technology is evaluated for its technical feasibility;
- commercial aspects, thus they try to understand whether such technology can lead to the emergence of a sufficient market demand and thus have a good commercial return;
- whether such technology can fit into the company's roadmap, trying to understand how it can support the development of their products and services.

Business roadmap considerations can also lead to diversification into other markets, a dynamic repeatedly described by respondents from medium and large enterprises interviewed. This is mainly due to the nature of the industry itself. Indeed, the aerospace industry is characterized by a wide variety of satellite applications, and thus companies operating in this area can adapt their satellite assets for various purposes. In addition, one respondent described his company's diversification process as a consequence of gradually saturating the market and reaching a plateau in profits: "*So the decision to diversify was related to a demand for growth that the company had, having brought some lines almost to saturation. So, so to speak, a share nibbling was done (...) also somewhat driven by ESA wanting to reduce some costs, however, clearly there are limits. There are geographic returns especially on institutional, so you cannot bring more than a certain amount to Italy and so clearly there was a plateau. (...) Therefore, the choice was made to open up to new markets where we had experience*". A consequence of this process is that the production of medium- and large-sized enterprises appears to be more diversified and, as a result, R&D activities have also become more cross-cutting. Smaller companies, on the other hand, are positioned in more niche sectors, thanks to highly specialized and cutting-edge micro-component production[43].

Among the various technical aspects to be considered when deciding whether to invest in a new technology, there are also important considerations regarding the TRL level. To ensure a

[43] This result confirms the findings of the literature review suggesting that SMEs in this sector focus primarily on very specific production of small components. They can specialize in these productions and offer products that take advantage of cutting-edge technologies and are unlikely to reach such a level of detail and complexity in other business contexts.

commercial return and thus profits, it is essential that such a technology enables commercial applications fairly quickly. This requires that the TRL level be high enough to make investments in the technology profitable. In this regard, one respondent stated: "*As a private company we can afford to invest a very small fraction of our R&D on low TRL projects. Instead, it is the medium TRL that has a closer market return over time and that is more attractive to us*". From two other interviews it also emerged that companies may also be interested in projects focused on low TRL technologies when there is considerable institutional interest. In other words, when institutions such as ASI and ESA show interest in a particular project by making funds available, companies can be more incentivized to work on low TRL technologies. In fact, in this case, the higher risk corresponding to the low TRL is balanced out by the public investment that supports the company.

6.2.2 Maintaining R&D in-house

The strategic role of R&D for companies in the space industry cannot be overstated. This, as described earlier, is why many companies are very reserved in their research activities and therefore avoid pursuing collaborations in this area, preferring partnerships in other stages of the production process. These considerations were expressed mainly by small and medium-sized companies, which thus prefer to base their R&D activities largely on internal resources. In contrast, it is larger companies that are more welcoming of open innovation in the research process, exclusion made for their core competencies and key technologies. However, it is worth mentioning that research activities conducted in-house within a company have high costs and therefore required significant economic investment, and this often contributes in practice to a mixing of internal and external sources of knowledge in companies' R&D activities.
However, the large costs that tend to be associated with research activities can also be reduced by the allocation of public funds, such as those that may come from the ASI or ESA. In addition, these projects often do not aim for the creation of a full production line and thus mass supply, but often require the production of prototypes intended for scientific missions. These factors help reduce companies' R&D costs, thus making in-house research more sustainable.

6.3 Balancing between exploratory and exploitative activities

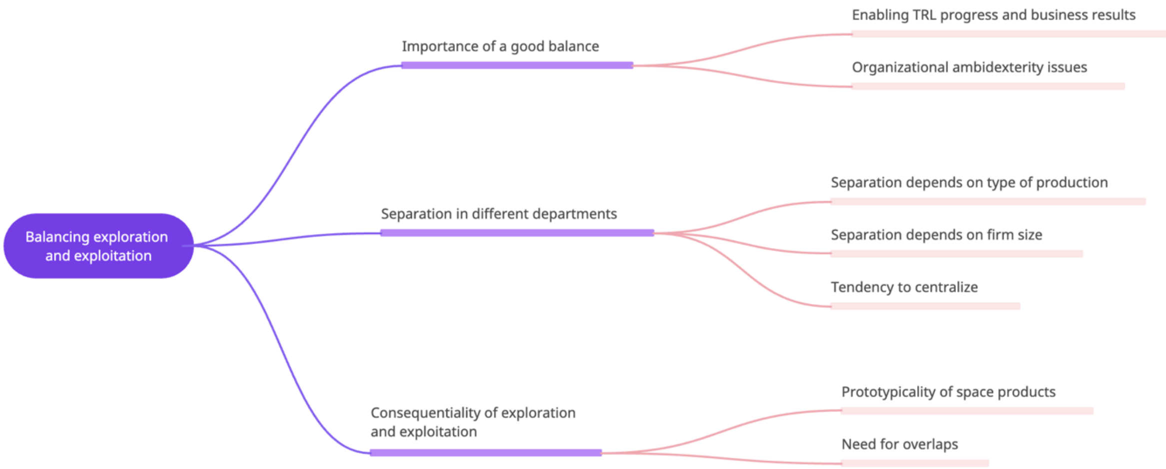


Table 9. Balancing exploratory and exploitative activities – Results map
Source: original

6.3.1 The importance of a good balance between exploratory and exploitative activities

This last group of questions was described as particularly interesting by the companies interviewed because it touches on a very difficult and topical issue that is often taken for granted, namely the right balance between companies' exploratory and exploitative activities. Indeed, this is an important issue because companies, by their very nature, should not do research for its own sake; on the contrary, the research activities conducted must be able to translate into some kind of commercial return. Thus, in an industry as dynamic as aerospace, companies must pursue both exploratory and exploitative activities to gain and maintain a comparative advantage in the market. Thus, given the crucial role of R&D in these companies and the need to carry on production that can ensure their survival, the issue of the balance between exploration and exploitation is of central importance.

One respondent suggested how maintaining a proper balance between the two activities goes mainly through a series of arrangements to ensure that research activities allow to reach actual results. In detail, he pointed out how "*this translates into a gradual increase in the TRL index, that is, a gradual increase in the maturity of a given technology*". Thus, a company's R&D is effective to the extent that it enables the advancement of a technology or a particular application of it, and the latter enables the company to have a commercial return. The interviewee also added that, to ensure that the TRL level is increased, prototyping is usually applied, so that each stage of development is matched by a time of application demonstration of the technology.

This strategy helps to ensure the exploitation of the results obtained from a company's research activities.

Despite these useful strategies that help to ensure the right balance between exploitation and exploration, it is still a difficult goal to achieve and especially to maintain. Another interviewee, for example, suggested how this balance can be compromised by the fluctuating of quantities produced. For example, a spike in production due to a new contract might make it necessary to change the schedule, thus slowing down the research process and speeding up the company's exploitative activities. It is therefore necessary to balance these two dimensions, while also trying to adapt them to the circumstances if necessary.

6.3.2 Separation of exploratory and exploitative activities

As extensively mentioned in the literature review, the issue of the right balance between exploitation and exploration has been referred to as organizational ambidexterity. Several strategies on how to organize these two dimensions in order to achieve efficiency have also been defined. The main differentiation is based on two dimensions: spatial (exploratory and exploitative activities are conducted within the same department, thus defying contextual ambidexterity, or in separate departments, defying structural ambidexterity instead) and temporal (exploratory and exploitative activities are conducted consequentially or simultaneously). The various companies interviewed were questioned on this issue.

Regarding the spatial organization of R&D and production, that is, their division into different departments, the interviews showed that it is mainly large companies that opt for a division between different departments. In contrast, medium-sized and small companies prefer to keep the two activities within the same (and often single) unit. A respondent from a medium-sized company also elaborated on how each technical area has a share of R&D that it uses and is allocated flexibly as needed. It follows, then, that one of the main advantages of keeping exploratory and exploitative activities together is that it provides considerable flexibility in allocating resources between the two activities in order to accommodate needs and circumstances.

The interviews also revealed how this division often also depends on the nature of production carried out. For example, many companies stated how a large part of their activity involves the production of prototypes, namely products created only once in which necessarily the development and production phases end up coinciding. In fact, the prototype that is developed is the product itself that is launched. Such coincidence between research and production lines occurs not only in the cases of prototypes developed by small companies but also in those of large companies, and that is due to the very nature of prototypes.

One interviewee from a large company pointed out that the separation between exploratory and exploitative activities becomes much more frequent when a prototype is not required, but rather a series, small or large, of products needs to be produced. In fact, when a full-fledged production line is started, the need to specialize the resources, both human resources and production resources, involved in production emerges. Moreover, the interviewee added how this separation between exploratory and exploitative activities can be framed in the terms of an evolutionary process, which corresponds to the product maturation process. To that, he added: "*Imagine it as a flow process, the product is developed, made in the first samples, then, if it works, I move it to the production line*". To exemplify this dynamic, the interviewee also offered an example: "*We are making two satellites with electric motors that will fly in the coming year. We were already on the verge of promiscuity between the development line and the production line here. But now we have acquired an order for eight more motors, and this has forced us to start an investment together with the Italian Space Agency to make a line exclusively dedicated to production. (...), so we are moving to small series production, which is then segregated from the research and development line*".

In a number of interviews, it also emerged how companies sometimes avoid a clear separation of the two activities, believing that compartmentalization may even be detrimental to the company. For example, one large company pointed out that within the same line of business there are people who are involved in exploratory activities and others who are in charge of exploitative activities, but that these are by no means completely separate silos. On the contrary, the two groups of employees operate in an integrated way and there is osmosis between the two activities. This fluidity ensures that knowledge and insights gained in one area can be readily applied to the other, improving innovation and execution processes.

Further confirmation of the extent to which osmosis, whether between exploration and exploitation or between business lines in the same company, is highly valued comes from the new trend toward centralization shown by some of the large companies interviewed. One in particular described their company's new trend toward creating centralized systems and structures that can be used by all departments and units in the company through a process of adaptation and customization. In this way it is possible to avoid the duplication of some developments, but more importantly, it allows to make sure that developments made because of a past need of one line of business can then be used by other lines of business if the same need emerges.

6.3.3 Consequentiality of exploratory and exploitative activities

Regarding the temporal separation between exploratory and exploitative activities, that is, whether they are conducted sequentially or simultaneously, the results were quite clear. All the companies interviewed, from micro-enterprises to large national leaders, suggested a consequentiality between the two phases. In most cases, the dynamics described saw an initial exploration phase and a subsequent exploitation phase. Thus, R&D was carried out before the product creation and exploitation phase and the mass production phase.

However, a few clarifications should be made to this dominant dynamic. First, as suggested earlier, much of the activity conducted by space companies is aimed at the creation of prototypes, that is, one-time products in which the exploration and exploitation phases necessarily coincide. In all such cases, therefore, the development of a prototype makes it very difficult to determine whether there is consequentiality or simultaneity between the two phases. In general, since the R&D of a unique product often coincides with its material creation, it could be concluded that there is simultaneity between exploratory and exploitative activities. In addition, another interviewee added that sometimes there can be an overlap between the two phases of exploration and exploitation. For example, he added, "*The first part of the economic exploitation of development actually coincides with the end tail of exploration*." In fact, he describes a dynamic whereby the final stage of the exploration process is the creation of a prototype that is also intended to probe the potential economic return. Thus, the development of such a prototype, which itself is in the final stage of the exploration process, actually already leans toward the exploitation stage.

In conclusion, in spite of these specifications, the general trend that has emerged shows a tendency towards the consequentialisation of exploratory and exploitative activities.

7. Discussion

The objective of this study was to investigate the main differences between large companies and SMEs of the Italian aerospace sector in their R&D activities. In particular, it sought to understand how and to what extent external sources of knowledge are used to fuel internal research processes and how these are reconciled with exploitative activities. Overall, an interesting picture of the R&D activities of companies in the sector emerged, with some relevant differences between large companies and SMEs. This chapter is devoted to the discussion of the results presented and will attempt to connect the dots, using this information to provide clear answers to the initial research questions.

First, it was confirmed how the aerospace sector, as a high-technology industry, makes it imperative for companies to focus heavily on R&D activities and allocate substantial resources and funding to it. Both large companies and SMEs are therefore heavily engaged in both internal research activities and external collaborations. In fact, these two modes of research appear to be complementary to each other, as they enable the company to pursue different strategic objectives. In this regard, both large companies and SMEs offered similar considerations regarding the make-or-buy option of their expertise, confirming the model proposed by Nerula (2001) in his static framework. In fact, they reported keeping core competencies and key technologies in-house, while other noncritical competencies are subject to a cost-benefit analysis that can often lead to a decision to acquire or develop them externally. In other words, many core competencies are indeed jealously guarded within the company because its competitive advantage is based on them, but many others require the use of external sources and collaborations. This may be a consequence of the great complexity of the technologies under consideration, so resorting to other companies or entities with highly specialized skills is essential. Other times, however, the use of collaborations is functional to reduce the degree of uncertainty inherent in the development of low TRL technologies that require large investments and costs that, thanks to the co-participation of multiple actors, can be shared.

Regarding inter-firm R&D investments in detail, both large firms and SMEs stressed that these are undertaken only if they are deemed to produce positive business benefits for the parties. In fact, when embarking on collaborations on this front, the need to pool extremely strategic resources and expertise involved in individual firms' R&D processes can bring up significant risks, potentially undermining firms' comparative advantage. In this regard, the importance of defining contracts as detailed and complete as possible to limit this problem also emerged. The problem of incomplete contracts poses risks especially for SMEs, which are the ones with the least bargaining power and thus with a greater risk of being at the mercy of other companies taking advantage of them. Moreover, in business-to-business relationships, trust plays a crucial role, reducing the transaction costs inherent in highly uncertain environments and alleviating the problem of incomplete contracts. In addition, in the case of inter-firm collaborations, it is much more common to develop application research projects, that is, aimed at the realization of a product or technology that can have an impact on the market and thus an economic return for companies. In other words, collaboration between companies becomes easier and more frequent as they approach the market. In fact, the development of a technology or product that can be quickly brought to market greatly reduces the uncertainty that normally accompanies the development of technologies with very low TRLs and therefore with market applications that are still very uncertain and far off in time.

Technology research projects, on the other hand, are more common in collaborations between companies and universities and research institutes. This is mainly due to the very nature of this category of industrial players, which are inherently research oriented. Indeed, companies resort to these actors because they can draw on extremely specialized expertise that is often too costly to internalize or because it is unlikely to lead to commercial results. However, this predisposition to research on the part of universities and academic centers, while reserving ample advantages, is often seen as problematic by medium and large enterprises. It is precisely the larger companies that report the greatest difficulties in managing projects with universities, complaining in fact of their low propensity to commercialize results. Among the small business ranks, however, this unease does not shine through. This is often attributable to the smaller size of their partnerships with universities and research centers and, in some cases, also to the smaller organizational distance. In fact, many of the small businesses surveyed come from or have some connection to academia, and it is this commonality that allows for increased trust between the parties and thus reduced transaction costs of collaborations.

Finally, it is worth emphasizing once again how the aerospace industry is peculiar in that it has a number of industry-specific elements that characterize its industrial landscape. Firstly, it is an industry that, especially in its space segment, has long been the exclusive domain of national and international public institutions and is only recently opening up more to the private sector. However, institutions such as ESA and ASI still play a key role, coordinating projects and holding tenders whose rules of engagement change the structure of the competition from time to time. In fact, as the interviews revealed, the aerospace industry, and the space segment in particular, is still far from classic market competition. On the contrary, the roles of companies change depending on the rules of engagement and competition to access ASI and ESA calls.

7.1 The use of external sources of knowledge: differences between SMEs and large corporations

First of all, our empirical evidence confirmed the importance of the so-called dynamic capabilities of companies operating in changing environments characterized by rapid technological progress, such as the aerospace industry. Therefore, these companies must always be alert of market developments and adapt accordingly to remain competitive in the market.

Relative to the industry survey activity, thus in terms of perception capability, there are no significant differences among companies in the industry. Both large companies and SMEs use a wide variety of tools and links to keep abreast of technological developments in the industry. The differences that have emerged in the use of these tools appear to be attributable to the preferences and habits of individual companies rather than their resource endowment.

On the other hand, the most significant differences are found in relation to acquisition and transformation capabilities. In fact, if we look at the ways and techniques companies use to acquire and create new knowledge and reconfigure existing knowledge internally, we notice greater differences. However, these differences do not reflect the initial considerations made on the basis of the literature review, namely that SMEs in the sector would make greater use of external sources of knowledge. On the contrary, it was found that SMEs in the sector do not use external sources of knowledge more frequently than large enterprises. In fact, this initial consideration was based on the incorrect assumption that the use of external sources of knowledge occurred mainly to compensate for the lack of internal resources. Rather, it turns out that all companies, whether large or small, resort to external sources because they recognize the added value that can be derived from collaborations with other players, such as other companies, research institutions or universities. The aerospace sector is characterized by high technological content and rapid and constant progress, characteristics for which companies are inclined to maintain continuous contact with their external environment. In addition, the type of technology employed often requires the possession of super-specialized skills that are difficult to bring in-house and contribute to companies maintaining relationships with each other and with other industry players.

However, this *necessity to cooperate* among industry players often leads to the emergence of added value in R&D processes. This awareness, while present among companies of all sizes, is particularly prevalent among large companies in the industry, which in recent years have shown a trend toward greater structuring of these external collaborations through open innovation schemes. Thus, in contrast to what was previously suggested, it is especially large companies that stimulate the use of these external sources of knowledge through dedicated structures. Realizing the value they can derive from the external environment, these companies are diverting their abundant resources from traditional in-house R&D to the creation and maintenance of facilities and laboratories dedicated to open innovation. In these areas, great attention is paid to small companies, particularly startups, which are often involved in incubation and acceleration programs. In this way, large companies claim to also be committed to the growth of the industrial ecosystem, but these programs and facilities also provide them with a competitive advantage by ensuring access to innovative ideas.

