The Spillover Effects in Brazil associated with the Gripen NG Project

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1 Introduction

Brazil is a country tightly bonded to the aerospace activities. From Bartolomeu de Gusmão to Santos Dumont, followed by the aircraft construction pioneers like Villela Jr, Muniz and Neiva, who were responsible for introducing interesting innovations locally, the country has been dedicating a good deal of efforts to catch up with and stay at the forefront among aeroplane producers globally. Unfortunately, as lone knights, the pioneer achievements were more the results of their personal efforts than a national strategy to develop aerospace technologies.

Nevertheless, in the late 1940’s, the Brazilian Air Force took the decision to establish a technological centre for aeronautics sciences, following the dreams of Santos Dumont, who thought Brazil should have a school to graduate high-quality technicians in the aeronautics field. Ultimately, the aim was to build internal capacity to form a critical mass that would form the basis for a national aeronautics industry.

The Technological Institute of Aeronautics (ITA) established in 1950 flew, eighteen years later, the first major passenger aircraft designed and built in Brazil. The following years saw the establishment of Embraer (1969), the Institute of Industrial Fostering and Coordination – IFI (1971), and the international recognition of the IFI certification of the Bandeirante (1979). All of which enabled operations to become global through opening the US and European markets for a total of more than 400 units sold. Hence, a bit more than thirty years after establishing an aeronautics technological centre, a big aircraft maker was flourishing in Brazil.

However, it is too nearsighted seeing just the explicit image of the Embraer’s success. The growth process of Embraer has brought together a myriad of local suppliers and partners. As well as fostered uncountable and unnoticed initiatives that have grown around its value chain. This includes: a) former suppliers that use aeronautics technologies for building high-quality car parts, boats, spacecraft, among others; b) former employees that run diverse businesses using a project management philosophy developed by the aeronautics industry; and c) non-destructive tests techniques, quality assurance procedures, certification, and even aeronautics standards have been spread over throughout different productive sectors in Brazil. These are true spillovers around this success history.

In time, some technological innovations enabled Embraer to become a key global player, such as the licenced production of the high subsonic Aermacchi 326; the joint development, production and logistic support of the transonic AM-X; and the different families of jet airliners. Currently, the supersonic Gripen NG project has the potential to leverage Embraer and the national aeronautics industry in partnership with SAAB. Moreover, the mentioned project also has the perspective of both developing emergent sectors and strengthening promising ones through its true spillover effects. Within the aeronautics industry, the Gripen NG project shall bring a whole bunch of leading edge technologies and will involve a significant number of local firms in its value chain. In this context, direct and indirect technology transfers are requirements of the contracts and the offset agreements. Moreover, outside the aeronautics sector, true spillovers must also certainly occur, and this is the subject of this study.

2 Methodology and theoretical framework

2.1 Theoretical framework

Taking a broad perspective, true spillovers are the additional effects on other sectors or economic activities that result from investments made in a given productive sector. These effects are not associated with those within the microeconomic equations that explains objectively the main processes and transactions considered. Moreover, these effects do generate significant social, economic and environmental benefits or consequences.

Theoretically speaking, true spillovers are externalities. As stated by Carlsson (2010):

> "In economics, an externality or spillover of an economic transaction is defined as an impact on a party that is not directly involved in the transaction. It was noted long ago by Abramovitz (1956) and Solow (1956) that only a small fraction of macroeconomic growth in the United States can be attributed to increased inputs of labour and capital, the rest (the "residual") being attributable to other factors, particularly technological change – "a measure of our ignorance" as Abramovitz put it."

When dealing with imperfect markets, it becomes easier to find spillover effects. This is the case of knowledge and technology markets, where there are a variety of attributes that supports failures in adequately attributing prices to what is being produced. There is also less rivalry in consumption than is usually seen since knowledge can be easily accessed by anyone inside or outside the system under analysis. Furthermore, there are also problems of appropriability: those who produce the original idea and develop the pioneer experimental production facility are not earning the entire proper returns. As stated by UK Department for Business and Innovation (BIS, 2014):

> "Knowledge is a non-rival good and, insofar as it is not wholly appropriable – in other words, insofar as there are knowledge spillovers – it is also, in the main, non-excludable".

In general, the resulting spillover effects are welcomed, as they add something positive to the economy and society. However, these effects can sometimes be negative. This is the classic case of the pollution associated with the use of fossil fuels, in which normally the consequences for the affected populations are not considered in the correspondent private calculations. Thus, the public sector must intervene as a mediator to collect, in the form of taxes, at least part of the funds needed to cover the costs of acting for the pollution reduction. It is worthwhile noting that history has been showing us that the positive effects tend to surpass the negative ones.

Hence, to understand macroeconomic growth in all its dimensions, one must capture the schemes in which these spillover effects do operate. Such schemes are on the basis of the theories of endogenous growth and, to a certain extent, related to the increasing returns of scale which are a product of those effects. To really understand them, one should retain in mind that knowledge - and technology, of course - are, indeed, their most relevant components. Knowledge can be replicated under certain conditions and as such can impel innovation processes that are at the heart of desired social and economic transformations. In Schumpeterian terms, development is a question of producing and diffusing innovations which can modify the current economic conditions of society permanently[1].

In a complex sector like aeronautics, the spillover effects can be more important than the product itself. That is why a country should mobilise funds to support research and development (R&D), promote the formation of qualified human resources, invest in Science and Technology facilities and so forth, to leverage its innovation strategies and achieve the desired goals.

In general terms, the closer one is to an innovator, the most one tends to benefit from him. According to Griliches (1998):

> "True spillovers are ideas borrowed by research teams of industry i from the research results of industry j. It is not clear that this kind of borrowing is particularly related to input purchase flows. The photographic equipment industry and the scientific instruments industry may not buy much from each other but may be, in a sense, working on similar things and hence benefiting much from each other's research. One could argue that this is what the SIC classification (Standard Industrial Classification*)* is for. Presumably, the usefulness of somebody else's research to you is highest if he is in the same four-digit SIC classification as you are; it is still high if he is in the same three-digit industry group; and, while lower than before, the results of research by a firm in your own two-digit classification (but not three-digit) are more likely to be valuable to you than the average results of research outside of it. The problem arises when we want to extend this notion across other two-digit industries".

It is worthwhile to remember, following Eliasson (2010), that the aeronautics is one of the few sectors in our country that could capture innovations at the forefront of the global technology frontier. There are at least three main reasons to consider in our case:

(i) Brazil can count with the strategic support of a major global player and leading firm, EMBRAER, which has already been developing a network of national suppliers. This production chain operates as a technical university, "both in generating new and tested technologies and in supplying well-educated and experienced workers and engineers to industry at large";

(ii) The country, therefore, can benefit most from the spillovers generated, the results depending on the country's ability to commercialise the intangible assets being produced; and

(iii) The government capacity to represent society in promoting the absorption of the spillovers for the overall industry, using instruments to extend the social value created. For Eliasson, "advanced public procurement can be seen as an act of effective industrial policy".

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[1] According to Schumpeter, "(…) a consequence of the innovation process will be the creation and destruction of enterprises. If creative destruction is the mechanism by which the economy transforms itself, it should be possible to see it as a link between own-innovation, exposure to innovation spillovers and firm demographics (births, deaths, churn – the sum of the birth and death rates – and survival rates) (*apud* BIS, 2014)

Having defined what are these effects and what is implied by them, the question that emerges now is how one can measure or at least estimate them? How would be possible to access such spillover effects?

In trying to answer the above questions, it is important to face a set of specific problems. A basic one is the time lags problem, which could lead to underestimations. It probably does take some time to properly get the entire spectrum of consequences generated by the spillover effects once diffusion of innovations represents processes that occur in long periods. This is also a reason why it is usually more suitable to estimate spillovers effects instead of measuring them.

Another problem is what BIS (2014) defined as “distance”. There are both a technological and a spatial distance, and both are important. The technological distance refers exactly to what Griliches said above with respect to industrial classification: a sectoral similarity explains much about the possibilities of cooperation and interaction between the firms and so about the possibilities to create true spillovers. The spatial distance, by another side, reinforces that the geographical proximity of firms and, accordingly, their easier communication flows, can also accelerate the diffusion of spillover effects.

Even considering all these aspects to develop a clear idea of what is involved in the concept of spillovers effects, an objective methodology to measure them in relation to a given technology or innovation trajectory is not that easy to define. Griliches (1998) says:

> “The more difficulty to measure and the possibly more interesting and pervasive aspect of R&D externalities is the impact of the discovered ideas or compounds on the productivity of the endeavors of others”. All this kind of spillovers effects are non pecuniary or have the sense that they fulfil the feature of being a nonrivalrous good. To estimate their impact one should assume that the effects are restricted to a certain well identified innovation in a particular industry or try to apply a regression model to capture the overall returns to a particular stream of “outside” R&D expenditures, outside the firm or sector in question”[2].

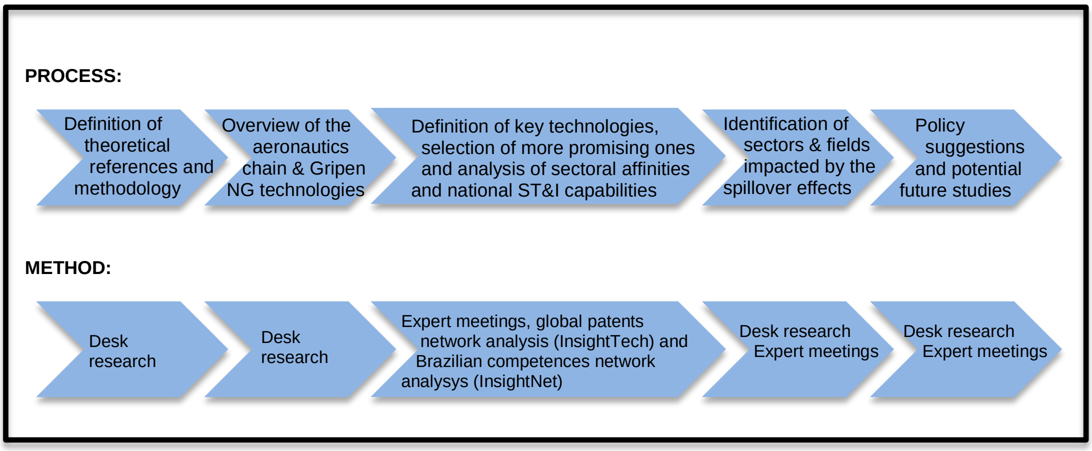
2.2 Overall methodology

The aim of this study is to identify sectors outside the aeronautics industry which can capture positive externalities, produce relevant impacts over the Brazilian economy and benefit most from the technologies associated with the Gripen NG project, developed jointly by Brazil and Sweden. Therefore, it will consider the actual scientific and technological environment in Brazil in which highly qualified human resources, innovations and technologies are already present. It is important to point out, due to time limitation, that the findings can give us only a glimpse of true spillovers and its significance for the Brazilian economy. Despite this, the findings do point out relevant clues to be explored in fostering true spillovers. Moreover, future studies could provide a more comprehensive analysis of these effects stemming from the desired co-creation process between Brazil and Sweden established around the Gripen NG project.

[2] Griliches (1998).

Figure 1 depicts the process of analysis employed in this study. In a nutshell, the departing point is the understanding of the theoretical approaches concerning the concepts of externalities and true spillovers. Then, a second important input is the identification of the critical technologies that Brazilian aeronautics industry has in its present state-of-art. In sequence, another question becomes which of these critical technologies could be identified on the Gripen NG Project and what are, at first sight, the more relevant ones for a spillover effects analysis over the Brazilian economy. In other words, these three inputs form the basis for an adequate approach of the theme and were mainly obtained from the existing literature and basic documents regarding the Gripen NG project.

Figure 1: overall process of analysis employed in this study



Taking into account these first inputs and going further into the analysis of spillover effects that emerge from the technological opportunities attached to the Gripen NG project, special attention is given to the most promising technological niches or technologies. Each one of these should be characterised, bringing together a broad analysis of the relevant interrelated technological niches. The scenario built aims to show evidence captured from a global patent's scheme drawn specifically for each selected niche. Besides it, an analysis of the Brazilian scientific and technological nets should point out the existing competencies to support the absorption of these technologies.

Both analysis was based on the specialists' experiences in the field and assisted by proprietary tools that cover, from one side, thousands of patents globally identified and, from another, Brazilian researcher's profiles and their respective affinities. These tools allow the identification of patterns and intersections from the information retrieval of different subject areas.

The relational analysis in the networks shown in these figures considers semantic similarity among curricula and co-authorships between professionals. The diameter of the circles is a function of the number of publications, which can be of different kinds, like articles in technical and scientific journals or proceedings, patents, and so forth. The bigger the diameter, the bigger is the number of technical or scientific productions. The relational analysis uses lines to connect nodes. Green lines are drawn when any co-authorship between nodes are found; red lines are drawn when semantic similarity is found. When both co-authorship and semantic similarity are detected between two nodes, a black line connects them. The line width is a measure of the connection strength amongst nodes. This tool is useful to determine the state-of-the-art of R&D in Brazil.

The analysis of patent documents may help to generate, combine and evaluate ideas, and may result in the selection and development of sound solutions for the implementation of technologies into products. The future identification of patent assignees, including priority countries, inventor, companies and so forth, is important for decision makers to guide their choices of partners for product development based on the real capabilities of these potential collaborators.

For the sake of simplicity, we use in this report some classical indicators of the currently available knowledge on such technologies. On the one hand, one of the most straightforward indicators is a patent deposit. By analyzing the number of such deposits, with the corresponding time trend, and the correlation between the main technological field to what a given patent refers to and other technological fields to which it applies, we could derive a simple measure of its externality. On the other hand, by analyzing the available human resources in an institution (or country) capable of applying the knowledge embedded in a patent, we could infer the institution`s (or countries, in our case) capability to further develop technologies or products. Having this in mind, we gathered patent information regarding the four chosen Gripen NG technologies.

Another tool developed by CGEE (InsightNet) is used to detect available human resources and capabilities in Brazil for team buildup or to foster scientific or technological collaborations. Brazil has a database of human resources with information about individuals somehow involved with public research and development (R&D) activities, which includes their academic background, technical production, among others. This database is called Lattes Platform and is provided by National Scientific and Technological Council (CNPq), a national research funding agency. The Lattes database currently provides access to about 4.4 million curricula. It does not necessarily include experts working in private companies as this platform is intended for academic personnel, but some individuals working on private companies have decided to provide their data to this platform.

To assess the available Brazilian human capital that can potentially take advantage of some of the Gripen NG associated technologies to promote innovation in different technology domains, we used InsightNet to search for professionals with knowledge related to the four technologies previously defined. InsightNet is based on network analysis. For such, researchers' curricula are considered network nodes and are represented by circles in corresponding Figures. The colours of the nodes are subdomains of the main subject area, each one representing a group of researchers acting in a convergent knowledge space. An agglomerate of researchers connected by an area (or subdomain) forms a cluster. Bigger the cluster and stronger the linkages, higher is the level of the absorptive capacity. The analysis of a cluster can also indicate sectors possibly connected to it.