However, the logic of open innovation is mainly exploited on a specific type of technological research, namely that characterized by low TRL and long-term interest. In fact, these technologies are still at an early stage of development, where experimentation and uncertainty are still very much present. The use of open innovation in such cases allows the company to draw on a wider pool of expertise, which can be useful in overcoming such uncertainties, thus accelerating the process of technological development. Instead, to be excluded from these open innovation structures are all of the company's core technologies and competencies, which are jealously guarded internally within the company and thus dealt exclusively by in-house R&D. Similarly, SMEs also suggested how some areas of their research, namely those most strategic to their business, are not open to collaborations because they are considered to be critical to maintaining competitive advantage. As aforementioned, this distribution of competencies reflects the pattern proposed by Nerula (2001), according to which it is the company's core competencies that are retained internally, while secondary competencies can be more easily outsourced or allocated to collaborations and alliances with other entities.

Thus, despite the growing appreciation by companies of all sizes in the aerospace industry for external sources of knowledge, internal ones continue to maintain a decisive and strategic role in defining companies' competitive advantage. Overall, then, these results confirm the complementarity of internal and external sources of knowledge, but more importantly, they underscore the increasing willingness of companies to leverage external expertise to fuel R&D activities, a desire that is extremely evident especially in open innovation laboratories run by the largest companies in the sector.

7.2 Organizational ambidexterity: differences between SMEs and large corporations

The focus of the second research question was to consider whether, in the case of SMEs active in aerospace, it is more convenient to pursue an exploration or exploitation strategy rather than a strategy based on organizational ambidexterity. This consideration is grounded in the contribution of Cao et al. (2009), who suggested that smaller firms with fewer resources may benefit more from a one-sided orientation. In detail, this consideration is rooted in the idea that low-resource enterprises cannot efficiently maximize both dimensions of exploitation and exploitation at the same time (according to the Combined Dimension of ambidexterity, namely CD); instead, these enterprises must seek the right balance between the two dimensions, making the necessary trade-offs based on the resources available to them (in line with what is suggested by the Balanced Dimension of ambidexterity, namely BD).

The responses provided by the respondents confirmed how the BD and CD distinction of organizational ambidexterity is useful for understanding resource utilization by Italian aerospace companies. Consistent with the views expressed by Cao et al. (2009), large companies in the industry with extensive resources engage in exploration and exploitation activities, seeking to maximize both. Indeed, the enormous resources at their disposal allow them to allocate efficient structures that can exploit current expertise and explore new possibilities. In these resource-rich settings, exploration and exploitation activities do not appear to be competing with each other, but rather the goal of companies is to create synergies between the two dimensions. Moreover, given the wide availability of resources, exploration and exploitation activities are often allocated within separate facilities, thus falling into the category of structural ambidexterity. For example, the laboratories dedicated to open innovation available to the large companies interviewed are facilities dedicated to the company's exploratory activities, as they are designed to pursue research related to technologies with low TRL and great potential and future prospects. In contrast, activities that fall under the exploitation dimension are managed in separate structures that, in the case of the companies surveyed, deal with the core technologies on which much of the company's competitive advantage is built and are therefore jealously guarded through exclusively in-house R&D. However, the interviews also showed that even when exploration and exploitation activities are structurally separated, it does not result in a sharp segregation between watertight compartments, but on the contrary, a certain degree of osmosis is always present.

In the case of SMEs, on the other hand, the limited availability of resources implies the inability to maximize exploitation and exploration activities as in the case of large companies. According to Cao et al. (2009), therefore, an alternative view of ambidexterity is preferable, which comes from finding a proper balance in the allocation of the firm's resources between the two dimensions. For this reason, it was hypothesized that, in the case of Italian aerospace SMEs, it might be more efficient to pursue a one-sided strategy focused on either exploration or exploitation. The interviews revealed a greater difficulty in balancing the different types of activities, as the tighter resource constraints imply that their allocation is framed in terms of a zero-sum game. Unlike large firms, SMEs' pursuit of organizational ambiguity is better framed in terms of balanced ambiguity size (BD). Thus, for firms with limited resources, it is more efficient to seek the right balance of resources between exploration and exploitation, rather than maximizing both dimensions. However, contrary to the suggestion made by Cao et al. (2009), these trade-offs are unlikely to result in the clear dominance of either dimension. In fact, the high technological content of the aerospace sector and the rapidity with which innovation proceeds are elements that contribute to the fact that for all companies, large and small, both the exploitation of existing skills and the exploration of new opportunities are critical for survival. Even for SMEs, therefore, it is necessary not to neglect either dimension even while operating in an environment of limited resources. In fact, in an industry such as aerospace, exploration and exploitation activities are often closely related. Therefore, focusing exclusively on one of them can lead the enterprise to be inefficient and achieve suboptimal results. For example, focusing only on exploration would not allow the company to achieve sufficient commercial returns; conversely, following a strategy focused only on exploitation would hardly allow the company to keep up with industry innovation.

Although aerospace SMEs try to maintain both exploration and exploitation activities, the limited availability of resources does not allow the creation of dedicated structures over which to distribute the different competencies. Therefore, aerospace SMEs do not exhibit the dual structure typical of structural ambidexterity. On the contrary, exploration and exploitation activities are often conducted within the same unit or department (often, especially in small companies, this is the only unit that constitutes the company). In the case of aerospace SMEs, therefore, one can rather speak of contextual ambidexterity, in which personnel from the same unit is involved in both exploring new opportunities and exploiting current ones.

To sum up, environmental dynamism of an industry makes exploration and exploitation activities essential for all companies in the market that want to gain and maintain a comparative advantage (O'Reilly and Tushman, 2013). The large aerospace companies surveyed have ample resources at their disposal, allowing them to maximize both activities without placing excessive risk on the survival of the company itself. In addition, given their wide availability of resources, exploration and exploitation activities are often divided into separate units, defining structural ambidexterity. In the case of small companies in the industry, however, maximizing both dimensions is either impossible or excessively risky. For this reason, SMEs of the aerospace sector must carefully allocate their resources, achieving the right balance between the two dimensions. In addition, it is difficult for them to create separate structures, each competent for its own activity, since most often SMEs consist of a single unit, within which personnel are competent for both exploration and exploitation activities. For this reason, although they do not possess the typical dual structure of organizational ambidexterity, they can still be framed as an instance of contextual ambidexterity.

8. Conclusions

The aerospace sector, with its high technological content and incredibly rapid pace of innovation, offers a unique landscape for studying the dynamics and motivations behind R&D choices of companies operating in it. This study attempted to reveal the differences that emerge between R&D decisions made by large companies and SMEs, particularly in the context of leveraging external sources of knowledge and the strategic balance between exploration and exploitation.

Regarding the use of external sources of knowledge, it was found that Italian aerospace SMEs do not use them more frequently than larger firms, contrary to what was projected initially based on the content of the literature review. In fact, the use of external sources of knowledge by aerospace firms does not tend to occur to compensate for the lack or scarcity of internal knowledge resources; on the contrary, since this is a very rich industrial landscape, firms of all sizes use them to tap into specialized and advanced competences. Thus, both SMEs and large firms recognize the intrinsic value of external collaborations, not as a compensation mechanism for internal resource limitations, but as a strategic move to tap the collective expertise of the industry. This is particularly evident in the increasingly widespread efforts of large companies to further structure, if not even internalize, open innovation structures. These efforts to internalize open innovation dynamics, for instance through dedicated laboratories, require substantial resources, which is why these initiatives come mainly from large companies. However, open innovation initiatives are not lacking even among smaller companies, confirming that the recognition of the importance of external sources of knowledge is widespread throughout the entire industry.

Regarding the right balance between exploitation and exploration, it was found that the high technological content and the speed of innovation that characterize the aerospace industry are factors that drive companies, regardless of their size, to engage in both exploration and exploitation activities. On the one hand, if a company were to devote itself exclusively to exploitation, thus excluding exploration activities from its mandate, it would risk the rapid obsolescence of its product and service offerings and, therefore, exclusion from the market; on the other hand, a company focused only on exploration would struggle to survive because it would have difficulties in commercializing the results of that exploration. It follows, then, that a strategy of organizational ambidexterity is preferable in both the case of SMEs and large companies of the aerospace industry. However, given their different resource endowments, there are substantial differences in the ways in which they pursue such strategy. Indeed, large companies with ample resources have more leeway and can allocate substantial funds on both the exploration and exploitation fronts. The two activities are not seen as competing with each other and, in fact, they are often allocated in separate units or departments, defining a kind of structural ambidexterity. The case of SMEs is different. These, in fact, have more limited resources at their disposal, which must be carefully balanced between the two dimensions of exploration and exploitation. The lower resource endowment also contributes to the fact that these activities are often carried out within the same structure. This also contributes to greater flexibility in the allocation of corporate resources among different exploration and exploitation needs, which are thus placed in a competitive perspective. In the case of aerospace SMEs, organizational ambidexterity thus does not result in the typical dual structure, but rather presents itself as contextual ambiguity.

In light of these results, it is worth remembering that all the above-mentioned results must be considered with reference to a number of industry-specific elements. The aerospace industry is in fact, in Italy as in the rest of the world, a very unique sector. In fact, it is a sector historically characterized by the massive presence of public players and in which a shift toward a more private sector-oriented paradigm has been underway for the past few decades. It is therefore an industry that has been profoundly evolving in just these years and in which the dynamics governing it are changing rapidly. Despite these recent developments toward an openness to more traditional competition, some industry-specific elements continue to profoundly influence competition. Hence, the combination of these industry-specific elements adds complexity to companies' R&D decisions.

Although this study has led to relevant results, it still has some important limitations. Among them, sample size is definitely one. Since the interviews were conducted on only six companies, the results, while interesting, may not capture the full spectrum of R&D dynamics within the Italian aerospace industry. The limited sample may not be fully representative of the industry as a whole and could potentially overlook some practices or perspectives present in companies that were not involved in the study. Building on this limitation, future research could focus precisely on expanding the sample to include a wider and more diverse range of companies.

In addition, the present study focused exclusively on the Italian context, which is traditionally rich in SMEs, not only in the aerospace sector but in all industries. The result was thus a comparative study between SMEs and large companies in the Italian aerospace sector. It would therefore be interesting if future research sought to broaden the geographic horizon, for instance by producing comparative studies between countries to understand variations in R&D

strategies and practices. Another promising avenue for future research could be to investigate the role of certain technological advances, such as digital transformation and artificial intelligence, in shaping the R&D activities of companies active in aerospace. Indeed, it is important to pursue research related to companies active in the aerospace sector, as this is an area that will play an increasingly central role in our economy in the coming years. To date, in fact, applications related to the satellite field have increased significantly, and more and more are expected in the coming decades, with spillover effects on the entire economic system.

9. Appendices

Appendix A – Topic Guide

Sensitizing concepts	Interview questions	Follow-up questions for probing and prompting
Surveillance of **market developments** and adoption of **new technologies**	- What tools does the company use to scan the industry in which it operates in order to stay abreast of the latest technological developments? - Once a new technology trend has been identified, what factors are considered when deciding whether to invest in that technology?	- Can you give an example of a technology your company has invested in and specify what factors were decisive in prompting you to choose that technology instead of another one?
Knowledge sourcing strategies	- When you decide to invest in research for a new technology, you may decide to proceed through internal R&D or through external or quasi-external research processes. Are there research processes that are conducted exclusively within your company, without any kind of collaboration with external parties? - When you decide to conduct research activities in collaboration with other entities, you may outsource to external parties or collaborate with them on	- If no, why is collaboration with external parties always necessary? - If yes, what are the reasons behind the choice of conducting research exclusively in-house? - What type of competences do you aim to achieve through in-house research? - What are the limitations or risks of this type of research? - If yes, what were the reasons behind this choice? - What kind of activities were externalized? - To whom?

	technology development. Are there instances in your company where you have decided to outsource, such as through licensing or outsourcing R&D? - Are there instances of R&D activities where you actively collaborate with other actors, for instances other firms, research centers or universities?	- What are pros and cons of such a decision? - Did this strategy significantly reduce costs? - If yes, are these found at local, national or international level? - Do you have a preference for collaboration with one of these?
Partnerships with **other firms**	- Were these firms' competitors? - What kind of partnership do you create when partnering with other firms? - What kind of competences/ products do you hope to develop? - What are the benefits of partnering with other firms in R&D activities? - What are the risks?	- What are the reasons that pushed competitititing firms to cooperate?
Collaborations with **research centers** or **universities**	- When and how are these collaborations set-in place? - What benefits can emerge from collaboration with research centers and universities? - Are there downsides to these collaborations?	

Balancing **exploration and exploitation**	- Does the company engage in both the research process and its own production line? - Are these two dimensions easily reconciled, or have you encountered difficulties in allocating resources between exploration and exploitation? - Are these two activities conducted within the same unit or department? - Are they undertaken simultaneously or does a period of exploration usually precede one of exploitation?	- If you encountered difficulties, what were they? How did you try to resolve the situation?

Appendix B – List of questions for Leonardo S.p.A.

- One would think that a company of Leonardo's size would have sufficient internal resources to conduct its research activities in-house. However, Leonardo Labs are proof that even within these large companies, open innovation systems are playing an increasingly important and strategic role. How do Leonardo Labs represent an evolution of the company's traditional in-house R&D areas? How do they differ from them?

- Are there still research processes that are conducted exclusively with internal company resources and without any kind of collaboration with external parties?

- Considering the various actors with whom Leonardo Labs collaborate, are these mostly located nationally or internationally?

- What advantages emerge for Leonardo from collaborating with universities, research centers, and other companies in R&D activities? Are there, on the other hand, risks or disadvantages associated with these types of collaborations?

- The innovation strategy deployed within Leonardo Labs enables the evolution of the industrial process from design to product. How do Leonardo Labs support the simultaneous pursuit of radically innovative projects (exploration activities) and incremental projects (exploitation activities)? What are the main challenges you encounter?

- Are R&D and production line split between separate departments within the company or are they conducted in the same unit? Finally, are R&D and production line undertaken simultaneously or sequentially?

Appendix C – Transcripts of the interviews

Interview Code 001

Date interview: May 29th, 2023
Respondent's role in the firm: Chief Executive Officer (CEO)
Company: Guizzo Space S.r.l.s

[Comments: a few emails and messages were exchanged in order to present briefly the aim of the project and organize the time for the interview]

I: Hello, good morning

P: Good morning, how are you?

I: Good, good, you?

P: Good, thank you.

I: Thank you for your willingness to participate in this interview, it was very kind of you to agree.

P: Sure, yes.

I: Sure. If it's okay with you we could also start with the questions.

P: Sure. Let me wait until I retrieve the questions that you sent me.

I: Yes, yes don't worry, I will still be the one to read them as the interview progresses.

P: Here they are, I found them!

I: Here we go. So, the first question I'm going to ask you is about the tools your company uses to stay up-to-date with industry innovations. What are the main tools you use?

P: Yes, so, uhmm, so. Staying current with respect to the latest technological updates. Like say... There are definitely tools like journals, we even publish papers every now and then when we can, so definitely through journals and attending symposiums and seminars on specific topics. That definitely yes, although I think though that participating in certain projects focused on research and development automatically leads to researching the state of the art, always documenting yourself through papers on potential competitors, and so it brings you intrinsic knowledge. Obviously, if you were to start from scratch on a technical topic, then yes, clearly you start from the literature, however, in cases where you are already included through financing on project development you still come to know the state of the art precisely because the people you interact with lead you to always stay up to date. It's something that you partly create and partly document through the bibliography, in short.

I: Perfect. So, the second question, again with reference to how you approach new trends in the market, try to understand what are, in your case, the factors that are most crucial in choosing to invest in a technology that emerges in the market. So, even through an example, could you tell me what factors you consider most important when focusing on a new technology or product?

P: Then, we when we decide what to invest in, we necessarily have to start from a very different vision than the big company. We are not Leonardo, we are a small company, which is growing, but we are small and clearly you need a strategy, a philosophy on where to go from there. But it's not like we basically do a market study to see where there is a lack of technology in the market and to fill that gap. That we don't do right now, but what we do do is to pick up opportunities for technology development that are not in the market, such as optical communications, or that are in the market but are being developed by very few companies in the world, and to be able to take something from that area. And gather the opportunity, including through collaboration with other companies, to be there as well. And so, maybe burning the candle at the seams and being more flexible than a lot of big companies in handling projects like this, because we are lighter, less elephantine in moving and so that can influence our choice. Maybe now we are more oriented toward opportunities that came to us and from there we realized that it was possible to go in that direction and that the sector was promising. Here that definitely yes, then we also do design and research and development not only for market products, like it might be telecommunications where we started, but also products that have purely scientific target. We are involved, for example, in space missions that involve a little bit of the whole European and even American scientific and technical community, and so where you go and design instruments like electronics at the edge of today's technology. This is done not for the purpose of putting a new product on the market, but for technological and scientific development, which needs a technology, a know-how that we go and create. That this then, one day tomorrow, is somehow transferred technologically to products that can also become of commercial use for space, that may well be.

I: Okay, great. Again with regard to research and development activities, you can lean toward research and development processes either internal or external to the company, such as in colaboration with universities and other companies. In your case is there any kind of research and development activity that is carried out only inetrnally to the company, or is there always some kind of collaboration with outside.

P: So, predominantly in-house. That is, we do research and development with internal resources. Then if there are opportunities, for example, one with the Polytechnic University of Turin recently faded away because we couldn't get the ways and timescales quailed. Currently there are none, but in the future maybe there will be collaborations with third-party entities that can bring in human resources. But at the moment we use internal, highly skilled resources who also have the interest and inclination to do research and development. Not to mention that even if we don't use resources from research institutions like that we have been collaborating with for years, however, we are in continuous and close contact with environments that do research and development. So by interacting we don't create technology transfer but we definitely create the conditions for collaboration.

I: Perfect. Next, I would like to ask if there are limits to research conducted only through internal resources? In your current case, where most of the research is conducted through internal resources, are there any limitations?