The next step in the process relates therefore to the identification of sectors or fields potentially receiving spillover effects which can shed light to their possible impacts on the Brazilian economy. From the global patent analysis to the one about the human resources and competences present in the Brazilian economy, followed both by specialist's reflexions, the evidences collected can only give a vague idea of the sectors probably impacted by the Gripen NG project. Finally, expert meetings and discussions within CGEE team took place in order to identify general policy recommendations and potential areas of future studies.

The study is structured as follows:

- Section two - The theoretical references adopted in the analysis of true spillovers and the overall methodological process are exposed;

- Section three - Starts with a summary of the most relevant studies recently done and gives a brief overview of the Brazilian aeronautics chain as well as defines its critical technologies; a starting point for our analysis;

- Section four - Discuss Gripen NG Project itself, its work packages and the technologies embedded in them;

- Session five - Exposes the most promising technologies identified for generating sound true spillovers and explains the reasons that lead to our choice of a limited set of four of them in this report. It also present the of the basic features of these four technologies and analyzes their associated sectoral affinities based on a broad picture of the global patent licences schemes, as well as shows the density in Brazil of the critical related scientific and technological competencies potentially linked to them;

- Session six - Discusses the potential impact of these technological spillovers over sectors and activities outside the aeronautics industry in Brazil, thus highlighting a first view of the absorptive capacity of our economy considering the diffusion path of the four key technologies chosen;

- Session seven - Presents broad policy recommendations which can help overcome some gaps to a better appropriation of the positive externalities generated and offers some suggestions for future studies on the subject that focus in possible interesting fields for the enlargement of the collaboration between Brazil and Sweden.

3 Aeronautics Chain in Brazil

> "Airplane manufacturers are essentially system integrators; they provide strategic and organisational leadership in designing complex systems. In the increasingly modularized global production system, the technology of most advanced engineering firms often involves the development of concepts, integration, and systems architecture rather than manufacturing" (Eliasson, 2010).

3.1 Previous studies

The mapping of propositions and recommendations in research, technology, development and innovation (RTDI) for the Brazilian aeronautics chain made by the CGEE (2014) selected some studies from the period 2003-2013. These studies were commissioned or conducted by various government bodies and institutions related to the sector, such as MCTI[3], CGEE[4], ABDI[5], and BNDES[6]. What follows is a synthesis of some studies present in the original mapping.

The CGEE (2014) report begins by mapping the Aeronautics Prospective Study published by ABDI in 2009. It took into account the current technological trajectories of the global aeronautics industry, and identified three macro-challenges:

1- industrial competitiveness (involves minimization of operating costs, attractiveness to the user and life cycle of the aircraft);

2- safety of operations (divided into safety in the cockpit; air operations in the 21st century and mitigation of consequences) and;

3- the activity of aviation and its effects on society (divided in green operation and preservation for future generations).

According to the study, the three major areas of R&D associated with these challenges are lightweight structures, embedded systems, and virtual modelling of the entire aircraft. Also, it identifies the critical success factors of the Brazilian aeronautics industry: financing, infrastructure, market, political-institutional, human resources and technology.

The study "Brazilian Aeronautics Productive Chain: Opportunities and Challenges", published in 2009, was conducted by a group of researchers from Unicamp, USP, and BNDES. The chapter Foresight Study of the Aeronautics Sector sets out some criteria for the identification of the technological trends and priority systems relevant to the Brazilian industry. It divides systems, components, and materials suppliers of Embraer into three categories.

[3] Ministry of Science, Technology and Innovation
[4] Center for Strategic Studies and Management in STI
[5] Brazilian Industrial Development Agency
[6] National Bank for Economic and Social Development

(i) items of high value and high technology (e.g. engines, avionics, air unit and auxiliary power unit – APU);

(ii) items of lower value (e.g. electrical components, hydraulic components and seats);

(iii) raw materials, consisting of aluminium alloys, special steels, and composite materials.

The "Sectoral monitoring report - aeronautics industry," vol. III, published in 2009 by ABDI in partnership with Unicamp (State University of Campinas), highlights the Boeing 787 Dreamliner project. The substitution of aluminium for composite materials represents a radical innovation in the sector, which impacts the design of the new aircraft and the development of key technologies for the industry. Vol. IV, also published in 2009, analyzes the economic, productive and financial impacts of the world crisis and the BNDES counter-cyclical measures to support the aeronautics sector.

In the study "The Aeronautics Industry in Brazil: Recent Developments and Perspectives," published in 2012, the then ongoing projects from Japan, China and Russia to enter the regional jet segment are examined. This analysis allows characterizing the technological challenges of the civil aviation sector for the next years. According to the study, the main challenge is related to the advent of greener aeroplanes, that is to say, with less environmental impacts. This is directly related to the development of a new generation of turbines for regional jets, namely Geared Turbofan (GTF). In addition to the efficiency gains brought by the new generation of turbines, composite materials, electric motors, embedded systems for optimizing energy consumption, control systems and air traffic that optimize aircraft operations; the development of new types of kerosene from biomass (algae, soybean oil, and maize) are also highlighted.

The "Sectorial aeronautics agenda," prepared by BNDES (Natinal Economic and Social Development Bank) in conjunction with ABDI (Brazilian Industrial Development Agency), Finep (Brazilian Innovations Agency) and the Brazilian Aerospace Industries Association (AIAB) in 2012, proposes a strategic orientation "to consolidate and expand the value chain of the aeronautics industry as a whole to serve the domestic and international markets." The study is divided into two sets of perspectives:

The point of view of market expansion highlights: (i) "To consolidate leadership in the world commercial jet market, increase participation in the markets for executive jets, helicopters and aeronautics maintenance (MRO)"; (ii) "To increase the Brazilian participation in the domestic market of the air traffic control subsector (CNS / ATM)"; (iii) "To improve the environment of the cost of investment in the country regarding financial, tax, regulatory and customs matters"; (iv) "To strengthen the vertical densification of the aeronautics productive chain"; (v) "To enable the development of a PD&I programme for the aeronautics sector".

In turn, the perspective of creating and strengthening critical competencies comprises: (i) "To develop and expand knowledge of future technologies and markets"; (ii) "To foster the training, updating and training of human resources for the aeronautics industry in all its levels and areas of operation"; (iii) "To develop a technological, industrial and commercial intelligence system within the government to support the decisions of government authorities in the Defence, aeronautics and space sectors on product requirements of the three sectors, technological orders and offset".

In the “Diagnosis of the aeronautics sector - Plano Brasil Maior,” presented by the Executive Committee for Defence, Aeronautics, and Space, in March 2013, the Brazilian sector is analyzed using the SWOT (Strengths, Weakness, Opportunities and Threats) methodology. Based on this diagnosis, the sectoral agenda is organized into four groups: (i) "Elaboration and implementation of a programme for demonstrating technology platforms for the Brazilian aeronautics industry"; (ii) "Stimulus to the productive and technological densification of the Brazilian aeronautics productive chain"; (iii) "Enhancement of the registration of intellectual property in Brazil"; (iv) "Incentive to the growth of the Brazilian aeronautics sector in the domestic and foreign markets" (CGEE, 2014).

The Inova Empresa Plan, announced by the then Ministry of Science and Technology in 2013, defines five priority technological areas for the allocation of investments: (i) ballistic and unmanned vehicles; (ii) sensors and command and control; (iii) space propulsion, space satellites and platform; (iv) technology platforms for more efficient aircraft; and (v) new materials.

The CGEE report (2014) list a series of technologies with the potential to be developed by the Brazilian aeronautics industry and discuss recommendations for its support. For instance, one is the formation of Brazilian capital holdings for external strengthening, and another is the redefinition of manufacturing processes, business management, highlighting the importance of locational factors in the industry for the coming years. Also, some technological and organizational trends are presented alongside the best experiences identified in the global scenario for the future, such as:

- new business strategies and the strengthening of national capital;
- technological support tools and decision support; manufacturing strategies and differentiation by services;
- management and organization of R&D in research institutes;
- organization of centres of excellence in manufacturing, technological parks and regional productive systems of innovation;
- certifications and quality policies;
- training of human resources competencies;
- partnership strategies and alliances for programme development;
- establishment of national training in new materials;
- training of internationalization and business management skills;
- implementation of offset practices; and
- development of programmes in the area of Defence.

3.2 Production capacity and Supply chain formation

According to data from the Brazilian Association of Aerospace Industries (AIAB), the Brazilian aeronautics industry presented an exceptional period of expansion until the financial crisis of 2008. It can be observed that between 2006 and 2008 the revenues of this industrial sector increased by about 75 percent, from $ 4.3 billion to $ 7.5 billion. Over the same period, the number of employees increased by 23%, from 22,000 to more than 27,100.

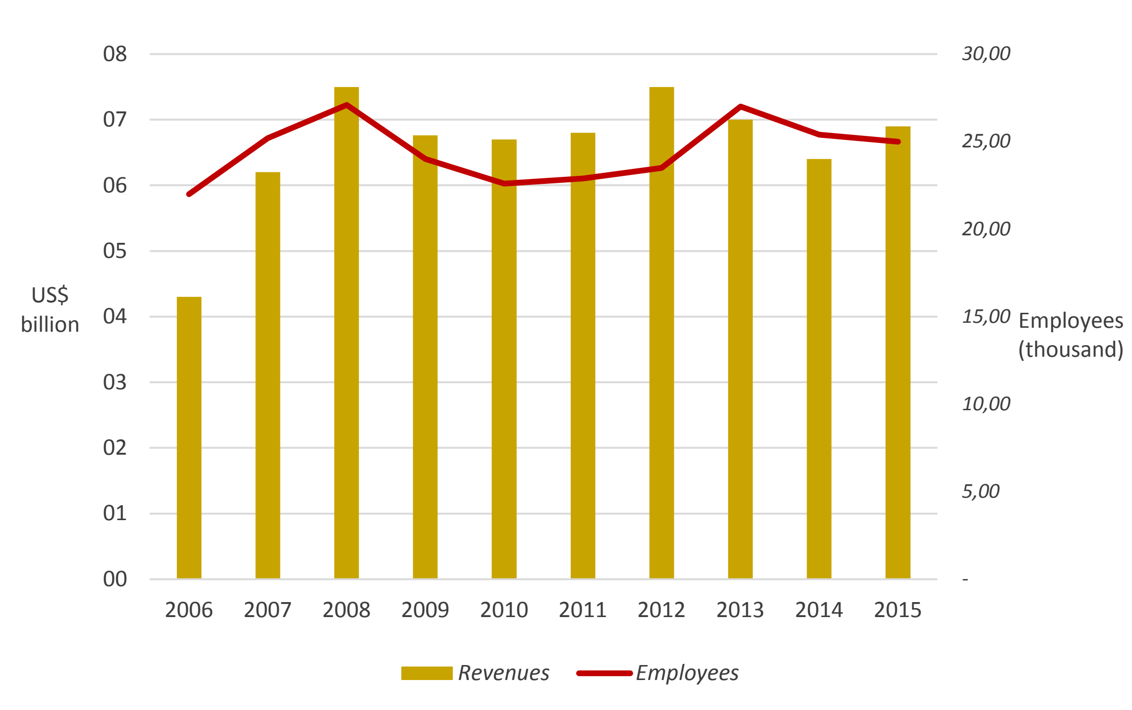


Figure 1: Brazilian aeronautics industry: Evolution of the AIAB associated companies (revenues and employees), 2006-2015

In the following years, revenues declined by around 10%, and recovered in 2012, with a slight deceleration in the following years, reaching 2015 revenues of US$ 6.9 billion. The number of employees started again to increase in 2013, with a small reduction in the following two years, reaching 25,000 employees in 2015, 7.7% less than in 2008.

The main characteristic of the productive chain of the Brazilian aeronautics industry is the very high concentration in its leading company. Embraer accounts for more than 80% of sales and more than 40% of the industry's workforce (AIAB, [wd]; Ferreira, 2016). Because of this, the performance of the industrial company has a very high correlation with the evolution of its leading company. Embraer is the only large company at the top of the production chain, leading a large and diversified set of domestic and foreign suppliers, which are distributed in the form of a stratified pyramid, as can be seen in Figure 2. A large part of companies that make up the Brazilian aeronautics industry concentrates their activities in the supply of products and services for Embraer.

Since its inception, Embraer has been planned as a company focused on the design, engineering, integration, assembly and commercialization of aircrafts. In this way, almost all the raw materials, components and systems were acquired in the international market. Only the parts of less technological complexity were made in Brazil by a group of micro and small subcontracted companies, usually Embraer's own spin-offs. Thus, the national supply chain has not followed the commercial success and technological breakthroughs achieved by the leading company throughout its history.

In the mid-1980s, FAB sought to use the AMX subsonic military jet programme to promote the training of national suppliers in the production of components and systems of greater technological sophistication. However, the results were heterogeneous. Embraer has expanded its technological capabilities, particularly in the development and production of jet propulsion aircraft. In addition, it has also advanced in the segment of landing gear with the formation of Eleb Equipamentos.

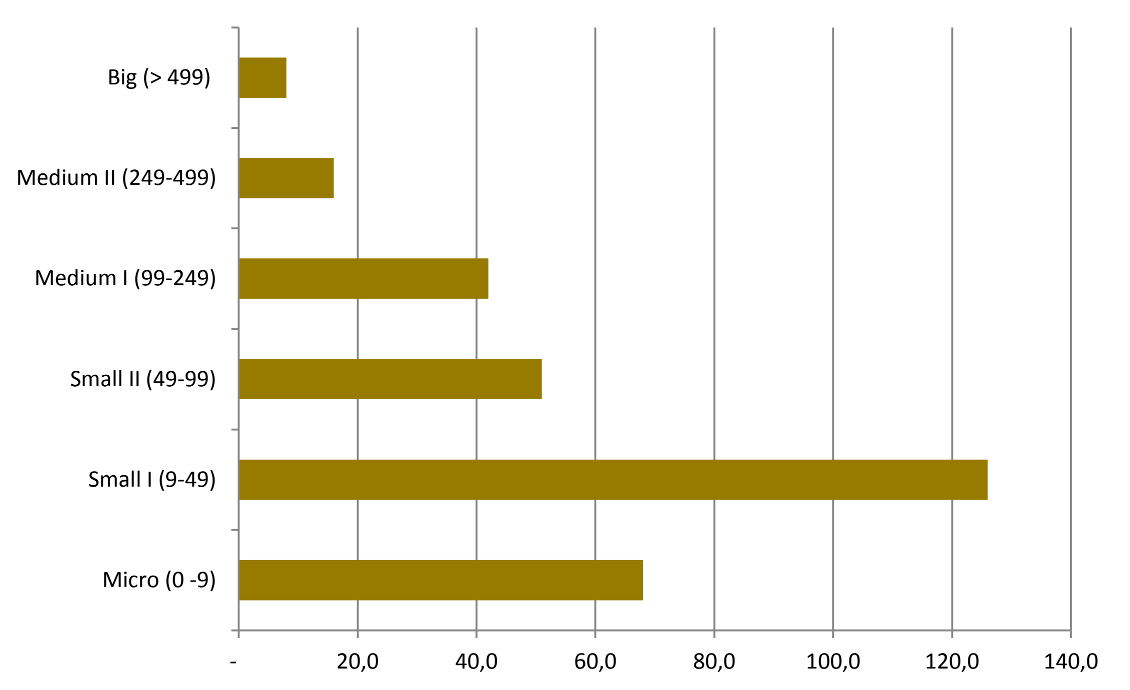


Figure 2: Brazilian aeronautics industry: Distribution of companies by size (number of employees), 2011. Source: Author´s elaboration based on RAIS/MTE data.

In the 1990s, Embraer established risk-sharing partnerships as an instrument to implement the ERJ-145 regional jet project. It had technical expertise, but still needed the financial resources and productive capacity of *risk partners* to enable the design of the new aircraft . In the decade of 2000 Embraer deepened the risk partnerships in the design of the new family of commercial aircrafts, the E-Jets. The selection of new *risk partners* came not only to the financial contribution, but also to the ability to aggregate technological value to the project. In this sense, only suppliers with global scale and high technological qualification were selected (Salerno, 2011; Ferreira, 2009).

Because of what has been presented, the first-tier suppliers - including the risk partners - of the Brazilian aeronautics industry are formed, almost entirely, by subsidiaries of large foreign groups. These companies, usually medium-sized, take intermediate steps in the supply chain, acting as systems manufacturers that will compose the aircraft, particularly the aerostructures, in addition to some avionics systems, hydraulic systems and interior.

At the bottom of the pyramid are the second level suppliers, most of which are formed by national micro and small enterprises, created by former Embraer employees. These companies are highly specialized and have a reasonable technological qualification, particularly in the areas of project engineering, machining, surface treatment and tooling manufacturing. These companies concentrate their activities on providing services to Embraer and its risk partners, which generally account for more than 90% of their revenues.

Despite pioneering the introduction of risk partnerships, Embraer has gradually changed its relationship model with suppliers in its last major projects. It is observed that a growing share of the aerostructures has been developed and produced internally. In addition, Embraer has been seeking to advance the technologies that allow the integration of systems in aircraft, thus reinforcing its control over the supply chain.

The exceptional growth of the Brazilian aeronautics industry, up to 2008, was mainly determined by the expansion of Embraer's commercial aircraft demand. Secondly, there is also an offensive strategy by Embraer in the executive aircraft market. Last but not least, the gradual and continuous expansion of investments made by the Ministry of Defence, particularly the Brazilian Air Force (FAB), has implemented several strategic projects aimed at modernizing and acquiring various types of military aeronautics platforms, explaining that a significant portion of this demand was destined for Brazilian companies, or as in the case of Gripen NG, aiming at the transfer of technology to the Brazilian industry. The growing demand from the executive and military segments was particularly important after the financial crisis of 2008, allowing the Brazilian aeronautics industry to sustain its revenue level in the following period.

3.3 Technological and productive capacity

When compared to the rest of the Brazilian manufacturing industry, the aeronautics industry has a high technological intensity. For instance, in 2011 R&D expenses corresponded to 0.83% of net revenue in the manufacturing industry and 4.2% in the aeronautics industry (De Negri and Cavalcante, 2013). However, the dynamics of innovation of this industry is conditioned by the performance of a few companies and the evolution of a few projects that concentrate the expenses and R&D activities of the sector.

According to data from the Industrial Research of Technological Innovation section of Pintec[7], the highest technological capabilities - innovations for the world - are concentrated in a few companies. In 2011, 19 companies from the Brazilian aeronautics industry presented product innovations for the domestic market, with five of these innovations worldwide. When analysing the process innovations, 12 companies from the Brazilian aeronautics industry indicated that they introduced innovations at the national level, but only one innovated worldwide. The data also demonstrate that the main innovative differential of the Brazilian aeronautics industry is focused on launching new products.

The “Mapping of Brazilian Defence Industrial Base”, presented in 2016, by the Institute of Applied Economic Research, assesses the competitiveness of the main activities carried out by the Brazilian aeronautics industry. According to the study, aeronautics engineering and the manufacturing of metallic components and aerostructures are the segments that present the greatest competencies in the Brazilian aeronautics industry. In turn, the production of aeronautics components in composite materials is very restricted in Brazil, and is concentrated in the manufacturing of parts of low technological

[7] Innovation Survey of the Brazilian Institute of Geography and Statistics (IBGE)

complexity. Electronic systems are also restricted to the initiatives of very few companies in the development and production of software and avionics systems of high complexity. Regarding the other embedded systems, the production of landing gear, hydraulic systems and interiors stand out. Finally, in the propulsion systems, only the assembly and maintenance of turbines are carried out in Brazil.

Even though the production capacity of the Brazilian aeronautics industry is increasing, and the supply chain is strengthening, it is necessary to improve the innovation capacity of this industry. The study developed by the CGEE (2014), enumerates a series of propositions for RTDI areas to accelerate the development of the aeronautics chain. In total a list of 78 technologies are elected from 18 major technology areas within 5 activities, as shown in Table 1 and Annex 1.

Table 1: Brazilian Aeronautics Industry – Main Areas of Technological Research

Activities	Areas of technological research
Aeronautics Project and Engineering	Project optimization
	Aerodynamics efficiency and Low consumption
	Technologies to maximize surveillance
	Engineering advanced tools and simulation
	Aeroacousti
Systems Integration and communication	Systems integration and embarked
	Aircraft integration with external systems (situational consciousness)
	Integration between embarked technologies and ground traffic
	Systems engineering methods, tools and processes
	Remote sensing and aircraft health
	Technologies to prevent and avoid
Production	Advanced manufacturing
	Technics and processes to reduce environmental impacts
	Materials and processes
Interior	Technologies for a differentiated cabin environment
Propulsion and fuel	Propulsion
	Aviation alternative fuels
Pre competitive technologies	Technological Platforms

Source: CGEE, 2014.

4 Gripen NG Project , its work packages and technologies

The strategic character of military aircraft, particularly fighter jets, demands a technically superior performance from their actual or potential opponents, leading to a continuing dispute between the countries and their respective companies for the primacy of incorporating cutting-edge technologies into their aeronautics combat platforms "(Ferreira, 2016, p.2).

In this sense, over the decades this category of aircraft has been incorporating a growing variety of systems and components, becoming increasingly complex and sophisticated products that are positioned in the "state of the art" of the world aeronautics industry.

The fact that fighter jets are highly complex products allows this segment of the aviation sector to benefit from internally generated technologies. It also opens space to absorb, improve and integrate innovations developed by other industrial sectors, such as information and communication technologies (ICT), as well as mechanics and materials (Crouch, 2008; Frenken, 2000). In this way, the segment of fighter jets has been benefiting increasingly from the intersectoral flow of innovations that characterizes modern industrial economies (Mowery & Rosemberg, 2006). According to Ferreira (2016, p.3):

> “The military aeronautics industry absorbs and deepens a series of technological innovations received from other industries, seeking to integrate them with the innovations developed in the segment itself. Also, it broadcasts this broad set of innovations to the most diverse industrial segments, thus being one of the most dynamic high-tech industries”.

4.1 The Programme F-X2 and the Gripen NG

After a long assessment process, the Gripen NG Project was selected by the Brazilian government under the Programme F-X2. The programme includes the acquisition of the aircraft, as well as technical support and technology transfer.

Embraer and Saab have already signed an agreement that establishes a partnership for the joint management of the Programme: "Embraer will be responsible for extensive work packages in systems development, integration, flight test, final assembly and aircraft deliveries. Embraer will also participate in the coordination of all development and production activities in Brazil. Furthermore, Embraer and Saab will be jointly responsible for the complete development of the two-seat version of the Gripen NG”[8].

It is worth remarking that the Brazilian partner companies will not simply learn from the Swedish, but will work together in co-creation. They will not only be taught but will learn by doing. It is so that, in November 2016, Saab and Embraer inaugurated the Gripen Design and Development Network (GDDN) in Gavião Peixoto (Embraer’s

[8] http://saab.com/air/gripen-fighter-system/gripen/gripen/newsandpress/gripen-updates/gripen-news-feed/saab-and-embraer-establish-partnership-for-joint-programme-management-for-brazils-f-x2-project/
http://www.embraer.com/en-US/ImprensaEventos/Press-releases/noticias/Pages/Embraer-e-Saab-estabelecem-parceria-para-a-gestao-conjunta-do-Projeto-FX2-no-Brasil.aspx

development, flight test and production facility). GDDN will be the hub for Gripen NG technology development in Brazil for Saab, Embraer, and the other Brazilian partner companies.

"The GDDN includes the development environment and simulators required to undertake the fighter development work. Also, the GDDN is connected to Saab in Sweden and the industrial partners in Brazil, securing both technology transfer and efficient development" (SAAB, 2016). Table 2 below summarizes what has been publicly agreed so far, with the work packages in which partnerships have already been defined.

Table 2: Gripen NG supply chain as for Dec. 2016

Workpackage	Area	Partner/Supplier
Programme Management	Programme	Embraer
Systems development	Aircraft systems	Embraer
Integration	Aircraft systems (and weapons suite)	Embraer
Flight Tests	Avionics, weapons, Two-seat version (TS)	Embraer
Final Assembly	Full aircraft	Embraer
Deliveries	Full aircraft	Embraer
Complete development	Two-seat version	Embraer
Structural Conception	Airframe: Wings	Akaer
Structural Conception	Landing gear: Main Landing Gear (MLG)	Akaer
Structural Conception	Airframe: Mid Fuselage	Akaer
Full Structural Conception	Airframe: Rear Fuselage	Akaer
Development	Avionics: Wide Area Display (WAD)	AEL Sistemas
Development	Avionics: Head-Up Display (HUD)	AEL Sistemas
Manufacture	Avionics: Helmet-Mounted Display (HMD)	AEL Sistemas

From the small yet significant snapshot of the supply chain presented in Table 2, it is possible to associate a series of technologies to each of the Gripen NG work packages.

4.2 Gripen's work packages and cross-references with CGEE study.

Having in mind the considerations above and the CGEE's study, some technologies can be associated to each Gripen NG work package, taking into account the kind of work to be done and the knowledge areas involved. In the following items, some of these associated technologies are presented, cross-referencing them, where applicable, to their matches in the CGEE 78 set (Annex 1). Finally, it is important to highlight that some work packages are grouped due to their similarities regarding associated technologies.

Systems development and integration of Gripen NG, and complete development of the TS version

The development of a new version of an aircraft can require only minor improvements or a more demanding mid-life update for levelling with the new operational and logistics requirements. However, driven by marketing requirements and significantly pulled by the Brazilian Air Force's procurement of F-X2, Saab has put its JAS-39 Gripen far ahead of its previous versions in terms of technological innovation.

Gripen NG fuselage and wings are bigger, therefore it carries more fuel (35%) and more weapons. It has an upgraded landing gear configuration (MLG is stowed in underwing fairings instead of the fuselage), the new engine delivers 25% more thrust, allowing Mach 1.4 “supercruise” without afterburner. Moreover, it will involve the integration of the aircraft's avionics that suites to the National Command & Control Systems and data-link protocols. As well as the establishment of the interfaces with the logistics system and the specification of the necessary infrastructure, the support for the aircraft commissioning to the flying squadrons, training needs to pilots and mechanics, and integration of weaponry and sensors.

Hence, the Gripen NG development of both single-seat and two-seat versions shall demand huge efforts in all areas of aircraft development, testing, and production.

Table 3 – Gripen NG supply chain technologies - Work packages SysDev&Int and CDevTS

Associated Technologies	CGEE#
2D and 3D Digital maps	-
Maintenance ground support systems	-
Synthetic training aids	-
New advanced materials: composites, nano-structured materials	2
New structural concepts	3
Sensors and Command&Control	18
Data communications: high bandwidth datalink, satcom, encryption, frequency hopping, centric networks	19
Data fusion	21
High-density data storage	22
On-board software	23
Certification of complex integrated systems	27
Integrated safety assessment	41
Digital terrain recognition	44
Safety critical applications software	48
CNS/ATM compatibility	50
Fault tolerant systems	54
Computational Fluid Dynamics – CFD	65
Aircraft systems engineering simulations	66
Knowledge-based engineering tools	67
Multidisciplinary Design Optimisation – MDO	68
Aeronautic systems modelling by systems engineering methods tools and processes.	69
Verification and Validation (V&V) processes	70
Methods and technics for systems integration	71
Computer-Aided Software Engineering (CASE)	74

Source: Author’s own elaboration

Flight tests

Flight testing an aircraft under development means that one will explore all the functionalities of that design and verify the full performance requirements to the design envelope borders, and beyond. Moreover, it will verify if the systems work by the specifications.

Flight test programmes must be very carefully planned and the testing facilities and test ranges must be adequate for the tasks to be accomplished, and safety standards. Aircraft sensors (even additions to the ones already present) will transmit data to ground stations to be interpreted, fused and analyzed to produce de required reports to the development team, the production managers, and the customer’s acceptance commissions. Flight tests activities will span from in-company development, production and delivery, to costumer's acceptance and in-service life.

Table 4 – Gripen NG supply chain technologies – Workpackage FT

Associated technologies	CGEE#
2D and 3D Digital maps	-
New advanced materials: composites, nano-structured materials	2
Fly-By-Wire	16
Sensors and Command&Control	18
Data communications: high bandwidth datalink satcom encryption frequency hopping centric networks	19
Data fusion	21
High-density data storage	22
Methods and processes for the design and certification of complex integrated systems	27
Full Authority Digital Engine Control (FADEC)	29
Integrated Safety Assessment	41
All-weather Synthetic Vision	43
Digital Terrain Recognition	44
Cockpit human-machine integration enhancement	47
Aeroelasticity	56
New high-lift devices	57
Aircraft systems engineering simulations	66
Knowledge-based engineering tools	67
Aeronautic systems modelling by systems engineering methods tools and processes.	69
Verification and Validation (V&V) processes	70

Source: Author’s own elaboration

Final assembly and aircraft delivery

Final assembly of a fighter aircraft is not so different from what Embraer already does for the civil airliners and the military light attack and advance trainer Super Tucano. It consists of assembling parts and segments, putting these together at near zero tolerances. Modern assembly and production technologies will be used on high standards of quality assurance. Fully assembled aircraft must be verified and validated by ground and flight tests. Verification and acceptance procedures must be defined with the customer and involve ground and flight tests.

Table 5 – Gripen NG supply chain technologies – Workpackage: FAssFA, DvyFA

Associated technologies	CGEE#
Composite materials production processes	5
Non-destructive tests – NDT	6
New production technologies: 5 Axes milling machines, Advanced cutting technics (water jet, laser beam, electrons beam)	7
Advanced jointing technologies	8
Reconfigurable and flexible tooling	9
Automated assembling processes	10
Reduced environmental impact fabrication processes and technics	12
Methods and processes for the design and certification of complex integrated systems	27
Innovative technologies for aircraft interiors	39
Knowledge-based engineering tools	67
Aeronautic systems modelling by systems engineering methods tools and processes.	69
Verification and Validation (V&V) processes	70

Source: Author's own elaboration

Structural conception of wings, main landing gear and mid-fuselage, and complete structural conception of the rear fuselage

There are significant modifications to make in the segments related to these work packages. The aircraft is bigger and heavier, and will thus be subjected to greater loads and stresses. Due to the possibility of "supercruiser", the airframe should sustain longer and continuous exposition to the supersonic flight. The fuselage will carry additional fuel tanks, and the wings will stow the MLG. The landing gear itself should be redesigned for the new loads and configuration.