P: Let's say that obviously the company is not so big that we can say I invest tot. Economic resources, but as we continue to acquire funded activities we can devote our effort to research through financing that comes from activities, public bodies, both Italian and European

I: Okat, great. You mentioned that collaborations with external actors are also pursued when there is a possibility, for example you were referring to the opportunity recently presented with the Polytechnic University of Turin. In these cases, do you prefer collaborations with companies or with universities and research centers?

P: Generally, if we have to choose, to do research and development, I prefer university or at least equivalent centers because I have a background... er... let's say, I did several years before I opened my company working with universities in collaborations with big Italian companies and so I was very attached to the research mentality, also to the enthusiasm that it brings. So if I have to choose, clearly I prefer to work with research institutions because I know the predisposition, in short, and the open-mindedness that you can have by collaborating with universities. Then it is clear that even recently we have had requests for collaboration, even from big companies, to do new products together. That becomes more of an application research than technology research, to create a product that is not there yet using a known technology that I already have. That is more typical of collaborations between companies. In those cases, companies try to put a little bit of ours, a little bit of yours, for example through joint ventures or other forms of business-to-business associations, creating a new company, for example, that is born with that very purpose. We are thinking about that and working on that as well.

I: Okay, yes, again relative to these collaborations with research organizations and companies, you mostly collaborate with entities at the national, local or international level.

P: There is no preference for one or the other. We do not exclude one or the other; it is equivalent. Maybe the way foreign companies operate, not so much universities, is a little different from the typical Italian way, maybe it is a little more pragmatic. (*his phone rings*) So here's no preference. I would say it's a 50/50. For example this afternoon I have another call with a small company, a spin-off from the University of Padua that deals with important technological institutes and they contacted us because we know how to do electronics for the space and for a possible collaboration. This is an Italian mentality. Perhaps it is easier to find financing in Europe. At the moment, then policies on research change from year to year, from a financing point of view it is easier to pursue a research project by doing it outside.

I: Okay, since you were briefly mentioning collaborations with other companies earlier, I would have a series of prepared questions on the topic. You already mentioned something, but if it is okay with you I would revise the questions.

P: Sure, yes, yes.

I: First of all, are these companies you work with your competitors or do they deal with other segments of the supply chain?

P: No, they are in other parts of the supply chain. Absolutely, for the time being we do not have collaborations with competitors on space electronics, generally it is a collaboration either complementary or otherwise not direct competitors. Also because it's hard to give a definition of a competitor, in the sense that being a sector um... sure there are competitors but then not even that much, maybe there are companies that are so big that they can't even be considered competitors because they do everything and more, including things that we do. They have capabilities and resources to be able to do them, but I wouldn't even call that competition, because competition is when you have a company with similar size to yours or at least comparable size that makes electronics for space and there are not many of them in Italy, and then yes you can say that is a potential competitor. But for now I can say that we are in partnership with complementary realities that need support from us.

I: Okay perfect. And from these kinds of collaborations, what kind of collaborations can arise?

P: Well, I would say that the collaborations that can arise ... um, some can become joint ventures, some can also become sub-contracting collaborations, in the sense that it can be both. Also because we're looking at just various types of them with various types of collaborations.

I: Sure, and when it comes to collaborations with companies, you said they are almost always aimed at creating a product

P: Yes, generally yes, then it's clear that we are young as a company, so I don't exclude that then there could be something that is born not to become a product but to become specific equipment for a scientific mission. So it's not a repetitive product.

I: Also in reference to these collaborations with other companies, have you had a chance to experiment or do you think any risks or drawbacks of these might emerge?

P: Clearly we try to gain experience from all the collaborations we have had so far, also to improve future ones. That is clear. It's clear that we need to put in place tools, including contractual tools, that will allow us to get out of any situations that are empirical or otherwise difficult to shell out. If there are gray areas they need to be clarified from the beginning. That's kind of the experience we've had, although less badly we've always managed to cooperate in some way, respecting contracts of course. Let's say that where there can be a growing interest in a product it can come up, then if things are not very clear, it's a problem that can be solved later.

I: Hmmh, sure.

P: So as long as you do a development you say let's do so-and-so and so-and-so, then as a potential product emerges then maybe points may come up that were not well clarified at the beginning and we are very careful about that so that we can prevent these kinds of situations from the beginning. We gain experience from our own experience.

I: Turning instead to collaborations with universities and research centers, precisely, in your experience, how did these kinds of collaborations come about. You also have an academic background and precisely, I wanted to ask you how did these relationships come about?

P: At the moment we do not have active collaborations with Italian universities, but only with foreign research centers. How they may arise is how they have arisen in the past as well, in the sense that it works that a company may finance a fellowship or a PhD of a doctoral student at the university, where he or she is followed by an internal contact person, a professor, who, however, is pursuing a PhD on a topic of interest to the company as well, then in this case there is an exchange of information or at least a shared research through fellowship financing, PhD financing. Or it can be as we are trying to do with some reality that you participate in specific calls for the development of certain technologies where the various actors are both companies and universities or research centers; so, you establish who is the prime contractor, you establish the sub-contractors and develop maybe something together. This is the second mode. A third mode, the one we have adopted in our collaboration with the marcs blanc, who definitely have great resources, but who may lack specific knowledge that we have. In this case they ask for consulting or long-term collaboration, and then we stay in touch and then through various contractual forms we guarantee a range of services that we can give as a company. This could be a third way, which in our case is more present with foreign countries… there is not much in Italy.

I: In your opinion, what are the main advantages and disadvantages of these collaborations with research centers and universities?

P: Ehmm... it's kind of hard to say... The advantages are that basically... er... that's a good question... ehm.... Certainly the advantage is that they are probably in the development of the activity there are less formalities in terms of, I don't know, it's true that there is a contract, there is an activity, but let's say that the mode is a little less rigid than the contracting between companies, where in short maybe... er... maybe that's a little bit the advantage. Let's put it this way, that you can also find it working with some corporate realities. But if you want to put it that way, there is a very flexible relationship with universities, because anyway you look less at formalisms and you look more at substance. And I see that as an advantage. A disadvantage I wouldn't even know why I could call it a disadvantage, I mean it's clear that it's more difficult to make a product for commercialization, you have to think about it more between companies on how to commercialize a product, but that's the business of so many companies so let's say, I don't know if you can call it a disadvantage. You rather have to think about the advantage of one and the advantage of the other. The advantage of the company is the more commercial and corporate mentality, with research organizations there is the advantage of being able to relate in a very easy way. But here, that doesn't take away from the fact that you can also do it with companies that you have a very good relationship with

I: Okay, great. The last questions are a slightly different topic because they also look at production, the company's production line, always in conjunction with research and development activities and focus on how these are balanced. So first of all, your company also carries on a production line, parallel to research, right?

P: Here we mainly do research with the purpose of making production okay? The purpose of the company is to do research with the purpose of making a product, unless it's in support of entities like the German one, which are doing scientific missions rather than making a product, but there's a lot of scientific research there as well. And let's say at the moment we are not big enough to separate the two. It is clear that as what we are making takes more and more shape as a product, it is clear that we will dedicate a line, a branch of the company to focus toward the production line.

I: Okay, so right now the two activities, research and production, are very much joined; so, there is no internal division between the two in the company?

P: No exactly, for the moment they are still joint however let's say that we are going to create a supply chain, so with other companies that are complementary to us that give us the possibility to create a product in a serial way; therefore, if tomorrow they come to me and ask for ten copies of a certain product we know exactly what to do to put in place this production line.

I: Okay, so I ask you to confirm that in your company the production phase always follows the research and development phase.

P: Yes absolutely, that is the process at our company.

I: Okay great, we come to the last question of the interview. Have you ever encountered any difficulties in balancing resources between the R&D conducted and the actual production?

P: But, I would say no because right now the problem of making a large-scale product does not arise. Right now we are working on follow-up products, of versions 2.0, 3.0 and so on. So we are not yet at the stage where we get an order for tot. Pieces. It is clear that we have a supply chain in place that can guarantee this production with resources decoupled from those doing R&D.

I: Okay, great. I think I have completed all the questions in my interview.

P: Yes.

I: Great, so thank you and as soon as I can complete this work, I would be very happy to show it to you if you are interested.

P: Of course, gladly. I am very curious to see the whole thesis!

I: Okay perfect, then I thank you

P: Thank you very much, see you soon!

I: Goodbye!

Interview Code 002

Date interview: May 30th, 2023
Respondent's role in the firm: Business Development Manager
Company: Aresys S.r.l.

[Comments: a few emails and messages were exchanged in order to present briefly the aim of the project and organize the time for the interview]

I. Good morning

P. Good morning, how are you?

I. Well thank, and you?

P. Good yes.

I. First, I would like to thank you for your willingness to participate in this interview. If it is no problem for you, I would prefer to record our meeting for research purposes.

P. Yes, yes, no problem

I. Great I will record directly with the phone. Great, then if it's okay with you we could also start with the interview questions, so I don't take up too much of your time.

P. Yes, yes.

I. So first of all, I wanted to ask you to give a brief overview of your main products and what you do.

P. Yes, so Aresys is an innovative SME that was born now 20 years ago as a startup of the radar group of the Polytechnic of Milan with Professor Monti Guarneri, who is now one of the leading European experts on Sar, recognized by ESA, in short, in the role typically he and part of his team act as PI in a number of projects on new space radars on behalf of ESA. So 20 years ago it started out to deal with SAR-related processing systems that ESA had in orbit at that time, which were those of Aeres and Eddisat, after that the company expanded on the SAR topic, both space-related and other markets. There have been several rearrangements of the ownership structure, of the private stakeholders who hold shares in Aresys, until one last spin-off this year, in which a slice of Aresys equal to 20-23% of last year's revenues was spun off and is part of a startup in which Aresys is a shareholder with Eni and is involved in oil and gas. So, let's say it's a rib that's a little bit out of the market space of Aresys that has been successful and so it entered this new program of Eni for super innovative startups. So, colleagues migrated from there and Aresys stayed with a mission related completely to the aerospace and defense world. The main focus is radars, tending to be synthetic aperture radars, so SAR, although we also have expertise in radar altimeters and optical-related activities as well. At the moment we are divided into five divisions that somewhat express the products and services performed by Aresys. Three divisions are the let's say historical divisions of Aresys, that is, present since the beginning. The engeeniring division, the one that offers engineering support services for the design of new radar concepts, generally for large system integrators and agencies, so Thales Alenia and Was UHD and with them we participate in all new radar concepts. So, any European and some even non-European radar projects have seen us participating with engineering and dual-entry systems simulation activities. In that case, the primes ask us, "We are thinking about this radar. How will it perform?" We have a product that is an end-to-end simulator that over the years has also evolved into hardware components that is part of the simulation area that, along with the engineering area, defines performance and supports the design of these new radars. Innovative concepts let's say. There is a third area, the processor-related area, which is history, precisely from the beginning we have provided processors to ESA, today we have provided and are sole maintainers of the Sentinel 1 processor, that is the core processor that does the focusing, we have provided and are maintaining that of Criosat 2, we are prime of the priomass processors and we have provided, are maintaining and are preparing evolutions of the Saucom processor on Argentine satellite. Then actually this area is also expanding by acquiring, let's say, third-party businesses to reinforce the processing part, we are among the first two companies at the European level doing low-level processing for radar systems. The processing area has also expanded in the last year dealing with optical processors, in the iris frame and in some programs for defense satellites, small satellites. We still have two small areas--excuse me, the processing area has expanded to include also an old HPC (high performance computing) area that in the past and even now, I should say, does activities related to the development of platforms for the use of high performance processors, supercomputers, just to be clear, maybe you don't have the concept, for the oil and gas world. We started with Eni, so Eni's supercomputer, and Cineca's supercomputer. Today we are closing, some we have already closed, demonstrators for ESA using the new European supercomputers. So, for example, Cineca's Leonardo, which today is the fourth in the world in terms of speed and which is also expected to be helped by Numi, the third in the world also funded by the European Community, and Finnish, where Cineca can access resources. So, we are bringing this activity on HPC into the space domain. I was saying then two other divisions. One division shifts the focus from the upstream of the first two to the middle-stream, the processor division of the second one, to the downstream. It's called application and it develops value-added systems and services for the energy and defense markets; so, where we exploit low-level radar data, because we are good at processing it and preserving the information content. So we work better than others on radar already starting from low level processing, up to using even optical, in that case at higher levels, because today we are starting with low level but we prefer to use higher levels. To offer energy services, so we have a service that we are selling very, very well that is about storing energy commodities in ports around the world. It is today already operational for oil... um... we have covered for now two hundred ports in the world with, I don't remember, two thousand tanks or something like that. And from satellite we assess the height of the moving roofs of the tanks storing the oil. As you can well imagine, the amount of oil in a port is directly related to the price, it is inversely proportional: the more there is the less it costs. So our client's customers who buy the service are big traders who move large amounts of oil, crude oil. Another service is related to coal, which we are just finishing developing, and heavy metals, so metals for metallurgical production, which are stored, generally, open-pit and in very large, elongated pyramids. Always services for traders, so related to the business market. And then for the defense part, you can imagine an interest in all that is maritime surveillance, the storage of apparatus and equipment for the end, in short these are services that we are starting, we started with collaborations with a big French partner and now we are trying to do our own services. Finally, instead a sensor area that is related to hardware, which produces ground radar systems and now with a couple of flagship projects that have started in the last year and a half it also produces space radar. We are completing ASI's d phase for the Saturn program, which sees a new concept, which does not exist in the world, of a marmor radar, so small radars housed on nano-satellites, so rather small satellites, which share resources and generate an acquisition that is then fused on the ground to achieve performance similar to that of larger radars. So it is a concept that goes to reduce the cost of production, the cost of operation, the cost of access to space, in the sense that the technology can evolve in a few years. A space radar, from concept to launch, takes about a dozen years. Here, here we are talking about evolving a product within two years, so really very much installments... all related, as you can imagine, to the new space economy, in short, where small, fast platforms, which, however, have to maintain a high performance, so the concept on which so many of us are moving is "let's not play anymore, it's not the university satellite, the toy, it's an object that has to guarantee a lifetime, but maintain a low cost. Here, on the Saturn, we were selected by ESA for one of the five innovative ideas in the ideas platform, with a little bit more system than the Saturn. So these are our flagship projects, so the lines of development there are on shared upstream, so with the resource as a shared tool on smaller satellites, today we are talking about nano, but we are thinking with prime investors also on micro. And then the other line is on upstream, especially on the defense part, growing services on territorial surveillance, that's it.

I. Okay perfect, thank you for the brief overview, absolutely very interesting. If it's okay with you, now we can move on to the more innovation-related questions. So first of all, I wanted to ask you how does your company sound out the sectors in which it operates, the defense, space and the more recent of energy and how does it keep up with the latest developments?

P. So, we currently invest about 20 percent in research and development, and this has been going on since Aresys was founded. Exactly, we are almost 20 years old today, which is a very special birthday and one that we will celebrate because it will mean a lot for very challenging development activities. We're going to start a whole process also for refunding the company to ensure that we accelerate in the next couple of years. In addition to the one we have, we are growing with EBIT between 15 and 20 percent over the last eight years at least, and what we produce as a margin we reinvest, we tend to. There, the numbers look like that, sometimes even more than what we produce. We are involved on all the institutional projects, from ESA and ASI on the European and global R&D tables, so images on Sentinel1, we participate in the bug and all the global working groups on radar. So our staff who personally follow those activities are involved by ESA as experts on those tables, as well as maintaining a very lively collaboration with the Polytechnic di Milano where we put together. We are often the ones who ask for their support and fund them, we have an open lab with them where we fund them for research activities, but on the other hand they also ask us for activities that have a fast industrial spin-off, on which they would not be able to anadre ahead. So the contact with research is very close, and for the last three or four years we have also started patenting, so protecting a whole range of content. So the first point is that, then the contact with the agencies and the large system integrators also there gives us a very wide visibility on the new and very often we are also the ones who have to present on the international trade shows and then understand a little bit how it works. So those are kind of the techniques.

I. Okay, sure. Again, relative to looking at the industry you operate in and understanding the major developments, how is it that from there you then decide whether to focus on research and development of a particular technology?

P. So, let's say that the decision-making process goes through a board, which is a management board, where the technical component is prevalent, although the business component, and this is my case, is always present and well heard. So, often, um--then--let's say the drivers come from both sides, here. In the last few years, which is the last three years that I've been in this company, I have to say that I've been leading these new lines of development, so I was selected by presenting a plan on the new lines of development. And that plan is being followed, it's paying off very well, so it started from a market and commercial analysis of what could interest the market stakeholders space first of all, here, it's not completely correct, but what has been done is this, let's say predominantly to the market stakeholders by embedding the rather advanced skills instead on the tools that were in the company. So the proposals are always going to beat with the company profile and the competencies and the capabilities, even the financing capacity that the company can afford. So the decision to move upstream was really related to a demand for growth that the company had. Having brought some lines almost to saturation, that is, the European market is what it is, and the company has market shares on the processor and system part that are important with maybe one other competitor at the French European level with whom you work very well anyway. And so, as it were, nibbling away at share has been done, which in the last three years has been done as well, nibbling away at share without bothering too much, somewhat driven by the ESA that wanted to reduce some costs, however, clearly there are limits. There are geographic returns especially on institutional, so you can't bring more than a tot to Italy and so clearly there had been a plateau. So the growth there could be but that was it. So the choice was made to open up to new markets where we had expertise. The upstream one, which then, in the closer to the ground area, also turned into the avionics for medium size drones, so on the 20 kg, and that is actually the path that and was and was recognized as the one with the most value added and where the growth could be explosive. Today we are reaching that close to explosive growth. I have to say that certain technologies that we are developing really need accelerators, that is, institutionally funded projects are slow and these are technologies that we are seeing that can work, we have them covered by patent, however, they are worth what they are worth. That is, the moment a big American player enters the market and you can protect yourself as much and not as much, anyway difficult in short to be seen. So we are at a level where we have to jump in with an accelerator. This is it. So to go back to the question: market analysis, analysis of internal capabilities and then technology ideas that we can bring and put on the table.

I. Okay, great. And on the other hand, in terms of the research and development that you guys conduct, is it mainly an activity that is carried out through the company's internal resources or are there also collaborations, for example, with universities, research centers, other companies?

P. So, both. Let's say there is the part of internal R&D which is that 20 percent we were saying. Then there is a part of collaborations, let's say, completely funded by us and that falls in that 20 percent and that typically today is for the Polytechnic of Milan. So there is a share of funds is related to the avionics world in that case, however there are these projects. And then there is a share where they are collaborations that come out of projects paid for by the institutions where we collaborate both with other private entities, each in their own section, and with entities that are research centers, generally radar groups so Polytechnic of Milan, Sapienza, Pavia, foreign institutes, even the Velar etc., so also international in scope. In that case they don't fall under that 20 percent, they are extra, paid by third parties, for us it's turnover.

I. Okay. And in terms of numbers, do these research centers companies universities that you collaborate with tend to be located more on the national territory or do they say have wider geographical scope?

P. Yes, as I was telling you they have European reach. If I had to say probably a 50/50 by volume.

I. Perfect. You were saying that you also collaborate with your competitor companies, not just companies that are at different stages of the supply chain?

P. Yes, absolutely.

I. Okay, and with these kinds of collaborations, what kind of partnerships can emerge?

P. They are formalized partnerships that have the breath of the duration of the project, so that for an informal part let's say we can say that instead they stretch even longer in time. That is, when the team wins you don't change. And so on some issues the team always remains quite solid, there may be slight changes in the team with some insertions or some departures or with changes even in the role, in some things it may happen that we are subcontractors in other things we are first.

I. Okay. And for what is your experience or the experience of the company, what do you think are the main advantages that can emerge from working with other companies and, if any, instead what are the disadvantages?

P. Eh, then eh, then I have to say that maybe, a little bit in the Italian way, they are a necessity. Well, I think no Italian company would collaborate with another one, even an Italian one not necessarily a foreign one - unfortunately it's a problem but that's the way it is - unless forced by necessity, that is, by the fact that often larger projects are accessed with skills that, therefore somehow are shared between partners and therefore they don't all have to be on the same company. This has pros and cons, in the sense that among the small ones less bad there is some growth, but we always look at each other a bit suspiciously, the big ones on the other hand tend to zero in on other holdings making the small ones essential. I mean, we ourselves work, to say with Thales, on so many projects as long as they are European institutional where they know that putting our name has added value. When it comes to the commercial, no, no we do it ourselves. While they don't have all the expertise that we have, however, they do on their own and that's how it is. With foreign companies it is different, there is more partnership. That is, the recognition of certain skills leads to involvement on projects of any scope, so not tied to a particular market, so it broadens the scope a lot. So, it is more positive with foreign countries, with Italy unfortunately it is always eh so almost a necessity. And it is done though, often, while proposing certain things you see that on some projects, we are today in Italy we will be 100% the most important company capable of developing radar processors. But for the Italian Cosmo Skymed radar processors but also Iride, Thales does it alone, it probably doesn't achieve that performance, we know that, in some cases we also have evidence. So, they don't care that there is somebody good, that costs less because we cost less than they themselves. Because big business has higher costs then, but it doesn't matter, they do it themselves. So that's kind of why we are all Italians, and we say because of the culture. 24.35

I. Sure, I understand. And on the other hand, regarding collaborations with universities and research centers, my next question would be how do these collaborations come into being? I guess in your case being a spin-off of the Milan Polytechnic this kind of collaboration has been in place from the beginning?

P. Yes, no of course, from the beginning you collaborate for that and then actually ... um ... then for the first 15 years I would say, almost 18 years of its life Aresys was recognized by everybody as a company very much related to research. So here in the last three years the effort has been to improve the perception of the company and to make ourselves seen as an industry as well. So that's kind of, that's been the step. So, we have always been close to all the European research organizations on the topic of course and so on some things we publish a lot as well. Now a little bit less because we are patenting more so you have to allow that delay, at least at the European level does patenting and publication. And so maybe we have reduced, or better, even publications are evaluated by a committee and often the commercial veto becomes important on certain things. And so, let's say that collaboration has always been very broad and required even from outside, from other research centers. Then, on some programs it is almost a obligation if we talk about biomass, another explorer, the component of scientific is strong we being prime have just built and we are carrying on with the new biomass projects of the mission frame, a scientific team that has 10 or 12 European players, so even just managing them is abominable. Also, because we don't have to manage them, I mean you have to manage them but without, because they don't want to be managed. So, you have to somehow please ESA to route them, to correct certain choices that are not industrial and then do not lead to concrete applications. Like say, one professor they suggested to us had a product calculation process, so a radar image of a week. We had to completely eviscerate it, change it, maintaining the level of quality to produce it in one minute. Because otherwise the mission would have failed. I mean a mission that has to produce hundreds of images a day, I can't take almost a week to process one. So eh, unfortunately you also have to manage here are the research centers by bringing out the added value, so really the scientific novelty components and then move on to industrialization. Here we do that business for that kind of activity...um...and that gets recognized, so they call us. On some projects we are the ones who call them and also when third parties call us or they call us, also called by third parties.

I. Perfect yes. You have partly already answered the next question, but I'll ask it again anyway if you want to add something. Still in line with the previous question about benefits and disadvantages of collaborating with other companies, what are the benefits and disadvantages of collaborating with research centers and universities instead?

P. They're hard to manage -- eh -- they're hard to manage, they don't get managed. If only as timing, which then the schedule is one of the relevant things in the market space, is really difficult. So very often we also get the best ideas out then we proceed in parallel. Because they won't converge, that's it. Then when ESA comes at the end, "You who are prime were you able to...? Look yes, they produced this one however I have this other one, look it's very similar, it works, take this one. We're glad they worked with us, that's it. Often you lose money like that because it's budget that we could also use differently, however they have to have it because they pay us PhDs, research grants.

I. Okay, while the last questions I ask you are slightly different because they are more about the production line the in-house production. First of all, I ask you if there are, have there been in the past some difficulties in allocating resources between the research and development part of the company and the actual production part or have there never been such difficulties?

P. No, we have never had any particular difficulties because then the space world is prototypical so, I must say, no I have never had many difficulties. There is a general, at least in the last two years, a general difficulty in acquiring new resources. That is, we are trying to grow, last year we hired 25 people. We are now a little over 70, taking out that part that migrated in February, as of today we are at about 70 people. Last year we hired 25, we lost almost 10, that's the flow. Because then, anyway, being based in Milan and Rome. Milan covers 90 percent of the employees, so there is a very high market and labor flexibility there, it is very fluid. So, it is difficult. It's true that we have very few exits, I must say, because to be more appealing, many end up in consulting companies that send them directly to agencies, that's it. Because that's the most interesting thing they see, let's say maybe after us. But still, there are other bigger realities that maybe contain more appealing. So, then you lose them, they kind of grow. Here we are very niche, so while there are software resources that well or poorly can be found, they are acquired in the same market or in contiguous markets, in the case of radar specialists no, there are very few. It is very difficult, exactly. We raise many of them from the university. And so, going back to the question, no, the real problem are just the acquisition in general resources at the time you're succeeding.

I. Okay, perfect. And the last two questions instead are just about the relationship between research and productivity of the company. Are there separate departments or units within the company that deal with research and development and production, or are the two activities combined?

P. No, the two activities go together; they are not separate. Each technical area has a share of R&D that it uses and that is allocated flexibly as needed. So new projects, new development ideas then require adjustment of resources as redefining priorities and so on. But they are not part of the, how to say, not more of a separately allocated team, as happens maybe in other companies but it is together.

I. Perfect, finally do production and R&D happen sequentially or do they somehow carry over differently?

P. Yes it tends to.

I. Perfect, I have finished my questions, so thank you very much for your time and if you are interested I would be glad to send you the full paper once I can finish it.

P. Certainly yes, absolutely helpful, extra information that is helpful for sure.

I. Perfect, thank you very much.

P. Thank you then, have a good day.

I. Thank you very much, equally have a good day.

Interview Code 003

Date interview: June 12^{th}, 2023
Respondent's role in the firm: Head of Research Laboratories
Company: Leonardo S.p.A.

[Comments: a few emails and messages were exchanged in order to present briefly the aim of the project and organize the time for the interview]

I. Good morning

P. Good morning, good morning.

I. Can you hear me well?

P. Yes, yes, I can hear and see you.

I. Okay great. So, first of all I would like to thank you for your willingness to participate in this interview, it was very kind of you to give me your time. I'll start first of all by introducing myself. My name is Giulia Missarelli and I am a student at Luiss Guido Carlo in the final year of the master's program in Global Management and Politics. I contacted you because I am writing my dissertation on the topic of innovation in Italian companies dealing with aerospace and defense, especially my goal is to describe a comparison between the research and development conducted within small and medium-sized companies in the sector in Italy and large companies, such as Leonardo.

P. Yes.

I. Okay, so since I don't want to take up too much of your time, I'll start right away with the questions, if that's okay with you?

P. Yes yes, of course.

I. The last thing I would ask you is if I can proceed by recording with the phone the interview. This recording will be necessary to then transcribe the content of our meeting for the purpose of my research. Is that okay?

P. Yes, go ahead and proceed.

I. Okay, so the first question I would like to ask you is as follows. One would think that a company the size of Leonardo would have sufficient internal resources to conduct its research activities in-house. However, Leonardo Labs are proof that even within these large companies, open innovation systems are playing an increasingly important and strategic role. How do Leonardo Labs represent an evolution of the company's traditional in-house R&D areas? How do they differ from them?

P. So, it is important to start with a basic premise. Do you know what Leonardo Labs are?

I. Yes, yes, of course. I did a special research to prepare the interview questions and got an idea of what your labs are.

P. Okay, so Leonardo Labs are a network of labs that were established three years ago out of the need to ensure a continuous focus on research. In fact, the emergence of the labs makes it possible to conduct long-term research on a continuous basis. In fact, this need emerged from the fact that previously the research and development process was marked by constant without the pressure on goal delivery. And instead Leonardo Labs have therefore enabled a shift in focus from delivery to a continuous focus on research. Precisely because it is a focus on research, the teams working in the labs are concerned with the development of technologies with a low TRL, or Technology Readiness Level index. In essence, these are technologies that are in the early stages of their development and are very promising. In addition to being technologies with low technology maturity, these are issues of long-term interest, precisely technologies that are very promising for their future development, and that is why related research and development is being pursued with a vision, a long-term perspective. Of course, in the case of Leonardo Labs there remains a strategic interest, that is, the goal still remains to develop a product. And that's why Leonardo Labs are not in the business of doing research for its own sake, and that's why they differ, for example, from the Academy, which is in the business of doing just that, of doing research for its own sake. Moreover, the labs carry out cross-cutting research. Leonardo's market is very different from that served by small and medium-sized companies. Leonardo does not operate in a vertical market, and therefore this implies that the research conducted internally is not focused on one area or product. Basically, Leonardo's internal research and development is conducted in the laboratories, making use precisely of open innovation, i.e., the contributions of people with specific and highly advanced skills working in each of the relevant fields in the research and development processes. And in fact in this way it is also possible to increase the shared knowledge and interdisciplinary nature of these processes, so that innovative research can be conducted. So Labs are the way to go along with this technological push, on the one hand you work on the business trying also to anticipate market demands, but on the other hand you do applied research, you try to be open to external ideas, moreover Labs represent a constant garrison on new technologies and new applications, and this is the plus compared to the past.

I. Okay, great. So instead, the second question I would like to ask is about internal research. Are there still research processes that are conducted exclusively with internal company resources and without any kind of collaboration with external parties?

P. Yes, um, as I was telling you in Leonardo Labs the company's internal research and development is conducted. This is internal research, using this open innovation system, which therefore allows Leonardo to actively collaborate with well-known universities and research institutes as well as also innovative startups, suppliers and customers. This provides access to innovative ideas and very specific and advanced expertise, thus accelerating the company's internal innovation process. So it is still internal research. The choice to proceed through an internal research process may actually be about a type of technology with more advanced maturity, and therefore with a higher TRL index. And consequently, with less uncertain business applications. But these are precisely technologies that are very different from those we deal with in Leonardo Labs.

I. Okay, great. The third question is about these actors that are involved in the internal research and development processes at Leonardo Labs. Are these mostly actors that are located nationally or internationally?

P. Then, to answer this question, it is best to differentiate rather than between domestic and international level actors, between domestic and non-domestic level actors. In fact, the main collaborations present in Leonardo Labs certainly are with domestic actors. So in addition to those from Italy, there are also those from countries like the United Kingdom, Japan or Israel, countries where research in Leonardo's areas of interest is very much at the forefront. But beware, Leonardo Labs at the moment are located only on Italian soil. We are yes trying to expand the network, opening new labs in other countries as well, first of all just the domestic countries I mentioned to you; so, the labs will soon try to extend to these other realities as well. But at the moment, here, they are only in Italy.

I. Okay, great, I understand. So, the fourth question instead ... um ... in your opinion, what are the main advantages for Leonardo that emerge from collaborations with universities, with research centers and with other companies in the area of research and development activities? And whether there are any risks or disadvantages associated with these types of collaborations?

P. Then, it is good to clarify that the advantages go both ways, they are bidirectional, both for Leonardo and for universities, startups, or others who collaborate with Leonardo Labs. Obviously, one of the main advantages is to be able to kick-start a given research process by making use of knowledge already developed and carried forward by other startups or research centers. This, of course, is an advantage for Leonardo, which starts in this way in an already more advanced position in the research process and therefore allows overall to accelerate the innovation process. Obviously, these collaborations also make it possible to draw on different skills and specializations, thus also expanding research opportunities and remaining at the forefront of the technological landscape. And of course the benefits are not only for Leonardo, quite the contrary. By collaborating with us, a start-up company, for example, can expect to be able to grow significantly, thanks to the collaboration that is created in the labs. In fact, Leonardo is also very committed to ensuring the advancement and development of the industrial sectors in which it is involved, so this is a commitment to ensure the development of the whole sector. This is of course due to the role it plays in the industry.

I. Okay, perfect. Let's come to the penultimate question. So, the innovation strategy deployed within Leonardo Labs enables the evolution of the industrial process, starting from design to product. How do Leonardo Labs support the simultaneous pursuit of radically innovative projects, i.e., exploration activities, and incremental projects, i.e., exploitation activities? What are the main challenges you encounter?

P. So this is a very interesting question, because the issue you raise is very important. It is crucial that a project is carried out and that you are able to achieve actual results, so that you know how to exploit the results that you achieve with the research and development activities. Therefore, to make sure that the correct balance between exploration and exploitation is achieved, it is essential that research activities then lead to actual results. This translates into a gradual increase in the TRL index, that is, a gradual increase in the maturity of a given technology. How is this guaranteed? Through prototyping. In fact, at Leonardo as R&D progresses, it is ensured that each stage of development is matched by a time of application demonstration of the technology. This strategy helps to ensure the exploitation of results obtained through research activities.

I. Okay, great. So, the last question is instead about strategies for organizing your activities. First of all, are the research and development activities and the production line split between separate departments within the company or are they conducted in the same unit?

P. Yes, definitely in separate departments.

I. Okay, while instead R&D and production line are undertaken simultaneously or sequentially?

P. Again, definitely sequentially. Although, as I mentioned earlier, through this prototyping strategy whereby during R&D there are application demonstration phases can basically lead to an overlap of the two activities. But essentially the research and development phase precedes the production phase.

I. Okay, great. So, I would have concluded the questions. Thank you very much for your availability.

P. Of course, yes.

I. Thank you very much indeed.

P. Sure. In case you need more information, I mean, you have my email, just write me and if I can answer you I will.

I. Okay great thank you very much! Have a great day.

P. You too. Goodbye.

I. Thank you, goodbye.

Interview Code 004

Date interview: June 5^{th}, 2023

Respondent's role in the firm: Mission Manager

Company: Arca Dynamics S.r.l.s

[Comments: a few emails and messages were exchanged in order to present briefly the aim of the project and organize the time for the interview]

P. Good morning.

I. Good morning, can you hear me well?

P. Sure yes, yes.

I. Great. So, first of all, I would like to thank you for your helpfulness.

P. Thank you for contacting us.

I. So, in brief, my name is Giulia and I am a student at Luiss Guido Carli in the final year of the master's program in Global Management. I am writing my thesis on the topic of innovation in Italian aerospace companies and that is precisely why I decided to contact you. If that's okay with you, we can proceed.

P. Sure, yes.

I. Okay, the last thing I ask you is if I can record our meeting? It is just a recording made with the… the…cell phone, no video recording.

P. That's right.

I. Yes, just the audio, just to have then something to base on for transcription. And nothing, if it's okay with you we can start with the questions directly so I don't take too much of your time.

P. Eh... yeah, that's fine, that's fine, no problem.

I. Perfect, so I'll ask you first of all, I found the name of your company in the catalog that was compiled by the ASI from the ICE, which lists the names of basically all the small and medium-sized companies, even the big ones, that are involved in aerospace in Italy. Exactly, here I found your name and also a brief description of what you do and what you are involved in, but precisely I would ask you if you could give me, let's say, a brief overview of what are your activities, your main lines of production, maybe even some hints about the history of the company. Just to get a more detailed overview than the brief description that is given in the catalog.

P. Yes, so... eh.... So Arca Dynamics is a company let's say in the New Space Economy and what we do is, our goal is to provide solutions for environmental sustainability of both space but also maritime and... that's what we do actually using our satellite platforms. What we want to offer is mainly are services on space traffic monitoring, so everything about Space Situational Awarness and at the same time also maritime traffic monitoring. So, for example, identification of non-cooperating vessels or tracking maybe cargo vessels. And we do all this by operating precisely neo-satellite platforms ranging from three-unit cubesats up to twelve, sixteen units. Um, the platforms, let's say the cubesats, we design and develop them in-house. So we take advantage of technologies that we develop in-house. Currently we don't have an active production line yet, but we are working precisely to, let's say, start it up, we are still in the phase of research and, let's say, demonstration in orbit of our technologies to be able to then start, let's say, a real production line and offer the services that we propose Eh... currently we are in the company about fifteen people and so we have grown, let's say we are growing. Here at the beginning we were less. And the company was born from three guys, three co-founders, who basically met in university; so, in university labs and decided to create this company, this startup. Eh... then I precisely entered, now it's three years, yes almost three years. It has been a very rich period of activity so and so it has gone by quite quickly.