Table 6 – Gripen NG supply chain technologies – Work packages: SCW, MLG&MF and CSCRF

Associated technologies	CGEE#
New metallic materials	1
New advanced materials: composites, nano-structured materials	2
New structural concepts	3
Surface protection	4
Composite materials production processes	5
New production technologies: 5 Axes milling machines, Advanced cutting technics (water jet, laser beam, electrons beam)	7
Advanced jointing technologies	8
Automated assembling processes	10
Crashworthiness improvement	11
Monitoring and diagnostics of structures health	14
Methods and processes for the design and certification of complex integrated systems	27
Integrated Safety Assessment	41
Aeroelasticity	56
Knowledge-based engineering tools	67

Table 6 – Gripen NG supply chain technologies – Work packages: SCW, MLG&MF and CSCRF

Associated technologies	CGEE#
Aeronautic systems modelling by systems engineering methods tools and processes	69
Verification and Validation (V&V) processes	70

Source: Author's own elaboration

Development of the WAD and HUD and manufacture of the HMD

This is a typical avionics systems development and integration with the whole avionics system of the aircraft. Moreover, it demands integration with the Brazilian command and control system.

This work package involves hardware design of airborne equipment which must be compact in size and lightweight. They must stand the harsh environment of a combat aircraft where there is high levels of vibrations, extremely high and extremely low temperatures, and rapid and wide variations in cabin pressure and humidity. They must also provide protective means against electronic countermeasures, be fault and damage tolerant and consider crashworthiness concepts. The WAD is of particular importance and safety critical once it is the primary source of information for the pilot. Although HUD technologies are well known from previous programmes, WAD and the HMD are new concepts even from the operations side. Intensive works must be done in integration, safety assessment, and human-machine interface.

Table 7 – Gripen NG supply chain technologies – Work packages: DevWAD&HUD, MnfHMD

Associated technologies	CGEE#
2D and 3D Digital maps	-
New advanced materials: composites, nano-structured materials	2
Crashworthiness improvement	11
Reduced environmental impact fabrication processes and technics	12
Monitoring and diagnostics of systems health	13
Data fusion	21
High-density data storage	22
On-board software	23
Integrated Modular Avionics (IMA) and Integrated Modular Electronics (IME)	26
Methods and processes for the design and certification of complex integrated systems	27
Electromagnetic Radiation Hardening	31
Fail-safe Avionics (or Fault-tolerant Avionics)	32
Integrated Safety Assessment	41
Weather hazards avoidance	42
All-weather Synthetic Vision	43
Digital Terrain Recognition	44
Cockpit human-machine integration enhancement	47
Safety Critical Applications Software	48
Systems allowing operation in rout management environments, cooperative rout planning and minimum separation reduction	50

Table 7 – Gripen NG supply chain technologies – Work packages: DevWAD&HUD, MnfHMD

Associated technologies	CGEE#
Fault Tolerant Systems	54
Aircraft systems engineering simulations	66
Knowledge-based engineering tools	67
Aeronautic systems modelling by systems engineering methods tools and processes.	69
Verification and Validation (V&V) processes	70
Methods and technics for systems integration	71
Computer-Aided Software Engineering (CASE)	74
High-performance computing	75

Source: Author's own elaboration

Considering the partnerships and the level of technologies being transferred and developed, it is expected that the Gripen NG project will promote the development of the Brazilian aeronautics industry, as well as generate spillovers to other productive sectors.

5 Key technologies

5.1 Selection process

As it has been said, this report does not have the intention to explore all possible spillovers from the Gripen NG project, but rather to analyze four technologies that have the greatest potential to impact other sectors in the Brazilian economy.

A selection of the technologies outlined in the previous section was made based on their estimated potential for spillovers. From the previous section, it is possible to identify a broad spectrum of technologies relevant to the Gripen NG programme work packages to be performed in Brazil. The partner companies and their suppliers, as well as the firms and institutions involved in the offset agreements, will all benefit directly by formal instruments. Moreover, it is possible to outline a myriad of outside players that can also benefit from the activities and knowledge flows that arise from the development and applications of these technologies.

Annex 1 outlines the aeronautics chain in Brazil and highlights its 78 critical technologies. This has been the departing point of analysis to understand which of these are relevant to the Gripen NG project.

Figure 3 explains the process to reach the chosen four technologies.

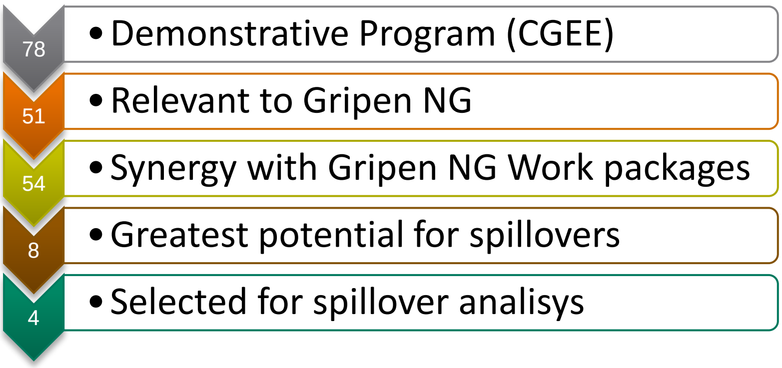


Figure 3: Selection Process: Key technologies

From the 78 critical technologies, 51 can be identified in Gripen NG project. In the “Relevant to Gripen NG” stage, 27 technologies were excluded from the initial list of 78 critical technologies as they are not related to the Gripen NG Project. The exclusion process considers the following technologies:

- Related to civil aircraft, such as traffic control and communication;
- Related propeller aircraft;
- Related to large capacity productivity chain;
- Related to alternative fuels, such as ethanol and electricity;
- That were in a pre-competitive condition.

In the stage “Synergy with Gripen NG work packages”, the Gripen’s were cross-referenced to the list of the 51 remaining technologies. All work packages but three did not have a direct connection with the technologies elected by the CGEE study. The 3 technologies are 1) 2D and 3D digital maps, 2) Maintenance ground support systems, and 3) Synthetic training aids. These are highlighted in the previous section in Table 3.

The remaining 54 technologies were analyzed under the "Greatest potential for spillovers" stage. A workshop with a group of experts downsized the list to 8 technologies that are most relevant to generate potential spillovers. This estimation is a "best guess" and has taken into consideration both the demand and the supply sides. From the technology side, it considered the intensity of work involved in each one of these technologies and their own potential for spillovers. From the receptors side, it was considered their absorptive capacity (locally associated knowledge, laboratories, related R&D activities) as well as existing demands outside the aeronautics value chain. The result of this stage is shown in Table 8.

Table 8: Indication of associated technologies

Technologies
2D and 3D digital maps (creation and administration of geographical databases used in the aircraft, simulators and support systems)
Aeroacoustic (noise reduction)
Certification of complex integrated systems
Composite materials
Data fusion
High-density data storage
Maintenance ground support systems (evaluation and administration of maintenance data recorded in the aircraft)
Synthetic training aids (training programmes that utilize the existing infrastructure together with synthetic training aids and the Gripen NG system itself in order to maximize the training benefit)

In the last stage "Selected for spillover analysis", again a group of experts selected four technologies among the eight to be developed from the perspective of potential spillovers. This selection was based on the relevance of these technologies for Brazil, the existing capacity in the country regarding human resources and/or existing facilities, and their potential for spillovers. Finally, a consensual selection was agreed upon to develop an analysis of these four technologies: digital maps, composite materials, data fusion and high-density data storage.

The following sub-sections characterize in detail the four selected technologies exploring their potentials for spillovers, thus enabling a better understanding of potential receiving sectors as well as generating inputs for an in-depth analysis regarding knowledge flows across sectors.

5.2 2D and 3D Digital maps

Gripen NG is a combat aircraft, a weapon system designed to operate in diverse and sometimes antagonist environments. Both harsh environments, including all-weather and day-and-night conditions, and cooperation with other tactical assets (surface forces, wing-men, Airborne Early-Warning & Control – AEW&C) demand high precision navigation and situational awareness resources. Hence, such a complex system demands the production and management of geographical databases to be used in the aircraft as well as in simulators and support systems.

2D and 3D digital maps are so designed to provide a highly accurate representation of the surface, thus enabling independent precision navigation, fixing inertial navigation systems (geographical reference updating), target recognition, terrain following (TF) and terrain avoidance (TA) navigation modes, and simulation (training and operations planning).

In this context, it is necessary the ability to collect, quickly process and store loads of data including multi-sensorial images of areas of interest in order to create the corresponding digital maps (DM). These should also include the relevant digital elevation models (DEM), in formats and compression rates required for being loaded into the aircraft's avionics system. Moreover, it is also important to develop the adequate means to autonomously accomplish these tasks once the resulting products or maps are part of a country's strategic information.

Remote sensing is a field of knowledge and research that encompasses these activities. As such, it is gaining increasing importance in the world and in Brazil. It demands advanced sensors in multiple spectra that are able "see" through clouds and forests and even underground. Furthermore, adequate space and airborne platforms for these sensors are required. Finally, it is critical to have in place advanced processing tools and technics that can automatically and precisely interpret and combine the data received, converting it into useful information.

From the brief analysis above, it is easy to tell that 2D/3D mapping and their resulting products are strategic not only for air power, but also national defence and a vast set of applications attached to Brazil's development, as remote sensing, urban and rural planning, deforestation control and enforcement, crops monitoring, border control, natural disasters management, human health among others.

Patents

Figure 4 shows the number of patents by year since 1989 up to mid-December 2016 related to 3D mapping. The total number of patents in this period is 927. It is obvious from this figure that the interest in this area has increased over the past decade. A substantive increase is noticed in the last 4 years, which may suggest that this field is very promising for the development of new products, as suggested by the consulted specialist in the field.

A correlation map for these patents, shown in Figure 5, clearly shows the interplay among different technological fields, which may indicate that spillovers outside the Gripen chain can be achieved in different technological domains.

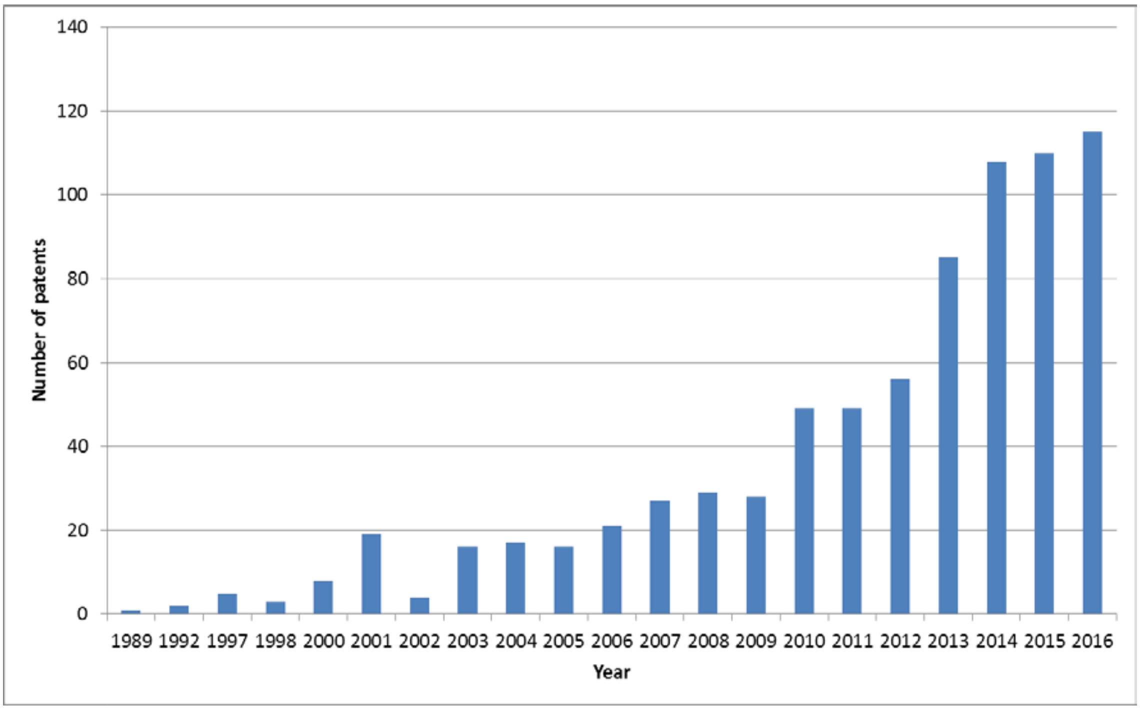


Fig. 4: Number of patents related 3D mapping.

The main potential area for spillovers is related to "instruments for performing medical examinations of the interior of cavities or tubes of the body by visual or photographic inspection", corresponding to 176 patents (19% of the total number of patents in the period). From this correlation map we can notice that "electric digital data processing", corresponding to 171 patents (18.4%), "image data processing or generation, in general", totalizing 112 patents (12%), share the same kind of technology. The strengths of the correlations of the main areas (most patents) show an elevated potential for spillovers in the areas of health, particularly medical instrumentation.

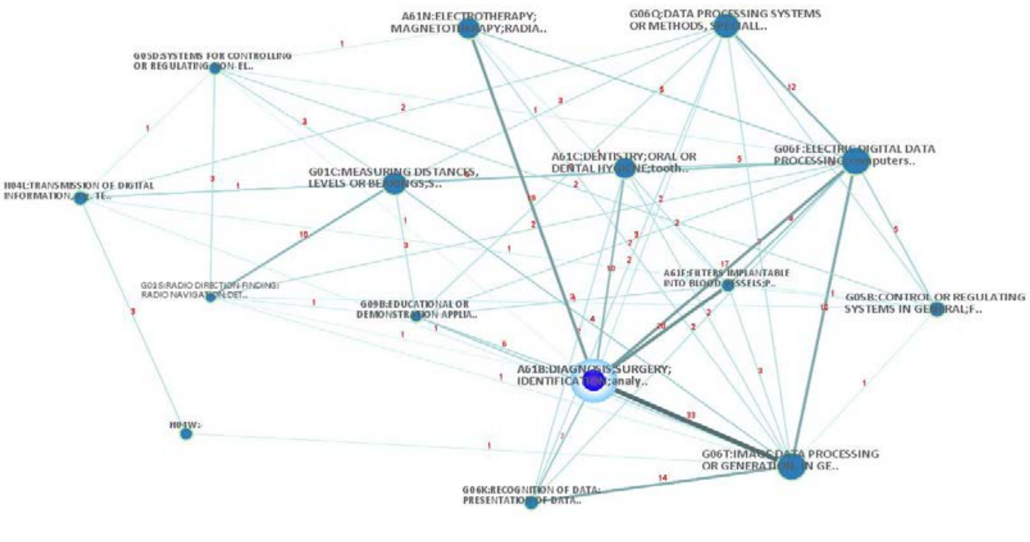


Fig. 5: Correlation among IPC codes related to 3D mapping.

Human Resources

Figure 8 presents a network built with 1255 Brazilian researchers with experience in 3D mapping, which encompasses researchers and technologists with different backgrounds. The figure shows very clearly that are 5 clusters, agglomerates of researchers, that indicate that are a strong level of collaboration of similar work done by the linked professionals.

We can also infer from this network, that the areas with the most potential to receive the technological cross-fertilization of the Gripen NG project are: health (187), transportation (133), mining (127), natural disaster management (120), urban and rural planning (84), and deforestation control enforcement (53).

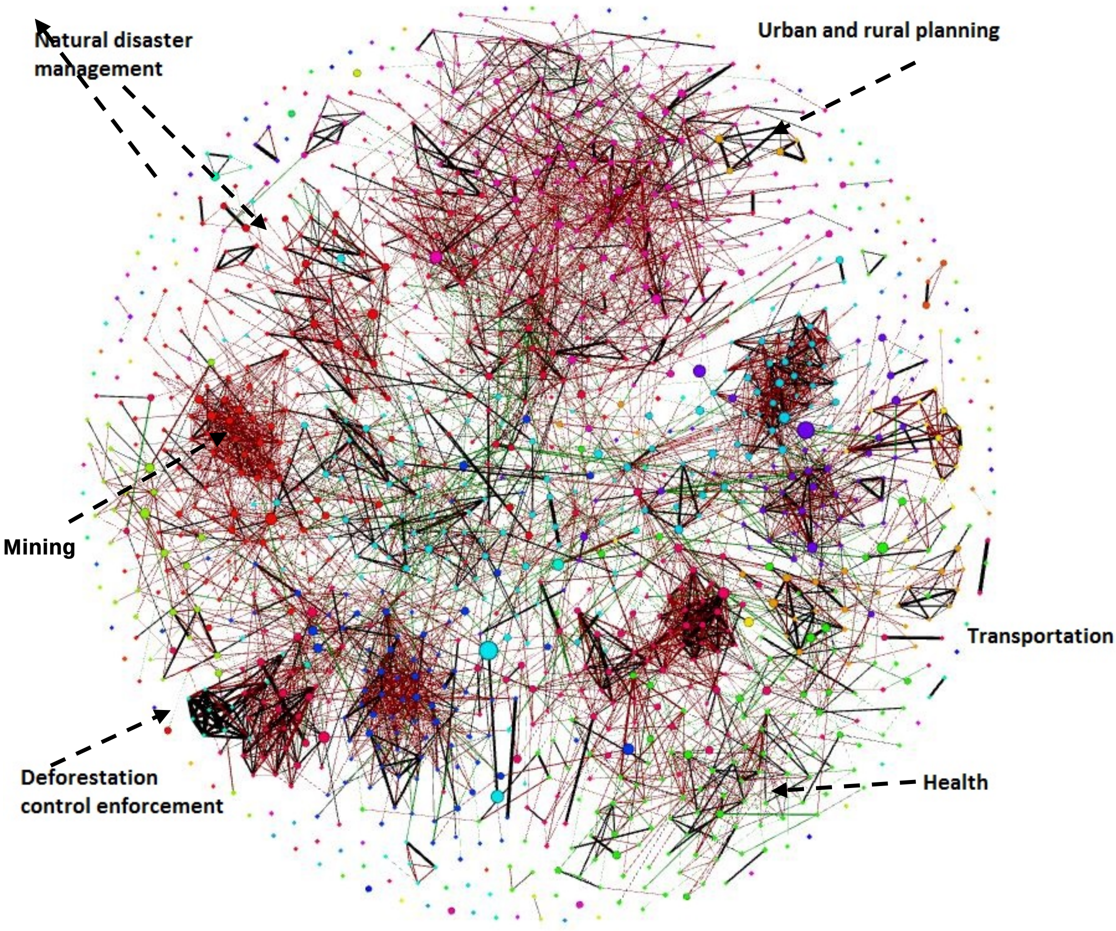


Fig.6: Knowledge network related to 3D mapping.

5.3 Data Fusion

Data fusion can be briefly defined as the integration of multiple data and knowledge representing a real-world object (e.g. target, cooperative asset, surface feature). Such a representation to become useful must be consistent and accurate, thus expanding the situational awareness and maximising cooperation in the theatre like operation. A more accurate and most accepted definition is provided by the Joint Directors of Laboratories (JDL)[9]:

> "A multi-level process dealing with the association, correlation, combination of data and information from single and multiple sources to achieve refined position, identify estimates and complete and timely assessments of situations, threats and their significance.The process is characterized by continuous refinements of its estimates and assessments, and the evaluation of the need for additional sources, or modification of the process itself, to achieve improved results." WHITE (1991)[10]

Data fusion is a key technology for the Gripen NG programme as it is in the core of the cooperative environment the aircraft is designed to operate in, namely the Tactical Information Data-Link System – TIDLS. A lot of work is expected for the development of the Brazilian defined configuration and its integration with national assets like radars, Command & Control – C2 network, weaponry, other types of aircraft, and surface forces.

Outside the value chain of the Gripen NG a number of applications can be found in decision support and coordination systems. This opens the possibility of spillovers in a broad range of sectors. Brazil has large demands in sectors that can benefit from the associated developments in data fusion, briefly described below:

- Security of urban areas is highly improved by integrating images from street security cameras, flow sensors of people and vehicles, weather forecast and real-time conditions, security personnel information and even pre-defined protocols. The integrated and processed information can provide early warnings of potentially risky situations and even automatically activate the adequate protocols.
- Manufacturing is benefited by the integration of multiple sensors to control machine tools, work centres, production lines, and factories. It is also a must have for computer integrated and agile manufacturing.
- Environmental monitoring is dependent to integrated data from a variety of sources to get a comprehensive understanding of the levels and flows of contaminants in the air, water supplies and oceans, and of illegal logging activities in remote areas.
- Medical practices like diagnostic or patient monitoring in an Intensive Care Unit, a long-term care facility, or at home by integrating data from various medical sensors and devices is also an example of data fusion technology usage.

Patents

Figure 3 shows 5.039 patents related to data fusion. These patents also refer to the period between 1989 and December 2016. As in the previous technology (3D mapping), the patent deposit time trend shows an increase in deposits over the past decade, therefore a substantive importance in the field. In 2013, the anomalous number of

[9] https://www.hindawi.com/journals/tswj/2013/704504/#B39
[10] JDL, Data Fusion Lexicon. Technical Panel For C3, F.E. White, San Diego, Calif, USA, Code 420, 1991.

deposit was due to a download problem in the database. It has to be taken as an error that will be fixed as soon as the database is corrected.

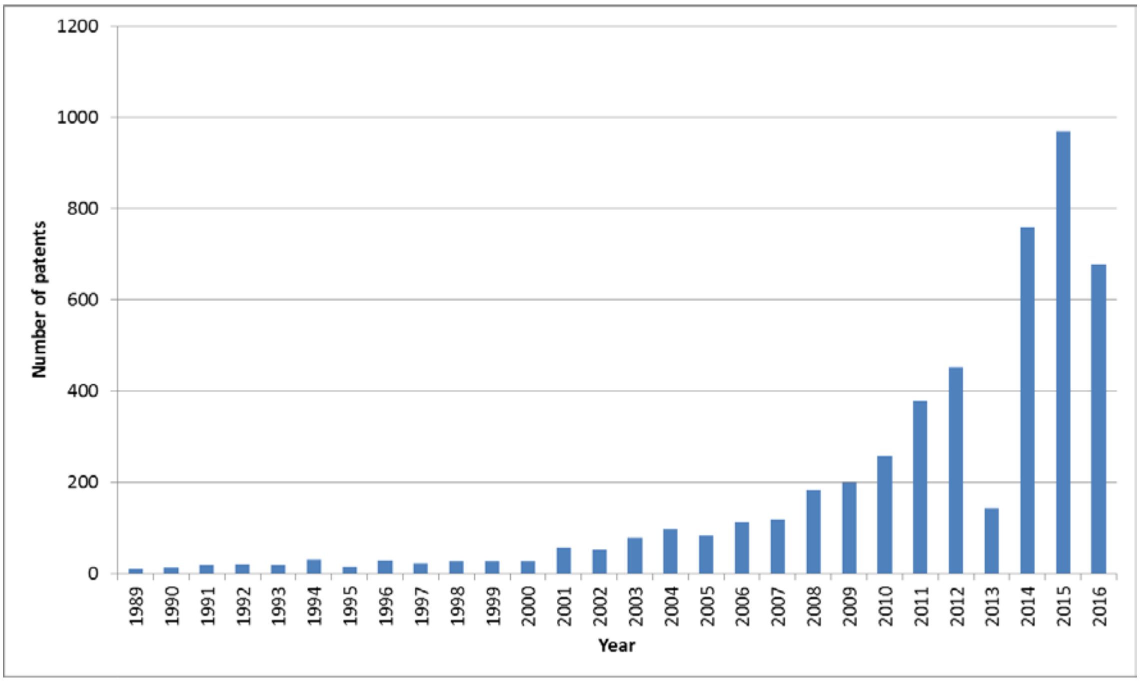


Fig. 7: Number of patents related data fusion.

In this set, 927 (18.4%) are classified “electric digital data processing”, 434 (8.6%) as “image data processing or generation” and 425 (8.4%) as “recognition of data; presentation of data; record carriers; handling record carriers”. Figure 4 presents the interplay among them. This correlation map shows that the main area (most patents and connections) is “electric digital data processing” which is transversal to all the spillover possibilities appointed by the experts.

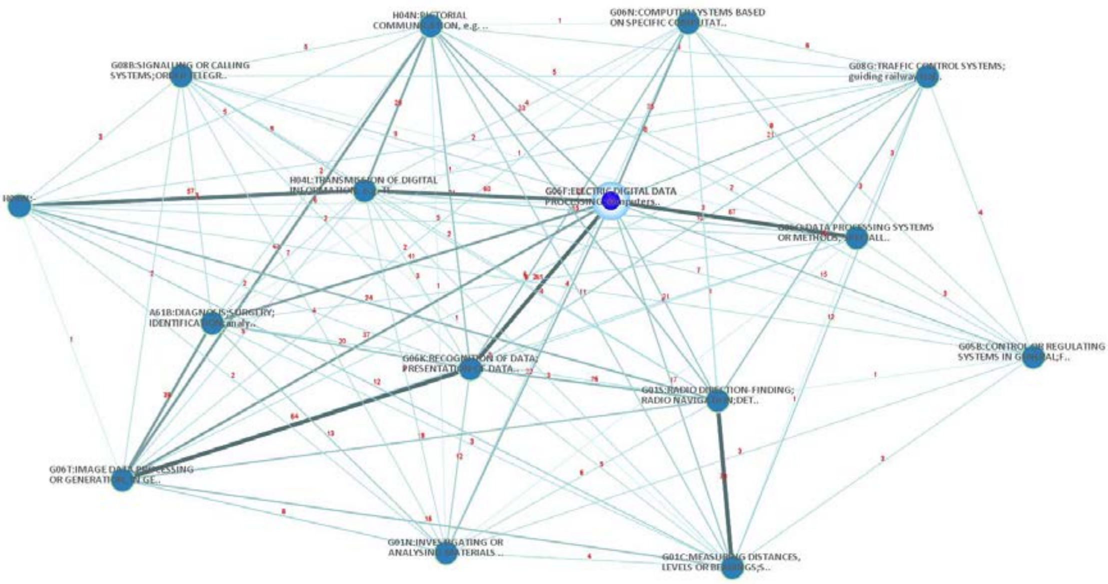


Fig. 8: Correlation among IPC codes related to data fusion.

Human resources

Figure 9 represents a network built with 1253 researchers with experience in data fusion. The figure shows that are 4 clusters that indicate that are a strong level of collaboration of similar work done by the linked professionals.

The experiences of such professionals spread over fields like management of complex systems (208), microprocessors (33), neural networks (172), and internet of things (62), among others. Furthermore, all those areas have a certain level of interaction with the spillovers appointed by the experts, as well as the technologies presented at the patent analysis. Based on those findings, it can be deduced that the Brazilian research environment is capable of absorbing the advanced technologies developed in the Gripen NG project.

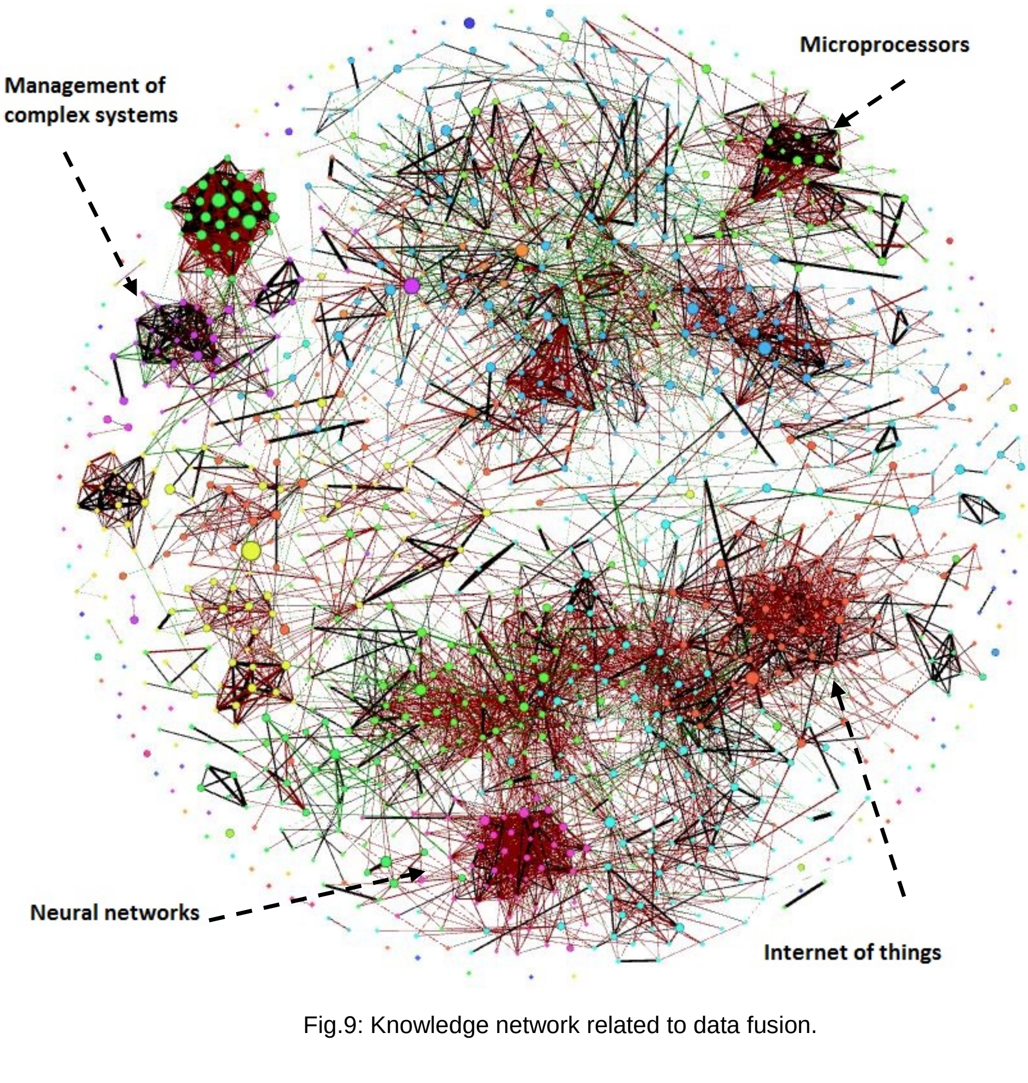


Fig.9: Knowledge network related to data fusion.