I. Of course, so the year the company was born is very recent anyway, right?

P. Eh... yes, I'll tell you the year. You're putting me on the spot, certainly it's in the catalog, it should be there, because I'm confusing when we entered the Esa Bic incubation program from when the three guys actually founded, from a let's say legal point of view, the company. Because I took over subsequently.

I. Sure, that's perfect then. So you guys don't currently have an active production line?

P. No, no, let's say it's under development.

I. Yeah, okay, so this will probably shorten our interview a little bit because especially the final questions focus more on that. But anyway it's very interesting because I'm, let's say, trying to make a comparison between what are the larger companies and the companies the smaller ones, and then also the ones that have been born more recently... um... and so precisely a view of a company that has not yet developed the production line and is still in that initial phase of research and development and demonstrations, in my opinion, could be precisely very interesting. So if, in addition to my questions, you feel that there are useful details just to give, let's say, an idea of what the situation is of companies that are at this stage. Of course all information is more than welcome, let's say, it's always useful, here. If it's okay with you I would then proceed with the questions.

P. Yes, I haven't actually introduced myself, in the sense what I do in the company. To make a long story short, I am the mission manager in Arca Dynamics; so, I am in charge of managing the cubesat missions mainly, so from planning, design, design and development, monitoring precisely the evolution of the cubesat missions. That's the main role, although, again, being a very small company, especially in the early days it was also required to work on multiple areas and multiple aspects, again inherent to the cubesat missions I've also had roles a little bit more as a systems engineer. Here's a short presentation of what I do, because I realized I didn't do that before.

I. Great, thank you very much. So, the first question I would like to ask you is about when the company decides to do research and development and then focus its energies on a particular technology or product development, what tools do you use to analyze the industry and, let's say, pick up what are the main technological developments within that?

P. Yes, so, mainly ... um ... in general, to stay updated on precisely new technological developments ... um ... the main tools are definitely newsletters from space agencies, from various industry associations, we participate in workshops, webinars, conferences. These are the main tools and means that we use. Obviously then once we identify a particular technology or a particular area, we then go on to perhaps further investigate the topic or at any rate the technology itself, doing more research, seeing the literature, what is there at the level of purely technological research. So by reading articles, publications, and even theses, because maybe there are often results of analyses that have been conducted by thesis writers that can still help in some way to understand or otherwise get a more general idea of a particular application or technology.

I. Sure, got it. So, once you identify a technology in which you are interested, what are the main factors that you take into consideration in deciding whether to actually proceed in investing in this technology? Rightly, there will be a part that is precisely more related to, let's say, technological considerations, and then there will also be that perhaps related to the business considerations of this product.

P. Yes, exactly, there is this distinction. In fact, first you have to see if the technological implementation is something that is feasible, achievable, even at the theoretical level as well as the company's internal resources and skills. But first what is evaluated is how this new technology trend can fit within the very corporate roadmap. So we however have a business goal of the company an established goal. And if we see that there are activities or technologies that, in some way, can fit within this line of the company, let's just see if we can explore that further. And then there is the issue related precisely to the market, so outlets at the market level are also evaluated to see whether it is worth investing resources and expertise to develop that particular technology or not.

I. Okay. So, on the other hand, as far as research and development activities are concerned, which, from what I understand, are therefore your focus at the moment, are there certain research processes that are conducted exclusively within your company, or in any kind of research and development process is there collaboration with external parties, whether they are other companies or research organizations such as universities?

P. So ... um ... in the processes related exclusively to research and development of technologies that we then intend to use and exploit for our services, these processes are conducted exclusively within the company. Because that is our strength at this stage. Innovation, the fact that we come up with an innovative service, an innovative technology is the strength that characterizes startups and small companies in some way compared to maybe large companies. So they are completely internalized research activities. However, we have cases of collaboration ... um ... we have had and we also have cases of collaboration with other companies but, in particular, with research centers and so far they have been at the national level. For example, we have in place a framework agreement with CNR, the National Research Council, for research and development activities in space. But almost all the activities are conducted precisely within the company, however by internal resource competence.

I. Okay, so no collaborations with other companies at the moment?

P. Then collaborations yes, but not really related to the R&D process. That is, we have collaborations with other companies, even competitors, because the aerospace environment is quite niche. So it's hard not to collaborate with other companies ... um ... but just at the level of activities inherent to the development and research and development of technologies, here these are all internalized.

I. Okay, um, you were also saying that the collaborations that you have at the moment with research organizations are nationally localized, right?

P. That's right yes.

I. Is that because at the moment it is simply more convenient to communicate with other entities that are nationally located, or are there other reasons behind this choice not to open up for the moment to other entities on an international scale?

P. No, then at the international level we are absolutely open, also because if not, the company would die immediately. So, the reason we have active collaborations in place at the national level is just for, let's say, simplicity, in the sense that it has been easier to have contacts and to have relationships with precisely national research centers, such as CNR or even Italian universities. But precisely because we come from university backgrounds, so it's easier to get to know the network or otherwise have more established networking at the national level. This does not take away from the fact that we are open to collaborations abroad. That's a given.

I. Okay, great. So, in terms of collaborations with other companies, I have a few questions. So first of all, you said that these are also competing companies, right?

P. Yes, that's correct.

I. Competitors in the sense that they are really in the business of producing products that are similar to what you are developing, or do they fit, let's say, in some way into other stages of the supply chain?

P. So, we have had collaborations both with non-competing companies, in the sense that they had different skills from ours so at a certain stage of development of some projects they were complementary skills. And we also have collaboration with competing companies that offer or otherwise can offer services similar to ours. And in that case we try precisely to have a collaboration that does not affect, let's put it this way, the interests of the two companies. That is, they are still kept separate, maybe working on projects where we are not going to do the same thing, to put it simply. In the sense that we therefore go and deal with different parts of the project, while knowing that however the company may have the same skills as us or at least may provide the same services as us.

I. Okay, great. So, the next question instead is about the kind of partnerships that may emerge from these collaborations with other companies. I don't know whether you tend to collaborate with other companies on the basis of partnerships that are formalized anyway or on the basis of new companies that emerge from these collaborations.

P. Then mainly they are collaborations with companies that precisely we have known through simply through networking activities. And we have had research and development collaborations, but it has a little bit broader sense. In the sense, for example we had collaborations for a project for the development of a cubesat mission where we would bring certain skills to the table and the other companies involved would bring other skills to the table in order to be able to accomplish the mission. So that everyone could demonstrate their technology in orbit. And these collaborations with even larger companies were let's say also in place in order to be able to participate in, for example, tenders, that is, development tenders, for example tenders also from Asi or even from the European Space Agency, but also collaborations on precisely complex projects where different skills are needed, as I said before, and resources that we don't have within the company. So these are mainly the types of partnerships with external companies that we have.

I. Um, perfect. So the goals that are pursued through these collaborations are still related to the development of a project or technology, right?

P. Yes, let's say these collaborations then have the ultimate goal of achieving the strategic goals of the company, precisely. Like an in-orbit demonstration of a technology or the validation of the delivery of a service or the validation of a product for which it is necessary, anyway, that we take advantage in some way of the opportunity that is given to us by satellite projects or missions that are feasible because of these skills and technologies developed by other companies. And so, right, these are collaborations that still allow us to demonstrate our technologies or our services in order to then be able to bring them to market or otherwise start our own production line.

I. Sure, okay. So the next question instead is about the advantages and disadvantages of collaborations with other companies. And it is my understanding precisely that the advantages are more related to being able to demonstrate precisely your own technologies. If you have other advantages precisely to mention, go ahead. And possibly if there are any risks or disadvantages.

P. The advantages are exactly these or at least the possibility of benefiting from skills and expertise other than those of our own company. And especially if you work on complex projects. Among the disadvantages ... eh ... there is always the risk despite the agreements and contracts, there is always the risk that from one moment to the next maybe the companies you are collaborating with can back out and therefore, even if there are legal aspects that are then addressed according to the contract that you enter into, this still goes in some way maybe to damage the progress of the project itself. So I would say risks maybe also related to the planning and the resources dedicated by the company that you are going to cooperate for, which could be different maybe from or otherwise undergo changes during the course of the project and be different than our timelines and needs. Or even the simple interest in that project maybe lower than our interest. Maybe we are more invested, so there might be a risk that the contribution of the outside company is somehow less and there is a risk precisely of, in some way, blocking. Of course, there are always means, methods to mitigate these risks, however, there is always the risk that they might back out.

I. There, okay perfect. While instead the questions more related to collaborations with universities and research centers are the next two. First of all you precisely were talking about collaborations that arise with centers of research centers and universities nationwide. And I wanted to ask you in your case, as a company, how did these collaborations come about?

P. Eh... mainly networking, getting to know people and people in charge of certain activities within research centers, for example CNR. Having these contacts then the relationships then developed thanks also to opportunities that emerged over the years. For example, the various calls of established by ASI and others in the field. Or otherwise, knowledge arising from, precisely, the university environment. It also happened that we were contacted by a university or research centers because, as in short in your case, they found our name in the ASI catalog and then interest emerged, so they contacted us directly and we established a conversation about possible collaborations.

I. Okay, great. So, again along the lines of the question I asked you previously, so what are the advantages and disadvantages of collaborating with companies, in your opinion and based on your experiences as a company, what are the advantages and disadvantages of collaborating with research centers and universities?

P. So, at the level of advantages, collaborating with universities of research centers somehow allows you to use very specialized skills, which can certainly be of interest for a very specific activity. Another advantage is that you have the opportunity to often work on highly innovative projects. Because basically that's what universities and research centers do, that is, they push themselves into especially very innovative areas and for which maybe in the company you don't always have the resources or even the time to be able to let's say delve into some extremely innovative aspect in detail. And so collaborating with university research centers would allow you to delve into those kinds of aspects as well. On the level of disadvantages I actually don't see very many. One of the disadvantages might be especially if you collaborate in the university setting maybe if you collaborate with doctoral students or thesis students, sooner or later there is a risk that anyway their course ends, maybe even shortly, and then there is a risk of not having that person who was dedicated to that specific activity anymore. Also, a research center or the university has to maybe have the time to find another person, another resource that can be dedicated to that activity. And so, let's say, maybe there is a little bit more prolonged time to carry out a given project. But, basically, other than those risks I don't see any other risks.

I. Okay perfect. So, the last questions are, as I mentioned to you earlier, are the ones that are more inherent to the company's production line, which you were telling me has not been started yet. And yet precisely what these questions go to is the focus on the difficulties that the company may face in balancing resources between research and development and the production line. Given precisely that these are companies that operate in a very technologically developed sector, so companies that have a need to invest heavily on research and development. So let's say, adapting this question a little bit to what your situation is, I would like to ask if there are any difficulties in resource allocation anyway? Especially since you are at this early stage and perhaps precisely being a very large investment on research and development, what are the main difficulties you are encountering at this stage precisely of launching new technologies and application demonstrations?

P. So, let's say one of the difficulties, but one that we somehow managed to overcome, was just finding people and resources with particular skills that were of particular interest to us. That was an initial difficulty that we had. Currently, however, I must say, precisely with the latest growth at the staff level, we are doing quite well at the level of especially research and development. Because that is what we are doing now. And yet we are also bringing forward, we are also planning a whole part related to a production line. And so, let's say, the idea is to simultaneously bring forward both the research and development aspects and the production part. That is, we are moving to balance resources on both fronts, that is.

I. Okay. So, I don't know how advanced let's say this initial development given by the introduction little by little of the production line is. So if you can't answer the next questions, that's not a problem. And so first of all I wanted to ask if you think these activities will be spread across different departments or will they be conducted within the same unit?

P. Then they will most likely be conducted within the same unit, because being still small, in the sense anyway in number we are quite small and still the activities will be at least in the early days conducted within the same unit. Without excluding the possibility, in a greater growth perspective, to separate and have different departments, that's it.

I. Sure, here. The last question I might as well not ask because it's pretty much related to whether you conduct the research and development phase first and then production. It seems pretty clear to me at this point that that is the case.

P. Yes, we are starting now, I mean necessarily so. We are at an early stage of research only. The idea, the intention, however, is to ,once the part, let's say the production line is consolidated and started, to continue however simultaneously the two activities both of research and development and the process that concerns precisely the production line. Here we are now just in the research and development phase to then continue with that production part. But still simultaneously maintaining the research activities as well.

I. Okay, great then with that I would have concluded my questions, thank you very much for your participation.

P. Ah, already finished. Quick!

I. Ah, yes. Do you have any questions or curiosity?

P. I don't think so, thank you again for contacting us.

I. But thank you! Have a good evening and see you soon

P. Have a good evening

I. Goodbye

Interview Code 005

Date interview: July 4th, 2023

Respondent's role in the firm: Managing Director Sales and Products

Company: Sitael S.p.A.

[Comments: a few emails and messages were exchanged in order to briefly present the aim of the research and organize the time for the interview. In this case, the outline of questions was sent by email as it was requested by the interviewee, who proceeded during the interview by following it step by step.]

P. Good morning

I. Good morning, how are you?

P. Good, good, thank you, you?

I. Good, well me too thank you. First of all, thank you very much for your time for this interview. It was very kind.

P. You're welcome.

I. Okay, so let me introduce myself. My name is Giulia and I am a student in the course in Global Management and Politics at Luiss. I contacted you as I am doing my master's thesis on the topic of innovation in companies operating in the Italian aerospace industry. So since this is my field of study, I am dealing with innovation from an organizational and not purely technological point of view.

P. Very interesting yes, you had already mentioned something to me by email.

I. Sure. So if it's okay with you I would proceed with the questions.

P. Sure yes.

I. Before we start, I'll ask you one last thing. Would it be okay with you if I recorded the audio of the video call? I would only need it for study purposes, as I am required to write transcripts of the interviews as part of my thesis work.

P. Certainly, in fact if you prefer I can record with Teams, which automatically generates the transcript as well.

I. Well, if it's not too much work for you, that would be perfect.

P. Of course not. So here goes. We've started the recording and so we all agree according to the privacy, because this is the message that comes up.

I. Certainly, okay, thank you very much.

P. So let's go in order with the questions, how did you propose them?

I. Right very well, that's fine, yes.

P. So let's start with the identifications of new technology trends. There are at least four tools to analyze the industry. Then the first one is sector studies, so the European company that does these sector studies and is the most authoritative is Euroconsult which then issues annual or biannual reports on the different branches of space activities. Launcher, the earth layer, communication, positioning, et cetera. So that is a very authoritative first source of information. And another extremely powerful method is the harmonization cycles of the European Space Agency. So for the purpose of aligning national technological developments with those of the European Space Agency, with periodicity that is a limitation right now because it's five to seven years, the dossiers of all the technologies that then contribute to the realization of a space mission are reviewed. And so basically a review is done. The reason they are done so thinned out over time is that the number of dossiers has multiplied. So right now it's I think almost 100, more than 70 for sure. And the method is to disseminate to all the national delegations who then do national censuses, collect them so that they can see if there are overlaps or complementarities between the lines of technological development of individual countries. And then you do the further work of harmonization with those in ESA.

I. Okay, got it.

P. Then there is a second one. In the case of events, on the other hand, we regularly preside over workshops, conferences, and this is another immediate source of information, because it is the one that has the least lag between information gathering and publications. So these are all more or less institutionalized techniques, and then we have our own technology scouting activities at universities and research centers. The second question that was, what are the factors, the rewarding parameters. For deciding whether to invest a certain technology, obviously they are the TRL, so the Technology readiness level at the beginning. Because as a private company we can afford to invest a very small fraction of our Rendi on low TRL projects, whereas it is the medium TRL, that is the one that then has a closer market return over time that is more attractive to us. And of course the low TRL alone is sometimes not enough, in the sense that the fact that there is institutional interest associated with a low TRL, I'll give you an example to understand, can make a technology interesting. Right now we are talking about collecting and transmitting electrical power from orbit. The SOLARIS project is the

European Space Agency. is both a low TRL project, however, the Space Agency has stated that it believes in it and wants to invest in it. Then in that case it is not only a corporate investment, but this is supported by a public investment and that obviously changes the level of interest. And then another, the last parameter that allows us to decide whether to invest or not is how much a certain technological element is part or can become part of our development roadmap. So we have, have and maintain roadmaps of technological developments in the various domains in which we are active-satellites, electric propulsion, electronics. So, where an element emerges that can become part of our green roadmap, at that point that tests and and and is worthy of more of an increased focus.

I. Okay, great, so this then is determined, basically, so by the technological developments that you have in place now, so based on what you are dealing with, you also determine what the technologies are, right.

P. Sure, correct, correct. Well, we actually have product roadmaps in the sense that we know what product we want to come to market with and in what year we intercept a demand. Supporting those products are the enabling technologies and then the upstream assessment is make or buy and then normally, as you can imagine a combination of the two, in the sense that then we'll get there because there's an argument about the selection criteria. The key technologies we keep them in house, so we exercise a make option, while those that are to be considered commodities we acquire them from outside.

I. Okay, perfect thank you.

P. Here, and this was really the next question, I thought it was further on instead, and so it was asking if there are processes conducted exclusively in-house, without collaboration with projects with external parties. This is the case, for example, in electric propulsion, electric propulsion is our proprietary asset and so in this case the kind of collaboration is complementary, so for example the electric motor element is done in-house, it is done, it means designed, modeled, numerically built, tested. The fluidic distribution system, which is not a core element, in some cases we have done it because we had a contract in opportunity to do it, but we are also looking at possibilities of buying it from third-party entities, which have precisely for other types of propulsion systems.