5.4 High density data storage (and access)

High-density data storage are recording technologies and materials that combine high density, fast response, long retention time, and rewriting capability.

This technology encompasses storage, access and transfers of technics and devices that can handle high amounts of data in a fast, secure and reliable way; all integrated into the highly stringent environment of a combat aircraft.

Modern warfare relies on a great variety of advanced electronics like global positioning systems, fibre optics inertial navigation systems, radars, Infrared Search and Track (IRST), digital maps, threat libraries, digital video cameras, digital radios, data link, among others. All these devices actively capture vast amounts of data.

In this context, the network-centric battlefields, which by design is embedded in the habitat of Gripen NG, is fuelled by information that must be gathered, shared, exploited and archived securely. Decision makers rely on immediate, reliable and secure access to this kind of mission-critical information.

Therefore, data store technologies must provide:

- Rugged storage design and construction to survive and continue to operate effectively in the environmental extremes of airborne platforms;
- High maintainability standards to assure long Mean-Time Between Failures (MTBF), easy access for modules replacement and short Mean-Time To Repair (MTTR);
- High throughput to reach the several hundreds of megabytes per second required by airborne intelligence, surveillance and reconnaissance applications;
- High accessible storage capacity taking into account that not all specified memory is actually available because some amount (of the memory) must be reserved for internal use, like for wear levelling and bad blocks management.
- Data-at-rest (DAR) encryption for protecting the data retained on storage devices. If a device is removed or stolen, the encrypted data must be inaccessible and, therefore, protected.

> "Protecting Data at Rest is a different challenge due to the way that cryptographic key management can be done. In COMSEC, both ends of the communications can change keys as often as the user chooses. As long as both the transmitter and receiver change to the same key at the same time the communication is not interrupted and the adversary’s task to intercept and decode is far more difficult. Data at Rest is encoded by a key and then stored to the drive. … The same key used to encode the data must be used to decode the data from the drive." BOHMAN (2011).

Patents

Figure 5 shows 555 patents related to high-density data storage for the same period as the previous plots. However, this one presents a decreasing trend in the number of deposits per year. This variation is likely to occur due to the relatively low number of patents when compared with the two previous technologies. Anyhow, this low number of patents may indicate an opportunity for Brazil to position itself as an important player in the near future by exploring new applications yet to be established.

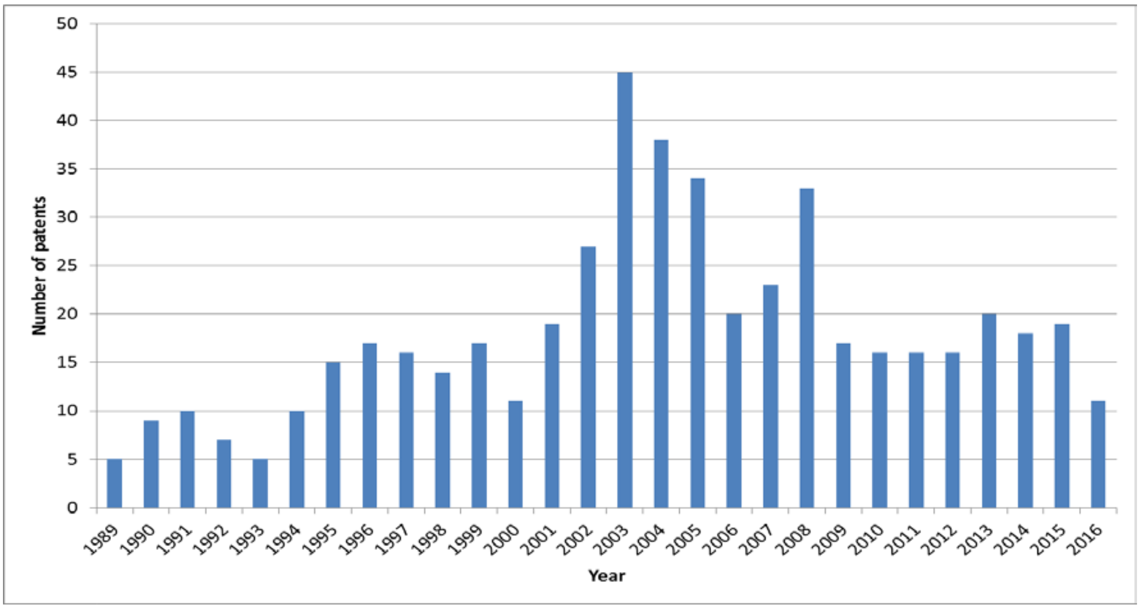


Fig. 10: Number of patents related high-density data storage.

In the set, Figure 6 shows that the main area with 348 (62.7%) patents is "information storage based on relative movement between record carrier and transducer", followed by "static stores" and "semiconductor devices, electric solid state devices".

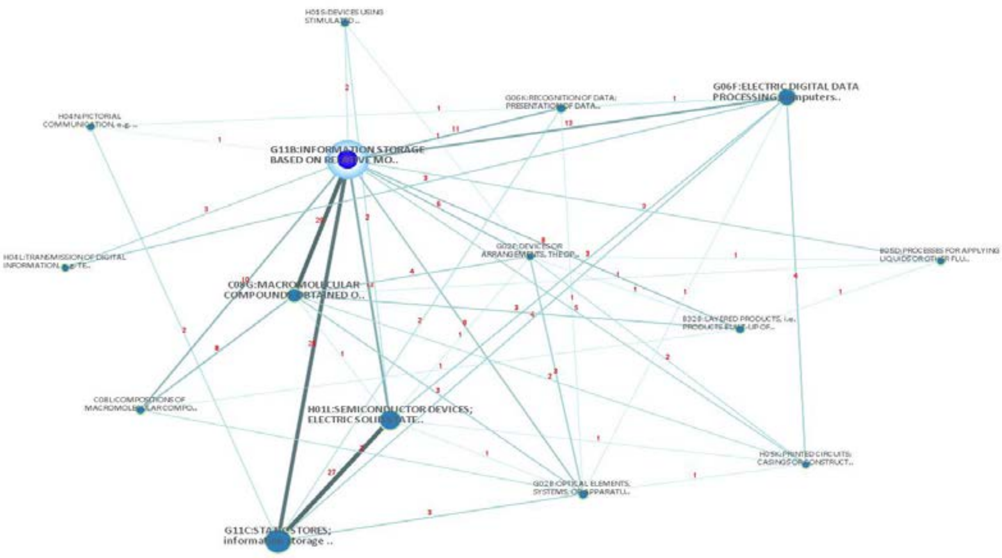


Fig. 11: Correlation among IPC codes related to high-density data storage.

Human resources

Figure 10 represents a network built with 3337 professionals with experience in high-density data storage. Tree clusters are more evident in this network, namely: information security (1639 professionals), cryptography (330 professionals), and microelectronics (166 professionals).

All those areas are linked to the spillovers appointed by the experts, as well as the technologies shown at the patent analysis. Therefore, it can be deduced that Brazil has high skilled human resources on areas that can absorb the advanced technologies developed in the Gripen NG project.

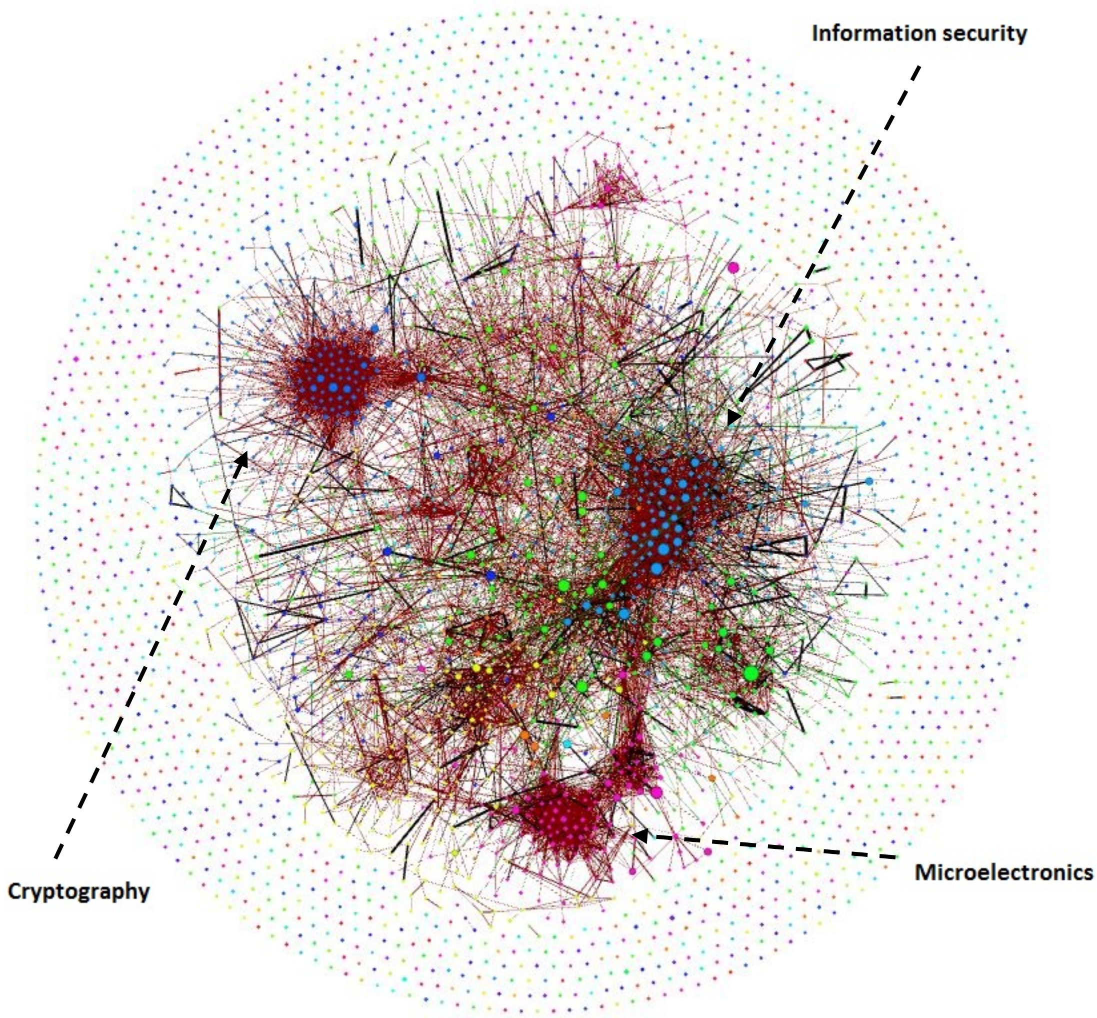


Fig.12: Knowledge network related to high-density data storage.

5.5 Composite materials

The first thing aeronautics engineering students learn is that they are going to work in a realm of trade-offs. Aircrafts are wonderful machines but one can't have the most effective aerodynamically design on the strongest airframe, neither a lighter aircraft with the most powerful engine. An aeronautics engineer must learn to design for the best possible matching between the operational requirements and constraints of budget, logistics support, human-machine integration, safety, security, and others.

The strength and stiffness of an airframe are of primary concern, as it must stand the aerodynamical design, be damage tolerant, and provide safety to its payload. An old saying in aviation is: “a 'good' landing is one from which you can walk away. A 'great' landing is one after which the plane can be used again”. Technology related to aircraft construction has evolved a lot since those first days though, from wood, fabric, metal alloys, new metals and composites.

A composite material is a combination of two or more distinct materials (matrix material and reinforcing material), which are chemically and physically different, and which delivers overall properties that are superior to those of the individual components. The matrix material stabilises the reinforcing material and bonds it to adjacent reinforcing materials. Composite materials can then be tailored to the expected loads in different directions by proerly disposing of the reinforcing material. The resulting design has an outstanding strength-to-weight ratio.

> “The greatest revolution in aircraft structures since the all-aluminum Northrop Alpha has been the ongoing adoption of composite materials for primary structure. In a typical aircraft part, the direct substitution of graphite-epoxy composite for aluminium yields a weight savings of 25%.” RAYMER (2006).

Composite materials can be quite safe when stored and handled properly. Nevertheless, in the production of composite products, storage and handling of constituent materials such as organic peroxides, fillers and reinforcing fibres have varying safety considerations.

For instance, organic peroxides, which are the most common catalysts, must be stored and handled with great care and have to comply with strict rules. Its storage is highly recommended to be in a separate building.

Some cleaning solvents are possible carcinogen and thus demand suitable eye and skin protection. They must be kept in closed containers and thrown away accordingly to local requirements.

Cutting, drilling and sanding composite products can generate dust consisting partly of particles with a size well below three microns, which can penetrate deep into the lungs when inhaled, therefore with the risk of leading to lung damage. Dust extraction equipment as well as skin and respiratory protections suitable for fine dust environments must always be used.

Prepreg is very sensible to temperature and humidity variations and so must be stored in environmentally controlled rooms, and have shelf-life limits. Common individual protection equipments are flock lined latex gloves, safety goggles, organic vapour respirator and protective disposable clothing.

Composite manufacturing[11] is characterised by the fact that the material and the structure are created at the same time. Thus a defect induced during the development process directly influences the strength and stiffness of the resulting material and structure.

[11] http://aerospaceengineeringblog.com/composite-manufacturing/

There are a variety of manufacturing processes including: contact moulding, compression moulding, vacuum bag/autoclave moulding, rotational moulding, resin transfer moulding (RTM), tape wrapping, filament winding, pultrusion, expanding bladder moulding, among others.

All these processes have several characteristics in common: the reinforcements are brought into the required shape in a tool or mould; resin and fibres are brought together mainly under elevated temperature and pressure to cure the resin; and the moulding stripped from the part once the resin has cured. The different fabrication techniques can either be classified as direct processes (e.g. RTM, pultrusion, contact moulding) that use separate fibres and resin brought together at the point of moulding or indirect processes that use fibres pre-impregnated with resin (e.g. vacuum bag/autoclave moulding, compression moulding). The selection of the manufacturing process will naturally have a great effect on the quality, the mechanical properties and fabrication cost of the component.

Composites are not safe from defects or damages. A flaw can and do occur in manufacturing, either as a contaminated bond-line surface or inclusions, such as prepreg backing paper or separation film, which is inadvertently left between plies during layup. Inadvertent (non-process) damage can occur in parts or whole components during assembly or transport or during operation[12].

In-service defects can happen due to environmental degradation, impact damage, fatigue, cracks from local overload, de-bonding, delamination, fibre fracturing, and erosion. Daily operations of a fighter squadron and even of a maintenance depot are prodigious sources of these in-service defects.

Bird-strike, air refuelling probe strike, lighting strike, hail strike and aerodynamic severe loads are among the inherent in-flight operations sources. Small collisions to aerospace ground equipment (AGE) during ground manoeuvres, tools dropping, mishaps during loading and unloading of external stores, fuel and oil spills, mishandling of parts and tools are among the avoidable yet common ground operations mishaps.

Repairing of composite parts is expected to be an intensive activity during the whole life-cycle of the Gripen NG fleet. Moreover, it shall use the same processes, materials and technics that suit any other composite material, no matter the sector it belongs to (i.e. civil aviation, surface transports, oil & gas, high-performance sports equipment etc.).

Patents

For the technologies related to composite materials, the number of patent deposits is very high for the period between 1989 and 2016. For instance, just in 2016, there were 2581 of them. For this reason, we decided not to include a plot showing these deposits but instead just to mention this field as being very active over the past decade and that the correlations among different areas play an interesting role in trying to estimate potential spillovers. There are 682 patents (26.42%) related to “compositions of macromolecular compounds”; 639 patents (24.75%) to the use of “inorganic or non-

[12] FAA Handbook Chapter 7

macromolecular organic substances as compounding ingredients"; and 316 patents (12.24%) to "shaping or joining of plastics; shaping of substances in a plastic state, in general; after-treatment of the shaped products, e.g. repairing". Figure 7 presents the correlation among patents that deals with composite materials.

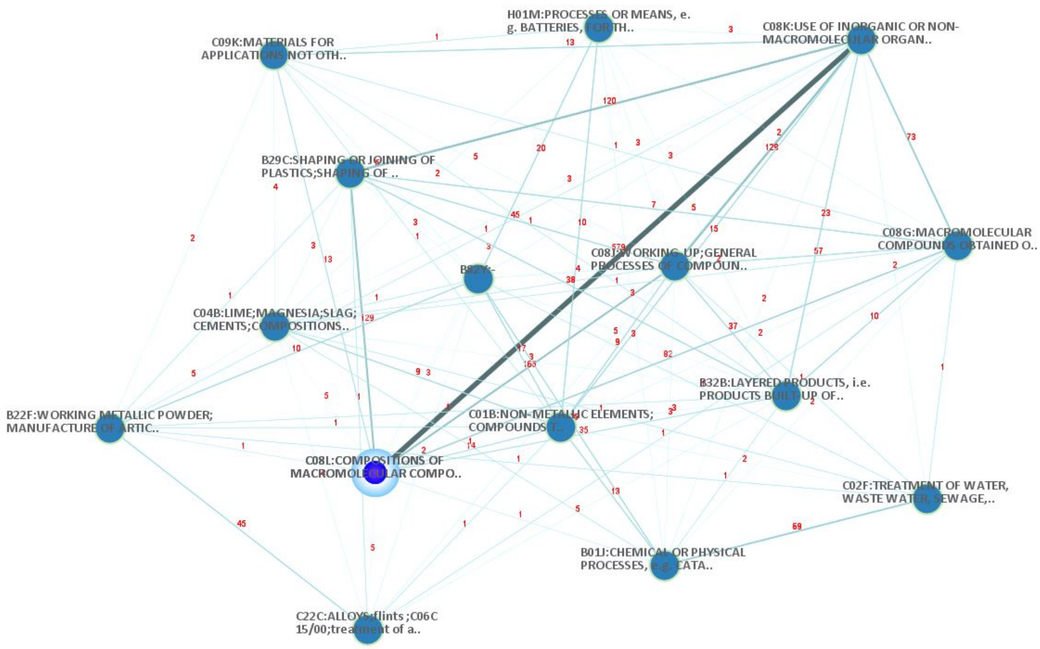


Fig. 13: Correlation among IPC codes related to composite materials.

Human resources

Figure 11 represents a network built with 2874 researchers with experience in composite materials. Their experiences are related to fields like energy (500 professionals), physical and mechanical properties of these materials (427 professionals), oil and gas (135 professionals), health and dentistry (126 professionals), and, automotive (61 professionals), among others.

The appraisal of worldwide patent production to the human resources capacity in Brazil show us that, overall, most of the Brazilian capacity is related to the use of composite materials in the energy sector, P&G and health. Nonetheless, there is a relevant number of high qualified researchers working on the physical and chemical aspects of that material. Based on this analysis we can infer that composite material is the most promising area for spillovers, as Brazil not only have the capacity to operate on the basic development, but also in state of the art applications in the industry.

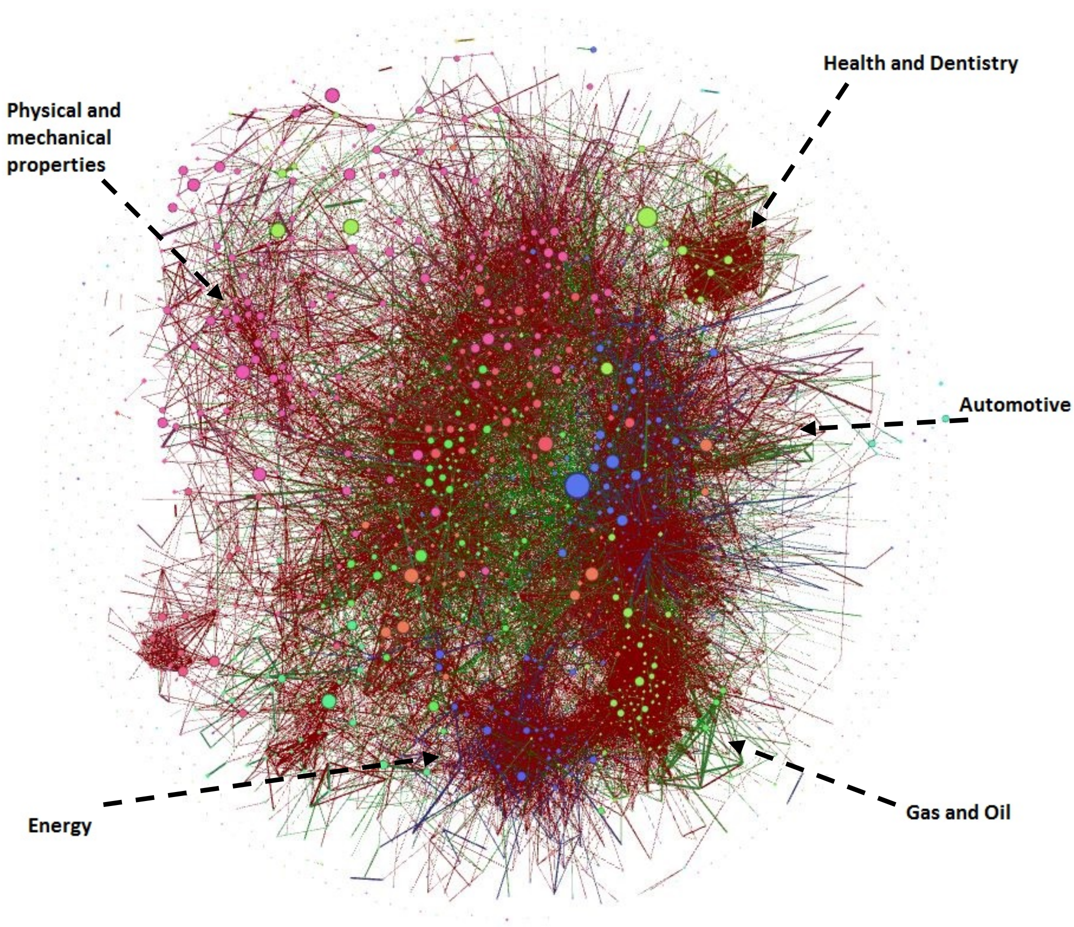


Fig.14: Knowledge network related to composite materials.

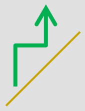
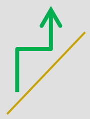
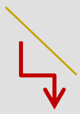
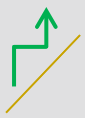
5.6 Summary of findings

An examination of the four selected technologies illustrated in the previous topics suggests the following framework (Table 9) derived from the balance of i) associated patent areas (measured at a global scale) and ii) national scientific and technological competence areas (measured at the national level).

First, the global dynamics of patents deposit shows a scenario in which three of the four technologies chosen are still increasing their number each year. Only one of them, High-Density Data Storage, presents a stable to declining trend, thus reinforcing the idea that it could have less importance in the near future.

The analysis of the correlation between patents areas indicates a large spectrum of technologies that is attached to the four technologies. Some appear in more than one row, inducing the idea that could have a greater impact on a larger number of sectors. Most of the correlated technologies derive from the Electronics and Informatics fields. But Composite Materials, in fact, do has a very different nature and should be associated with a lot of technologies concerning the field of New Materials, like plastics, alloys, metallic powder and so on.

Table 9: Summary of evidence collected for the four selected technologies

SELECTED TECHNOLOGIES	GLOBAL PATENTS		BRAZIL HUMAN RESOURCES
	Trend	*Correlated areas*	*S&T Competence areas*
2D AND 3D DIGITAL MAPS		Diagnosis, surgery Dentistry, oral dental Electrotherapy, magnetotherapy Electric digital data processing Image data processing or generation Measuring distances, levels, bearings Radio direction finding, radio navigation	Health Mining Transportation Deforestation control Natural disaster management Urban and rural planning
DATA FUSION		Electronic digital data processing Image data processing or generation Recognition and presentation of data Pictorial communication Signalling or calling systems Traffic control systems Diagnosis, surgery Radio direction finding, radio navigation	Management of complex systems Microprocessors Neural network Internet of things
HIGH DENSITY DATA STORAGE (AND ACCESS)		Information storage - record carrier and transducer Static stores Semiconductor devices, electric solid state devices	Information security Microelectronics Cryptography
COMPOSITE MATERIALS		Compositions of macromolecular compounds Inorganic or non-macromolecular organic substances Shaping or joining of plastics Treatment of water, water sewage Alloys Working metallic powder Layered products	Energy Physical and mechanical properties of materials Health and dentistry Automotive Oil and gas

Source:

On the other side, from the ST&I human resources perspective, the highlighted competence's areas show less convergence. A large set of areas of competence's areas is associated with each selected technology It means that the scientific and technological communities dealing with each one of them is more or less dedicated to subdomains areas which vary a lot from one selected technology to another. Few subdomains can be seen in more than one row of Figure 9.

Some areas or subdomains are almost sectors (Oil & Gas, Automotive, Microelectronics etc.); others can be identified with modern services (Deforestation control enforcement; Urban and rural planning, Internet of things, and so on).

6 Sectors potentially impacted by Gripen NG spillovers

6.1 Sectors suggested from evidence-based analysis

The four selected technologies characterized in the previous section shed light on sectors receiving potentials spillovers. As follow, Table 10 examine the connections between the selected technologies, the global patents correlated areas, the critical masses of human resources competences that already exists in Brazil and, respectively, the sectors receiving such spillovers impacts.

Table 10: Selected technologies and indication of sectors potentially impacted

SELECTED TECHNOLOGIES	GLOBAL PATENTS		HUMAN RESOURCES	
	Correlation area	*Sectors*	*Competence areas*	*Sectors*
2D AND 3D DIGITAL MAPS	Diagnosis, surgery Dentistry, oral dental Electrotherapy, magnetotherapy Electric digital data processing Image data processing or generation Measuring distances, levels, bearings Radio direction finding, radio navigation	Health Information Transport	Health Mining Transportation Deforestation control Natural disaster management Urban and rural planning	Health Mining Transport Environment Public management
DATA FUSION	Electronic digital data processing Image data processing or generation Recognition and presentation of data Pictorial communication Signalling or calling systems Traffic control systems Diagnosis, surgery Radio direction finding, radio navigation	Information Transport Communication Health	Management of complex systems Microprocessors Neural network Internet of things	Transport Information Urban management Energy
HIGH-DENSITY DATA STORAGE (AND ACCESS)	Information storage - record carrier and transducer Static stores Semiconductor devices, electric solid state devices	Defence Information Materials Communication	Information security Microelectronics Cryptography	Defense Information Communication Finance
COMPOSITE MATERIALS	Compositions of macromolecular compounds Inorganic or non-macromolecular organic substances Shaping or joining of plastics Treatment of water, water sewage Alloys Working metallic powder Layered products	Chemicals 3D Manufacturing Environment	Energy Physical and mechanical properties of materials Health and dentistry Automotive Oil and gas	Energy Materials Health Automotive Oil and gas

There are many possible insights for interpreting the whole list of proposed sectors. An analysis by types of sectors do help clarify some aspects.

The first group of sectors (Group A) is related to government-like business, as are the cases of Public management, Urban management and others. Here it is possible to include also Health, Defence and Finance.

Another group (Group B) can be associated with big infrastructures, with a huge potential to produce a relevant impact on the Brazilian economy: Transportation, Energy, Environment and, particularly, Information and Communication.

The last group (Group C) comprehends traditional industrial sectors, like Mining, Chemicals, Automotive or Oil & Gas. But it also comprises emerging sectors, like 3D manufacturing. All of them have also potential to generate significant impacts on the economy.

Table 11: List of sectors potentially receiving technological spillovers impacts (sectoral affinity)

Technologies
GROUP A (Government-like) – Health, Defence, Public management, Urban management, Finance
GROUP B (Big infrastructures) – Transport, Energy, Environment. Information and Communication
GROUP C (Industrial)– Mining; Materials; Chemicals, Automotive, Oil & Gas, 3D Manufacturing

There are other possible ways to organize the same list of sectors. It is interesting, for example, to bring about policy purposes to that classification and divide the sectors between those which do form part of the group that contributes to the United Nations 2030 Agenda for sustainable development from others that cannot be included in it and do not provide support to the transformations needed. Therefore, another meaning based on a policy goal can be used to generate two different groups, changing the logic of the sectors list, as shown in Table 12:

Table 12: List of sectors potentially receiving technological spillovers impacts (policy affinity)

Technologies
GROUP 1 (contributing to 2030 UN Agenda) – Public management, Urban management, Transport, Energy, Environment. Information and Communication, Health, Finance
GROUP 2 (others) – Defence, Mining; Materials; Chemicals, Automotive, Oil & Gas, 3D Manufacturing

Those sectors having a huge influence on essential activities for the 2030 Agenda are Public management (especially considering important improvements over activities like Deforestation control enforcement; Urban and rural planning; Natural disaster management; Surveillance, command and control of urban areas); Transport, Energy, Information and Communication; Health and Finance. The others, less influent on UN 2030 Agenda, include Defence, Mining, Materials, Chemicals, Automotive, Oil & Gas and 3D Manufacturing.

There are of course, many other ways to classify the sectors in different groups, simply by changing the criteria that orient the typology.

6.2 Additional aspects (for analysis of relevant sectors)

This topic aims to provide additional information about aspects that can better orient the reach of results for some activities involving the sectors grouped in Government-like activities (Group A) or in those attached to the 2030 UN sustainable development Agenda (Group 1).

Group A (Government missions) or Group 1 (UN 2030 Agenda)

For sectors from Group A, identified with government missions, or Group 1, which are directly attached to 2030 UN sustainable development Agenda, some areas of activities seem immediately relevant.

Deforestation control enforcement - The Brazilian territory holds 60% of the Amazon forest, the biggest rainforest in the world, and represents one of its more praised natural assets. Logging and agriculture had pushed their boundaries into the forest for decades before a legal framework came into force, trying to halt this process. Nevertheless, law enforcement in such remote areas is a very difficult task and remote sensing is the key instrument for any successful achievement.

Multispectral data received from space and airborne sensors are collected, analyzed and combined to produce a variety of maps for interpretation by specialists, who monitors the changes on the landscape, allowing the detection of illegal activities. This is a time-consuming task and very dependent to the operator's skills. A further development is the use of digital maps, that make possible automation of the analysis process, thus increasing the quality of the outputs and improving the readiness of the enforcement actions.