I. Okay perfect.

P. So far we have not gone to extremes in research, so the size of sitael, we are about 250 people, is such that this kind of opportunity has not yet arisen, but I think mainly because of the small size of the company.

I. Okay.

P. Regarding active collaboration with other actors that is the third question in this block and the answer is yes, in the sense that it is mandatory in our industry to collaborate with national, European actors mainly. We have had in the past some non-European collaboration as well, however, let's say in proportion and this non-European share is marginal and at the moment the proportion is 80 percent with Italian and 20 percent European research organizations and institutes.

I. Understood.

P. So, to understand, all Italian universities that have an aerospace vocation have a more or less direct form of collaboration with us. Collaboration that starts from conducting theses to financing doctorates suitable for joint projects, in short. Shall we proceed? I am galloping to be able to stay on schedule.

I. All right, all right, go, I'm following you without any problems.

P. All right. So as far as collaboration with competing companies is concerned, let me make a comment, in the space domain the notion of a market does not yet exist, beyond the of the predicate of the space economy of the New Space economy, however, in fact we are still far from a market economy with real competition, because it is a competition that is very tamed by the rules of engagement and the presence of incumbent, very strong. So that means, this in this aside I do because it is difficult to even give a definition of our competing companies, in the sense that the pattern is one of partnership and competition depending on the circumstances and depending on the rules of engagement. That is, the same company in different contexts can be our partner, and when I say partner it can be an equal partner, a sub-supplier or our prime. Or in another context, for example of European tender where an international stringer is advantaged, that same company that in national context was our partner, becomes our competitor. So it's an extremely flexible, extremely varied pattern. And so the answer is that yes, we partner with our competitor companies because there is no clear perimeter of what the competitor companies are, i.e., unlike in the aviation sector, where it is established that Airbus's competitor is Boeing and vice versa, in the case of SITAEL, but in the case of any other space actor, at least in a European context, these roles are interchangeable.

I. Okay, perfect.

P. In terms of the types of partnerships, we said it in the previous answer, that is, all three forms, an equal partnership rather than a partnership rather than a subcontract are schemes that allow you to establish partnerships. The fundamental goal let's go to the third question is to increase critical mass, to be able to have the size to compete at the European level. So um, only from these types of alliances do we manage to have dimensions that make us competitive at the European level. The advantage, of the European and international in general, the advantage of collaborating with other companies in research and development is that risk sharing, so of risk reduction through sharing. And the disadvantages, the drawbacks, are about the risk of failure. So I share an R&D enterprise, they spread the items to be developed over different parties, failure in the case of failure and failure when the TRL is low has a high probability of happening that the cost of failure is spread over different parties. The disadvantage, of course, is that of not full ownership of the invention. So let's call it invention for understanding, right? So that means it has to be exercised. I'm not saying it's impossible, because otherwise we won't make these partnerships. But a great deal of caution has to be exercised in the regulated structure of the partnership, so that the rights of use are clear. So the la the duration of these rights of use rather than who pays royalties to who else, who has the right of economic exploitation and so on. So the moment this regulatory frame is well implemented, then yes you can then proceed expeditiously to the commercialization part and you overcome this risk, this limitation of not full ownership. When, on the other hand, the research is of such a size that it can all be done at the company level, then it is clear that this kind of obstacle is not there, because then the ownership is fully with the person who carried it out.

I. Of course.

P. We are proceeding very well. So in terms of collaborations with universities and research centers, then these collaborations, we were mentioning it earlier. We start with dissertations, so sharing a dissertation pathway is a way to be able to engage the expertise of the university, retain a student who becomes the bridge between the university and the company. Then this can turn into for example a PhD opportunity. Then they can turn into opportunities for research contracts, research contracts, we distinguish two types, research contracts, funded by the same that then commissioned. It is a certain study, and actually in saying this I realize that I am debunking what I had said earlier about penalizing research, because this is a form of de facto extreme of research. It is the most frequent case, however, is to pursue jointly with universities and research centers, opportunities for financing, at least partial financing of research, both in a national context and in an international context. So the Italian Space Agency, the European Commission, the European Space Agency. periodically announce more or less free themed opportunities in which aggregations of companies and research centers are promoted. And we are always very interested in this kind of partnership. Now a big project is about to start, which is called Space up, which involves on funds from the PNRR, from the national recovery and resilience plan.The biggest players in Italian space activities, including Sitael, is practically all the universities that have a space-type vocation for the development of services and new enabling technologies for Earth observation services, and so, in this case the opportunity is a call on funds from the PNRR of the Italian Space Agency, which is done through. An extended partnership, so a public-private partnership with a co-funding share, to raise the low TRL, the consortium is very broad, in the sense that there are more than 20 actors and that means that you really do research. Right after basic research where we still don't have those problems of non-ownership and dependence on the inventors and when they are not they don't coincide with ourselves and the benefit, of course, is to go and find the best expertise in different areas. So, the vocation of different universities corresponds based on their history, experiences in certain domains, materials, listics, planetary exploration, human flight depending on what I need I have the ability to go and find the mega. The disadvantage is the mentality, which is innate in the university researcher, in the desire to publish, the desire to share because it is part of the scientific method, the fact that any discovery is verifiable by anyone else, but this is perfectly antithetical to the company's need for protection. So the dialectic, very, very intense dialectic with researchers is that as soon as we discover something, the researcher would like to publish, because then his KPA, his merit marker and the fact that he has made a prestigious publication. We would like to disincentivize that, we normally find points of agreement, for example in masking the results by dimensionalizing them, making them Eh, let's say Parametric, so giving obviously scientifically rigorous indications but not giving numerical indications associated with a unit of measurement that can allow one of our competitors to repeat the discovery, so through dimensionalized parameterizations, we can for example publish results of the performance of an engine without having revealed beforehand what is actually the thrust in Newtons that our engine can achieve. It is a tremendous effort, though, this is a tremendous effort because precisely it is different. The researcher's goal is our goal.

I. Of course.

P. And the last block of questions is the one about the relationship between the R&D part and the production line. So, granted that in most of the realizations that we do in space, what flies is the prototype. Then, when what flies is the prototype, it's only going to fly. I mean the first artifact, the first specimen. So, it is clear that the two lines research and production coincide. The goal is to make a prototype, a single specimen; therefore, you are far from the canonical idea of production, clear? And that, in my 30 years of work, has been eighty-five percent of the projects I've followed. The client asks me to make a satellite to observe cosmic rays. In that case, I do all the development work on the cosmic ray satellite, launch it, and I will never do the same one again. So, in that case, the production line is the research and development line coincides. Where, on the other hand, we are obliged to differentiate them is when we start talking about even small series, that is, even just two examples, so not just the prototype, but also a second model that will fly a third, a fourth or even 10 or 20 models then in that case we have to specialize the two lines, so going in order. The first question I have already answered, so we inherently carry on research, development, product and production which comes to coincide with product development. The need to segregate to separate them, that of research and development is that of production. It emerges when the numerosity of the products, the numerosity of the lines, of the objects we have to make starts to grow. Because at that point there is a need to specialize resources, and when I say resources I don't know if in the question we mean resources of all kinds, human resources, but also production resources. Then we are making two satellites that will fly in the next year with two electric motors each. Here we are at the limit of promiscuity between the development line and the production line. Since we have acquired an order for eight more, this has forced us to also together with the Italian Space Agency to start an investment to make a line exclusively dedicated to production, where we do what the industrial revolution did in other manufacturing contexts, that is, we move to small series production, which is then segregated from the research and development line. So I don't know if I've managed to give the idea, so really the answer is that this segregation of the R&D line and the production line, it happens evolutionarily, and the evolution corresponds to the maturation of the product. So what happens then? Imagine it as a flow process, the product is developed, made in the first few samples, it works, I pass it to the production line. Where I have a large incidence of operators for manufacturing and little engineering support just for troubleshooting, but that means that at that point the resources, both human and physical from the research part, have been offloaded from the load of that specific product. At that point I can employ them for other types of products in the same family, for example, because in this case then there is a specialization, that is, I have a clean room that is used to make electric thrusters. At that point I will try new materials, new priming techniques, higher powers, tankless systems and so on. Okay however segregating the two lines.

I. Okay, yes perfect.

P. Finally, the last question asking whether they are undertaken simultaneously or sequentially. I would say that implicitly I have already answered, it is always sequential the exploration part and then the exploitation part, indeed. The first part of economic exploitation of development actually coincides with the tail end of exploration. As we said, right? That is, I hope I have rendered this idea well, that there is not a sharp transition, but the realization of the first prototype, which then will be the first product because the customer pays for it, we fly it, and we also benefit economically. That in fact is still part of the research cycle. So it is in fact just la la la, the very driven serialization leads us to segregate the two chains.

I. Okay, great. I think we have concluded the questions, right?

P. Yes, the questions are finished.

I. Great, thank you very much for your answers.

P. But you are welcome, I will send you the recording as soon as it uploads.

I. Okay great. So, thank you again, for the interview and for the recording.

P. But you're welcome, it was my pleasure. Goodbye.

I. Thank you, have a good day.

Interview Code 006

Date interview: July 11th, 2023
Respondent's role in the firm: Head of Technology, IPR and Product Policy
Company: Telespazio S.p.A.

[Comments: a few e-mails and messages were exchanged to briefly present the purpose of the research and organize the time for the interview. In this case, the outline of questions was emailed as requested by the interviewee, who proceeded during the interview by creating a single speech that combined the answers to all questions.]

I. Good morning

P. Good morning, how are you?

I. Good thanks, how are you?

P. I am fine thanks.

I. Well, first thing I would like to introduce myself. My name is Giulia, and I am a student at Luiss and I am currently completing my master in Global Management and Politics. I am in the process of writing my thesis on the topic of innovation and R&D activities in firms that operate in the aerospace sector here in Italy. As part of it, I am conducting a series of interviews and that is the reason that led me to contact you.

P. Very interesting thesis.

I. Many thanks. Before starting the interview, I would like to ask you one last thing. As part of my thesis, I have to write the transcripts of all the interviews that I conduct, so that I can analyze them better. So, is it okay if I proceed by recording the interview? It is a simple record done with my phone, so no video or anything else, just the voice.

P. That is alright, sure.

I. Great. Then we can proceed with the interview.

P. Sure, great, but I'll ask you the first question.

I. Tell me.

P. How well do you know Telespazio?

I. So, I know it broadly, I would say. Because I just, actually a few months ago, I completed an internship on the editorial side of Airpress, Formiche magazine. I was just on the Airpress side, so let's say I had a chance more, from the more editorial and journalistic point of view, to get a feel just for the aerospace field in general. And then

I've also happened on a couple of occasions to do some articles a little bit more specific about Telespazio, but lo and behold, most of the knowledge that I have related just to the company is because I got a little bit updated this morning on how it works. Then actually I, again as part my thesis, had already interviewed Leonardo, specifically the director of Leonardo Labs.

P. Alessandro Massa.

I. That's right. And just from here my additional question because this morning doing my research I saw that you also do a lot of open innovation or at least accept a lot of contributions from universities, small and medium-sized companies as well. And so I also wanted to look at that aspect a little bit. So, ask some questions precisely about open innovation, however here basically the outline of the questions remains that.

P. Okay, so if you want to tell you very broadly, as I say thank you in a nutshell, Telespazio. So Telespazio is a group that has an international footprint. Definitely born from Italy it is focused on Europe. So the general management is in Italy, half the Telespazio employees, which are about 3500/3600 at the moment, half in Italy and the other half in the rest of the world. Where by the rest of the world we mean France, Germany, Belgium, UK, Romania then in Latin America, Brazil and Argentina. And from Brazil and Argentina we actually also take care of business in Panama, Peru, in Bolivia and a number of other areas in Latin America. As I said of about 3500 employees half are in Italy and the other half are abroad. In Italy in addition to Telespazio S.p.A. there is also the E-geos, which is a company of the Telespazio group, 80% Telespazio 20% Italian Space Agency, which was born a the dozen years ago as a spin-off of Telespazio in the Earth observation area of Telespazio and as a result of an agreement made with the Italian Space Agency to exploit the data of the Cosmo Skymed constellation satellite. It started from there, then clearly today we are the exclusive pursuers of the Cosmo Skymed project, but it is a di cui of the data set that we go to process to provide our services on which we have developed our applications. And on which we serve our customers, but today it is so much and so much more. So as well as in Germany, in addition to Telespazio Germany, that is the entity emanating from Telespazio in Germany which is 100% Telespazio S.p.A., there is also another company which is Gap and instead as E-Geos deals with geo-information, it is a 100% E-geos company because that is exactly the market and that deals with geo-information and basically let's say focused on what is the land and forestry business. By the very nature of Germany, somewhat if you will. So the land management, the forest management, the applications that they have are mainly focused on land cultures. Whereas like E-Geos and also all the other parts that deal with geo-information within the realm of Telespazio and they also deal with maritime surveillance, asset management, that is asset monitoring, rather than water exception, management also precision agriculture. More management is a support to all these application domains that we have. Telespazio in turn is 67% owned by Leonardo and 33% Thales. Percentages reversed in the case of Thales Alenia Space, and so it is 67 Thales 3% Leonardo. Together we form the so-called Space Alliance, which is not a legal entity but it's simply a brand, let's call it that, which brings together the upstream activities, which are those strictly of Thales and Alenia Space, and the mainstream and downstream activities which are those more typically of Telespazio. Actually, on mainstream we collaborate, let's say it's our boundary point between those who make the satellite and those who then operate it on the ground, who start from there and then provide data and value-added services. All of this within Telespazio spans a basically three lines of business, which clearly follow a market that is evolving.

I. Certainly.

P. We were born in 1961, and when we had our 60th anniversary celebration in 2021, we liked to call ourselves a startup with 60 years of experience. In the sense that it is clear that we are a large and structured company, under the Leonardo umbrella so absolutely structured and managed in the most canonical way of the term. But at the same time, for obvious reasons of growth of the company, we can't not be, I don't want to say right at the frontier of technology, because that's not true. And then maybe going forward with the questions I'll specify that a little bit better. But we certainly have an extreme focus on technological evolutions, market evolution, and then figuring out how to meet the demand. Clearly we are paying attention to the evolution of the market, both the market of our more traditional business, such as precisely satellite communications, but also of businesses that for us are the more innovative ones or at least those that have come more in the last years of our life. For example, satellite navigation, hybrid navigation, hybrid communications and then 5G and so on. So anyway there has always been a focus on new technologies, not for the technologies per se but how these offerings vis-à-vis a market that is going to evolve and also grow can be supported by new technologies. So, I remember there was a question that said "But what do you do with new technologies? You go and investigate them and then how do you decide whether to invest in them?" It's actually kind of the other way around. We try to understand how the market evolves and we then try to understand how we want to position ourselves vis-à-vis more traditional or mature markets or in new markets, and at that point we start to understand what technologies can support an evolution of our product or our service. I may be using the word product now but actually we are not a manufacturing company; so, for us the product is more of a service more of a platform with which we offer services rather than the product understood as the piece of iron. And so going to understand how technological evolution can support the evolution of our product in order to be more competitive in the market or to be more appealing to the customer. This is the virtuous circle that we try to set up. When I said earlier that we don't really stand at the edge of technology, it's because in order to do that we can't be all-knowing and we can't jump in first hand on anything that comes along, on any new technology, but we have to rely on those who do this for a living, those who really stand at the edge of technology for a living. And we learn from them, maybe we guide them if we need to understand how this new technology can support our business, and then from there we go and decide if this is a part of our core business that we can't have done outside and that we need to invest in ourselves as well. And so we also have to deal with internalizing certain competencies to carry on a research and development. So let's go from the lower levels of technology readiness, let's also internalize the competencies, possibly even the resources with the competencies, and then we take it forward because it's part of our col business and it's appropriate for us to maintain governance of it. Rather than maybe trying to figure out with universities, research centers and maybe startups, the latter is something that we're getting into in the last few years, a little bit with difficulty a little bit with satisfaction, but in short let's say it's starting and also with support from Leonardo. If you've talked to Alessandro Massa he will certainly have told you something about that as well. And we try to use these external competencies to do innovation, but in short the concept is not to innovate alone except for what is really core, but to try to work with an ecosystem. And potentially as far as startups are concerned to also grow it, not so much by breeding our competitors but by breeding our collaborators, with whom we can then do even more business operations rather than maybe one day who knows we can do a merge and acquisition and we bring in then the company. This then will depend on a thousand things and however here is kind of the concept. And so that's led us over the years, as I said before, to move from more mature and more traditional markets for us to space exploration, and so we've been engaging for a few years now on the big Moonlight program the