The Brazilian Ministry of Defence licences firms and institutions that can do remote sensing over the national territory and holds the rights to the data produced.[13] To date, there are 26 institutions allowed to collect and process data, 62 allowed to process data, and three that only collect data, and they are scattered throughout the country regions. A significant number of firms are able to benefit from the Gripen NG programme 2D and 3D digital maps technology. It is worth noting that the production of digital maps is dependent of data fusion, for it integrates data from a variety of sources, and to high-density data storage as well, for the information produced must be loaded, stored and securely accessed in airborne devices.

Urban and rural planning - Brazil has a very large territorial dimension and six different biomes. The preservation of its natural wealth constitutes a major challenge, which still demands large sums of resources and intelligent policies. Along the territory, forests follow Savannas and Drylands, huge rivers, distributed in great basins, cut the soil everywhere and big cities are seen aside of extensive rural areas. The geographical panorama is always being transformed and so proper planning is intensively needed.

Brazil has an important programme for the planning and management of rural areas, the "Cadastro Ambiental Rural" (CAR), or rural environmental registry. It consists of geo-referenced information of the property, identifying the Permanent Protection Areas (APP), Legal Reserve (RL), remnants of native vegetation, consolidated rural area and

[13] A list of these institutions can be found at: http://www.defesa.gov.br/cartografia-e-aerolevantamento-claten/entidades-executantes-de-aerolevantamento, categorized by their roles in operating the sensors platforms (space or airborne) and collecting the data, and/or processing the data.

areas of social or public interest, with the objective of producing digital maps from which the values of the areas for environmental diagnosis are calculated.

Up to March 2016, 70% of the rural properties were registered, but a lot of work still must be done. And even after completion of this registering phase, there will be the need for continual monitoring, and accurate maps will still be demanded.

Urban planning is of a great concern in Brazil as well, for the cities never stop expanding. Fundamental tools, in this context, are geographical information systems (GIS). These systems allow to manage and to update urban cartography, to design and manage urban registers, to handle land use and occupation data, to analyze and predict urban events, as well as to plan and manage housing resources, transportation, etc. They also allow to integrate, process and aggregate data from diverse sources into useful information about the city and its processes, to manage this information, to monitor changes, to simulate the impact produced by new projects and to simulate urban growth according to various hypotheses.

Natural disaster management[14] - Brazil has its share of natural disasters. For instance, long drought periods, fires, floods and landslides are unfortunately frequent, especially during the more intensive seasons of winter and summer. And as the cycle of global warming continues in its ascending path, those phenomena have had their intensity increased year after year. This puts a big challenge for the Brazilian authorities on how to manage the so-called four-part cycle. From mitigation to recovery, all parts of the cycle demand products and services related to the production, processing and distribution of digital maps.

Table 13: Roles for digital maps technologies in natural disaster management

Disaster	Mitigation	Preparedness	Response	Recovery
Drought	Land and water management planning.	Vegetation monitoring; Crop water requirement mapping;	Monitoring vegetation; Damage assessment.	
Fire	Mapping fire-prone areas;	Predicting spread/direction of fire.		Damage assessment.
Flood	Mapping flood-prone areas; Delineating flood-plains; Land-use mapping.		Flood mapping; Evacuation planning; Damage assessment.	Damage assessment; Spatial planning.
Landslide	Hazard mapping; Digital elevation models.		Mapping affected areas;	Damage assessment; Spatial planning;

Source: Lewis, S (2009)

Surveillance, command and control of urban areas - According to official statistics, the population of Brazil is 206,08 million in 2016. Seventeen municipalities hold 21,9% of this population and only 5,5% of all municipalities hold 56,4%, being 80% (roughly) of the people living in urban areas. These figures can help to form a picture of the great agglomeration of people that exists in cities. With so many people moving around, security becomes of primary concern, and authorities seek adequate means to keep life, especially in city centres, in a “steady flow”.

[14] "Natural events can't be prevented, but potential disasters can be 'managed' to minimise losses of life through a four-part cycle of: mitigation, preparedness, response and recovery.” LEWIS (2009)

Fortunately, surveillance equipment like cameras and flow detectors are currently far from being expensive and, together with gadgets of our connected life, are sources of data that can be gathered, combined, analyzed and shown on big screens in centralized control rooms. With data fusion technology, these data are handled by sophisticated algorithms running on powerful machines that can show tailored useful information for decision making and timely interventions. The integrated and processed data can provide early warnings of potentially risky situations and even automatically activate the adequate protocols.

One tiny city of 3.000 citizens, about 187 km from São Paulo, is implementing a project for becoming the first “smart city” in Brazil. Partnering with a communications service provider and an electronics producer, the municipality’s goal is to deliver smarter services to its population in the areas of health, education, security and tourism.

The possibilities here are, therefore, endless.

Information and communication technologies (ICT) - When one thinks of ICT, two basic concepts come to mind: computer sciences (which include electronics) and communications. But the ever increasing computational and data storage capacities are lifting off every aspect of social and corporative life to the broader concept of the information society.

Our daily life is filled with electronic devices and gadgets that have been transforming even the simplest task of walking a pet into a technology-based operation. Apps in your smartphone, wirelessly connected to a smart city network and the world-wide-web, are fed by data related to animal-friendly parks, weather and traffic conditions, hazards warnings, whereabouts of your friends, people with the same interests as you on the vicinity and even data related to your pet. These data is then combined, using highly sophisticated algorithms and powerful computational resources, to provide you with suggestions like what is the best time to leave home, which is the best path to follow and the recommended pace, when is the best advisable time to return, and even what to carry along. Everything is on the small device one is carrying on, and taking it all for granted.

What are unnoticed is a reliable, effective communications infrastructure and sophisticated software and hardware, incorporated into the smartphone and into the distributed sources from which it receives data. This simple example can be extrapolated to any level and illustrates the huge potential of this sector.

Management of complex systems - The name “complex systems” speaks for itself in showing a picture of something that cannot be dealt with through simple solutions. Some examples are: energy generating power plants (especially nuclear), special steels production, intensive care units (ICU) and air-traffic management (ATM). These systems have in common a multiplicity of inputs from different sources and different types, all related to the same real situation.

Even though some of the aforementioned examples could be considered as closed niches, they are all spread over the country’s regions, especially ICU, and represents a large demand for data fusion technology.

UAV applications - The widespread use of UAV’s, which essentially are flying robots, just do not stop growing. From the simple amusement tasks of taking selfies or providing a bird’s eye view of an event, to the more complex of military operations, they are accessible to almost everyone. Farmers can use it to monitor their crops or cattle, energy companies can use it to monitor their transmission lines, and businesses can use it to deliver goods.

But as the access to UAV expands so does the demand for newer capabilities. Another growing trend is related to the need to make these diverse applications more independent, which translates into more information stored onboard and, therefore, demanding more capable storage devices.

7 Final remarks, policy recommendations and further developments

Gripen NG technologies potential spillovers in Brazil have been discussed in this report. It started by recalling a list of 78 key technologies compiled in a 2014 study from CGEE. A small yet significant part of the publicly announced Gripen NG supply chain was drawn and, for each of its work packages, it was listed the associated technologies.

Although lacking field data due to the amount of time available, a best guess indication of the associated technologies was made, having in mind the technology's potential to generate spillovers on Brazilian economic sectors and our internal absorptive capability. This indication was discussed between CGEE team and experts resulting in a selection of four technologies. The selected technologies were then characterized for a better understanding of their potential for spillovers and, finally, for an identification of the potential receiving sectors.

Despite not having a robust field data, sectoral speculations have been done. Hence, a first general analysis of the relationships between sectors with the potential to receive spillovers, core technologies involved and scientific and technological competences needed were set out. The work arrived at the following general conclusions:

1. The technologies associated with the Gripen NG Project do have strong potential for generating true spillovers that can be explored in Brazil;

2. The work done has shown useful this preliminary approach for the analysis of the technology-based true spillovers that results from Gripen NG project jointly developed by Brazil and Sweden on a timespan of more than four decades;

3. Further improvements need to be done to achieve a detailed framework of the impacts being generated, particularly considering the quantification of these true spillover effects and the confirmation of the sectoral matrix that is influenced by them.

In view of the data presented in this report, we clearly collect evidence and notice that Brazil has a reasonable capacity to take advantage of the technologies involved in the Gripen NG project that has potential to generate spillovers outside the aeronautics chain. Hence, in a first sight and considering the four chosen technologies, is it possible to identify which are the technological fields of major interest for the country. An analysis of the impacts of such technologies and of their possible evolution trajectory could be inferred by the significance of the innovations' spectre attached to the sectors highlighted.

In the recent study of Mazzucatto and Pena (2016), it is suggested that Brazil must organize missions-oriented policy agendas. In such direction, a clear possibility is to define the sustainable development UN 2030 Agenda as a target to exploit the contributions stemming from the technological opportunities associated with the Gripen NG project. In line with the Brazilian iNDC document (intended Nationally Determined Contributions to the Paris Agreement), the government should undertake efforts to implement an agenda for science, technology and innovation to enhance performance in areas like land use monitoring systems; renewable energy; low carbon and resilient agriculture; restoration and reforestation activities; management of protected areas; capacity building for national communications.

The sectors' analysis set out something about priorities for operating with a 'true spillover' agenda in Brazil. Addressing the UN 2030 Agenda enhance the possibilities for both Brazil and Sweden to advance in the implementation of a kind of disruptive agenda focusing on the critical contributions to the achievement of the sustainable development goals (ODS). The necessary sociotechnical transformations imply a radical departure from business as usual way of doing things, forcing national communities to take full advantage of the possibilities generated by a future Science , Technology and Innovation-based sustainable development agenda.

To advance in this direction, it is necessary to look beyond by shaping the future and exercising long-term perspectives to achieve transformative changes in livelihoods across the world. Such guideline requires rethinking the role of government and public policy in the economy, demanding new justifications for government intervention, that go beyond the usual argument of simply fixing market failures.

This is something which is well addressed in the analysis of Eliasson (2010) about the aeronautics chain, which suggests that missions-oriented policies should impel societies in search of the desired transformations. Such an agenda needs systemic public policies that draw on frontier knowledge to attain specific goals. As largely discussed there, the role of the public sector will be particularly important in the early phases and capital-intensive high-risk areas from which the private sector tends to shy away from.

For Brazil, this new approach means developing, implementing and monitoring a set of strategic policies and investments that use innovation to overcome the country’s weaknesses and to address its challenges, thus seizing the opportunities offered by such a vast and richly endowed country. This requires putting innovation at the heart of economic growth policy, taking advantage of previous government investments, especially able to reorient and guide public and private partnerships and opportunities.

A key factor in facilitating technology transfer is, as shown, the absorptive capacity of recipient users. The higher the level of domestic human capital and maturity of economic sectors, the higher the level of technology transfer possibilities. This illustrates the importance of long-term capacity building and education in technical and scientific areas.

Finally, it is important to understand what can be obtained as research enhancements considering the possibilities in fully applying the technological intelligence tools developed by CGEE and, consequently, to explore in-depth the refinements needed to estimate with a certain degree of accuracy the potential impacts associated with the true spillovers from Gripen NG project:

1) First, there is a need to organize a good database of the sectors and technologies of interest. It is perfectly possible to quickly gather quantitative information about sectoral economic dynamics in Brazil and bring to light an econometric analysis that can form a baseline for a calculus of the spillovers impacts. With such an investigation, one can easily produce some references and set the ground for a more quantitative approach to the analysis inserted in this report

2) Next, it is viable to explore other ways of connecting both patents information and scientific and technological competences. The global patent analysis could be put side by side with the national patent system's information and confronted with the access Brazil can have to the critical technological niches, clarifying the critical issue of accessibility. In parallel, an investigation of the roles other forms of ownership control can play should be launched.

3) With these results in hands, a more detailed and refined set of technical words and expressions can be submitted to analysis and used to gather information from the Lattes CVs database. Also, a more complete and precise understanding of both the existing and lacking competences in Brazil can be produced from this natural language processing. Moreover, additional quantitative methods can be applied, producing a more robust picture of the related competences and absorptive capacity in Brazil.

4) There are other lines of investigation that were not directly considered in this report. For instance, better results can be obtained by combining patent analysis with the sound information that can be generated by InsightData. It is possible, for example, to monitor trends for a set of technical words and expressions simply by collecting information from a large bibliographical database covering journals, specialized magazines and texts from diverse sources.

To sum up, a careful consideration of the results achieved so far and their submission to a larger group of experts for validation purpose could also refine the findings and leverage their potential use as an important reference to design and implement specific policies and programmes as well as to strengthen further collaborations.

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9 Annex - Critical technologies for Brazilian aeronautics industry

For a full list of the 78 critical technologies identified for aeronautics chain, see: (http://www.cgee.org.br/busca/ConsultaProdutoNcomTopo.php?f=1&idProduto=9020), pp. 54 to 61. For complete list associated to chapter 5, see below:

Complete List

CGEE	Technology
1	New metallic materials
2	New advanced materials: composites (Prepreg, CFRP); nano-structured; carbon nano-tubes; metal-ceramic.
3	New structural concepts
4	Surface protection
5	Composite materials production processes: RTM, RFI Fibre-placement etc
6	Non-destructive tests – NDT
7	New production technologies: 5 Axes milling machines Advanced cutting technics (water, laser, electrons)
8	Advanced jointing technologies
9	Reconfigurable and flexible tooling
10	Automated assembling processes
11	Crashworthiness improvement
12	Reduced environmental impact fabrication processes and technics
13	Monitoring and diagnostics of systems health
14	Monitoring and diagnostics of structures health
16	Fly-By-Wire
17	Adaptive control
18	Sensors and Command&Control
19	Data communications: high bandwidth datalink satcom encryption frequency hopping centric networks
21	Data fusion
22	High density data storage
23	On-board software
26	Integrated Modular Avionics (IMA) and Integrated Modular Electronics (IME)
27	Methods and processes for the design and certification of complex integrated systems
29	Full Authority Digital Engine Control (FADEC)
31	Electromagnetic Radiation Hardening
32	Fail-safe Avionics (or Fault-tolerant Avionics)

39	Innovative technologies for aircraft interiors (humidity temperature and lighting active controls electrochromic devices seat cover etc.)
40	Interior design
41	Integrated Safety Assessment
42	Weather hazards avoidance
43	All-weather Synthetic Vision
44	Digital Terrain Recognition
47	Cockpit human-machine integration enhancement
48	Safety Critical Applications Software
50	Systems for CNS/ATM
54	Fault Tolerant Systems
55	Methods and tools for safe flying in adverse weather (e.g.: icing prediction)
56	Aeroelasticity (Aeroservoelasticity)
57	New high-lift devices
58	Low external noise structural and aerodynamic solutions
61	Aerodynamic-structural integrated design for minimum noise generation
63	Virtual reality
65	Computational Fluid Dynamics – CFD
66	Aircraft systems engineering simulations
67	Knowledge-based engineering tools
68	Multidisciplinary Design Optimisation – MDO
69	Aeronautic systems modelling by systems engineering methods tools and processes.
70	Verification and Validation (V&V) processes
71	Methods and technics for systems integration
74	Computer-Aided Software Engineering (CASE)
75	High-performance computing
76	Distributed computer architeture
77	Technological platforms for more eficiente aircrafts
78	Demonstrative platforms for precompetitive technologies