European Space Agency which provides a satellite communication and navigation infrastructure to support the new lunar exploration. And so we have been involved in the high-level design phase of the whole constellation, the whole service actually. In fact, the constellation is in support of what is then the service, the constellation will be done by the manufacturers, who go by the name of Space Italia, for example, with whom we have collaborated. All this is needed for us to be able to provide services on the Moon. Today we provide hybrid satellite communication services on Earth, we want to do it on the Moon. Clearly this means moving, raising the bar, let me say therefore, moving a little bit further what is a more traditional quote-unquote business, certainly much more traditional is the communications business while it is newer the navigation business. We're moving it to another place in the universe though, because still we're leveraging our expertise but we're also going to benefit the most from our technologies and what is the evolution of just the future business. Because today there is not there yet, but we are doing the business plan that clearly targets a series of investments of a business even far away, but in the future the idea is precisely to have a business related to services and supporting the new human installations Moon, rather than new explorations on Mars. One step at a time is going in that direction. We talked about satellite navigation services, we say we received from the Fucino Center, as a satellite control system in orbit, the first signals from the second satellite of the Galileo constellation. Because we had that contract to do that work, but from there then we evolved, so in addition to being partnered with the company Space Opal that manages all of the services both of managing the Galileo constellation and delivering services from this constellation. There are two partners, namely Telespazio for 50 percent and DLR which is the German Space Agency for the other 50 percent. Clearly this is another piece of the satellite navigation business along with then the infrastructure to provide certified navigation data with high accuracy, with as little margin of error as possible, to enable autonomous navigation as well. And here with that I give myself let's say the hook to move on. In 2019 we started working with drones. We tried to figure out how all our expertise in satellite communication, satellite navigation, geo-information could be brought to bear and support the unmanned world. We started with the more traditional drones, the ones that fly, but in principle it is something that can be extended to any unmanned system. The concept is we understand how, with a whole series of experiments that we have done and that we have invested in as a company, how all these skills that we see disjointed today and that we see in disjointed markets and also in disjointed customers, can actually be brought together to be able to offer a new service offering. Clearly, we also understood how these technologies could be best used. We also understood what were the limits of the rules that there are today for flying drones, which are not allowed to make flights beyond the line of sight, the radio line of sight, but everything must be under the command and control of a pilot with his terminal. But clearly in order to do experimentation, though, we asked for a series of special authorizations also from Enac, which at that time and on that well-defined area, with the municipal police stopping people and not letting anyone pass, we conducted a whole series of experiments. We started, as I said, from 2019 until we do experiments also together with Leonardo in 2020 and 2021 on the transport of biological material from one site to another of the Bambino Gesù Children's Hospital, which has three sites. In Rome, right in central Rome, on the Janiculum Hill, and we didn't go there because the permits would never be given to us. But then it has two other locations on the sea, one Palidoro and one in Civitavecchia. And clearly getting samples for blood testing from one location to another by going overland clearly has timescales that sometimes can be compatible with the needs that you have from an application standpoint. And so we started doing a whole series of testing and experimentation. Even there, to date the regulator won't allow us, so it's been all these things that have been authorized on an ad hoc basis to transport these samples by sea with drones of different types and also with a collaboration between drones and Navy helicopters. And so a very specific airspace segregation with certain kinds of rules of engagement and also with the ability to have these drones flying completely autonomously. So with a communication system that was always on, that regardless of whether I lost the 4G radio cell on the ground, I still had the ability to have satellite communication that allowed me to continue to maintain the link from my central platform with the drones that were flying and not necessarily with a pilot who had to see the drone on sight. Because then when you're 20 kilometers over the sea in sight… There's no sight and there's no radio sight either if I'm only going over land radio links. So I need satellite rather than precision navigation for safe and accurate approach to various landing sites and so on. These are all experiments, of course. We today have the technology and the capabilities to be able to also offer services. Regulation still doesn't allow me to do that. But we are already ready. Experiments that we have done precisely also together with Leonardo also on delivery of heavier material and with much, much larger drones. But our platform can handle, if the regulations allow it, multiple drones at the same time with one pilot, let's say. That is not possible today. And in addition to that another domain on which we traditionally operate in some way, but by necessity because of the job we have always done of command and control of satellites in orbit, is what is called space awareness, space situation awareness. So having an awareness of what is really going around in the sky starting with debris, so debris removal, debris avoidance, everything in orbit servicing and then how to provide in-orbit services and all that is also the world related to what we call space intelligence, so to the services of analyzing how they set up, maybe even uncooperative or trivially uncooperative not because I have the enemy that is carrying a threat but because I have a satellite that is completely out of control rather than precisely there is debris that clearly follow orbits that can be estimated but they don't have someone controlling them from the ground and designating how they spin. Here for all that you have to have a complete painting of the space world in order to be able to best manage all that is space traffic, in continuity with air traffic, with drone traffic. So let's say from altitude zero to altitude 36,000 kilometers to have the ability then to provide space management services, in the broadest most sense of the word. Clearly everything that is in-orbit servicing is also in support of a ... eh it's so fashionable this word and so I use it ... greater sustainability of space. Because today it is in the daily newspapers practically launching dozens and hundreds of satellites to provide new satellite connectivity services from low orbit and so on. But beyond the fact that then the astronomers complain because instead of seeing the stars and the cosmos, they see the little train of Starlink one after the other, however then anyway granted the busy up there. The orbits the low orbits those are and sooner or later there will be no more space. So rather than keep sending new things into space let's try to extend life and maintain in orbit. That sounds like a bit of a fairy tale and it's not that simple, of course. Because if I send my tow truck I have to have something that is capable of being picked up by the tow truck. And the satellites that are in orbit today don't have all these features, I can't change a solar panel because they weren't built to be operated that way. But waiting for these is also another set of services that can make space more sustainable. But continuing to provide so many more services than were being provided when Telespazio in 1969 brought to Italy the signal of the man who put his foot on the moon. And that was a satellite from Houston, the satellite at Fucino, and the signal came to television with Tito Stagno. And that was a satellite from Houston, the satellite at Fucino, and the signal came to television with Tito Stagno. And now everything is much more complicated. Now we're all more connected, we have billions of systems that connect to the network and we all want to use them to the best of our ability. So it's clear that then there are all these evolutions and as therefore I would have understood from the, precisely I gave the example of the first step the man on the moon, to today, even simply the world of satellite transmissions, satellite communications, has evolved infinitely, because the technology itself has evolved. And we, as I say, have tried and are trying and we are always trying to understand the market, with what customers, what positioning we want to have in the market and then consequently what are the technologies and technological or product innovations that can support so that Telespazio maintains its positioning or follows its strategic plan. This is kind of the virtuous circle. I've kind of dumbed you down a little bit but maybe all these things no actually important.

I. Actually, they are very interesting. By the way, you mentioned your drone project that carried blood samples, right? I remember we had done a short piece in an edition of Airpress in the past few months, and I had worked on that short piece. So I remembered. And then I wanted to ask you, you mentioned precisely that you make a lot of reference to research centers and other agencies for research. So I wanted to ask you if your collaborations with research centers and universities, you were saying precisely that you need them mainly to understand what are the developments in the field and to understand what are the most innovative technologies that are also low TRL. And whether these relationships are in some way formalized or, I don't know, do you have maybe certain research centers that you always rely on let's say entities that you already have well fixed well clear or have had relationships with for a long time anyway.

P. So both of those things. In the sense that maybe on certain domains and on certain particular technologies, on certain application fields, we already have a greater familiarity. For example, with the University of Rome La Sapienza for everything related to space assets and space systems, in general. We assume a master's degree in space systems at La Sapienza and so we have a greater familiarity with them. As well as perhaps with the Polytechnic of Milan on what concerns orbital arrangements, the dynamics part of flight, etc. etc. And clearly all these relationships have been consolidated over time, by dint of doing collaboration. Maybe born more or less by chance on some national or European research development project. For example, we are quite involved today in a whole series of projects in PNRR measure four, letter four, component two, which is the one related precisely to research innovation. These are all of these projects that range from a low to medium TRL and are basically driven therefore by the research world, so universities and research studies, and in which, however, industries have to be in. Because on the one hand they give you what the needs are, I mean I would like to do this thing when I grow up; you, who are at the beating edge of technology, you help me, you show me what new developments. I work with you and then from there, what comes out of me, which can be promising you continue to do either if, we give them something particularly core inside the house, or in collaboration. Maybe at this point forging more structured collaborations, beyond the project that goes from start to finish, but with more structured collaborations through long-term research agreements. And so both cases. In other cases precisely we start to understand which universities, and now I'm talking about Italy but the same thing our colleagues abroad are doing, that are more established or more, let's say, ready on certain issues and we approach them. For example, a few years ago we became interested in the world of quantum communications because it will be the future somehow. Or at least it will be the technology that can support our business of secure, satellite or even hybrid communications in the future. Clearly all this meant first understanding who in Italy is doing these things. And so we started approaching the University of Padua, the University of Florence. We did maybe some projects together, sometimes then things stopped because there were no opportunities to maybe go and find financing to do something together. In other cases we went on with universities and research centers and with Leonardo, but not only, so with other companies as well, to collaborate on national research and development projects from both the military and the civilian sector. So Ministry of Made in Italy, Ministry of University. And so let's also say partnerships that initially with a university that we initially didn't know we started to consolidate. For the past few years, as I said before, we are also beginning to enter the world of start-ups. Again, we say following in some way a trend that in Leonardo also started a few years ago. And so we took advantage of being part of Leonardo to work with them as well, but not only. And so with equal opportunities, such as Open Italy with which companies can do challenges for startups that then suffer to solve a problem that the company has exposed. Rather also with other internal tools that we have created in Leonardo and Telespazio. For example, Telespazio for four years already, and now we are about to launch the fifth edition, has invented the Technology Contest, the Telespazio Technology Contest, the T-Tech, in which we invite, or rather initially we invited precisely because we said, "But let's see what effect it has. Let's invite the professors we know and see if they are willing to have their students participate in this." And now, for two years now, it's been open internationally without invitation letters. And so we invite universities around the world to support their undergraduate, graduate, Ph.D. and young research students to respond to challenges that we pose on topics that are ones that are part of our present, but more importantly future business. So tell us, we have this theme. Do you have any ideas that can go to bear this theme, that can solve this problem. We don't do very timely Challenges, that is, we don't give the problem to solve but we give a little bit broader thematic. And we receive proposals, we then select them with an evaluation panel that is made by colleagues from Telespazio, from the Telespazio group, but also with the support of colleagues from the Italian Space Agency and the European Space Agency, and two years ago, since we did the award ceremony as part of the Expo in Dubai, we also invited a representative from the United Arab Emirates Space Agency to support us in the evaluation. And we evaluate all these all these proposals. We have them present, they make pitches, which is maybe quite fashionable now among startups. And then we then give them a cash prize, first, second and third place. But since last year, I mean since this edition that ended in January this year, so the 2022 edition, we also selected some teams that were willing to form into startups and offered them incubation or acceleration programs. I don't know if in talking with Alessandro Massa he also told you about Bif, Leonardo's Business Innovation Factory.

I. Yes, he had mentioned it briefly.

P. Here in the 2022 edition, which started at the end of May, there is one of our startups. That is, it is the team that won the first prize and had given us the impression that they were mature enough from a prototyping and proposition point of view to start a path the acceleration. And they settled into startup at the end of January and so as a startup they are participating in this acceleration course. So they skipped all the selection steps that Leonardo imposes, and we also as a Telespazio representative are participating, among all the startups that applied to be able to join. So the T-tech has been recognized as an object a valid tool to be able to define who can enter this acceleration course. So this year, beyond the prize money that is then divided by all the team members, we supported this startup this path the acceleration. And another team that in the meantime, during the incubation path that also had settled in startups and with incubation paths, at this year was at the incubator of the Polytechnic Turin. Which is actually preparing them, in fact it's concluding just this week this pathway, and it's also preparing them to access the selections of the Business Innovation Center of the European Space Agency, of which ITP is the manager for the Turin part. So they are opportunities. They are opportunities that therefore, beyond the award, beyond then the collaboration that we also have with some of the universities that have won in the past. So securing first with a non-Disclosure agreement and then maybe participating in activities or rather than actual projects. But here we are trying to grow the ecosystem. Clearly in our industry, in areas that are of our interest, which then will be of our interest should these startups that we work on have a good future, that they succeed in their project. . And at this point, as I said before, with business arrangements rather than entering the capital, certainly it's an added value to participate in these techs. So you go in student, you come out entrepreneur. Now, when you say it like that, it just sounds like it has an advertising purpose. I mean, that's the idea. Maybe we will add a few more things however let's say we have started the trend by now. In all this we are also supported by Leonardo of course because we are part of that innovation ecosystem of the whole Leonardo group. Our T-tech is one of the vignettes within this innovation puzzle. And so we say this is the way we go about research, development and innovation. And then some things are done opportunistically while other things are done in a more structured way. And so with more long-term collaborations and with a communication team.

I. Okay, okay, great. So I'm going to take over the list of questions if you want I can ask them, although actually a good portion of the topics have been touched on.

P. What do you think you might be missing?

I. Maybe just the final part, actually, the part about the relationship between research and development and the production line.

P. Yeah, that's right. That question when we reviewed it with Marco Brancati, we went, "eh, good question!"

I. Ah, yes. I'll explain briefly, excuse me. Because basically there's a part of my thesis that deals with how some companies in general, not just aerospace companies, may find it difficult to carry on both research and production. So this difficulty in keeping both dimensions up to date. It is, let's say, a topic that is not touched upon in the literature as far as aerospace companies are concerned. So I thought it was quite interesting to look for some information on that as well. So you tell me, you are free precisely to follow the outline or tell me what you prefer, precisely.

P. So then I'll go through the list of questions. Is the company committed to continuing its production? Yes, of course. And we do that within the same lines of business. So, in the history of Telespazio and throughout its evolution, so from all the R&D at the center and then all out, in short, a series of organizational evolutions as well. The situation today is as follows. We have a center that is transversal for the whole Telespazio group, so not only for Telespazio spa, to which then the Cdo organizational unit also belongs. However, our task is transversal over the whole group. We have at the center let's say the Cto with the technology innovation unit, which is concerned with understanding how the technology evolves, but based on what are the needs coming from our market, potential customers or a necessary evolution of platforms. Because platforms no longer scale a certain amount of services required. And this technology innovation unit, which I'm in charge of, is also in charge of and concerned with rolling out the technology and product innovation plan that builds on the strategic plan. And clearly I say, "if this is where we want to go when we grow up, what we want to become, in these markets, with these positioning, et cetera, et cetera. Well, how can we get our business, and therefore our products and services developed with new technologies. And this is the roadmap for the next say five years. Clearly, next year is almost all defined and certain. Obviously, the further we go, the visibility a little bit more blurred. Also because the speed at which technologies evolve is such that really maybe after three years you're already old, you're already out. And that's why we, within this of this technological and product innovation plan, we also put a kind of outlook on the technologies of the medium and long term. So technologies that today we are not using yet, or we are using them minimally, that we are just beginning to study, to smell, to see. But that potentially will be useful in the evolution of our product, our services therefore our business. Clearly, as I said before, on what is far beyond to come, the evolutions, the generative artificial hospitalization, the evolution of new neural networks, new navigation systems in contested or stealth environments. We clearly follow them, but we are still in less mature areas. In this case, we rely either on Leonardo labs, for example. We as Telespazio together with E-Geos host one of the laboratories, the one for space technologies, which today is basically focused on the use of new systems, algorithms, artificial intelligence, to solve problems that we have today and that have to be solved in more traditional ways and with more traditional technologies, to understand how instead what has a lower TRL today will be able to enter, maybe two years from now, three years from now, into our production chain. So to then be able to offer the final service, the final information to the user with our geo-information platforms, for example. And on that we rely on the labs, which were just created precisely to fill that science skills gap that we don't have and that it's not even fair that we have and that we keep at home. And so the labs are designed to work at a TRL of one to 3 or 4. And we flank them because we have to give them the problem, okay? So we have this big problem, you who are the technologist solving it? You who know new technologies, you who are a smart researcher, let us understand how these new technologies can support solving our problem. And here we go back to what I was saying at the beginning, we don't go looking for technologies but, having understood what the problem is, we look for what technologies can support us. And after that what promising we will bring it in and figure out when and how to do it. Um so there's this central part that gives a little bit of direction, gives governance, and that ties in with the whole execution and delivery part, but that works a little bit higher. After that, within the various lines of business, Telespazio is basically divided into three lines of business: satellite business and operations, satellite communication, and formation. In fact almost all legal entities have somewhat all the same lines of business, some have only two because maybe it is the specificity of the market, for example, in Germany it is such that there is only one part. But in other in other legal entities elsewhere instead all of the markets are active and alive. And within the lines of business there are both those who carry on the production line and those who do research and development. They are not completely separate silos. There is osmosis, so there are colleagues doing research and development projects at some times and delivery projects at another time. And you try to bring the successful results that we get in the R&D and innovation projects within our products that we then plan to sell to the customer. And this is also taking into account the product development roadmaps, in some way the service, let's say the business plan, which identify, based on market, analysis, needs, customer, and so on, what kind of business plan or strategy is needed. For example, let's set up this digital platform. To do this there is to make estimates of time, cost, needs, collaborations, etc. But at this point we then go and look for opportunities, so if I told you to do this I need 100. I can find a co-funding opportunity such that 10 I take it from some other financing source and that result is a building block that goes into the roadmap and then develops a piece of my product, my solution, welcome. And so that's what I was saying when those results of these research development projects become part of what will be, let's say, our product that will be on the market maybe in a year or two. Those are a component. In some cases they have to be engineered, in other cases something has to be redone because then again, research and development is all about prototyping, and maybe even getting it wrong, and then modifying it. But let's say the roadmap is that there is input from these kinds of projects and these activities. And that's why therefore these activities are carried out within the same line of business, which is then the one that provides the service to the customer and develops it. However, what we have been trying to do lately in the company is to centralize, so just as the Cdo is centralized, to also re-center a part of engineering that goes into developing digital platforms that can be used across the board. So not only in satellite communication, not only in France but from all the legal entities, the lines of business of the company. Maybe then they have to be customized, maybe then they have to be dropped into the context, maybe they can be somewhat tailored to the specific problem of the customer, but the platform is developed centrally. So then it's not owned by that line of business or that other, but it's a common asset of the company. And when we say companies we mean group, so here we are also setting up a series of systems for licensing and cross-licensing within the company, that is, the group. So this is the new goal that we are setting for ourselves, which is to avoid duplicating maybe some of the developments, but more importantly to make sure that developments that maybe are more advanced because there was a need a few years earlier within one line of business, can then be put to the benefit of another line of business, which can leverage this digital platform to offer its services. Maybe as I was saying specific customizations or particularities. So now I turn to the next question. Are they conducted in the same departments? They are not silos, they are not separate. But are these two dimensions easily reconciled or have you encountered difficulties? So, they are managed but it is not easy. Precisely because not being silos that not having to, it would just be counterintuitive and completely unnecessary because if not then how do I take these components and these competencies to put them inside my product roadmap if I keep the silos completely separate. It's clear that you make plans, you try to plan and manage and verify and then allocate a set of performance rather than resources rather than money to research and development activities, regardless of name and surname. But then there are those times, which happen all the time, when delivery activities maybe have an increase because there was something unexpected, welcome, for example, a new contract. But that means that while waiting to grow the workforce, I still have to manage things. And then you sacrifice or you slow down, you cancel this no, it has never happened, but it has certainly happened that you have to slow down those research development and innovation activities, which also risk going to the detriment of that stuff I was saying before. But then again when there is a customer with a contract what do you do? Do I risk the penalty there because there is a roadmap? And so you always try to manage that. Sometimes it's pretty simple, sometimes a little less so. Leaving out, outsourcing research and development, as I said before, if it's not a core aspect of our business or our product, that's fine and you can even see it. And that's a little bit also to handle maybe unexpected spikes of work on the delivery part. But if not that has to stay in house. Rather I go slow, rather I suspend it for a few months waiting to spend the night, rather than see a more organic intervention, but nothing I give out. Because for me it becomes so strategic because precisely it is part of my core business. So they are not easily reconciled, but sometimes it happens that you have to stand there and do the math. And so maybe not to spend all the budget at the end of the year that was planned on research development and innovation, because we had more revenue, because we had more margin somewhere else. That is not bad in absolute terms, but not good in absolute terms either. Because then if we close that part there you go ahead with contracts but then you run out of contracts. And then in a few years we end up not being on the piece anymore. And so we can no longer call ourselves a startup with sixty years of experience. I think I also answered the last bullet, are they undertaken simultaneously or sequentially? Definitely simultaneously, in the sense that then maybe some things are sequenced, but actually there is a development and things that come in, results that are brought by this activity, anyway in parallel.

I. Sure, yes perfect. I think you've answered all the questions so thank you again so much for your availability and your time. It was really very kind.

P. And nothing, I hope it's helpful.

I. Absolutely, yes. Thank you very much. Then of course if you'd like I can also send you just a brief summary of what my research results will be. I think at this point around September, when I am able to finalize the work, if you would be interested.

P. Of course, I would be very pleased.

I. Perfect thank you very much again and have a good evening

P. Thank you, good luck with your thesis.

I. Thank you very much. Bye.

P. Bye.

Appendix D – Open, Axial and Selective Codes (coding process realized with NVivo)

Name	Files	References
SEPARATION IN DIFFERENT DEPARTMENTS	0	0
tendency to centralize	1	2
different lines of business	1	1
separation depends on the type of production	0	0
separate departments	2	3
production of series	1	3
no separation R&D and production	4	8
separation depends on firm size	0	0
ROLE OF INSTITUTIONS	1	5
smoother collaboration	1	1
easier to cooperate in institutional contexts	1	1
applying for tenders	4	5
OPEN INNOVATION	1	1
working with specialized skills	0	0
open innovation is value added anyways	2	4
low RTL and long-term interest	2	3
having much resources available	1	1
interdisciplinary nature of research	1	3
creation of dedicated laboratories	4	7
contests and open innovation programs	1	3
acceleration programs	2	2
acceleration and incubation programs	1	1
aiming at anticipating the market	2	3
MAINTAINING R&D IN-HOUSE	2	3
support given by EU and national funds	1	1
strategic role of in-house R&D	1	1
predominance of in-house R&D	2	3
need for constant focus on R&D	2	3
requirement of large economic investments	1	1

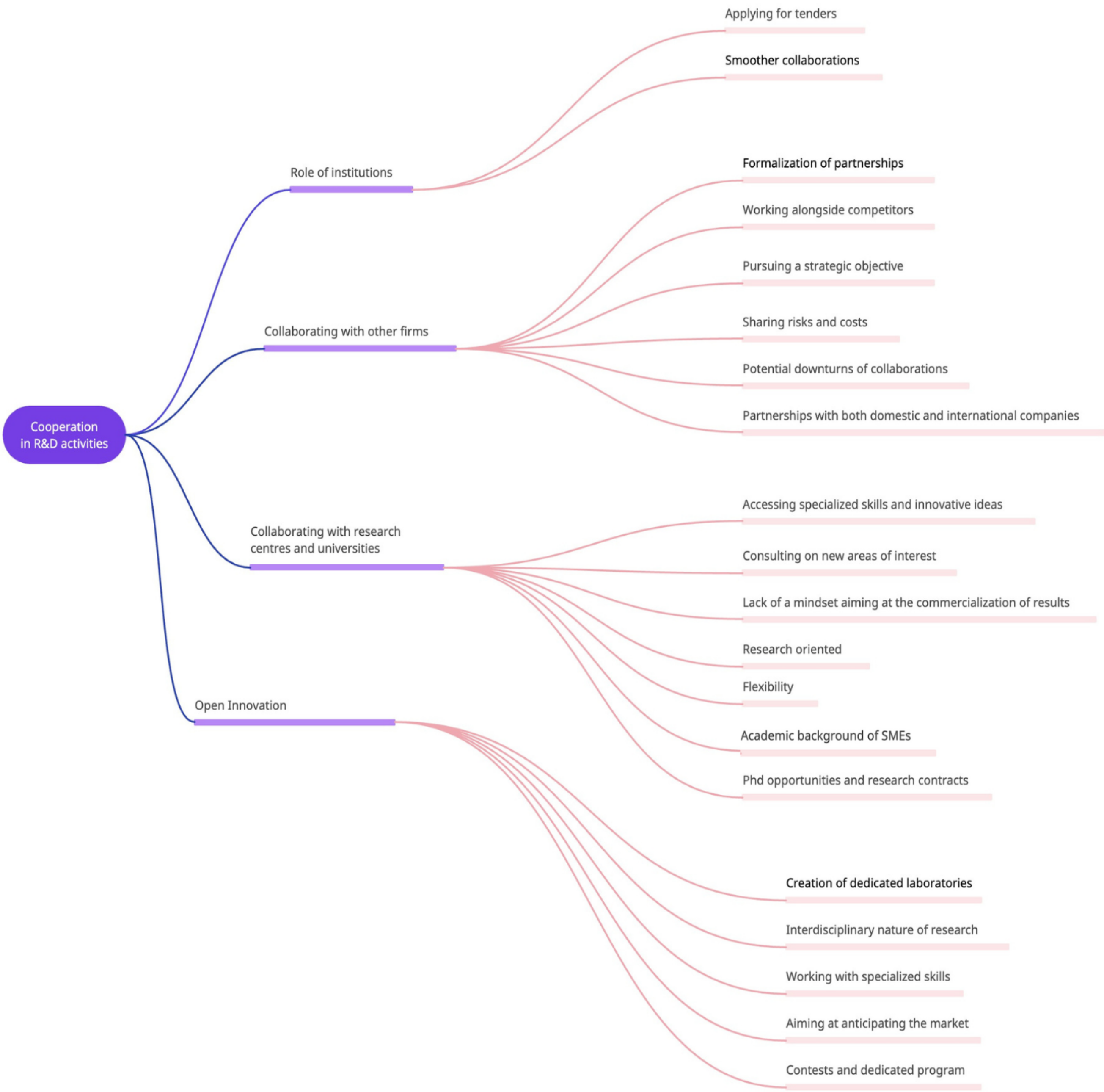
Name	Files	References
limited economic resources	1	1
combination of internal and non-internal R&D	1	1
prototypicality of production	1	1
provision of specific micro-components	2	4
products with only scientific purpose	1	2
no organizational ambidexterity issues	1	1
no large scale production in place	1	1
easiness of producing 1 time only product in SMEs (scientific missions)	1	1
difficulties in finding skilled human resources	1	1
INVESTMENT STRATEGIES	1	1
variety of tools to explore the market	1	1
taking part into projects	1	2
symposiums and seminars	3	3
sector studies	1	1
partaking into trade shows	1	1
partake into R&D working tables	1	1
own scouting activities	1	1
newsletters	1	1
looking at scientific literature	1	2
journals and papers	2	2
harmonization cycles and reviews by ESA	1	1
ESA and ASI calls	1	1
close contact with institutions enabling awarness of latest developments	1	3
need to fit into corporate roadmap	2	4
market analysis as first step	1	3
relying on specialists for newest tech developments	1	1
how technologies can support evolution of own product	2	6
forecast developments in the market	2	3
constant attention for tech developments in the sector	1	1

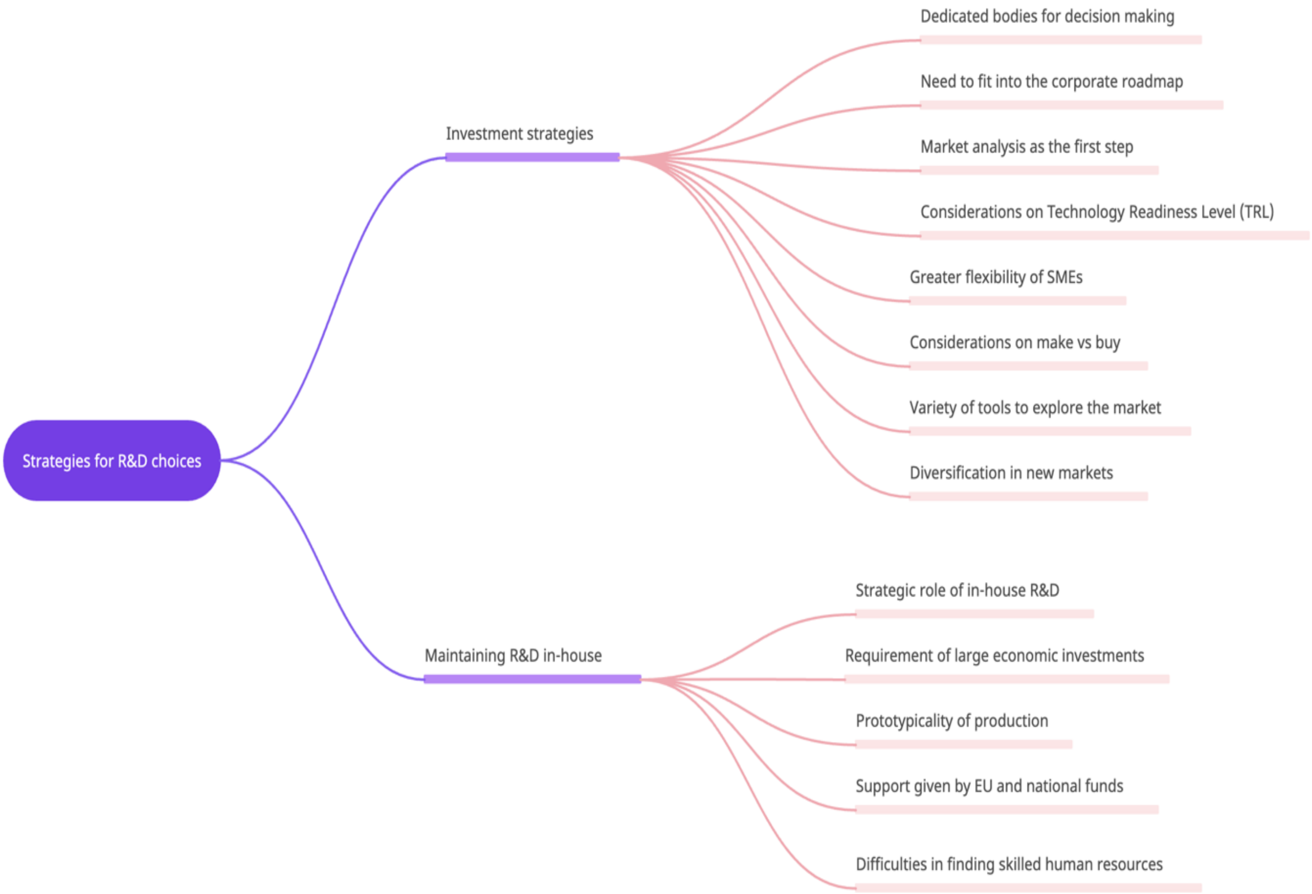
Name	Files	References
greater flexibility of SMEs	1	1
trying to find a niche market	1	1
SMEs avoid structural approach	2	3
diversification in new markets	4	13
limits of regulamentations	1	2
dedicated bodies for decision-making	1	1
technical + business considerations	2	3
considerations on TRL	1	2
institutional interest	1	1
considerations on make vs buy	3	7
in-house R&D for core competencies	1	1
favouring the ecosystem development	1	2
IMPORTANCE OF A GOOD BALANCE BETWEEN PRODUCTION AND R&D	0	0
organizational ambidexterity issues	2	2
enabling TRL progress and business results	1	1
CONSEQUENTIALITY OF R&D AND PRODUCTION	1	1
prototypicality of space products	0	0
small size limits division of R&D and production	1	1
prototypicality of space products	2	2
need for overlaps	5	5
COLLABORATING WITH RESEARCH CENTRES AND UNIVERSITIES	2	2
research oriented	1	1
research bodies are hard to manage	2	2
phd opportunities and research contracts	0	0
phd opportunities and research contracts	2	3
how do collaborations with unis emerge	1	1
high turnover in unis and research centers	1	1
lack of a mindset aiming at the commercialization of results	2	2
different mentality of researchers	1	1

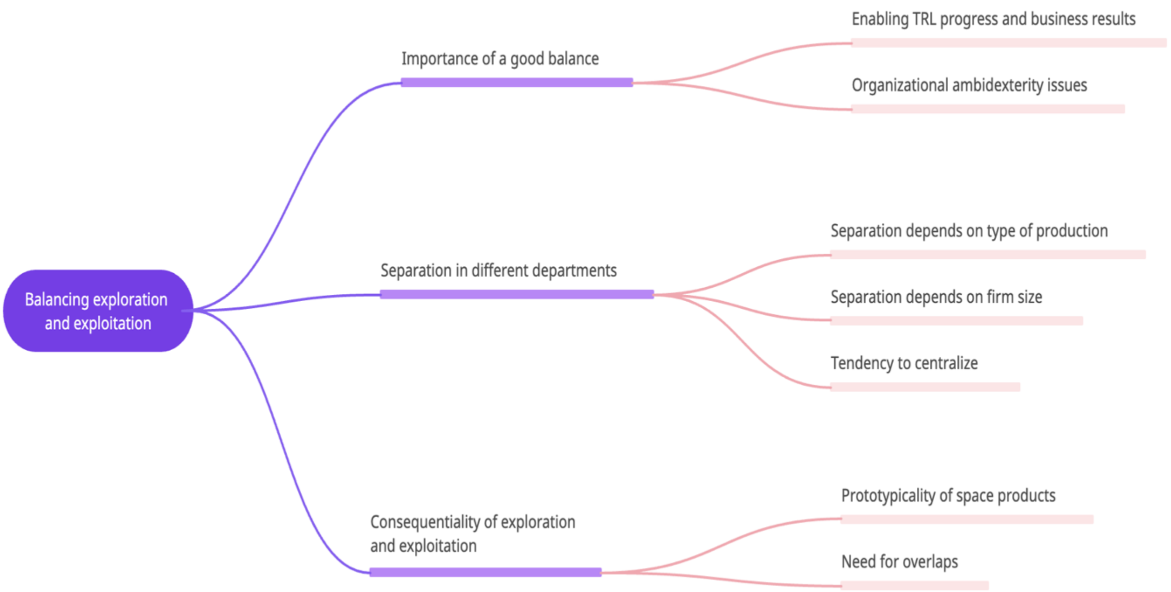
Name	Files	References
flexibility	1	3
— easier to cooperate with national bodies	1	1
consulting on new areas of interest	1	1
— interest in new fields	1	1
accessing specialized skills and innovative ideas	2	3
— working with specialized skills	3	3
— willing to collaborate with unis and research centres	1	1
— continuous contact with uni and research centres	1	1
academic background of SMEs	3	6
— academic background enabling partnerships	1	2
COLLABORATING WITH OTHER FIRMS	1	1
working alongside competitors	3	6
— need to cooperate	2	3
— difficulty in defying competitors	2	2
— complementarity of contributions in firm collaborations	3	3
sharing risks and costs	1	2
pursuing a strategic objective	1	1
— increasing critical mass	1	1
— firms collaborating for products	1	4
— avoiding collaboration in R&D	1	2
potential downturns of collaborations	1	3
— learning from experience to avoid downturns	1	2
— incomplete ownership of inventions	1	1
— contractual tools to reduce downturns of collaborations	3	3
partnerships with both domestic and international companies	4	5
formalization of partnerships	1	1
— sub-contracting	1	1
— raise of joint ventures	2	3
— informal collaborations	1	1

Name	Files	References
easier to cooperate with national bodies	1	1
consulting on new areas of interest	1	1
interest in new fields	1	1
accessing specialized skills and innovative ideas	2	3
working with specialized skills	3	3
willing to collaborate with unis and research centres	1	1
continuous contact with uni and research centres	1	1
academic background of SMEs	3	6
academic background enabling partnerships	1	2
COLLABORATING WITH OTHER FIRMS	1	1
working alongside competitors	3	6
need to cooperate	2	3
difficulty in defying competitors	2	2
complementarity of contributions in firm collaborations	3	3
sharing risks and costs	1	2
pursuing a strategic objective	1	1
increasing critical mass	1	1
firms collaborating for products	1	4
avoiding collaboration in R&D	1	2
potential downturns of collaborations	1	3
learning from experience to avoid downturns	1	2
incomplete ownership of inventions	1	1
contractual tools to reduce downturns of collaborations	3	3
partnerships with both domestic and international companies	4	5
formalization of partnerships	1	1
sub-contracting	1	1
raise of joint ventures	2	3
informal collaborations	1	1
consistency in firm partnerships	1	1

Appendix E – Results Maps




Strategies for R&D choices
Investment strategies
Dedicated bodies for decision making
Need to fit into the corporate roadmap
Market analysis as the first step
Considerations on Technology Readiness Level (TRL)
Greater flexibility of SMEs
Considerations on make vs buy
Variety of tools to explore the market
Diversification in new markets
Maintaining R&D in-house
Strategic role of in-house R&D
Requirement of large economic investments
Prototypicality of production
Support given by EU and national funds
Difficulties in finding skilled human resources


Balancing exploration and exploitation
Importance of a good balance
Enabling TRL progress and business results
Organizational ambidexterity issues
Separation in different departments
Separation depends on type of production
Separation depends on firm size
Tendency to centralize
Consequentiality of exploration and exploitation
Prototypicality of space products
Need for overlaps

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